UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

APR 03 2019

OFFICE OF
SOLID WASTE AND
EMERGENCY RESPONSE

NOW THE
OFFICE OF LAND AND
EMERGENCY MANAGEMENT

Mr. John Greenewald
27305 W. Live Oak Road
Suite 1203
Castaic, CA 91384

RE: Freedom of Information Request EPA-HQ-2018-004446

Dear Mr. Greenewald:

This is in response to your Freedom of Information Act request of March 16, 2018, requesting a copy of records, electronic or otherwise of the following: a DVD of higher quality or version of the EPA video, *Recovering from a Nuclear Incident – Lessons Learned from Chernobyl,* a copy of all scripts and draft scripts of this video, a copy of all communications regarding the production of this video (this would include, but not be limited to, all emails, letters, memos, inter-agency communications, etc. from all parties involved in the production of this video), and a copy of all drafts, including the final budget for the video. Enclosed are copies of records responsive to your request; unfortunately, we're unable to provide better quality video as you had requested.

This letter concludes our response to your request. You may appeal this response by email at hq.foia@epa.gov, or by mail to the EPA's National FOIA Office, U.S. EPA, 1200 Pennsylvania Avenue, N.W. (2310A), Washington, DC 20460 or through FOIAonline if you are an account holder. If you are submitting your appeal by hand delivery, courier service, or overnight delivery, you must address your correspondence to 1200 Pennsylvania Avenue, N.W., Room 5315, Washington, DC 20460. Your appeal must be in writing, and it must be received no later than 90 calendar days from the date of this letter. The agency will not consider appeals *received* after the 90-calendar-day limit. Appeals received after 5:00 p.m. EST will be considered received the next business day. The appeal letter should include the FOIA tracking number listed above. For quickest possible handling, the subject line of your email, the appeal letter, and its envelope, if applicable, should be marked "Freedom of Information Act Appeal." Additionally, you may seek dispute resolution services from the EPA's FOIA Public Liaison at hq.foia@epa.gov or (202) 566-1667 or from the Office of Government Information Services (OGIS). You may contact OGIS in any of the following ways: by mail, Office of Government Information

Services, National Archives and Records Administration, Room 2510, 8610 Adelphi Road, College Park, MD 20740-6001; email, ogis@nara.gov; telephone, (202) 741-5770 or (877) 684-6448; or fax, (202) 741-5769.

Sincerely,

Reggie Cheatham, Director
Office of Emergency Management

Chernobyl - Status of images:

Corbis – primary image source and basis of earlier quote. Corbis has changed prices since original quote in11/07, and now wants $180/photo (as opposed to $155 in quote), and now is releasing 2-year rights-managed photos rather than rights managed forever. Cost varies depending on pictures, but is generally around $180 for 2-yrs and $300 for 5-yrs.

Getty Images – A second big source of photos stock – they have some photos of the Chernobyl incident. We are waiting on pricing.

Thoughtequity – capture stills from video, videos are all recent "what's it like now" images of Pripyat and such. Still capture from videos for $130 each, $750 (6 images) minimum.

ElenaFilatova.com – good videos and images, free as long as photos are attributed

BBC archives – no still photos, video mostly marginal newscast and so forth

REMM website – all images are public domain, lots of good general renderings of radioactivity concepts that we can use, dirty bomb exploding and scattering blue glowing stuff we used in the intro is from this source. We have contacted them and confirmed that we can use these images.

IAEA – We can use images from their photobank so long as the images are properly credited. The photobank images are good, but limited in number. We will use what we can.

Summary – public domain images are out there, and we can lean heavily on the free ones but we'll still need to spend some money on images

Objectives and justification for the Chernobyl film

The NDT is developing a film describing what might happen if there was a radiological attack on the United States and the recovery issues associated with such an event. This film will examine the basic scenarios under which such an attack might occur (such as a dirty bomb or the explosion of an improvised nuclear device), what countermeasures and restoration actions are likely to happen following the event, and where more information can be obtained to help people understand and prepare for such a possibility. The lessons learned as a result of the Chernobyl nuclear accident are described to illustrate recovery issues and methods, and interviews with two women who lived through the Chernobyl experience are featured in the film. The audiences for the film are members of the response community and the general public.

The primary objective of the film is to illustrate that exposures following a radiological attack are likely to be limited and the ability of people to safely cope with low levels of subsequent contamination are excellent. The film demonstrates that being aware of the basic facts surrounding a radiological incident, and being familiar with techniques that can minimize exposure to contamination are helpful in limiting damages and recovering safely from such an event. The film describes where members of the public can obtain timely and credible information on these topics, and seeks to build confidence that recovery from such a threat is achievable with acceptable risk.

Development of such an educational film is consistent with the NDT's responsibility to prepare for and support the recovery from a potential major radiological event. In addition, the team is uniquely qualified to communicate with the response community and the public on this topic. By improving public awareness and helping people to educate themselves on the issues associated with a possible radiological emergency, the work of the response community will be facilitated and the power of such an event to terrorize citizens will be reduced.

Chernobyl Documentary Introduction

Description of incident

Description of response

Purpose of documentary

Introduce participants

In the early morning hours of April 24, 1986, the Chernobyl nuclear plant near the town of Pripyat in what is now the Ukraine, experienced the worst nuclear power accident in history, an uncontrolled nuclear reaction and resulting explosion and fire, which sent a cloud of radioactive material over the western Soviet Union and Europe. The Chernobyl nuclear plant is located near the border of Russia, Ukraine, and Belarus, about 70 miles northwest of the City of Kiev, the nearest major population center. Kiev had a population of about 2.5 million at the time of the disaster. The town of Pripyat is located about 2 miles from the reactor and had a population of about 45,000 people at the time of the accident.

The exact cause of the accident is still uncertain, but it is widely accepted that a combination of design flaws and operator error caused the accident. At around 1:00 AM on April 24, the plant was conducting a safety test to determine if the cooling system pumps could operate by using the reactor turbine if the external electricity supply failed. According to the generally recognized account of the incident, operators powered down the reactor by inserting control rods into the core to create the low power conditions required for the test. However, the power decrease was greater than anticipated, and the operators later increased the power output by manually removing some of the control rods. In addition, the operators disabled an automatic shutdown system as a part of the test. Within seconds of withdrawing the control rods, power in the reactor shot up to dangerous levels, vaporizing water in the reactor and creating an energy spike. Operators reacted by attempting to reinsert the control rods, but due to the power spike in the reactor, the rods shattered and could not be lowered any further to control the reaction.

The cooling water vaporized within seconds, causing a steam explosion that blew the lid off the reactor. The sudden inrush of oxygen caused a graphite fire, and the ruptured reactor core and building burned and released radioactive isotopes onto the atmosphere for 10 days. The Chernobyl incident released more than 100 times the radioactivity released by the bombing of Hiroshima, and the radioisotopes traveled upward into the atmosphere and to the northwest with the prevailing winds. Deposition of the radioactive fallout cloud was irregular, and strongly influenced by rainfall.

Response to the disaster was disorganized, improvised, and chaotic. The first on the scene were local firefighters and soldiers who were not aware of the grave threat of exposure to radioactivity. Many of these heroic firefighters and soldiers died of radioactivity poisoning within hours or days.

At the time of the accident, Ukraine was part of the Soviet Union, and the Soviet Union was a closed society with centralized control of the press. Soviet premier Mikhail Gorbachev had taken office about 1 year earlier, and had not yet implemented his policy of Glasnost, or openness. The first public notice of the gravity of the situation came from Sweden, when workers at the Forsmark Nuclear Power Plant (approximately 700 miles away) detected elevated levels of radioactivity that were not from local sources on April 27. Soviet authorities either did not fully comprehend or

intentionally downplayed the severity of the accident. The evacuation of the town of Pripyat began at 2:00 in the afternoon of April 27, a full 36 hours after the accident. As late as May 1, major Soviet newspapers featured May Day celebrations rather than the Chernobyl disaster on their front pages, projecting an air of normality and muting the significance of the incident. Soviet premier Gorbachev did not appear on television to discuss the incident until May 14. An initial period of governmental silence, followed by reassuring comments, appears to have had the opposite effect to that which was intended.

The incident involved unprecedented radiological contamination of a huge inhabited area combined with a lack of reliable information from a closed society, which created suspicion, uncertainty, and inefficiency. What can we learn from the incident? A lot went wrong; what went right? How did miscommunication and a lack of communication affect public perception and willingness to alter their lives to accommodate the new reality? How did the decontamination of the area proceed and how did it facilitate rehabilitation the affected areas?

To examine these questions we have Vira Yakusha, Dr. Larisa Leonova, and Dr. John Cardarelli. Ms. Yakusha is an XXX, who was a mother with a young child, living in Kiev at the time of the accident. Dr. Leonova is a physical chemist, who was in the early wave of "liquidators", who responded to the incident. Dr. Cardarelli is decontamination expert for USEPA. Together, we will examine the incident from several perspectives to see what we can learn from the response to the worst nuclear accident yet experienced, so that we are better able to deal with future radiological incidents.

The Chernobyl Incident – Experiences, Recovery, and Lessons Learned

1. Introduction

In an age of growing incidence and awareness of terrorism aimed at mass casualties and disruption, the U.S. faces a risk of experiencing a "dirty bomb" or even an improvised nuclear device. EPA has been preparing for such an eventuality, and is ready to respond, if necessary. *[Images may include standard radiation images – the symbols (old and new), some images of the disaster – smoldering fire, helicopters, first responders, people spraying water to decontaminate …]*

A dirty bomb or improvised nuclear device would be likely to detonate with little or no warning and contaminate a large, densely inhabited area. To address the key issues that would confront the U.S. and in such an event, this discussion will examine an event that forced the USSR to confront some of the same issues: response and recovery from the Chernobyl nuclear incident. The Chernobyl incident was the uncontrolled meltdown of one of the core reactors of the Chernobyl nuclear power plant in 1986 near what is now Kiev, Ukraine. The meltdown caused a fire that burned for 10 days, emitting enormous amounts of radiation into the atmosphere, and contaminating large parts of Ukraine, Belarus, Russia, and western Europe. In this documentary, we'll examine how recovery from that that incident was managed, focusing on effective countermeasures in the aftermath of the disaster and eventual restoration and recovery of the area. We will enhance our discussion of the response and recovery from that incident with direct, first-hand, personal perspectives of an early responder who provided technical assistance in the early phase of recovery, and of a resident of Kiev, who was a young mother in Ukraine at the time of the disaster. *[More detailed resumes when they first appear on screen]*

Dr. John Cardarelli, an Industrial Hygienist and Health Physicist with U.S. EPA, explains why this documentary focuses on Chernobyl:

> *[Image: JC1 5:00:50 – 5:01:24 "Chernobyl brings us a unique perspective in the fact that it was uh, uh, a real, live situation where hundreds of thousands of square kilometers were contaminated with radioactive material that had been um, dispersed from the reactor accident. And it exposed hundreds of thousands of humans, requiring a large amount of environmental clean up. So what we can learn from those aspects and apply them here in the United States could be very valuable if we were to ever experience something similar to that here in the United States."]*

Before we delve into the details of the Chernobyl incident, we need to refresh our knowledge of some key concepts about radioactivity. For the next few minutes, we'll define what radioactivity is, different types of radioactivity, and the key differences between the types and persistence of radioactivity released by nuclear power plant disasters, nuclear bombs, and radioactive dispersal devices, or "dirty bombs".

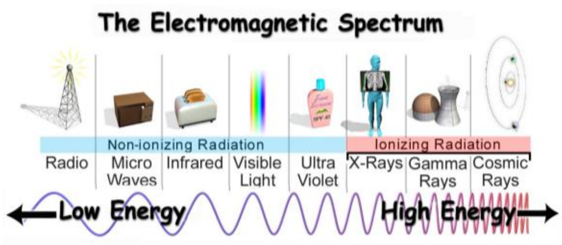
***Outline of what's to come** (1 min) – road map of where we're going: Definition of terms, description of incident, immediate response, long-term response, and discussion of U.S. preparedness for such an event.*

2. General Info about Radioactivity and nuclear devices

2.1 A Radiation Primer

To understand some of the concepts we will present in this documentary, it is important to first review some basic radiation terminology and characteristics.

The word *radiation* has many meanings. There are different types of radiation, many which are not harmful at all. *[Graphic - electromagnetic spectrum]* Television waves, radio waves, and radar are all examples of radiation, and none of these cause harm to living organisms. These types of radiation do not have enough energy to cause damage to living tissue, and are called *non-ionizing radiation.*



The other general category of radiation is called *ionizing radiation* which does have enough energy to cause damage to living tissue. Ionization is a destructive process that causes atoms or molecules to lose electrons. X-rays, cosmic rays, and nuclear radiation are types of ionizing radiation.

Many radioactive materials occur naturally. For example, granite contains remnant radioactive isotopes from the formation of the earth, and when granite erodes, these radioisotopes are carried away as sand and clay that form the soil around us – there are beaches in Brazil with such high natural radiation levels that they have restricted access. Sand and clay are also used to make building materials such as brick and concrete, which may emit low levels of radiation. Other naturally occurring radioactive isotopes are created when cosmic rays interact with atoms in the atmosphere. We are also exposed to manmade radioactive materials that have been released into the environment. Nuclear weapon testing has contributed to a slight increase in background radiation. You may also be exposed to radiation through medical procedures such as x-rays. You are exposed to radiation, known as background radiation, every day, and the amount of background radiation you are exposed to depends on where you live.

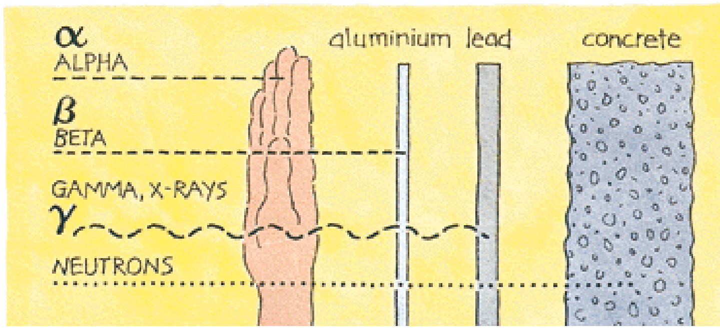
Nuclear radiation, which comes from the nucleus of an atom, is the type of radiation that most people think of when discussing radioactivity, and that is the focus of our discussion.

Remember that an atom is made of neutrons and protons that form the nucleus and electrons that orbit around the nucleus. *[Graphic: an atom that looks like a bunch of balls with a couple of electrons flying around it]* There are over100 different types of atoms and each has a specific number of protons that identifies the atom as an *element*, such as oxygen or iron. For example, the element uranium always has 92 protons. However, the number of neutrons can vary. Elements with the same number of protons but different numbers of neutrons are called *isotopes*. For example, uranium can have 138 neutrons or 146 neutrons. Uranium with 146 neutrons is known as the isotope U-238.

[Graphic: table of uranium isotopes]

Radionuclide	**Protons**	**Neutrons**
Uranium-230	92	138
Uranium-235	92	143
Uranium-238	92	146

Certain isotopes are unstable because they have too many protons or neutrons. They essentially have too much energy and they release that extra energy to become more stable. This happens spontaneously and is called *radioactive decay,* and these isotopes are radioactive and are called *radioisotopes*. Radioisotopes release energy primarily as four types of radiation: alpha particles, beta particles, gamma rays, and neutrons. Each type of radiation has a different ability to penetrate materials *[see graphic]*. For example, alpha particles can be stopped by a piece of paper, whereas gamma rays can penetrate skin and thin sheets of metal.



Nuclear radiation is measured in several different ways. When we talk about the amount of radioactive material, we don't use weigh or volume because it does not have much meaning. Instead, we talk about the amount of radiation emitted from the material, the *radioactivity* (or *activity* for short) of the material.

Activity is usually measured in *curies,* which is the amount of radiation emitted by one gram of Radium-226. A curie is equal to 37 billion disintegrations per second, or 37 billion gamma rays, alpha particles, or beta particles per second. The physical amount of material to make one curie could be one gram of Radium-226 or thousands of kilograms of some other radioactive material. That is why the amount of material is not important but the activity of the material is!

The activity of a radioactive material is closely related to the material's *half-life,* or the amount of time it takes for the radioactivity of the material to decrease by half. For example, if the half-life of a radioisotope is one day, then after one day, half of the material will have decayed. The remaining half is still radioactive, so after another day, half of this portion will have decayed. The decay process continues until no more radioactive material remains. Depending on the starting amount, it takes about 7 to 10 half-lives before the radioactivity is near background levels of radiation.

Each radioactive isotope has a unique half-life. *[graphic - half-life table]* Half-lives of some isotopes are billions of years; other isotopes have half-lives of just a few seconds. Isotopes with shorter half-lives have higher activity, and tend to pose more serious health threats. This makes sense because a short half-life means a material is emitting a lot of radiation in a short time.

Isotope	**Half-Life**	**Origin**	**Uses**
Uranium-238	4.5 billion years	Naturally occurring	Armor-piercing projectiles
Carbon-14	5,730 years	Naturally occurring	Carbon dating fossils
Cesium-137	30 years	Manmade	Geiger counters
Iodine-131	8 days	Manmade	Treat thyroid cancer
Technetium-99m	6 hours	Manmade	Medical imaging
Strontium-97	9 seconds	Manmade	None

Half-life is also important from the perspective of environmental cleanup. If a material with a long half-life is released, it will take a long time to decay to a harmless level. Cesium-137, one of the isotopes released by the Chernobyl accident, has a half-life of 30 years. Cesium-137 continues to be the primary contaminant of concern in most of the areas affected by the Chernobyl accident to this day. After 32 years, almost half of the Cesium-137 released by the accident remains. On the other hand, one of the other major isotopes released by the accident (Iodine-131) has a half-life of 8 days. Iodine-131 was a major health concern shortly after the accident, but it has decayed away by now and it is no longer a problem.

There is one more basic element of radioactivity that we'll need to understand before we proceed: *nuclear reactions*. A nuclear reaction is one where the nucleus of an atom is changed, releasing incredible amounts of energy. At Hiroshima and Nagasaki, *uncontrolled* nuclear reactions occurred in a split second, releasing huge amounts of energy and radioisotopes with short half-lives. Most of these short half-life isotopes have decayed away, and the cities of Hiroshima and Nagasaki are now vibrant urban centers. C*ontrolled* nuclear reactions such as those used at nuclear power plants, on the other hand, take place over longer periods and create more radioisotopes with long half-lives. Both controlled and uncontrolled nuclear reactions create long and short half-life radioactive isotopes, but a controlled nuclear reaction creates a much higher proportion of long half-life isotopes. This is a fundamental reason that Hiroshima and Nagasaki are active urban centers with large populations, but the exclusion zone around the Chernobyl plant is expected to be uninhabitable for hundreds of years.

[NOTE – We may need to get into the discussion of dose later in the documentary, especially when we kick into the residual levels of contamination that are left. At this point, we've defined too many new terms, yet hit the highlights – isotopes are created by nuclear reactions, and they can be radioactive. The short half-life isotopes are a problem because they release a lot of energy fast. The longer half-lives are an ongoing problem because they really don't go away.

In a similar vein, we may want to introduce the idea of fallout, dispersal patterns, and hot particles later rather than here in the primer. I chose to put that later in the story, as this is a long section with a lot of new terms and it's pretty dry – best to keep it short and focused if we can.]

2.2 Types of incidents we might face - *Introduce the types of incidents we might face and draw distinctions between them:*

Now that we've covered some of the basics of nuclear radiation, we need to consider what sort of threats we are up against. Terrorists are unlikely to engage in conventional warfare. Quite simply, they're outnumbered and outgunned. To compensate for this handicap, they seize whatever advantage they can to even the odds and multiply their influence. One worrisome possibility is that terrorists may gain access to chemical, biological, or radiological agents. This documentary focuses only on radiological agents. There are three ways terrorists might release radioisotopes: radiological dispersal devices (RDDs) that release radioactive materials without creating a nuclear reaction, causing a release from a nuclear power plant, or an improvised nuclear bombs.

<u>Radioactive dispersal device (RDD):</u>

- An RDD is a device that disperses radioactive materials. It could be a conventional bomb that contains radioactive materials and scatters those materials and other debris when it detonates, or it could scatter radioactive materials using a non-explosive device, such as a crop duster. The easiest and therefore most likely way to release radiological agents would be to detonate a type of RDD known as a dirty bomb. *[image – an explosion in a city]* This type of weapon would use radioactive materials, but the materials would not undergo a nuclear reaction that releases large quantities of energy or creates radioisotopes. An RDD would probably use existing medical radioactive materials such as Cesium-137 and Cobalt-60 which are used to treat cancer or industrial radioactive materials such as Americium-241 and Iridium-192, which are used in devices that measure density and thickness.
- A dirty bomb could cause serious injuries from the explosion, but it most likely would not have enough radioactive material to cause serious radiation sickness among large numbers of people. *[Dirty bomb clip from REMM Website radiation principals video? http://remm.nlm.nih.gov/radprinciplesvideo.htm]*
- An RDD would likely involve contamination over a densely populated area and initial confusion and lack of information, but would differ from Chernobyl in that the contaminated area would be

significantly smaller and the total amount and intensity of radioactivity released would likely be much, much lower.

A second way terrorists could release radioactive materials would be to intentionally cause an accident at a Nuclear Power Plant (NPP).

- Radioactive materials could be released from a nuclear plant by a fire or explosion or an accident involving the reactor core.
- The world has suffered several NPP accidents, including the Chernobyl meltdown in 1986, partial meltdowns at the Three Mile Island nuclear plant near Harrisburg, Pennsylvania in 1979 and the Chalk River Nuclear Plant near Ottowa, Ontario in 1952, and radioactive releases caused by a fire at the Windscale reactor near Liverpool, England in 1957 and by an earthquake at a nuclear plant near Kashiwazaki , Japan in 2007. *[still images of a couple of these disasters – TMI and images of steam being released from the Kashiwazaki plant ought to be available – perhaps response personnel running around as well.] From Google images "Kashiwazaki":*



- There are a several technical reasons that a nuclear accident like the Chernobyl meltdown are not likely to happen in America. First, the design of all U.S. reactors is different from the design of the Chernobyl reactor, and second, safety and design regulations are more stringent. The technical design of U.S. reactors is different than the Chernobyl reactor and makes major releases of radioactive materials extremely unlikely, if at all possible.

The most devastating way to release radiological agents would be to construct and detonate an Improvised Nuclear Device (IND).

- An IND is a small nuclear bomb where materials undergo a nuclear reaction. An IND would be catastrophic and would likely cause mass casualties. The technical difficulty of obtaining the materials and creating the conditions for a nuclear reaction make this a less likely scenario than an RDD. . However, a stolen nuclear weapon by a terrorist organization is of great concern. *[graphic – mushroom cloud]*
- The contaminated area would be big but the amount of highly contaminated land would still be smaller than Chernobyl. The reasons for this are complex, but simply put, a nuclear bomb produces less radioactive materials and spreads them less far than the Chernobyl accident.
- Most of the types of radioactive materials released by an IND would decay relatively quickly; most is gone within the first 24 hours and almost all within 2 weeks. However, a small amount of residual contamination would remain for a relatively long time.

Summary: To sum up, we face three main types of incidents that might release radioactive materials: RDDs, nuclear power plant accidents, and improvised nuclear bombs.

- A dirty bomb is probably the most likely scenario, and it would likely disperse commercially available medical or industrial radioactive materials over a wide area without undergoing a nuclear reaction. The radioactive materials released would probably be persistent in the environment for a relatively long time, and they may contaminate a populated downtown area.

- A nuclear power plant accident could release similar types of radioisotopes to those released by the Chernobyl incident: both long- and short-lived radioisotopes that may cause widespread contamination. However, the scale of the disaster is not likely to match the uncontrolled meltdown at Chernobyl, where a fire raged for 10 days, spewing nuclear and radioactive materials into the atmosphere and spreading them over hundreds of thousands of square miles.
- Detonation of an improvised nuclear bomb would be a catastrophic event that could devastate a city and cause widespread destruction. A nuclear bomb would involve a nuclear reaction that releases formidable amounts of energy and scatters radioactive fallout over a large region. Most of the types of radioactive materials released would decay relatively quickly. However, a small amount of residual contamination would remain for a relatively long time.

Switch gears – Now that we've covered a few of the basics about radioactivity and have a better feel for the types of incidents we're up against, we can get back to our story about Chernobyl. The common element to all of these types of incidents is the potential radiological contamination of a wide area. We will use the Chernobyl experience to discuss the issues involved with recovery from a wide-scale radiological event. Let's take a look at what happened at Chernobyl.

3. The Chernobyl Incident – What happened?

Explanation of why they had a meltdown in the first place, how the disaster unfolded, and what happened as a result. The focus of this section is what happened up to the evacuation of Pripyat. There will be good footage here that should give the viewer an idea of the magnitude of the disaster and it'll set the stage for the recovery. Also discuss fallout, what it is, heavy (hot) particles close, lighter particles far, control of wind, precipitation.

In the early morning hours of April 26, 1986, the Chernobyl nuclear plant near the town of Pripyat in what is now the Ukraine, experienced the worst nuclear power accident in history, an uncontrolled nuclear reaction and resulting explosion and fire, which sent a cloud of radioactive material over the western Soviet Union and Europe. The reactor burned for 10 days, releasing radioactive gases, vapors, aerosols, and particles and contaminating thousands of square miles in Ukraine, Belarus, Russia, and western Europe. *[image – nuclear technicians at the plant, the plant on fire, people suiting up to deal with it…]*

The Chernobyl nuclear plant is located near the border between Russia, Ukraine, and Belarus, about 70 miles northwest of the City of Kiev, the nearest major population center. Kiev had a population of about 2.5 million at the time of the disaster. The town of Pripyat is located about 2 miles from the reactor and had a population of about 45,000 people at the time of the accident. *[image – a map showing the three countries, the plant, Pripyat, and Kiev – we may have to make this]*

The exact cause of the accident is still uncertain, but it is widely accepted that a combination of design flaws and operator error caused the accident. At around 1:00 AM on April 24, the plant was conducting a safety test to determine if the cooling system pumps could operate if the external power failed. The generally recognized account of the incident is that operators disabled an automatic shutdown system and powered down the reactor by inserting control rods into the core to create the low power conditions required for the test. However, the power decrease was greater than anticipated, and the operators increased the power output by manually removing some of the control rods. Within seconds of withdrawing the control rods, power in the reactor shot up to dangerous levels, creating an energy spike. Operators tried to reinsert the control rods to slow the reaction, but due to the power spike in the reactor, the rods shattered and could not be lowered further into the reactor core to control the reaction. *[Image – reactor personnel, the power plant, and a plant exploding- could be a generic explosion if we can find such a thing]*

The cooling water vaporized within seconds, causing a steam explosion that blew the lid off the reactor. The sudden inrush of oxygen caused a graphite fire, and the reactor core and building burned for 10 days, releasing into the atmosphere more than 100 times the total radioactivity of the Hiroshima bombing. The fire carried radioisotopes upward into the atmosphere where they traveled with the prevailing winds. According to an IAEA report, *[IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience p.21]* winds were initially to the northwest, but varied over the next several days so that all points of the compass were downwind at some point while the fire in the core continued burning. To further complicate matters, scattered thunderstorms and rainfall throughout the area brought down some of the airborne material to ground level and deposited it, forming an irregular radioactive fallout pattern over thousands of square miles. *[graphic – figure 3.2 IAEA report, image of fallout pattern IAEA report Fig 3.6 and http://www.chernobyl.info/index.php?navID=2]* ,

At the time of the accident, Ukraine was part of the former Soviet Union, a closed society with centralized control of the press. Soviet premier Mikhail Gorbachev had taken office about 1 year earlier, and had not yet implemented his policy of Glasnost, or openness. *[image of Mikhail Sergeyevich]* The first public notice of the gravity of the situation came on April 27from Sweden, when workers at the Forsmark Nuclear Power Plant (about 700 miles away) detected elevated levels of radioactivity that were not from local sources. *[image – map showing Forsmark plan on east central coast of Sweden and Chernobyl/Kiev, perhaps with an arrow showing distance between them]* Soviet authorities either did not fully understand or intentionally downplayed the severity of the accident. Evacuation of the nearby town of Pripyat began at 2:00 in the afternoon of April 27, a full 36 hours after the accident. As late as May 1, major Soviet newspapers featured May Day celebrations rather than the Chernobyl disaster on their front pages, projecting an air of normality and muting the significance of the incident. *[images of soviet newspapers – Pravda]* Soviet premier Gorbachev did not appear on television to discuss the incident until May 14, several weeks later. An initial period of silence, followed by reassuring comments from the government, appears to have had the opposite effect to that which was intended: concerned citizens feared that the incident was far worse than they were being told.

Transition: The incident involved unprecedented radiological contamination of a huge inhabited area combined with a lack of reliable information in a closed society, which created suspicion, uncertainty, and inefficiency. What can we learn from the incident? How did miscommunication and a lack of communication affect public perception and willingness to alter their lives to accommodate the new reality? How did the decontamination of the area proceed and what was life like in the affected areas?

To examine these questions, we interviewed Larisa Leonova and Vira Yakusha. Larisa is a chemist with USEPA who was one of the early responders. At the time of the accident, she was managing a laboratory in Moscow part-time while earning her PhD in chemistry. Larissa volunteered to offer her services and traveled to Kiev several weeks after the incident, and worked in the area around Pripyat, trying to convince local residents to leave the area.

> *[Image – LL8 3:51:54 – 3:52:21 "My Name is Larisa Leanova and I live in United States oh, it's my twentieth years. And um, back when Chernobyl happened I was ah, twenty-eight years old and four years is graduated from ah, university. And I was working as a chemist, basically part time a lab manager and part time doing my Ph.D research work. Back when the Chernobyl happened I was in Moscow, I always lived in Moscow."]*

Vira Yakusha is a computer scientist with a consulting firm in Washington DC. At the time of the incident, Vira was a resident of Kiev and a recent graduate of Kiev University. Perhaps most important, Vira was pregnant with her first child, and she brings the perspective of an expecting mother, and a member of the general public reacting to the events occurring around her.

> *[Image – VY4 2:33:03 – 2:34:00 "My name is Vira Yakusha and ah, I was born in Kiev. And ah, I lived there for my entire life. And I loved the city a lot. And ah, I was there as a just a member of general population when Chernobyl tragedy struck. And so my perspective is a perspective of a lay person who is not professionally involved in the nuclear, in the nuclear industry, but who was, who's life*

was directly affected by what happened. And ah, my story is a story of person who is trying to comprehend what's going on and trying to do the best, what is best for my family, for health of my family and ah, trying to live my life as ah, as simple as possible if it's possible in the difficult circumstance."

4. The Early Response

We'll certainly be able to identify some good footage/photos of this part, then we can get into the more meaty and meaningful information in the Health Physics articles. We can also discuss the fallout pattern and how it was highly variable based on precipitation (Balinov, p. 385), and what fell out where (short-lived and long-lived isotopes (nuclear reactions) We could introduce the concept of distance, time, and shielding here - Dose rates decreased by three orders of magnitude in the 3 km from the plant to Pripyat (Hinton et. al. p.430).

Balanov mentions evacuation, distribution of stable iodine KI tablets to Pripyat (but not the surrounding area), and restriction of the food supply as the most effective immediate measures. For the immediate affected area, outline the basic measures – establishment of 30 km exclusion zone, evacuation, nuclear waste repositories. For the larger (and more populous) area, outline other measures - bathing, clothing, hygiene … We can discuss these systematically, and we can follow each with CDC/REMM/DHS recommendations. I like that approach because we can tie together history, first-hand anecdotes, and current recommendations:

Response to the disaster was disorganized, improvised, and chaotic. The main priority of the first responders was to put out the fire and then isolate the reactor core. The first on the scene were local firefighters and soldiers who were not aware of the grave threat of exposure to very high levels of radioactivity. By 5:00 AM, the firefighters extinguished the fires on the roof of the reactor building and in the surrounding area, thus protecting the other reactors at the Chernobyl facility, but they were not able to put out the burning reactor core. Many of these heroic firefighters and soldiers died of exposure to radiation within days or weeks. *[They are commemorated with a statue in the town of Pripyat – image of the famous firefighter statue?]*

To put out the fire in the core, the authorities tried several approaches, including dropping 5,000 tons of sand, clay, and lead onto the core by helicopter. *[image of helicopters dropping bags of stuff]* and injecting liquid nitrogen into the surrounding soil in order to cool the reactor. These efforts were not terribly effective at first – because of the extremely dangerous conditions and the extremely hot graphite fire, it took workers 10 days to put out the fire in the core.

Although the very first responders – the firefighters and the soldiers who first arrived on the scene to put out the fires – did not realize that the disaster was releasing high levels of radioation, the authorities soon recognized that the disaster had exposed the core and was releasing highly radioactive particles and smoke, and ordered evacuation of the surrounding area. The town of Pripyat, located 2 miles northwest (and downwind) of the reactor, was evacuated on Sunday, April 27, one and one half days after the disaster. The residents were told to pack for three days and to leave household pets behind. The motivation for giving such a short timeframe for the evacuation was logistical: to limit the amount of baggage and personal belongings to be transported and to expedite the evacuation. A convoy of 1200 buses carried the residents and their belongings away, and the evacuation was reportedly completed in about three hours. *[image – there are lots of images of evacuation of Pripyat – the long line of buses, lines of people getting on them and so forth.]*

In the following days, authorities measured radiation levels in the areas surrounding Chernobyl to determine the extent of contamination. Radiation levels above background were measured at distances of hundreds of miles away, but the government focused on the most heavily contaminated areas. The USSR Ministry of Public Health had set maximum permissible radiation limits for workers based on a one year exposure. However, the limit assumed a person would only be exposed to the radiation while working, or less than 1/3 of a year instead of the entire year. This limit was used to determine the area that would be evacuated and become known as the Chernobyl Exclusion Zone. The zone was determined to be a 30-kilometer (about 19 miles) radius around Chernobyl.

Isolating the reactor was an immediate priority once the fires were extinguished and the nearby towns were evacuated. To make a safer work zone, the area surrounding the reactor was cleared of debris. The contaminated debris, reactor core fragments, and surface soils from the immediate area around the reactor were placed in a concrete reinforced gallery hastily constructed around the reactor. Removal and shielding of this material made the area safer to work in.

Other soils and debris were stored in a large number of temporary shallow trenches and impoundments within the exclusion zone and covered with soil to provide minimal shielding and to reduce potential for wind to mobilize the contaminants. These trenches and small impoundments were not designed as permanent storage, yet most of them remain to this day. *[Important to demonstrate residual sources – Image – a generic trench and pile of dirt. Doesn't have to be from Chernobyl]*

After cleaning the blast area, a structure known as *the sarcophagus* was constructed of concrete, steel plates, and beams to isolate the most contaminated wastes and the reactor. The sarcophagus was constructed between May and November 1986 under very hazardous working conditions. *[images of the sarcophagus abound. Let's get some]* The structure was hastily designed and erected and has been exposed to the elements and infiltrated by moisture for more than 20 years. A new safe confinement structure is currently being designed to address the shortcomings of the sarcophagus and to isolate the reactor core and the most contaminated wastes for the next100 years. *[Image: New safe confinement structure image is on cover of IAEA report: Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience]*

5. The New Reality –*The focus of this section is what happened right afterwards in Kiev. The structure of this section will go into the nuts and bolts of living in the contaminated environment interspersed w/ tidbits from interviews. The objective is to pair "what they did" with what CDC says you are supposed to do, and to examine it in the order of: information flow, hygiene that immediately knocks back the contamination (washing, clothing), the food supply (food, farmland, etc.), and cleaning up the town.*

After the immediate issues of putting out the fires, evacuating the exclusion zone, gathering up and removing the radioactive debris, and isolating the reactor were taken care of, life continued in the surrounding areas. However, in the face of an unprecedented event, the local and national authorities were uncertain how to proceed. Larissa Leonova, a chemist who now works for USEPA, volunteered to travel to Kiev in the first weeks after the accident to lend a hand.

> *[LL4:01:56- 4:02:35 "our group of volunteers were basically invited by um, some sort of the organization which were created back there and basically consist um, of very strange group of people who -- represented by Army and by some ah, local officials which were not scientists. They were just the politicians and they were trying, trying to create some sort of the response. And um, again you know first couple of weeks it was basically you know not enough data or no information about plume or no information which territory it's more affected."] and*

> *[LL4:03:03 – 4:03:14 "we were among of the first, to my knowledge, volunteer group who went there and who got um, ah, who were involved in ah, um, some sort of the response."]*

One of the first assignments of the group of volunteers was to provide the local populace with some basic guidance about how to limit exposure to the radioisotopes released by the plant.

> *[LL4:05:05 – 4:05:25 "that's the season when everybody in the Ukraine um, pick up the strawberries. And Ukraine, it's very high in the strawberries and actually you know like um, everybody over there -- middle of the May and June the strawberries is the best place -- taste unbelievably good and everybody has a strawberry growing in their backyards and garden."] and*

[LY4:05:40 – 4:05:51 "So, the first advice which we wrote was very silly, we're saying like do not eat the strawberries if they are you know like right besides the dripping line um, from your roof."] and

[LL4:06:00 –4:06:15 "The other thing was we were basically advising that ah, try to have at least a bucket of water near the entrance of your door and before -- after you coming from the street to your house, wash you um, shoes and remove your shoes, try to not bring the additional dust."]

5.1 Information Sources

One of the biggest problems with the Soviet response to the Chernobyl disaster was a lack of credible information. At the time of the accident, the Soviet Union was a closed society, and the official Soviet news sources were not known for their openness. Almost a week after the accident, the major newspapers were not discussing the ongoing nuclear disaster that was contaminating much of the USSR and Europe. As a result, citizens were forced to turn to informal news channels, networks of associates, and whatever international news they could find on short-wave radios.

[LY8 3:52:26 – 3:53:33 "we didn't get any information about Chernobyl um, officially -- almost like a week after the accident happened. When I first time heard about it -- it was the first day ah, first working day basically it was a Monday, I believe it was 27th or 28 of the April. I came to work and one of my co-workers told me, "Did you hear the news that BBC's announcing"? And I said, "No, I basically was very busy this weekend, I didn't listen to any BBC". And we all had the habit to listen one of them ah, for a radio station and um, early morning Monday exchange the news. What really was get -- what we were getting from the abroad and what was um, broadcast in the Russian radio stations. So, my co-worker told me that he heard that something happen in the Ukraine and Sweden is picking up ah, increased radioactivity levels. And I said, "I haven't heard of that". But you know from that moment on we were basically very ah, uptight and tried to catch any news we could."] and/or

[VY1 1:29:29 – 1:29:41 "Because nobody was giving you any, uh, hard information at this point, assumption was that, uh, probably things are much, much worse than officials would tell you. And, uh, so the first week, uh, we were living our life more or less our life as usual] and

[VY1 1:23:21 – 1:23:36 "we were very skeptical about official sources of information per usual, uh, so we turned onto the, uh, Radio Free, uh, uh, what was that, what was commonly called The Voices From Abroad, and, uh, there were several radio stations that they were broadcasting towards the Soviet territory, and one of them was Voice of America, another was Radio Free Europe and one of them was BBC and such. And they were all, um, the Soviet, uh, government tried to jam them, and so you had intelligence or people who were curious about what was going on and wanted to have more information that was officially available, they were trying to find the Voices on the short wave bands."]

VY2 02:05:28 – 2:05:37 "There is a difference between, uh, questioning authorities or expecting answers to a question. So I was, uh, very aware that authorities are not telling the whole truth. But I never expected to, uh, get answers, truthful answers, if -- if I would start questioning."

[VY2 1:58:10 – 1:58:50 "I am sitting in the back seat of the car, and, uh, our radio is on, and the radio is official so it's radio and there's a news report and oh, everything is, uh, contained in Chernobyl, everything is fine, in Kiev there is no danger at all in Kiev, I mean, the population should not worry. And I'm thinking yeah, that's, it's an interesting twist because here I am from Kiev, and, uh, I'm too dirty to enter Moscow but in Kiev everything is fine. Yeah, and, um, it was a surreal moment"]

If a similar incident were to happen in the U.S., we can expect a much more open flow of information. Not only would the major news media cover the disaster, but the U.S. Department of Homeland Security, the Centers for Disease Control (CDC), the U.S. Environmental Protection Agency (U.S. EPA) and other agencies would post information on what do. Some good internet sites to obtain information on how the public should respond to a radiological incident can be found at the Department of Health and Human Services' Radiation Event Medical Management site *[Show a screen shot and the web address: www.remm.nlm.gov]* U.S. EPA's Radiation Protection program page *[show screen shot and address: www.epa.gov/radiation]* and the U.S. Department of Homeland Security's Ready America Radiation Threat site *[Screen shot and www.ready.gov/america/beinformed/radiation.html]*.

[JC2 5:08:32 - 5:09:42 "There's a lot of resources available to folks to learn more about long-term recovery and the types of information that they -— that's going to be concerned or they're going to be interested on. I would recommend a lot of folks visit uh, vetted, scientific, internet websites. Uh, for example, usepa.gov uh, the cdc.gov for public health inquiries, there's a nice website that's available by various professional societies, the Health/Physics Society, which is hps.org. Um, the National Commission for Radiological Protection is also another good website uh, the ncrp.com and there's various international uh, websites as well.
I.A.E.A, that stands for the International Atomic Energy Association, as well as the I.C.R.P., the International Commission for Radiological Protection. These are all scientifically valid, vetted information that can provide a lot of information to folks that are concerned about the public health issues, environmental issues and some of the socio-economic aspects of why certain things and clean, cleanup levels have been set the way they have."] and

[JC 5:10:00 – 5: 10:36 "You're going to have a large variety of professional folks, subject matter experts, some who will say, any amount of radiation is not good for you. Others will say, you can take X amount and it's not going to hurt you at all. The truth probably is somewhere in between and what's more important is that folks understand that and they have to come to, to a conclusion themselves. The best way to do that is to educate yourself on what the risks are to you, your family, your friends, your loved ones um, and do that by educating yourself at these various websites."]

Close this section with

[VY4 2:41:07 - 2:2:42:14 "This is such a society where ah, different ah, groups of people have their say. So there is always a balance of forces. And the result of this balance, ah there is a much better possibility that the real information, the scientific information will come out and be available and be widely available and with the internet, it's, it's, it's even, it's even better now. Because I remember how I was just raking my mind trying to remember what I was taught about levels of radiation. And now I fully expect it to be available, this information to be available on the web. And probably guidelines that I will have from authorities. I will be more willing to trust them and to follow their recommendation, because I um, understand that it's much more reliable and much more better grounded reality than it used to be on the Soviet. So it's a different story."]

[Not sure this is the right place for this quote, but it touches on the transparency issue that is the heart of this section … JC1 5:06:45 - 5:07:29 "here in America, our culture is one who is much more informed of the area and will have a lot more activity uh, and involvement in the decision-making. Which can make this process cumbersome, and much longer uh, as opposed to living in a culture where you were dictated what was going to happen and how things were going to be done. That's not likely to occur here. Um, so it could be a challenge for us to deal with all the different stake holders which is an important process. The big lesson is, transparency, tell them the truth and dealing with some of the toughest questions are ultimately what going to make this a successful effort for the agency."]

5.2 Food Supply

The massive amount of radioactive fallout had far-reaching consequences. Internal exposure to radiological contaminants through consumption of contaminated food and water is a very significant exposure mechanism and the food supply was an immediate concern. According to an IAEA review of the incident, the most effective countermeasures were prohibiting animal feeding with pasture grasses in the affected areas and rejection of milk based on radiological monitoring. 20,000 agricultural and domestic animals were slaughtered immediately, and the remainder evacuated. Due to lack of forage and animal care facilities, an additional 120,000 animals were slaughtered from May to June 1986. *[image – here we can show images of pigs and cows being screened with radioactivity meters by a guy in a moon suit (ex: 42-15882699 and* 0000316032-056*), images of dead fish on the shore near the reactor]* Early responders were advised not to eat locally grown food, and surprisingly, to drink red wine instead of water:

> *[LL8: 4:20:00 – 4:20:06 "We were ordered -- we were basically -- that was our order to drink red wine, not drink water. So, that was our liquid consumption. " and LY8 04:27:54 – 4:28:08 "We were not given anything besides red wine. We were strictly advised not drink water or milk. And we were advised do not eat any um, grown -- locally grown product -- produce, nothing, no vegetables, no fruit, nothing."]*

Many locals used common sense and avoided eating locally grown foods that were probably contaminated

> *[LY8 4:14:29 - 4:14:45 "We found the people who were very educated and um, they were not eating any fresh food since the accident, since the first they heard about the accident. They were trying to eat canned food only."*

Vira Yakusha explains *her* dietary habits when she returned to Kiev with a young baby in the months following the accident:

> *[VY3 02:27:15 – 2:27:43 Well first concern ah, at that point was the food. And ah, food and again official line was that all food is carefully screened. Sources of food that contaminated milk or other ah, ah, necessities are discarded and thrown away and so you don't have worry about that. But of course we did worry. And of course we, we will try to buy imported food. As much as it was possible. But it was not that readily available.*
>
> *VY3 2:22:18 – 2:24:00 "if there is a cereal made in Hungary, probably there is less ah, a less chance that it's radiologically contaminated than the sour cream made on the local factory. Because God knows where this local factory gets their milk from. And in the first couple of weeks we were so ardent about it that I even didn't eat any bread because bread was definitely make over, made of local grains. And again, local grains could be contaminated. But after a couple of weeks without bread, I said you know what? I'm going to eat bread. Because I cannot. I need to eat something, right?"*
>
> *[VY3 02:28:35 – 2:28:51 "So there are very, there are always efforts. There are always efforts to make sure your food sources are clear. But it is almost impossible. So you have to accept at some point that you have to, continue with your life or otherwise you will just go mad."*
>
> *VY3 2:27:44 – 2:28:12 "And again, there were um, ah, some things that you cannot buy imported. For example, like your greens, your apples. And ah, sometimes you will come across imported apples with big luck. I remember my husband bought five kilos of ah, ah, a golden ah, golden delicious which is a common brand in America and they were ah, grown somewhere ah, from north of imported apples. And we were very happy. We were feeing our baby these apples for quite a long time while they lasted."*

Effects of the disaster were profound and long-lasting. As time went on and the threats posed by contaminated farmland became better understood, the local authorities undertook more sophisticated

measures to manage agricultural production from contaminated farmland. According to Mikhail Balinov of the International Atomic Energy Agency (IAEA), the most effective countermeasures were soil treatment; removal of some areas from agricultural production altogether based on radiological screening; switching to fodder crops such as rapeseed that don't assimilate key radionuclides in the contaminated areas; switching animals to clean fodder from uncontaminated areas before slaughter and milking; and feeding animals dietary supplements such as cesium binders to help the radionuclides pass through the animals without being incorporated in food products. *[image: Here we can show images like the guys in moon suits walking through a field (42-15800571), a guy with a rototiller (42-15784775), peasant gardeners (DWF15-682237), and a fallow field with a rad sign in front of it (42-15784775)]. [I think the preceding paragraph is important to keep hitting the "life goes on, radioactive contamination can be managed" theme.]*

The countermeasures described above went a long way to reducing the radiological contamination of foods from the affected areas. However, economic hardship caused by dissolution of the Soviet Union reduced the effectiveness of the agricultural countermeasures. As recently as 2001, 9% of the milk supply in the affected areas did not meet the standards for Cesium -137, according to R. M. Alexakhin and others of the Russian Institute of Agricultural Radiology and Agroecology. *[This seems to undermine the earlier message that things can be managed, but maybe it's important to note that it's not going to be perfect?]*

We close with an image of John saying something to the effect that we can't undo it, we have to manage it – the quote below is as close as I could find, and it fits this section reasonably well.]

> *[JC1 05:06:25- 5:06:43 "I think one of the largest lessons that I'm learning from the Chernobyl environment is that well, we have a contaminated area that we will never be able to get back to natural background levels. We can't turn the clock back, is what one of the quotes was said. I think that that's reality."]*

5.3 Hygiene Precautions

Contaminated dust and dirt are a very significant source of contamination to the public in the aftermath of a nuclear incident. CDC's radiation emergency web page [www.bt.cdc.gov/radiation] recommends leaving outer clothing and shoes outside and showering after an incident to reduce or eliminate radiological contamination. More recommendations can be found at the CDC web site. *[image – web address and screen shot. There's also a cheesy but understandable image of a silhouette guy showering off yellow dots at http://www.remm.nlm.gov/deconimage.htm]* Once the local authorities accepted the significance of the Chernobyl incident, they began to issue advice on hygienic practices to reduce exposure to contaminated dust:

> *VY1 01:34:00 - 01:34:30 "First Monday after, uh, after Easter so it was May -- May 5th, and the May 5th was the first day when, uh, when authorities, uh, Soviet authorities officially on the radio started to say well, things are, um, under control, but, um, for, just for personal precautions please shower regularly, try to keep dust out of the rooms, and, uh, keep your clothes laundered often, and cover the food and bread if you buy something so, uh, it's, uh, to prevent dust from, uh, coming on the food. Uh, so there were first official guidelines for general population to minimize, uh, the exposure."*

> *VY3 02:25:56 - 02:26:32 " After that first announcement, ah, they say that you should wash ah, take shower often, wash your ah, clothing often. Ah, try to prevent dust from setting on your household items. Ah, there was more information. And ah, it will become more and more detailed and instructions more elaborate this time. Then they were not that afraid to accept or admit that something wrong is going on. And, ah, we were doing this religiously. Our family. We were trying to follow everything and some more."*

> *VY3 02:14:21- 02:14:18"my family just tried to keep everything as clean as possible. Free from dust, from dirt. But ah, the thing is that you can not be 100% sure, of course. And later on, of*

course, it was not about the surfaces, of your living space, but more about the food that you are getting and ah, and ah, probably some accidental contamination that, for example, like there, rooftops for um, perceived to be very dirty. And they were in fact. So we were told or people were telling the children were told to avoid the downpours from the, from the roof, for example. If ah, water is pouring from the roof, it' probably, if it goes and fills in your overcoat, you don't want to have your overcoat to get dirty and to get rid of it later on."

Closing statement - One of the primary ways the public is exposed to radioactivity after a radiological event is through contaminated dust and soil that adheres to hair, skin, clothing, and shoes. One effective way to reduce this exposure is to shower frequently, launder clothing frequently, remove shoes and outer clothing before entering living areas, and general good housekeeping to reduce dust and dirt indoors. These hygiene precautions were successful in areas like Kiev after the Chernobyl accident, and they are also recommended by CDC and other sources. These websites provide good information on actions you can take to minimize your exposure after a radiological incident. *[image CDC rad website and address www.bt.cdc.gov/radiation, image of DHS Ready.gov rad website and address http://www.ready.gov/america/beinformed/radiation.html.]*

5.4 Children/pregnancy

Exposure to radiation can cause health problems for the general population, depending on the type of radiation, the exposure, and the individual's general health and susceptibility to illness. Some populations are particularly susceptible to the affects of radiation, and these include pregnant women and especially unborn babies. The Centers for Disease Control say that unborn babies are particularly sensitive to radiation during their early development, between weeks 2 and 15 of pregnancy, and can experience severe health effects such as birth defects, stunted growth, and brain damage. From 16- to 25-weeks, unborn babies may experience health consequences, but only if the doses radiation are very large, such as large enough to cause radiation sickness in the mother. After the 26th week of pregnancy, the radiation sensitivity of an unborn baby is similar to that of a newborn. *[Image – CDC web site and fact sheet at http://www.bt.cdc.gov/radiation/prenatal.asp]*

For the people affected by Chernobyl, radiation exposure of unborn babies was a major concern. Ms. Yakusha was living in Kiev and pregnant with her first child at the time of the accident. Upon learning of the disaster, she tried to leave Kiev as soon as she was able, to try to put as much distance between her baby and the radiation emergency as she could. Unfortunately, many people were trying the same, and Vira was unable to buy a train or plane ticket *[image –we can show a few generic Russian-looking pregnant women and happy babies, perhaps a bunch of Russians queued up at a ticket booth… We do have some photos of kids hooked up to tubes and wires, and one with their head marked in obvious prelude to brain surgery, but I think they are too negative and unsettling]*

> *VY1 1:29:20 - 01:29:27 "I was really determined, uh, to keep my baby healthy and, uh, as far as harm's way was possible."*
>
> *VY1 1:50:49 "I don't know what to do, it's impossible to buy tickets for -- for a plane, it's impossible to buy tickets for a train, but we need to get you out. And we were sitting in the kitchen and trying to figure out what kind of plan that could work"*
>
> *VY2 01:51:36 – 1:51:41 "And so we were thinking about this and that, and there is suddenly, um, uh, a buzz on the door …"*
>
> *VY2 1:51:54 – 1:52:44 "I opened the door and this is, uh, again my friend, uh, Yenna, who, uh, head of the family who were taking me to Karnyov, and he sort of looks grim, and he said you know what, I made a decision, uh, I take my, uh, girls away to Mosc -- I'm taking my girls away to Moscow because I want to get my kids out of here as soon as possible. And his, his thinking was pretty much*

the same that if the government admits so much that, uh, it's dangerous, then it's really, really dangerous. Yeah, and he said, um, okay, so my car is downstairs, uh, waiting for you, um, my wife and my kids are in the car, and we have still one place left in this car, this is for Vira. If you want to go with us you have 40 minutes to pack yourself."
[Image – How about a man standing next to an old, Soviet-style car?]

Vira left Kiev that night, and gave birth to Doreena, a healthy baby girl, four months later in Moscow. We can't say whether getting out of Kiev, about 70 miles from the disaster, in the weeks after the accident helped her give birth to a healthy child. Her child may very well have been fine had she continued to live in Kiev.

VY1 01:32:46 – 1:33:18 "Doreena, and she is, uh, 21 years old right now, and, uh, I never had any, uh, uh, health problems with her that I should, could attribute to potential exposure. But unfortunately, uh, my understanding of the nature of the whole thing is that you never can, if you have some sort of health problem you can never be 100 percent sure if it was the result of, uh, your exposure to the radioactivity at some point or it's just your particular body type or, uh, other factors that were contributing."

Reflecting on her actions many years later, Vira feels that she made the right choice given the information that she had:

VY4 02:42:38 – 2:43:38 "my personal feeling is the health of your children or your child is the first priority, because this is something that you are ulta, ultimately responsible for. So I would say what I said to myself. Put as many miles as you can between the source of radiation and yourself and your baby and try to get as much information as much reliable information as you can. And try to… I mean panic is never a good helper or a good advisor. So probably understanding is our best weapon and to know how things work and what is real danger and what is imagined danger. It is a real important difference. And the more you understand, the better your choices are, the better your behavior is. At least you're choosing between least, least possible evils. And ah, it's impossible to be in a perfect world. But in our imperfect world, you have to make your own choices. And it's better to be based on the, on the ways of reason."

[Note – one danger of this section is that it gives some cause for panic – I feel that the 'woman in the street' perspective is valuable, but the message is get the hell out of Dodge, and it appears that Vira's actions may have saved the day. If I was a pregnant woman watching this, I'd think – get away first and ask questions later. Just want to be sure we're OK with that message.]

5.4 Decontamination of Kiev

[I'm not certain how much we want to devote to how we would do things here. I reviewed the PAGs and my brief PAG description could be beefed up. I didn't spend a lot of effort on it, as I think John will have some very detailed ideas of where he wants it to go. Note that the PAG document is very detailed, yet also very flexible. Explaining the nuances of that document is not the focus of this documentary. I think the more important message is that there is a process for getting on with life after an accident, that it's already figured out, and that we'll employ it after an accident if we need to. That's how I shaded the discussion.]

Intentional detonation of a nuclear device is likely to take place in a city, and thus is quite different from the rural environment surrounding the Chernobyl plant. One of the most significant affects of the Chernobyl accident was contamination of locally grown food, which is not likely to be a significant concern in a modern American city. Nevertheless, the Chernobyl disaster contaminated urban areas such as Kiev, and lessons about decontaminating the urban environment following Chernobyl are relevant for a radiological incident in the U.S.

In the early period after the incident, military personnel decontaminated the area. Inhalation of dust particles was a particular concern, and the area around the plant and the most contaminated areas in the exclusion zone were sprayed with organic solutions to create a thin film that would immobilize dust. Buildings, vehicles, and city streets were washed frequently and sprayed with water, which suppressed the dust and rinsed the radionuclides into sewer system. *[Image – guys spraying water on trucks, buildings, and streets – we have several]*

Streets in Kiev were washed daily in the weeks following the accident. In surrounding areas, roads and buildings were washed, contaminated soils were removed (especially along drip lines next to buildings) *[image guys peeling back sod (42-15785116)]*, and sediments were removed from the bottom of reservoirs. Decontamination focused on schools, hospitals and other buildings with large numbers of people. Tens of thousands of public buildings and residences were treated in about 1000 cities and towns.

> *VY4 02:45:17 – 2:45-31 "I've heard from people who stayed there that um, street washing was much more frequent during that memorable summer that there is. When much more often than usual and they were doing a good job of keeping the city clean after all."*

> *VY4 2:58:48 – 2:59:05 "In my understanding and my feeling that ah, in the long term during that summer, during consequent months, government did a lot. I mean what they could at this given time. Given level of technology. To clean up what they could."*

> *VY4 02:57:04 – 2:57:12 "Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that."*

> *VY4 2:57:19 – 2:58:00 "For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do. And then possibly they should ah, government should concentrate more of getting help to the sick people. To get proper medicare for people who got ah really affected, seriously affected by whole scenarios. Because ah, really there were all sorts of circulation in the media because media was better ah, better in the covering what's going on in the real life. And so very, a lot of reports of sick people, sick children, so the whole idea was to get help to people who are affected."*

> *VY4 2:59:54 – 3:00:00 "And of course, it's, it was very good to know that somebody is caring something is done."*

The urban decontamination experience after Chernobyl gives us an idea of what techniques were most effective to reduce exposure to contamination in Kiev. Much of the radioactivity from the accident was concentrated in surface soil, plants, on asphalt and concrete, and to a lesser extent on roofs and walls. According to IAEA, street cleaning, removing trees and shrubs, and plowing soils in yards to bury the surface soils were efficient and inexpensive means of achieving significant reductions of dose. Roofs and walls also contribute to dose, but are costly and difficult to clean. *[images – Images for this section could be a montage of people scrubbing, plowing, and spraying the streets, buildings, and yards]*

Based on their accumulated experience, IAEA recommends:

- Removing the upper 2- to 4-inches of soil in front of residential buildings; around schools and public buildings, in private gardens; and along roadsides.
- Replacing soils that are removed by clean soils from holes dug in less trafficked areas, and filling those holes with contaminated surface soils. Although the surface soils used to fill the holes may be contaminated, they are unlikely to be contaminated enough to merit special treatment as radiological waste.
- Covering the decontaminated parts of courtyards, etc., with a layer of clean sand or gravel where soil is not available to attenuate residual radiation.

- Washing streets and buildings
- Cleaning or replacing roofs.

In the U.S., EPA has prepared a Manual of Protective Action Guidelines (PAGs) for nuclear accidents to guide responding to an incident and cleaning up and restoring contaminated areas. *[Image – the PAG document cover, and perhaps a few shots of key areas like the figure showing zones to evacuate, shelter in place, etc (Figure 7-1), a schedule of events (Figure 7-2), and perhaps some tables of particular isotopes, like Table 7-1 and 7-5. The information will not come across on screen; It's too detailed and dense, but it looks somewhat impressive and it shows that we have such a thing.]* The PAG document is a complex compendium of information that provides a flexible framework for responding to release of radiological contaminants. The document provides guidelines for establishing exclusion zones, relocating residents, and actions to reduce exposure. The document will guide emergency responders, and provides key information and some basic considerations that should be accounted for in responding to an emergency situation, and also provides guidance on the early, intermediate, and long-term responses – the actions to take to address an emergency and then bring life back to normal in the affected areas. For example, the PAGs establish techniques to estimate dose for one year based on internal exposure and external exposure to radiological contaminants, and specifies a numerical dose value for relocating the population that is exposed to levels above the numerical value. Below the value, EPA recommends dose reduction techniques, such as washing building and hard surfaces, spot soil removal, plowing to distribute and bury the surficial contamination, and spending less time outdoors. The guidance recommends focusing initial efforts on residences of pregnant women.

The PAG document also provides guidelines for when to administer dietary supplements to counteract internal exposure, how to determine when decontamination is effective, when and how to restrict food supplies, and a myriad of other considerations. In short, EPA has established a flexible framework describing how to respond to radiological emergencies, so all of the authorities involved share a common set of goals and methods to achieve them. A U.S. response to radiological emergency would not have to be improvised.

[Note: At this point, I did not feel comfortable taking the story farther without concrete guidance on where we want to go. We could go into more detail about the PAGs, but I feel that this will lose the viewers. So basically I structured this section as follows: Here's what they did in Kiev, here's what IAEA recommends, and we have a document that will tell us how to figure out these same issues here in the U.S. We have a challenge in the visuals for this part need to liven it up a bit. This piece naturally segues into the close – We're ready for something similar if it were to happen here.]

Epilogue: U.S. response to a similar incident

Recap:

- We'll have a much more transparent flow of information
- The place is never going to be cleaned up to background or pre-incident state, but it's not the end of the world
- We've got better decon technology, and we won't have to make it up as we go along
- We have a plan in place for figuring out how to proceed after a nuclear incident

Close with a reassuring message that EPA/NDT has been considering responding to such incidents and has plans in place to avoid major pitfalls experienced at Chernobyl. We have technologies here that they didn't have, and have preparation that they did not (ex: stockpiles of KI, cesium binders; organizational structure to transmit info). *[John is knowledgeable about this material, and I assume has great ideas about what this message needs to be.]*

Some other good quotes that we could weave into the story:

VY3 02:29:45 2:29:56 "they are very dear friends of mine. Ah, a husband and wife and wife was my classmate in the University. And she is a wonderful woman. Full of life, full of energy. Smart bride."

VY3 02:30:53- 2:30:55 "And three years after Chernobyl she developed breast cancer. And ah, later on ah, information was more readily available. And later on we learned that this particular day when they were planting potatoes that cloud of radiation." ~~And it was, again it was a Russian Roulette.~~ "It was ah, radiation was blowing where the wind was blowing.

VY3 02:31:21-2:31:47 "And ah, radiation cloud was passing above us. On top of us and I was sitting in the shadow at that moment. And she was exposed to the sun working in the field, and ah, she got sick. And ah, some and she died later." So, um, and it was terrible ah, shock for me. Very personal. And every time I think about it, I wish I could rewind the, the movie and get her out from that." < good footage. Near tears

VY4 02:48:48- 2:49:18 " the worst thing about the whole ah, Chernobyl is invisible menace, menace situation, that ah, you can not definitely tell or prove that if you have some health problems is because of you were not careful enough or you were overexposed. Or just, I mean people get sick all the time. And ah, ah like I mentioned. My friend who died and ah, I, you ask me, I'm still in the heart of my heart, I'm sure that this was because what it was."

VY3 2:31 55 -2:32:40 "Do you perceive yourself as a survivor? No. I think I'm, I'm um, more or less of a bystander. Because I am um, more or less a bystander. Because I, I have seen again you've seen this information. And there were people who were sacrificing their lives to contain this horrible accident. Who were doing most, more than everybody could ask from the others. Um, um, doing more than everybody could ask from the other human being. And um, I was just trying to make sure that my baby and I am healthy. And ah, it worked well, very well for me so I, I just um, I, I, pray for people who are much more affected than I am. I don't feel sorry for myself."

Windowsill showed contamination: VY4 02:51:19 – 2:51:44 "Well, what we did, of course we washed it. Well, what we did, we washed it a little bit. With soap and sponge. And of course we disposed of the sponge and throw away. And then we ah, ah, we covered it over with a layer of fresh paint. So it's ah, sort of to seal in the particles that were still radioactive to prevent them from dislodging and getting into your fingers, for example."

VY4 2:56: 51 – 2:58:03 "did you feel that the government needed to continue to clean up to levels before the tragedy or did they just accept living in a contaminated environment? Ah, ah, I guess everybody, I guess everybody understood that it was not visible. Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that. So something that was contaminated could be ah, took out from the ah, ah, recycling. Life cycle so to speak. For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do. And then possibly they should ah, government should concentrate more of getting help to the sick people. To get proper medicare for people who got ah really affected, seriously affected by whole scenarios. Because ah, really there were all sorts of circulation in the, in the, in the media because media was better ah, better in the covering what's going on in the real life. And so very, a lot of reports of sick people, sick children, so the whole idea was to get help to people who are affected."

VY4 02:46:05– 2:47:42 "our whole culture is very much, uh, agriculture or centered ah, centered around agricultural cycles. And ah, it's very much in our ah, everyday culture for people who have perfectly good paying ah professional jobs still to maintain some garden plots outside or inside the city

and trying to grow their own vegetables or their own apples. Ah, and it was only in part economical necessity and a big part of it is just desire to have something that you watch growing. And people kept doing this. But again there was a, a whole spectrum of responses from some of our people who just quit doing this altogether or just keep planting but they would not consume what they grew. And many people continued to grow and eat what they grew. And some of them would follow uh, those um, guidelines. Turn the soil over. Put probably what I've heard put more calcium in the soil so it will ah, ah, sort of neutralize some bad elements. And uh, I've seen people who just didn't care much and they were thinking oh you cannot touch it, you cannot smell it, it's clean. Why do I bother? So ah, there's a, the whole, again, the whole rainbow of responses from probably super-paranoid and like I was trying not to eat bread for two weeks and see how it go to more than relaxed. And probably truth is always somewhere in between."

	Edited 4/27/11
	The Chernobyl Incident—Experiences, Recovery and Lessons Learned
Twin Towers Car bomb Atom bomb Dead bodies Rioters / Cops Men in decon suits	In an age in which terrorist attacks are becoming more frequent and more lethal, an attack on the United States that releases radiation—the explosion of a "dirty bomb" or improvised nuclear device—is a frightening and very real threat. Such a radiological assault would aim to inflict mass casualties, widespread panic and disruption, and could cause contamination that lasts for months or even years after the initial event.
Agency logos Map of US Evacuation Men in decon suits Abondoned cities	U.S. government agencies at the state, local and federal levels are preparing for such an event and have been rehearsing the emergency responses that would occur immediately after such an attack. But how would we cope with the aftermath of the event? What could we do to recover from its longer-term consequences?
Chernobyl aftermath Text build Video frame build: Larissa Vira	The long-term recovery lessons learned from the 1986 Chernobyl nuclear plant disaster help to answer these questions. The Soviet response to that disaster and the analyses that followed give us insights into what does and doesn't work in responding to such a situation. In this film, we will examine the basics of what a radiological attack on the United States would involve, and what the countermeasures and restoration actions taken after the Chernobyl accident tell us about what we might expect following such an event. We will enhance our discussion with the first-hand, personal perspectives of an early responder who provided technical assistance during the first phases of the recovery from Chernobyl, and of a resident of Kiev who was a young mother in Ukraine at the time of the disaster.
John	Dr. John Cardarelli, an Industrial Hygienist and Health Physicist with the U.S.

	Environmental Protection Agency explains why it is useful to focus on Chernobyl:
[Image: JC1 5:00:50 – 5:01:24	*"Chernobyl brings us a unique perspective in the fact that it was uh, uh, a real, live situation where hundreds of thousands of square kilometers were contaminated with radioactive material that had been um, dispersed from the reactor accident. And it exposed hundreds of thousands of humans, requiring a large amount of environmental clean up. So what we can learn from those aspects and apply them here in the United States could be very valuable if we were to ever experience something similar to that here in the United States."]*
Classroom Emergency Preparedness pdf	By improving public awareness and helping people to educate themselves on the issues associated with a possible radiological emergency, we will not only be better prepared, but the power of such an event to terrorize our citizens can be greatly reduced.
	2. Radiation and Radioactivity
People on city streets Text: Radiation Pan: Electromagnetic Spectrum Text: Non-Ionizing Radiation	All of us are continuously exposed to radiation from both natural and man-made sources. The word "radiation" has many meanings, and there are many types of radiation. Television and radio waves, radar and visible light are all examples of radiation, and none of these cause harm to living organisms under normal conditions. These lower-energy types of radiation are called "non-ionizing radiation."
Text: Ionizing Radiation Periodic Table – Uranium, etc. Video: am_reflect1 Medical x-ray Street scene Text: Background Radiation	The other general category of radiation is called "ionizing radiation." Ionizing radiation is higher in energy than non-ionizing radiation and can damage living cells. It comes from radioactive materials, including naturally occurring radioactive elements found on earth, cosmic rays from space and man-made radiation sources such as medical x-rays. The level of radiation from naturally occurring sources to which we are exposed on a daily

	basis is called "background radiation," and it varies throughout the world depending on such factors as altitude, soil conditions and location on earth.
Text: pretty obvious BG: radioactive symbol	There are four main types of ionizing radiation: alpha particles, beta particles, gamma rays and neutrons.
[Text and graphic from the REMM Video 1 min 33 sec:]	*"Alpha particles may be ejected from the nucleus of an atom during radioactive decay. They are relatively heavy and only travel about an inch in air. Alpha particles can easily be shielded by a single sheet of paper, and cannot penetrate the outer dead layer of skin, so they pose no danger when their source is outside the human body.*
	Beta particles are essentially electrons emitted from the nucleus of a radioactive atom. They are lighter than alpha particles, and can travel farther in air, up to several yards. Very energetic beta particles can penetrate up to one half an inch through skin and into the body. They can be shielded with less than an inch of material such as plastic. In the case of lower energy beta particles, the outer layer of clothing can act as an effective shield.
	Gamma rays can be emitted from the nucleus of an atom during radioactive decay. They are able to travel tens of yards, or more, in air, and can easily penetrate the human body. Shielding this very penetrating type of ionizing radiation requires thick dense material such as several inches of lead or concrete.
	Neutrons can be released from the nucleus of an atom during a fission reaction, such as within a nuclear reactor, or upon detonation of a nuclear weapon. Neutrons, like gamma rays, are very penetrating, and several feet of concrete is needed to shield against them.
Street scene FX: turn it red & yellow w/heat waves Earth from space, with 'cloud'	If radioactive materials are released into the environment as the result a terrorist attack or accident, people could be exposed to higher than background levels of ionizing radiation that could contaminate them and their surroundings. When vaporized radioactive

spreading out Animation: radioactive plume Text: Fallout	material is released into the atmosphere, it cools, condenses into solid particles, and falls back to earth. These particles can be carried by the wind as a plume, and can contaminate surfaces far from the explosion itself, including food and water supplies. This phenomenon is known as "fallout."
[*Will use RMM Website video here with narration by our narrator using text below. Text in italics is exactly that from the existing video. Time = 1 min 52 seconds. Additional text not in italics has been added to explain how medical treatment can help.*]	*"When a person is near a source of radiation, some type of radioactive material, he or she can be exposed to the radiation emitted by this source. However, he or she does not become contaminated.*
	One way to think about exposure is to think about X-rays. When a person has a chest X-ray, he or she is exposed to radiation, but does not become contaminated with radioactive material.
	A person can reduce his or her exposure to radiation, if he or she is shielded in some ways from the radiation, for example, if the person is behind a concrete wall, or if the radioactive source is inside of a lead container.
	In order to become contaminated, radioactive material must get on the skin, or clothing, or inside of the body. For example, if radioactive material is incorporated into a dirty bomb, a conventional explosive, such as dynamite that has been laced with radioactive material, then people could become contaminated when the device is detonated. Radioactive material on the outside of the body is called external contamination. When a person becomes externally contaminated, simply removing the clothing can remove up to 90% of the contamination. Gently washing the skin and the hair can remove most of the remaining contamination.
	If a person ingests or inhales radioactive material, it can become incorporated in the organs of the body. This is called internal contamination. When a person is internally contaminated, depending on the type of radioactive material with which they were

BG: Pill in PDR, dissolve to farm animal, then to people eating Text: Prussian Blue BG: different pills Text: Potassium Iodine	*contaminated, certain medications can be administered to speed up the rate at which the radioactive material is eliminated from the body."* For example, Prussian Blue is an effective drug that can be used to eliminate Cesium from the body, and was used on animals following the Chernobyl incident so the population could drink animal milk and eat meat. Potassium Iodine tablets were also taken by many people to counter the negative effects of the Iodine-131 gas that was released during the accident.
Shots of abandoned city & countryside	Once released, radioactive materials remain a threat to the environment for varying periods of time. The long half-life of some radioactive elements such as Cesium presents difficult challenges since people may be exposed to a contaminated environment for many years unless action is taken to decontaminate the area affected by the accident.
	~~To summarize some of the key points about radiation and radioactivity:~~
➢	➢ ~~All of us are continuously exposed to low-level radiation from both natural and man-made sources. This level is called "background radiation" and is not harmful to living things.~~
➢	➢ ~~If radioactive materials are utilized in a radiological attack, living things could be exposed to higher than background levels of ionizing radiation that could harm them and contaminate their surroundings.~~
➢	➢ ~~The potential harm from radiation may be seen within days or weeks after exposure if the dose is extremely high – for example, millions of times higher than normal background levels – or, it may present itself as cancer decades later.~~
➢	➢ ~~People can reduce their exposure to this harmful radiation by shielding themselves from its source, taking~~

	~~precautions to prevent unnecessary exposure, removing contaminated dust from their skin and clothing, and cleaning, decontaminating or leaving the area.~~
➢	~~➢ There are effective medical treatments to help counter the harmful health effects of internal radiation contamination.~~
➢	~~➢ Radioactivity decays with time. The "half-life" of many radioactive elements is relatively short, but others with much longer half-lives will present challenges to cleaning-up the areas affected by the attack.~~
	3. Types of Incidents We Might Face
Street scene or aerial Text: Radiological Threats	What types of radiological threats might we face should radioactive materials be used in a terrorist attack?
	Experts have identified four potential scenarios:
➢ Stylized street scene ➢ Text	➢ A **Radiological Exposure Device, or "RED,"** is a non-explosive device made of highly radioactive material that is hidden in a highly populated area. When people pass by it, they are unknowingly exposed to potentially harmful levels of radiation.
➢ Car bomb & aftermath ➢ Text Car bomb explosion Aftermath of car bomb Men in decon suits	➢ A **Radiological Dispersal Device, or "RDD,"** is a device that releases radioactive materials into the environment by using conventional explosives or another method. This device is commonly referred to as a "Dirty Bomb." It is important to realize that a dirty bomb is not the same thing as a nuclear bomb. A dirty bomb uses radioactive materials, but these materials do not undergo the type of nuclear reaction that releases large quantities of energy and produces an atomic mushroom cloud.

[*Need to find or create a video clip to illustrate the dirty bomb scenario. At John Cardarelli's suggestion we are evaluating the potential use of DHS video coverage from TOPOFF 2*]	The main dangers from a dirty bomb are the serious injuries and damage that would result from the explosion itself. It most likely would not have enough radioactive material to cause serious radiation sickness among large numbers of people.
➢ Cooling Tower ➢ Text	➢ A targeted **attack on a nuclear power plant or installation** could result in the release of radioactive materials from the nuclear reactor, spent fuel or other nuclear materials stored on site. Such an incident could require evacuation of the geographic area proximate to the facility and cause widespread contamination from both long and short-lived radioisotopes released as a result of the attack.
➢ Atom bomb explosion ➢ Text	➢ An **Improvised Nuclear Device, or "IND,"** is a crude nuclear bomb, built from scratch or from stolen components, that is capable of producing damage similar to that experienced at Hiroshima or Nagasaki.
Atom bomb exploding Shots improvised bomb Shots of hooded terrorists	Explosion of an IND would be devastating and would likely cause mass casualties and major property damage. However, the technical difficulty of obtaining the necessary materials and creating the conditions for a nuclear reaction make this a less likely scenario than a RDD. A stolen nuclear weapon by a terrorist organization is of greater concern.
Montage of 4 scenes from above	~~The radiation exposures and effects that would result from events such as these vary widely from scenario to scenario, so we will examine each one separately.~~
Text: **Radiological Exposure Device (RED)** Shot of subway station Shot of sport stadium Shots of crowds of people	~~A RED contains highly radioactive materials in a sealed device that is intended to expose people to significant doses of ionizing radiation without their knowledge. The total dose that would result from exposure to a RED would depend on the type of radioactive material used, how close the person was to the material, and for how long the person was near~~

	~~the device.~~
Text: **Radiological Dispersal Device (RDD)** Car bomb explosion Aftermath of car bomb Men in decon suits	~~A RDD is a device that releases radioactive materials into the environment. The easiest way to release radiological agents would be to detonate a type of RDD known as a "dirty bomb".~~
[*Need to find or create a video clip to illustrate the dirty bomb scenario. At John Cardarelli's suggestion we are evaluating the potential use of DHS video coverage from TOPOFF 2*]	~~The main dangers from a dirty bomb are the serious injuries and damage that would result from the explosion itself. It most likely would not have enough radioactive material to cause serious radiation sickness among large numbers of people.~~
Text: An **attack on a nuclear plant or installation** Area surrounding cooling tower Aerial or shot from space	~~Terrorists could release radioactive materials by intentionally causing a fire or explosion at a nuclear power plant or nuclear installation. Such an incident could require evacuation of the geographic area proximate to the facility and cause widespread contamination from both long and short-lived radioisotopes released as a result of the attack.~~
Text: An **Improvised Nuclear Device (IND):** Animation of atomic fission Atom bomb exploding Shots improvised bomb Shots of hooded terrorists	~~The most devastating way to release radiological agents would be to construct and detonate an Improvised Nuclear Device, or IND. An IND is a small nuclear bomb in which radioactive materials undergo a nuclear reaction and release massive amounts of energy. Explosion of an IND would be devastating and would likely cause mass casualties and major property damage. However, the technical difficulty of obtaining the necessary materials and creating the conditions for a nuclear reaction make this a less likely scenario than a RDD. A stolen nuclear weapon by a terrorist organization is of greater concern.~~
Atom bomb explosion in city (iStock)	Although explosion of an IND would be a catastrophic event, its long-term contamination effects could actually be less than those

Shots of guys in decon suits (from box.net)	experienced following the Chernobyl accident. The Chernobyl accident resulted in the continuous release of radioactive materials into the environment over a period of ten days. An IND contains much less radioactive material and releases all of it in an instant. These materials would be spread over less distance compared with Chernobyl, but the area could be highly contaminated.
BG: Radioactivity symbol Text: pretty obvious	To sum up, we face four main types of incidents that might result in the exposure to or release of radioactive materials: a Radiological Exposure Device, a Radiological Dispersal Device, an attack at a nuclear plant or installation, and an Improvised Nuclear Device.
	4. The Chernobyl Incident and the Initial Response
Text: list Aerial shot of Chernobyl reactor (Elena video 3)	Now that we've covered a few of the basics about radiation, radioactivity and the types of emergencies that may occur, we can better examine the issues associated with radiological contamination. The 1986 accident at the Chernobyl power plant in the Soviet Union gives us insight into how we might recover from a wide-scale radiological event. First, let's take a look at the accident itself.
[Images: nuclear technicians at the plant, the plant on fire, people suiting up to respond.] From Corbis folder Zoom out from map (IAEA radiation area)	In the early morning hours of April 26, 1986, the Chernobyl nuclear plant experienced the worst nuclear power accident in history. The accident created an uncontrolled nuclear reaction and the resulting explosion and fire sent a massive cloud of radioactive material into the atmosphere. The reactor burned for 10 days, releasing radioactive gases, vapors, aerosols and particles, and contaminating thousands of square miles in Ukraine, Belarus, Russia, and Western Europe.
Shots of firefighters Firefighters on roof	The initial response to the disaster was disorganized, improvised, and chaotic. The firefighters extinguished the fires on the roof of

WS of reactor burning	the reactor building and in the surrounding area, thus protecting the other reactors at the Chernobyl facility, but they were not able to put out the burning reactor core.
[Image: helicopters dropping bags of materials.]	To put out the fire in the core, local authorities tried several approaches, including dropping 5,000 tons of sand, clay, and lead onto the core by helicopter. But because of the dangerous conditions and extreme heat, it took workers 10 days to put out the fire.
[Images of the evacuation of Pripyat – the long line of buses, lines of people getting on them and so forth.]	The town of Pripyat, located 2 miles northwest (and downwind) of the reactor, was evacuated on Sunday, April 27, one and one half days after the accident began. ~~A convoy of 1200 buses carried the residents and their belongings away, and the evacuation was reportedly completed in about three hours.~~
WS of reactor	Isolating the reactor was an immediate priority once the fires were extinguished and the nearby towns were evacuated.
[Images of the Chernobyl sarcophagus.] *[Image: New safe confinement structure image is on cover of IAEA report: Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience.]*	After the fires were extinguished, a structure known as the sarcophagus was constructed of concrete, steel plates and beams to isolate the most contaminated wastes and the reactor. The sarcophagus was constructed between May and November 1986 under very hazardous working conditions. The structure was hastily designed and erected and has been exposed to the elements and infiltrated by moisture for more than 20 years. A new safer confinement structure is currently being designed to address the shortcomings of the sarcophagus and to further isolate the reactor core and the most contaminated wastes for the next 100 years.
	5. Living in the Aftermath of Chernobyl—Lessons from the Recovery

Map of contamination area Shots of urban dwellers working, etc. Shots of evacuation Shots of cleanup in decon suits	The accident at Chernobyl resulted in unprecedented radiological contamination of a densely inhabited area. It caused major economic, social and psychological hardships to those living in the region. Local and national authorities were not prepared for an incident of such size and severity. How did people in the region react and what measures did they take to cope after the accident? How did the cleanup of the area proceed and what was life like in the affected areas?
Comp of stills of both women Still of Larissa w/title	The reports of two women with first-hand, personal experiences living in the aftermath of Chernobyl help to answer these questions. The first is Larisa Leonova, a chemist with the U.S. Environmental Protection Agency who was one of the early responders to the Chernobyl event. At the time of the accident, she was managing a laboratory in Moscow on a part-time basis while earning her PhD in chemistry. Larissa volunteered to help with the response and traveled to Kiev several weeks after the incident. She worked in the area around Pripyat, trying to convince local residents to leave the area.
	[Image – LL8 3:51:54 – 3:52:21 ~~"My Name is Larisa Leanova and I live in United States oh, it's my twentieth years. And um,~~ back when Chernobyl happened I was ah, twenty-eight years old and four years is graduated from ah, university. And I was working as a chemist, basically part time a lab manager and part time doing my PhD research work. Back when the Chernobyl happened I was in Moscow, I always lived in Moscow."]
	[Image—LL8 4:00.44--?? "So, I basically ah, set up the vacation time and I called to my uncle in the Kiev and I said like you know me and another group of ah, chemists we are ready to provide whatever the type of the help we can."]
Still of Vira w/title	Vira Yakusha is a computer scientist with a consulting firm in Washington DC. At the

	time of the accident, Vira was a resident of Kiev and a recent graduate of Kiev University. Vira was pregnant with her first child, and she brings the perspective of an expectant mother and member of the general public reacting to the events occurring around her.
	[Image – VY4 2:33:03 – 2:34:00 ~~"My name is Vira Yakusha and ah, I was born in Kiev. And ah, I lived there for my entire life. And I loved the city a lot. And ah, I was there as a just a member of general population when Chernobyl tragedy struck. And so~~ my perspective is a perspective of a lay person who is not professionally involved in the nuclear, in the nuclear industry, but who was, whose life was directly affected by what happened. And ah, my story is a story of person who is trying to comprehend what's going on and trying to do the best, what is best for my family, for health of my family ~~and ah, trying to live my life as ah, as simple as possible if it's possible in the difficult circumstance."]~~
BG: Aerial of Reactor (still) Text: list	Using the first-hand accounts of Larissa and Vira, we will look at several key aspects of the recovery from a radiological event: countermeasures to reduce exposure to the radiation released during the incident, coping with contamination of the food supply, and the special health concerns for pregnant women and their children associated with the accident.
	5.1 Limiting Exposure and Cleaning Up
Firefighters Evacuation Sarcophagus Cleanup guys in decon suits	Once the pressing issues of putting out the fires, evacuating the immediate area, removing debris and isolating the reactor were taken care of, attention turned to the impact of the accident on the broader area. Radioactive dust and dirt were a major source of contamination in both agricultural and urban areas.
Cleanup guys in decon suits	Because of the magnitude of the accident, local and national authorities were initially uncertain how to proceed.

	[LL4:01:56- 4:02:35 "our group of volunteers were basically invited by um, some sort of the organization which were created back there and basically consist um, of very strange group of people who -- represented by Army and by some ah, local officials which were not scientists. They were just the politicians and they were trying, trying to create some sort of the response. And um, again you know first couple of weeks it was basically you know not enough data or no information about plume or no information which territory it's more affected."]
	[LL4:03:03 – 4:03:14 "we were among of the first, to my knowledge, volunteer group who went there and who got um, ah, who were involved in ah, um, some sort of the response."]
Instructors and civilians	One of the first assignments of the group of volunteers was to provide the local populace with some basic guidance about how to limit their exposure to the radioisotopes released by the plant.
	[LL4:05:05 – 4:05:25 "that's the season when everybody in the Ukraine um, pick up the strawberries. And Ukraine, it's very high in the strawberries and actually you know like um, everybody over there -- middle of the May and June the strawberries is the best place -- taste unbelievably good and everybody has a strawberry growing in their backyards and garden."]
	[LY4:05:40 – 4:05:51 "So, the first advice which we wrote was very silly, we're saying like do not eat the strawberries if they are you know like right besides the dripping line um, from your roof."]

	[LL4:06:00 –4:06:15 "The other thing was we were basically advising that ah, try to have at least a bucket of water near the entrance of your door and before -- after you
	coming from the street to your house, wash you um, shoes and remove your shoes, try to not bring the additional dust."]
Instructors and civilians OR Printed guidelines	Once the authorities began to realize the significance of the accident, they began to issue further guidance on ways to reduce exposure to contaminated dust:
	[VY1 01:34:00 - 01:34:30 "~~First Monday after, uh, after Easter so it was May -- May 5th, and the~~ May 5th was the first day when, uh, when authorities, uh, Soviet authorities officially on the radio started to say well, things are, um, under control, but, um, for, just for personal precautions please shower regularly, try to keep dust out of the rooms, and, uh, keep your clothes laundered often, and cover the food and bread if you buy something so, uh, it's, uh, to prevent dust from, uh, coming on the food. Uh, so there were first official guidelines for general population to minimize, uh, the exposure."
	~~VY3 02:25:56 - 02:26:32 "After that first announcement, ah, they say that you should wash ah, take shower often, wash your ah, clothing often. Ah, try to prevent dust from setting on your household items. Ah, there was more information. And ah, it will become more and more detailed and instructions more elaborate this time. Then they were not that afraid to accept or admit that something wrong is going on. And, ah, we were doing this religiously. Our family. We were trying to follow everything and some more."~~
	VY3 02:14:21- 02:14:18"my family just tried to keep everything as clean as possible. Free from dust, from dirt. But ah, the thing is that you cannot be 100% sure, of course. And later on, of course, it was not about the surfaces, of

	your living space, but more about the food that you are getting and ah, and ah, probably some accidental contamination that, for example, like there, rooftops for um, perceived to be very dirty. And they were in fact. So we were told or people were telling the children were told to avoid the downpours from the, from the roof, for example. If ah, water is pouring from the roof, it' probably, if it goes and fills in your overcoat, you don't want to have your overcoat to get dirty and to get rid of it later on."]
Fallout portion of atom bomb movie OR other image of fallout Text: list CDC logo	As we can see from these examples, one of the primary ways people are exposed to radioactivity after a radiological event is through contaminated dust and soil that adheres to hair, skin, clothing, and shoes. One effective way to reduce this exposure is to shower frequently, launder clothing frequently, remove shoes and outer clothing before entering living areas, and practice general good housekeeping to reduce dust and dirt indoors. These hygiene precautions were successful in areas like Kiev after the Chernobyl accident, and they are also recommended by Centers for Disease Control and others.
[Image: workers spraying water on trucks, buildings, and streets.]	The decontamination activities performed after Chernobyl gives us an idea of what techniques are most effective to reduce the dose received from exposures to radiation. In the days following the accident, the area around the Chernobyl plant and the most contaminated areas in the exclusion zone were sprayed with organic solutions to create a thin film that would immobilize dust. Buildings, vehicles, and city streets were washed frequently and sprayed with water to suppress dust.
Pan of planted field Pan paved road Tilt from roof to wall Washing streets	Much of the radioactivity from the accident was concentrated in surface soil, plants, on asphalt and concrete, and to a lesser extent on roofs and walls. Streets in Kiev were washed daily in the weeks following the accident. In surrounding areas, roads and buildings were washed, residential areas were cleaned,

[Image: men peeling back sod (42-15785116).] Guys in decon suits around buildings	contaminated soils were removed--especially along drip lines next to buildings--and sediments were removed from the bottom of reservoirs. Decontamination activities concentrated on schools, hospitals and other high-use buildings. Overall, tens of thousands of public buildings and residences were treated in about 1000 cities and towns.
IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience) [*Images for this section could be a montage of people scrubbing, plowing, and spraying the streets, buildings, and yards.]*	According to the International Atomic Energy Agency, street cleaning, removing trees and shrubs, and plowing soils in yards to bury the surface soils were efficient and inexpensive means of achieving significant reductions of dose. Roofs and walls also contribute to dose, but they are costly and difficult to clean and thus present a more difficult issue in the event of a radiological emergency in an urban setting.
	VY4 02:45:17 – 2:45-31 "I've heard from people who stayed there that um, street washing was much more frequent during that memorable summer that there is. When much more often than usual and they were doing a good job of keeping the city clean after all."
	VY4 2:58:48 – 2:59:05 "In my understanding and my feeling that ah, in the long term during that summer, during consequent months, government did a lot. I mean what they could at this given time. Given level of technology. To clean up what they could."
	~~*VY4 02:57:04 – 2:57:12 "Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that."*~~
	VY4 2:57:19 – ? "For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they

	could do."
Shot of report *(Reference: ICRP Publication 111, October, 2008, page 12.)* Text: list	In 2008, the International Commission on Radiological Protection issued a report that provided guidance on the protection of people living in areas that had been contaminated on a long-term basis from a radiological event. The report identifies numerous actions and strategies that can be used to reduce exposures, improve living conditions and rehabilitate the affected areas. Among the actions identified in the report that should be implemented by authorities are "…clean-up of buildings, remediation of soils and vegetation, changes in animal husbandry, monitoring of the environment and produce, provision of clean foodstuffs, managing of waste..., health surveillance…" and public information. The report also identifies actions that can be taken by the inhabitants of the area, including monitoring the radiological quality of their living areas and food, and the radiation exposure of themselves and their children.
[*Images: CDC rad website and address www.bt.cdc.gov/radiation, image of DHS Ready.gov rad website and address http://www.ready.gov/america/beinformed/radiation.html*.	The following websites also provide good information on actions that can be taken to limit exposure after a radiological incident.
	5.2 Managing the Food Supply
Shot of farm *(Reference: ICRP Publication 104, 2007.)* Text: spell out passage People eating at restaurants and home	The massive amount of radioactive fallout from Chernobyl also had far-reaching consequences for the food supply in the contaminated area. As noted by the International Commission on Radiological Protection, "the management of contaminated foodstuffs and other commodities produced in areas affected by a nuclear accident or a radiation emergency…presents a particularly difficult problem because of issues of market acceptance." While external exposures are likely to dominate radiation doses, internal exposure to

	radiological contaminants through consumption of contaminated food and water can be a very significant exposure concern. Early responders were advised not to eat locally grown food, and surprisingly, to drink red wine instead of water:
	~~*[LL8: 4:20:00 – 4:20:06 "We were ordered – we were basically – that was our order to drink red wine, not drink water. So, that was our liquid consumption. "and*~~ *LY8 04:27:54 – 4:28:08 "We were not given anything besides red wine. We were strictly advised not drink water or milk. And we were advised do not eat any um, grown -- locally grown product -- produce, nothing, no vegetables, no fruit, nothing."]*
Shot of a garden	Many locals used common sense and avoided eating locally grown foods that were probably contaminated:
	[LY8 4:14:29 - 4:14:45 "We found the people who were very educated and um, they were not eating any fresh food since the accident, since the first they heard about the accident. They were trying to eat canned food only."
[Images – pigs and cows being screened with radioactivity meters by a worker in a moon suit (ex: 42-15882699 and 0000316032-056), images of dead fish on the shore near the reactor (I suggest no using an image of dead fish because their death was not caused by radiation which some may be led to believe by using it in this context. were likely killed due to the contaminated water from efforts to put the fires out – not the radiation in the water.)]	Local authorities prohibited animal feeding with pasture grasses in the affected areas and rejected milk based on radiological monitoring. Many thousands of agricultural and domestic animals were slaughtered immediately, and the remainder evacuated.

Shots of people shopping in grocery store	People living in the area tried to obtain imported food as much as possible, but this was often difficult. Vira Yakusha explains her dietary habits when she returned to Kiev with a young baby in the months following the accident:
	[VY3 02:27:15 – 2:27:43 Well first concern ah, at that point was the food. And ah, food and again official line was that all food is carefully screened. Sources of food that contaminated milk or other ah, ah, necessities are discarded and thrown away and so you don't have worry about that. But of course we did worry. And of course we, we will try to buy imported food. As much as it was possible. But it was not that readily available.
	VY3 2:22:18 – 2:24:00 "…if there is a cereal made in Hungary, probably there is less ah, a less chance that it's radiologically contaminated than the sour cream made on the local factory. Because God knows where this local factory gets their milk from. And in the first couple of weeks we were so ardent about it that I even didn't eat any bread because bread was definitely make over, made of local grains. And again, local grains could be contaminated. But after a couple of weeks without bread, I said you know what? I'm going to eat bread. Because I cannot. I need to eat something, right?"
	[VY3 02:28:35 – 2:28:51 "So there are very, there are always efforts. There are always efforts to make sure your food sources are clear. But it is almost impossible. So you have to accept at some point that you have to, continue with your life or otherwise you will just go mad."
	VY3 2:27:43– 2:28:12 "And of course, ah, ah, we will try to buy imported food. As, as much as it was possible. But it was not that readily available. And again, there were um, ah, some things that you cannot buy imported. For example, like your greens, your apples. And

	~~ah, sometimes you will come across imported apples with big luck~~. I remember my husband bought five kilos of ah, ah, a golden ah, golden delicious which is a common brand in America and they were ah, grown somewhere ah, from north of imported apples. And we were very happy. We were feeding our baby these apples for quite a long time while they lasted."
*[Images: workers in suits walking through a field (42-15800571), a man with a rotor tiller (*42-15784775*), peasant gardeners (DWF15-682237), and a fallow field with a rad sign in front of it (42-15784775)].*	According to the International Atomic Energy Agency, some of the most effective countermeasures were treating the soil; removing some areas from agricultural production altogether based on radiological screening; switching animals to clean fodder from uncontaminated areas; and providing dietary supplements such as cesium binders to help the radio nuclides pass through the animals without being incorporated in food products.
Text: Previous list of countermeasures	~~The countermeasures described above went a long way to reducing the radiological contamination of foods from the areas affected by the Chernobyl accident. However, the long half life of some of the contaminants, particularly Cesium-137, and the economic hardships following the fall of the Soviet Union, resulted in continued barriers to agricultural restoration in the affected area.~~
	5.3 Coping with Health Concerns
BG: stylized shot of group of people, defocused & red Text (Header): Health Problems Text: list	Exposure of humans to radiation can cause health problems, depending on the type of radiation, the amount of radiation exposure, and the individual's general health and susceptibility to illness. For the people affected by Chernobyl, the potential impact of the accident on their health was a major concern.

[image –we could show a few generic Russian-looking group queued up at a ticket booth, as Vira spoke about the crush of people waiting to purchase airline or train tickets.]	Vira Yakusha was living in Kiev and pregnant with her first child at the time of the accident. ~~Upon learning of the disaster, she tried to leave Kiev as soon as she was able, to try to put as much distance between her baby and the radiation emergency as she could. Unfortunately, many people were trying to do the same, and Vira was unable to buy a train or plane ticket~~
Shot of Vira before she speaks	Vira discussed this situation urgently with her husband and her family:
	~~*VY1 1:29:20 – 01:29:27 "I was really determined, uh, to keep my baby healthy and, uh, as far as harm's way was possible."*~~
	~~*VY1 1:50:49 "I don't know what to do, it's impossible to buy tickets for – for a plane, it's impossible to buy tickets for a train, but we need to get you out. And we were sitting in the kitchen and trying to figure out what kind of plan that could work"*~~
	VY2 01:51:36 – 1:51:41 "And so we were thinking about this and that, and there is suddenly, um, uh, a buzz on the door …"
[Images – Possibly a man standing next to an old, Soviet-style car? A family around a table talking about something obviously upsetting or pressing.]	*VY2 1:51:54 – 1:52:44 "I opened the door and this is, uh, again my friend, uh, Yenna, who, uh, head of the family who were taking me to Karnyov, and he sort of looks grim, and he said you know what, I made a decision, uh, I take my, uh, girls away to Mosc -- I'm taking my girls away to Moscow because I want to get my kids out of here as soon as possible. And his, his thinking was pretty much the same that if the government admits so much that, uh, it's dangerous, then it's really, really dangerous. Yeah, and he said, um, okay, so my car is downstairs, uh, waiting for you, um, my wife and my kids are in the car, and we have still one place left in this car, this is for Vira. If you want to go with us you have 40 minutes to pack yourself."*

Shot of a hospital / Maternity ward	Vira left Kiev that night, and four months later in Moscow she gave birth to Doreena, a healthy baby girl. We can't say whether getting out of Kiev, about 70 miles from the disaster, in the weeks after the accident helped her give birth to a healthy child. Her child may very well have been fine had she continued to live in Kiev.
	~~*VY1 01:32:46 – 1:33:18 "Doreena, and she is, uh, 21 years old right now, and, uh, I never had any, uh, uh, health problems with her that I should, could attribute to potential exposure. But unfortunately, uh, my understanding of the nature of the whole thing is that you never can, if you have some sort of health problem you can never be 100 percent sure if it was the result of, uh, your exposure to the radioactivity at some point or it's just your particular body type or, uh, other factors that were contributing."*~~
Shot clouds or sunset, etc.	~~Reflecting on her actions many years later, Vira feels that she made the right choice given the information that she had:~~
	VY4 02:42:38 – 2:43:38 "My personal feeling is the health of your children or your child is the first priority, because this is something that you are ulta, ultimately responsible for. So I would say what I said to myself. Put as many miles as you can between the source of radiation and yourself and your baby and try to get as much information as much reliable information as you can~~*. And try to… I mean panic is never a good helper or a good advisor. So probably understanding is our best weapon and to know how things work and what is real danger and what is imagined danger. It is a real important difference. And the more you understand, the better your choices are, the better your behavior is. At least you're choosing between least, least possible evils. And ah, it's impossible to be in a perfect world. But in our imperfect world,*~~

	~~*you have to make your own choices. And it's better to be based on the, on the ways of reason."*~~
Shots of pregnant women IAEA logo Text (Header): Potential Health Risks Text: list	Pregnant women and their unborn babies are particularly vulnerable to the effects of radiation. ~~However, termination of a pregnancy is rarely justified unless the dose absorbed by the pregnant woman or unborn child is very very high.~~ According to the International Atomic Energy Agency, the potential health risks associated with radiation exposure are highest when a baby is in its early stages of development~~– during weeks 2 through 15 of the pregnancy.~~ Exposure to large doses of radiation during this time could result in severe health effects such as birth defects, stunted growth, and brain damage.
Shot of pregnant woman Appropriate text to cover	The risks associated with radiation exposure are somewhat lower during the second and third trimesters of pregnancy. During weeks 16 to 25 of a pregnancy, unborn babies exposed to radiation may experience health consequences, but only if the doses of radiation are very very high, such as those large enough to cause radiation sickness in the mother. After the 26th week of pregnancy, the risks to the unborn baby are lowest since the baby's organs have already been formed. ~~Exposure to radiation from any source during pregnancy can cause significant anxiety and fear, and pregnant women should consult with their doctors about their concerns.~~
[Image – CDC web site and fact sheet at http://www.bt.cdc.gov/radiation/prenatal.asp	More information about the special health concerns associated with exposure to radiation during pregnancy can be found on the Centers for Disease Control Website
Shot of reactor exterior WHO logo 'Expert Meetings'	Since the Chernobyl accident, much knowledge has been gained about its effect on the health of the people who were exposed to radioactive contamination in the areas surrounding the plant. Between 2003 and 2006, the World Health Organization ~~(WHO)~~

‘Thyroid Cancer’ over map of contamination area	conducted a series of expert meeting to review all the scientific evidence and evaluate the health impacts of Chernobyl. The WHO expert group reported in April 2006 that the main cancer consequence observed as of that date was the significant increase in thyroid cancer among young people who had lived in the most contaminated areas of Belarus, the Russian Federation and the Ukraine. These cancers occurred primarily among children and adolescents who drank milk contaminated with radioactive iodine immediately after the accident.
Shot of report: *(Source: “Health Effects of the Chernobyl Accident and Special Health Care Programmes: Report of the UN Chernobyl Forum Health Expert Group,” Editors Burton Bennett, Michael Repacholi and Zhanat Carr, World Health Organization, Geneva, 2006.)* Text: as appropriate	The WHO expert group also reported that “The Chernobyl accident led to extensive relocation of people, loss of economic stability, and long-term threats to health in current and possibly future generations…High levels of stress, anxiety and medically unexplained physical symptoms continue to be reported among those affected by the accident…Designation of the affected population as “victims” rather than “survivors” has led to feelings of helplessness and lack of control over their future. This has resulted in excessive health concerns or reckless behavior…”
Shot of report: *(Source: Journal of Radiological Protection 26 (2006) 127-140, Cancer consequences of the Chernobyl accident: 20 years on).* Text: as appropriate	The WHO expert group concluded overall that “…the large increase in thyroid cancer incidence among those exposed in childhood and adolescence continues; fortunately, few of these have been fatal. In contrast, at this time, no clearly demonstrated increase in the incidence of other cancers can be attributed to radiation exposure from the accident.” However, the report went on to note that this did not mean that the longer-term cancer risk of those who were exposed had not increased. Based on the experience of other populations exposed to ionizing radiation, the WHO experts predicted that “…a small increase in the relative risk of cancer is expected, even at the low to moderate doses received” and said that further studies are required to understand the full health effects of the accident.

	6.0 What if it happens here
WS of reactor on fire Shot of the Kremlin	One of the biggest problems with the Soviet response to the Chernobyl disaster was a lack of credible information about the accident and its effects on the population. Due to the closed nature of Soviet society, Soviet authorities either did not fully understand the severity of the accident, or they intentionally downplayed it.
[image – map showing Forsmark plant on the east central coast of Sweden and Chernobyl/Kiev, perhaps with a scale showing distance between them.]	The first public notice of the accident came on April 27, 1986 from Sweden when workers at the Forsmark Nuclear Power Plant (about 700 miles away) detected elevated levels of radioactivity that were not from local sources.
[Images of soviet newspapers and political figures; some possible footage at www.encyclomedia.com, "The Chernobyl Nuclear Disaster," September 15, 2006.] Shot of Gorbachev Text: date Shot of radio Shot of people in a city	Almost a week after the accident, the major Soviet newspapers were still not discussing the ongoing nuclear disaster that was contaminating much of the USSR and Europe. Soviet premier Mikhail Gorbachev did not appear on television to discuss the incident until May 14, 1986, several weeks after the event. As a result, citizens were forced to turn to informal news channels, networks of associates and whatever international news they could find on short-wave radios. The lack of reliable information about the accident and its effects created uncertainty, inefficiency and suspicion that the incident was far worse than was being reported.
	Larisa Leanova and Vira Yukasha describe the situation.
	(Possible quotes in order of preference here; how many depends on time)
	[LY8 3:52:26 – 3:53:33 "~~we didn't get any information about Chernobyl um, officially — almost like a week after the accident happened. When I first time heard about it — it was the~~

	~~first day ah, first working day basically~~ it was a Monday, I believe it was 27th or 28 of the April. I came to work and one of my co-workers told me, "Did you hear the news that BBC's announcing"? ~~And I said, "No, I basically was very busy this weekend, I didn't listen to any BBC". And we all had the habit to listen one of them ah, for a radio station and um, early morning Monday exchange the news. What really was get — what we were getting from the abroad and what was um, broadcast in the Russian radio stations~~. So, my co-worker told me that he heard that something happen in the Ukraine and Sweden is picking up ah, increased radioactivity levels. And I said, "I haven't heard of that".]
	~~[VY1 1:29:29 – 1:29:41 "Because nobody was giving you any, uh, hard information at this point, assumption was that, uh, probably things are much, much worse than officials would tell you. And, uh, so the first week, uh, we were living our life more or less our life as usual."]~~
	~~[VY1 1:23:21 – 1:23:36 "we were very skeptical about official sources of information per usual, uh, so we turned onto the, uh, Radio Free, uh, uh, what was that, what was commonly called The Voices From Abroad, and, uh, there were several radio stations that they were broadcasting towards the Soviet territory, and one of them was Voice of America, another was Radio Free Europe and one of them was BBC and such. And they were all, um, the Soviet, uh, government tried to jam them, and so you had intelligence or people who were curious about what was going on and wanted to have more information that was officially available, they were trying to find the Voices on the short wave bands."]~~
	[VY2 1:58:10 – 1:58:50 "I am sitting in the back seat of the car, and, uh, our radio is on, and the radio is official so it's radio and there's a news report and oh, everything is, uh, contained in Chernobyl, everything is fine, in Kiev there is no danger at all in Kiev, I mean,

	the population should not worry. And I'm thinking yeah, that's, it's an interesting twist because here I am from Kiev, and, uh, I'm too dirty to enter Moscow but in Kiev everything is fine. Yeah, and, um, it was a surreal moment"]
	VY2 02:05:28 – 2:05:37 "There is a difference between, uh, questioning authorities or expecting answers to a question. So I was, uh, very aware that authorities are not telling the whole truth. But I never expected to, uh, get answers, truthful answers, if — if I would start questioning."
People watching TV Logos of agencies cited	If a similar incident were to happen in the U.S., we can in fact expect a much more open flow of information. Not only would the major news media cover the disaster, but the U.S. Department of Homeland Security, the Centers for Disease Control, the U.S. Environmental Protection Agency and other agencies would post information on what do.
	~~*[VY4 2:41:07 – 2:42:14 "This is such a society where ah, different ah, groups of people have their say. So there is always a balance of forces. And the result of this balance, ah there is a much better possibility that the real information, the scientific information will come out and be available and be widely available and with the internet, it's, it's, it's even, it's even better now. Because I remember how I was just raking my mind trying to remember what I was taught about levels of radiation. And now I fully expect it to be available, this information to be available on the web. And probably guidelines that I will have from authorities. I will be more willing to trust them and to follow their recommendation, because I um, understand that it's much more reliable and much more better grounded reality than it used to be on the Soviet. So it's a different story."]*~~

	6.1 Being Prepared
EPA logo DoD, FEMA, CDC logos Over map of USA Shots of plans from EPA website *(Source: EPA Radiation Website.)*	The U.S. Environmental Protection Agency works closely with other civilian and military federal agencies as well as state and local governments to develop radiological emergency response plans and procedures. These plans specify how emergency response organizations will work together and what will actually happen during an emergency response operation. In addition to planning activities, EPA provides training and guidance to first responders, and conducts and participates in exercises that simulate radiological emergencies.
Still shot of Mitchell Text as appropriate	Jim Mitchell is an On-Scene Coordinator for the U.S. Environmental Protection Agency. On-Scene Coordinators are responsible for coordinating response activities carried out by federal, state and local officials after a significant incident. Jim describes one of their exercises, called TOP OFF, as an example of how the U.S. is preparing at every level for a possible radiological attack:
	[JM6 3:24:05-3:24:37 "…Top Off was an, was an exercise, uh, that took place about four years ago and it took place in Seattle where there was a, uh, a radiological dirty bomb, a device that was set off in Seattle. Now numerous federal, um, uh, the local, you know, the local city was Seattle and also local communities, you know, took part in responding to this exercise. And it was specifically to look at how the federal government, the federal, state and local governments would respond and outline the issues, uh, that were surrounding their response, identify gaps and try to find ways to fill those gaps."]
	[JM7 3:42:27 – 3:43:20 "…we're working towards, um, a level of preparedness

	that we haven't seen in the past. An, and, um, you know, as a, as, as a part of the region and as part of our, our, um, uh, response experts, uh, for responding to these types of incidents, we're working there. Uh, we need to continually develop exercises and training not only from On Scene Coordinators and, and our own responders, both regionally and nationally, but we need to, we need to, uh, to integrate our plans and procedures with the locals, with state and local, um, plans, with other federal agencies. So we clearly have a defined role and we have a, a developed, uh, a working path so if something like this happens, we're not, you know, we're not arguing over who's doing what or who's responsible for what. That we, that we continue to achieve a level of preparedness, um, you know, everyday. It's, it's an ongoing process."]
	[JM7 3:43:27 – 3:43:42 "We cannot anticipate all the conditions, um, or the, or the, or the impacts from something like this. We can take the knowledge that we, that we have to develop through exercises, through training, um, through research from our national laboratories and try to bring it to a level of preparedness that we have not seen in the past. And we're working towards that on a daily basis."]
Shot of public school / university	Public education is another essential element in preparing for a possible incident.
	[LV10 4:49:00 – 4:50:56 "...So, my message will be prepare yourself as much as you can, read the literature which is advising you how you have to act in case of the um, pandemic flu, in case of the emergency evacuations, what you have to keep in your home in case of the first couple of days of survival you know like in the case of the accident. Meaning you have to trust your government but you have to trust yourself also because it's so many of us, it's only one government. So if you will not help yourself in

	the very few first moments after the accident your government may be too late when it finally—government will be helping you. So you have to give the government opportunity to save you. And to do that basically educate yourself what you can do for yourself and you know take the responsible action."
~~Still shot of Cardarelli, OR video of him prior to his sound bite~~	~~Dr. John Cardarelli of the U.S. Environmental Protection Agency discusses some of the information resources available to the public:~~
Title: John Cardarelli	*[JC2 5:08:32 - 5:09:42 ~~"There's a lot of resources available to folks to learn more about long-term recovery and the types of information that they — that's going to be concerned or they're going to be interested on.~~ I would recommend a lot of folks visit uh, vetted, scientific, internet websites. ~~Uh, for example, usepa.gov uh, the cdc.gov for public health inquiries, there's a nice website that's available by various professional societies, the Health/Physics Society, which is hps.org. Um, the National Commission for Radiological Protection is also another good website uh, the ncrp.com and there's various international uh, websites as well.~~*
[Show a screen shot and the web address: www.remm.nlm.gov]; *[show screen shot and address: www.epa.gov/radiation];* *[Screen shot and www.ready.gov/america/beinformed/radiation.html*	Examples of good internet sites for information on how to respond to a radiological incident are: the Department of Health and Human Services' Radiation Event Medical Management site, U.S. EPA's Radiation Protection program page, and the U.S. Department of Homeland Security's Ready America Radiation Threat site.
Text only: **usepa.gov** **cdc.gov** ~~**hps.org**~~ **ncrp.com** **IAEA** **ICRP**	*~~I.A.E.A, that stands for the International Atomic Energy Association, as well as the I.C.R.P., the International Commission for Radiological Protection.~~ These are all scientifically valid, vetted ~~information~~ websites that can provide a lot of information to folks that are concerned about the public health issues, environmental issues and some of the socio-economic aspects of why certain things and clean, cleanup levels have been set the way they have."]*

	[JC 5:10:00 – 5: 10:36 "You're going to have a large variety of professional folks, subject matter experts, some who will say, any amount of radiation is not good for you. Others will say, you can take X amount and it's not going to hurt you at all. The truth probably is somewhere in between and what's more important is that folks understand that and they have to come to, to a conclusion themselves. The best way to do that is to educate yourself on what the risks are to you, your family, your friends, your loved ones um, and do that by educating yourself at these various websites."]
	7.0 Conclusion
Car bomb Atom bomb	As frightening as the possibility of a "dirty Bomb" or other radiological incident may seem, we know from experience that we can recover safely from such an event. And, the United States is better prepared than ever before to cope with such an eventuality.
Chernobyl reactor burning People glowing red Guys in decon suits	In this film, we have reviewed the incident at the Chernobyl power plant—the worst nuclear accident in history and which released much more radiation than would be expected from a dirty bomb or radiological attack. We learned that there are many effective ways to limit the exposure of people to radiation and live safely in long-term contaminated areas.
Cool BG	Let's recap the main points:
BG: Car bomb Text	• Although we can forecast the potential types of radiological threats might we face, we cannot forecast with precision the exact facts that will accompany any specific incident. However, a dirty bomb or other radiological attack is not likely to release nearly as much radiation as was released from the Chernobyl accident.

BG: farm animals Text	• If radioactive materials are used in a terrorist attack, living things could be exposed to higher than normal levels of radiation that could harm them and contaminate their surroundings.
BG: hospital Text	• Exposure to radiation can cause health problems. The possible health risks vary widely depending on the type of radiation, the amount of exposure and the individual's general health.
BG: pregnant woman Text	• Pregnant women should recognize that exposure to small doses of radiation during pregnancy is not likely to increase the risk of birth defects. However, each situation must be evaluated carefully and people with special health concerns should seek advice from their doctor.
BG: watching TV Text	• A radiological incident will cause real fear and anxiety among people in the affected area. Being prepared and relying on sound, accurate scientific information can help people to make better-informed decisions and allay these fears.
BG: evacuation Text	• People can reduce their exposure to harmful radiation by shielding themselves from the source, removing contaminated dust from their skin and clothing, and cleaning or temporarily leaving the area.
BG: Crew cleaning building Text	• Governmental authorities can employ a number of effective counter measures after a release, including cleaning-up buildings, remediating soils and vegetation, monitoring the environment and establishing health surveillance programs. They also play an important role in restoring supplies of safe water and food to those in the affected area.

BG: Street scene colored red Text	• Radioactivity decays with time. The "half-life" of many radioactive elements is relatively short, but others with much longer half-lives will cause areas to remain contaminated on a long-term basis. Even though such areas may have a higher than background level of radiation, they can be cleaned to a level that allows people to live in them safely.
BG: Big WS (aerial) of city Text	• Recovering from a large-scale radiological incident may require long periods of time to heal the environment, repair damage to the local economy and mitigate the psychosocial impacts on the population.
BG: comp of reports Text	• There are many high quality sources of public information about the health, environmental and socio-economic issues associated with radiation exposure. If a radiological emergency were to occur in the United States, government and news sources would provide additional information to guide those being affected.
Reactor Map of contamination Decon suits Shots of reports EPA logo	We have learned much about how to cope and recover from a major radiological release since the Chernobyl accident. This knowledge will help us to effectively respond to a future possible incident. The best way for citizens to prepare is to educate themselves about the possible scenarios that could occur and the risks they pose. We hope this film has helped you begin this process.

The Chernobyl Incident – Experiences, Recovery, and Lessons Learned

1. Introduction

In an age of growing incidence and awareness of terrorism aimed at mass casualties and disruption, the U.S. faces a risk of experiencing a "dirty bomb" or even an improvised nuclear device. EPA has been preparing for such an eventuality~~, and is ready to respond, if necessary~~. *[Images may include standard radiation images – the symbols (old and new), some images of the disaster – smoldering fire, helicopters, first responders, people spraying water to decontaminate …]*

A dirty bomb or improvised nuclear device would be likely to detonate with little or no warning and contaminate a large, densely inhabited area. To address the key issues that would confront the U.S. ~~and~~ in such an event, this discussion will use~~examine~~ ~~an event that forced the USSR to confront some of~~ the long-term recovery lessons learned from the Chernobyl nuclear plant disaster~~same issues: response and recovery from the Chernobyl nuclear incident~~. In 1986, The Chernobyl nuclear power plant experienced ~~incident was the~~ an uncontrolled meltdown of one of its~~the core~~ reactors~~ of the Chernobyl nuclear power plant in 1986 near what is now Kiev, Ukraine~~. The meltdown caused a fire that burned for 10 days, emitting enormous amounts of radiation into the atmosphere, and contaminating large parts of Ukraine, Belarus, Russia, and western Europe. In this documentary, we'll examine how recovery issues ~~from that that incident was~~ were managed, focusing on effective countermeasures in the aftermath of the disaster and eventual long-term restoration and recovery of the area. We will enhance our discussion of the response and recovery from that incident with direct, first-hand, personal perspectives of an early responder who provided technical assistance in the early phase of recovery, and of a resident of Kiev, who was a young mother in Ukraine at the time of the disaster. *[More detailed resumes when they first appear on screen]*

Dr. John Cardarelli, an Industrial Hygienist and Health Physicist with U.S. EPA, explains why this documentary focuses on Chernobyl:

> *[Image: JC1 5:00:50 – 5:01:24 "Chernobyl brings us a unique perspective in the fact that it was uh, uh, a real, live situation where hundreds of thousands of square kilometers were contaminated with radioactive material that had been um, dispersed from the reactor accident. And it exposed hundreds of thousands of humans, requiring a large amount of environmental clean up. So what we can learn from those aspects and apply them here in the United States could be very valuable if we were to ever experience something similar to that here in the United States."]*

This documentary will also use cesium-137, a radioactive element still present following the Chernobyl disaster and one that has been identified by scientific organization as a threat to be used in a dirty-bomb attack.

2. General Info about Radioactivity and nuclear devices

Before we delve into the details of the Chernobyl incident and the long-term recovery issues, we will summarize ~~need to refresh our knowledge of~~ some key concepts about radiation~~activity~~. ~~For the next few minutes, w~~We'll define what radioactivity is, different types of radioactivity, how ones becomes contaminated with radioactive material, and the key differences between ~~the types and persistence of~~ radioactivity potentially released from ~~by~~ nuclear power plant disasters, nuclear bombs, or~~and~~ radioactive dispersal devices~~, or "dirty bombs"~~.

The word *radiation* has many meanings. There are different types of radiation, many which are not harmful at all. *[Graphic - electromagnetic spectrum]* Television waves, radio waves, and radar are all examples of radiation, and none of these cause harm to living organisms under normal conditions. These types of radiation are called *non-ionizing radiation.*

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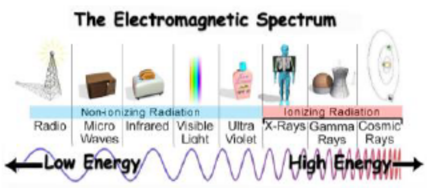

The other general category of radiation is called *ionizing radiation* which is different from non-ionizing radiation because it has enough energy to displace an orbiting electron from its nuclear structure. *[Graphic: an atom that looks like a bunch of balls with a couple of electrons flying around it]* Humans have evolved in a radioactive environment from naturally occurring radioactive elements of uranium, thorium, and potassium elements found on earth; cosmic rays from space; and more-recently man-made radiation sources from medical X-rays. This background radiation varies throughout the world and depends on many factors like altitude, soil conditions, and location on earth.

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Outline of what's to come *(1 min) – road map of where we're going: Definition of terms, description of incident, immediate response, long-term response, and discussion of U.S. preparedness for such an event.*

Language from REMM Website video. Can we take the video from REMM website and have it narrated by our narrator? Time = 1 min 52 seconds.

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"When a person is near a source of radiation, some type of radioactive material, he or she can be exposed to the radiation emitted by this source. However, he or she does not become contaminated.

One way to think about exposure is to think about X-rays. When a person has a chest X-ray, he or she is exposed to radiation, but does not become contaminated with radioactive material.

A person can reduce his or her exposure to radiation, if he or she is shielded in some ways from the radiation, for example, if the person is behind a concrete wall, or if the radioactive source is inside of a lead container.

In order to become contaminated, radioactive material must get on the skin, or clothing, or inside of the body. For example, if radioactive material is incorporated into a dirty bomb, a conventional explosive, such as dynamite, that has been laced with radioactive material, then people could become contaminated when the device is detonated. Radioactive material on the outside of the body is called external contamination. When a person becomes externally contaminated, simply removing the clothing can remove up to 90% of the contamination. Gently washing the skin and the hair can remove most of the remaining contamination.

If a person ingests or inhales radioactive material, it can become incorporated in the organs of the body. This is called internal contamination. When a person is internally contaminated, depending on the type of radioactive material with which they were contaminated, certain medications can be administered to speed up the rate at which the radioactive material is eliminated from the body." For example Prussian blue is effective to eliminate cesium from the body and was used on animals following the Chernobyl incident to lessen the cesium concentration so the population can drink their milk and eat their meat.

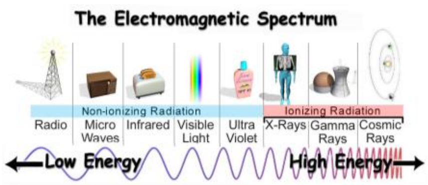
Commented [JJC3]: This last sentence is my insertion

~~**2. General Info about Radioactivity and nuclear devices**~~

~~**2.1 A Radiation Primer**~~

To understand some of the concepts we will present in this documentary, it is important to first review some basic radiation terminology and characteristics.

The word *radiation* has many meanings. There are different types of radiation, many which are not harmful at all. *[Graphic - electromagnetic spectrum]* Television waves, radio waves, and radar are all examples of radiation, and none of these cause harm to living organisms. These types of radiation do not have enough energy to cause damage to living tissue, and are called *non-ionizing radiation*.



The other general category of radiation is called *ionizing radiation* which does have enough energy to cause damage to living tissue. Ionization is a destructive process that causes atoms or molecules to lose electrons.   X-rays, cosmic rays, and nuclear radiation are types of ionizing radiation.

Many radioactive materials occur naturally. For example, granite contains remnant radioactive isotopes from the formation of the earth, and when granite erodes, these radioisotopes are carried away as sand and clay that form the soil around us – there are beaches in Brazil with such high natural radiation levels that they have restricted access. Sand and clay are also used to make building materials such as brick and concrete, which may emit low levels of radiation. Other naturally occurring radioactive isotopes are created when cosmic rays interact with atoms in the atmosphere. We are also exposed to manmade radioactive materials that have been released into the environment. Nuclear weapon testing has contributed to a slight increase in background radiation. You may also be exposed to radiation through medical procedures such as x rays. You are exposed to radiation, known as background radiation, every day, and the amount of background radiation you are exposed to depends on where you live.

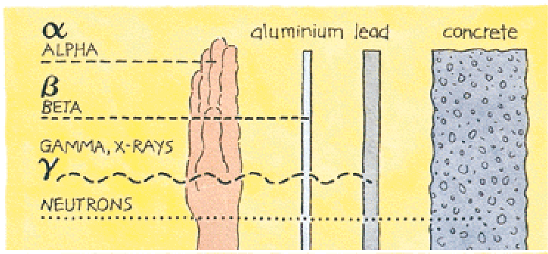
Nuclear radiation, which comes from the nucleus of an atom, is the type of radiation that most people think of when discussing radioactivity, and that is the focus of our discussion.

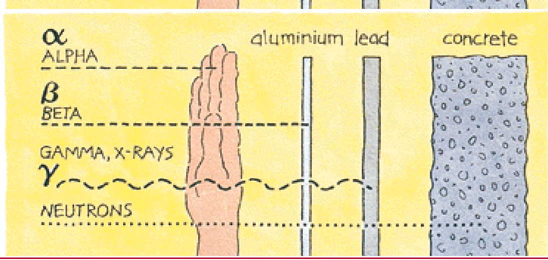
Remember that an atom is made of neutrons and protons that form the nucleus and electrons that orbit around the nucleus. *[Graphic: an atom that looks like a bunch of balls with a couple of electrons flying around it]* There are over100 different types of atoms and each has a specific number of protons that identifies the atom as an *element*, such as oxygen or iron. For example, the element uranium always has 92 protons. However, the number of neutrons can vary. Elements with the same number of protons but different numbers of neutrons are called *isotopes*. For example, uranium can have 138 neutrons or 146 neutrons. Uranium with 146 neutrons is known as the isotope U-238.

[Graphic: table of uranium isotopes]

Radionuclide	**Protons**	**Neutrons**
Uranium-230	92	138
Uranium-235	92	143
Uranium-238	92	146

~~Certain isotopes are unstable because they have too many protons or neutrons. They essentially have too much energy and they release that extra energy to become more stable. This happens spontaneously and is called *radioactive decay*, and these isotopes are radioactive and are called *radioisotopes*.~~ Radiactive materials ~~oisotopes~~ release energy primarily as four types of radiation: alpha particles, beta particles, gamma rays, and neutrons~~. Each type of radiation has a different ability to penetrate materials~~ *[see graphic]*. ~~For example, alpha particles can be stopped by a piece of paper, whereas gamma rays can penetrate skin and thin sheets of metal.~~





Text from the REMM Video 1 min 33 sec: [I suggest we use the REMM Video for this section.]

"Alpha particles may be ejected from the nucleus of an atom during radioactive decay. They are relatively heavy and only travel about an inch in air. Alpha particles can easily be shielded by a single sheet of paper, and cannot penetrate the outer dead layer of skin, so they pose no danger when their source is outside the human body.

Beta particles are essentially electrons emitted from the nucleus of a radioactive atom. They are lighter than alpha particles, and can travel farther in air, up to several yards. Very energetic beta particles can penetrate up to one half an inch through skin and into the body. They can be shielded with less than an inch of material such as plastic. In the case of lower energy beta particles, the outer layer of clothing can act as an effective shield.

Gamma rays can be emitted from the nucleus of an atom during radioactive decay. They are able to travel tens of yards, or more, in air, and can easily penetrate the human body. Shielding this very penetrating type of ionizing radiation requires thick dense material such as several inches of lead or concrete.

Neutrons can be released from the nucleus of an atom during a fission reaction, such as within a nuclear reactor, or upon detonation of a nuclear weapon. Neutrons, like gamma rays, are very penetrating, and several feet of concrete is needed to shield against them.

~~Nuclear radiation is measured in several different ways. When we talk about the amount of radioactive material, we don't use weigh or volume because it does not have much meaning. Instead, we talk about the amount of radiation emitted from the material, the *radioactivity* (or *activity* for short) of the material.~~

~~Activity is usually measured in *curies*, which is the amount of radiation emitted by one gram of Radium-226. A curie is equal to 37 billion disintegrations per second, or 37 billion gamma rays, alpha particles, or beta particles per second. The physical amount of material to make one curie could be one gram of Radium-226 or thousands of kilograms of some other radioactive material. That is why the amount of material is not important but the activity of the material is!~~

How quickly a radioactive material decays is measured by it's ~~The activity of a radioactive material is closely related to the material's~~ *half-life*, or the amount of time it takes for the radioactivity of the material to decrease by half. For example, cesium-137 ~~if the h~~half-life is about 30 years~~of a radioisotope is one day~~, so about half of the cesium-137 released during Chernobyl accident in 1986 will have decayed by 2016. ~~then after one day, half of the material will have decayed. The remaining half is still radioactive, so after another day, half of this portion will have decayed.~~ The decay process continues ~~until no more radioactive material remains. Depending on the starting amount, i~~and after ~~t takes about~~ 7 to 10 half-lives (210 years to 300 years), ~~before~~ the cesium- radioactivity decays to ~~is~~ near background levels ~~of radiation~~. This presents a long-term scenario in which humans may be exposed in a contaminated environment unless something is done to decontaminate the area.

~~Each radioactive isotope has a unique half-life. *[graphic - half-life table]* Half-lives of some isotopes are billions of years; other isotopes have half-lives of just a few seconds. Isotopes with shorter half-lives have higher activity, and tend to pose more serious health threats. This makes sense because a short half-life means a material is emitting a lot of radiation in a short time.~~

~~**Isotope**~~	~~**Half Life**~~	~~**Origin**~~	~~**Uses**~~
~~Uranium-238~~	~~4.5 billion years~~	~~Naturally occurring~~	~~Armor-piercing projectiles~~
~~Carbon-14~~	~~5,730 years~~	~~Naturally occurring~~	~~Carbon dating fossils~~
~~Cesium-137~~	~~30 years~~	~~Manmade~~	~~Geiger counters~~
~~Iodine-131~~	~~8 days~~	~~Manmade~~	~~Treat thyroid cancer~~
~~Technetium-99m~~	~~6 hours~~	~~Manmade~~	~~Medical imaging~~
~~Strontium-97~~	~~9 seconds~~	~~Manmade~~	~~None~~

~~Half-life is also important from the perspective of environmental cleanup. If a material with a long half-life is released, it will take a long time to decay to a harmless level. Cesium-137, one of the isotopes released by the Chernobyl accident, has a half-life of 30 years. Cesium-137 continues to be the primary contaminant of concern in most of the areas affected by the Chernobyl accident to this day. After 32 years, almost half of the Cesium-137 released by the accident remains.~~ On the other hand, another~~one of the other major isotopes~~ radioactive element released by the accident, ~~(~~Iodine-131, ~~)~~ has a half-life of 8 days. This presents a short-term scenario because it decayed away about 56 to 80 days after the accident. During that period Iodine-131, released as gas and was inhaled by a large population. It also was found in the milk from animals that ate Iodine contaminated feed. An effective treatment to reduce or prevent the adverse affects from Iodine is to take Potassium Iodine tablets. The stable form of iodine in these tablets prevent the radioactive form of iodine from depositing into organs in the body. Iodine is only a concern where certain nuclear reactions occur like in a nuclear reactor or atomic explosion and is not likely to be an agent used in an RDD attack. ~~was a major health concern shortly after the accident, but it has decayed away by now and it is no longer a problem.~~

~~There is one more basic element of radioactivity that we'll need to understand before we proceed: *nuclear reactions*. A nuclear reaction is one where the nucleus of an atom is changed, releasing incredible amounts of energy. At Hiroshima and Nagasaki, *uncontrolled* nuclear reactions occurred in a split second, releasing huge amounts of energy and radioisotopes with short half-lives. Most of these short half-life isotopes have decayed away, and the cities of Hiroshima and Nagasaki are now vibrant urban centers. *Controlled* nuclear reactions such as those used at nuclear power plants, on the other hand, take place over~~

~~longer periods and create more radioisotopes with long half-lives. Both controlled and uncontrolled nuclear reactions create long and short half-life radioactive isotopes, but a controlled nuclear reaction creates a much higher proportion of long half-life isotopes. This is a fundamental reason that Hiroshima and Nagasaki are active urban centers with large populations, but the exclusion zone around the Chernobyl plant is expected to be uninhabitable for hundreds of years.~~

[NOTE – We may need to get into the discussion of dose later in the documentary, especially when we kick into the residual levels of contamination that are left. At this point, we've defined too many new terms, yet hit the highlights – isotopes are created by nuclear reactions, and they can be radioactive. The short half-life isotopes are a problem because they release a lot of energy fast. The longer half-lives are an ongoing problem because they really don't go away.

In a similar vein, we may want to introduce the idea of fallout, dispersal patterns, and hot particles later rather than here in the primer. I chose to put that later in the story, as this is a long section with a lot of new terms and it's pretty dry – best to keep it short and focused if we can.]

Commented [JJC4]: I agree with your comment

2.2 Types of incidents we might face - *Introduce the types of incidents we might face and draw distinctions between them:*

Now that we've covered some of the basics of ~~nuclear~~ radiation, we need to consider what sort of threats we are up against. Terrorists are unlikely to engage in conventional warfare. Quite simply, they're outnumbered and outgunned. To compensate for this handicap, they seize whatever advantage they can to even the odds and multiply their influence. One worrisome possibility is that terrorists may gain access to chemical, biological, or radiological agents. This documentary focuses only on radiological agents. There are four~~three~~ scenarios~~ways~~ terrorists might use~~release~~ radiation in a terrorist attack.

- ~~radioisotopes.~~The first scenario is called a radiological exposure device or "RED". In this scenario, a highly radioactive source is placed it in a hidden space near a populated area to expose those who wander near it.
- The second scenario is called a radiological dispersal device~~s~~, or "RDD" ~~(RDDs)~~ that releases radioactive materials via many different dispersal techniques, including the most recognized form of using conventional explosives to form a "dirty bomb."
- The third scenario is an attack on a commercial nuclear facility ~~without creating a nuclear reaction,~~ causing a release from the~~a~~ nuclear power plant or from the spent nuclear fuel stored on-site.
- And the final scenario, the one most feared, ~~or~~ an improvised nuclear device or "IND" where a terrorist organization steals or creates a bomb capable of providing the destruction nearly equal to that of the Hiroshima or Nagasaki atomic explosions. ~~bombs~~.

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Radioactive dispersal device (RDD):

- An RDD is a device that disperses radioactive materials. It could be a conventional bomb that contains radioactive materials and scatters those materials and other debris when it detonates, or it could scatter radioactive materials using a non-explosive device, such as a crop duster. The easiest and therefore most likely way to release radiological agents would be to detonate a type of RDD known as a dirty bomb. *[image – an explosion in a city]* This type of weapon would use radioactive materials, but the materials would not undergo a nuclear reaction that releases large quantities of energy or creates radioisotopes. An RDD would probably use existing medical radioactive materials such as Cesium-137 and Cobalt-60 which are used to treat cancer or industrial radioactive materials such as Americium-241 and Iridium-192, which are used in devices that measure density and thickness.

- A dirty bomb could cause serious injuries from the explosion, but it most likely would not have enough radioactive material to cause serious radiation sickness among large numbers of people. *[Dirty bomb clip from REMM Website radiation principals video? http://remm.nlm.nih.gov/radprinciplesvideo.htm]*

- An RDD would likely involve contamination over a densely populated area and initial confusion and lack of information, but would differ from Chernobyl in that the contaminated area would be significantly smaller and the total amount and intensity of radioactivity released would likely be much, much lower.

A second way terrorists could release radioactive materials would be to intentionally cause an accident at a Nuclear Power Plant (NPP).

- Radioactive materials could be released from a nuclear plant by a fire or explosion or an accident involving the reactor core.
- The world has suffered several NPP accidents, including the Chernobyl meltdown in 1986, partial meltdowns at the Three Mile Island nuclear plant near Harrisburg, Pennsylvania in 1979 and the Chalk River Nuclear Plant near Ottowa, Ontario in 1952, and radioactive releases caused by a fire at the Windscale reactor near Liverpool, England in 1957 and by an earthquake at a nuclear plant near Kashiwazaki , Japan in 2007. *[still images of a couple of these disasters – TMI and images of steam being released from the Kashiwazaki plant ought to be available – perhaps response personnel running around as well.] From Google images "Kashiwazaki":*



- There are a several technical reasons that a nuclear accident like the Chernobyl meltdown are not likely to happen in America. First, the design of all U.S. reactors is different from the design of the Chernobyl reactor, and second, safety and design regulations are more stringent. The technical design of U.S. reactors is different than the Chernobyl reactor and makes major releases of radioactive materials extremely unlikely, if at all possible.

The most devastating way to release radiological agents would be to construct and detonate an Improvised Nuclear Device (IND).

- An IND is a small nuclear bomb where materials undergo a nuclear reaction. An IND would be catastrophic and would likely cause mass casualties. The technical difficulty of obtaining the materials and creating the conditions for a nuclear reaction make this a less likely scenario than an RDD. . However, a stolen nuclear weapon by a terrorist organization is of great concern. *[graphic – mushroom cloud]*
- The contaminated area would be big but the amount of highly contaminated land would still be smaller than Chernobyl. The reasons for this are complex, but simply put, a nuclear bomb produces less radioactive materials and spreads them less far than the Chernobyl accident.
- Most of the types of radioactive materials released by an IND would decay relatively quickly; most is gone within the first 24 hours and almost all within 2 weeks. However, a small amount of residual contamination would remain for a relatively long time.

Summary: To sum up, we face three main types of incidents that might release radioactive materials: RDDs, nuclear power plant accidents, and improvised nuclear bombs.

- A dirty bomb is probably the most likely scenario, and it would likely disperse commercially available medical or industrial radioactive materials over a wide area without undergoing a nuclear reaction. The radioactive materials released would probably be persistent in the environment for a relatively long time, and they may contaminate a populated downtown area.

- A nuclear power plant accident could release similar types of radioisotopes to those released by the Chernobyl incident: both long- and short-lived radioisotopes that may cause widespread contamination. However, the scale of the disaster is not likely to match the uncontrolled meltdown at Chernobyl, where a fire raged for 10 days, spewing nuclear and radioactive materials into the atmosphere and spreading them over hundreds of thousands of square miles.
- Detonation of an improvised nuclear bomb would be a catastrophic event that could devastate a city and cause widespread destruction. A nuclear bomb would involve a nuclear reaction that releases formidable amounts of energy and scatters radioactive fallout over a large region. Most of the types of radioactive materials released would decay relatively quickly. However, a small amount of residual contamination would remain for a relatively long time.

Switch gears – Now that we've covered a few of the basics about radioactivity and have a better feel for the types of incidents we're up against, we can get back to our story about Chernobyl. The common element to all of these types of incidents is the potential radiological contamination of a wide area. We will use the Chernobyl experience to discuss the issues involved with recovery from a wide-scale radiological event. Let's take a look at what happened at Chernobyl.

3. The Chernobyl Incident – What happened?

Explanation of why they had a meltdown in the first place, how the disaster unfolded, and what happened as a result. The focus of this section is what happened up to the evacuation of Pripyat. There will be good footage here that should give the viewer an idea of the magnitude of the disaster and it'll set the stage for the recovery. Also discuss fallout, what it is, heavy (hot) particles close, lighter particles far, control of wind, precipitation.

In the early morning hours of April 26, 1986, the Chernobyl nuclear plant near the town of Pripyat in what is now the Ukraine, experienced the worst nuclear power accident in history, an uncontrolled nuclear reaction and resulting explosion and fire, which sent a cloud of radioactive material over the western Soviet Union and Europe. The reactor burned for 10 days, releasing radioactive gases, vapors, aerosols, and particles and contaminating thousands of square miles in Ukraine, Belarus, Russia, and western Europe. *[image – nuclear technicians at the plant, the plant on fire, people suiting up to deal with it…]*

The Chernobyl nuclear plant is located near the border between Russia, Ukraine, and Belarus, about 70 miles northwest of the City of Kiev, the nearest major population center. Kiev had a population of about 2.5 million at the time of the disaster. The town of Pripyat is located about 2 miles from the reactor and had a population of about 45,000 people at the time of the accident. *[image – a map showing the three countries, the plant, Pripyat, and Kiev – we may have to make this]*

The exact cause of the accident is still uncertain, but it is widely accepted that a combination of design flaws and operator error caused the accident. At around 1:00 AM on April 24, the plant was conducting a safety test to determine if the cooling system pumps could operate if the external power failed. The generally recognized account of the incident is that operators disabled an automatic shutdown system and powered down the reactor by inserting control rods into the core to create the low power conditions required for the test. However, the power decrease was greater than anticipated, and the operators increased the power output by manually removing some of the control rods. Within seconds of withdrawing the control rods, power in the reactor shot up to dangerous levels, creating an energy spike. Operators tried to reinsert the control rods to slow the reaction, but due to the power spike in the reactor, the rods shattered and could not be lowered further into the reactor core to control the reaction. *[Image – reactor personnel, the power plant, and a plant exploding- could be a generic explosion if we can find such a thing]*

The cooling water vaporized within seconds, causing a steam explosion that blew the lid off the reactor. The sudden inrush of oxygen caused a graphite fire, and the reactor core and building burned for 10 days, releasing into the atmosphere more than 100 times the total radioactivity of the Hiroshima bombing. The fire carried radioisotopes upward into the atmosphere where they traveled with the prevailing winds. According to an IAEA report, *[IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience p.21]* winds were initially to the northwest, but varied over the next several days so that all points of the compass were downwind at some point while the fire in the core continued burning. To further complicate matters, scattered thunderstorms and rainfall throughout the area brought down some of the airborne material to ground level and deposited it, forming an irregular radioactive fallout pattern over thousands of square miles. *[graphic – figure 3.2 IAEA report, image of fallout pattern IAEA report Fig 3.6 and http://www.chernobyl.info/index.php?navID=2]* ,

At the time of the accident, Ukraine was part of the former Soviet Union, a closed society with centralized control of the press. Soviet premier Mikhail Gorbachev had taken office about 1 year earlier, and had not yet implemented his policy of Glasnost, or openness. *[image of Mikhail Sergeyevich]* The first public notice of the gravity of the situation came on April 27from Sweden, when workers at the Forsmark Nuclear Power Plant (about 700 miles away) detected elevated levels of radioactivity that were not from local sources. *[image – map showing Forsmark plan on east central coast of Sweden and Chernobyl/Kiev, perhaps with an arrow showing distance between them]* Soviet authorities either did not fully understand or intentionally downplayed the severity of the accident. Evacuation of the nearby town of Pripyat began at 2:00 in the afternoon of April 27, a full 36 hours after the accident. As late as May 1, major Soviet newspapers featured May Day celebrations rather than the Chernobyl disaster on their front pages, projecting an air of normality and muting the significance of the incident. *[images of soviet newspapers – Pravda]* Soviet premier Gorbachev did not appear on television to discuss the incident until May 14, several weeks later. An initial period of silence, followed by reassuring comments from the government, appears to have had the opposite effect to that which was intended: concerned citizens feared that the incident was far worse than they were being told.

Transition: The incident involved unprecedented radiological contamination of a huge inhabited area combined with a lack of reliable information in a closed society, which created suspicion, uncertainty, and inefficiency. What can we learn from the incident? How did miscommunication and a lack of communication affect public perception and willingness to alter their lives to accommodate the new reality? How did the decontamination of the area proceed and what was life like in the affected areas?

To examine these questions, we interviewed Larisa Leonova and Vira Yakusha. Larisa is a chemist with USEPA who was one of the early responders. At the time of the accident, she was managing a laboratory in Moscow part-time while earning her PhD in chemistry. Larissa volunteered to offer her services and traveled to Kiev several weeks after the incident, and worked in the area around Pripyat, trying to convince local residents to leave the area.

> *[Image – LL8 3:51:54 – 3:52:21 "My Name is Larisa Leanova and I live in United States oh, it's my twentieth years. And um, back when Chernobyl happened I was ah, twenty-eight years old and four years is graduated from ah, university. And I was working as a chemist, basically part time a lab manager and part time doing my Ph.D research work. Back when the Chernobyl happened I was in Moscow, I always lived in Moscow."]*

Vira Yakusha is a computer scientist with a consulting firm in Washington DC. At the time of the incident, Vira was a resident of Kiev and a recent graduate of Kiev University. Perhaps most important, Vira was pregnant with her first child, and she brings the perspective of an expecting mother, and a member of the general public reacting to the events occurring around her.

> *[Image – VY4 2:33:03 – 2:34:00 "My name is Vira Yakusha and ah, I was born in Kiev. And ah, I lived there for my entire life. And I loved the city a lot. And ah, I was there as a just a member of general population when Chernobyl tragedy struck. And so my perspective is a perspective of a lay person who is not professionally involved in the nuclear, in the nuclear industry, but who was, who's life*

was directly affected by what happened. And ah, my story is a story of person who is trying to comprehend what's going on and trying to do the best, what is best for my family, for health of my family and ah, trying to live my life as ah, as simple as possible if it's possible in the difficult circumstance."

4. The Early Response

We'll certainly be able to identify some good footage/photos of this part, then we can get into the more meaty and meaningful information in the Health Physics articles. We can also discuss the fallout pattern and how it was highly variable based on precipitation (Balinov, p. 385), and what fell out where (short-lived and long-lived isotopes (nuclear reactions) We could introduce the concept of distance, time, and shielding here - Dose rates decreased by three orders of magnitude in the 3 km from the plant to Pripyat (Hinton et. al. p.430).

Balanov mentions evacuation, distribution of stable iodine KI tablets to Pripyat (but not the surrounding area), and restriction of the food supply as the most effective immediate measures. For the immediate affected area, outline the basic measures – establishment of 30 km exclusion zone, evacuation, nuclear waste repositories. For the larger (and more populous) area, outline other measures - bathing, clothing, hygiene … We can discuss these systematically, and we can follow each with CDC/REMM/DHS recommendations. I like that approach because we can tie together history, first-hand anecdotes, and current recommendations:

Response to the disaster was disorganized, improvised, and chaotic. The main priority of the first responders was to put out the fire and then isolate the reactor core. The first on the scene were local firefighters and soldiers who were not aware of the grave threat of exposure to very high levels of radioactivity. By 5:00 AM, the firefighters extinguished the fires on the roof of the reactor building and in the surrounding area, thus protecting the other reactors at the Chernobyl facility, but they were not able to put out the burning reactor core. Many of these heroic firefighters and soldiers died of exposure to radiation within days or weeks. *[They are commemorated with a statue in the town of Pripyat – image of the famous firefighter statue?]*

To put out the fire in the core, the authorities tried several approaches, including dropping 5,000 tons of sand, clay, and lead onto the core by helicopter. *[image of helicopters dropping bags of stuff]* and injecting liquid nitrogen into the surrounding soil in order to cool the reactor. These efforts were not terribly effective at first – because of the extremely dangerous conditions and the extremely hot graphite fire, it took workers 10 days to put out the fire in the core.

Although the very first responders – the firefighters and the soldiers who first arrived on the scene to put out the fires – did not realize that the disaster was releasing high levels of radioation, the authorities soon recognized that the disaster had exposed the core and was releasing highly radioactive particles and smoke, and ordered evacuation of the surrounding area. The town of Pripyat, located 2 miles northwest (and downwind) of the reactor, was evacuated on Sunday, April 27, one and one half days after the disaster. The residents were told to pack for three days and to leave household pets behind. The motivation for giving such a short timeframe for the evacuation was logistical: to limit the amount of baggage and personal belongings to be transported and to expedite the evacuation. A convoy of 1200 buses carried the residents and their belongings away, and the evacuation was reportedly completed in about three hours. *[image – there are lots of images of evacuation of Pripyat – the long line of buses, lines of people getting on them and so forth.]*

In the following days, authorities measured radiation levels in the areas surrounding Chernobyl to determine the extent of contamination. Radiation levels above background were measured at distances of hundreds of miles away, but the government focused on the most heavily contaminated areas. The USSR Ministry of Public Health had set maximum permissible radiation limits for workers based on a one year exposure. However, the limit assumed a person would only be exposed to the radiation while working, or less than 1/3 of a year instead of the entire year. This limit was used to determine the area that would be evacuated and become known as the Chernobyl Exclusion Zone. The zone was determined to be a 30-kilometer (about 19 miles) radius around Chernobyl.

Isolating the reactor was an immediate priority once the fires were extinguished and the nearby towns were evacuated. To make a safer work zone, the area surrounding the reactor was cleared of debris. The contaminated debris, reactor core fragments, and surface soils from the immediate area around the reactor were placed in a concrete reinforced gallery hastily constructed around the reactor. Removal and shielding of this material made the area safer to work in.

Other soils and debris were stored in a large number of temporary shallow trenches and impoundments within the exclusion zone and covered with soil to provide minimal shielding and to reduce potential for wind to mobilize the contaminants. These trenches and small impoundments were not designed as permanent storage, yet most of them remain to this day. *[Important to demonstrate residual sources – Image – a generic trench and pile of dirt. Doesn't have to be from Chernobyl]*

After cleaning the blast area, a structure known as *the sarcophagus* was constructed of concrete, steel plates, and beams to isolate the most contaminated wastes and the reactor. The sarcophagus was constructed between May and November 1986 under very hazardous working conditions. *[images of the sarcophagus abound. Let's get some]* The structure was hastily designed and erected and has been exposed to the elements and infiltrated by moisture for more than 20 years. A new safe confinement structure is currently being designed to address the shortcomings of the sarcophagus and to isolate the reactor core and the most contaminated wastes for the next100 years. *[Image: New safe confinement structure image is on cover of IAEA report: Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience]*

5. The New Reality *–The focus of this section is what happened right afterwards in Kiev. The structure of this section will go into the nuts and bolts of living in the contaminated environment interspersed w/ tidbits from interviews. The objective is to pair "what they did" with what CDC says you are supposed to do, and to examine it in the order of: information flow, hygiene that immediately knocks back the contamination (washing, clothing), the food supply (food, farmland, etc.), and cleaning up the town.*

After the immediate issues of putting out the fires, evacuating the exclusion zone, gathering up and removing the radioactive debris, and isolating the reactor were taken care of, life continued in the surrounding areas. However, in the face of an unprecedented event, the local and national authorities were uncertain how to proceed. Larissa Leonova, a chemist who now works for USEPA, volunteered to travel to Kiev in the first weeks after the accident to lend a hand.

> *[LL4:01:56- 4:02:35 "our group of volunteers were basically invited by um, some sort of the organization which were created back there and basically consist um, of very strange group of people who -- represented by Army and by some ah, local officials which were not scientists. They were just the politicians and they were trying, trying to create some sort of the response. And um, again you know first couple of weeks it was basically you know not enough data or no information about plume or no information which territory it's more affected."] and*
>
> *[LL4:03:03 – 4:03:14 "we were among of the first, to my knowledge, volunteer group who went there and who got um, ah, who were involved in ah, um, some sort of the response."]*

One of the first assignments of the group of volunteers was to provide the local populace with some basic guidance about how to limit exposure to the radioisotopes released by the plant.

> *[LL4:05:05 – 4:05:25 "that's the season when everybody in the Ukraine um, pick up the strawberries. And Ukraine, it's very high in the strawberries and actually you know like um, everybody over there -- middle of the May and June the strawberries is the best place -- taste unbelievably good and everybody has a strawberry growing in their backyards and garden."] and*

[LY4:05:40 – 4:05:51 "So, the first advice which we wrote was very silly, we're saying like do not eat the strawberries if they are you know like right besides the dripping line um, from your roof."] and

[LL4:06:00 –4:06:15 "The other thing was we were basically advising that ah, try to have at least a bucket of water near the entrance of your door and before -- after you coming from the street to your house, wash you um, shoes and remove your shoes, try to not bring the additional dust."]

5.1 Information Sources

One of the biggest problems with the Soviet response to the Chernobyl disaster was a lack of credible information. At the time of the accident, the Soviet Union was a closed society, and the official Soviet news sources were not known for their openness. Almost a week after the accident, the major newspapers were not discussing the ongoing nuclear disaster that was contaminating much of the USSR and Europe. As a result, citizens were forced to turn to informal news channels, networks of associates, and whatever international news they could find on short-wave radios.

[LY8 3:52:26 – 3:53:33 "we didn't get any information about Chernobyl um, officially -- almost like a week after the accident happened. When I first time heard about it -- it was the first day ah, first working day basically it was a Monday, I believe it was 27th or 28 of the April. I came to work and one of my co-workers told me, "Did you hear the news that BBC's announcing"? And I said, "No, I basically was very busy this weekend, I didn't listen to any BBC". And we all had the habit to listen one of them ah, for a radio station and um, early morning Monday exchange the news. What really was get -- what we were getting from the abroad and what was um, broadcast in the Russian radio stations. So, my co-worker told me that he heard that something happen in the Ukraine and Sweden is picking up ah, increased radioactivity levels. And I said, "I haven't heard of that". But you know from that moment on we were basically very ah, uptight and tried to catch any news we could."] and/or

[VY1 1:29:29 – 1:29:41 "Because nobody was giving you any, uh, hard information at this point, assumption was that, uh, probably things are much, much worse than officials would tell you. And, uh, so the first week, uh, we were living our life more or less our life as usual] and

[VY1 1:23:21 – 1:23:36 "we were very skeptical about official sources of information per usual, uh, so we turned onto the, uh, Radio Free, uh, uh, what was that, what was commonly called The Voices From Abroad, and, uh, there were several radio stations that they were broadcasting towards the Soviet territory, and one of them was Voice of America, another was Radio Free Europe and one of them was BBC and such. And they were all, um, the Soviet, uh, government tried to jam them, and so you had intelligence or people who were curious about what was going on and wanted to have more information that was officially available, they were trying to find the Voices on the short wave bands."]

VY2 02:05:28 – 2:05:37 "There is a difference between, uh, questioning authorities or expecting answers to a question. So I was, uh, very aware that authorities are not telling the whole truth. But I never expected to, uh, get answers, truthful answers, if -- if I would start questioning."

[VY2 1:58:10 – 1:58:50 "I am sitting in the back seat of the car, and, uh, our radio is on, and the radio is official so it's radio and there's a news report and oh, everything is, uh, contained in Chernobyl, everything is fine, in Kiev there is no danger at all in Kiev, I mean, the population should not worry. And I'm thinking yeah, that's, it's an interesting twist because here I am from Kiev, and, uh, I'm too dirty to enter Moscow but in Kiev everything is fine. Yeah, and, um, it was a surreal moment"]

If a similar incident were to happen in the U.S., we can expect a much more open flow of information. Not only would the major news media cover the disaster, but the U.S. Department of Homeland Security, the Centers for Disease Control (CDC), the U.S. Environmental Protection Agency (U.S. EPA) and other agencies would post information on what do. Some good internet sites to obtain information on how the public should respond to a radiological incident can be found at the Department of Health and Human Services' Radiation Event Medical Management site *[Show a screen shot and the web address: www.remm.nlm.gov]* U.S. EPA's Radiation Protection program page *[show screen shot and address: www.epa.gov/radiation]* and the U.S. Department of Homeland Security's Ready America Radiation Threat site *[Screen shot and www.ready.gov/america/beinformed/radiation.html]*.

> *[JC2 5:08:32 - 5:09:42 "There's a lot of resources available to folks to learn more about long-term recovery and the types of information that they -– that's going to be concerned or they're going to be interested on. I would recommend a lot of folks visit uh, vetted, scientific, internet websites. Uh, for example, usepa.gov uh, the cdc.gov for public health inquiries, there's a nice website that's available by various professional societies, the Health/Physics Society, which is hps.org. Um, the National Commission for Radiological Protection is also another good website uh, the ncrp.com and there's various international uh, websites as well.*
> *I.A.E.A, that stands for the International Atomic Energy Association, as well as the I.C.R.P., the International Commission for Radiological Protection. These are all scientifically valid, vetted information that can provide a lot of information to folks that are concerned about the public health issues, environmental issues and some of the socio-economic aspects of why certain things and clean, cleanup levels have been set the way they have."] and*

> *[JC 5:10:00 – 5: 10:36 "You're going to have a large variety of professional folks, subject matter experts, some who will say, any amount of radiation is not good for you. Others will say, you can take X amount and it's not going to hurt you at all. The truth probably is somewhere in between and what's more important is that folks understand that and they have to come to, to a conclusion themselves. The best way to do that is to educate yourself on what the risks are to you, your family, your friends, your loved ones um, and do that by educating yourself at these various websites."]*

Close this section with

> *[VY4 2:41:07 - 2:2:42:14 "This is such a society where ah, different ah, groups of people have their say. So there is always a balance of forces. And the result of this balance, ah there is a much better possibility that the real information, the scientific information will come out and be available and be widely available and with the internet, it's, it's, it's even, it's even better now. Because I remember how I was just raking my mind trying to remember what I was taught about levels of radiation. And now I fully expect it to be available, this information to be available on the web. And probably guidelines that I will have from authorities. I will be more willing to trust them and to follow their recommendation, because I um, understand that it's much more reliable and much more better grounded reality than it used to be on the Soviet. So it's a different story."]*

> *[Not sure this is the right place for this quote, but it touches on the transparency issue that is the heart of this section … JC1 5:06:45 - 5:07:29 "here in America, our culture is one who is much more informed of the area and will have a lot more activity uh, and involvement in the decision-making. Which can make this process cumbersome, and much longer uh, as opposed to living in a culture where you were dictated what was going to happen and how things were going to be done. That's not likely to occur here. Um, so it could be a challenge for us to deal with all the different stake holders which is an important process. The big lesson is, transparency, tell them the truth and dealing with some of the toughest questions are ultimately what going to make this a successful effort for the agency."]*

5.2 Food Supply

The massive amount of radioactive fallout had far-reaching consequences. Internal exposure to radiological contaminants through consumption of contaminated food and water is a very significant exposure mechanism and the food supply was an immediate concern. According to an IAEA review of the incident, the most effective countermeasures were prohibiting animal feeding with pasture grasses in the affected areas and rejection of milk based on radiological monitoring. 20,000 agricultural and domestic animals were slaughtered immediately, and the remainder evacuated. Due to lack of forage and animal care facilities, an additional 120,000 animals were slaughtered from May to June 1986. *[image – here we can show images of pigs and cows being screened with radioactivity meters by a guy in a moon suit (ex: 42-15882699 and* 0000316032-056*), images of dead fish on the shore near the reactor]* Early responders were advised not to eat locally grown food, and surprisingly, to drink red wine instead of water:

> *[LL8: 4:20:00 – 4:20:06 "We were ordered -- we were basically -- that was our order to drink red wine, not drink water. So, that was our liquid consumption. " and LY8 04:27:54 – 4:28:08 "We were not given anything besides red wine. We were strictly advised not drink water or milk. And we were advised do not eat any um, grown -- locally grown product -- produce, nothing, no vegetables, no fruit, nothing."]*

Many locals used common sense and avoided eating locally grown foods that were probably contaminated

> *[LY8 4:14:29 - 4:14:45 "We found the people who were very educated and um, they were not eating any fresh food since the accident, since the first they heard about the accident. They were trying to eat canned food only."*

Vira Yakusha explains *her* dietary habits when she returned to Kiev with a young baby in the months following the accident:

> *[VY3 02:27:15 – 2:27:43 Well first concern ah, at that point was the food. And ah, food and again official line was that all food is carefully screened. Sources of food that contaminated milk or other ah, ah, necessities are discarded and thrown away and so you don't have worry about that. But of course we did worry. And of course we, we will try to buy imported food. As much as it was possible. But it was not that readily available.*
>
> *VY3 2:22:18 – 2:24:00 "if there is a cereal made in Hungary, probably there is less ah, a less chance that it's radiologically contaminated than the sour cream made on the local factory. Because God knows where this local factory gets their milk from. And in the first couple of weeks we were so ardent about it that I even didn't eat any bread because bread was definitely make over, made of local grains. And again, local grains could be contaminated. But after a couple of weeks without bread, I said you know what? I'm going to eat bread. Because I cannot. I need to eat something, right?"*
>
> *[VY3 02:28:35 – 2:28:51 "So there are very, there are always efforts. There are always efforts to make sure your food sources are clear. But it is almost impossible. So you have to accept at some point that you have to, continue with your life or otherwise you will just go mad."*
>
> *VY3 2:27:44 – 2:28:12 "And again, there were um, ah, some things that you cannot buy imported. For example, like your greens, your apples. And ah, sometimes you will come across imported apples with big luck. I remember my husband bought five kilos of ah, ah, a golden ah, golden delicious which is a common brand in America and they were ah, grown somewhere ah, from north of imported apples. And we were very happy. We were feeing our baby these apples for quite a long time while they lasted."*

Effects of the disaster were profound and long-lasting. As time went on and the threats posed by contaminated farmland became better understood, the local authorities undertook more sophisticated

measures to manage agricultural production from contaminated farmland. According to Mikhail Balinov of the International Atomic Energy Agency (IAEA), the most effective countermeasures were soil treatment; removal of some areas from agricultural production altogether based on radiological screening; switching to fodder crops such as rapeseed that don't assimilate key radionuclides in the contaminated areas; switching animals to clean fodder from uncontaminated areas before slaughter and milking; and feeding animals dietary supplements such as cesium binders to help the radionuclides pass through the animals without being incorporated in food products. *[image: Here we can show images like the guys in moon suits walking through a field (42-15800571), a guy with a rototiller (42-15784775), peasant gardeners (DWF15-682237), and a fallow field with a rad sign in front of it (42-15784775)]. [I think the preceding paragraph is important to keep hitting the "life goes on, radioactive contamination can be managed" theme.]*

The countermeasures described above went a long way to reducing the radiological contamination of foods from the affected areas. However, economic hardship caused by dissolution of the Soviet Union reduced the effectiveness of the agricultural countermeasures. As recently as 2001, 9% of the milk supply in the affected areas did not meet the standards for Cesium -137, according to R. M. Alexakhin and others of the Russian Institute of Agricultural Radiology and Agroecology. *[This seems to undermine the earlier message that things can be managed, but maybe it's important to note that it's not going to be perfect?]*

We close with an image of John saying something to the effect that we can't undo it, we have to manage it – the quote below is as close as I could find, and it fits this section reasonably well.]

> *[JC1 05:06:25- 5:06:43 "I think one of the largest lessons that I'm learning from the Chernobyl environment is that well, we have a contaminated area that we will never be able to get back to natural background levels. We can't turn the clock back, is what one of the quotes was said. I think that that's reality."]*

5.3 Hygiene Precautions

Contaminated dust and dirt are a very significant source of contamination to the public in the aftermath of a nuclear incident. CDC's radiation emergency web page [www.bt.cdc.gov/radiation] recommends leaving outer clothing and shoes outside and showering after an incident to reduce or eliminate radiological contamination. More recommendations can be found at the CDC web site. *[image – web address and screen shot. There's also a cheesy but understandable image of a silhouette guy showering off yellow dots at http://www.remm.nlm.gov/deconimage.htm]* Once the local authorities accepted the significance of the Chernobyl incident, they began to issue advice on hygienic practices to reduce exposure to contaminated dust:

> *VY1 01:34:00 - 01:34:30 "First Monday after, uh, after Easter so it was May -- May 5th, and the May 5th was the first day when, uh, when authorities, uh, Soviet authorities officially on the radio started to say well, things are, um, under control, but, um, for, just for personal precautions please shower regularly, try to keep dust out of the rooms, and, uh, keep your clothes laundered often, and cover the food and bread if you buy something so, uh, it's, uh, to prevent dust from, uh, coming on the food. Uh, so there were first official guidelines for general population to minimize, uh, the exposure."*

> *VY3 02:25:56 - 02:26:32 " After that first announcement, ah, they say that you should wash ah, take shower often, wash your ah, clothing often. Ah, try to prevent dust from setting on your household items. Ah, there was more information. And ah, it will become more and more detailed and instructions more elaborate this time. Then they were not that afraid to accept or admit that something wrong is going on. And, ah, we were doing this religiously. Our family. We were trying to follow everything and some more."*

> *VY3 02:14:21- 02:14:18"my family just tried to keep everything as clean as possible. Free from dust, from dirt. But ah, the thing is that you can not be 100% sure, of course. And later on, of*

course, it was not about the surfaces, of your living space, but more about the food that you are getting and ah, and ah, probably some accidental contamination that, for example, like there, rooftops for um, perceived to be very dirty. And they were in fact. So we were told or people were telling the children were told to avoid the downpours from the, from the roof, for example. If ah, water is pouring from the roof, it' probably, if it goes and fills in your overcoat, you don't want to have your overcoat to get dirty and to get rid of it later on."

Closing statement - One of the primary ways the public is exposed to radioactivity after a radiological event is through contaminated dust and soil that adheres to hair, skin, clothing, and shoes. One effective way to reduce this exposure is to shower frequently, launder clothing frequently, remove shoes and outer clothing before entering living areas, and general good housekeeping to reduce dust and dirt indoors. These hygiene precautions were successful in areas like Kiev after the Chernobyl accident, and they are also recommended by CDC and other sources. These websites provide good information on actions you can take to minimize your exposure after a radiological incident. *[image CDC rad website and address www.bt.cdc.gov/radiation, image of DHS Ready.gov rad website and address http://www.ready.gov/america/beinformed/radiation.html.]*

5.4 Children/pregnancy

Exposure to radiation can cause health problems for the general population, depending on the type of radiation, the exposure, and the individual's general health and susceptibility to illness. Some populations are particularly susceptible to the affects of radiation, and these include pregnant women and especially unborn babies. The Centers for Disease Control say that unborn babies are particularly sensitive to radiation during their early development, between weeks 2 and 15 of pregnancy, and can experience severe health effects such as birth defects, stunted growth, and brain damage. From 16- to 25-weeks, unborn babies may experience health consequences, but only if the doses radiation are very large, such as large enough to cause radiation sickness in the mother. After the 26th week of pregnancy, the radiation sensitivity of an unborn baby is similar to that of a newborn. *[Image – CDC web site and fact sheet at http://www.bt.cdc.gov/radiation/prenatal.asp]*

For the people affected by Chernobyl, radiation exposure of unborn babies was a major concern. Ms. Yakusha was living in Kiev and pregnant with her first child at the time of the accident. Upon learning of the disaster, she tried to leave Kiev as soon as she was able, to try to put as much distance between her baby and the radiation emergency as she could. Unfortunately, many people were trying the same, and Vira was unable to buy a train or plane ticket *[image –we can show a few generic Russian-looking pregnant women and happy babies, perhaps a bunch of Russians queued up at a ticket booth… We do have some photos of kids hooked up to tubes and wires, and one with their head marked in obvious prelude to brain surgery, but I think they are too negative and unsettling]*

> *VY1 1:29:20 - 01:29:27 "I was really determined, uh, to keep my baby healthy and, uh, as far as harm's way was possible."*
>
> *VY1 1:50:49 "I don't know what to do, it's impossible to buy tickets for -- for a plane, it's impossible to buy tickets for a train, but we need to get you out. And we were sitting in the kitchen and trying to figure out what kind of plan that could work"*
>
> *VY2 01:51:36 – 1:51:41 "And so we were thinking about this and that, and there is suddenly, um, uh, a buzz on the door …"*
>
> *VY2 1:51:54 – 1:52:44 "I opened the door and this is, uh, again my friend, uh, Yenna, who, uh, head of the family who were taking me to Karnyov, and he sort of looks grim, and he said you know what, I made a decision, uh, I take my, uh, girls away to Mosc -- I'm taking my girls away to Moscow because I want to get my kids out of here as soon as possible. And his, his thinking was pretty much*

the same that if the government admits so much that, uh, it's dangerous, then it's really, really dangerous. Yeah, and he said, um, okay, so my car is downstairs, uh, waiting for you, um, my wife and my kids are in the car, and we have still one place left in this car, this is for Vira. If you want to go with us you have 40 minutes to pack yourself."
[Image – How about a man standing next to an old, Soviet-style car?]

Vira left Kiev that night, and gave birth to Doreena, a healthy baby girl, four months later in Moscow. We can't say whether getting out of Kiev, about 70 miles from the disaster, in the weeks after the accident helped her give birth to a healthy child. Her child may very well have been fine had she continued to live in Kiev.

VY1 01:32:46 – 1:33:18 "Doreena, and she is, uh, 21 years old right now, and, uh, I never had any, uh, uh, health problems with her that I should, could attribute to potential exposure. But unfortunately, uh, my understanding of the nature of the whole thing is that you never can, if you have some sort of health problem you can never be 100 percent sure if it was the result of, uh, your exposure to the radioactivity at some point or it's just your particular body type or, uh, other factors that were contributing."

Reflecting on her actions many years later, Vira feels that she made the right choice given the information that she had:

VY4 02:42:38 – 2:43:38 "my personal feeling is the health of your children or your child is the first priority, because this is something that you are ulta, ultimately responsible for. So I would say what I said to myself. Put as many miles as you can between the source of radiation and yourself and your baby and try to get as much information as much reliable information as you can. And try to… I mean panic is never a good helper or a good advisor. So probably understanding is our best weapon and to know how things work and what is real danger and what is imagined danger. It is a real important difference. And the more you understand, the better your choices are, the better your behavior is. At least you're choosing between least, least possible evils. And ah, it's impossible to be in a perfect world. But in our imperfect world, you have to make your own choices. And it's better to be based on the, on the ways of reason."

[Note – one danger of this section is that it gives some cause for panic – I feel that the 'woman in the street' perspective is valuable, but the message is get the hell out of Dodge, and it appears that Vira's actions may have saved the day. If I was a pregnant woman watching this, I'd think – get away first and ask questions later. Just want to be sure we're OK with that message.]

5.4 Decontamination of Kiev

[I'm not certain how much we want to devote to how we would do things here. I reviewed the PAGs and my brief PAG description could be beefed up. I didn't spend a lot of effort on it, as I think John will have some very detailed ideas of where he wants it to go. Note that the PAG document is very detailed, yet also very flexible. Explaining the nuances of that document is not the focus of this documentary. I think the more important message is that there is a process for getting on with life after an accident, that it's already figured out, and that we'll employ it after an accident if we need to. That's how I shaded the discussion.]

Intentional detonation of a nuclear device is likely to take place in a city, and thus is quite different from the rural environment surrounding the Chernobyl plant. One of the most significant affects of the Chernobyl accident was contamination of locally grown food, which is not likely to be a significant concern in a modern American city. Nevertheless, the Chernobyl disaster contaminated urban areas such as Kiev, and lessons about decontaminating the urban environment following Chernobyl are relevant for a radiological incident in the U.S.

In the early period after the incident, military personnel decontaminated the area. Inhalation of dust particles was a particular concern, and the area around the plant and the most contaminated areas in the exclusion zone were sprayed with organic solutions to create a thin film that would immobilize dust. Buildings, vehicles, and city streets were washed frequently and sprayed with water, which suppressed the dust and rinsed the radionuclides into sewer system. *[Image – guys spraying water on trucks, buildings, and streets – we have several]*

Streets in Kiev were washed daily in the weeks following the accident. In surrounding areas, roads and buildings were washed, contaminated soils were removed (especially along drip lines next to buildings) *[image guys peeling back sod (42-15785116)]*, and sediments were removed from the bottom of reservoirs. Decontamination focused on schools, hospitals and other buildings with large numbers of people. Tens of thousands of public buildings and residences were treated in about 1000 cities and towns.

> *VY4 02:45:17 – 2:45-31 "I've heard from people who stayed there that um, street washing was much more frequent during that memorable summer that there is. When much more often than usual and they were doing a good job of keeping the city clean after all."*
>
> *VY4 2:58:48 – 2:59:05 "In my understanding and my feeling that ah, in the long term during that summer, during consequent months, government did a lot. I mean what they could at this given time. Given level of technology. To clean up what they could."*
>
> *VY4 02:57:04 – 2:57:12 "Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that."*
>
> *VY4 2:57:19 – 2:58:00 "For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do. And then possibly they should ah, government should concentrate more of getting help to the sick people. To get proper medicare for people who got ah really affected, seriously affected by whole scenarios. Because ah, really there were all sorts of circulation in the media because media was better ah, better in the covering what's going on in the real life. And so very, a lot of reports of sick people, sick children, so the whole idea was to get help to people who are affected."*
>
> *VY4 2:59:54 – 3:00:00 "And of course, it's, it was very good to know that somebody is caring something is done."*

The urban decontamination experience after Chernobyl gives us an idea of what techniques were most effective to reduce exposure to contamination in Kiev. Much of the radioactivity from the accident was concentrated in surface soil, plants, on asphalt and concrete, and to a lesser extent on roofs and walls. According to IAEA, street cleaning, removing trees and shrubs, and plowing soils in yards to bury the surface soils were efficient and inexpensive means of achieving significant reductions of dose. Roofs and walls also contribute to dose, but are costly and difficult to clean. *[images – Images for this section could be a montage of people scrubbing, plowing, and spraying the streets, buildings, and yards]*

Based on their accumulated experience, IAEA recommends:

- Removing the upper 2- to 4-inches of soil in front of residential buildings; around schools and public buildings, in private gardens; and along roadsides.
- Replacing soils that are removed by clean soils from holes dug in less trafficked areas, and filling those holes with contaminated surface soils. Although the surface soils used to fill the holes may be contaminated, they are unlikely to be contaminated enough to merit special treatment as radiological waste.
- Covering the decontaminated parts of courtyards, etc., with a layer of clean sand or gravel where soil is not available to attenuate residual radiation.

- Washing streets and buildings
- Cleaning or replacing roofs.

In the U.S., EPA has prepared a Manual of Protective Action Guidelines (PAGs) for nuclear accidents to guide responding to an incident and cleaning up and restoring contaminated areas. *[Image – the PAG document cover, and perhaps a few shots of key areas like the figure showing zones to evacuate, shelter in place, etc (Figure 7-1), a schedule of events (Figure 7-2), and perhaps some tables of particular isotopes, like Table 7-1 and 7-5. The information will not come across on screen; It's too detailed and dense, but it looks somewhat impressive and it shows that we have such a thing.]* The PAG document is a complex compendium of information that provides a flexible framework for responding to release of radiological contaminants. The document provides guidelines for establishing exclusion zones, relocating residents, and actions to reduce exposure. The document will guide emergency responders, and provides key information and some basic considerations that should be accounted for in responding to an emergency situation, and also provides guidance on the early, intermediate, and long-term responses – the actions to take to address an emergency and then bring life back to normal in the affected areas. For example, the PAGs establish techniques to estimate dose for one year based on internal exposure and external exposure to radiological contaminants, and specifies a numerical dose value for relocating the population that is exposed to levels above the numerical value. Below the value, EPA recommends dose reduction techniques, such as washing building and hard surfaces, spot soil removal, plowing to distribute and bury the surficial contamination, and spending less time outdoors. The guidance recommends focusing initial efforts on residences of pregnant women.

The PAG document also provides guidelines for when to administer dietary supplements to counteract internal exposure, how to determine when decontamination is effective, when and how to restrict food supplies, and a myriad of other considerations. In short, EPA has established a flexible framework describing how to respond to radiological emergencies, so all of the authorities involved share a common set of goals and methods to achieve them. A U.S. response to radiological emergency would not have to be improvised.

[Note: At this point, I did not feel comfortable taking the story farther without concrete guidance on where we want to go. We could go into more detail about the PAGs, but I feel that this will lose the viewers. So basically I structured this section as follows: Here's what they did in Kiev, here's what IAEA recommends, and we have a document that will tell us how to figure out these same issues here in the U.S. We have a challenge in the visuals for this part need to liven it up a bit. This piece naturally segues into the close – We're ready for something similar if it were to happen here.]

Epilogue: U.S. response to a similar incident

Recap:

- We'll have a much more transparent flow of information
- The place is never going to be cleaned up to background or pre-incident state, but it's not the end of the world
- We've got better decon technology, and we won't have to make it up as we go along
- We have a plan in place for figuring out how to proceed after a nuclear incident

Close with a reassuring message that EPA/NDT has been considering responding to such incidents and has plans in place to avoid major pitfalls experienced at Chernobyl. We have technologies here that they didn't have, and have preparation that they did not (ex: stockpiles of KI, cesium binders; organizational structure to transmit info). *[John is knowledgeable about this material, and I assume has great ideas about what this message needs to be.]*

Some other good quotes that we could weave into the story:

VY3 02:29:45 2:29:56 "they are very dear friends of mine. Ah, a husband and wife and wife was my classmate in the University. And she is a wonderful woman. Full of life, full of energy. Smart bride."

VY3 02:30:53- 2:30:55 "And three years after Chernobyl she developed breast cancer. And ah, later on ah, information was more readily available. And later on we learned that this particular day when they were planting potatoes that cloud of radiation." ~~And it was, again it was a Russian Roulette.~~ "It was ah, radiation was blowing where the wind was blowing.

VY3 02:31:21-2:31:47 "And ah, radiation cloud was passing above us. On top of us and I was sitting in the shadow at that moment. And she was exposed to the sun working in the field, and ah, she got sick. And ah, some and she died later." So, um, and it was terrible ah, shock for me. Very personal. And every time I think about it, I wish I could rewind the, the movie and get her out from that." < good footage. Near tears

VY4 02:48:48- 2:49:18 " the worst thing about the whole ah, Chernobyl is invisible menace, menace situation, that ah, you can not definitely tell or prove that if you have some health problems is because of you were not careful enough or you were overexposed. Or just, I mean people get sick all the time. And ah, ah like I mentioned. My friend who died and ah, I, you ask me, I'm still in the heart of my heart, I'm sure that this was because what it was."

VY3 2:31 55 -2:32:40 "Do you perceive yourself as a survivor? No. I think I'm, I'm um, more or less of a bystander. Because I am um, more or less a bystander. Because I, I have seen again you've seen this information. And there were people who were sacrificing their lives to contain this horrible accident. Who were doing most, more than everybody could ask from the others. Um, um, doing more than everybody could ask from the other human being. And um, I was just trying to make sure that my baby and I am healthy. And ah, it worked well, very well for me so I, I just um, I, I, pray for people who are much more affected than I am. I don't feel sorry for myself."

Windowsill showed contamination: VY4 02:51:19 – 2:51:44 "Well, what we did, of course we washed it. Well, what we did, we washed it a little bit. With soap and sponge. And of course we disposed of the sponge and throw away. And then we ah, ah, we covered it over with a layer of fresh paint. So it's ah, sort of to seal in the particles that were still radioactive to prevent them from dislodging and getting into your fingers, for example."

VY4 2:56: 51 – 2:58:03 "did you feel that the government needed to continue to clean up to levels before the tragedy or did they just accept living in a contaminated environment? Ah, ah, I guess everybody, I guess everybody understood that it was not visible. Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that. So something that was contaminated could be ah, took out from the ah, ah, recycling. Life cycle so to speak. For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do. And then possibly they should ah, government should concentrate more of getting help to the sick people. To get proper medicare for people who got ah really affected, seriously affected by whole scenarios. Because ah, really there were all sorts of circulation in the, in the, in the media because media was better ah, better in the covering what's going on in the real life. And so very, a lot of reports of sick people, sick children, so the whole idea was to get help to people who are affected."

VY4 02:46:05– 2:47:42 "our whole culture is very much, uh, agriculture or centered ah, centered around agricultural cycles. And ah, it's very much in our ah, everyday culture for people who have perfectly good paying ah professional jobs still to maintain some garden plots outside or inside the city

and trying to grow their own vegetables or their own apples. Ah, and it was only in part economical necessity and a big part of it is just desire to have something that you watch growing. And people kept doing this. But again there was a, a whole spectrum of responses from some of our people who just quit doing this altogether or just keep planting but they would not consume what they grew. And many people continued to grow and eat what they grew. And some of them would follow uh, those um, guidelines. Turn the soil over. Put probably what I've heard put more calcium in the soil so it will ah, ah, sort of neutralize some bad elements. And uh, I've seen people who just didn't care much and they were thinking oh you cannot touch it, you cannot smell it, it's clean. Why do I bother? So ah, there's a, the whole, again, the whole rainbow of responses from probably super-paranoid and like I was trying not to eat bread for two weeks and see how it go to more than relaxed. And probably truth is always somewhere in between."

The Chernobyl Incident – Experiences, Recovery, and Lessons Learned

1. Introduction

In an age of growing incidence and awareness of terrorism aimed at mass casualties and disruption, the U.S. faces a risk of experiencing a "dirty bomb" or even an improvised nuclear device. EPA has been preparing for such an eventuality~~, and is ready to respond, if necessary.~~ *[Images may include standard radiation images – the symbols (old and new), some images of the disaster – smoldering fire, helicopters, first responders, people spraying water to decontaminate …]*

A dirty bomb or improvised nuclear device would be likely to detonate with little or no warning and contaminate a large, densely inhabited area. To address the key issues that would confront the U.S. ~~and~~ in such an event, this discussion will use~~examine~~ ~~an event that forced the USSR to confront some of~~ the long-term recovery lessons learned from the Chernobyl nuclear plant disaster~~same issues: response and recovery from the Chernobyl nuclear incident~~. In 1986, The Chernobyl nuclear power plant experienced ~~incident was the~~ an uncontrolled meltdown of one of its~~the core~~ reactors~~ of the Chernobyl nuclear power plant in 1986 near what is now Kiev, Ukraine~~. The meltdown caused a fire that burned for 10 days, emitting enormous amounts of radiation into the atmosphere, and contaminating large parts of Ukraine, Belarus, Russia, and western Europe. In this documentary, we'll examine how recovery issues ~~from that that incident was~~ were managed, focusing on effective countermeasures in the aftermath of the disaster and eventual long-term restoration and recovery of the area. We will enhance our discussion of the response and recovery from that incident with direct, first-hand, personal perspectives of an early responder who provided technical assistance in the early phase of recovery, and of a resident of Kiev, who was a young mother in Ukraine at the time of the disaster. *[More detailed resumes when they first appear on screen]*

Dr. John Cardarelli, an Industrial Hygienist and Health Physicist with U.S. EPA, explains why this documentary focuses on Chernobyl:

> *[Image: JC1 5:00:50 – 5:01:24 "Chernobyl brings us a unique perspective in the fact that it was uh, uh, a real, live situation where hundreds of thousands of square kilometers were contaminated with radioactive material that had been um, dispersed from the reactor accident. And it exposed hundreds of thousands of humans, requiring a large amount of environmental clean up. So what we can learn from those aspects and apply them here in the United States could be very valuable if we were to ever experience something similar to that here in the United States."]*

This documentary will also use cesium-137, a radioactive element still present following the Chernobyl disaster and one that has been identified by scientific organization as a threat to be used in a dirty-bomb attack.

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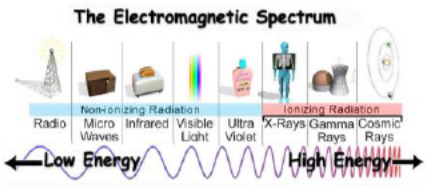
2. General Info about Radioactivity and nuclear devices

Before we delve into the details of the Chernobyl incident and the long-term recovery issues, we will summarize ~~need to refresh our knowledge of~~ some key concepts about radiation~~activity~~. ~~For the next few minutes, w~~We'll define what radioactivity is, different types of radioactivity, how ones becomes contaminated with radioactive material, and the key differences between ~~the types and persistence of~~ radioactivity potentially released from ~~by~~ nuclear power plant disasters, nuclear bombs, or~~and~~ radioactive dispersal devices~~, or "dirty bombs"~~.

The word *radiation* has many meanings. There are different types of radiation, many which are not harmful at all. *[Graphic - electromagnetic spectrum]* Television waves, radio waves, and radar are all examples of radiation, and none of these cause harm to living organisms under normal conditions. These types of radiation are called *non-ionizing radiation.*



The other general category of radiation is called *ionizing radiation* which is different from non-ionizing radiation because it has enough energy to displace an orbiting electron from its nuclear structure. *[Graphic: an atom that looks like a bunch of balls with a couple of electrons flying around it]* Humans have evolved in a radioactive environment from naturally occurring radioactive elements of uranium, thorium, and potassium elements found on earth; cosmic rays from space; and more-recently man-made radiation sources from medical X-rays. This background radiation varies throughout the world and depends on many factors like altitude, soil conditions, and location on earth.

Outline of what's to come *(1 min) – road map of where we're going: Definition of terms, description of incident, immediate response, long-term response, and discussion of U.S. preparedness for such an event.*

Language from REMM Website video. Can we take the video from REMM website and have it narrated by our narrator? Time = 1 min 52 seconds.

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"When a person is near a source of radiation, some type of radioactive material, he or she can be exposed to the radiation emitted by this source. However, he or she does not become contaminated.

One way to think about exposure is to think about X-rays. When a person has a chest X-ray, he or she is exposed to radiation, but does not become contaminated with radioactive material.

A person can reduce his or her exposure to radiation, if he or she is shielded in some ways from the radiation, for example, if the person is behind a concrete wall, or if the radioactive source is inside of a lead container.

In order to become contaminated, radioactive material must get on the skin, or clothing, or inside of the body. For example, if radioactive material is incorporated into a dirty bomb, a conventional explosive, such as dynamite, that has been laced with radioactive material, then people could become contaminated when the device is detonated. Radioactive material on the outside of the body is called external contamination. When a person becomes externally contaminated, simply removing the clothing can remove up to 90% of the contamination. Gently washing the skin and the hair can remove most of the remaining contamination.

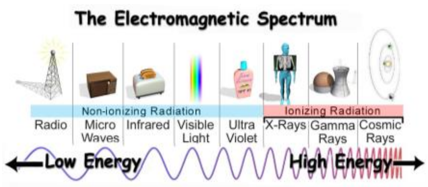
If a person ingests or inhales radioactive material, it can become incorporated in the organs of the body. This is called internal contamination. When a person is internally contaminated, depending on the type of radioactive material with which they were contaminated, certain medications can be administered to speed up the rate at which the radioactive material is eliminated from the body." For example Prussian blue is effective to eliminate cesium from the body and was used on animals following the Chernobyl incident to lessen the cesium concentration so the population can drink their milk and eat their meat.

~~2. General Info about Radioactivity and nuclear devices~~

~~2.1 A Radiation Primer~~

To understand some of the concepts we will present in this documentary, it is important to first review some basic radiation terminology and characteristics.

The word *radiation* has many meanings. There are different types of radiation, many which are not harmful at all. *[Graphic - electromagnetic spectrum]* Television waves, radio waves, and radar are all examples of radiation, and none of these cause harm to living organisms. These types of radiation do not have enough energy to cause damage to living tissue, and are called *non-ionizing radiation*.



The other general category of radiation is called *ionizing radiation* which does have enough energy to cause damage to living tissue. Ionization is a destructive process that causes atoms or molecules to lose electrons. X-rays, cosmic rays, and nuclear radiation are types of ionizing radiation.

Many radioactive materials occur naturally. For example, granite contains remnant radioactive isotopes from the formation of the earth, and when granite erodes, these radioisotopes are carried away as sand and clay that form the soil around us – there are beaches in Brazil with such high natural radiation levels that they have restricted access. Sand and clay are also used to make building materials such as brick and concrete, which may emit low levels of radiation. Other naturally occurring radioactive isotopes are created when cosmic rays interact with atoms in the atmosphere. We are also exposed to manmade radioactive materials that have been released into the environment. Nuclear weapon testing has contributed to a slight increase in background radiation. You may also be exposed to radiation through medical procedures such as x rays. You are exposed to radiation, known as background radiation, every day, and the amount of background radiation you are exposed to depends on where you live.

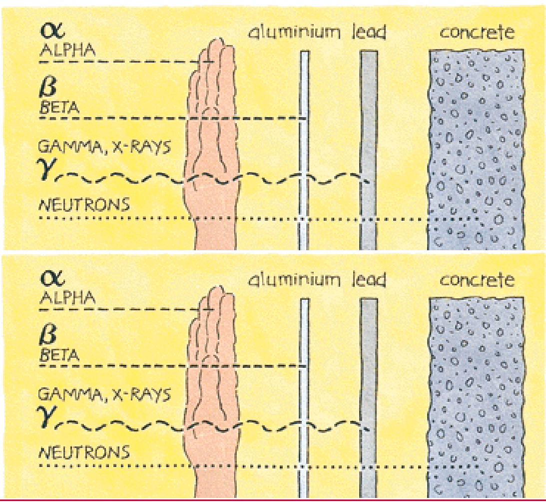
Nuclear radiation, which comes from the nucleus of an atom, is the type of radiation that most people think of when discussing radioactivity, and that is the focus of our discussion.

Remember that an atom is made of neutrons and protons that form the nucleus and electrons that orbit around the nucleus. *[Graphic: an atom that looks like a bunch of balls with a couple of electrons flying around it]* There are over100 different types of atoms and each has a specific number of protons that identifies the atom as an *element*, such as oxygen or iron. For example, the element uranium always has 92 protons. However, the number of neutrons can vary. Elements with the same number of protons but different numbers of neutrons are called *isotopes*. For example, uranium can have 138 neutrons or 146 neutrons. Uranium with 146 neutrons is known as the isotope U-238.

[Graphic: table of uranium isotopes]

Radionuclide	**Protons**	**Neutrons**
Uranium-230	92	138
Uranium-235	92	143
Uranium-238	92	146

~~Certain isotopes are unstable because they have too many protons or neutrons. They essentially have too much energy and they release that extra energy to become more stable. This happens spontaneously and is called *radioactive decay*, and these isotopes are radioactive and are called *radioisotopes*.~~ Radiactive materials ~~oisotopes~~ release energy primarily as four types of radiation: alpha particles, beta particles, gamma rays, and neutrons. ~~Each type of radiation has a different ability to penetrate materials~~ *[see graphic]*. ~~For example, alpha particles can be stopped by a piece of paper, whereas gamma rays can penetrate skin and thin sheets of metal.~~



Text from the REMM Video 1 min 33 sec: [I suggest we use the REMM Video for this section.]

"Alpha particles may be ejected from the nucleus of an atom during radioactive decay. They are relatively heavy and only travel about an inch in air. Alpha particles can easily be shielded by a single sheet of paper, and cannot penetrate the outer dead layer of skin, so they pose no danger when their source is outside the human body.

Beta particles are essentially electrons emitted from the nucleus of a radioactive atom. They are lighter than alpha particles, and can travel farther in air, up to several yards. Very energetic beta particles can penetrate up to one half an inch through skin and into the body. They can be shielded with less than an inch of material such as plastic. In the case of lower energy beta particles, the outer layer of clothing can act as an effective shield.

Gamma rays can be emitted from the nucleus of an atom during radioactive decay. They are able to travel tens of yards, or more, in air, and can easily penetrate the human body. Shielding this very penetrating type of ionizing radiation requires thick dense material such as several inches of lead or concrete.

Neutrons can be released from the nucleus of an atom during a fission reaction, such as within a nuclear reactor, or upon detonation of a nuclear weapon. Neutrons, like gamma rays, are very penetrating, and several feet of concrete is needed to shield against them.

~~Nuclear radiation is measured in several different ways. When we talk about the amount of radioactive material, we don't use weigh or volume because it does not have much meaning. Instead, we talk about the amount of radiation emitted from the material, the *radioactivity* (or *activity* for short) of the material.~~

~~Activity is usually measured in *curies*, which is the amount of radiation emitted by one gram of Radium 226. A curie is equal to 37 billion disintegrations per second, or 37 billion gamma rays, alpha particles, or beta particles per second. The physical amount of material to make one curie could be one gram of Radium 226 or thousands of kilograms of some other radioactive material. That is why the amount of material is not important but the activity of the material is!~~

How quickly a radioactive material decays is measured by it's ~~The activity of a radioactive material is closely related to the material's~~ *half-life*, or the amount of time it takes for the radioactivity of the material to decrease by half. For example, cesium-137 ~~if the h~~half-life is about 30 years~~of a radioisotope is one day~~, so about half of the cesium-137 released during Chernobyl accident in 1986 will have decayed by 2016. ~~then after one day, half of the material will have decayed. The remaining half is still radioactive, so after another day, half of this portion will have decayed.~~ The decay process continues ~~until no more radioactive material remains. Depending on the starting amount, i~~and after ~~t takes about~~ 7 to 10 half-lives (210 years to 300 years), ~~before~~ the cesium- radioactivity decays to ~~is~~ near background levels ~~of radiation~~. This presents a long-term scenario in which humans may be exposed in a contaminated environment unless something is done to decontaminate the area.

~~Each radioactive isotope has a unique half-life. *[graphic - half-life table]* Half-lives of some isotopes are billions of years; other isotopes have half-lives of just a few seconds. Isotopes with shorter half-lives have higher activity, and tend to pose more serious health threats. This makes sense because a short half-life means a material is emitting a lot of radiation in a short time.~~

~~**Isotope**~~	~~**Half Life**~~	~~**Origin**~~	~~**Uses**~~
~~Uranium 238~~	~~4.5 billion years~~	~~Naturally occurring~~	~~Armor piercing projectiles~~
~~Carbon 14~~	~~5,730 years~~	~~Naturally occurring~~	~~Carbon dating fossils~~
~~Cesium 137~~	~~30 years~~	~~Manmade~~	~~Geiger counters~~
~~Iodine 131~~	~~8 days~~	~~Manmade~~	~~Treat thyroid cancer~~
~~Technetium 99m~~	~~6 hours~~	~~Manmade~~	~~Medical imaging~~
~~Strontium 97~~	~~9 seconds~~	~~Manmade~~	~~None~~

~~Half-life is also important from the perspective of environmental cleanup. If a material with a long half-life is released, it will take a long time to decay to a harmless level. Cesium 137, one of the isotopes released by the Chernobyl accident, has a half-life of 30 years. Cesium 137 continues to be the primary contaminant of concern in most of the areas affected by the Chernobyl accident to this day. After 32 years, almost half of the Cesium 137 released by the accident remains.~~ On the other hand, another~~one of the other major isotopes~~ radioactive element released by the accident, ~~(~~Iodine-131, ~~)~~ has a half-life of 8 days. This presents a short-term scenario because it decayed away about 56 to 80 days after the accident. During that period Iodine-131, released as gas and was inhaled by a large population. It also was found in the milk from animals that ate Iodine contaminated feed. An effective treatment to reduce or prevent the adverse affects from Iodine is to take Potassium Iodine tablets. The stable form of iodine in these tablets prevent the radioactive form of iodine from depositing into organs in the body. Iodine is only a concern where certain nuclear reactions occur like in a nuclear reactor or atomic explosion and is not likely to be an agent used in an RDD attack. ~~was a major health concern shortly after the accident, but it has decayed away by now and it is no longer a problem.~~

~~There is one more basic element of radioactivity that we'll need to understand before we proceed: *nuclear reactions*. A nuclear reaction is one where the nucleus of an atom is changed, releasing incredible amounts of energy. At Hiroshima and Nagasaki, *uncontrolled* nuclear reactions occurred in a split second, releasing huge amounts of energy and radioisotopes with short half-lives. Most of these short half-life isotopes have decayed away, and the cities of Hiroshima and Nagasaki are now vibrant urban centers. *Controlled* nuclear reactions such as those used at nuclear power plants, on the other hand, take place over~~

~~longer periods and create more radioisotopes with long half-lives. Both controlled and uncontrolled nuclear reactions create long and short half-life radioactive isotopes, but a controlled nuclear reaction creates a much higher proportion of long half-life isotopes. This is a fundamental reason that Hiroshima and Nagasaki are active urban centers with large populations, but the exclusion zone around the Chernobyl plant is expected to be uninhabitable for hundreds of years.~~

[NOTE – We may need to get into the discussion of dose later in the documentary, especially when we kick into the residual levels of contamination that are left. At this point, we've defined too many new terms, yet hit the highlights – isotopes are created by nuclear reactions, and they can be radioactive. The short half-life isotopes are a problem because they release a lot of energy fast. The longer half-lives are an ongoing problem because they really don't go away.

In a similar vein, we may want to introduce the idea of fallout, dispersal patterns, and hot particles later rather than here in the primer. I chose to put that later in the story, as this is a long section with a lot of new terms and it's pretty dry – best to keep it short and focused if we can.]

2.2 Types of incidents we might face - *Introduce the types of incidents we might face and draw distinctions between them:*

Now that we've covered some of the basics of ~~nuclear~~ radiation, we need to consider what sort of threats we are up against. Terrorists are unlikely to engage in conventional warfare. Quite simply, they're outnumbered and outgunned. To compensate for this handicap, they seize whatever advantage they can to even the odds and multiply their influence. One worrisome possibility is that terrorists may gain access to chemical, biological, or radiological agents. This documentary focuses only on radiological agents. There are four~~three~~ scenarios~~ways~~ terrorists might use~~release~~ radiation in a terrorist attack.

- ~~radioisotopes.~~The first scenario is called a radiological exposure device or "RED". In this scenario, a highly radioactive source is placed it in a hidden space near a populated area to expose those who wander near it.
- The second scenario is called a radiological dispersal device~~s~~, or "RDD" ~~(RDDs)~~ that releases radioactive materials via many different dispersal techniques, including the most recognized form of using conventional explosives to form a "dirty bomb."
- The third scenario is an attack on a commercial nuclear facility ~~without creating a nuclear reaction,~~ causing a release from the~~a~~ nuclear power plant or from the spent nuclear fuel stored on-site.
- And the final scenario, the one most feared, ~~or~~ an improvised nuclear device or "IND" where a terrorist organization steals or creates a bomb capable of providing the destruction nearly equal to that of the Hiroshima or Nagasaki atomic explosions. ~~bombs~~.

Radioactive dispersal device (RDD):

- An RDD is a device that disperses radioactive materials. It could be a conventional bomb that contains radioactive materials and scatters those materials and other debris when it detonates, or it could scatter radioactive materials using a non-explosive device, such as a crop duster. The easiest and therefore most likely way to release radiological agents would be to detonate a type of RDD known as a dirty bomb. *[image – an explosion in a city]* This type of weapon would use radioactive materials, but the materials would not undergo a nuclear reaction that releases large quantities of energy or creates radioisotopes. An RDD would probably use existing medical radioactive materials such as Cesium-137 and Cobalt-60 which are used to treat cancer or industrial radioactive materials such as Americium-241 and Iridium-192, which are used in devices that measure density and thickness.

- A dirty bomb could cause serious injuries from the explosion, but it most likely would not have enough radioactive material to cause serious radiation sickness among large numbers of people. *[Dirty bomb clip from REMM Website radiation principals video? http://remm.nlm.nih.gov/radprinciplesvideo.htm]*

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- An RDD would likely involve contamination over a densely populated area and initial confusion and lack of information, but would differ from Chernobyl in that the contaminated area would be significantly smaller and the total amount and intensity of radioactivity released would likely be much, much lower.

A second way terrorists could release radioactive materials would be to intentionally cause an accident at a Nuclear Power Plant (NPP).

- Radioactive materials could be released from a nuclear plant by a fire or explosion or an accident involving the reactor core.
- The world has suffered several NPP accidents, including the Chernobyl meltdown in 1986, partial meltdowns at the Three Mile Island nuclear plant near Harrisburg, Pennsylvania in 1979 and the Chalk River Nuclear Plant near Ottowa, Ontario in 1952, and radioactive releases caused by a fire at the Windscale reactor near Liverpool, England in 1957 and by an earthquake at a nuclear plant near Kashiwazaki , Japan in 2007. *[still images of a couple of these disasters – TMI and images of steam being released from the Kashiwazaki plant ought to be available – perhaps response personnel running around as well.] From Google images "Kashiwazaki":*

  

- There are a several technical reasons that a nuclear accident like the Chernobyl meltdown are not likely to happen in America. First, the design of all U.S. reactors is different from the design of the Chernobyl reactor, and second, safety and design regulations are more stringent. The technical design of U.S. reactors is different than the Chernobyl reactor and makes major releases of radioactive materials extremely unlikely, if at all possible.

The most devastating way to release radiological agents would be to construct and detonate an Improvised Nuclear Device (IND).

- An IND is a small nuclear bomb where materials undergo a nuclear reaction. An IND would be catastrophic and would likely cause mass casualties. The technical difficulty of obtaining the materials and creating the conditions for a nuclear reaction make this a less likely scenario than an RDD. . However, a stolen nuclear weapon by a terrorist organization is of great concern. *[graphic – mushroom cloud]*
- The contaminated area would be big but the amount of highly contaminated land would still be smaller than Chernobyl. The reasons for this are complex, but simply put, a nuclear bomb produces less radioactive materials and spreads them less far than the Chernobyl accident.
- Most of the types of radioactive materials released by an IND would decay relatively quickly; most is gone within the first 24 hours and almost all within 2 weeks. However, a small amount of residual contamination would remain for a relatively long time.

Summary: To sum up, we face three main types of incidents that might release radioactive materials: RDDs, nuclear power plant accidents, and improvised nuclear bombs.

- A dirty bomb is probably the most likely scenario, and it would likely disperse commercially available medical or industrial radioactive materials over a wide area without undergoing a nuclear reaction. The radioactive materials released would probably be persistent in the environment for a relatively long time, and they may contaminate a populated downtown area.

- A nuclear power plant accident could release similar types of radioisotopes to those released by the Chernobyl incident: both long- and short-lived radioisotopes that may cause widespread contamination. However, the scale of the disaster is not likely to match the uncontrolled meltdown at Chernobyl, where a fire raged for 10 days, spewing nuclear and radioactive materials into the atmosphere and spreading them over hundreds of thousands of square miles.
- Detonation of an improvised nuclear bomb would be a catastrophic event that could devastate a city and cause widespread destruction. A nuclear bomb would involve a nuclear reaction that releases formidable amounts of energy and scatters radioactive fallout over a large region. Most of the types of radioactive materials released would decay relatively quickly. However, a small amount of residual contamination would remain for a relatively long time.

Switch gears – Now that we've covered a few of the basics about radioactivity and have a better feel for the types of incidents we're up against, we can get back to our story about Chernobyl. The common element to all of these types of incidents is the potential radiological contamination of a wide area. We will use the Chernobyl experience to discuss the issues involved with recovery from a wide-scale radiological event. Let's take a look at what happened at Chernobyl.

3. The Chernobyl Incident – What happened?

Explanation of why they had a meltdown in the first place, how the disaster unfolded, and what happened as a result. The focus of this section is what happened up to the evacuation of Pripyat. There will be good footage here that should give the viewer an idea of the magnitude of the disaster and it'll set the stage for the recovery. Also discuss fallout, what it is, heavy (hot) particles close, lighter particles far, control of wind, precipitation.

In the early morning hours of April 26, 1986, the Chernobyl nuclear plant near the town of Pripyat in what is now the Ukraine, experienced the worst nuclear power accident in history, an uncontrolled nuclear reaction and resulting explosion and fire, which sent a cloud of radioactive material over the western Soviet Union and Europe. The reactor burned for 10 days, releasing radioactive gases, vapors, aerosols, and particles and contaminating thousands of square miles in Ukraine, Belarus, Russia, and western Europe. *[image – nuclear technicians at the plant, the plant on fire, people suiting up to deal with it…]*

The Chernobyl nuclear plant is located near the border between Russia, Ukraine, and Belarus, about 70 miles northwest of the City of Kiev, the nearest major population center. Kiev had a population of about 2.5 million at the time of the disaster. The town of Pripyat is located about 2 miles from the reactor and had a population of about 45,000 people at the time of the accident. *[image – a map showing the three countries, the plant, Pripyat, and Kiev – we may have to make this]*

The exact cause of the accident is still uncertain, but it is widely accepted that a combination of design flaws and operator error caused the accident. At around 1:00 AM on April 24, the plant was conducting a safety test to determine if the cooling system pumps could operate if the external power failed. The generally recognized account of the incident is that operators disabled an automatic shutdown system and powered down the reactor by inserting control rods into the core to create the low power conditions required for the test. However, the power decrease was greater than anticipated, and the operators increased the power output by manually removing some of the control rods. Within seconds of withdrawing the control rods, power in the reactor shot up to dangerous levels, creating an energy spike. Operators tried to reinsert the control rods to slow the reaction, but due to the power spike in the reactor, the rods shattered and could not be lowered further into the reactor core to control the reaction. *[Image – reactor personnel, the power plant, and a plant exploding- could be a generic explosion if we can find such a thing]*

The cooling water vaporized within seconds, causing a steam explosion that blew the lid off the reactor. The sudden inrush of oxygen caused a graphite fire, and the reactor core and building burned for 10 days, releasing into the atmosphere more than 100 times the total radioactivity of the Hiroshima bombing. The fire carried radioisotopes upward into the atmosphere where they traveled with the prevailing winds. According to an IAEA report, *[IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience p.21]* winds were initially to the northwest, but varied over the next several days so that all points of the compass were downwind at some point while the fire in the core continued burning. To further complicate matters, scattered thunderstorms and rainfall throughout the area brought down some of the airborne material to ground level and deposited it, forming an irregular radioactive fallout pattern over thousands of square miles. *[graphic – figure 3.2 IAEA report, image of fallout pattern IAEA report Fig 3.6 and http://www.chernobyl.info/index.php?navID=2]* ,

At the time of the accident, Ukraine was part of the former Soviet Union, a closed society with centralized control of the press. Soviet premier Mikhail Gorbachev had taken office about 1 year earlier, and had not yet implemented his policy of Glasnost, or openness. *[image of Mikhail Sergeyevich]* The first public notice of the gravity of the situation came on April 27from Sweden, when workers at the Forsmark Nuclear Power Plant (about 700 miles away) detected elevated levels of radioactivity that were not from local sources. *[image – map showing Forsmark plan on east central coast of Sweden and Chernobyl/Kiev, perhaps with an arrow showing distance between them]* Soviet authorities either did not fully understand or intentionally downplayed the severity of the accident. Evacuation of the nearby town of Pripyat began at 2:00 in the afternoon of April 27, a full 36 hours after the accident. As late as May 1, major Soviet newspapers featured May Day celebrations rather than the Chernobyl disaster on their front pages, projecting an air of normality and muting the significance of the incident. *[images of soviet newspapers – Pravda]* Soviet premier Gorbachev did not appear on television to discuss the incident until May 14, several weeks later. An initial period of silence, followed by reassuring comments from the government, appears to have had the opposite effect to that which was intended: concerned citizens feared that the incident was far worse than they were being told.

Transition: The incident involved unprecedented radiological contamination of a huge inhabited area combined with a lack of reliable information in a closed society, which created suspicion, uncertainty, and inefficiency. What can we learn from the incident? How did miscommunication and a lack of communication affect public perception and willingness to alter their lives to accommodate the new reality? How did the decontamination of the area proceed and what was life like in the affected areas?

To examine these questions, we interviewed Larisa Leonova and Vira Yakusha. Larisa is a chemist with USEPA who was one of the early responders. At the time of the accident, she was managing a laboratory in Moscow part-time while earning her PhD in chemistry. Larissa volunteered to offer her services and traveled to Kiev several weeks after the incident, and worked in the area around Pripyat, trying to convince local residents to leave the area.

> *[Image – LL8 3:51:54 – 3:52:21 "My Name is Larisa Leanova and I live in United States oh, it's my twentieth years. And um, back when Chernobyl happened I was ah, twenty-eight years old and four years is graduated from ah, university. And I was working as a chemist, basically part time a lab manager and part time doing my Ph.D research work. Back when the Chernobyl happened I was in Moscow, I always lived in Moscow."]*

Vira Yakusha is a computer scientist with a consulting firm in Washington DC. At the time of the incident, Vira was a resident of Kiev and a recent graduate of Kiev University. Perhaps most important, Vira was pregnant with her first child, and she brings the perspective of an expecting mother, and a member of the general public reacting to the events occurring around her.

> *[Image – VY4 2:33:03 – 2:34:00 "My name is Vira Yakusha and ah, I was born in Kiev. And ah, I lived there for my entire life. And I loved the city a lot. And ah, I was there as a just a member of general population when Chernobyl tragedy struck. And so my perspective is a perspective of a lay person who is not professionally involved in the nuclear, in the nuclear industry, but who was, who's life*

was directly affected by what happened. And ah, my story is a story of person who is trying to comprehend what's going on and trying to do the best, what is best for my family, for health of my family and ah, trying to live my life as ah, as simple as possible if it's possible in the difficult circumstance."

4. The Early Response

We'll certainly be able to identify some good footage/photos of this part, then we can get into the more meaty and meaningful information in the Health Physics articles. We can also discuss the fallout pattern and how it was highly variable based on precipitation (Balinov, p. 385), and what fell out where (short-lived and long-lived isotopes (nuclear reactions) We could introduce the concept of distance, time, and shielding here - Dose rates decreased by three orders of magnitude in the 3 km from the plant to Pripyat (Hinton et. al. p.430).

Balanov mentions evacuation, distribution of stable iodine KI tablets to Pripyat (but not the surrounding area), and restriction of the food supply as the most effective immediate measures. For the immediate affected area, outline the basic measures – establishment of 30 km exclusion zone, evacuation, nuclear waste repositories. For the larger (and more populous) area, outline other measures - bathing, clothing, hygiene … We can discuss these systematically, and we can follow each with CDC/REMM/DHS recommendations. I like that approach because we can tie together history, first-hand anecdotes, and current recommendations:

Response to the disaster was disorganized, improvised, and chaotic. The main priority of the first responders was to put out the fire and then isolate the reactor core. The first on the scene were local firefighters and soldiers who were not aware of the grave threat of exposure to very high levels of radioactivity. By 5:00 AM, the firefighters extinguished the fires on the roof of the reactor building and in the surrounding area, thus protecting the other reactors at the Chernobyl facility, but they were not able to put out the burning reactor core. Many of these heroic firefighters and soldiers died of exposure to radiation within days or weeks. *[They are commemorated with a statue in the town of Pripyat – image of the famous firefighter statue?]*

To put out the fire in the core, the authorities tried several approaches, including dropping 5,000 tons of sand, clay, and lead onto the core by helicopter. *[image of helicopters dropping bags of stuff]* and injecting liquid nitrogen into the surrounding soil in order to cool the reactor. These efforts were not terribly effective at first – because of the extremely dangerous conditions and the extremely hot graphite fire, it took workers 10 days to put out the fire in the core.

Although the very first responders – the firefighters and the soldiers who first arrived on the scene to put out the fires – did not realize that the disaster was releasing high levels of radioation, the authorities soon recognized that the disaster had exposed the core and was releasing highly radioactive particles and smoke, and ordered evacuation of the surrounding area. The town of Pripyat, located 2 miles northwest (and downwind) of the reactor, was evacuated on Sunday, April 27, one and one half days after the disaster. The residents were told to pack for three days and to leave household pets behind. The motivation for giving such a short timeframe for the evacuation was logistical: to limit the amount of baggage and personal belongings to be transported and to expedite the evacuation. A convoy of 1200 buses carried the residents and their belongings away, and the evacuation was reportedly completed in about three hours. *[image – there are lots of images of evacuation of Pripyat – the long line of buses, lines of people getting on them and so forth.]*

In the following days, authorities measured radiation levels in the areas surrounding Chernobyl to determine the extent of contamination. Radiation levels above background were measured at distances of hundreds of miles away, but the government focused on the most heavily contaminated areas. The USSR Ministry of Public Health had set maximum permissible radiation limits for workers based on a one year exposure. However, the limit assumed a person would only be exposed to the radiation while working, or less than 1/3 of a year instead of the entire year. This limit was used to determine the area that would be evacuated and become known as the Chernobyl Exclusion Zone. The zone was determined to be a 30-kilometer (about 19 miles) radius around Chernobyl.

Isolating the reactor was an immediate priority once the fires were extinguished and the nearby towns were evacuated. To make a safer work zone, the area surrounding the reactor was cleared of debris. The contaminated debris, reactor core fragments, and surface soils from the immediate area around the reactor were placed in a concrete reinforced gallery hastily constructed around the reactor. Removal and shielding of this material made the area safer to work in.

Other soils and debris were stored in a large number of temporary shallow trenches and impoundments within the exclusion zone and covered with soil to provide minimal shielding and to reduce potential for wind to mobilize the contaminants. These trenches and small impoundments were not designed as permanent storage, yet most of them remain to this day. *[Important to demonstrate residual sources – Image – a generic trench and pile of dirt. Doesn't have to be from Chernobyl]*

After cleaning the blast area, a structure known as *the sarcophagus* was constructed of concrete, steel plates, and beams to isolate the most contaminated wastes and the reactor. The sarcophagus was constructed between May and November 1986 under very hazardous working conditions. *[images of the sarcophagus abound. Let's get some]* The structure was hastily designed and erected and has been exposed to the elements and infiltrated by moisture for more than 20 years. A new safe confinement structure is currently being designed to address the shortcomings of the sarcophagus and to isolate the reactor core and the most contaminated wastes for the next100 years. *[Image: New safe confinement structure image is on cover of IAEA report: Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience]*

5. The New Reality *–The focus of this section is what happened right afterwards in Kiev. The structure of this section will go into the nuts and bolts of living in the contaminated environment interspersed w/ tidbits from interviews. The objective is to pair "what they did" with what CDC says you are supposed to do, and to examine it in the order of: information flow, hygiene that immediately knocks back the contamination (washing, clothing), the food supply (food, farmland, etc.), and cleaning up the town.*

After the immediate issues of putting out the fires, evacuating the exclusion zone, gathering up and removing the radioactive debris, and isolating the reactor were taken care of, life continued in the surrounding areas. However, in the face of an unprecedented event, the local and national authorities were uncertain how to proceed. Larissa Leonova, a chemist who now works for USEPA, volunteered to travel to Kiev in the first weeks after the accident to lend a hand.

> *[LL4:01:56- 4:02:35 "our group of volunteers were basically invited by um, some sort of the organization which were created back there and basically consist um, of very strange group of people who -- represented by Army and by some ah, local officials which were not scientists. They were just the politicians and they were trying, trying to create some sort of the response. And um, again you know first couple of weeks it was basically you know not enough data or no information about plume or no information which territory it's more affected."] and*
>
> *[LL4:03:03 – 4:03:14 "we were among of the first, to my knowledge, volunteer group who went there and who got um, ah, who were involved in ah, um, some sort of the response."]*

One of the first assignments of the group of volunteers was to provide the local populace with some basic guidance about how to limit exposure to the radioisotopes released by the plant.

> *[LL4:05:05 – 4:05:25 "that's the season when everybody in the Ukraine um, pick up the strawberries. And Ukraine, it's very high in the strawberries and actually you know like um, everybody over there -- middle of the May and June the strawberries is the best place -- taste unbelievably good and everybody has a strawberry growing in their backyards and garden."] and*

[LY4:05:40 – 4:05:51 "So, the first advice which we wrote was very silly, we're saying like do not eat the strawberries if they are you know like right besides the dripping line um, from your roof."] and

[LL4:06:00 –4:06:15 "The other thing was we were basically advising that ah, try to have at least a bucket of water near the entrance of your door and before -- after you coming from the street to your house, wash you um, shoes and remove your shoes, try to not bring the additional dust."]

5.1 Information Sources

One of the biggest problems with the Soviet response to the Chernobyl disaster was a lack of credible information. At the time of the accident, the Soviet Union was a closed society, and the official Soviet news sources were not known for their openness. Almost a week after the accident, the major newspapers were not discussing the ongoing nuclear disaster that was contaminating much of the USSR and Europe. As a result, citizens were forced to turn to informal news channels, networks of associates, and whatever international news they could find on short-wave radios.

[LY8 3:52:26 – 3:53:33 "we didn't get any information about Chernobyl um, officially -- almost like a week after the accident happened. When I first time heard about it -- it was the first day ah, first working day basically it was a Monday, I believe it was 27th or 28 of the April. I came to work and one of my co-workers told me, "Did you hear the news that BBC's announcing"? And I said, "No, I basically was very busy this weekend, I didn't listen to any BBC". And we all had the habit to listen one of them ah, for a radio station and um, early morning Monday exchange the news. What really was get -- what we were getting from the abroad and what was um, broadcast in the Russian radio stations. So, my co-worker told me that he heard that something happen in the Ukraine and Sweden is picking up ah, increased radioactivity levels. And I said, "I haven't heard of that". But you know from that moment on we were basically very ah, uptight and tried to catch any news we could."] and/or

[VY1 1:29:29 – 1:29:41 "Because nobody was giving you any, uh, hard information at this point, assumption was that, uh, probably things are much, much worse than officials would tell you. And, uh, so the first week, uh, we were living our life more or less our life as usual] and

[VY1 1:23:21 – 1:23:36 "we were very skeptical about official sources of information per usual, uh, so we turned onto the, uh, Radio Free, uh, uh, what was that, what was commonly called The Voices From Abroad, and, uh, there were several radio stations that they were broadcasting towards the Soviet territory, and one of them was Voice of America, another was Radio Free Europe and one of them was BBC and such. And they were all, um, the Soviet, uh, government tried to jam them, and so you had intelligence or people who were curious about what was going on and wanted to have more information that was officially available, they were trying to find the Voices on the short wave bands."]

VY2 02:05:28 – 2:05:37 "There is a difference between, uh, questioning authorities or expecting answers to a question. So I was, uh, very aware that authorities are not telling the whole truth. But I never expected to, uh, get answers, truthful answers, if -- if I would start questioning."

[VY2 1:58:10 – 1:58:50 "I am sitting in the back seat of the car, and, uh, our radio is on, and the radio is official so it's radio and there's a news report and oh, everything is, uh, contained in Chernobyl, everything is fine, in Kiev there is no danger at all in Kiev, I mean, the population should not worry. And I'm thinking yeah, that's, it's an interesting twist because here I am from Kiev, and, uh, I'm too dirty to enter Moscow but in Kiev everything is fine. Yeah, and, um, it was a surreal moment"]

If a similar incident were to happen in the U.S., we can expect a much more open flow of information. Not only would the major news media cover the disaster, but the U.S. Department of Homeland Security, the Centers for Disease Control (CDC), the U.S. Environmental Protection Agency (U.S. EPA) and other agencies would post information on what do. Some good internet sites to obtain information on how the public should respond to a radiological incident can be found at the Department of Health and Human Services' Radiation Event Medical Management site *[Show a screen shot and the web address: www.remm.nlm.gov]* U.S. EPA's Radiation Protection program page *[show screen shot and address: www.epa.gov/radiation]* and the U.S. Department of Homeland Security's Ready America Radiation Threat site *[Screen shot and www.ready.gov/america/beinformed/radiation.html]*.

[JC2 5:08:32 - 5:09:42 "There's a lot of resources available to folks to learn more about long-term recovery and the types of information that they -– that's going to be concerned or they're going to be interested on. I would recommend a lot of folks visit uh, vetted, scientific, internet websites. Uh, for example, usepa.gov uh, the cdc.gov for public health inquiries, there's a nice website that's available by various professional societies, the Health/Physics Society, which is hps.org. Um, the National Commission for Radiological Protection is also another good website uh, the ncrp.com and there's various international uh, websites as well.
I.A.E.A, that stands for the International Atomic Energy Association, as well as the I.C.R.P., the International Commission for Radiological Protection. These are all scientifically valid, vetted information that can provide a lot of information to folks that are concerned about the public health issues, environmental issues and some of the socio-economic aspects of why certain things and clean, cleanup levels have been set the way they have."] and

[JC 5:10:00 – 5: 10:36 "You're going to have a large variety of professional folks, subject matter experts, some who will say, any amount of radiation is not good for you. Others will say, you can take X amount and it's not going to hurt you at all. The truth probably is somewhere in between and what's more important is that folks understand that and they have to come to, to a conclusion themselves. The best way to do that is to educate yourself on what the risks are to you, your family, your friends, your loved ones um, and do that by educating yourself at these various websites."]

Close this section with
[VY4 2:41:07 - 2:2:42:14 "This is such a society where ah, different ah, groups of people have their say. So there is always a balance of forces. And the result of this balance, ah there is a much better possibility that the real information, the scientific information will come out and be available and be widely available and with the internet, it's, it's, it's even, it's even better now. Because I remember how I was just raking my mind trying to remember what I was taught about levels of radiation. And now I fully expect it to be available, this information to be available on the web. And probably guidelines that I will have from authorities. I will be more willing to trust them and to follow their recommendation, because I um, understand that it's much more reliable and much more better grounded reality than it used to be on the Soviet. So it's a different story."]

[Not sure this is the right place for this quote, but it touches on the transparency issue that is the heart of this section … JC1 5:06:45 - 5:07:29 "here in America, our culture is one who is much more informed of the area and will have a lot more activity uh, and involvement in the decision-making. Which can make this process cumbersome, and much longer uh, as opposed to living in a culture where you were dictated what was going to happen and how things were going to be done. That's not likely to occur here. Um, so it could be a challenge for us to deal with all the different stake holders which is an important process. The big lesson is, transparency, tell them the truth and dealing with some of the toughest questions are ultimately what going to make this a successful effort for the agency."]

5.2 Food Supply

The massive amount of radioactive fallout had far-reaching consequences. Internal exposure to radiological contaminants through consumption of contaminated food and water is a very significant exposure mechanism and the food supply was an immediate concern. According to an IAEA review of the incident, the most effective countermeasures were prohibiting animal feeding with pasture grasses in the affected areas and rejection of milk based on radiological monitoring. 20,000 agricultural and domestic animals were slaughtered immediately, and the remainder evacuated. Due to lack of forage and animal care facilities, an additional 120,000 animals were slaughtered from May to June 1986. *[image – here we can show images of pigs and cows being screened with radioactivity meters by a guy in a moon suit (ex: 42-15882699 and* 0000316032-056*), images of dead fish on the shore near the reactor]* Early responders were advised not to eat locally grown food, and surprisingly, to drink red wine instead of water:

> *[LL8: 4:20:00 – 4:20:06 "We were ordered -- we were basically -- that was our order to drink red wine, not drink water. So, that was our liquid consumption. " and LY8 04:27:54 – 4:28:08 "We were not given anything besides red wine. We were strictly advised not drink water or milk. And we were advised do not eat any um, grown -- locally grown product -- produce, nothing, no vegetables, no fruit, nothing."]*

Many locals used common sense and avoided eating locally grown foods that were probably contaminated

> *[LY8 4:14:29 - 4:14:45 "We found the people who were very educated and um, they were not eating any fresh food since the accident, since the first they heard about the accident. They were trying to eat canned food only."*

Vira Yakusha explains *her* dietary habits when she returned to Kiev with a young baby in the months following the accident:

> *[VY3 02:27:15 – 2:27:43 Well first concern ah, at that point was the food. And ah, food and again official line was that all food is carefully screened. Sources of food that contaminated milk or other ah, ah, necessities are discarded and thrown away and so you don't have worry about that. But of course we did worry. And of course we, we will try to buy imported food. As much as it was possible. But it was not that readily available.*
>
> *VY3 2:22:18 – 2:24:00 "if there is a cereal made in Hungary, probably there is less ah, a less chance that it's radiologically contaminated than the sour cream made on the local factory. Because God knows where this local factory gets their milk from. And in the first couple of weeks we were so ardent about it that I even didn't eat any bread because bread was definitely make over, made of local grains. And again, local grains could be contaminated. But after a couple of weeks without bread, I said you know what? I'm going to eat bread. Because I cannot. I need to eat something, right?"*
>
> *[VY3 02:28:35 – 2:28:51 "So there are very, there are always efforts. There are always efforts to make sure your food sources are clear. But it is almost impossible. So you have to accept at some point that you have to, continue with your life or otherwise you will just go mad."*
>
> *VY3 2:27:44 – 2:28:12 "And again, there were um, ah, some things that you cannot buy imported. For example, like your greens, your apples. And ah, sometimes you will come across imported apples with big luck. I remember my husband bought five kilos of ah, ah, a golden ah, golden delicious which is a common brand in America and they were ah, grown somewhere ah, from north of imported apples. And we were very happy. We were feeing our baby these apples for quite a long time while they lasted."*

Effects of the disaster were profound and long-lasting. As time went on and the threats posed by contaminated farmland became better understood, the local authorities undertook more sophisticated

measures to manage agricultural production from contaminated farmland. According to Mikhail Balinov of the International Atomic Energy Agency (IAEA), the most effective countermeasures were soil treatment; removal of some areas from agricultural production altogether based on radiological screening; switching to fodder crops such as rapeseed that don't assimilate key radionuclides in the contaminated areas; switching animals to clean fodder from uncontaminated areas before slaughter and milking; and feeding animals dietary supplements such as cesium binders to help the radionuclides pass through the animals without being incorporated in food products. *[image: Here we can show images like the guys in moon suits walking through a field (42-15800571), a guy with a rototiller (42-15784775), peasant gardeners (DWF15-682237), and a fallow field with a rad sign in front of it (42-15784775)]. [I think the preceding paragraph is important to keep hitting the "life goes on, radioactive contamination can be managed" theme.]*

The countermeasures described above went a long way to reducing the radiological contamination of foods from the affected areas. However, economic hardship caused by dissolution of the Soviet Union reduced the effectiveness of the agricultural countermeasures. As recently as 2001, 9% of the milk supply in the affected areas did not meet the standards for Cesium -137, according to R. M. Alexakhin and others of the Russian Institute of Agricultural Radiology and Agroecology. *[This seems to undermine the earlier message that things can be managed, but maybe it's important to note that it's not going to be perfect?]*

We close with an image of John saying something to the effect that we can't undo it, we have to manage it – the quote below is as close as I could find, and it fits this section reasonably well.]

> *[JC1 05:06:25- 5:06:43 "I think one of the largest lessons that I'm learning from the Chernobyl environment is that well, we have a contaminated area that we will never be able to get back to natural background levels. We can't turn the clock back, is what one of the quotes was said. I think that that's reality."]*

5.3 Hygiene Precautions

Contaminated dust and dirt are a very significant source of contamination to the public in the aftermath of a nuclear incident. CDC's radiation emergency web page [www.bt.cdc.gov/radiation] recommends leaving outer clothing and shoes outside and showering after an incident to reduce or eliminate radiological contamination. More recommendations can be found at the CDC web site. *[image – web address and screen shot. There's also a cheesy but understandable image of a silhouette guy showering off yellow dots at http://www.remm.nlm.gov/deconimage.htm]* Once the local authorities accepted the significance of the Chernobyl incident, they began to issue advice on hygienic practices to reduce exposure to contaminated dust:

> *VY1 01:34:00 - 01:34:30 "First Monday after, uh, after Easter so it was May -- May 5th, and the May 5th was the first day when, uh, when authorities, uh, Soviet authorities officially on the radio started to say well, things are, um, under control, but, um, for, just for personal precautions please shower regularly, try to keep dust out of the rooms, and, uh, keep your clothes laundered often, and cover the food and bread if you buy something so, uh, it's, uh, to prevent dust from, uh, coming on the food. Uh, so there were first official guidelines for general population to minimize, uh, the exposure."*

> *VY3 02:25:56 - 02:26:32 " After that first announcement, ah, they say that you should wash ah, take shower often, wash your ah, clothing often. Ah, try to prevent dust from setting on your household items. Ah, there was more information. And ah, it will become more and more detailed and instructions more elaborate this time. Then they were not that afraid to accept or admit that something wrong is going on. And, ah, we were doing this religiously. Our family. We were trying to follow everything and some more."*

> *VY3 02:14:21- 02:14:18"my family just tried to keep everything as clean as possible. Free from dust, from dirt. But ah, the thing is that you can not be 100% sure, of course. And later on, of*

course, it was not about the surfaces, of your living space, but more about the food that you are getting and ah, and ah, probably some accidental contamination that, for example, like there, rooftops for um, perceived to be very dirty. And they were in fact. So we were told or people were telling the children were told to avoid the downpours from the, from the roof, for example. If ah, water is pouring from the roof, it' probably, if it goes and fills in your overcoat, you don't want to have your overcoat to get dirty and to get rid of it later on."

Closing statement - One of the primary ways the public is exposed to radioactivity after a radiological event is through contaminated dust and soil that adheres to hair, skin, clothing, and shoes. One effective way to reduce this exposure is to shower frequently, launder clothing frequently, remove shoes and outer clothing before entering living areas, and general good housekeeping to reduce dust and dirt indoors. These hygiene precautions were successful in areas like Kiev after the Chernobyl accident, and they are also recommended by CDC and other sources. These websites provide good information on actions you can take to minimize your exposure after a radiological incident. *[image CDC rad website and address www.bt.cdc.gov/radiation, image of DHS Ready.gov rad website and address http://www.ready.gov/america/beinformed/radiation.html.]*

5.4 Children/pregnancy

Exposure to radiation can cause health problems for the general population, depending on the type of radiation, the exposure, and the individual's general health and susceptibility to illness. Some populations are particularly susceptible to the affects of radiation, and these include pregnant women and especially unborn babies. The Centers for Disease Control say that unborn babies are particularly sensitive to radiation during their early development, between weeks 2 and 15 of pregnancy, and can experience severe health effects such as birth defects, stunted growth, and brain damage. From 16- to 25-weeks, unborn babies may experience health consequences, but only if the doses radiation are very large, such as large enough to cause radiation sickness in the mother. After the 26th week of pregnancy, the radiation sensitivity of an unborn baby is similar to that of a newborn. *[Image – CDC web site and fact sheet at http://www.bt.cdc.gov/radiation/prenatal.asp]*

For the people affected by Chernobyl, radiation exposure of unborn babies was a major concern. Ms. Yakusha was living in Kiev and pregnant with her first child at the time of the accident. Upon learning of the disaster, she tried to leave Kiev as soon as she was able, to try to put as much distance between her baby and the radiation emergency as she could. Unfortunately, many people were trying the same, and Vira was unable to buy a train or plane ticket *[image –we can show a few generic Russian-looking pregnant women and happy babies, perhaps a bunch of Russians queued up at a ticket booth… We do have some photos of kids hooked up to tubes and wires, and one with their head marked in obvious prelude to brain surgery, but I think they are too negative and unsettling]*

> *VY1 1:29:20 - 01:29:27 "I was really determined, uh, to keep my baby healthy and, uh, as far as harm's way was possible."*
>
> *VY1 1:50:49 "I don't know what to do, it's impossible to buy tickets for -- for a plane, it's impossible to buy tickets for a train, but we need to get you out. And we were sitting in the kitchen and trying to figure out what kind of plan that could work"*
>
> *VY2 01:51:36 – 1:51:41 "And so we were thinking about this and that, and there is suddenly, um, uh, a buzz on the door …"*
>
> *VY2 1:51:54 – 1:52:44 "I opened the door and this is, uh, again my friend, uh, Yenna, who, uh, head of the family who were taking me to Karnyov, and he sort of looks grim, and he said you know what, I made a decision, uh, I take my, uh, girls away to Mosc -- I'm taking my girls away to Moscow because I want to get my kids out of here as soon as possible. And his, his thinking was pretty much*

the same that if the government admits so much that, uh, it's dangerous, then it's really, really dangerous. Yeah, and he said, um, okay, so my car is downstairs, uh, waiting for you, um, my wife and my kids are in the car, and we have still one place left in this car, this is for Vira. If you want to go with us you have 40 minutes to pack yourself."
[Image – How about a man standing next to an old, Soviet-style car?]

Vira left Kiev that night, and gave birth to Doreena, a healthy baby girl, four months later in Moscow. We can't say whether getting out of Kiev, about 70 miles from the disaster, in the weeks after the accident helped her give birth to a healthy child. Her child may very well have been fine had she continued to live in Kiev.

VY1 01:32:46 – 1:33:18 "Doreena, and she is, uh, 21 years old right now, and, uh, I never had any, uh, uh, health problems with her that I should, could attribute to potential exposure. But unfortunately, uh, my understanding of the nature of the whole thing is that you never can, if you have some sort of health problem you can never be 100 percent sure if it was the result of, uh, your exposure to the radioactivity at some point or it's just your particular body type or, uh, other factors that were contributing."

Reflecting on her actions many years later, Vira feels that she made the right choice given the information that she had:

VY4 02:42:38 – 2:43:38 "my personal feeling is the health of your children or your child is the first priority, because this is something that you are ulta, ultimately responsible for. So I would say what I said to myself. Put as many miles as you can between the source of radiation and yourself and your baby and try to get as much information as much reliable information as you can. And try to… I mean panic is never a good helper or a good advisor. So probably understanding is our best weapon and to know how things work and what is real danger and what is imagined danger. It is a real important difference. And the more you understand, the better your choices are, the better your behavior is. At least you're choosing between least, least possible evils. And ah, it's impossible to be in a perfect world. But in our imperfect world, you have to make your own choices. And it's better to be based on the, on the ways of reason."

[Note – one danger of this section is that it gives some cause for panic – I feel that the 'woman in the street' perspective is valuable, but the message is get the hell out of Dodge, and it appears that Vira's actions may have saved the day. If I was a pregnant woman watching this, I'd think – get away first and ask questions later. Just want to be sure we're OK with that message.]

5.4 Decontamination of Kiev

[I'm not certain how much we want to devote to how we would do things here. I reviewed the PAGs and my brief PAG description could be beefed up. I didn't spend a lot of effort on it, as I think John will have some very detailed ideas of where he wants it to go. Note that the PAG document is very detailed, yet also very flexible. Explaining the nuances of that document is not the focus of this documentary. I think the more important message is that there is a process for getting on with life after an accident, that it's already figured out, and that we'll employ it after an accident if we need to. That's how I shaded the discussion.]

Intentional detonation of a nuclear device is likely to take place in a city, and thus is quite different from the rural environment surrounding the Chernobyl plant. One of the most significant affects of the Chernobyl accident was contamination of locally grown food, which is not likely to be a significant concern in a modern American city. Nevertheless, the Chernobyl disaster contaminated urban areas such as Kiev, and lessons about decontaminating the urban environment following Chernobyl are relevant for a radiological incident in the U.S.

In the early period after the incident, military personnel decontaminated the area. Inhalation of dust particles was a particular concern, and the area around the plant and the most contaminated areas in the exclusion zone were sprayed with organic solutions to create a thin film that would immobilize dust. Buildings, vehicles, and city streets were washed frequently and sprayed with water, which suppressed the dust and rinsed the radionuclides into sewer system. *[Image – guys spraying water on trucks, buildings, and streets – we have several]*

Streets in Kiev were washed daily in the weeks following the accident. In surrounding areas, roads and buildings were washed, contaminated soils were removed (especially along drip lines next to buildings) *[image guys peeling back sod (42-15785116)]*, and sediments were removed from the bottom of reservoirs. Decontamination focused on schools, hospitals and other buildings with large numbers of people. Tens of thousands of public buildings and residences were treated in about 1000 cities and towns.

> *VY4 02:45:17 – 2:45-31 "I've heard from people who stayed there that um, street washing was much more frequent during that memorable summer that there is. When much more often than usual and they were doing a good job of keeping the city clean after all."*
>
> *VY4 2:58:48 – 2:59:05 "In my understanding and my feeling that ah, in the long term during that summer, during consequent months, government did a lot. I mean what they could at this given time. Given level of technology. To clean up what they could."*
>
> *VY4 02:57:04 – 2:57:12 "Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that."*
>
> *VY4 2:57:19 – 2:58:00 "For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do. And then possibly they should ah, government should concentrate more of getting help to the sick people. To get proper medicare for people who got ah really affected, seriously affected by whole scenarios. Because ah, really there were all sorts of circulation in the media because media was better ah, better in the covering what's going on in the real life. And so very, a lot of reports of sick people, sick children, so the whole idea was to get help to people who are affected."*
>
> *VY4 2:59:54 – 3:00:00 "And of course, it's, it was very good to know that somebody is caring something is done."*

The urban decontamination experience after Chernobyl gives us an idea of what techniques were most effective to reduce exposure to contamination in Kiev. Much of the radioactivity from the accident was concentrated in surface soil, plants, on asphalt and concrete, and to a lesser extent on roofs and walls. According to IAEA, street cleaning, removing trees and shrubs, and plowing soils in yards to bury the surface soils were efficient and inexpensive means of achieving significant reductions of dose. Roofs and walls also contribute to dose, but are costly and difficult to clean. *[images – Images for this section could be a montage of people scrubbing, plowing, and spraying the streets, buildings, and yards]*

Based on their accumulated experience, IAEA recommends:

- Removing the upper 2- to 4-inches of soil in front of residential buildings; around schools and public buildings, in private gardens; and along roadsides.
- Replacing soils that are removed by clean soils from holes dug in less trafficked areas, and filling those holes with contaminated surface soils. Although the surface soils used to fill the holes may be contaminated, they are unlikely to be contaminated enough to merit special treatment as radiological waste.
- Covering the decontaminated parts of courtyards, etc., with a layer of clean sand or gravel where soil is not available to attenuate residual radiation.

- Washing streets and buildings
- Cleaning or replacing roofs.

In the U.S., EPA has prepared a Manual of Protective Action Guidelines (PAGs) for nuclear accidents to guide responding to an incident and cleaning up and restoring contaminated areas. *[Image – the PAG document cover, and perhaps a few shots of key areas like the figure showing zones to evacuate, shelter in place, etc (Figure 7-1), a schedule of events (Figure 7-2), and perhaps some tables of particular isotopes, like Table 7-1 and 7-5. The information will not come across on screen; It's too detailed and dense, but it looks somewhat impressive and it shows that we have such a thing.]* The PAG document is a complex compendium of information that provides a flexible framework for responding to release of radiological contaminants. The document provides guidelines for establishing exclusion zones, relocating residents, and actions to reduce exposure. The document will guide emergency responders, and provides key information and some basic considerations that should be accounted for in responding to an emergency situation, and also provides guidance on the early, intermediate, and long-term responses – the actions to take to address an emergency and then bring life back to normal in the affected areas. For example, the PAGs establish techniques to estimate dose for one year based on internal exposure and external exposure to radiological contaminants, and specifies a numerical dose value for relocating the population that is exposed to levels above the numerical value. Below the value, EPA recommends dose reduction techniques, such as washing building and hard surfaces, spot soil removal, plowing to distribute and bury the surficial contamination, and spending less time outdoors. The guidance recommends focusing initial efforts on residences of pregnant women.

The PAG document also provides guidelines for when to administer dietary supplements to counteract internal exposure, how to determine when decontamination is effective, when and how to restrict food supplies, and a myriad of other considerations. In short, EPA has established a flexible framework describing how to respond to radiological emergencies, so all of the authorities involved share a common set of goals and methods to achieve them. A U.S. response to radiological emergency would not have to be improvised.

[Note: At this point, I did not feel comfortable taking the story farther without concrete guidance on where we want to go. We could go into more detail about the PAGs, but I feel that this will lose the viewers. So basically I structured this section as follows: Here's what they did in Kiev, here's what IAEA recommends, and we have a document that will tell us how to figure out these same issues here in the U.S. We have a challenge in the visuals for this part need to liven it up a bit. This piece naturally segues into the close – We're ready for something similar if it were to happen here.]

Epilogue: U.S. response to a similar incident

Recap:

- We'll have a much more transparent flow of information
- The place is never going to be cleaned up to background or pre-incident state, but it's not the end of the world
- We've got better decon technology, and we won't have to make it up as we go along
- We have a plan in place for figuring out how to proceed after a nuclear incident

Close with a reassuring message that EPA/NDT has been considering responding to such incidents and has plans in place to avoid major pitfalls experienced at Chernobyl. We have technologies here that they didn't have, and have preparation that they did not (ex: stockpiles of KI, cesium binders; organizational structure to transmit info). *[John is knowledgeable about this material, and I assume has great ideas about what this message needs to be.]*

Some other good quotes that we could weave into the story:

VY3 02:29:45 2:29:56 "they are very dear friends of mine. Ah, a husband and wife and wife was my classmate in the University. And she is a wonderful woman. Full of life, full of energy. Smart bride."

VY3 02:30:53- 2:30:55 "And three years after Chernobyl she developed breast cancer. And ah, later on ah, information was more readily available. And later on we learned that this particular day when they were planting potatoes that cloud of radiation." ~~And it was, again it was a Russian Roulette.~~ "It was ah, radiation was blowing where the wind was blowing.

VY3 02:31:21-2:31:47 "And ah, radiation cloud was passing above us. On top of us and I was sitting in the shadow at that moment. And she was exposed to the sun working in the field, and ah, she got sick. And ah, some and she died later." So, um, and it was terrible ah, shock for me. Very personal. And every time I think about it, I wish I could rewind the, the movie and get her out from that." < good footage. Near tears

VY4 02:48:48- 2:49:18 " the worst thing about the whole ah, Chernobyl is invisible menace, menace situation, that ah, you can not definitely tell or prove that if you have some health problems is because of you were not careful enough or you were overexposed. Or just, I mean people get sick all the time. And ah, ah like I mentioned. My friend who died and ah, I, you ask me, I'm still in the heart of my heart, I'm sure that this was because what it was."

VY3 2:31 55 -2:32:40 "Do you perceive yourself as a survivor? No. I think I'm, I'm um, more or less of a bystander. Because I am um, more or less a bystander. Because I, I have seen again you've seen this information. And there were people who were sacrificing their lives to contain this horrible accident. Who were doing most, more than everybody could ask from the others. Um, um, doing more than everybody could ask from the other human being. And um, I was just trying to make sure that my baby and I am healthy. And ah, it worked well, very well for me so I, I just um, I, I, pray for people who are much more affected than I am. I don't feel sorry for myself."

Windowsill showed contamination: VY4 02:51:19 – 2:51:44 "Well, what we did, of course we washed it. Well, what we did, we washed it a little bit. With soap and sponge. And of course we disposed of the sponge and throw away. And then we ah, ah, we covered it over with a layer of fresh paint. So it's ah, sort of to seal in the particles that were still radioactive to prevent them from dislodging and getting into your fingers, for example."

VY4 2:56: 51 – 2:58:03 "did you feel that the government needed to continue to clean up to levels before the tragedy or did they just accept living in a contaminated environment? Ah, ah, I guess everybody, I guess everybody understood that it was not visible. Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that. So something that was contaminated could be ah, took out from the ah, ah, recycling. Life cycle so to speak. For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do. And then possibly they should ah, government should concentrate more of getting help to the sick people. To get proper medicare for people who got ah really affected, seriously affected by whole scenarios. Because ah, really there were all sorts of circulation in the, in the, in the media because media was better ah, better in the covering what's going on in the real life. And so very, a lot of reports of sick people, sick children, so the whole idea was to get help to people who are affected."

VY4 02:46:05– 2:47:42 "our whole culture is very much, uh, agriculture or centered ah, centered around agricultural cycles. And ah, it's very much in our ah, everyday culture for people who have perfectly good paying ah professional jobs still to maintain some garden plots outside or inside the city

and trying to grow their own vegetables or their own apples. Ah, and it was only in part economical necessity and a big part of it is just desire to have something that you watch growing. And people kept doing this. But again there was a, a whole spectrum of responses from some of our people who just quit doing this altogether or just keep planting but they would not consume what they grew. And many people continued to grow and eat what they grew. And some of them would follow uh, those um, guidelines. Turn the soil over. Put probably what I've heard put more calcium in the soil so it will ah, ah, sort of neutralize some bad elements. And uh, I've seen people who just didn't care much and they were thinking oh you cannot touch it, you cannot smell it, it's clean. Why do I bother? So ah, there's a, the whole, again, the whole rainbow of responses from probably super-paranoid and like I was trying not to eat bread for two weeks and see how it go to more than relaxed. And probably truth is always somewhere in between."

The Chernobyl Incident – Experiences, Recovery, and Lessons Learned

1. Introduction

In an age of growing incidence and awareness of terrorism aimed at mass casualties and disruption, the U.S. faces a risk of experiencing a "dirty bomb" or even an improvised nuclear device. EPA has been preparing for such an eventuality~~, and is ready to respond, if necessary~~. *[Images may include standard radiation images – the symbols (old and new), some images of the disaster – smoldering fire, helicopters, first responders, people spraying water to decontaminate …]*

A dirty bomb or improvised nuclear device would be likely to detonate with little or no warning and contaminate a large, densely inhabited area. To address the key issues that would confront the U.S. ~~and~~ in such an event, this discussion will useexamine ~~an event that forced the USSR to confront some of~~ the long-term recovery lessons learned from the Chernobyl nuclear plant disaster~~same issues: response and recovery from the Chernobyl nuclear incident~~. In 1986, The Chernobyl nuclear power plant experienced ~~incident was the~~ an uncontrolled meltdown of one of itsthe core reactors ~~of the Chernobyl nuclear power plant in 1986 near what is now Kiev, Ukraine~~. The meltdown caused a fire that burned for 10 days, emitting enormous amounts of radiation into the atmosphere, and contaminating large parts of Ukraine, Belarus, Russia, and western Europe. In this documentary, we'll examine how recovery issues ~~from that that incident was~~ were managed, focusing on effective countermeasures in the aftermath of the disaster and eventual long-term restoration and recovery of the area. We will enhance our discussion of the response and recovery from that incident with direct, first-hand, personal perspectives of an early responder who provided technical assistance in the early phase of recovery, and of a resident of Kiev, who was a young mother in Ukraine at the time of the disaster. *[More detailed resumes when they first appear on screen]*

Dr. John Cardarelli, an Industrial Hygienist and Health Physicist with U.S. EPA, explains why this documentary focuses on Chernobyl:

> *[Image: JC1 5:00:50 – 5:01:24 "Chernobyl brings us a unique perspective in the fact that it was uh, uh, a real, live situation where hundreds of thousands of square kilometers were contaminated with radioactive material that had been um, dispersed from the reactor accident. And it exposed hundreds of thousands of humans, requiring a large amount of environmental clean up. So what we can learn from those aspects and apply them here in the United States could be very valuable if we were to ever experience something similar to that here in the United States."]*

This documentary will also use cesium-137, a radioactive element still present following the Chernobyl disaster and one that has been identified by scientific organizations as a threat to be used in a dirty-bomb attack.

2. General Info about Radioactivity and nuclear devices

Before we delve into the details of the Chernobyl incident and the long-term recovery issues, we will summarize ~~need to refresh our knowledge of~~ some key concepts about radiationactivity. ~~For the next few minutes, w~~We'll define what radioactivity is, different types of radioactivity, how ones becomes contaminated with radioactive material, and the key differences between ~~the types and persistence of~~ radioactivity potentially released from ~~by~~ nuclear power plant disasters, nuclear bombs, orand radioactive dispersal devices~~, or "dirty bombs"~~.

The word *radiation* has many meanings. There are different types of radiation, many which are not harmful at all. *[Graphic - electromagnetic spectrum]* Television waves, radio waves, and radar are all examples of radiation, and none of these cause harm to living organisms under normal conditions. These types of radiation are called *non-ionizing radiation.*

Commented [JJC1]: Tom Dunn has been saying we are not ready to respond, so I think we need to say we are preparing to respond without giving assurance that we are ready to respond This sentence may need a little support

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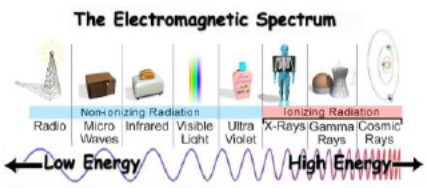

The other general category of radiation is called *ionizing radiation* which is different from non-ionizing radiation because it has enough energy to displace an orbiting electron from its nuclear structure. *[Graphic: an atom that looks like a bunch of balls with a couple of electrons flying around it]* Humans have evolved in a radioactive environment from naturally occurring radioactive elements of uranium, thorium, and potassium elements found on earth; cosmic rays from space; and more-recently man-made radiation sources from medical X-rays. This background radiation varies throughout the world and depends on many factors like altitude, soil conditions, and location on earth.

Outline of what's to come *(1 min) – road map of where we're going: Definition of terms, description of incident, immediate response, long-term response, and discussion of U.S. preparedness for such an event.*

Language from REMM Website video. Can we take the video from REMM website and have it narrated by our narrator? Time = 1 min 52 seconds.

"When a person is near a source of radiation, some type of radioactive material, he or she can be exposed to the radiation emitted by this source. However, he or she does not become contaminated.

One way to think about exposure is to think about X-rays. When a person has a chest X-ray, he or she is exposed to radiation, but does not become contaminated with radioactive material.

A person can reduce his or her exposure to radiation, if he or she is shielded in some ways from the radiation, for example, if the person is behind a concrete wall, or if the radioactive source is inside of a lead container.

In order to become contaminated, radioactive material must get on the skin, or clothing, or inside of the body. For example, if radioactive material is incorporated into a dirty bomb, a conventional explosive, such as dynamite, that has been laced with radioactive material, then people could become contaminated when the device is detonated. Radioactive material on the outside of the body is called external contamination. When a person becomes externally contaminated, simply removing the clothing can remove up to 90% of the contamination. Gently washing the skin and the hair can remove most of the remaining contamination.

If a person ingests or inhales radioactive material, it can become incorporated in the organs of the body. This is called internal contamination. When a person is internally contaminated, depending on the type of radioactive material with which they were contaminated, certain medications can be administered to speed up the rate at which the radioactive material is eliminated from the body." For example Prussian blue is effective to eliminate cesium from the body and was used on animals following the Chernobyl incident to lessen the cesium concentration so the population can drink their milk and eat their meat.

~~2. General Info about Radioactivity and nuclear devices~~

~~2.1 A Radiation Primer~~

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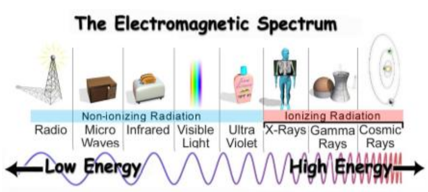
To understand some of the concepts we will present in this documentary, it is important to first review some basic radiation terminology and characteristics.

The word *radiation* has many meanings. There are different types of radiation, many which are not harmful at all. *[Graphic - electromagnetic spectrum]* Television waves, radio waves, and radar are all examples of radiation, and none of these cause harm to living organisms. These types of radiation do not have enough energy to cause damage to living tissue, and are called *non-ionizing radiation*.



The other general category of radiation is called *ionizing radiation* which does have enough energy to cause damage to living tissue. Ionization is a destructive process that causes atoms or molecules to lose electrons. X-rays, cosmic rays, and nuclear radiation are types of ionizing radiation.

Many radioactive materials occur naturally. For example, granite contains remnant radioactive isotopes from the formation of the earth, and when granite erodes, these radioisotopes are carried away as sand and clay that form the soil around us – there are beaches in Brazil with such high natural radiation levels that they have restricted access. Sand and clay are also used to make building materials such as brick and concrete, which may emit low levels of radiation. Other naturally occurring radioactive isotopes are created when cosmic rays interact with atoms in the atmosphere. We are also exposed to manmade radioactive materials that have been released into the environment. Nuclear weapon testing has contributed to a slight increase in background radiation. You may also be exposed to radiation through medical procedures such as x rays. You are exposed to radiation, known as background radiation, every day, and the amount of background radiation you are exposed to depends on where you live.

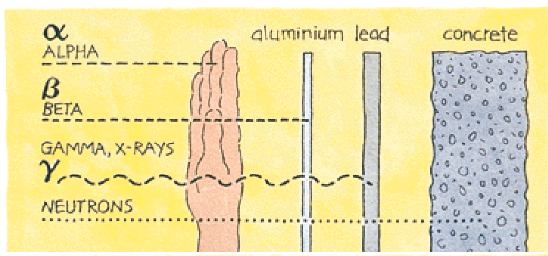
Nuclear radiation, which comes from the nucleus of an atom, is the type of radiation that most people think of when discussing radioactivity, and that is the focus of our discussion.

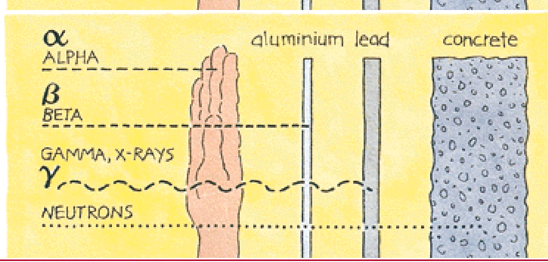
Remember that an atom is made of neutrons and protons that form the nucleus and electrons that orbit around the nucleus. *[Graphic: an atom that looks like a bunch of balls with a couple of electrons flying around it]* There are over100 different types of atoms and each has a specific number of protons that identifies the atom as an *element*, such as oxygen or iron. For example, the element uranium always has 92 protons. However, the number of neutrons can vary. Elements with the same number of protons but different numbers of neutrons are called *isotopes*. For example, uranium can have 138 neutrons or 146 neutrons. Uranium with 146 neutrons is known as the isotope U-238.

[Graphic: table of uranium isotopes]

Radionuclide	**Protons**	**Neutrons**
Uranium-230	92	138
Uranium-235	92	143
Uranium-238	92	146

~~Certain isotopes are unstable because they have too many protons or neutrons. They essentially have too much energy and they release that extra energy to become more stable. This happens spontaneously and is called *radioactive decay*, and these isotopes are radioactive and are called *radioisotopes*.~~ Radiactive materials ~~oisotopes~~ release energy primarily as four types of radiation: alpha particles, beta particles, gamma rays, and neutrons~~. Each type of radiation has a different ability to penetrate materials~~ *[see graphic]*. ~~For example, alpha particles can be stopped by a piece of paper, whereas gamma rays can penetrate skin and thin sheets of metal.~~





Text from the REMM Video 1 min 33 sec: [I suggest we use the REMM Video for this section.]

"Alpha particles may be ejected from the nucleus of an atom during radioactive decay. They are relatively heavy and only travel about an inch in air. Alpha particles can easily be shielded by a single sheet of paper, and cannot penetrate the outer dead layer of skin, so they pose no danger when their source is outside the human body.

Beta particles are essentially electrons emitted from the nucleus of a radioactive atom. They are lighter than alpha particles, and can travel farther in air, up to several yards. Very energetic beta particles can penetrate up to one half an inch through skin and into the body. They can be shielded with less than an inch of material such as plastic. In the case of lower energy beta particles, the outer layer of clothing can act as an effective shield.

Gamma rays can be emitted from the nucleus of an atom during radioactive decay. They are able to travel tens of yards, or more, in air, and can easily penetrate the human body. Shielding this very penetrating type of ionizing radiation requires thick dense material such as several inches of lead or concrete.

Neutrons can be released from the nucleus of an atom during a fission reaction, such as within a nuclear reactor, or upon detonation of a nuclear weapon. Neutrons, like gamma rays, are very penetrating, and several feet of concrete is needed to shield against them.

~~Nuclear radiation is measured in several different ways. When we talk about the amount of radioactive material, we don't use weigh or volume because it does not have much meaning. Instead, we talk about the amount of radiation emitted from the material, the *radioactivity* (or *activity* for short) of the material.~~

~~Activity is usually measured in *curies*, which is the amount of radiation emitted by one gram of Radium-226. A curie is equal to 37 billion disintegrations per second, or 37 billion gamma rays, alpha particles, or beta particles per second. The physical amount of material to make one curie could be one gram of Radium-226 or thousands of kilograms of some other radioactive material. That is why the amount of material is not important but the activity of the material is!~~

How quickly a radioactive material decays is measured by it's ~~The activity of a radioactive material is closely related to the material's~~ *half-life*, or the amount of time it takes for the radioactivity of the material to decrease by half. For example, cesium-137 ~~if the h~~half-life is about 30 years~~of a radioisotope is one day~~, so about half of the cesium-137 released during Chernobyl accident in 1986 will have decayed by 2016. ~~then after one day, half of the material will have decayed. The remaining half is still radioactive, so after another day, half of this portion will have decayed.~~ The decay process continues ~~until no more radioactive material remains. Depending on the starting amount, i~~and after ~~t takes about~~ 7 to 10 half-lives (210 years to 300 years), ~~before~~ the cesium- radioactivity decays to ~~is~~ near background levels~~ of radiation~~. This presents a long-term scenario in which humans may be exposed in a contaminated environment unless something is done to decontaminate the area.

~~Each radioactive isotope has a unique half-life. *[graphic - half-life table]* Half-lives of some isotopes are billions of years; other isotopes have half-lives of just a few seconds. Isotopes with shorter half-lives have higher activity, and tend to pose more serious health threats. This makes sense because a short half-life means a material is emitting a lot of radiation in a short time.~~

~~**Isotope**~~	~~**Half Life**~~	~~**Origin**~~	~~**Uses**~~
~~Uranium-238~~	~~4.5 billion years~~	~~Naturally occurring~~	~~Armor-piercing projectiles~~
~~Carbon-14~~	~~5,730 years~~	~~Naturally occurring~~	~~Carbon dating fossils~~
~~Cesium-137~~	~~30 years~~	~~Manmade~~	~~Geiger counters~~
~~Iodine-131~~	~~8 days~~	~~Manmade~~	~~Treat thyroid cancer~~
~~Technetium-99m~~	~~6 hours~~	~~Manmade~~	~~Medical imaging~~
~~Strontium-97~~	~~9 seconds~~	~~Manmade~~	~~None~~

~~Half-life is also important from the perspective of environmental cleanup. If a material with a long half-life is released, it will take a long time to decay to a harmless level. Cesium-137, one of the isotopes released by the Chernobyl accident, has a half-life of 30 years. Cesium-137 continues to be the primary contaminant of concern in most of the areas affected by the Chernobyl accident to this day. After 32 years, almost half of the Cesium-137 released by the accident remains.~~ On the other hand, another~~one of the other major isotopes~~ radioactive element released by the accident, ~~(~~Iodine-131, ~~)~~ has a half-life of 8 days. This presents a short-term scenario because it decayed away about 56 to 80 days after the accident. During that period Iodine-131, released as gas and was inhaled by a large population. It also was found in the milk from animals that ate Iodine contaminated feed. An effective treatment to reduce or prevent the adverse affects from Iodine is to take Potassium Iodine tablets. The stable form of iodine in these tablets prevent the radioactive form of iodine from depositing into organs in the body. Iodine is only a concern where certain nuclear reactions occur like in a nuclear reactor or atomic explosion and is not likely to be an agent used in an RDD attack. ~~was a major health concern shortly after the accident, but it has decayed away by now and it is no longer a problem.~~

~~There is one more basic element of radioactivity that we'll need to understand before we proceed: *nuclear reactions*. A nuclear reaction is one where the nucleus of an atom is changed, releasing incredible amounts of energy. At Hiroshima and Nagasaki, *uncontrolled* nuclear reactions occurred in a split second, releasing huge amounts of energy and radioisotopes with short half-lives. Most of these short half-life isotopes have decayed away, and the cities of Hiroshima and Nagasaki are now vibrant urban centers. *Controlled* nuclear reactions such as those used at nuclear power plants, on the other hand, take place over~~

longer periods and create more radioisotopes with long half-lives. Both controlled and uncontrolled nuclear reactions create long and short half-life radioactive isotopes, but a controlled nuclear reaction creates a much higher proportion of long half-life isotopes. This is a fundamental reason that Hiroshima and Nagasaki are active urban centers with large populations, but the exclusion zone around the Chernobyl plant is expected to be uninhabitable for hundreds of years.

[NOTE – We may need to get into the discussion of dose later in the documentary, especially when we kick into the residual levels of contamination that are left. At this point, we've defined too many new terms, yet hit the highlights – isotopes are created by nuclear reactions, and they can be radioactive. The short half-life isotopes are a problem because they release a lot of energy fast. The longer half-lives are an ongoing problem because they really don't go away.

In a similar vein, we may want to introduce the idea of fallout, dispersal patterns, and hot particles later rather than here in the primer. I chose to put that later in the story, as this is a long section with a lot of new terms and it's pretty dry – best to keep it short and focused if we can.]

Commented [JJC4]: I agree with your comment

2.2 Types of incidents we might face - *Introduce the types of incidents we might face and draw distinctions between them:*

Now that we've covered some of the basics of nuclear radiation, we need to consider what sort of threats we are up against. Terrorists are unlikely to engage in conventional warfare. Quite simply, they're outnumbered and outgunned. To compensate for this handicap, they seize whatever advantage they can to even the odds and multiply their influence. One worrisome possibility is that terrorists may gain access to chemical, biological, or radiological agents. This documentary focuses only on radiological agents. There are fourthree scenariosways terrorists might userelease radiation in a terrorist attack.

- radioisotopes.The first scenario is called a radiological exposure device or "RED". In this scenario, a highly radioactive source is placed in a hidden space near a populated area to expose those who wander near it.
- The second scenario is called a radiological dispersal devices, or "RDD" (RDDs) that releases radioactive materials via many different dispersal techniques, including the most recognized form of using conventional explosives to form a "dirty bomb."
- The third scenario is an attack on a commercial nuclear facility without creating a nuclear reaction, causing a release from thea nuclear power plant or from the spent nuclear fuel stored on-site.
- And the final scenario, the one most feared, or an improvised nuclear device or "IND" where a terrorist organization steals or creates a bomb capable of providing the destruction nearly equal to that of the Hiroshima or Nagasaki atomic explosions. bombs.

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Radioactive dispersal device (RDD):

oAn RDD is a device that disperses radioactive materials. It could be a conventional bomb that contains radioactive materials and scatters those materials and other debris when it detonates, or it could scatter radioactive materials using a non-explosive device, such as a crop duster. The easiest and therefore most likely way to release radiological agents would be to detonate a type of RDD known as a dirty bomb. *[image – an explosion in a city]* This type of weapon would use radioactive materials, but the materials would not undergo a nuclear reaction that releases large quantities of energy or creates radioisotopes. An RDD would probably use existing medical radioactive materials such as Cesium-137 and Cobalt-60 which are used to treat cancer or industrial radioactive materials such as Americium-241 and Iridium-192, which are used in devices that measure density and thickness.

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oA dirty bomb could cause serious injuries from the explosion, but it most likely would not have enough radioactive material to cause serious radiation sickness among large numbers of people. An RDD is more like a weapon of mass disruption than destruction. It *[Dirty bomb clip from REMM Website radiation principals video? http://remm.nlm.nih.gov/radprinciplesvideo.htm]*

~~oAn RDD~~ would likely ~~involve~~ contaminat~~e~~ion ~~over~~ a densely populated area, ~~and~~ create~~initial~~ confusion and instill fear among those potentially exposed to the radiation leading to psychosocial response lack of information, but would differ from Chernobyl in that the contaminated area would be significantly smaller and the total amount and intensity of radioactivity released would likely be much, much lower.

A second way terrorists could release radioactive materials would be to intentionally cause an accident at a Nuclear Power Plant (NPP).

- Radioactive materials could be released from a nuclear plant by a fire or explosion or an accident involving the reactor core.
- The world has suffered several NPP accidents, including the Chernobyl meltdown in 1986, partial meltdowns at the Three Mile Island nuclear plant near Harrisburg, Pennsylvania in 1979 and the Chalk River Nuclear Plant near Ottowa, Ontario in 1952, and radioactive releases caused by a fire at the Windscale reactor near Liverpool, England in 1957 and by an earthquake at a nuclear plant near Kashiwazaki , Japan in 2007. *[still images of a couple of these disasters – TMI and images of steam being released from the Kashiwazaki plant ought to be available – perhaps response personnel running around as well.] From Google images "Kashiwazaki":*



- There are a several technical reasons that a nuclear accident like the Chernobyl meltdown are not likely to happen in America. First, the design of all U.S. reactors is different from the design of the Chernobyl reactor, and second, safety and design regulations are more stringent. The technical design of U.S. reactors is different than the Chernobyl reactor and makes major releases of radioactive materials extremely unlikely, if at all possible.

The most devastating way to release radiological agents would be to construct and detonate an Improvised Nuclear Device (IND).

- An IND is a small nuclear bomb where materials undergo a nuclear reaction. An IND would be catastrophic and would likely cause mass casualties. The technical difficulty of obtaining the materials and creating the conditions for a nuclear reaction make this a less likely scenario than an RDD. . However, a stolen nuclear weapon by a terrorist organization is of great concern. *[graphic – mushroom cloud]*
- The contaminated area would be big but the amount of highly contaminated land would still be smaller than Chernobyl. The reasons for this are complex, but simply put, a nuclear bomb produces less radioactive materials and spreads them less far than the Chernobyl accident.
- Most of the types of radioactive materials released by an IND would decay relatively quickly; most is gone within the first 24 hours and almost all within 2 weeks. However, a small amount of residual contamination would remain for a relatively long time.

Summary: To sum up, we face three main types of incidents that might release radioactive materials: RDDs, nuclear power plant accidents, and improvised nuclear bombs.

- A dirty bomb is probably the most likely scenario, and it would likely disperse commercially available medical or industrial radioactive materials over a wide area without undergoing a nuclear reaction. The radioactive materials released would probably be persistent in the environment for a relatively long time, and they may contaminate a populated downtown area.

- A nuclear power plant accident could release similar types of radioisotopes to those released by the Chernobyl incident: both long- and short-lived radioisotopes that may cause widespread contamination. However, the scale of the disaster is not likely to match the uncontrolled meltdown at Chernobyl, where a fire raged for 10 days, spewing nuclear and radioactive materials into the atmosphere and spreading them over hundreds of thousands of square miles.
- Detonation of an improvised nuclear bomb would be a catastrophic event that could devastate a city and cause widespread destruction. A nuclear bomb would involve a nuclear reaction that releases formidable amounts of energy and scatters radioactive fallout over a large region. Most of the types of radioactive materials released would decay relatively quickly. However, a small amount of residual contamination would remain for a relatively long time.

Switch gears – Now that we've covered a few of the basics about radioactivity and have a better feel for the types of incidents we're up against, we can get back to our story about Chernobyl. The common element to all of these types of incidents is the potential radiological contamination of a wide area. We will use the Chernobyl experience to discuss the issues involved with recovery from a wide-scale radiological event. Let's take a look at what happened at Chernobyl.

3. The Chernobyl Incident – What happened?

Explanation of why they had a meltdown in the first place, how the disaster unfolded, and what happened as a result. The focus of this section is what happened up to the evacuation of Pripyat. There will be good footage here that should give the viewer an idea of the magnitude of the disaster and it'll set the stage for the recovery. Also discuss fallout, what it is, heavy (hot) particles close, lighter particles far, control of wind, precipitation.

In the early morning hours of April 26, 1986, the Chernobyl nuclear plant near the town of Pripyat in what is now the Ukraine, experienced the worst nuclear power accident in history, an uncontrolled nuclear reaction and resulting explosion and fire, which sent a cloud of radioactive material over the western Soviet Union and Europe. The reactor burned for 10 days, releasing radioactive gases, vapors, aerosols, and particles and contaminating thousands of square miles in Ukraine, Belarus, Russia, and western Europe. *[image – nuclear technicians at the plant, the plant on fire, people suiting up to deal with it…]*

The Chernobyl nuclear plant is located near the border between Russia, Ukraine, and Belarus, about 70 miles northwest of the City of Kiev, the nearest major population center. Kiev had a population of about 2.5 million at the time of the disaster. The town of Pripyat is located about 2 miles from the reactor and had a population of about 45,000 people at the time of the accident. *[image – a map showing the three countries, the plant, Pripyat, and Kiev – we may have to make this]*

The exact cause of the accident is still uncertain, but it is widely accepted that a combination of design flaws and operator error caused the accident. At around 1:00 AM on April 24, the plant was conducting a safety test to determine if the cooling system pumps could operate if the external power failed. The generally recognized account of the incident is that operators disabled an automatic shutdown system and powered down the reactor by inserting control rods into the core to create the low power conditions required for the test. However, the power decrease was greater than anticipated, and the operators increased the power output by manually removing some of the control rods. Within seconds of withdrawing the control rods, power in the reactor shot up to dangerous levels, creating an energy spike. Operators tried to reinsert the control rods to slow the reaction, but due to the power spike in the reactor, the rods shattered and could not be lowered further into the reactor core to control the reaction. *[Image –*

reactor personnel, the power plant, and a plant exploding- could be a generic explosion if we can find such a thing]

The cooling water vaporized within seconds, causing a steam explosion that blew the lid off the reactor. The sudden inrush of oxygen caused a graphite fire, and the reactor core and building burned for 10 days, releasing into the atmosphere more than 100 times the total radioactivity of the Hiroshima bombing. The fire carried radioisotopes upward into the atmosphere where they traveled with the prevailing winds. According to an IAEA report, *[IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience p.21]* winds were initially to the northwest, but varied over the next several days so that all points of the compass were downwind at some point while the fire in the core continued burning. To further complicate matters, scattered thunderstorms and rainfall throughout the area brought down some of the airborne material to ground level and deposited it, forming an irregular radioactive fallout pattern over thousands of square miles. *[graphic – figure 3.2 IAEA report, image of fallout pattern IAEA report Fig 3.6 and http://www.chernobyl.info/index.php?navID=2]* ,

At the time of the accident, Ukraine was part of the former Soviet Union, a closed society with centralized control of the press. Soviet premier Mikhail Gorbachev had taken office about 1 year earlier, and had not yet implemented his policy of Glasnost, or openness. *[image of Mikhail Sergeyevich]* The first public notice of the gravity of the situation came on April 27from Sweden, when workers at the Forsmark Nuclear Power Plant (about 700 miles away) detected elevated levels of radioactivity that were not from local sources. *[image – map showing Forsmark plan on east central coast of Sweden and Chernobyl/Kiev, perhaps with an arrow showing distance between them]* Soviet authorities either did not fully understand or intentionally downplayed the severity of the accident. Evacuation of the nearby town of Pripyat began at 2:00 in the afternoon of April 27, a full 36 hours after the accident. As late as May 1, major Soviet newspapers featured May Day celebrations rather than the Chernobyl disaster on their front pages, projecting an air of normality and muting the significance of the incident. *[images of soviet newspapers – Pravda]* Soviet premier Gorbachev did not appear on television to discuss the incident until May 14, several weeks later. An initial period of silence, followed by reassuring comments from the government, appears to have had the opposite effect to that which was intended: concerned citizens feared that the incident was far worse than they were being told.

Transition: The incident involved unprecedented radiological contamination of a huge inhabited area combined with a lack of reliable information in a closed society, which created suspicion, uncertainty, and inefficiency. What can we learn from the incident? How did miscommunication and a lack of communication affect public perception and willingness to alter their lives to accommodate the new reality? How did the decontamination of the area proceed and what was life like in the affected areas?

To examine these questions, we interviewed Larisa Leonova and Vira Yakusha. Larisa is a chemist with USEPA who was one of the early responders. At the time of the accident, she was managing a laboratory in Moscow part-time while earning her PhD in chemistry. Larissa volunteered to offer her services and traveled to Kiev several weeks after the incident, and worked in the area around Pripyat, trying to convince local residents to leave the area.

> *[Image – LL8 3:51:54 – 3:52:21 "My Name is Larisa Leanova and I live in United States oh, it's my twentieth years. And um, back when Chernobyl happened I was ah, twenty-eight years old and four years is graduated from ah, university. And I was working as a chemist, basically part time a lab manager and part time doing my Ph.D research work. Back when the Chernobyl happened I was in Moscow, I always lived in Moscow."]*

Vira Yakusha is a computer scientist with a consulting firm in Washington DC. At the time of the incident, Vira was a resident of Kiev and a recent graduate of Kiev University. Perhaps most important, Vira was pregnant with her first child, and she brings the perspective of an expecting mother, and a member of the general public reacting to the events occurring around her.

> *[Image – VY4 2:33:03 – 2:34:00 "My name is Vira Yakusha and ah, I was born in Kiev. And ah, I lived there for my entire life. And I loved the city a lot. And ah, I was there as a just a member of*

general population when Chernobyl tragedy struck. And so my perspective is a perspective of a lay person who is not professionally involved in the nuclear, in the nuclear industry, but who was, who's life was directly affected by what happened. And ah, my story is a story of person who is trying to comprehend what's going on and trying to do the best, what is best for my family, for health of my family and ah, trying to live my life as ah, as simple as possible if it's possible in the difficult circumstance."

4. The Early Response

We'll certainly be able to identify some good footage/photos of this part, then we can get into the more meaty and meaningful information in the Health Physics articles. We can also discuss the fallout pattern and how it was highly variable based on precipitation (Balinov, p. 385), and what fell out where (short-lived and long-lived isotopes (nuclear reactions) We could introduce the concept of distance, time, and shielding here - Dose rates decreased by three orders of magnitude in the 3 km from the plant to Pripyat (Hinton et. al. p.430).

Balanov mentions evacuation, distribution of stable iodine KI tablets to Pripyat (but not the surrounding area), and restriction of the food supply as the most effective immediate measures. For the immediate affected area, outline the basic measures – establishment of 30 km exclusion zone, evacuation, nuclear waste repositories. For the larger (and more populous) area, outline other measures - bathing, clothing, hygiene … We can discuss these systematically, and we can follow each with CDC/REMM/DHS recommendations. I like that approach because we can tie together history, first-hand anecdotes, and current recommendations:

Response to the disaster was disorganized, improvised, and chaotic. The main priority of the first responders was to put out the fire and then isolate the reactor core. The first on the scene were local firefighters and soldiers who were not aware of the grave threat of exposure to very high levels of radioactivity. By 5:00 AM, the firefighters extinguished the fires on the roof of the reactor building and in the surrounding area, thus protecting the other reactors at the Chernobyl facility, but they were not able to put out the burning reactor core. Many of these heroic firefighters and soldiers died of exposure to radiation within days or weeks. *[They are commemorated with a statue in the town of Pripyat – image of the famous firefighter statue?]*

To put out the fire in the core, the authorities tried several approaches, including dropping 5,000 tons of sand, clay, and lead onto the core by helicopter. *[image of helicopters dropping bags of stuff]* and injecting liquid nitrogen into the surrounding soil in order to cool the reactor. These efforts were not terribly effective at first – because of the extremely dangerous conditions and the extremely hot graphite fire, it took workers 10 days to put out the fire in the core.

Although the very first responders – the firefighters and the soldiers who first arrived on the scene to put out the fires – did not realize that the disaster was releasing high levels of radioation, the authorities soon recognized that the disaster had exposed the core and was releasing highly radioactive particles and smoke, and ordered evacuation of the surrounding area. The town of Pripyat, located 2 miles northwest (and downwind) of the reactor, was evacuated on Sunday, April 27, one and one half days after the disaster. The residents were told to pack for three days and to leave household pets behind. The motivation for giving such a short timeframe for the evacuation was logistical: to limit the amount of baggage and personal belongings to be transported and to expedite the evacuation. A convoy of 1200 buses carried the residents and their belongings away, and the evacuation was reportedly completed in about three hours. *[image – there are lots of images of evacuation of Pripyat – the long line of buses, lines of people getting on them and so forth.]*

In the following days, authorities measured radiation levels in the areas surrounding Chernobyl to determine the extent of contamination. Radiation levels above background were measured at distances of hundreds of miles away, but the government focused on the most heavily contaminated areas. The USSR Ministry of Public Health had set maximum permissible radiation limits for workers based on a one year exposure. However, the limit assumed a person would only be exposed to the radiation while working, or less than 1/3 of a year instead of the entire year. This limit was used to determine the area that would be evacuated and become known as the Chernobyl Exclusion Zone. The zone was determined to be a 30-kilometer (about 19 miles) radius around Chernobyl.

Isolating the reactor was an immediate priority once the fires were extinguished and the nearby towns were evacuated. To make a safer work zone, the area surrounding the reactor was cleared of debris. The contaminated debris, reactor core fragments, and surface soils from the immediate area around the reactor were placed in a concrete reinforced gallery hastily constructed around the reactor. Removal and shielding of this material made the area safer to work in.

Other soils and debris were stored in a large number of temporary shallow trenches and impoundments within the exclusion zone and covered with soil to provide minimal shielding and to reduce potential for wind to mobilize the contaminants. These trenches and small impoundments were not designed as permanent storage, yet most of them remain to this day. *[Important to demonstrate residual sources – Image – a generic trench and pile of dirt. Doesn't have to be from Chernobyl]*

After cleaning the blast area, a structure known as *the sarcophagus* was constructed of concrete, steel plates, and beams to isolate the most contaminated wastes and the reactor. The sarcophagus was constructed between May and November 1986 under very hazardous working conditions. *[images of the sarcophagus abound. Let's get some]* The structure was hastily designed and erected and has been exposed to the elements and infiltrated by moisture for more than 20 years. A new safe confinement structure is currently being designed to address the shortcomings of the sarcophagus and to isolate the reactor core and the most contaminated wastes for the next100 years. *[Image: New safe confinement structure image is on cover of IAEA report: Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience]*

5. The New Reality *–The focus of this section is what happened right afterwards in Kiev. The structure of this section will go into the nuts and bolts of living in the contaminated environment interspersed w/ tidbits from interviews. The objective is to pair "what they did" with what CDC says you are supposed to do, and to examine it in the order of: information flow, hygiene that immediately knocks back the contamination (washing, clothing), the food supply (food, farmland, etc.), and cleaning up the town.*

After the immediate issues of putting out the fires, evacuating the exclusion zone, gathering up and removing the radioactive debris, and isolating the reactor were taken care of, life continued in the surrounding areas. However, in the face of an unprecedented event, the local and national authorities were uncertain how to proceed. Larissa Leonova, a chemist who now works for USEPA, volunteered to travel to Kiev in the first weeks after the accident to lend a hand.

> *[LL4:01:56- 4:02:35 "our group of volunteers were basically invited by um, some sort of the organization which were created back there and basically consist um, of very strange group of people who -- represented by Army and by some ah, local officials which were not scientists. They were just the politicians and they were trying, trying to create some sort of the response. And um, again you know first couple of weeks it was basically you know not enough data or no information about plume or no information which territory it's more affected."] and*

> *[LL4:03:03 – 4:03:14 "we were among of the first, to my knowledge, volunteer group who went there and who got um, ah, who were involved in ah, um, some sort of the response."]*

One of the first assignments of the group of volunteers was to provide the local populace with some basic guidance about how to limit exposure to the radioisotopes released by the plant.

> *[LL4:05:05 – 4:05:25 "that's the season when everybody in the Ukraine um, pick up the strawberries. And Ukraine, it's very high in the strawberries and actually you know like um, everybody over there -- middle of the May and June the strawberries is the best place -- taste unbelievably good and everybody has a strawberry growing in their backyards and garden."] and*

[LY4:05:40 – 4:05:51 "So, the first advice which we wrote was very silly, we're saying like do not eat the strawberries if they are you know like right besides the dripping line um, from your roof."] and

[LL4:06:00 –4:06:15 "The other thing was we were basically advising that ah, try to have at least a bucket of water near the entrance of your door and before -- after you coming from the street to your house, wash you um, shoes and remove your shoes, try to not bring the additional dust."]

5.1 Information Sources

One of the biggest problems with the Soviet response to the Chernobyl disaster was a lack of credible information. At the time of the accident, the Soviet Union was a closed society, and the official Soviet news sources were not known for their openness. Almost a week after the accident, the major newspapers were not discussing the ongoing nuclear disaster that was contaminating much of the USSR and Europe. As a result, citizens were forced to turn to informal news channels, networks of associates, and whatever international news they could find on short-wave radios.

[LY8 3:52:26 – 3:53:33 "we didn't get any information about Chernobyl um, officially -- almost like a week after the accident happened. When I first time heard about it -- it was the first day ah, first working day basically it was a Monday, I believe it was 27th or 28 of the April. I came to work and one of my co-workers told me, "Did you hear the news that BBC's announcing"? And I said, "No, I basically was very busy this weekend, I didn't listen to any BBC". And we all had the habit to listen one of them ah, for a radio station and um, early morning Monday exchange the news. What really was get -- what we were getting from the abroad and what was um, broadcast in the Russian radio stations. So, my co-worker told me that he heard that something happen in the Ukraine and Sweden is picking up ah, increased radioactivity levels. And I said, "I haven't heard of that". But you know from that moment on we were basically very ah, uptight and tried to catch any news we could."] and/or

[VY1 1:29:29 – 1:29:41 "Because nobody was giving you any, uh, hard information at this point, assumption was that, uh, probably things are much, much worse than officials would tell you. And, uh, so the first week, uh, we were living our life more or less our life as usual] and

[VY1 1:23:21 – 1:23:36 "we were very skeptical about official sources of information per usual, uh, so we turned onto the, uh, Radio Free, uh, uh, what was that, what was commonly called The Voices From Abroad, and, uh, there were several radio stations that they were broadcasting towards the Soviet territory, and one of them was Voice of America, another was Radio Free Europe and one of them was BBC and such. And they were all, um, the Soviet, uh, government tried to jam them, and so you had intelligence or people who were curious about what was going on and wanted to have more information that was officially available, they were trying to find the Voices on the short wave bands."]

VY2 02:05:28 – 2:05:37 "There is a difference between, uh, questioning authorities or expecting answers to a question. So I was, uh, very aware that authorities are not telling the whole truth. But I never expected to, uh, get answers, truthful answers, if -- if I would start questioning."

[VY2 1:58:10 – 1:58:50 "I am sitting in the back seat of the car, and, uh, our radio is on, and the radio is official so it's radio and there's a news report and oh, everything is, uh, contained in Chernobyl, everything is fine, in Kiev there is no danger at all in Kiev, I mean, the population should not worry. And I'm thinking yeah, that's, it's an interesting twist because here I am from Kiev, and, uh, I'm too dirty to enter Moscow but in Kiev everything is fine. Yeah, and, um, it was a surreal moment"]

If a similar incident were to happen in the U.S., we can expect a much more open flow of information. Not only would the major news media cover the disaster, but the U.S. Department of Homeland Security, the Centers for Disease Control (CDC), the U.S. Environmental Protection Agency (U.S. EPA) and other agencies would post information on what do. Some good internet sites to obtain information on how the public should respond to a radiological incident can be found at the Department of Health and Human Services' Radiation Event Medical Management site *[Show a screen shot and the web address: www.remm.nlm.gov]* U.S. EPA's Radiation Protection program page *[show screen shot and address: www.epa.gov/radiation]* and the U.S. Department of Homeland Security's Ready America Radiation Threat site *[Screen shot and www.ready.gov/america/beinformed/radiation.html]*.

[JC2 5:08:32 - 5:09:42 "There's a lot of resources available to folks to learn more about long-term recovery and the types of information that they -– that's going to be concerned or they're going to be interested on. I would recommend a lot of folks visit uh, vetted, scientific, internet websites. Uh, for example, usepa.gov uh, the cdc.gov for public health inquiries, there's a nice website that's available by various professional societies, the Health/Physics Society, which is hps.org. Um, the National Commission for Radiological Protection is also another good website uh, the ncrp.com and there's various international uh, websites as well.
I.A.E.A, that stands for the International Atomic Energy Association, as well as the I.C.R.P., the International Commission for Radiological Protection. These are all scientifically valid, vetted information that can provide a lot of information to folks that are concerned about the public health issues, environmental issues and some of the socio-economic aspects of why certain things and clean, cleanup levels have been set the way they have."] and

[JC 5:10:00 – 5: 10:36 "You're going to have a large variety of professional folks, subject matter experts, some who will say, any amount of radiation is not good for you. Others will say, you can take X amount and it's not going to hurt you at all. The truth probably is somewhere in between and what's more important is that folks understand that and they have to come to, to a conclusion themselves. The best way to do that is to educate yourself on what the risks are to you, your family, your friends, your loved ones um, and do that by educating yourself at these various websites."]

Close this section with
[VY4 2:41:07 - 2:2:42:14 "This is such a society where ah, different ah, groups of people have their say. So there is always a balance of forces. And the result of this balance, ah there is a much better possibility that the real information, the scientific information will come out and be available and be widely available and with the internet, it's, it's, it's even, it's even better now. Because I remember how I was just raking my mind trying to remember what I was taught about levels of radiation. And now I fully expect it to be available, this information to be available on the web. And probably guidelines that I will have from authorities. I will be more willing to trust them and to follow their recommendation, because I um, understand that it's much more reliable and much more better grounded reality than it used to be on the Soviet. So it's a different story."]

[Not sure this is the right place for this quote, but it touches on the transparency issue that is the heart of this section … JC1 5:06:45 - 5:07:29 "here in America, our culture is one who is much more informed of the area and will have a lot more activity uh, and involvement in the decision-making. Which can make this process cumbersome, and much longer uh, as opposed to living in a culture where you were dictated what was going to happen and how things were going to be done. That's not likely to occur here. Um, so it could be a challenge for us to deal with all the different stake holders which is an important process. The big lesson is, transparency, tell them the truth and dealing with some of the toughest questions are ultimately what going to make this a successful effort for the agency."]

5.2 Food Supply

The massive amount of radioactive fallout had far-reaching consequences. Internal exposure to radiological contaminants through consumption of contaminated food and water is a very significant exposure mechanism and the food supply was an immediate concern. According to an IAEA review of the incident, the most effective countermeasures were prohibiting animal feeding with pasture grasses in the affected areas and rejection of milk based on radiological monitoring. 20,000 agricultural and domestic animals were slaughtered immediately, and the remainder evacuated. Due to lack of forage and animal care facilities, an additional 120,000 animals were slaughtered from May to June 1986. *[image – here we can show images of pigs and cows being screened with radioactivity meters by a guy in a moon suit (ex: 42-15882699 and* 0000316032-056*), images of dead fish on the shore near the reactor]* Early responders were advised not to eat locally grown food, and surprisingly, to drink red wine instead of water:

> *[LL8: 4:20:00 – 4:20:06 "We were ordered -- we were basically -- that was our order to drink red wine, not drink water. So, that was our liquid consumption. " and LY8 04:27:54 – 4:28:08 "We were not given anything besides red wine. We were strictly advised not drink water or milk. And we were advised do not eat any um, grown -- locally grown product -- produce, nothing, no vegetables, no fruit, nothing."]*

Many locals used common sense and avoided eating locally grown foods that were probably contaminated

> *[LY8 4:14:29 - 4:14:45 "We found the people who were very educated and um, they were not eating any fresh food since the accident, since the first they heard about the accident. They were trying to eat canned food only."*

Vira Yakusha explains *her* dietary habits when she returned to Kiev with a young baby in the months following the accident:

> *[VY3 02:27:15 – 2:27:43 Well first concern ah, at that point was the food. And ah, food and again official line was that all food is carefully screened. Sources of food that contaminated milk or other ah, ah, necessities are discarded and thrown away and so you don't have worry about that. But of course we did worry. And of course we, we will try to buy imported food. As much as it was possible. But it was not that readily available.*
>
> *VY3 2:22:18 – 2:24:00 "if there is a cereal made in Hungary, probably there is less ah, a less chance that it's radiologically contaminated than the sour cream made on the local factory. Because God knows where this local factory gets their milk from. And in the first couple of weeks we were so ardent about it that I even didn't eat any bread because bread was definitely make over, made of local grains. And again, local grains could be contaminated. But after a couple of weeks without bread, I said you know what? I'm going to eat bread. Because I cannot. I need to eat something, right?"*
>
> *[VY3 02:28:35 – 2:28:51 "So there are very, there are always efforts. There are always efforts to make sure your food sources are clear. But it is almost impossible. So you have to accept at some point that you have to, continue with your life or otherwise you will just go mad."*
>
> *VY3 2:27:44 – 2:28:12 "And again, there were um, ah, some things that you cannot buy imported. For example, like your greens, your apples. And ah, sometimes you will come across imported apples with big luck. I remember my husband bought five kilos of ah, ah, a golden ah, golden delicious which is a common brand in America and they were ah, grown somewhere ah, from north of imported apples. And we were very happy. We were feeing our baby these apples for quite a long time while they lasted."*

Effects of the disaster were profound and long-lasting. As time went on and the threats posed by contaminated farmland became better understood, the local authorities undertook more sophisticated

measures to manage agricultural production from contaminated farmland. According to Mikhail Balinov of the International Atomic Energy Agency (IAEA), the most effective countermeasures were soil treatment; removal of some areas from agricultural production altogether based on radiological screening; switching to fodder crops such as rapeseed that don't assimilate key radionuclides in the contaminated areas; switching animals to clean fodder from uncontaminated areas before slaughter and milking; and feeding animals dietary supplements such as cesium binders to help the radionuclides pass through the animals without being incorporated in food products. *[image: Here we can show images like the guys in moon suits walking through a field (42-15800571), a guy with a rototiller (42-15784775), peasant gardeners (DWF15-682237), and a fallow field with a rad sign in front of it (42-15784775)]. [I think the preceding paragraph is important to keep hitting the "life goes on, radioactive contamination can be managed" theme.]*

The countermeasures described above went a long way to reducing the radiological contamination of foods from the affected areas. However, economic hardship caused by dissolution of the Soviet Union reduced the effectiveness of the agricultural countermeasures. As recently as 2001, 9% of the milk supply in the affected areas did not meet the standards for Cesium -137, according to R. M. Alexakhin and others of the Russian Institute of Agricultural Radiology and Agroecology. *[This seems to undermine the earlier message that things can be managed, but maybe it's important to note that it's not going to be perfect?]*

We close with an image of John saying something to the effect that we can't undo it, we have to manage it – the quote below is as close as I could find, and it fits this section reasonably well.]

> *[JC1 05:06:25- 5:06:43 "I think one of the largest lessons that I'm learning from the Chernobyl environment is that well, we have a contaminated area that we will never be able to get back to natural background levels. We can't turn the clock back, is what one of the quotes was said. I think that that's reality."]*

5.3 Hygiene Precautions

Contaminated dust and dirt are a very significant source of contamination to the public in the aftermath of a nuclear incident. CDC's radiation emergency web page [www.bt.cdc.gov/radiation] recommends leaving outer clothing and shoes outside and showering after an incident to reduce or eliminate radiological contamination. More recommendations can be found at the CDC web site. *[image – web address and screen shot. There's also a cheesy but understandable image of a silhouette guy showering off yellow dots at http://www.remm.nlm.gov/deconimage.htm]* Once the local authorities accepted the significance of the Chernobyl incident, they began to issue advice on hygienic practices to reduce exposure to contaminated dust:

> *VY1 01:34:00 - 01:34:30 "First Monday after, uh, after Easter so it was May -- May 5th, and the May 5th was the first day when, uh, when authorities, uh, Soviet authorities officially on the radio started to say well, things are, um, under control, but, um, for, just for personal precautions please shower regularly, try to keep dust out of the rooms, and, uh, keep your clothes laundered often, and cover the food and bread if you buy something so, uh, it's, uh, to prevent dust from, uh, coming on the food. Uh, so there were first official guidelines for general population to minimize, uh, the exposure."*

> *VY3 02:25:56 - 02:26:32 " After that first announcement, ah, they say that you should wash ah, take shower often, wash your ah, clothing often. Ah, try to prevent dust from setting on your household items. Ah, there was more information. And ah, it will become more and more detailed and instructions more elaborate this time. Then they were not that afraid to accept or admit that something wrong is going on. And, ah, we were doing this religiously. Our family. We were trying to follow everything and some more."*

> *VY3 02:14:21- 02:14:18"my family just tried to keep everything as clean as possible. Free from dust, from dirt. But ah, the thing is that you can not be 100% sure, of course. And later on, of*

course, it was not about the surfaces, of your living space, but more about the food that you are getting and ah, and ah, probably some accidental contamination that, for example, like there, rooftops for um, perceived to be very dirty. And they were in fact. So we were told or people were telling the children were told to avoid the downpours from the, from the roof, for example. If ah, water is pouring from the roof, it' probably, if it goes and fills in your overcoat, you don't want to have your overcoat to get dirty and to get rid of it later on."

Closing statement - One of the primary ways the public is exposed to radioactivity after a radiological event is through contaminated dust and soil that adheres to hair, skin, clothing, and shoes. One effective way to reduce this exposure is to shower frequently, launder clothing frequently, remove shoes and outer clothing before entering living areas, and general good housekeeping to reduce dust and dirt indoors. These hygiene precautions were successful in areas like Kiev after the Chernobyl accident, and they are also recommended by CDC and other sources. These websites provide good information on actions you can take to minimize your exposure after a radiological incident. *[image CDC rad website and address www.bt.cdc.gov/radiation, image of DHS Ready.gov rad website and address http://www.ready.gov/america/beinformed/radiation.html.]*

5.4 Children/pregnancy

Exposure to radiation can cause health problems for the general population, depending on the type of radiation, the exposure, and the individual's general health and susceptibility to illness. Some populations are particularly susceptible to the affects of radiation, and these include pregnant women and especially unborn babies. The Centers for Disease Control say that unborn babies are particularly sensitive to radiation during their early development, between weeks 2 and 15 of pregnancy, and can experience severe health effects such as birth defects, stunted growth, and brain damage. From 16- to 25-weeks, unborn babies may experience health consequences, but only if the doses radiation are very large, such as large enough to cause radiation sickness in the mother. After the 26th week of pregnancy, the radiation sensitivity of an unborn baby is similar to that of a newborn. *[Image – CDC web site and fact sheet at http://www.bt.cdc.gov/radiation/prenatal.asp]*

For the people affected by Chernobyl, radiation exposure of unborn babies was a major concern. Ms. Yakusha was living in Kiev and pregnant with her first child at the time of the accident. Upon learning of the disaster, she tried to leave Kiev as soon as she was able, to try to put as much distance between her baby and the radiation emergency as she could. Unfortunately, many people were trying the same, and Vira was unable to buy a train or plane ticket *[image –we can show a few generic Russian-looking pregnant women and happy babies, perhaps a bunch of Russians queued up at a ticket booth… We do have some photos of kids hooked up to tubes and wires, and one with their head marked in obvious prelude to brain surgery, but I think they are too negative and unsettling]*

VY1 1:29:20 - 01:29:27 "I was really determined, uh, to keep my baby healthy and, uh, as far as harm's way was possible."

VY1 1:50:49 "I don't know what to do, it's impossible to buy tickets for -- for a plane, it's impossible to buy tickets for a train, but we need to get you out. And we were sitting in the kitchen and trying to figure out what kind of plan that could work"

VY2 01:51:36 – 1:51:41 "And so we were thinking about this and that, and there is suddenly, um, uh, a buzz on the door …"

VY2 1:51:54 – 1:52:44 "I opened the door and this is, uh, again my friend, uh, Yenna, who, uh, head of the family who were taking me to Karnyov, and he sort of looks grim, and he said you know what, I made a decision, uh, I take my, uh, girls away to Mosc -- I'm taking my girls away to Moscow because I want to get my kids out of here as soon as possible. And his, his thinking was pretty much

the same that if the government admits so much that, uh, it's dangerous, then it's really, really dangerous. Yeah, and he said, um, okay, so my car is downstairs, uh, waiting for you, um, my wife and my kids are in the car, and we have still one place left in this car, this is for Vira. If you want to go with us you have 40 minutes to pack yourself."
[Image – How about a man standing next to an old, Soviet-style car?]

Vira left Kiev that night, and gave birth to Doreena, a healthy baby girl, four months later in Moscow. We can't say whether getting out of Kiev, about 70 miles from the disaster, in the weeks after the accident helped her give birth to a healthy child. Her child may very well have been fine had she continued to live in Kiev.

VY1 01:32:46 – 1:33:18 "Doreena, and she is, uh, 21 years old right now, and, uh, I never had any, uh, uh, health problems with her that I should, could attribute to potential exposure. But unfortunately, uh, my understanding of the nature of the whole thing is that you never can, if you have some sort of health problem you can never be 100 percent sure if it was the result of, uh, your exposure to the radioactivity at some point or it's just your particular body type or, uh, other factors that were contributing."

Reflecting on her actions many years later, Vira feels that she made the right choice given the information that she had:

VY4 02:42:38 – 2:43:38 "my personal feeling is the health of your children or your child is the first priority, because this is something that you are ulta, ultimately responsible for. So I would say what I said to myself. Put as many miles as you can between the source of radiation and yourself and your baby and try to get as much information as much reliable information as you can. And try to… I mean panic is never a good helper or a good advisor. So probably understanding is our best weapon and to know how things work and what is real danger and what is imagined danger. It is a real important difference. And the more you understand, the better your choices are, the better your behavior is. At least you're choosing between least, least possible evils. And ah, it's impossible to be in a perfect world. But in our imperfect world, you have to make your own choices. And it's better to be based on the, on the ways of reason."

[Note – one danger of this section is that it gives some cause for panic – I feel that the 'woman in the street' perspective is valuable, but the message is get the hell out of Dodge, and it appears that Vira's actions may have saved the day. If I was a pregnant woman watching this, I'd think – get away first and ask questions later. Just want to be sure we're OK with that message.]

5.4 Decontamination of Kiev

[I'm not certain how much we want to devote to how we would do things here. I reviewed the PAGs and my brief PAG description could be beefed up. I didn't spend a lot of effort on it, as I think John will have some very detailed ideas of where he wants it to go. Note that the PAG document is very detailed, yet also very flexible. Explaining the nuances of that document is not the focus of this documentary. I think the more important message is that there is a process for getting on with life after an accident, that it's already figured out, and that we'll employ it after an accident if we need to. That's how I shaded the discussion.]

Intentional detonation of a nuclear device is likely to take place in a city, and thus is quite different from the rural environment surrounding the Chernobyl plant. One of the most significant affects of the Chernobyl accident was contamination of locally grown food, which is not likely to be a significant concern in a modern American city. Nevertheless, the Chernobyl disaster contaminated urban areas such as Kiev, and lessons about decontaminating the urban environment following Chernobyl are relevant for a radiological incident in the U.S.

In the early period after the incident, military personnel decontaminated the area. Inhalation of dust particles was a particular concern, and the area around the plant and the most contaminated areas in the exclusion zone were sprayed with organic solutions to create a thin film that would immobilize dust. Buildings, vehicles, and city streets were washed frequently and sprayed with water, which suppressed the dust and rinsed the radionuclides into sewer system. *[Image – guys spraying water on trucks, buildings, and streets – we have several]*

Streets in Kiev were washed daily in the weeks following the accident. In surrounding areas, roads and buildings were washed, contaminated soils were removed (especially along drip lines next to buildings) *[image guys peeling back sod (42-15785116)]*, and sediments were removed from the bottom of reservoirs. Decontamination focused on schools, hospitals and other buildings with large numbers of people. Tens of thousands of public buildings and residences were treated in about 1000 cities and towns.

> *VY4 02:45:17 – 2:45-31 "I've heard from people who stayed there that um, street washing was much more frequent during that memorable summer that there is. When much more often than usual and they were doing a good job of keeping the city clean after all."*
>
> *VY4 2:58:48 – 2:59:05 "In my understanding and my feeling that ah, in the long term during that summer, during consequent months, government did a lot. I mean what they could at this given time. Given level of technology. To clean up what they could."*
>
> *VY4 02:57:04 – 2:57:12 "Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that."*
>
> *VY4 2:57:19 – 2:58:00 "For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do. And then possibly they should ah, government should concentrate more of getting help to the sick people. To get proper medicare for people who got ah really affected, seriously affected by whole scenarios. Because ah, really there were all sorts of circulation in the media because media was better ah, better in the covering what's going on in the real life. And so very, a lot of reports of sick people, sick children, so the whole idea was to get help to people who are affected."*
>
> *VY4 2:59:54 – 3:00:00 "And of course, it's, it was very good to know that somebody is caring something is done."*

The urban decontamination experience after Chernobyl gives us an idea of what techniques were most effective to reduce exposure to contamination in Kiev. Much of the radioactivity from the accident was concentrated in surface soil, plants, on asphalt and concrete, and to a lesser extent on roofs and walls. According to IAEA, street cleaning, removing trees and shrubs, and plowing soils in yards to bury the surface soils were efficient and inexpensive means of achieving significant reductions of dose. Roofs and walls also contribute to dose, but are costly and difficult to clean. *[images – Images for this section could be a montage of people scrubbing, plowing, and spraying the streets, buildings, and yards]*

Based on their accumulated experience, IAEA recommends:

- Removing the upper 2- to 4-inches of soil in front of residential buildings; around schools and public buildings, in private gardens; and along roadsides.
- Replacing soils that are removed by clean soils from holes dug in less trafficked areas, and filling those holes with contaminated surface soils. Although the surface soils used to fill the holes may be contaminated, they are unlikely to be contaminated enough to merit special treatment as radiological waste.
- Covering the decontaminated parts of courtyards, etc., with a layer of clean sand or gravel where soil is not available to attenuate residual radiation.

- Washing streets and buildings
- Cleaning or replacing roofs.

In the U.S., EPA has prepared a Manual of Protective Action Guidelines (PAGs) for nuclear accidents to guide responding to an incident and cleaning up and restoring contaminated areas. *[Image – the PAG document cover, and perhaps a few shots of key areas like the figure showing zones to evacuate, shelter in place, etc (Figure 7-1), a schedule of events (Figure 7-2), and perhaps some tables of particular isotopes, like Table 7-1 and 7-5. The information will not come across on screen; It's too detailed and dense, but it looks somewhat impressive and it shows that we have such a thing.]* The PAG document is a complex compendium of information that provides a flexible framework for responding to release of radiological contaminants. The document provides guidelines for establishing exclusion zones, relocating residents, and actions to reduce exposure. The document will guide emergency responders, and provides key information and some basic considerations that should be accounted for in responding to an emergency situation, and also provides guidance on the early, intermediate, and long-term responses – the actions to take to address an emergency and then bring life back to normal in the affected areas. For example, the PAGs establish techniques to estimate dose for one year based on internal exposure and external exposure to radiological contaminants, and specifies a numerical dose value for relocating the population that is exposed to levels above the numerical value. Below the value, EPA recommends dose reduction techniques, such as washing building and hard surfaces, spot soil removal, plowing to distribute and bury the surficial contamination, and spending less time outdoors. The guidance recommends focusing initial efforts on residences of pregnant women.

The PAG document also provides guidelines for when to administer dietary supplements to counteract internal exposure, how to determine when decontamination is effective, when and how to restrict food supplies, and a myriad of other considerations. In short, EPA has established a flexible framework describing how to respond to radiological emergencies, so all of the authorities involved share a common set of goals and methods to achieve them. A U.S. response to radiological emergency would not have to be improvised.

[Note: At this point, I did not feel comfortable taking the story farther without concrete guidance on where we want to go. We could go into more detail about the PAGs, but I feel that this will lose the viewers. So basically I structured this section as follows: Here's what they did in Kiev, here's what IAEA recommends, and we have a document that will tell us how to figure out these same issues here in the U.S. We have a challenge in the visuals for this part need to liven it up a bit. This piece naturally segues into the close – We're ready for something similar if it were to happen here.]

Epilogue: U.S. response to a similar incident

Recap:

- We'll have a much more transparent flow of information
- The place is never going to be cleaned up to background or pre-incident state, but it's not the end of the world
- We've got better decon technology, and we won't have to make it up as we go along
- We have a plan in place for figuring out how to proceed after a nuclear incident

Close with a reassuring message that EPA/NDT has been considering responding to such incidents and has plans in place to avoid major pitfalls experienced at Chernobyl. We have technologies here that they didn't have, and have preparation that they did not (ex: stockpiles of KI, cesium binders; organizational structure to transmit info). *[John is knowledgeable about this material, and I assume has great ideas about what this message needs to be.]*

Some other good quotes that we could weave into the story:

VY3 02:29:45 2:29:56 "they are very dear friends of mine. Ah, a husband and wife and wife was my classmate in the University. And she is a wonderful woman. Full of life, full of energy. Smart bride."

VY3 02:30:53- 2:30:55 "And three years after Chernobyl she developed breast cancer. And ah, later on ah, information was more readily available. And later on we learned that this particular day when they were planting potatoes that cloud of radiation." ~~*And it was, again it was a Russian Roulette.*~~ *"It was ah, radiation was blowing where the wind was blowing.*

VY3 02:31:21-2:31:47 "And ah, radiation cloud was passing above us. On top of us and I was sitting in the shadow at that moment. And she was exposed to the sun working in the field, and ah, she got sick. And ah, some and she died later." So, um, and it was terrible ah, shock for me. Very personal. And every time I think about it, I wish I could rewind the, the movie and get her out from that." < good footage. Near tears

VY4 02:48:48- 2:49:18 " the worst thing about the whole ah, Chernobyl is invisible menace, menace situation, that ah, you can not definitely tell or prove that if you have some health problems is because of you were not careful enough or you were overexposed. Or just, I mean people get sick all the time. And ah, ah like I mentioned. My friend who died and ah, I, you ask me, I'm still in the heart of my heart, I'm sure that this was because what it was."

VY3 2:31 55 -2:32:40 "Do you perceive yourself as a survivor? No. I think I'm, I'm um, more or less of a bystander. Because I am um, more or less a bystander. Because I, I have seen again you've seen this information. And there were people who were sacrificing their lives to contain this horrible accident. Who were doing most, more than everybody could ask from the others. Um, um, doing more than everybody could ask from the other human being. And um, I was just trying to make sure that my baby and I am healthy. And ah, it worked well, very well for me so I, I just um, I, I, pray for people who are much more affected than I am. I don't feel sorry for myself."

Windowsill showed contamination: VY4 02:51:19 – 2:51:44 "Well, what we did, of course we washed it. Well, what we did, we washed it a little bit. With soap and sponge. And of course we disposed of the sponge and throw away. And then we ah, ah, we covered it over with a layer of fresh paint. So it's ah, sort of to seal in the particles that were still radioactive to prevent them from dislodging and getting into your fingers, for example."

VY4 2:56: 51 – 2:58:03 "did you feel that the government needed to continue to clean up to levels before the tragedy or did they just accept living in a contaminated environment? Ah, ah, I guess everybody, I guess everybody understood that it was not visible. Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that. So something that was contaminated could be ah, took out from the ah, ah, recycling. Life cycle so to speak. For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do. And then possibly they should ah, government should concentrate more of getting help to the sick people. To get proper medicare for people who got ah really affected, seriously affected by whole scenarios. Because ah, really there were all sorts of circulation in the, in the, in the media because media was better ah, better in the covering what's going on in the real life. And so very, a lot of reports of sick people, sick children, so the whole idea was to get help to people who are affected."

VY4 02:46:05– 2:47:42 "our whole culture is very much, uh, agriculture or centered ah, centered around agricultural cycles. And ah, it's very much in our ah, everyday culture for people who have perfectly good paying ah professional jobs still to maintain some garden plots outside or inside the city

and trying to grow their own vegetables or their own apples. Ah, and it was only in part economical necessity and a big part of it is just desire to have something that you watch growing. And people kept doing this. But again there was a, a whole spectrum of responses from some of our people who just quit doing this altogether or just keep planting but they would not consume what they grew. And many people continued to grow and eat what they grew. And some of them would follow uh, those um, guidelines. Turn the soil over. Put probably what I've heard put more calcium in the soil so it will ah, ah, sort of neutralize some bad elements. And uh, I've seen people who just didn't care much and they were thinking oh you cannot touch it, you cannot smell it, it's clean. Why do I bother? So ah, there's a, the whole, again, the whole rainbow of responses from probably super-paranoid and like I was trying not to eat bread for two weeks and see how it go to more than relaxed. And probably truth is always somewhere in between."

Draft 8/11/09

4. The Chernobyl Incident and the Initial Response

Now that we've covered a few of the basics about radiation, radioactivity and the types of emergencies that may occur, we can better examine the issues associated with radiological contamination. The 1986 accident at the Chernobyl power plant in the Soviet Union gives us insight into how we might recover from a wide-scale radiological event. First, let's take a look at the accident itself.

In the early morning hours of April 26, 1986, the Chernobyl nuclear plant experienced the worst nuclear power accident in history. The accident created an uncontrolled nuclear reaction and the resulting explosion and fire sent a massive cloud of radioactive material into the atmosphere. The reactor burned for 10 days, releasing radioactive gases, vapors, aerosols and particles, and contaminating thousands of square miles in Ukraine, Belarus, Russia, and Western Europe. *[Images: nuclear technicians at the plant, the plant on fire, people suiting up to respond.]*

The Chernobyl nuclear plant is located near the border between Russia, Ukraine, and Belarus, about 70 miles northwest of the city of Kiev, the nearest major population center. Kiev had a population of about 2.5 million people at the time of the disaster. The town of Pripyat, located about two miles from the reactor, had a population of about 45,000 people at the time of the accident. *[Image – a map showing the broader geographic area, the plant, Pripyat, and Kiev—there is a good one at world-nuclear.org/info/chernobyl.]*

The exact cause of the accident is still uncertain, but it is widely accepted that a combination of reactor design flaws and mistakes made by the plant operators caused the accident. On April 25, plant personnel began conducting a safety test to determine if the reactor's cooling system pumps could operate if the external power failed. The reactor operators disabled an automatic shutdown system and inserted control rods into the reactor's core to create the low power conditions required for the test. However, the power level in the reactor dropped more than anticipated, and the operators tried to increase it by manually withdrawing some of the control rods. Within seconds of withdrawing the control rods, the power level in the reactor shot up to dangerous levels. When the operators tried to reinsert the control rods again, the rods shattered and could not be lowered further into the reactor core to control the reaction. *[Images – reactor personnel, the power plant, and a plant exploding.]*

The cooling water located around the reactor core vaporized within seconds, causing a steam explosion that blew the lid off the reactor. The sudden inrush of oxygen caused a tremendous fire, and the reactor core and building burned for 10 days, releasing more than 100 times the amount of radioactivity into the atmosphere that occurred during the bombing of Hiroshima. Radioisotopes were carried upward into the atmosphere where they traveled with the prevailing winds.

According to reliable reports (*IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience p.21,* winds were initially to the northwest, but they varied over the next several days so that all areas were downwind at some point while the fire in the core continued burning. To further complicate matters, scattered thunderstorms and rainfall throughout the area brought down some of the airborne material to ground level, forming an irregular radioactive fallout pattern over thousands of square miles. *[graphic – figure 3.2 IAEA report, image of fallout pattern IAEA report Fig 3.6 and http://www.chernobyl.info/index.php?navID=2]*

The initial response to the disaster was disorganized, improvised, and chaotic. The main priority of the first responders was to put out the fire and then isolate the reactor core. First on the scene were local firefighters and soldiers who were not aware of the grave threat of exposure to very high levels of radioactivity. The firefighters extinguished the fires on the roof of the reactor building and in the surrounding area, thus protecting the other reactors at the Chernobyl facility, but they were not able to put out the burning reactor core. Many of these heroic firefighters and soldiers died of exposure to radiation within days or weeks. *[Image: commemorative statue to lost firefighters in the town of Pripyat.]*

To put out the fire in the core, local authorities tried several approaches, including dropping 5,000 tons of sand, clay, and lead onto the core by helicopter. *[Image: helicopters dropping bags of materials.]* But because of the dangerous conditions and extreme heat, it took workers 10 days to put out the fire.

Although the very first responders did not realize that the reactor was releasing high levels of radiation, the authorities soon recognized that the disaster had exposed the reactor core and ordered evacuation of the surrounding area. The town of Pripyat, located 2 miles northwest (and downwind) of the reactor, was evacuated on Sunday, April 27, one and one half days after the accident began. Residents were told to pack for three days and to leave household pets behind. The motivation for giving such a short timeframe for the evacuation was logistical: to limit the amount of baggage and personal belongings to be transported and to expedite the evacuation. A convoy of 1200 buses carried the residents and their belongings away, and the evacuation was reportedly completed in about three hours. *[Images of the evacuation of Pripyat – the long line of buses, lines of people getting on them and so forth.]*

In the following days, authorities measured radiation levels in the areas surrounding Chernobyl to determine the extent of contamination. Radiation levels above background were measured at distances of hundreds of miles away, but the government focused on the most heavily contaminated areas. The Soviet Ministry of Public Health determined that a 30 kilometer (about 19 miles) radius around the plant site would be evacuated.

Isolating the reactor was an immediate priority once the fires were extinguished and the nearby towns were evacuated. To make a safer work zone, the area surrounding the reactor was cleared of debris. The contaminated debris, reactor core fragments, and surface soils from the immediate area around the reactor were placed in a concrete reinforced gallery hastily constructed around the reactor. Removal and shielding of this material made the area safer to work in.

Other soils and debris were stored in a large number of temporary shallow trenches and impoundments within the exclusion zone and covered with soil to provide minimal shielding and to reduce potential for wind to mobilize the contaminants. These trenches and small impoundments were not designed as permanent storage, yet most of them remain to this day.

[Possible image – trenches around Chernobyl or a generic trench and piles of debris to illustrate concept.]

After cleaning the blast area, a structure known as the sarcophagus was constructed of concrete, steel plates and beams to isolate the most contaminated wastes and the reactor. The sarcophagus was constructed between May and November 1986 under very hazardous working conditions. *[Images of the Chernobyl sarcophagus.]* The structure was hastily designed and erected and has been exposed to the elements and infiltrated by moisture for more than 20 years. A new safer confinement structure is currently being designed to address the shortcomings of the sarcophagus and to isolate the reactor core and the most contaminated wastes for the next 100 years. *[Image: New safe confinement structure image is on cover of IAEA report: Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience.]*

Draft 8/11/09

5. Living in the Aftermath of Chernobyl—Lessons from the Recovery

The accident at Chernobyl resulted in unprecedented radiological contamination of a densely inhabited area. Local and national authorities were not prepared for an incident of such size and severity. How did people in the region react and what measures did they take to cope after the accident? How did the cleanup of the area proceed and what was life like in the affected areas?

The reports of two women with first-hand, personal experiences living in the aftermath of Chernobyl help to answer these questions. The first is Larisa Leonova, a chemist with the U.S. Environmental Protection Agency who was one of the early responders to the Chernobyl event. At the time of the accident, she was managing a laboratory in Moscow on a part-time basis while earning her PhD in chemistry. Larissa volunteered to help with the response and traveled to Kiev several weeks after the incident. She worked in the area around Pripyat, trying to convince local residents to leave the area.

> *[Image – LL8 3:51:54 – 3:52:21 "My Name is Larisa Leanova and I live in United States oh, it's my twentieth years. And um, back when Chernobyl happened I was ah, twenty-eight years old and four years is graduated from ah, university. And I was working as a chemist, basically part time a lab manager and part time doing my PhD research work. Back when the Chernobyl happened I was in Moscow, I always lived in Moscow."]*
>
> *[Image—LL8 4:00.44--?? "So, I basically ah, set up the vacation time and I called to my uncle in the Kiev and I said like you know me and another group of ah, chemists we are ready to provide whatever the type of the help we can."]*

Vira Yakusha is a computer scientist with a consulting firm in Washington DC. At the time of the accident, Vira was a resident of Kiev and a recent graduate of Kiev University. Vira was pregnant with her first child, and she brings the perspective of an expectant mother and member of the general public reacting to the events occurring around her.

> *[Image – VY4 2:33:03 – 2:34:00 "My name is Vira Yakusha and ah, I was born in Kiev. And ah, I lived there for my entire life. And I loved the city a lot. And ah, I was there as a just a member of general population when Chernobyl tragedy struck. And so my perspective is a perspective of a lay person who is not professionally involved in the nuclear, in the nuclear industry, but who was, whose life was directly affected by what happened. And ah, my story is a story of person who is trying to comprehend what's going on and trying to do the best, what is best for my family, for health of my family and ah, trying to live my life as ah, as simple as possible if it's possible in the difficult circumstance."]*

Using the first-hand accounts of Larissa and Vira, we will look at several key aspects of the recovery from a radiological event: countermeasures to reduce exposure to the radiation released during the incident, coping with contamination of the food supply, and the special health concerns for pregnant women and their children associated with the accident.

5.1 Limiting Exposure and Cleaning Up

Once the pressing issues of putting out the fires, evacuating the immediate area, removing debris and isolating the reactor were taken care of, attention turned to the impact of the accident on the broader area. Radioactive dust and dirt were a major source of contamination in both agricultural and urban areas.

Because of the magnitude of the accident, local and national authorities were initially uncertain how to proceed. Larissa Leonova, a chemist who now works for the U.S. EPA, volunteered to travel to Kiev in the first weeks after the accident to lend a hand.

> *[LL4:01:56- 4:02:35 "our group of volunteers were basically invited by um, some sort of the organization which were created back there and basically consist um, of very strange group of people who -- represented by Army and by some ah, local officials which were not scientists. They were just the politicians and they were trying, trying to create some sort of the response. And um, again you know first couple of weeks it was basically you know not enough data or no information about plume or no information which territory it's more affected."]*

> *[LL4:03:03 – 4:03:14 "we were among of the first, to my knowledge, volunteer group who went there and who got um, ah, who were involved in ah, um, some sort of the response."]*

One of the first assignments of the group of volunteers was to provide the local populace with some basic guidance about how to limit their exposure to the radioisotopes released by the plant.

> *[LL4:05:05 – 4:05:25 "that's the season when everybody in the Ukraine um, pick up the strawberries. And Ukraine, it's very high in the strawberries and actually you know like um, everybody over there -- middle of the May and June the strawberries is the best place -- taste unbelievably good and everybody has a strawberry growing in their backyards and garden."]*

> *[LY4:05:40 – 4:05:51 "So, the first advice which we wrote was very silly, we're saying like do not eat the strawberries if they are you know like right besides the dripping line um, from your roof."]*

> *[LL4:06:00 –4:06:15 "The other thing was we were basically advising that ah, try to have at least a bucket of water near the entrance of your door and before -- after you coming from the street to your house, wash you um, shoes and remove your shoes, try to not bring the additional dust."]*

Once the authorities began to realize the significance of the accident, they began to issue further guidance on ways to reduce exposure to contaminated dust:

> *[VY1 01:34:00 - 01:34:30 "First Monday after, uh, after Easter so it was May -- May 5th, and the May 5th was the first day when, uh, when authorities, uh, Soviet authorities*

officially on the radio started to say well, things are, um, under control, but, um, for, just for personal precautions please shower regularly, try to keep dust out of the rooms, and, uh, keep your clothes laundered often, and cover the food and bread if you buy something so, uh, it's, uh, to prevent dust from, uh, coming on the food. Uh, so there were first official guidelines for general population to minimize, uh, the exposure."

VY3 02:25:56 - 02:26:32 "After that first announcement, ah, they say that you should wash ah, take shower often, wash your ah, clothing often. Ah, try to prevent dust from setting on your household items. Ah, there was more information. And ah, it will become more and more detailed and instructions more elaborate this time. Then they were not that afraid to accept or admit that something wrong is going on. And, ah, we were doing this religiously. Our family. We were trying to follow everything and some more."

VY3 02:14:21- 02:14:18"my family just tried to keep everything as clean as possible. Free from dust, from dirt. But ah, the thing is that you cannot be 100% sure, of course. And later on, of course, it was not about the surfaces, of your living space, but more about the food that you are getting and ah, and ah, probably some accidental contamination that, for example, like there, rooftops for um, perceived to be very dirty. And they were in fact. So we were told or people were telling the children were told to avoid the downpours from the, from the roof, for example. If ah, water is pouring from the roof, it' probably, if it goes and fills in your overcoat, you don't want to have your overcoat to get dirty and to get rid of it later on."]

As we can see from these examples, one of the primary ways people are exposed to radioactivity after a radiological event is through contaminated dust and soil that adheres to hair, skin, clothing, and shoes. One effective way to reduce this exposure is to shower frequently, launder clothing frequently, remove shoes and outer clothing before entering living areas, and practice general good housekeeping to reduce dust and dirt indoors. These hygiene precautions were successful in areas like Kiev after the Chernobyl accident, and they are also recommended by Centers for Disease Control and others.

The decontamination activities performed after Chernobyl gives us an idea of what techniques are most effective to reduce the dose received from exposures to radiation. In the days following the accident, the area around the Chernobyl plant and the most contaminated areas in the exclusion zone were sprayed with organic solutions to create a thin film that would immobilize dust. Buildings, vehicles, and city streets were washed frequently and sprayed with water to suppress dust. *[Image: workers spraying water on trucks, buildings, and streets.]*

Much of the radioactivity from the accident was concentrated in surface soil, plants, on asphalt and concrete, and to a lesser extent on roofs and walls. Streets in Kiev were washed daily in the weeks following the accident. In surrounding areas, roads and buildings were washed, residential areas were cleaned, contaminated soils were removed--especially along drip lines next to buildings--and sediments were removed from the bottom of reservoirs. *[Image: men peeling back sod (42-15785116).]* Decontamination activities concentrated on schools, hospitals and other high-use buildings. Overall, tens of thousands of public buildings and residences were treated in about 1000 cities and towns.

According to the International Atomic Energy Agency (*IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience)*, street cleaning, removing trees and shrubs, and plowing soils in yards to bury the surface soils were efficient and inexpensive means of achieving significant reductions of dose. Roofs and walls also contribute to dose, but they are costly and difficult to clean and thus present a more difficult issue in the event of a radiological emergency in an urban setting. [*Images for this section could be a montage of people scrubbing, plowing, and spraying the streets, buildings, and yards.]*

> *VY4 02:45:17 – 2:45-31 "I've heard from people who stayed there that um, street washing was much more frequent during that memorable summer that there is. When much more often than usual and they were doing a good job of keeping the city clean after all."*

> *VY4 2:58:48 – 2:59:05 "In my understanding and my feeling that ah, in the long term during that summer, during consequent months, government did a lot. I mean what they could at this given time. Given level of technology. To clean up what they could."*

> *VY4 02:57:04 – 2:57:12 "Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that."*

> *VY4 2:57:19 – ? "For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do."*

The following websites provide good information on actions that can be taken to limit exposure after a radiological incident. [*Images: CDC rad website and address www.bt.cdc.gov/radiation, image of DHS Ready.gov rad website and address http://www.ready.gov/america/beinformed/radiation.html*.

There's also a not-so-great quality but understandable image of a silhouette guy showering off yellow dots at http://www.remm.nlm.gov/deconimage.htm]

5.2 Managing the Food Supply

The massive amount of radioactive fallout from Chernobyl also had far-reaching consequences for the food supply in the contaminated area. Internal exposure to radiological contaminants through consumption of contaminated food and water is a very significant exposure concern. Early responders were advised not to eat locally grown food, and surprisingly, to drink red wine instead of water:

> *[LL8: 4:20:00 – 4:20:06 "We were ordered -- we were basically -- that was our order to drink red wine, not drink water. So, that was our liquid consumption. "and LY8 04:27:54 – 4:28:08 "We were not given anything besides red wine. We were strictly advised not drink water or milk. And we were advised do not eat any um, grown -- locally grown product -- produce, nothing, no vegetables, no fruit, nothing."]*

Many locals used common sense and avoided eating locally grown foods that were probably contaminated:

> *[LY8 4:14:29 - 4:14:45 "We found the people who were very educated and um, they were not eating any fresh food since the accident, since the first they heard about the accident. They were trying to eat canned food only."*

Local authorities prohibited animal feeding with pasture grasses in the affected areas and rejected milk based on radiological monitoring. Many thousands of agricultural and domestic animals were slaughtered immediately, and the remainder evacuated. *[Images – pigs and cows being screened with radioactivity meters by a worker in a moon suit (ex: 42-15882699 and* 0000316032-056*), images of dead fish on the shore near the reactor]*

People living in the area tried to obtain imported food as much as possible, but this was often difficult. Vira Yakusha explains her dietary habits when she returned to Kiev with a young baby in the months following the accident:

> *[VY3 02:27:15 – 2:27:43 Well first concern ah, at that point was the food. And ah, food and again official line was that all food is carefully screened. Sources of food that contaminated milk or other ah, ah, necessities are discarded and thrown away and so you don't have worry about that. But of course we did worry. And of course we, we will try to buy imported food. As much as it was possible. But it was not that readily available.*
>
> *VY3 2:22:18 – 2:24:00 "…if there is a cereal made in Hungary, probably there is less ah, a less chance that it's radiologically contaminated than the sour cream made on the local factory. Because God knows where this local factory gets their milk from. And in the first couple of weeks we were so ardent about it that I even didn't eat any bread because bread was definitely make over, made of local grains. And again, local grains could be contaminated. But after a couple of weeks without bread, I said you know what? I'm going to eat bread. Because I cannot. I need to eat something, right?"*
>
> *[VY3 02:28:35 – 2:28:51 "So there are very, there are always efforts. There are always efforts to make sure your food sources are clear. But it is almost impossible. So you have to accept at some point that you have to, continue with your life or otherwise you will just go mad."*
>
> *VY3 2:27:43– 2:28:12 "And of course, ah, ah, we will try to buy imported food. As, as much as it was possible. But it was not that readily available. And again, there were um, ah, some things that you cannot buy imported. For example, like your greens, your apples. And ah, sometimes you will come across imported apples with big luck. I remember my husband bought five kilos of ah, ah, a golden ah, golden delicious which is a common brand in America and they were ah, grown somewhere ah, from north of imported apples. And we were very happy. We were feeding our baby these apples for quite a long time while they lasted."*

As time went on and the threats posed by contaminated farmland became better understood, the local authorities undertook more sophisticated measures to manage agricultural production from contaminated farmland. According to the International Atomic Energy Agency, some of the most effective countermeasures were treating the soil; removing some areas from agricultural production altogether based on radiological screening; switching animals to clean fodder from uncontaminated areas; and feeding animals dietary supplements such as cesium binders to help the radio nuclides pass through the animals without being incorporated in food products. *[Images: workers in suits walking through a field (42-15800571), a man with a rotor tiller (*42-15784775*), peasant gardeners (DWF15-682237), and a fallow field with a rad sign in front of it (42-15784775)]*.

The countermeasures described above went a long way to reducing the radiological contamination of foods from the affected areas. However, the long half life of some of the contaminants, particularly Cesium-137, as well as economic hardships following the fall of the Soviet Union resulted in continued barriers to agricultural restoration in the area.

ARE THERE ANY GOOD WEB SITE CITATIONS HERE RE: FOOD? WASN'T ABLE TO FIND MUCH

5.3 Coping with Special Health Concerns

For the people affected by Chernobyl, radiation exposure of unborn babies was a major concern. Vira Yakusha was living in Kiev and pregnant with her first child at the time of the accident. Upon learning of the disaster, she tried to leave Kiev as soon as she was able, to try to put as much distance between her baby and the radiation emergency as she could. Unfortunately, many people were trying to do the same, and Vira was unable to buy a train or plane ticket *[image –we could show a few generic Russian-looking group queued up at a ticket booth, as Vira spoke about the crush of people waiting to purchase airline or train tickets.]* Vira discussed this situation urgently with her husband and her family:

> *VY1 1:29:20 - 01:29:27 "I was really determined, uh, to keep my baby healthy and, uh, as far as harm's way was possible."*
>
> *VY1 1:50:49 "I don't know what to do, it's impossible to buy tickets for -- for a plane, it's impossible to buy tickets for a train, but we need to get you out. And we were sitting in the kitchen and trying to figure out what kind of plan that could work"*
>
> *VY2 01:51:36 – 1:51:41 "And so we were thinking about this and that, and there is suddenly, um, uh, a buzz on the door …"*
>
> *VY2 1:51:54 – 1:52:44 "I opened the door and this is, uh, again my friend, uh, Yenna, who, uh, head of the family who were taking me to Karnyov, and he sort of looks grim, and he said you know what, I made a decision, uh, I take my, uh, girls away to Mosc -- I'm taking my girls away to Moscow because I want to get my kids out of here as soon as possible. And his, his thinking was pretty much the same that if the government admits so much that, uh, it's dangerous, then it's really, really dangerous. Yeah, and he said, um,*

okay, so my car is downstairs, uh, waiting for you, um, my wife and my kids are in the car, and we have still one place left in this car, this is for Vira. If you want to go with us you have 40 minutes to pack yourself."

[Images – Possibly a man standing next to an old, Soviet-style car? A family around a table talking about something obviously upsetting or pressing.]

Vira left Kiev that night, and four months later in Moscow she gave birth to Doreena, a healthy baby girl. We can't say whether getting out of Kiev, about 70 miles from the disaster, in the weeks after the accident helped her give birth to a healthy child. Her child may very well have been fine had she continued to live in Kiev.

VY1 01:32:46 – 1:33:18 "Doreena, and she is, uh, 21 years old right now, and, uh, I never had any, uh, uh, health problems with her that I should, could attribute to potential exposure. But unfortunately, uh, my understanding of the nature of the whole thing is that you never can, if you have some sort of health problem you can never be 100 percent sure if it was the result of, uh, your exposure to the radioactivity at some point or it's just your particular body type or, uh, other factors that were contributing."

Reflecting on her actions many years later, Vira feels that she made the right choice given the information that she had:

VY4 02:42:38 – 2:43:38 "My personal feeling is the health of your children or your child is the first priority, because this is something that you are ulta, ultimately responsible for. So I would say what I said to myself. Put as many miles as you can between the source of radiation and yourself and your baby and try to get as much information as much reliable information as you can. And try to… I mean panic is never a good helper or a good advisor. So probably understanding is our best weapon and to know how things work and what is real danger and what is imagined danger. It is a real important difference. And the more you understand, the better your choices are, the better your behavior is. At least you're choosing between least, least possible evils. And ah, it's impossible to be in a perfect world. But in our imperfect world, you have to make your own choices. And it's better to be based on the, on the ways of reason."

[Note – one danger of this section is that it gives some cause for panic – I feel that the 'woman in the street' perspective is valuable, but the message is clearly to flee the area, and it appears that Vira's actions may have saved the day. If I was a pregnant woman watching this, I'd think – get away first and ask questions later. Just want to be sure we're OK with that message.]

Exposure to radiation can cause health problems depending on the type of radiation, the exposure, and the individual's general health and susceptibility to illness. Some populations are particularly susceptible to the effects of radiation, and these include pregnant women and especially unborn babies. The Centers for Disease Control say that unborn babies are particularly sensitive to radiation during their early development, between weeks 2 and 15 of pregnancy, and can experience severe health effects such as birth defects, stunted growth, and brain damage. From 16- to 25-weeks, unborn babies may experience health consequences, but only if the doses radiation are very large, such as those large enough to cause radiation sickness in the mother. After the 26th week of pregnancy, the radiation sensitivity of an unborn baby is similar to that of a newborn. More information about the special health concerns associated with exposure to radiation during pregnancy can be found on the Centers for Disease Control Web site. *[Image – CDC web site and fact sheet at http://www.bt.cdc.gov/radiation/prenatal.asp]*

Final 2/21/2011

The Chernobyl Incident—Experiences, Recovery and Lessons Learned

Ideas for Alternate titles:

Recovering from a Radiological Terrorist Attack—Lessons Learned from the Chernobyl Incident

Nuclear Terrorism—What Can We Expect? Experiences, Recovery and Lessons Learned from the Chernobyl Incident

Recovering from a Nuclear Terrorist Attack—What We Can Learn from the Chernobyl Accident

1. Introduction

In an age in which terrorist attacks are becoming more frequent and more lethal, an attack on the United States that releases radiation—the explosion of a "dirty bomb" or improvised nuclear device—is a frightening and very real threat. Such a radiological assault would aim to inflict mass casualties, widespread panic and disruption, and could cause contamination that lasts for months or even years after the initial event.

U.S. government agencies at the state, local and federal levels are preparing for such an event and have been rehearsing the emergency responses that would occur immediately after such an attack. But how would we cope with the aftermath of the event? What could we do to recover from its longer-term consequences?

The long-term recovery lessons learned from the 1986 Chernobyl nuclear plant disaster help to answer these questions. The Soviet response to that disaster and the analyses that followed give us insights into what does and doesn't work in responding to such a situation. In this film, we will examine the basics of what a radiological attack on the United States would involve, and what the countermeasures and restoration actions taken after the Chernobyl accident tell us about what we might expect following such an event. We will enhance our discussion with the first-hand, personal perspectives of an early responder who provided technical assistance during the first phases of the recovery from Chernobyl, and of a resident of Kiev who was a young mother in Ukraine at the time of the disaster.

Dr. John Cardarelli, an Industrial Hygienist and Health Physicist with the U.S. Environmental Protection Agency explains why it is useful to focus on Chernobyl:

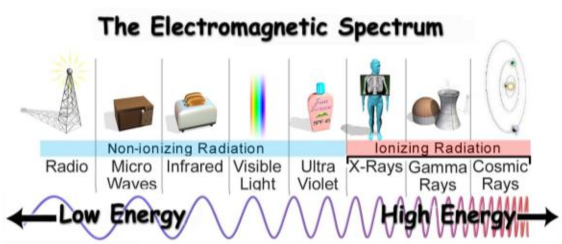
[Image: JC1 5:00:50 – 5:01:24 "Chernobyl brings us a unique perspective in the fact that it was uh, uh, a real, live situation where hundreds of thousands of square kilometers

were contaminated with radioactive material that had been um, dispersed from the reactor accident. And it exposed hundreds of thousands of humans, requiring a large amount of environmental clean up. So what we can learn from those aspects and apply them here in the United States could be very valuable if we were to ever experience something similar to that here in the United States."]

By improving public awareness and helping people to educate themselves on the issues associated with a possible radiological emergency, we will not only be better prepared, but the power of such an event to terrorize our citizens can be greatly reduced.

2. Radiation and Radioactivity

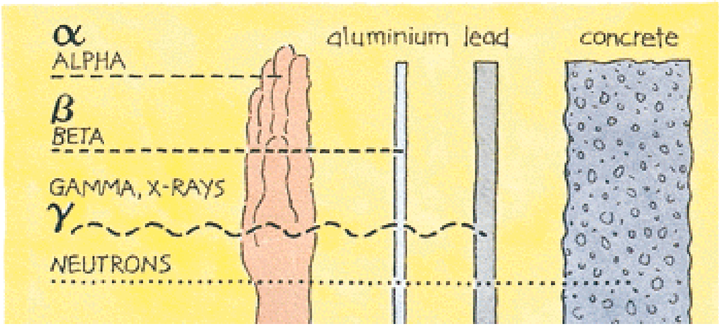
In order to more fully understand the effects of a radiological emergency and the long-term recovery issues associated with it, we will first review some of the basic concepts and terms about radiation and radioactivity.



All of us are continuously exposed to radiation from both natural and man-made sources. For example, natural background radiation varies throughout the world and its level depends on many factors such as altitude, soil conditions and location on earth. The word "radiation" has many meanings, and there are many types of radiation. [*Graphic—electromagnetic spectrum*] Television and radio waves, radar and visible light are all examples of radiation, and none of these cause harm to living organisms under normal conditions. These lower-energy types of radiation are called "non-ionizing radiation."

The other general category of radiation is called "ionizing radiation." Ionizing radiation is higher in energy than non-ionizing radiation and can damage living cells. It comes from radioactive materials, including naturally occurring radioactive elements found on earth, cosmic rays from space and man-made radiation sources such as medical x-rays. The level of radiation from naturally occurring sources to which we are exposed on a daily basis is called "background radiation," and it varies throughout the world depending on such factors as altitude, soil conditions and location on earth.

There are four main types of ionizing radiation: alpha particles, beta particles, gamma rays and neutrons.



[Text and graphic from the REMM Video 1 min 33 sec:]

"Alpha particles may be ejected from the nucleus of an atom during radioactive decay. They are relatively heavy and only travel about an inch in air. Alpha particles can easily be shielded by a single sheet of paper, and cannot penetrate the outer dead layer of skin, so they pose no danger when their source is outside the human body.

Beta particles are essentially electrons emitted from the nucleus of a radioactive atom. They are lighter than alpha particles, and can travel farther in air, up to several yards. Very energetic beta particles can penetrate up to one half an inch through skin and into the body. They can be shielded with less than an inch of material such as plastic. In the case of lower energy beta particles, the outer layer of clothing can act as an effective shield.

Gamma rays can be emitted from the nucleus of an atom during radioactive decay. They are able to travel tens of yards, or more, in air, and can easily penetrate the human body. Shielding this very penetrating type of ionizing radiation requires thick dense material such as several inches of lead or concrete.

Neutrons can be released from the nucleus of an atom during a fission reaction, such as within a nuclear reactor, or upon detonation of a nuclear weapon. Neutrons, like gamma rays, are very penetrating, and several feet of concrete is needed to shield against them.

If radioactive materials are released into the environment as the result a terrorist attack or accident, people could be exposed to higher than background levels of ionizing radiation that could contaminate them and their surroundings. When vaporized radioactive material is released into the atmosphere, it cools, condenses into solid particles, and falls back to earth. These particles can be carried by the wind as a plume, and can contaminate surfaces far from the explosion itself, including food and water supplies. This phenomenon is known as "fallout."

[*Will use RMM Website video here with narration by our narrator using text below. Text in italics is exactly that from the existing video. Time = 1 min 52 seconds. Additional text not in italics has been added to explain how medical treatment can help.*]

"When a person is near a source of radiation, some type of radioactive material, he or she can be exposed to the radiation emitted by this source. However, he or she does not become contaminated.

One way to think about exposure is to think about X-rays. When a person has a chest X-ray, he or she is exposed to radiation, but does not become contaminated with radioactive material.

A person can reduce his or her exposure to radiation, if he or she is shielded in some ways from the radiation, for example, if the person is behind a concrete wall, or if the radioactive source is inside of a lead container.

In order to become contaminated, radioactive material must get on the skin, or clothing, or inside of the body. For example, if radioactive material is incorporated into a dirty bomb, a conventional explosive, such as dynamite that has been laced with radioactive material, then people could become contaminated when the device is detonated. Radioactive material on the outside of the body is called external contamination. When a person becomes externally contaminated, simply removing the clothing can remove up to 90% of the contamination. Gently washing the skin and the hair can remove most of the remaining contamination.

If a person ingests or inhales radioactive material, it can become incorporated in the organs of the body. This is called internal contamination. When a person is internally contaminated, depending on the type of radioactive material with which they were contaminated, certain medications can be administered to speed up the rate at which the radioactive material is eliminated from the body."   For example, Prussian Blue is an effective drug that can be used to eliminate Cesium from the body, and was used on animals following the Chernobyl incident so the population could drink animal milk and eat meat. Potassium Iodine tablets were also taken by many people to counter the negative effects of the Iodine-131 gas that was released during the accident.

Once released, radioactive materials remain a threat to the environment for varying periods of time. How quickly a radioactive material decays is measured by its "half-life," or the amount of time it takes for the radioactivity of the material to decrease by half. For example, the half-life of Cesium-137 is about 30 years. This means that about half of the Cesium-137 released during the Chernobyl accident will have decayed by the year 2016. This decay process will continue, and after 7-10 half-lives, or 210-300 years, the Cesium radioactivity from Chernobyl will have decayed to near background levels. The long half-life of some radioactive elements such as Cesium presents difficult challenges since people may be exposed to a contaminated environment for many years unless action is taken to decontaminate the area affected by the accident.

On the other hand, another radioactive element released at Chernobyl was Iodine-131, which has a half-life of 8 days. This presented a much shorter-term challenge because it decayed away in about 56 to 80 days after the accident.

[*May be good to have a graphic here to help summarize the key points to take away from this section, with simple voice over*.]

To summarize some of the key points about radiation and radioactivity:

- All of us are continuously exposed to low-level radiation from both natural and man-made sources. This level is called "background radiation" and is not harmful to living things.
- If radioactive materials are utilized in a radiological attack, living things could be exposed to higher than background levels of ionizing radiation that could harm them and contaminate their surroundings.
- The potential harm from radiation may be seen within days or weeks after exposure if the dose is extremely high--for example, millions of times higher than normal background levels—or, it may present itself as cancer decades later.
- People can reduce their exposure to this harmful radiation by shielding themselves from its source, taking precautions to prevent unnecessary exposure, removing contaminated dust from their skin and clothing, and cleaning, decontaminating or leaving the area.
- There are effective medical treatments to help counter the harmful health effects of internal radiation contamination.
- Radioactivity decays with time. The "half-life" of many radioactive elements is relatively short, but others with much longer half-lives will present challenges to cleaning-up the areas affected by the attack.

3. Types of Incidents We Might Face

What types of radiological threats might we face should radioactive materials be used in a terrorist attack?

Experts have identified four potential scenarios: *(NOTE: some simple graphics depicting these four scenarios could be helpful here—there are some on the REMM website.)*

- A **Radiological Exposure Device, or "RED,"** is a non-explosive device made of highly radioactive material that is hidden in a highly populated area. When people pass by it, they are unknowingly exposed to potentially harmful levels of radiation.
- A **Radiological Dispersal Device, or "RDD,"** is a device that releases radioactive materials into the environment by using conventional explosives or another method. This device is commonly referred to as a "Dirty Bomb."

- A targeted **attack on a nuclear power plant or installation** could result in the release of radioactive materials from the nuclear reactor, spent fuel or other nuclear materials stored on site.
- An **Improvised Nuclear Device, or "IND,"** is a crude nuclear bomb, built from scratch or from stolen components, that is capable of producing damage similar to that experienced at Hiroshima or Nagasaki.

The radiation exposures and effects that would result from events such as these vary widely from scenario to scenario, so we will examine each one separately.

The **Radiological Exposure Device (RED):**

A RED contains highly radioactive materials in a sealed device that is intended to expose people to significant doses of ionizing radiation without their knowledge. Such a device could be hidden in a public place such as in a subway car or sports stadium in order to expose a large number of people. A RED causes exposure to high levels of radiation, but unless the seal around the radioactive materials is broken, it does not cause radioactive contamination. The amount of radiation received is measured in dose. The total dose that would result from exposure to a RED would depend on the type of radioactive material used, how close the person was to the material, and for how long the person was near the device. The adverse health risk would increase as the dose increases.

The **Radiological Dispersal Device (RDD):**

A RDD is a device that releases radioactive materials into the environment. It could combine conventional explosives with radioactive materials so that when it is detonated, it volatizes and disperses radioactive material and other debris into the surrounding area. Or, it could spray radioactive materials into the environment using a mechanical device such as a crop duster. The easiest way to release radiological agents would be to detonate a type of RDD known as a "dirty bomb" [*image—an explosion in a city*]. It is important to realize that a dirty bomb is not the same thing as a nuclear bomb. A dirty bomb uses radioactive materials, but these materials do not undergo the type of nuclear reaction that releases large quantities of energy and produces an atomic mushroom cloud.

The main dangers from a dirty bomb are the serious injuries and damage that would result from the explosion itself. It most likely would not have enough radioactive material to cause serious radiation sickness among large numbers of people. Nonetheless, it would contaminate the immediate area surrounding the explosion with radioactive dust, smoke or other materials that could be dangerous if inhaled and potentially cause long-term contamination and recovery problems. Since it would likely be detonated in a densely populated area, it could cause significant disruption and panic.

[*Need to find or create a video clip to illustrate the dirty bomb scenario. At John Cardarelli's suggestion we are evaluating the potential use of DHS video coverage from TOPOFF 2*]

An **attack on a nuclear plant or installation:**

Terrorists could release radioactive materials by intentionally causing a fire or explosion at a nuclear power plant or nuclear installation. Such an incident could require evacuation of the geographic area proximate to the facility and cause widespread contamination from both long and short-lived radioisotopes released as a result of the attack.

The world has suffered several accidents at nuclear power plants, including the Chernobyl reactor meltdown in 1986, and partial reactor meltdowns at the Three Mile Island Nuclear Plant near Harrisburg, Pennsylvania in 1979 and the Chalk River Nuclear Plant near Ottowa, Ontario in 1952. Radioactive releases were also caused by a fire at the Windscale reactor near Liverpool, England in 1957 and by an earthquake at a reactor near Kashiwazaki, Japan in 2007. [*Show still images of several of these sites and possibly some of the newspaper headlines that went with these accidents.*]

The worst of these incidents was that at the Chernobyl plant, which we will discuss in more detail shortly. Although a terrorist attack on a U.S. nuclear facility could have serious consequences, it is important to keep in mind that nuclear power plants in the United States are not like those found in the former Soviet Union. The design of U.S. reactors is very different from the design of the Chernobyl reactors, and U.S. nuclear safety and security regulations are more stringent. The technical design of U.S. reactors makes major releases of radioactive materials under any circumstances extremely unlikely, if at all possible.

An **Improvised Nuclear Device (IND):**

The most devastating way to release radiological agents would be to construct and detonate an Improvised Nuclear Device, or IND. An IND is a small nuclear bomb in which radioactive materials undergo a nuclear reaction and release massive amounts of energy. Explosion of an IND would be devastating and would likely cause mass casualties and major property damage. However, the technical difficulty of obtaining the necessary materials and creating the conditions for a nuclear reaction make this a less likely scenario than a RDD. A stolen nuclear weapon by a terrorist organization is of greater concern.

Although explosion of an IND would be a catastrophic event, its long-term contamination effects could actually be less than those experienced following the Chernobyl accident. The Chernobyl accident resulted in the continuous release of radioactive materials into the environment over a period of ten days. An IND contains much less radioactive material and releases all of it in an instant. These materials would be spread over less distance compared with Chernobyl, but the area could be highly contaminated. Most of the radioactive materials released by an IND would decay within in the first few months.

However, a small amount of residual contamination would remain for a relatively long time. Cesium-137 and Strontium-90 are the two long-lived isotopes common to both Chernobyl and INDs.

To sum up, we face four main types of incidents that might result in the exposure to or release of radioactive materials: a Radiological Exposure Device, a Radiological Dispersal Device, an attack at a nuclear plant or installation, and an Improvised Nuclear Device. [*Could use a simple graphic here.*]

A dirty bomb is a likely scenario. The radioactive materials released would likely remain persistent in the environment for a relatively long time, and may contaminate a populated downtown area.

An attack on a nuclear power plant or installation could release both long- and short-lived radioisotopes that may cause widespread contamination, similar to those released during the Chernobyl incident. The scale of such a disaster is not likely to match the uncontrolled meltdown at Chernobyl, where a fire raged for 10 days, spewing nuclear and radioactive materials into the atmosphere and spreading them over hundreds of thousands of square miles.

Detonation of an improvised nuclear device would be a catastrophic event that could devastate a city and cause widespread destruction. A nuclear bomb would involve a nuclear reaction and release formidable amounts of energy and scatters radioactive fallout over a large region. Most of the types of materials released would decay relatively quickly. However, a small amount of residual contamination would remain for a relatively long time, posing more challenging recovery issues.

4. The Chernobyl Incident and the Initial Response

Now that we've covered a few of the basics about radiation, radioactivity and the types of emergencies that may occur, we can better examine the issues associated with radiological contamination. The 1986 accident at the Chernobyl power plant in the Soviet Union gives us insight into how we might recover from a wide-scale radiological event. First, let's take a look at the accident itself.

In the early morning hours of April 26, 1986, the Chernobyl nuclear plant experienced the worst nuclear power accident in history. The accident created an uncontrolled nuclear reaction and the resulting explosion and fire sent a massive cloud of radioactive material into the atmosphere. The reactor burned for 10 days, releasing radioactive gases, vapors, aerosols and particles, and contaminating thousands of square miles in Ukraine, Belarus, Russia, and Western Europe. *[Images: nuclear technicians at the plant, the plant on fire, people suiting up to respond.]*

The Chernobyl nuclear plant is located near the border between Russia, Ukraine, and Belarus, about 70 miles northwest of the city of Kiev, the nearest major population center. Kiev had a population of about 2.5 million people at the time of the disaster. The town of Pripyat, located about two miles from the reactor, had a population of about

45,000 people at the time of the accident. *[Image – a map showing the broader geographic area, the plant, Pripyat, and Kiev—there is a good one at world-nuclear.org/info/chernobyl.]*

On April 25, 1986, Chernobyl plant personnel began conducting a safety test to determine if the reactor's cooling system pumps could operate if the plant's external power failed. Errors made by the plant operators and deficiencies in the reactor's design and operating procedures caused the reactor to go out of control during the test, resulting in a series of explosions and massive fires. *(References: World Nuclear Association Website, Chernobyl Accident, November 2009; IAEA Safety Series Report 75-INSAG-7, The Chernobyl Accident: Updating of INSAG-1, 1992.)* The reactor core and building burned for 10 days, and radioisotopes were carried upward into the atmosphere where they traveled with the prevailing winds. The accident at Chernobyl released about 400 times more radioactive material into the atmosphere than the bomb dropped on Hiroshima during the second World War. (*Ten Years After Chernobyl: What Do We Really Know?, IAEA, 1996).*

According to reliable reports (*IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience p.21,*) winds were initially to the northwest, but they varied over the next several days so that all areas were downwind at some point while the fire in the core continued burning. To further complicate matters, scattered thunderstorms and rainfall throughout the area brought down some of the airborne material to ground level, forming an irregular radioactive fallout pattern over thousands of square miles. *[graphic – figure 3.2 IAEA report, image of fallout pattern IAEA report Fig 3.6 and http://www.chernobyl.info/index.php?navID=2]*

The initial response to the disaster was disorganized, improvised, and chaotic. The main priority of the first responders was to put out the fire and then isolate the reactor core. First on the scene were local firefighters and soldiers who were not aware of the grave threat of exposure to very high levels of radioactivity. The firefighters extinguished the fires on the roof of the reactor building and in the surrounding area, thus protecting the other reactors at the Chernobyl facility, but they were not able to put out the burning reactor core. Many of these heroic firefighters and soldiers died from their enormous radiation exposure within days or weeks. *[Image: commemorative statue to lost firefighters in the town of Pripyat.]*

To put out the fire in the core, local authorities tried several approaches, including dropping 5,000 tons of sand, clay, and lead onto the core by helicopter. *[Image: helicopters dropping bags of materials.]* But because of the dangerous conditions and extreme heat, it took workers 10 days to put out the fire.

The town of Pripyat, located 2 miles northwest (and downwind) of the reactor, was evacuated on Sunday, April 27, one and one half days after the accident began. Residents were told to pack for three days and to leave household pets behind. The motivation for giving such a short timeframe for the evacuation was logistical: to limit the amount of baggage and personal belongings to be transported and to expedite the evacuation. A convoy of 1200 buses carried the residents and their belongings away, and the evacuation was reportedly completed in about three hours*. [Images of the evacuation of Pripyat – the long line of buses, lines of people getting on them and so forth.]*

In the following days, authorities measured radiation levels in the areas surrounding Chernobyl to determine the extent of contamination. Radiation levels above background were measured at distances of hundreds of miles away, but the government focused on the most heavily contaminated areas. The Soviet Ministry of Public Health determined that a 30 kilometer (about 19 miles) radius around the plant site would be evacuated.

Isolating the reactor was an immediate priority once the fires were extinguished and the nearby towns were evacuated. To make a safer work zone, the area surrounding the reactor was cleared of debris. The contaminated debris, reactor core fragments, and surface soils from the immediate area around the reactor were placed in a concrete reinforced gallery hastily constructed around the reactor. Removal and shielding of this material made the area safer to work in.

Other soils and debris were stored in a large number of temporary shallow trenches and impoundments within the exclusion zone and covered with soil to provide minimal shielding and to reduce potential for wind to mobilize the contaminants. These trenches and small impoundments were not designed as permanent storage, yet most of them remain to this day. *[Possible image – trenches around Chernobyl or a generic trench and piles of debris to illustrate concept.*

]

After the fires were extinguished, a structure known as the sarcophagus was constructed of concrete, steel plates and beams to isolate the most contaminated wastes and the reactor. The sarcophagus was constructed between May and November 1986 under very hazardous working conditions. *[Images of the Chernobyl sarcophagus.]* The structure was hastily designed and erected and has been exposed to the elements and infiltrated by moisture for more than 20 years. A new safer confinement structure is currently being designed to address the shortcomings of the sarcophagus and to further isolate the reactor core and the most contaminated wastes for the next 100 years*. [Image: New safe confinement structure image is on cover of IAEA report: Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience.]*

5. Living in the Aftermath of Chernobyl—Lessons from the Recovery

The accident at Chernobyl resulted in unprecedented radiological contamination of a densely inhabited area. It caused major economic, social and psychological hardships to those living in the region. Local and national authorities were not prepared for an incident of such size and severity. How did people in the region react and what measures did they take to cope after the accident? How did the cleanup of the area proceed and what was life like in the affected areas?

The reports of two women with first-hand, personal experiences living in the aftermath of Chernobyl help to answer these questions. The first is Larisa Leonova, a chemist with the U.S. Environmental Protection Agency who was one of the early responders to the Chernobyl event. At the time of the accident, she was managing a laboratory in Moscow on a part-time basis while earning her PhD in chemistry. Larissa volunteered to help with the response and traveled to Kiev several weeks after the incident. She worked in the area around Pripyat, trying to convince local residents to leave the area.

> *[Image – LL8 3:51:54 – 3:52:21 "My Name is Larisa Leanova and I live in United States oh, it's my twentieth years. And um, back when Chernobyl happened I was ah, twenty-eight years old and four years is graduated from ah, university. And I was working as a chemist, basically part time a lab manager and part time doing my PhD research work. Back when the Chernobyl happened I was in Moscow, I always lived in Moscow."]*

> *[Image—LL8 4:00.44--?? "So, I basically ah, set up the vacation time and I called to my uncle in the Kiev and I said like you know me and another group of ah, chemists we are ready to provide whatever the type of the help we can."]*

Vira Yakusha is a computer scientist with a consulting firm in Washington DC. At the time of the accident, Vira was a resident of Kiev and a recent graduate of Kiev University. Vira was pregnant with her first child, and she brings the perspective of an expectant mother and member of the general public reacting to the events occurring around her.

> *[Image – VY4 2:33:03 – 2:34:00 "My name is Vira Yakusha and ah, I was born in Kiev. And ah, I lived there for my entire life. And I loved the city a lot. And ah, I was there as a just a member of general population when Chernobyl tragedy struck. And so my perspective is a perspective of a lay person who is not professionally involved in the nuclear, in the nuclear industry, but who was, whose life was directly affected by what happened. And ah, my story is a story of person who is trying to comprehend what's going on and trying to do the best, what is best for my family, for health of my family and ah, trying to live my life as ah, as simple as possible if it's possible in the difficult circumstance."]*

Using the first-hand accounts of Larissa and Vira, we will look at several key aspects of the recovery from a radiological event: countermeasures to reduce exposure to the radiation released during the incident, coping with contamination of the food supply, and the special health concerns for pregnant women and their children associated with the accident.

5.1 Limiting Exposure and Cleaning Up

Once the pressing issues of putting out the fires, evacuating the immediate area, removing debris and isolating the reactor were taken care of, attention turned to the impact of the accident on the broader area. Radioactive dust and dirt were a major source of contamination in both agricultural and urban areas.

Because of the magnitude of the accident, local and national authorities were initially uncertain how to proceed. Larissa Leonova, a chemist who now works for the U.S. EPA, volunteered to travel to Kiev in the first weeks after the accident to lend a hand.

> *[LL4:01:56- 4:02:35 "our group of volunteers were basically invited by um, some sort of the organization which were created back there and basically consist um, of very strange group of people who -- represented by Army and by some ah, local officials which were not scientists. They were just the politicians and they were trying, trying to create some sort of the response. And um, again you know first couple of weeks it was basically you know not enough data or no information about plume or no information which territory it's more affected."]*

> *[LL4:03:03 – 4:03:14 "we were among of the first, to my knowledge, volunteer group who went there and who got um, ah, who were involved in ah, um, some sort of the response."]*

One of the first assignments of the group of volunteers was to provide the local populace with some basic guidance about how to limit their exposure to the radioisotopes released by the plant.

> *[LL4:05:05 – 4:05:25 "that's the season when everybody in the Ukraine um, pick up the strawberries. And Ukraine, it's very high in the strawberries and actually you know like um, everybody over there -- middle of the May and June the strawberries is the best place -- taste unbelievably good and everybody has a strawberry growing in their backyards and garden."]*

> *[LY4:05:40 – 4:05:51 "So, the first advice which we wrote was very silly, we're saying like do not eat the strawberries if they are you know like right besides the dripping line um, from your roof."]*

[LL4:06:00 –4:06:15 "The other thing was we were basically advising that ah, try to have at least a bucket of water near the entrance of your door and before -- after you

coming from the street to your house, wash you um, shoes and remove your shoes, try to not bring the additional dust."]

Once the authorities began to realize the significance of the accident, they began to issue further guidance on ways to reduce exposure to contaminated dust:

[VY1 01:34:00 - 01:34:30 "First Monday after, uh, after Easter so it was May -- May 5th, and the May 5th was the first day when, uh, when authorities, uh, Soviet authorities officially on the radio started to say well, things are, um, under control, but, um, for, just for personal precautions please shower regularly, try to keep dust out of the rooms, and, uh, keep your clothes laundered often, and cover the food and bread if you buy something so, uh, it's, uh, to prevent dust from, uh, coming on the food. Uh, so there were first official guidelines for general population to minimize, uh, the exposure."

VY3 02:25:56 - 02:26:32 "After that first announcement, ah, they say that you should wash ah, take shower often, wash your ah, clothing often. Ah, try to prevent dust from setting on your household items. Ah, there was more information. And ah, it will become more and more detailed and instructions more elaborate this time. Then they were not that afraid to accept or admit that something wrong is going on. And, ah, we were doing this religiously. Our family. We were trying to follow everything and some more."

VY3 02:14:21- 02:14:18"my family just tried to keep everything as clean as possible. Free from dust, from dirt. But ah, the thing is that you cannot be 100% sure, of course. And later on, of course, it was not about the surfaces, of your living space, but more about the food that you are getting and ah, and ah, probably some accidental contamination that, for example, like there, rooftops for um, perceived to be very dirty. And they were in fact. So we were told or people were telling the children were told to avoid the downpours from the, from the roof, for example. If ah, water is pouring from the roof, it' probably, if it goes and fills in your overcoat, you don't want to have your overcoat to get dirty and to get rid of it later on."]

As we can see from these examples, one of the primary ways people are exposed to radioactivity after a radiological event is through contaminated dust and soil that adheres to hair, skin, clothing, and shoes. One effective way to reduce this exposure is to shower frequently, launder clothing frequently, remove shoes and outer clothing before entering living areas, and practice general good housekeeping to reduce dust and dirt indoors. These hygiene precautions were successful in areas like Kiev after the Chernobyl accident, and they are also recommended by Centers for Disease Control and others.

The decontamination activities performed after Chernobyl gives us an idea of what techniques are most effective to reduce the dose received from exposures to radiation. In the days following the accident, the area around the Chernobyl plant and the most contaminated areas in the exclusion zone were sprayed with organic solutions to create a thin film that would immobilize dust. Buildings, vehicles, and city streets were washed frequently and sprayed with water to suppress dust. *[Image: workers spraying water on trucks, buildings, and streets.]*

Much of the radioactivity from the accident was concentrated in surface soil, plants, on asphalt and concrete, and to a lesser extent on roofs and walls. Streets in Kiev were washed daily in the weeks following the accident. In surrounding areas, roads and buildings were washed, residential areas were cleaned, contaminated soils were removed--especially along drip lines next to buildings--and sediments were removed from the bottom of reservoirs. *[Image: men peeling back sod (42-15785116).]* Decontamination activities concentrated on schools, hospitals and other high-use buildings. Overall, tens of thousands of public buildings and residences were treated in about 1000 cities and towns.

According to the International Atomic Energy Agency (*IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience)*, street cleaning, removing trees and shrubs, and plowing soils in yards to bury the surface soils were efficient and inexpensive means of achieving significant reductions of dose. Roofs and walls also contribute to dose, but they are costly and difficult to clean and thus present a more difficult issue in the event of a radiological emergency in an urban setting. [*Images for this section could be a montage of people scrubbing, plowing, and spraying the streets, buildings, and yards.]*

> *VY4 02:45:17 – 2:45-31 "I've heard from people who stayed there that um, street washing was much more frequent during that memorable summer that there is. When much more often than usual and they were doing a good job of keeping the city clean after all."*
>
> *VY4 2:58:48 – 2:59:05 "In my understanding and my feeling that ah, in the long term during that summer, during consequent months, government did a lot. I mean what they could at this given time. Given level of technology. To clean up what they could."*
>
> *VY4 02:57:04 – 2:57:12 "Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that."*
>
> *VY4 2:57:19 – ? "For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do."*

In 2008, the International Commission on Radiological Protection issued a report that provided guidance on the protection of people living in areas that had been contaminated on a long-term basis from a radiological event. The report identifies numerous actions and strategies that can be used to reduce exposures, improve living conditions and rehabilitate the affected areas. Among the actions identified in the report that should be implemented by authorities are "…clean-up of buildings, remediation of soils and vegetation, changes in animal husbandry, monitoring of the environment and produce, provision of clean foodstuffs, managing of waste..., health surveillance…" and public information. The report also identifies actions that can be taken by the inhabitants of the area, including monitoring the radiological quality of their living areas and food, and the radiation exposure of themselves and their children. *(Reference: ICRP Publication 111, October, 2008, page 12.)*

The following websites also provide good information on actions that can be taken to limit exposure after a radiological incident. [*Images: CDC rad website and address www.bt.cdc.gov/radiation, image of DHS Ready.gov rad website and address http://www.ready.gov/america/beinformed/radiation.html.*

There's also a not-so-great quality but understandable image of a silhouette guy showering off yellow dots at http://www.remm.nlm.gov/deconimage.htm]

5.2 Managing the Food Supply

The massive amount of radioactive fallout from Chernobyl also had far-reaching consequences for the food supply in the contaminated area. As noted by the International Commission on Radiological Protection, "the management of contaminated foodstuffs and other commodities produced in areas affected by a nuclear accident or a radiation emergency…presents a particularly difficult problem because of issues of market acceptance." *(Reference: ICRP Publication 104, 2007.)* While external exposures are likely to dominate radiation doses, internal exposure to radiological contaminants through consumption of contaminated food and water can be a very significant exposure concern. Early responders were advised not to eat locally grown food, and surprisingly, to drink red wine instead of water:

> *[LL8: 4:20:00 – 4:20:06 "We were ordered -- we were basically -- that was our order to drink red wine, not drink water. So, that was our liquid consumption. "and LY8 04:27:54 – 4:28:08 "We were not given anything besides red wine. We were strictly advised not drink water or milk. And we were advised do not eat any um, grown -- locally grown product -- produce, nothing, no vegetables, no fruit, nothing."]*

Many locals used common sense and avoided eating locally grown foods that were probably contaminated:

[LY8 4:14:29 - 4:14:45 "We found the people who were very educated and um, they were not eating any fresh food since the accident, since the first they heard about the accident. They were trying to eat canned food only."

Local authorities prohibited animal feeding with pasture grasses in the affected areas and rejected milk based on radiological monitoring. Many thousands of agricultural and domestic animals were slaughtered immediately, and the remainder evacuated. *[Images – pigs and cows being screened with radioactivity meters by a worker in a moon suit (ex: 42-15882699 and* 0000316032-056*), images of dead fish on the shore near the reactor (I suggest no using an image of dead fish because their death was not caused by radiation which some may be led to believe by using it in this context. These fish were likely killed due to the contaminated water from efforts to put the fires out – not the radiation in the water.)]*

People living in the area tried to obtain imported food as much as possible, but this was often difficult. Vira Yakusha explains her dietary habits when she returned to Kiev with a young baby in the months following the accident:

[VY3 02:27:15 – 2:27:43 Well first concern ah, at that point was the food. And ah, food and again official line was that all food is carefully screened. Sources of food that contaminated milk or other ah, ah, necessities are discarded and thrown away and so you don't have worry about that. But of course we did worry. And of course we, we will try to buy imported food. As much as it was possible. But it was not that readily available.

VY3 2:22:18 – 2:24:00 "…if there is a cereal made in Hungary, probably there is less ah, a less chance that it's radiologically contaminated than the sour cream made on the local factory. Because God knows where this local factory gets their milk from. And in the first couple of weeks we were so ardent about it that I even didn't eat any bread because bread was definitely make over, made of local grains. And again, local grains could be contaminated. But after a couple of weeks without bread, I said you know what? I'm going to eat bread. Because I cannot. I need to eat something, right?"
[VY3 02:28:35 – 2:28:51 "So there are very, there are always efforts. There are always efforts to make sure your food sources are clear. But it is almost impossible. So you have to accept at some point that you have to, continue with your life or otherwise you will just go mad."

VY3 2:27:43– 2:28:12 "And of course, ah, ah, we will try to buy imported food. As, as much as it was possible. But it was not that readily available. And again, there were um, ah, some things that you cannot buy imported. For example, like your greens, your apples. And ah, sometimes you will come across imported apples with big luck. I remember my husband bought five kilos of ah, ah, a golden ah, golden delicious which is a common brand in America and they were ah, grown somewhere ah, from north of imported apples. And we were very happy. We were feeding our baby these apples for quite a long time while they lasted."

According to the International Atomic Energy Agency, some of the most effective countermeasures were treating the soil; removing some areas from agricultural production altogether based on radiological screening; switching animals to clean fodder from uncontaminated areas; and providing dietary supplements such as cesium binders to help the radio nuclides pass through the animals without being incorporated in food products. *[Images: workers in suits walking through a field (42-15800571), a man with a rotor tiller (*42-15784775*), peasant gardeners (DWF15-682237), and a fallow field with a rad sign in front of it (42-15784775)]*.

The countermeasures described above went a long way to reducing the radiological contamination of foods from the areas affected by the Chernobyl accident. However, the long half life of some of the contaminants, particularly Cesium-137, and the economic hardships following the fall of the Soviet Union, resulted in continued barriers to agricultural restoration in the affected area.

5.3 Coping with Health Concerns

Exposure of humans to radiation can cause health problems, depending on the type of radiation, the amount of radiation exposure, and the individual's general health and susceptibility to illness. For the people affected by Chernobyl, the potential impact of the accident on their health was a major concern.

Vira Yakusha was living in Kiev and pregnant with her first child at the time of the accident. Upon learning of the disaster, she tried to leave Kiev as soon as she was able, to try to put as much distance between her baby and the radiation emergency as she could. Unfortunately, many people were trying to do the same, and Vira was unable to buy a train or plane ticket *[image –we could show a few generic Russian-looking group queued up at a ticket booth, as Vira spoke about the crush of people waiting to purchase airline or train tickets.]*

Vira discussed this situation urgently with her husband and her family:

> *VY1 1:29:20 - 01:29:27 "I was really determined, uh, to keep my baby healthy and, uh, as far as harm's way was possible."*
>
> *VY1 1:50:49 "I don't know what to do, it's impossible to buy tickets for -- for a plane, it's impossible to buy tickets for a train, but we need to get you out. And we were sitting in the kitchen and trying to figure out what kind of plan that could work"*
>
> *VY2 01:51:36 – 1:51:41 "And so we were thinking about this and that, and there is suddenly, um, uh, a buzz on the door …"*
>
> *VY2 1:51:54 – 1:52:44 "I opened the door and this is, uh, again my friend, uh, Yenna, who, uh, head of the family who were taking me to Karnyov, and he sort of looks grim, and he said you know what, I made a decision, uh, I take my, uh, girls*

away to Mosc -- I'm taking my girls away to Moscow because I want to get my kids out of here as soon as possible. And his, his thinking was pretty much the same that if the government admits so much that, uh, it's dangerous, then it's really, really dangerous. Yeah, and he said, um, okay, so my car is downstairs, uh, waiting for you, um, my wife and my kids are in the car, and we have still one place left in this car, this is for Vira. If you want to go with us you have 40 minutes to pack yourself."

[Images – Possibly a man standing next to an old, Soviet-style car? A family around a table talking about something obviously upsetting or pressing.]

Vira left Kiev that night, and four months later in Moscow she gave birth to Doreena, a healthy baby girl. We can't say whether getting out of Kiev, about 70 miles from the disaster, in the weeks after the accident helped her give birth to a healthy child. Her child may very well have been fine had she continued to live in Kiev.

VY1 01:32:46 – 1:33:18 "Doreena, and she is, uh, 21 years old right now, and, uh, I never had any, uh, uh, health problems with her that I should, could attribute to potential exposure. But unfortunately, uh, my understanding of the nature of the whole thing is that you never can, if you have some sort of health problem you can never be 100 percent sure if it was the result of, uh, your exposure to the radioactivity at some point or it's just your particular body type or, uh, other factors that were contributing."

Reflecting on her actions many years later, Vira feels that she made the right choice given the information that she had:

VY4 02:42:38 – 2:43:38 "My personal feeling is the health of your children or your child is the first priority, because this is something that you are ulta, ultimately responsible for. So I would say what I said to myself. Put as many miles as you can between the source of radiation and yourself and your baby and try to get as much information as much reliable information as you can. And try to… I mean panic is never a good helper or a good advisor. So probably understanding is our best weapon and to know how things work and what is real danger and what is imagined danger. It is a real important difference. And the more you understand, the better your choices are, the better your behavior is. At least you're choosing between least, least possible evils. And ah, it's impossible to be in a perfect world. But in our imperfect world, you have to make your own choices. And it's better to be based on the, on the ways of reason."

Pregnant women and their unborn babies are particularly vulnerable to the effects of radiation. However, termination of a pregnancy is rarely justified unless the dose absorbed by the pregnant woman or unborn child is very very high. According to the International Atomic Energy Agency, the potential health risks associated with radiation exposure are highest when a baby is in its early stages of development--during weeks 2 through 15 of the pregnancy. Exposure to large doses of radiation during this time could result in severe health effects such as birth defects, stunted growth, and brain damage.

The risks associated with radiation exposure are somewhat lower during the second and third trimesters of pregnancy. During weeks 16 to 25 of a pregnancy, unborn babies exposed to radiation may experience health consequences, but only if the doses of radiation are very very high, such as those large enough to cause radiation sickness in the mother. After the 26th week of pregnancy, the risks to the unborn baby are lowest since the baby's organs have already been formed. Exposure to radiation from any source during pregnancy can cause significant anxiety and fear, and pregnant women should consult with their doctors about their concerns.
More information about the special health concerns associated with exposure to radiation during pregnancy can be found on the Centers for Disease Control Website *[Image – CDC web site and fact sheet at http://www.bt.cdc.gov/radiation/prenatal.asp*

Coping with uncertain future health risks to people of any age is a significant challenge following a radiological incident. Widespread fear after the Chernobyl accident caused many people to attribute their subsequent health problems to the effects of the accident, even though these problems may have developed anyway.

Vira Yakusha helps us understand: [NOTE: *This is based on statements from Vira but we do not have video of it so we have to discuss how best to portray: (why don't we have video? I remember this story being taped.]*

> ***" It was Vira's best friend, Nadia, and her husband who helped her leave Kiev and took her with them in their car to Moscow because of concerns about contamination levels following the accident. Vira and Nadia were classmates at the university. She had never in her life met a more energetic, bright and sunny person than Nadia.***
>
> ***"On the drive to Moscow, they took a detour—in part to avoid the roadblocks already established on the main roads between Kiev and Moscow, and in part to help Nadia's relatives plant potatoes. The crop from their vegetable patch was a main source of their food in the winter. They ended up on a little field near Kanev city, and Nadia and her husband were planting potatoes. It was a sunny, very bright spring day. They all had this feeling then that the danger was all around them, and the fact that they could not see, smell or feel it made it even more menacing. But Vira felt that they were out of danger at that moment—they were already far away from Kiev and even further away from Chernobyl, after all. She felt uncomfortable that they were working very hard physically while she was just sitting under a shade tree due to her pregnancy.***
>
> ***"Only a month later, information that had been previously suppressed became more or less public, and they learned that the wind had moved the invisible cloud of radioactive dust southward, so the idyllic countryside with the potato***

patch was exactly underneath it. Vira was never able to get more specific information, and she didn't even know if it really existed, but when they learned in 1994 that Nadia had been diagnosed with breast cancer, the thought of that perfect sunny day came to her mind immediately. She didn't think there was any way to prove the link scientifically, but in the mind of everyone involved there is no doubt about the "cause and effect" between the exposure and her illness."

Since the Chernobyl accident, much knowledge has been gained about its effect on the health of the people who were exposed to radioactive contamination in the areas surrounding the plant. Between 2003 and 2006, the World Health Organization (WHO) conducted a series of expert meeting to review all the scientific evidence and evaluate the health impacts of Chernobyl. The WHO expert group reported in April 2006 that the main cancer consequence observed as of that date was the significant increase in thyroid cancer among young people who had lived in the most contaminated areas of Belarus, the Russian Federation and the Ukraine. These cancers occurred primarily among children and adolescents who drank milk contaminated with radioactive iodine immediately after the accident.

The WHO expert group also reported that "The Chernobyl accident led to extensive relocation of people, loss of economic stability, and long-term threats to health in current and possibly future generations…High levels of stress, anxiety and medically unexplained physical symptoms continue to be reported among those affected by the accident…Designation of the affected population as "victims" rather than "survivors" has led to feelings of helplessness and lack of control over their future. This has resulted in excessive health concerns or reckless behavior…"
(Source: "Health Effects of the Chernobyl Accident and Special Health Care Programmes: Report of the UN Chernobyl Forum Health Expert Group," Editors Burton Bennett, Michael Repacholi and Zhanat Carr, World Health Organization, Geneva, 2006.)

The WHO expert group concluded overall that "…the large increase in thyroid cancer incidence among those exposed in childhood and adolescence continues; fortunately, few of these have been fatal. In contrast, at this time, no clearly demonstrated increase in the incidence of other cancers can be attributed to radiation exposure from the accident." However, the report went on to note that this did not mean that the longer-term cancer risk of those who were exposed had not increased. Based on the experience of other populations exposed to ionizing radiation, the WHO experts predicted that "…a small increase in the relative risk of cancer is expected, even at the low to moderate doses received" and said that further studies are required to understand the full health effects of the accident. *(Source: Journal of Radiological Protection 26 (2006) 127-140, Cancer consequences of the Chernobyl accident: 20 years on).*

Vira Yakusha shared her thoughts on the question of whether or not she perceives herself more as a "victim" or as a "survivor" of Chernobyl: [NOTE: *This is based on statements* *from Vira but we do not have video of it so we have to discuss how best to portray: I know we have video of this.]*

"She said the distinction is more like the difference between having a positive versus a negative attitude towards life. Based on her experience and her communications with fellow denizens of Kiev, there is no way to tell exactly who is a victim and who is a survivor. Everyone's attitude fluctuated between those two poles, depending the weather, the mood etc. But she would agree that people with a prevailing "survivor" attitude had better outcomes in fighting the consequences of Chernobyl. It is impossible to know if they have a "survivor" attitude because they are stronger, or if they are stronger because of their "survivor" attitude." *(These were not the same responses she gave during the interview. We can definitely use this statement but I would also like to find the original video response to this question.)*

6.0 What if it happens here? (NOTE TO KIRK: Please double check the noted video times in this section as I was working from the transcript, not the DVD.)

One of the biggest problems with the Soviet response to the Chernobyl disaster was a lack of credible information about the accident and its effects on the population. Due to the closed nature of Soviet society, Soviet authorities either did not fully understand the severity of the accident, or they intentionally downplayed it.

The first public notice of the accident came on April 27, 1986 from Sweden when workers at the Forsmark Nuclear Power Plant (about 700 miles away) detected elevated levels of radioactivity that were not from local sources. *[image – map showing Forsmark plant on the east central coast of Sweden and Chernobyl/Kiev, perhaps with a scale showing distance between them.]*

Almost a week after the accident, the major Soviet newspapers were still not discussing the ongoing nuclear disaster that was contaminating much of the USSR and Europe. *[Images of soviet newspapers and political figures; some possible footage at www.encyclomedia.com, "The Chernobyl Nuclear Disaster," September 15, 2006.]* Soviet premier Mikhail Gorbachev did not appear on television to discuss the incident until May 14, 1986, several weeks after the event. As a result, citizens were forced to turn to informal news channels, networks of associates and whatever international news they could find on short-wave radios. The lack of reliable information about the accident and its effects created uncertainty, inefficiency and suspicion that the incident was far worse than was being reported.

Larisa Leanova and Vira Yukasha describe the situation.

(Possible quotes in order of preference here; how many depends on time)

> *[LY8 3:52:26 – 3:53:33 "we didn't get any information about Chernobyl um, officially — almost like a week after the accident happened. When I first time*

heard about it — it was the first day ah, first working day basically it was a Monday, I believe it was 27th or 28 of the April. I came to work and one of my co-workers told me, "Did you hear the news that BBC's announcing"? And I said, "No, I basically was very busy this weekend, I didn't listen to any BBC". And we all had the habit to listen one of them ah, for a radio station and um, early morning Monday exchange the news. What really was get — what we were getting from the abroad and what was um, broadcast in the Russian radio stations. So, my co-worker told me that he heard that something happen in the Ukraine and Sweden is picking up ah, increased radioactivity levels. And I said, "I haven't heard of that".]

[VY1 1:29:29 – 1:29:41 "Because nobody was giving you any, uh, hard information at this point, assumption was that, uh, probably things are much, much worse than officials would tell you. And, uh, so the first week, uh, we were living our life more or less our life as usual."]

[VY1 1:23:21 – 1:23:36 "we were very skeptical about official sources of information per usual, uh, so we turned onto the, uh, Radio Free, uh, uh, what was that, what was commonly called The Voices From Abroad, and, uh, there were several radio stations that they were broadcasting towards the Soviet territory, and one of them was Voice of America, another was Radio Free Europe and one of them was BBC and such. And they were all, um, the Soviet, uh, government tried to jam them, and so you had intelligence or people who were curious about what was going on and wanted to have more information that was officially available, they were trying to find the Voices on the short wave bands."]

[VY2 1:58:10 – 1:58:50 "I am sitting in the back seat of the car, and, uh, our radio is on, and the radio is official so it's radio and there's a news report and oh, everything is, uh, contained in Chernobyl, everything is fine, in Kiev there is no danger at all in Kiev, I mean, the population should not worry. And I'm thinking yeah, that's, it's an interesting twist because here I am from Kiev, and, uh, I'm too dirty to enter Moscow but in Kiev everything is fine. Yeah, and, um, it was a surreal moment"]

VY2 02:05:28 – 2:05:37 "There is a difference between, uh, questioning authorities or expecting answers to a question. So I was, uh, very aware that authorities are not telling the whole truth. But I never expected to, uh, get answers, truthful answers, if — if I would start questioning."

Vira later observed:

"that her personal observations are not at all scientific, but it seems that people who were critical and distrustful of then-Soviet government information had much better chances to avoid the negative consequences of radioactive contamination. Her own story is an example of it because she decided to move away from Kiev in order to protect her baby, even when official sources told the population that there was no real danger in the city. She would caution against applying this 'rule of thumb' to U.S. realities because, in her opinion, there are

many mechanisms that will allow better and more truthful information to reach the general population in the case of a negative event." *[NOTE: we have to decide how to best include this quote since it is not on video—either tape her saying it or use her voice here?(I don't understand why we are missing the video).]*

If a similar incident were to happen in the U.S., we can in fact expect a much more open flow of information. Not only would the major news media cover the disaster, but the U.S. Department of Homeland Security, the Centers for Disease Control, the U.S. Environmental Protection Agency and other agencies would post information on what do.

[VY4 2:41:07 — 2:42:14 "This is such a society where ah, different ah, groups of people have their say. So there is always a balance of forces. And the result of this balance, ah there is a much better possibility that the real information, the scientific information will come out and be available and be widely available and with the internet, it's, it's, it's even, it's even better now. Because I remember how I was just raking my mind trying to remember what I was taught about levels of radiation. And now I fully expect it to be available, this information to be available on the web. And probably guidelines that I will have from authorities. I will be more willing to trust them and to follow their recommendation, because I um, understand that it's much more reliable and much more better grounded reality than it used to be on the Soviet. So it's a different story."]

6.1 Being Prepared

The U.S. Environmental Protection Agency works closely with other civilian and military federal agencies as well as state and local governments to develop radiological emergency response plans and procedures. These plans specify how emergency response organizations will work together and what will actually happen during an emergency response operation. In addition to planning activities, EPA provides training and guidance to first responders, and conducts and participates in exercises that simulate radiological emergencies. *(Source: EPA Radiation Website.)*

Jim Mitchell is an On-Scene Coordinator for the U.S. Environmental Protection Agency. On-Scene Coordinators are responsible for coordinating response activities carried out by federal, state and local officials after a significant incident. Jim describes one of their exercises, called TOP OFF, as an example of how the U.S. is preparing at every level for a possible radiological attack:

[JM6 3:24:05-3:24:37 "...Top Off was an, was an exercise, uh, that took place about four years ago and it took place in Seattle where there was a, uh, a radiological dirty bomb, a device that was set off in Seattle. Now numerous federal, um, uh, the local, you know, the local city was Seattle and also local communities, you know, took part in responding to this exercise. And it was specifically to look at how the federal government, the federal, state and local governments would respond and outline the

issues, uh, that were surrounding their response, identify gaps and try to find ways to fill those gaps."]

[JM7 3:42:27 – 3:43:20 "…we're working towards, um, a level of preparedness that we haven't seen in the past. An, and, um, you know, as a, as, as a part of the region and as part of our, our, um, uh, response experts, uh, for responding to these types of incidents, we're working there. Uh, we need to continually develop exercises and training not only from On Scene Coordinators and, and our own responders, both regionally and nationally, but we need to, we need to, uh, to integrate our plans and procedures with the locals, with state and local, um, plans, with other federal agencies. So we clearly have a defined role and we have a, a developed, uh, a working path so if something like this happens, we're not, you know, we're not arguing over who's doing what or who's responsible for what. That we, that we continue to achieve a level of preparedness, um, you know, everyday. It's, it's an ongoing process."]

[JM7 3:43:27 – 3:43:42 "We cannot anticipate all the conditions, um, or the, or the, or the impacts from something like this. We can take the knowledge that we, that we have to develop through exercises, through training, um, through research from our national laboratories and try to bring it to a level of preparedness that we have not seen in the past. And we're working towards that on a daily basis."]

Public education is another essential element in preparing for a possible incident.

[LV10 4:49:00 – 4:50:56 "…So, my message will be prepare yourself as much as you can, read the literature which is advising you how you have to act in case of the um, pandemic flu, in case of the emergency evacuations, what you have to keep in your home in case of the first couple of days of survival you know like in the case of the accident. Meaning you have to trust your government but you have to trust yourself also because it's so many of us, it's only one government. So if you will not help yourself in the very few first moments after the accident your government may be too late when it finally—government will be helping you. So you have to give the government opportunity to save you. And to do that basically educate yourself what you can do for yourself and you know take the responsible action."

Dr. John Cardarelli of the U.S. Environmental Protection Agency discusses some of the information resources available to the public:

> *[JC2 5:08:32 - 5:09:42 "There's a lot of resources available to folks to learn more about long-term recovery and the types of information that they — that's going to be concerned or they're going to be interested on. I would recommend a lot of folks visit uh, vetted, scientific, internet websites. Uh, for example, usepa.gov uh, the cdc.gov for public health inquiries, there's a nice website that's available by various professional societies, the Health/Physics Society, which is hps.org. Um, the National Commission for Radiological Protection is also another good website uh, the ncrp.com and there's various international uh, websites as well.*

I.A.E.A, that stands for the International Atomic Energy Association, as well as the I.C.R.P., the International Commission for Radiological Protection. These are all scientifically valid, vetted information that can provide a lot of information to folks that are concerned about the public health issues, environmental issues and some of the socio-economic aspects of why certain things and clean, cleanup levels have been set the way they have."]

[JC 5:10:00 – 5: 10:36 "You're going to have a large variety of professional folks, subject matter experts, some who will say, any amount of radiation is not good for you. Others will say, you can take X amount and it's not going to hurt you at all. The truth probably is somewhere in between and what's more important is that folks understand that and they have to come to, to a conclusion themselves. The best way to do that is to educate yourself on what the risks are to you, your family, your friends, your loved ones um, and do that by educating yourself at these various websites."]

Examples of good internet sites for information on how to respond to a radiological incident are: the Department of Health and Human Services' Radiation Event Medical Management site *[Show a screen shot and the web address: www.remm.nlm.gov];* U.S. EPA's Radiation Protection program page *[show screen shot and address: www.epa.gov/radiation];* and the U.S. Department of Homeland Security's Ready America Radiation Threat site *[Screen shot and www.ready.gov/america/beinformed/radiation.html]*.

7.0 Conclusion

As frightening as the possibility of a "dirty Bomb" or other radiological incident may seem, we know from experience that we can recover safely from such an event. And, the United States is better prepared than ever before to cope with such an eventuality.

In this film, we have reviewed the incident at the Chernobyl power plant—the worst nuclear accident in history and which released much more radiation than would be expected from a dirty bomb or radiological attack. We learned that there are many effective ways to limit the exposure of people to radiation and live safely in long-term contaminated areas.
Let's recap the main points:

- Although we can forecast the potential types of radiological threats might we face, we cannot forecast with precision the exact facts that will accompany any specific incident. However, a dirty bomb or other radiological attack is not likely to release nearly as much radiation as was released from the Chernobyl accident.

- If radioactive materials are used in a terrorist attack, living things could be exposed to higher than normal levels of radiation that could harm them and contaminate their surroundings.

- Exposure to radiation can cause health problems. The possible health risks vary widely depending on the type of radiation, the amount of exposure and the individual's general health.

- Pregnant women should recognize that exposure to small doses of radiation during pregnancy is not likely to increase the risk of birth defects. However, each situation must be evaluated carefully and people with special health concerns should seek advice from their doctor.

- A radiological incident will cause real fear and anxiety among people in the affected area. Being prepared and relying on sound, accurate scientific information can help people to make better-informed decisions and allay these fears.

- People can reduce their exposure to harmful radiation by shielding themselves from the source, removing contaminated dust from their skin and clothing, and cleaning or temporarily leaving the area.

- Governmental authorities can employ a number of effective counter measures after a release, including cleaning-up buildings, remediating soils and vegetation, monitoring the environment and establishing health surveillance programs. They also play an important role in restoring supplies of safe water and food to those in the affected area.

- Radioactivity decays with time. The "half-life" of many radioactive elements is relatively short, but others with much longer half-lives will cause areas to remain contaminated on a long-term basis. Even though such areas may have a higher than background level of radiation, they can be cleaned to a level that allows people to live in them safely.

- Recovering from a large-scale radiological incident may require long periods of time to heal the environment, repair damage to the local economy and mitigate the psychosocial impacts on the population.

- There are many high quality sources of public information about the health, environmental and socio-economic issues associated with radiation exposure. If a radiological emergency were to occur in the United States, government and news sources would provide additional information to guide those being affected.

We have learned much about how to cope and recover from a major radiological release since the Chernobyl accident. This knowledge will help us to effectively respond to a future possible incident. The best way for citizens to prepare is to educate themselves about the possible scenarios that could occur and the risks they pose. We hope this film has helped you begin this process.

Draft 9/30/09

The Chernobyl Incident—Experiences, Recovery and Lessons Learned

Ideas for Alternate titles:

Recovering from a Radiological Terrorist Attack—Lessons Learned from the Chernobyl Incident

Nuclear Terrorism—What Can We Expect? Experiences, Recovery and Lessons Learned from the Chernobyl Incident

Recovering from a Nuclear Terrorist Attack—What We Can Learn from the Chernobyl Accident

1. Introduction

In an age in which terrorist attacks are becoming more frequent and more lethal, an attack on the United States that releases radiation—the explosion of a "dirty bomb" or improvised nuclear device—is a frightening and very real threat. Such a radiological assault would aim to inflict mass casualties, widespread panic and disruption, and could cause contamination that lasts for months or even years after the initial event.

U.S. government agencies at the state, local and federal levels are preparing for such an event and have been rehearsing the emergency responses that would occur immediately after such an attack. But how would we cope with the aftermath of the event? What could we do to recover from its longer-term consequences?

The long-term recovery lessons learned from the 1986 Chernobyl nuclear plant disaster help to answer these questions. The Soviet response to that disaster and the analyses that followed give us insights into what does and doesn't work in responding to such a situation. In this film, we will examine the basics of what a radiological attack on the United States would involve, and what the countermeasures and restoration actions taken after the Chernobyl accident tell us about what we might expect following such an event. We will enhance our discussion with the first-hand, personal perspectives of an early responder who provided technical assistance during the first phases of the recovery from Chernobyl, and of a resident of Kiev who was a young mother in Ukraine at the time of the disaster.

Dr. John Cardarelli, an Industrial Hygienist and Health Physicist with the U.S. Environmental Protection Agency explains why it is useful to focus on Chernobyl:

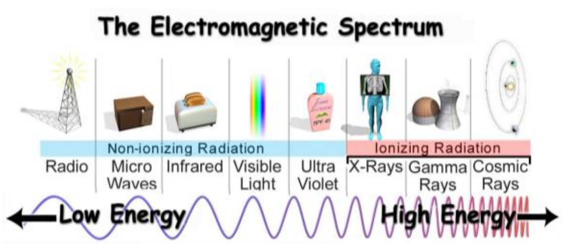
[Image: JC1 5:00:50 – 5:01:24 "Chernobyl brings us a unique perspective in the fact that it was uh, uh, a real, live situation where hundreds of thousands of square kilometers

were contaminated with radioactive material that had been um, dispersed from the reactor accident. And it exposed hundreds of thousands of humans, requiring a large amount of environmental clean up. So what we can learn from those aspects and apply them here in the United States could be very valuable if we were to ever experience something similar to that here in the United States."]

By improving public awareness and helping people to educate themselves on the issues associated with a possible radiological emergency, we will not only be better prepared, but the power of such an event to terrorize our citizens can be greatly reduced.

2. Radiation and Radioactivity

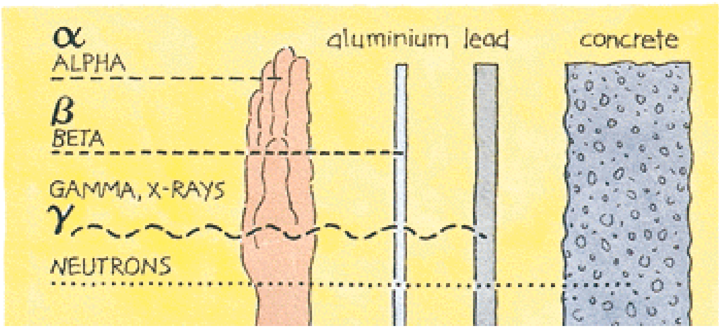
In order to more fully understand the effects of a radiological emergency and the long-term recovery issues associated with it, we will first review some of the basic concepts and terms about radiation and radioactivity.



All of us are continuously exposed to radiation from both natural and man-made sources. For example, natural background radiation varies throughout the world and its level depends on many factors such as altitude, soil conditions and location on earth. The word "radiation" has many meanings, and there are many types of radiation. [*Graphic—electromagnetic spectrum*] Television and radio waves, radar and visible light are all examples of radiation, and none of these cause harm to living organisms under normal conditions. These lower-energy types of radiation are called "non-ionizing radiation."

The other general category of radiation is called "ionizing radiation." Ionizing radiation is higher in energy than non-ionizing radiation and can damage living cells. It comes from radioactive materials, including naturally occurring radioactive elements found on earth, cosmic rays from space and man-made radiation sources such as medical x-rays. The level of radiation from naturally occurring sources to which we are exposed on a daily basis is called "background radiation," and it varies throughout the world depending on such factors as altitude, soil conditions and location on earth.

There are four main types of ionizing radiation: alpha particles, beta particles, gamma rays and neutrons.



[Text and graphic from the REMM Video 1 min 33 sec:]

"Alpha particles may be ejected from the nucleus of an atom during radioactive decay. They are relatively heavy and only travel about an inch in air. Alpha particles can easily be shielded by a single sheet of paper, and cannot penetrate the outer dead layer of skin, so they pose no danger when their source is outside the human body.

Beta particles are essentially electrons emitted from the nucleus of a radioactive atom. They are lighter than alpha particles, and can travel farther in air, up to several yards. Very energetic beta particles can penetrate up to one half an inch through skin and into the body. They can be shielded with less than an inch of material such as plastic. In the case of lower energy beta particles, the outer layer of clothing can act as an effective shield.

Gamma rays can be emitted from the nucleus of an atom during radioactive decay. They are able to travel tens of yards, or more, in air, and can easily penetrate the human body. Shielding this very penetrating type of ionizing radiation requires thick dense material such as several inches of lead or concrete.

Neutrons can be released from the nucleus of an atom during a fission reaction, such as within a nuclear reactor, or upon detonation of a nuclear weapon. Neutrons, like gamma rays, are very penetrating, and several feet of concrete is needed to shield against them.

If radioactive materials are released into the environment as the result a terrorist attack or accident, people could be exposed to higher than background levels of ionizing radiation that could contaminate them and their surroundings. When vaporized radioactive material is released into the atmosphere, it cools, condenses into solid particles, and falls back to earth. These particles can be carried by the wind as a plume, and can contaminate surfaces far from the explosion itself, including food and water supplies. This phenomenon is known as "fallout."

[*Will use RMM Website video here with narration by our narrator using text below. Text in italics is exactly that from the existing video. Time = 1 min 52 seconds. Additional text not in italics has been added to explain how medical treatment can help.*]

"When a person is near a source of radiation, some type of radioactive material, he or she can be exposed to the radiation emitted by this source. However, he or she does not become contaminated.

One way to think about exposure is to think about X-rays. When a person has a chest X-ray, he or she is exposed to radiation, but does not become contaminated with radioactive material.

A person can reduce his or her exposure to radiation, if he or she is shielded in some ways from the radiation, for example, if the person is behind a concrete wall, or if the radioactive source is inside of a lead container.

In order to become contaminated, radioactive material must get on the skin, or clothing, or inside of the body. For example, if radioactive material is incorporated into a dirty bomb, a conventional explosive, such as dynamite that has been laced with radioactive material, then people could become contaminated when the device is detonated. Radioactive material on the outside of the body is called external contamination. When a person becomes externally contaminated, simply removing the clothing can remove up to 90% of the contamination. Gently washing the skin and the hair can remove most of the remaining contamination.

If a person ingests or inhales radioactive material, it can become incorporated in the organs of the body. This is called internal contamination. When a person is internally contaminated, depending on the type of radioactive material with which they were contaminated, certain medications can be administered to speed up the rate at which the radioactive material is eliminated from the body." For example, Prussian Blue is an effective drug that can be used to eliminate Cesium from the body, and was used on animals following the Chernobyl incident so the population could drink animal milk and eat meat. Potassium Iodine tablets were also taken by many people to counter the negative effects of the Iodine-131 gas that was released during the accident.

Once released, radioactive materials remain a threat to the environment for varying periods of time. How quickly a radioactive material decays is measured by its "half-life," or the amount of time it takes for the radioactivity of the material to decrease by half. For example, the half-life of Cesium-137 is about 30 years. This means that about half of the Cesium-137 released during the Chernobyl accident will have decayed by the year 2016. This decay process will continue, and after 7-10 half-lives, or 210-300 years, the Cesium radioactivity from Chernobyl will have decayed to near background levels. The long half-life of some radioactive elements such as Cesium presents difficult challenges since people may be exposed to a contaminated environment for many years unless action is taken to decontaminate the area affected by the accident.

On the other hand, another radioactive element released at Chernobyl was Iodine-131, which has a half-life of 8 days. This presented a much shorter-term challenge because it decayed away in about 56 to 80 days after the accident.

[*May be good to have a graphic here to help summarize the key points to take away from this section, with simple voice over*.]

To summarize some of the key points about radiation and radioactivity:

- All of us are continuously exposed to low-level radiation from both natural and man-made sources. This level is called "background radiation" and is not harmful to living things.
- If radioactive materials are utilized in a radiological attack, living things could be exposed to higher than background levels of ionizing radiation that could harm them and contaminate their surroundings.
- The potential harm from radiation may be seen within days or weeks after exposure if the dose is extremely high--for example, ~~hundreds~~ millions of times higher than normal background levels—or, it may present itself as cancer decades later.
- People can reduce their exposure to this harmful radiation by shielding themselves from its source, taking precautions to prevent unnecessary exposure, removing contaminated dust from their skin and clothing, and cleaning, decontaminating or leaving the area.
- There are effective medical treatments to help counter the harmful health effects of internal radiation contamination.
- Radioactivity decays with time. The "half-life" of many radioactive elements is relatively short, but others with much longer half-lives will present challenges to cleaning-up the areas affected by the attack.

3. Types of Incidents We Might Face

What types of radiological threats might we face should radioactive materials be used in a terrorist attack?

Experts have identified four potential scenarios: *(NOTE: some simple graphics depicting these four scenarios could be helpful here—there are some on the REMM website.)*

- A **Radiological Exposure Device, or "RED,"** is a non-explosive device made of highly radioactive material that is hidden in a highly populated area. When people pass by it, they are unknowingly exposed to potentially harmful levels of radiation.
- A **Radiological Dispersal Device, or "RDD,"** is a device that releases radioactive materials into the environment by using conventional explosives or another method. This device is commonly referred to as a "Dirty Bomb."

- A targeted **attack on a nuclear power plant or installation** could result in the release of radioactive materials from the nuclear reactor, spent fuel or other nuclear materials stored on site.
- An **Improvised Nuclear Device, or "IND,"** is a crude nuclear bomb, built from scratch or from stolen components, that is capable of producing damage similar to that experienced at Hiroshima or Nagasaki.

The radiation exposures and effects that would result from events such as these vary widely from scenario to scenario, so we will examine each one separately.

The **Radiological Exposure Device (RED):**

A RED contains highly radioactive materials in a sealed device that is intended to expose people to significant doses of ionizing radiation without their knowledge. Such a device could be hidden in a public place such as in a subway car or sports stadium in order to expose a large number of people. A RED causes exposure to high levels of radiation, but unless the seal around the radioactive materials is broken, it does not cause radioactive contamination. The amount of radiation received is measured in dose. The total dose that would result from exposure to a RED would depend on the type of radioactive material used, how close the person was to the material, and for how long the person was near the device. The damage to the body would increase as the dose increases.

The **Radiological Dispersal Device (RDD):**

A RDD is a device that releases radioactive materials into the environment. It could combine conventional explosives with radioactive materials so that when it is detonated, it volatizes and disperses radioactive material and other debris into the surrounding area. Or, it could spray radioactive materials into the environment using a mechanical device such as a crop duster. The easiest way to release radiological agents would be to detonate a type of RDD known as a "dirty bomb" [*image—an explosion in a city*]. It is important to realize that a dirty bomb is not the same thing as a nuclear bomb. A dirty bomb uses radioactive materials, but these materials do not undergo the type of nuclear reaction that releases large quantities of energy and produces an atomic mushroom cloud.

The main dangers from a dirty bomb are the serious injuries and damage that would result from the explosion itself. It most likely would not have enough radioactive material to cause serious radiation sickness among large numbers of people. Nonetheless, it would contaminate the immediate area surrounding the explosion with radioactive dust, smoke or other materials that could be dangerous if inhaled and potentially cause long-term contamination and recovery problems. Since it would likely be detonated in a densely populated area, it would cause significant disruption and panic.

[*Need to find or create a video clip to illustrate the dirty bomb scenario. At John Cardarelli's suggestion we are evaluating the potential use of DHS video coverage from TOPOFF 2*]

An **attack on a nuclear plant or installation:**

Terrorists could release radioactive materials by intentionally causing a fire or explosion at a nuclear power plant or nuclear installation. Such an incident could require evacuation of the geographic area proximate to the facility and cause widespread contamination from both long and short-lived radioisotopes released as a result of the attack.

The world has suffered several accidents at nuclear power plants, including the Chernobyl reactor meltdown in 1986, and partial reactor meltdowns at the Three Mile Island Nuclear Plant near Harrisburg, Pennsylvania in 1979 and the Chalk River Nuclear Plant near Ottowa, Ontario in 1952. Radioactive releases were also caused by a fire at the Windscale reactor near Liverpool, England in 1957 and by an earthquake at a reactor near Kashiwazaki, Japan in 2007. [*Show still images of several of these sites and possibly some of the newspaper headlines that went with these accidents.*]

The worst of these incidents was that at the Chernobyl plant, which we will discuss in more detail shortly. Although a terrorist attack on a U.S. nuclear facility could have serious consequences, it is important to keep in mind that nuclear power plants in the United States are not like those found in the former Soviet Union. The design of U.S. reactors is very different from the design of the Chernobyl reactors, and U.S. nuclear safety and security regulations are more stringent. The technical design of U.S. reactors makes major releases of radioactive materials under any circumstances extremely unlikely, if at all possible.

An **Improvised Nuclear Device (IND):**

The most devastating way to release radiological agents would be to construct and detonate an Improvised Nuclear Device, or IND. An IND is a small nuclear bomb in which radioactive materials undergo a nuclear reaction and release massive amounts of energy. Explosion of an IND would be devastating and would likely cause mass casualties and major property damage. However, the technical difficulty of obtaining the necessary materials and creating the conditions for a nuclear reaction make this a less likely scenario than a RDD. A stolen nuclear weapon by a terrorist organization is of greater concern.

Although explosion of an IND would be a catastrophic event, its long-term contamination effects could actually be less than those experienced following the Chernobyl accident. The Chernobyl accident resulted in the continuous release of radioactive materials into the environment over a period of ten days. An IND contains much less radioactive material and releases all of it in an instant. These materials would be spread over less distance compared with Chernobyl, but the area could be highly contaminated. Most of the radioactive materials released by an IND would decay within in the first few months.

However, a small amount of residual contamination would remain for a relatively long time. Cesium-137 and Strontium-90 are the two long-lived isotopes common to both Chernobyl and INDs.

To sum up, we face four main types of incidents that might result in the exposure to or release of radioactive materials: a Radiological Exposure Device, a Radiological Dispersal Device, an attack at a nuclear plant or installation, and an Improvised Nuclear Device. [*Could use a simple graphic here.*]

A dirty bomb is a likely scenario. The radioactive materials released would likely remain persistent in the environment for a relatively long time, and may contaminate a populated downtown area.

An attack on a nuclear power plant or installation could release both long- and short-lived radioisotopes that may cause widespread contamination, similar to those released during the Chernobyl incident. The scale of such a disaster is not likely to match the uncontrolled meltdown at Chernobyl, where a fire raged for 10 days, spewing nuclear and radioactive materials into the atmosphere and spreading them over hundreds of thousands of square miles.

Detonation of an improvised nuclear device would be a catastrophic event that could devastate a city and cause widespread destruction. A nuclear bomb would involve a nuclear reaction and release formidable amounts of energy and scatters radioactive fallout over a large region. Most of the types of materials released would decay relatively quickly. However, a small amount of residual contamination would remain for a relatively long time, posing more challenging recovery issues.

4. The Chernobyl Incident and the Initial Response

Now that we've covered a few of the basics about radiation, radioactivity and the types of emergencies that may occur, we can better examine the issues associated with radiological contamination.   The 1986 accident at the Chernobyl power plant in the Soviet Union gives us insight into how we might recover from a wide-scale radiological event. First, let's take a look at the accident itself.

In the early morning hours of April 26, 1986, the Chernobyl nuclear plant experienced the worst nuclear power accident in history. The accident created an uncontrolled nuclear reaction and the resulting explosion and fire sent a massive cloud of radioactive material into the atmosphere. The reactor burned for 10 days, releasing radioactive gases, vapors, aerosols and particles, and contaminating thousands of square miles in Ukraine, Belarus, Russia, and Western Europe. *[Images: nuclear technicians at the plant, the plant on fire, people suiting up to respond.]*

The Chernobyl nuclear plant is located near the border between Russia, Ukraine, and Belarus, about 70 miles northwest of the city of Kiev, the nearest major population center. Kiev had a population of about 2.5 million people at the time of the disaster. The town of Pripyat, located about two miles from the reactor, had a population of about 45,000 people at the time of the accident. *[Image – a map showing the broader* *geographic area, the plant, Pripyat, and Kiev—there is a good one at world-nuclear.org/info/chernobyl.]*

On April 25, 1986, Chernobyl plant personnel began conducting a safety test to determine if the reactor's cooling system pumps could operate if the plant's external power failed. Errors made by the plant operators and deficiencies in the reactor's design and operating procedures caused the reactor to go out of control during the test, resulting in a series of explosions and massive fires. *(References: World Nuclear Association Website, Chernobyl Accident, November 2009; IAEA Safety Series Report 75-INSAG-7, The Chernobyl Accident: Updating of INSAG-1, 1992.)* The reactor core and building burned for 10 days, and radioisotopes were carried upward into the atmosphere where they traveled with the prevailing winds. The accident at Chernobyl released about 400 times more radioactive material into the atmosphere than the bomb dropped on Hiroshima during the second World War. (*Ten Years After Chernobyl: What Do We Really Know?, IAEA, 1996).*

According to reliable reports (*IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience p.21,*) winds were initially to the northwest, but they varied over the next several days so that all areas were downwind at some point while the fire in the core continued burning. To further complicate matters, scattered thunderstorms and rainfall throughout the area brought down some of the airborne material to ground level, forming an irregular radioactive fallout pattern over thousands of square miles. *[graphic – figure 3.2 IAEA report, image of fallout pattern IAEA report Fig 3.6 and http://www.chernobyl.info/index.php?navID=2]*

The initial response to the disaster was disorganized, improvised, and chaotic. The main priority of the first responders was to put out the fire and then isolate the reactor core. First on the scene were local firefighters and soldiers who were not aware of the grave threat of exposure to very high levels of radioactivity. The firefighters extinguished the fires on the roof of the reactor building and in the surrounding area, thus protecting the other reactors at the Chernobyl facility, but they were not able to put out the burning reactor core. Many of these heroic firefighters and soldiers died from their enormous radiation exposure within days or weeks. *[Image: commemorative statue to lost firefighters in the town of Pripyat.]*

To put out the fire in the core, local authorities tried several approaches, including dropping 5,000 tons of sand, clay, and lead onto the core by helicopter. *[Image: helicopters dropping bags of materials.]* But because of the dangerous conditions and extreme heat, it took workers 10 days to put out the fire.

The town of Pripyat, located 2 miles northwest (and downwind) of the reactor, was evacuated on Sunday, April 27, one and one half days after the accident began. Residents were told to pack for three days and to leave household pets behind. The motivation for giving such a short timeframe for the evacuation was logistical: to limit the amount of baggage and personal belongings to be transported and to expedite the evacuation. A convoy of 1200 buses carried the residents and their belongings away, and the evacuation was reportedly completed in about three hours. *[Images of the evacuation of Pripyat – the long line of buses, lines of people getting on them and so forth.]*

In the following days, authorities measured radiation levels in the areas surrounding Chernobyl to determine the extent of contamination. Radiation levels above background were measured at distances of hundreds of miles away, but the government focused on the most heavily contaminated areas. The Soviet Ministry of Public Health determined that a 30 kilometer (about 19 miles) radius around the plant site would be evacuated.

Isolating the reactor was an immediate priority once the fires were extinguished and the nearby towns were evacuated. To make a safer work zone, the area surrounding the reactor was cleared of debris. The contaminated debris, reactor core fragments, and surface soils from the immediate area around the reactor were placed in a concrete reinforced gallery hastily constructed around the reactor. Removal and shielding of this material made the area safer to work in.

Other soils and debris were stored in a large number of temporary shallow trenches and impoundments within the exclusion zone and covered with soil to provide minimal shielding and to reduce potential for wind to mobilize the contaminants. These trenches and small impoundments were not designed as permanent storage, yet most of them remain to this day. *[Possible image – trenches around Chernobyl or a generic trench and piles of debris to illustrate concept.*

]

After cleaning the blast area, a structure known as the sarcophagus was constructed of concrete, steel plates and beams to isolate the most contaminated wastes and the reactor. The sarcophagus was constructed between May and November 1986 under very hazardous working conditions. *[Images of the Chernobyl sarcophagus.]* The structure was hastily designed and erected and has been exposed to the elements and infiltrated by moisture for more than 20 years. A new safer confinement structure is currently being designed to address the shortcomings of the sarcophagus and to isolate the reactor core and the most contaminated wastes for the next 100 years. *[Image: New safe confinement structure image is on cover of IAEA report: Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience.]*

5. Living in the Aftermath of Chernobyl—Lessons from the Recovery

The accident at Chernobyl resulted in unprecedented radiological contamination of a densely inhabited area. It caused major economic, social and psychological hardships to those living in the region. Local and national authorities were not prepared for an incident of such size and severity. How did people in the region react and what measures did they take to cope after the accident? How did the cleanup of the area proceed and what was life like in the affected areas?

The reports of two women with first-hand, personal experiences living in the aftermath of Chernobyl help to answer these questions. The first is Larisa Leonova, a chemist with the U.S. Environmental Protection Agency who was one of the early responders to the Chernobyl event. At the time of the accident, she was managing a laboratory in Moscow on a part-time basis while earning her PhD in chemistry. Larissa volunteered to help with the response and traveled to Kiev several weeks after the incident. She worked in the area around Pripyat, trying to convince local residents to leave the area.

> *[Image – LL8 3:51:54 – 3:52:21 "My Name is Larisa Leanova and I live in United States oh, it's my twentieth years. And um, back when Chernobyl happened I was ah, twenty-eight years old and four years is graduated from ah, university. And I was working as a chemist, basically part time a lab manager and part time doing my PhD research work. Back when the Chernobyl happened I was in Moscow, I always lived in Moscow."]*

> *[Image—LL8 4:00.44--?? "So, I basically ah, set up the vacation time and I called to my uncle in the Kiev and I said like you know me and another group of ah, chemists we are ready to provide whatever the type of the help we can."]*

Vira Yakusha is a computer scientist with a consulting firm in Washington DC. At the time of the accident, Vira was a resident of Kiev and a recent graduate of Kiev University. Vira was pregnant with her first child, and she brings the perspective of an expectant mother and member of the general public reacting to the events occurring around her.

> *[Image – VY4 2:33:03 – 2:34:00 "My name is Vira Yakusha and ah, I was born in Kiev. And ah, I lived there for my entire life. And I loved the city a lot. And ah, I was there as a just a member of general population when Chernobyl tragedy struck. And so my perspective is a perspective of a lay person who is not professionally involved in the nuclear, in the nuclear industry, but who was, whose life was directly affected by what happened. And ah, my story is a story of person who is trying to comprehend what's going on and trying to do the best, what is best for my family, for health of my family and ah, trying to live my life as ah, as simple as possible if it's possible in the difficult circumstance."]*

Using the first-hand accounts of Larissa and Vira, we will look at several key aspects of the recovery from a radiological event: countermeasures to reduce exposure to the radiation released during the incident, coping with contamination of the food supply, and the special health concerns for pregnant women and their children associated with the accident.

5.1 Limiting Exposure and Cleaning Up

Once the pressing issues of putting out the fires, evacuating the immediate area, removing debris and isolating the reactor were taken care of, attention turned to the impact of the accident on the broader area. Radioactive dust and dirt were a major source of contamination in both agricultural and urban areas.

Because of the magnitude of the accident, local and national authorities were initially uncertain how to proceed. Larissa Leonova, a chemist who now works for the U.S. EPA, volunteered to travel to Kiev in the first weeks after the accident to lend a hand.

> *[LL4:01:56- 4:02:35 "our group of volunteers were basically invited by um, some sort of the organization which were created back there and basically consist um, of very strange group of people who -- represented by Army and by some ah, local officials which were not scientists. They were just the politicians and they were trying, trying to create some sort of the response. And um, again you know first couple of weeks it was basically you know not enough data or no information about plume or no information which territory it's more affected."]*

> *[LL4:03:03 – 4:03:14 "we were among of the first, to my knowledge, volunteer group who went there and who got um, ah, who were involved in ah, um, some sort of the response."]*

One of the first assignments of the group of volunteers was to provide the local populace with some basic guidance about how to limit their exposure to the radioisotopes released by the plant.

> *[LL4:05:05 – 4:05:25 "that's the season when everybody in the Ukraine um, pick up the strawberries. And Ukraine, it's very high in the strawberries and actually you know like um, everybody over there -- middle of the May and June the strawberries is the best place -- taste unbelievably good and everybody has a strawberry growing in their backyards and garden."]*

> *[LY4:05:40 – 4:05:51 "So, the first advice which we wrote was very silly, we're saying like do not eat the strawberries if they are you know like right besides the dripping line um, from your roof."]*

> *[LL4:06:00 –4:06:15 "The other thing was we were basically advising that ah, try to have at least a bucket of water near the entrance of your door and before -- after you*

coming from the street to your house, wash you um, shoes and remove your shoes, try to not bring the additional dust."]

Once the authorities began to realize the significance of the accident, they began to issue further guidance on ways to reduce exposure to contaminated dust:

> *[VY1 01:34:00 - 01:34:30 "First Monday after, uh, after Easter so it was May -- May 5th, and the May 5th was the first day when, uh, when authorities, uh, Soviet authorities officially on the radio started to say well, things are, um, under control, but, um, for, just for personal precautions please shower regularly, try to keep dust out of the rooms, and, uh, keep your clothes laundered often, and cover the food and bread if you buy something so, uh, it's, uh, to prevent dust from, uh, coming on the food. Uh, so there were first official guidelines for general population to minimize, uh, the exposure."*
>
> *VY3 02:25:56 - 02:26:32 "After that first announcement, ah, they say that you should wash ah, take shower often, wash your ah, clothing often. Ah, try to prevent dust from setting on your household items. Ah, there was more information. And ah, it will become more and more detailed and instructions more elaborate this time. Then they were not that afraid to accept or admit that something wrong is going on. And, ah, we were doing this religiously. Our family. We were trying to follow everything and some more."*
>
> *VY3 02:14:21- 02:14:18"my family just tried to keep everything as clean as possible. Free from dust, from dirt. But ah, the thing is that you cannot be 100% sure, of course. And later on, of course, it was not about the surfaces, of your living space, but more about the food that you are getting and ah, and ah, probably some accidental contamination that, for example, like there, rooftops for um, perceived to be very dirty. And they were in fact. So we were told or people were telling the children were told to avoid the downpours from the, from the roof, for example. If ah, water is pouring from the roof, it' probably, if it goes and fills in your overcoat, you don't want to have your overcoat to get dirty and to get rid of it later on."]*

As we can see from these examples, one of the primary ways people are exposed to radioactivity after a radiological event is through contaminated dust and soil that adheres to hair, skin, clothing, and shoes. One effective way to reduce this exposure is to shower frequently, launder clothing frequently, remove shoes and outer clothing before entering living areas, and practice general good housekeeping to reduce dust and dirt indoors. These hygiene precautions were successful in areas like Kiev after the Chernobyl accident, and they are also recommended by Centers for Disease Control and others.

The decontamination activities performed after Chernobyl gives us an idea of what techniques are most effective to reduce the dose received from exposures to radiation. In the days following the accident, the area around the Chernobyl plant and the most contaminated areas in the exclusion zone were sprayed with organic solutions to create a thin film that would immobilize dust. Buildings, vehicles, and city streets were washed frequently and sprayed with water to suppress dust. *[Image: workers spraying water on trucks, buildings, and streets.]*

Much of the radioactivity from the accident was concentrated in surface soil, plants, on asphalt and concrete, and to a lesser extent on roofs and walls. Streets in Kiev were washed daily in the weeks following the accident. In surrounding areas, roads and buildings were washed, residential areas were cleaned, contaminated soils were removed--especially along drip lines next to buildings--and sediments were removed from the bottom of reservoirs. *[Image: men peeling back sod (42-15785116).]* Decontamination activities concentrated on schools, hospitals and other high-use buildings. Overall, tens of thousands of public buildings and residences were treated in about 1000 cities and towns.

According to the International Atomic Energy Agency (*IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience)*, street cleaning, removing trees and shrubs, and plowing soils in yards to bury the surface soils were efficient and inexpensive means of achieving significant reductions of dose. Roofs and walls also contribute to dose, but they are costly and difficult to clean and thus present a more difficult issue in the event of a radiological emergency in an urban setting. [*Images for this section could be a montage of people scrubbing, plowing, and spraying the streets, buildings, and yards.]*

> *VY4 02:45:17 – 2:45-31 "I've heard from people who stayed there that um, street washing was much more frequent during that memorable summer that there is. When much more often than usual and they were doing a good job of keeping the city clean after all."*
>
> *VY4 2:58:48 – 2:59:05 "In my understanding and my feeling that ah, in the long term during that summer, during consequent months, government did a lot. I mean what they could at this given time. Given level of technology. To clean up what they could."*
>
> *VY4 02:57:04 – 2:57:12 "Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that."*
>
> *VY4 2:57:19 – ? "For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything. You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do."*

In 2008, the International Commission on Radiological Protection issued a report that provided guidance on the protection of people living in areas that had been contaminated on a long-term basis from a radiological event. The report identifies numerous actions and strategies that can be used to reduce exposures, improve living conditions and rehabilitate the affected areas. Among the actions identified in the report that should be implemented by authorities are "…clean-up of buildings, remediation of soils and vegetation, changes in animal husbandry, monitoring of the environment and produce, provision of clean foodstuffs, managing of waste..., health surveillance…" and public information. The report also identifies actions that can be taken by the inhabitants of the area, including monitoring the radiological quality of their living areas and food, and the radiation exposure of themselves and their children. *(Reference: ICRP Publication 111, October, 2008, page 12.)*

The following websites also provide good information on actions that can be taken to limit exposure after a radiological incident. [*Images: CDC rad website and address www.bt.cdc.gov/radiation, image of DHS Ready.gov rad website and address http://www.ready.gov/america/beinformed/radiation.html.*

There's also a not-so-great quality but understandable image of a silhouette guy showering off yellow dots at http://www.remm.nlm.gov/deconimage.htm]

5.2 Managing the Food Supply

The massive amount of radioactive fallout from Chernobyl also had far-reaching consequences for the food supply in the contaminated area. As noted by the International Commission on Radiological Protection, "the management of contaminated foodstuffs and other commodities produced in areas affected by a nuclear accident or a radiation emergency…presents a particularly difficult problem because of issues of market acceptance." *(Reference: ICRP Publication 104, 2007.)* Internal exposure to radiological contaminants through consumption of contaminated food and water can be a very significant exposure concern. Early responders were advised not to eat locally grown food, and surprisingly, to drink red wine instead of water:

> *[LL8: 4:20:00 – 4:20:06 "We were ordered -- we were basically -- that was our order to drink red wine, not drink water. So, that was our liquid consumption. "and LY8 04:27:54 – 4:28:08 "We were not given anything besides red wine. We were strictly advised not drink water or milk. And we were advised do not eat any um, grown -- locally grown product -- produce, nothing, no vegetables, no fruit, nothing."]*

Many locals used common sense and avoided eating locally grown foods that were probably contaminated:

> *[LY8 4:14:29 - 4:14:45 "We found the people who were very educated and um, they were not eating any fresh food since the accident, since the first they heard about the accident. They were trying to eat canned food only."*

Local authorities prohibited animal feeding with pasture grasses in the affected areas and rejected milk based on radiological monitoring. Many thousands of agricultural and domestic animals were slaughtered immediately, and the remainder evacuated. *[Images – pigs and cows being screened with radioactivity meters by a worker in a moon suit (ex: 42-15882699 and* 0000316032-056*), images of dead fish on the shore near the reactor]*

People living in the area tried to obtain imported food as much as possible, but this was often difficult. Vira Yakusha explains her dietary habits when she returned to Kiev with a young baby in the months following the accident:

> *[VY3 02:27:15 – 2:27:43 Well first concern ah, at that point was the food. And ah, food and again official line was that all food is carefully screened. Sources of food that contaminated milk or other ah, ah, necessities are discarded and thrown away and so you don't have worry about that. But of course we did worry. And of course we, we will try to buy imported food. As much as it was possible. But it was not that readily available.*
>
> *VY3 2:22:18 – 2:24:00 "...if there is a cereal made in Hungary, probably there is less ah, a less chance that it's radiologically contaminated than the sour cream made on the local factory. Because God knows where this local factory gets their milk from. And in the first couple of weeks we were so ardent about it that I even didn't eat any bread because bread was definitely make over, made of local grains. And again, local grains could be contaminated. But after a couple of weeks without bread, I said you know what? I'm going to eat bread. Because I cannot. I need to eat something, right?"*
> *[VY3 02:28:35 – 2:28:51 "So there are very, there are always efforts. There are always efforts to make sure your food sources are clear. But it is almost impossible. So you have to accept at some point that you have to, continue with your life or otherwise you will just go mad."*
>
> *VY3 2:27:43– 2:28:12 "And of course, ah, ah, we will try to buy imported food. As, as much as it was possible. But it was not that readily available. And again, there were um, ah, some things that you cannot buy imported. For example, like your greens, your apples. And ah, sometimes you will come across imported apples with big luck. I remember my husband bought five kilos of ah, ah, a golden ah, golden delicious which is a common brand in America and they were ah, grown somewhere ah, from north of imported apples. And we were very happy. We were feeding our baby these apples for quite a long time while they lasted."*

According to the International Atomic Energy Agency, some of the most effective countermeasures were treating the soil; removing some areas from agricultural production altogether based on radiological screening; switching animals to clean fodder from uncontaminated areas; and providing dietary supplements such as cesium binders to help the radio nuclides pass through the animals without being incorporated in food products. *[Images: workers in suits walking through a field (42-15800571), a man with a rotor tiller (*42-15784775*), peasant gardeners (DWF15-682237), and a fallow field with a rad sign in front of it (42-15784775)]*.

The countermeasures described above went a long way to reducing the radiological contamination of foods from the areas affected by the Chernobyl accident. However, the long half life of some of the contaminants, particularly Cesium-137, and the economic hardships following the fall of the Soviet Union, resulted in continued barriers to agricultural restoration in the affected area.

5.3 Coping with Health Concerns

Exposure of humans to radiation can cause health problems, depending on the type of radiation, the amount of radiation exposure, and the individual's general health and susceptibility to illness. For the people affected by Chernobyl, the potential impact of the accident on their health was a major concern.

Vira Yakusha was living in Kiev and pregnant with her first child at the time of the accident. Upon learning of the disaster, she tried to leave Kiev as soon as she was able, to try to put as much distance between her baby and the radiation emergency as she could. Unfortunately, many people were trying to do the same, and Vira was unable to buy a train or plane ticket *[image –we could show a few generic Russian-looking group queued up at a ticket booth, as Vira spoke about the crush of people waiting to purchase airline or train tickets.]*

Vira discussed this situation urgently with her husband and her family:

> *VY1 1:29:20 - 01:29:27 "I was really determined, uh, to keep my baby healthy and, uh, as far as harm's way was possible."*
>
> *VY1 1:50:49 "I don't know what to do, it's impossible to buy tickets for -- for a plane, it's impossible to buy tickets for a train, but we need to get you out. And we were sitting in the kitchen and trying to figure out what kind of plan that could work"*
>
> *VY2 01:51:36 – 1:51:41 "And so we were thinking about this and that, and there is suddenly, um, uh, a buzz on the door …"*
>
> *VY2 1:51:54 – 1:52:44 "I opened the door and this is, uh, again my friend, uh, Yenna, who, uh, head of the family who were taking me to Karnyov, and he sort of looks grim, and he said you know what, I made a decision, uh, I take my, uh, girls away to Mosc -- I'm taking my girls away to Moscow because I want to get my kids out of here as soon as possible. And his, his thinking was pretty much the same that if the government admits so much that, uh, it's dangerous, then it's really, really dangerous. Yeah, and he said, um, okay, so my car is downstairs, uh, waiting for you, um, my wife and my kids are in the car, and we have still one place left in this car, this is for Vira. If you want to go with us you have 40 minutes to pack yourself."*
>
> *[Images – Possibly a man standing next to an old, Soviet-style car? A family around a table talking about something obviously upsetting or pressing.]*

Vira left Kiev that night, and four months later in Moscow she gave birth to Doreena, a healthy baby girl. We can't say whether getting out of Kiev, about 70 miles from the disaster, in the weeks after the accident helped her give birth to a healthy child. Her child may very well have been fine had she continued to live in Kiev.

> *VY1 01:32:46 – 1:33:18 "Doreena, and she is, uh, 21 years old right now, and, uh, I never had any, uh, uh, health problems with her that I should, could attribute to potential exposure. But unfortunately, uh, my understanding of the nature of the whole thing is that you never can, if you have some sort of health problem you can never be 100 percent sure if it was the result of, uh, your exposure to the radioactivity at some point or it's just your particular body type or, uh, other factors that were contributing."*

Reflecting on her actions many years later, Vira feels that she made the right choice given the information that she had:

> *VY4 02:42:38 – 2:43:38 "My personal feeling is the health of your children or your child is the first priority, because this is something that you are ulta, ultimately responsible for. So I would say what I said to myself. Put as many miles as you can between the source of radiation and yourself and your baby and try to get as much information as much reliable information as you can. And try to… I mean panic is never a good helper or a good advisor. So probably understanding is our best weapon and to know how things work and what is real danger and what is imagined danger. It is a real important difference. And the more you understand, the better your choices are, the better your behavior is. At least you're choosing between least, least possible evils. And ah, it's impossible to be in a perfect world. But in our imperfect world, you have to make your own choices. And it's better to be based on the, on the ways of reason."*

Pregnant women and their unborn babies are particularly vulnerable to the effects of radiation. However, termination of a pregnancy is rarely justified unless the dose absorbed by the pregnant woman or unborn child is high. According to the International Atomic Energy Agency and the Centers for Disease Control, the potential health risks associated with radiation exposure are highest when a baby is in its early stages of development--during weeks 2 through 15 of the pregnancy. Exposure to large doses of radiation during this time could result in severe health effects such as birth defects, stunted growth, and brain damage.

The risks associated with radiation exposure are somewhat lower during the second and third trimesters of pregnancy. During weeks 16 to 25 of a pregnancy, unborn babies exposed to radiation may experience health consequences, but only if the doses of radiation are very high, such as those large enough to cause radiation sickness in the mother. After the 26th week of pregnancy, the risks to the unborn baby are lowest since the baby's organs have already been formed. Exposure to radiation from any source

during pregnancy can cause significant anxiety and fear, and pregnant women should consult with their doctors about their concerns.
More information about the special health concerns associated with exposure to radiation during pregnancy can be found on the Centers for Disease Control Website *[Image – CDC web site and fact sheet at http://www.bt.cdc.gov/radiation/prenatal.asp*

Coping with uncertain future health risks to people of any age is a significant challenge following a radiological incident. Widespread fear after the Chernobyl accident caused many people to attribute their subsequent health problems to the effects of the accident, even though these problems may have developed anyway.

Vira Yakusha helps us understand: [NOTE: *This is based on statements from Vira but we do not have video of it so we have to discuss how best to portray:]*

> *" It was my best friend, Nadia, and her husband who helped me leave Kiev and took me with them in their car to Moscow because of our concerns about contamination levels following the accident. Nadia and I were classmates at the university. I never in my life met a more energetic, bright and sunny person than Nadia.*
>
> *"On the drive to Moscow, we took a detour—in part to avoid the roadblocks already established on the main roads between Kiev and Moscow, and in part to help Nadia's relatives plant potatoes. The crop from their vegetable patch was a main source of their food in the winter. We ended up on a little field near Kanev city, and Nadia and her husband were planting potatoes. It was a sunny, very bright spring day. We all had this feeling then that the danger was all around us, and the fact that we could not see, smell or feel it made it even more menacing. But I felt that we were out of danger at that moment—we were already far away from Kiev and even further away from Chernobyl, after all. I just feel very uncomfortable that they were working very hard physically while I was just sitting under a shade tree due to my pregnancy.*
>
> *"Only a month later, information that had been previously suppressed became more or less public, and we learned that the wind had moved the invisible cloud of radioactive dust southward, so the idyllic countryside with the potato patch was exactly underneath it. I was never able to get more specific information, and I don't even know if it really exists, but when we learned in 1994 that Nadia had been diagnosed with breast cancer, the thought of that perfect sunny day came to my mind immediately. I don't think there is any way to prove the link scientifically, but in the mind of everyone involved there is no doubt about the "cause and effect" between the exposure and her illness."*

Since the Chernobyl accident, much knowledge has been gained about its effect on the health of the people who were exposed to radioactive contamination in the areas surrounding the plant. Between 2003 and 2006, the World Health Organization (WHO) conducted a series of expert meeting to review all the scientific evidence and evaluate the health impacts of Chernobyl. The WHO expert group reported in April 2006 that the main cancer consequence observed as of that date was the significant increase in thyroid cancer among young people who had lived in the most contaminated areas of Belarus, the Russian Federation and the Ukraine. These cancers occurred primarily among children and adolescents who drank milk contaminated with radioactive iodine immediately after the accident.

The WHO expert group also reported that "The Chernobyl accident led to extensive relocation of people, loss of economic stability, and long-term threats to health in current and possibly future generations…High levels of stress, anxiety and medically unexplained physical symptoms continue to be reported among those affected by the accident…Designation of the affected population as "victims" rather than "survivors" has led to feelings of helplessness and lack of control over their future. This has resulted in excessive health concerns or reckless behavior…"
(Source: "Health Effects of the Chernobyl Accident and Special Health Care Programmes: Report of the UN Chernobyl Forum Health Expert Group," Editors Burton Bennett, Michael Repacholi and Zhanat Carr, World Health Organization, Geneva, 2006.)

The WHO expert group concluded overall that "…the large increase in thyroid cancer incidence among those exposed in childhood and adolescence continues; fortunately, few of these have been fatal. In contrast, at this time, no clearly demonstrated increase in the incidence of other cancers can be attributed to radiation exposure from the accident." However, the report went on to note that this did not mean that the longer-term cancer risk of those who were exposed had not increased. Based on the experience of other populations exposed to ionizing radiation, the WHO experts predicted that "…a small increase in the relative risk of cancer is expected, even at the low to moderate doses received" and said that further studies are required to understand the full health effects of the accident. *(Source: Journal of Radiological Protection 26 (2006) 127-140, Cancer consequences of the Chernobyl accident: 20 years on).*

Vira Yakusha shares her thoughts on the question of whether or not she perceives herself more as a "victim" or as a "survivor" of Chernobyl: [NOTE: *This is based on statements from Vira but we do not have video of it so we have to discuss how best to portray:]*

"The distinction is more like the difference between having a positive versus a negative attitude towards life. Based on my experience and my communications with fellow denizens of Kiev, there is no way to tell exactly who is a victim and who is a survivor. I guess everyone's attitude fluctuated between those two poles, depending the weather, the mood etc. But I would agree that people with a prevailing "survivor" attitude had better outcomes in fighting the consequences of Chernobyl. It is impossible to know if they have a "survivor" attitude because they are stronger, or if they are stronger because of their "survivor" attitude."

6.0 What if it happens here? (NOTE TO KIRK: Please double check the noted video times in this section as I was working from the transcript, not the DVD.)

One of the biggest problems with the Soviet response to the Chernobyl disaster was a lack of credible information about the accident and its effects on the population. Due to the closed nature of Soviet society, Soviet authorities either did not fully understand the severity of the accident, or they intentionally downplayed it.

The first public notice of the accident came on April 27, 1986 from Sweden when workers at the Forsmark Nuclear Power Plant (about 700 miles away) detected elevated levels of radioactivity that were not from local sources. *[image – map showing Forsmark plant on the east central coast of Sweden and Chernobyl/Kiev, perhaps with a scale showing distance between them.]*

Almost a week after the accident, the major Soviet newspapers were still not discussing the ongoing nuclear disaster that was contaminating much of the USSR and Europe. *[Images of soviet newspapers and political figures; some possible footage at www.encyclomedia.com, "The Chernobyl Nuclear Disaster," September 15, 2006.]* Soviet premier Mikhail Gorbachev did not appear on television to discuss the incident until May 14, 1986, several weeks after the event. As a result, citizens were forced to turn to informal news channels, networks of associates and whatever international news they could find on short-wave radios. The lack of reliable information about the accident and its effects created uncertainty, inefficiency and suspicion that the incident was far worse than was being reported.

Larisa Leanova and Vira Yukasha describe the situation.

(Possible quotes in order of preference here; how many depends on time)

> *[LY8 3:52:26 – 3:53:33 "we didn't get any information about Chernobyl um, officially — almost like a week after the accident happened. When I first time heard about it — it was the first day ah, first working day basically it was a Monday, I believe it was 27th or 28 of the April. I came to work and one of my co-workers told me, "Did you hear the news that BBC's announcing"? And I said, "No, I basically was very busy this weekend, I didn't listen to any BBC". And we all had the habit to listen one of them ah, for a radio station and um, early morning Monday exchange the news. What really was get — what we were getting from the abroad and what was um, broadcast in the Russian radio stations. So, my co-worker told me that he heard that something happen in the Ukraine and Sweden is picking up ah, increased radioactivity levels. And I said, "I haven't heard of that".]*

> *[VY1 1:29:29 – 1:29:41 "Because nobody was giving you any, uh, hard information at this point, assumption was that, uh, probably things are much, much worse than officials would tell you. And, uh, so the first week, uh, we were living our life more or less our life as usual."]*

[VY1 1:23:21 – 1:23:36 "we were very skeptical about official sources of information per usual, uh, so we turned onto the, uh, Radio Free, uh, uh, what was that, what was commonly called The Voices From Abroad, and, uh, there were several radio stations that they were broadcasting towards the Soviet territory, and one of them was Voice of America, another was Radio Free Europe and one of them was BBC and such. And they were all, um, the Soviet, uh, government tried to jam them, and so you had intelligence or people who were curious about what was going on and wanted to have more information that was officially available, they were trying to find the Voices on the short wave bands."]

[VY2 1:58:10 – 1:58:50 "I am sitting in the back seat of the car, and, uh, our radio is on, and the radio is official so it's radio and there's a news report and oh, everything is, uh, contained in Chernobyl, everything is fine, in Kiev there is no danger at all in Kiev, I mean, the population should not worry. And I'm thinking yeah, that's, it's an interesting twist because here I am from Kiev, and, uh, I'm too dirty to enter Moscow but in Kiev everything is fine. Yeah, and, um, it was a surreal moment"]
VY2 02:05:28 – 2:05:37 "There is a difference between, uh, questioning authorities or expecting answers to a question. So I was, uh, very aware that authorities are not telling the whole truth. But I never expected to, uh, get answers, truthful answers, if — if I would start questioning."

Vira later observed:

"…my personal observations are not at all scientific, but it seems that people who were critical and distrustful of then-Soviet government information had much better chances to avoid the negative consequences of radioactive contamination. My own story is an example of it because I decided to move away from Kiev in order to protect my baby, even when official sources told the population that there was no real danger in the city. I would caution against applying this 'rule of thumb' to U.S. realities because, in my opinion, here there are many mechanisms that will allow better and more truthful information to reach the general population in the case of a negative event." [NOTE: we have to decide how to best include this quote since it is not on video—either tape her saying it or use her voice here?]

If a similar incident were to happen in the U.S., we can in fact expect a much more open flow of information. Not only would the major news media cover the disaster, but the U.S. Department of Homeland Security, the Centers for Disease Control, the U.S. Environmental Protection Agency and other agencies would post information on what do.

[VY4 2:41:07 — 2:42:14 "This is such a society where ah, different ah, groups of people have their say. So there is always a balance of forces. And the result of this balance, ah there is a much better possibility that the real information, the scientific information will come out and be available and be widely available and with the internet, it's, it's, it's even, it's even better now. Because I remember how

I was just raking my mind trying to remember what I was taught about levels of radiation. And now I fully expect it to be available, this information to be available on the web. And probably guidelines that I will have from authorities. I will be more willing to trust them and to follow their recommendation, because I um, understand that it's much more reliable and much more better grounded reality than it used to be on the Soviet. So it's a different story."]

6.1 Being Prepared

The U.S. Environmental Protection Agency works closely with other civilian and military federal agencies as well as state and local governments to develop radiological emergency response plans and procedures. These plans specify how emergency response organizations will work together and what will actually happen during an emergency response operation. In addition to planning activities, EPA provides training and guidance to first responders, and conducts and participates in exercises that simulate radiological emergencies. *(Source: EPA Radiation Website.)*

Jim Mitchell is an On-Scene Coordinator for the U.S. Environmental Protection Agency. On-Scene Coordinators are responsible for coordinating response activities carried out by federal, state and local officials after a significant incident. Jim describes one of their exercises, called TOP OFF, as an example of how the U.S. is preparing at every level for a possible radiological attack:

[JM6 3:24:05-3:24:37 "…Top Off was an, was an exercise, uh, that took place about four years ago and it took place in Seattle where there was a, uh, a radiological dirty bomb, a device that was set off in Seattle. Now numerous federal, um, uh, the local, you know, the local city was Seattle and also local communities, you know, took part in responding to this exercise. And it was specifically to look at how the federal government, the federal, state and local governments would respond and outline the issues, uh, that were surrounding their response, identify gaps and try to find ways to fill those gaps."]

[JM7 3:42:27 – 3:43:20 "…we're working towards, um, a level of preparedness that we haven't seen in the past. An, and, um, you know, as a, as, as a part of the region and as part of our, our, um, uh, response experts, uh, for responding to these types of incidents, we're working there. Uh, we need to continually develop exercises and training not only from On Scene Coordinators and, and our own responders, both regionally and nationally, but we need to, we need to, uh, to integrate our plans and procedures with the locals, with state and local, um, plans, with other federal agencies. So we clearly have a defined role and we have a, a developed, uh, a working path so if something like this happens, we're not, you know, we're not arguing over who's doing what or who's responsible for what. That we, that we continue to achieve a level of preparedness, um, you know, everyday. It's, it's an ongoing process."]

[JM7 3:43:27 – 3:43:42 "We cannot anticipate all the conditions, um, or the, or the, or the impacts from something like this. We can take the knowledge that we, that we

have to develop through exercises, through training, um, through research from our national laboratories and try to bring it to a level of preparedness that we have not seen in the past. And we're working towards that on a daily basis."]

Public education is another essential element in preparing for a possible incident.

[LV10 4:49:00 – 4:50:56 "…So, my message will be prepare yourself as much as you can, read the literature which is advising you how you have to act in case of the um, pandemic flu, in case of the emergency evacuations, what you have to keep in your home in case of the first couple of days of survival you know like in the case of the accident. Meaning you have to trust your government but you have to trust yourself also because it's so many of us, it's only one government. So if you will not help yourself in the very few first moments after the accident your government may be too late when it finally—government will be helping you. So you have to give the government opportunity to save you. And to do that basically educate yourself what you can do for yourself and you know take the responsible action."

Dr. John Cardarelli of the U.S. Environmental Protection Agency discusses some of the information resources available to the public:

> *[JC2 5:08:32 - 5:09:42 "There's a lot of resources available to folks to learn more about long-term recovery and the types of information that they — that's going to be concerned or they're going to be interested on. I would recommend a lot of folks visit uh, vetted, scientific, internet websites. Uh, for example, usepa.gov uh, the cdc.gov for public health inquiries, there's a nice website that's available by various professional societies, the Health/Physics Society, which is hps.org. Um, the National Commission for Radiological Protection is also another good website uh, the ncrp.com and there's various international uh, websites as well.*
>
> *I.A.E.A, that stands for the International Atomic Energy Association, as well as the I.C.R.P., the International Commission for Radiological Protection. These are all scientifically valid, vetted information that can provide a lot of information to folks that are concerned about the public health issues, environmental issues and some of the socio-economic aspects of why certain things and clean, cleanup levels have been set the way they have."]*
>
> *[JC 5:10:00 – 5: 10:36 "You're going to have a large variety of professional folks, subject matter experts, some who will say, any amount of radiation is not good for you. Others will say, you can take X amount and it's not going to hurt you at all. The truth probably is somewhere in between and what's more important is that folks understand that and they have to come to, to a conclusion themselves. The best way to do that is to educate yourself on what the risks are to you, your family, your friends, your loved ones um, and do that by educating yourself at these various websites."]*

Examples of good internet sites for information on how to respond to a radiological incident are: the Department of Health and Human Services' Radiation Event Medical Management site *[Show a screen shot and the web address: www.remm.nlm.gov];* U.S. EPA's Radiation Protection program page *[show screen shot and address: www.epa.gov/radiation];* and the U.S. Department of Homeland Security's Ready America Radiation Threat site *[Screen shot and www.ready.gov/america/beinformed/radiation.html]*.

7.0 Conclusion

As frightening as the possibility of a "dirty Bomb" or other radiological incident may seem, we know from experience that we can recover safely from such an event. And, the United States is better prepared than ever before to cope with such an eventuality.

In this film, we have reviewed the incident at the Chernobyl power plant—the worst nuclear accident in history and which released much more radiation than would be expected from a dirty bomb or radiological attack. We learned that there are many effective ways to limit the exposure of people to radiation and live safely in long-term contaminated areas.
Let's recap the main points:

- Although we can forecast the potential types of radiological threats might we face, we cannot forecast with precision the exact facts that will accompany any specific incident. However, a dirty bomb or other radiological attack is not likely to release nearly as much radiation as was released from the Chernobyl accident.

- If radioactive materials are used in a terrorist attack, living things could be exposed to higher than normal levels of radiation that could harm them and contaminate their surroundings.

- Exposure to radiation can cause health problems. The possible health risks vary widely depending on the type of radiation, the amount of exposure and the individual's general health.

- Pregnant women should recognize that exposure to small doses of radiation during pregnancy is not likely to increase the risk of birth defects. However, each situation must be evaluated carefully and people with special health concerns should seek advice from their doctor.

- A radiological incident will cause real fear and anxiety among people in the affected area. Being prepared and relying on sound, accurate scientific information can help people to make better-informed decisions and allay these fears.

- People can reduce their exposure to harmful radiation by shielding themselves from the source, removing contaminated dust from their skin and clothing, and cleaning or temporarily leaving the area.

- Governmental authorities can employ a number of effective counter measures after a release, including cleaning-up buildings, remediating soils and vegetation, monitoring the environment and establishing health surveillance programs. They also play an important role in restoring supplies of safe water and food to those in the affected area.

- Radioactivity decays with time. The "half-life" of many radioactive elements is relatively short, but others with much longer half-lives will cause areas to remain contaminated on a long-term basis. Even though such areas may have a higher than background level of radiation, they can be cleaned to a level that allows people to live in them safely.

- Recovering from a large-scale radiological incident may require long periods of time to heal the environment, repair damage to the local economy and mitigate the psychosocial impacts on the population.

- There are many high quality sources of public information about the health, environmental and socio-economic issues associated with radiation exposure. If a radiological emergency were to occur in the United States, government and news sources would provide additional information to guide those being affected.

We have learned much about how to cope and recover from a major radiological release since the Chernobyl accident. This knowledge will help us to effectively respond to a future possible incident. The best way for citizens to prepare is to educate themselves about the possible scenarios that could occur and the risks they pose. We hope this film has helped you begin this process.

Draft 9/30/09

The Chernobyl Incident—Experiences, Recovery and Lessons Learned

Ideas for Alternate titles:

Recovering from a Radiological Terrorist Attack—Lessons Learned from the Chernobyl Incident

Nuclear Terrorism—What Can We Expect? Experiences, Recovery and Lessons Learned from the Chernobyl Incident

Recovering from a Nuclear Terrorist Attack—What We Can Learn from the Chernobyl Accident

1. Introduction

In an age in which terrorist attacks are becoming more frequent and more lethal, an attack on the United States that releases radiation—the explosion of a "dirty bomb" or improvised nuclear device—is a frightening and very real threat. Such a radiological assault would aim to inflict mass casualties, widespread panic and disruption, and could cause contamination that lasts for months or even years after the initial event.

U.S. government agencies at the state, local and federal levels are preparing for such an event and have been rehearsing the emergency responses that would occur immediately after such an attack. But how would we cope with the aftermath of the event? What could we do to recover from its longer-term consequences?

The long-term recovery lessons learned from the 1986 Chernobyl nuclear plant disaster help to answer these questions. The Soviet response to that disaster and the analyses that followed give us insights into what does and doesn't work in responding to such a situation. In this film, we will examine the basics of what a radiological attack on the United States would involve, and what the countermeasures and restoration actions taken after the Chernobyl accident tell us about what we might expect following such an event. We will enhance our discussion with the first-hand, personal perspectives of an early responder who provided technical assistance during the first phases of the recovery from Chernobyl, and of a resident of Kiev who was a young mother in Ukraine at the time of the disaster.

Dr. John Cardarelli, an Industrial Hygienist and Health Physicist with the U.S. Environmental Protection Agency explains why it is useful to focus on Chernobyl:

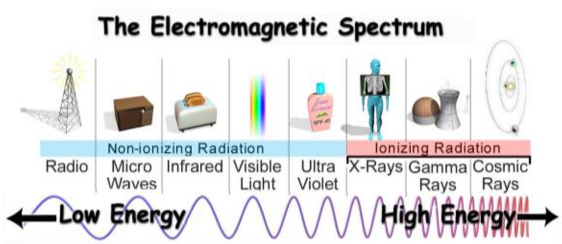
[Image: JC1 5:00:50 – 5:01:24 "Chernobyl brings us a unique perspective in the fact that it was uh, uh, a real, live situation where hundreds of thousands of square kilometers

were contaminated with radioactive material that had been um, dispersed from the reactor accident. And it exposed hundreds of thousands of humans, requiring a large amount of environmental clean up. So what we can learn from those aspects and apply them here in the United States could be very valuable if we were to ever experience something similar to that here in the United States."]

By improving public awareness and helping people to educate themselves on the issues associated with a possible radiological emergency, we will not only be better prepared, but the power of such an event to terrorize our citizens can be greatly reduced.

2. Radiation and Radioactivity

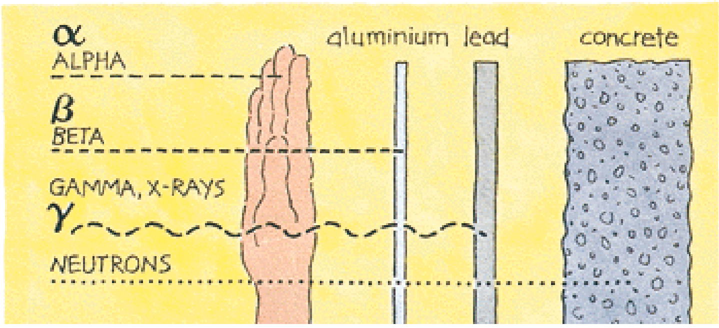
In order to more fully understand the effects of a radiological emergency and the long-term recovery issues associated with it, we will first review some of the basic concepts and terms about radiation and radioactivity.



All of us are continuously exposed to radiation from both natural and man-made sources. For example, natural background radiation varies throughout the world and its level depends on many factors such as altitude, soil conditions and location on earth. The word "radiation" has many meanings, and there are many types of radiation. [*Graphic—electromagnetic spectrum*] Television and radio waves, radar and visible light are all examples of radiation, and none of these cause harm to living organisms under normal conditions. These lower-energy types of radiation are called "non-ionizing radiation."

The other general category of radiation is called "ionizing radiation." Ionizing radiation is higher in energy than non-ionizing radiation and can damage living cells. It comes from radioactive materials, including naturally occurring radioactive elements found on earth, cosmic rays from space and man-made radiation sources such as medical x-rays. The level of radiation from naturally occurring sources to which we are exposed on a daily basis is called "background radiation," and it varies throughout the world depending on such factors as altitude, soil conditions and location on earth.

There are four main types of ionizing radiation: alpha particles, beta particles, gamma rays and neutrons.



[Text and graphic from the REMM Video 1 min 33 sec:]

"Alpha particles may be ejected from the nucleus of an atom during radioactive decay. They are relatively heavy and only travel about an inch in air. Alpha particles can easily be shielded by a single sheet of paper, and cannot penetrate the outer dead layer of skin, so they pose no danger when their source is outside the human body.

Beta particles are essentially electrons emitted from the nucleus of a radioactive atom. They are lighter than alpha particles, and can travel farther in air, up to several yards. Very energetic beta particles can penetrate up to one half an inch through skin and into the body. They can be shielded with less than an inch of material such as plastic. In the case of lower energy beta particles, the outer layer of clothing can act as an effective shield.

Gamma rays can be emitted from the nucleus of an atom during radioactive decay. They are able to travel tens of yards, or more, in air, and can easily penetrate the human body. Shielding this very penetrating type of ionizing radiation requires thick dense material such as several inches of lead or concrete.

Neutrons can be released from the nucleus of an atom during a fission reaction, such as within a nuclear reactor, or upon detonation of a nuclear weapon. Neutrons, like gamma rays, are very penetrating, and several feet of concrete is needed to shield against them.

If radioactive materials are released into the environment as the result a terrorist attack or accident, people could be exposed to higher than background levels of ionizing radiation that could contaminate them and their surroundings. When vaporized radioactive material is released into the atmosphere, it cools, condenses into solid particles, and falls back to earth. These particles can be carried by the wind as a plume, and can contaminate surfaces far from the explosion itself, including food and water supplies. This phenomenon is known as "fallout."

[*Will use RMM Website video here with narration by our narrator using text below. Text in italics is exactly that from the existing video. Time = 1 min 52 seconds. Additional text not in italics has been added to explain how medical treatment can help.*]

"When a person is near a source of radiation, some type of radioactive material, he or she can be exposed to the radiation emitted by this source. However, he or she does not become contaminated.

One way to think about exposure is to think about X-rays. When a person has a chest X-ray, he or she is exposed to radiation, but does not become contaminated with radioactive material.

A person can reduce his or her exposure to radiation, if he or she is shielded in some ways from the radiation, for example, if the person is behind a concrete wall, or if the radioactive source is inside of a lead container.

In order to become contaminated, radioactive material must get on the skin, or clothing, or inside of the body. For example, if radioactive material is incorporated into a dirty bomb, a conventional explosive, such as dynamite that has been laced with radioactive material, then people could become contaminated when the device is detonated. Radioactive material on the outside of the body is called external contamination. When a person becomes externally contaminated, simply removing the clothing can remove up to 90% of the contamination. Gently washing the skin and the hair can remove most of the remaining contamination.

If a person ingests or inhales radioactive material, it can become incorporated in the organs of the body. This is called internal contamination. When a person is internally contaminated, depending on the type of radioactive material with which they were contaminated, certain medications can be administered to speed up the rate at which the radioactive material is eliminated from the body." For example, Prussian Blue is an effective drug that can be used to eliminate Cesium from the body, and was used on animals following the Chernobyl incident so the population could drink animal milk and eat meat. Potassium Iodine tablets were also taken by many people to counter the negative effects of the Iodine-131 gas that was released during the accident.

Once released, radioactive materials remain a threat to the environment for varying periods of time. How quickly a radioactive material decays is measured by its "half-life," or the amount of time it takes for the radioactivity of the material to decrease by half. For example, the half-life of Cesium-137 is about 30 years. This means that about half of the Cesium-137 released during the Chernobyl accident will have decayed by the year 2016. This decay process will continue, and after 7-10 half-lives, or 210-300 years, the Cesium radioactivity from Chernobyl will have decayed to near background levels. The long half-life of some radioactive elements such as Cesium presents difficult challenges since people may be exposed to a contaminated environment for many years unless action is taken to decontaminate the area affected by the accident.

On the other hand, another radioactive element released at Chernobyl was Iodine-131, which has a half-life of 8 days. This presented a much shorter-term challenge because it decayed away in about 56 to 80 days after the accident.

[*May be good to have a graphic here to help summarize the key points to take away from this section, with simple voice over*.]

To summarize some of the key points about radiation and radioactivity:

- All of us are continuously exposed to low-level radiation from both natural and man-made sources. This level is called "background radiation" and is not harmful to living things.
- If radioactive materials are utilized in a radiological attack, living things could be exposed to higher than background levels of ionizing radiation that could harm them and contaminate their surroundings.
- The potential harm from radiation may be seen within days or weeks after exposure if the dose is extremely high--for example, ~~hundreds~~ millions of times higher than normal background levels—or, it may present itself as cancer decades later.
- People can reduce their exposure to this harmful radiation by shielding themselves from its source, taking precautions to prevent unnecessary exposure, removing contaminated dust from their skin and clothing, and cleaning, decontaminating or leaving the area.
- There are effective medical treatments to help counter the harmful health effects of internal radiation contamination.
- Radioactivity decays with time. The "half-life" of many radioactive elements is relatively short, but others with much longer half-lives will present challenges to cleaning-up the areas affected by the attack.

3. Types of Incidents We Might Face

What types of radiological threats might we face should radioactive materials be used in a terrorist attack?

Experts have identified four potential scenarios: *(NOTE: some simple graphics depicting these four scenarios could be helpful here—there are some on the REMM website.)*

- A **Radiological Exposure Device, or "RED,"** is a non-explosive device made of highly radioactive material that is hidden in a highly populated area. When people pass by it, they are unknowingly exposed to potentially harmful levels of radiation.
- A **Radiological Dispersal Device, or "RDD,"** is a device that releases radioactive materials into the environment by using conventional explosives or another method. This device is commonly referred to as a "Dirty Bomb."

- A targeted **attack on a nuclear power plant or installation** could result in the release of radioactive materials from the nuclear reactor, spent fuel or other nuclear materials stored on site.
- An **Improvised Nuclear Device, or "IND,"** is a crude nuclear bomb, built from scratch or from stolen components, that is capable of producing damage similar to that experienced at Hiroshima or Nagasaki.

The radiation exposures and effects that would result from events such as these vary widely from scenario to scenario, so we will examine each one separately.

The **Radiological Exposure Device (RED):**

A RED contains highly radioactive materials in a sealed device that is intended to expose people to significant doses of ionizing radiation without their knowledge. Such a device could be hidden in a public place such as in a subway car or sports stadium in order to expose a large number of people. A RED causes exposure to high levels of radiation, but unless the seal around the radioactive materials is broken, it does not cause radioactive contamination. The amount of radiation received is measured in dose. The total dose that would result from exposure to a RED would depend on the type of radioactive material used, how close the person was to the material, and for how long the person was near the device. The adverse health risk~~damage to the body~~ would increase as the dose increases.

The **Radiological Dispersal Device (RDD):**

A RDD is a device that releases radioactive materials into the environment. It could combine conventional explosives with radioactive materials so that when it is detonated, it volatizes and disperses radioactive material and other debris into the surrounding area. Or, it could spray radioactive materials into the environment using a mechanical device such as a crop duster. The easiest way to release radiological agents would be to detonate a type of RDD known as a "dirty bomb" [*image—an explosion in a city*]. It is important to realize that a dirty bomb is not the same thing as a nuclear bomb. A dirty bomb uses radioactive materials, but these materials do not undergo the type of nuclear reaction that releases large quantities of energy and produces an atomic mushroom cloud.

The main dangers from a dirty bomb are the serious injuries and damage that would result from the explosion itself. It most likely would not have enough radioactive material to cause serious radiation sickness among large numbers of people. Nonetheless, it would contaminate the immediate area surrounding the explosion with radioactive dust, smoke or other materials that could be dangerous if inhaled and potentially cause long-term contamination and recovery problems. Since it would likely be detonated in a densely populated area, it c~~w~~ould cause significant disruption and panic.

[*Need to find or create a video clip to illustrate the dirty bomb scenario. At John Cardarelli's suggestion we are evaluating the potential use of DHS video coverage from TOPOFF 2*]

An **attack on a nuclear plant or installation:**

Terrorists could release radioactive materials by intentionally causing a fire or explosion at a nuclear power plant or nuclear installation. Such an incident could require evacuation of the geographic area proximate to the facility and cause widespread contamination from both long and short-lived radioisotopes released as a result of the attack.

The world has suffered several accidents at nuclear power plants, including the Chernobyl reactor meltdown in 1986, and partial reactor meltdowns at the Three Mile Island Nuclear Plant near Harrisburg, Pennsylvania in 1979 and the Chalk River Nuclear Plant near Ottowa, Ontario in 1952. Radioactive releases were also caused by a fire at the Windscale reactor near Liverpool, England in 1957 and by an earthquake at a reactor near Kashiwazaki, Japan in 2007. [*Show still images of several of these sites and possibly some of the newspaper headlines that went with these accidents.*]

The worst of these incidents was that at the Chernobyl plant, which we will discuss in more detail shortly. Although a terrorist attack on a U.S. nuclear facility could have serious consequences, it is important to keep in mind that nuclear power plants in the United States are not like those found in the former Soviet Union. The design of U.S. reactors is very different from the design of the Chernobyl reactors, and U.S. nuclear safety and security regulations are more stringent. The technical design of U.S. reactors makes major releases of radioactive materials under any circumstances extremely unlikely, if at all possible.

An **Improvised Nuclear Device (IND):**

The most devastating way to release radiological agents would be to construct and detonate an Improvised Nuclear Device, or IND. An IND is a small nuclear bomb in which radioactive materials undergo a nuclear reaction and release massive amounts of energy. Explosion of an IND would be devastating and would likely cause mass casualties and major property damage. However, the technical difficulty of obtaining the necessary materials and creating the conditions for a nuclear reaction make this a less likely scenario than a RDD. A stolen nuclear weapon by a terrorist organization is of greater concern.

Although explosion of an IND would be a catastrophic event, its long-term contamination effects could actually be less than those experienced following the Chernobyl accident. The Chernobyl accident resulted in the continuous release of radioactive materials into the environment over a period of ten days. An IND contains much less radioactive material and releases all of it in an instant. These materials would be spread over less distance compared with Chernobyl, but the area could be highly contaminated. Most of the radioactive materials released by an IND would decay within in the first few months. However, a small amount of residual contamination would remain for a relatively long time. Cesium-137 and Strontium-90 are the two long-lived isotopes common to both Chernobyl and INDs.

To sum up, we face four main types of incidents that might result in the exposure to or release of radioactive materials: a Radiological Exposure Device, a Radiological Dispersal Device, an attack at a nuclear plant or installation, and an Improvised Nuclear Device. [*Could use a simple graphic here.*]

A dirty bomb is a likely scenario. The radioactive materials released would likely remain persistent in the environment for a relatively long time, and may contaminate a populated downtown area.

An attack on a nuclear power plant or installation could release both long- and short-lived radioisotopes that may cause widespread contamination, similar to those released during the Chernobyl incident. The scale of such a disaster is not likely to match the uncontrolled meltdown at Chernobyl, where a fire raged for 10 days, spewing nuclear and radioactive materials into the atmosphere and spreading them over hundreds of thousands of square miles.

Detonation of an improvised nuclear device would be a catastrophic event that could devastate a city and cause widespread destruction. A nuclear bomb would involve a nuclear reaction and release formidable amounts of energy and scatters radioactive fallout over a large region. Most of the types of materials released would decay relatively quickly. However, a small amount of residual contamination would remain for a relatively long time, posing more challenging recovery issues.

4. The Chernobyl Incident and the Initial Response

Now that we’ve covered a few of the basics about radiation, radioactivity and the types of emergencies that may occur, we can better examine the issues associated with radiological contamination.   The 1986 accident at the Chernobyl power plant in the Soviet Union gives us insight into how we might recover from a wide-scale radiological event. First, let’s take a look at the accident itself.

In the early morning hours of April 26, 1986, the Chernobyl nuclear plant experienced the worst nuclear power accident in history. The accident created an uncontrolled nuclear reaction and the resulting explosion and fire sent a massive cloud of radioactive material into the atmosphere. The reactor burned for 10 days, releasing radioactive gases, vapors, aerosols and particles, and contaminating thousands of square miles in Ukraine, Belarus, Russia, and Western Europe. *[Images: nuclear technicians at the plant, the plant on fire, people suiting up to respond.]*

The Chernobyl nuclear plant is located near the border between Russia, Ukraine, and Belarus, about 70 miles northwest of the city of Kiev, the nearest major population center. Kiev had a population of about 2.5 million people at the time of the disaster. The town of Pripyat, located about two miles from the reactor, had a population of about 45,000 people at the time of the accident. *[Image – a map showing the broader geographic area, the plant, Pripyat, and Kiev—there is a good one at world-nuclear.org/info/chernobyl.]*

On April 25, 1986, Chernobyl plant personnel began conducting a safety test to determine if the reactor's cooling system pumps could operate if the plant's external power failed. Errors made by the plant operators and deficiencies in the reactor's design and operating procedures caused the reactor to go out of control during the test, resulting in a series of explosions and massive fires. *(References: World Nuclear Association Website, Chernobyl Accident, November 2009; IAEA Safety Series Report 75-INSAG-7, The Chernobyl Accident: Updating of INSAG-1, 1992.)* The reactor core and building burned for 10 days, and radioisotopes were carried upward into the atmosphere where they traveled with the prevailing winds. The accident at Chernobyl released about 400 times more radioactive material into the atmosphere than the bomb dropped on Hiroshima during the second World War. (*Ten Years After Chernobyl: What Do We Really Know?, IAEA, 1996).*

According to reliable reports (*IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience p.21,*) winds were initially to the northwest, but they varied over the next several days so that all areas were downwind at some point while the fire in the core continued burning. To further complicate matters, scattered thunderstorms and rainfall throughout the area brought down some of the airborne material to ground level, forming an irregular radioactive fallout pattern over thousands of square miles. *[graphic – figure 3.2 IAEA report, image of fallout pattern IAEA report Fig 3.6 and http://www.chernobyl.info/index.php?navID=2]*

The initial response to the disaster was disorganized, improvised, and chaotic. The main priority of the first responders was to put out the fire and then isolate the reactor core. First on the scene were local firefighters and soldiers who were not aware of the grave threat of exposure to very high levels of radioactivity. The firefighters extinguished the fires on the roof of the reactor building and in the surrounding area, thus protecting the other reactors at the Chernobyl facility, but they were not able to put out the burning reactor core. Many of these heroic firefighters and soldiers died from their enormous radiation exposure within days or weeks. *[Image: commemorative statue to lost firefighters in the town of Pripyat.]*

To put out the fire in the core, local authorities tried several approaches, including dropping 5,000 tons of sand, clay, and lead onto the core by helicopter. *[Image: helicopters dropping bags of materials.]* But because of the dangerous conditions and extreme heat, it took workers 10 days to put out the fire.

The town of Pripyat, located 2 miles northwest (and downwind) of the reactor, was evacuated on Sunday, April 27, one and one half days after the accident began. Residents were told to pack for three days and to leave household pets behind. The motivation for giving such a short timeframe for the evacuation was logistical: to limit the amount of baggage and personal belongings to be transported and to expedite the evacuation. A convoy of 1200 buses carried the residents and their belongings away, and the evacuation was reportedly completed in about three hours. *[Images of the evacuation of Pripyat – the long line of buses, lines of people getting on them and so forth.]*

In the following days, authorities measured radiation levels in the areas surrounding Chernobyl to determine the extent of contamination. Radiation levels above background were measured at distances of hundreds of miles away, but the government focused on the most heavily contaminated areas. The Soviet Ministry of Public Health determined that a 30 kilometer (about 19 miles) radius around the plant site would be evacuated.

Isolating the reactor was an immediate priority once the fires were extinguished and the nearby towns were evacuated. To make a safer work zone, the area surrounding the reactor was cleared of debris. The contaminated debris, reactor core fragments, and surface soils from the immediate area around the reactor were placed in a concrete reinforced gallery hastily constructed around the reactor. Removal and shielding of this material made the area safer to work in.

Other soils and debris were stored in a large number of temporary shallow trenches and impoundments within the exclusion zone and covered with soil to provide minimal shielding and to reduce potential for wind to mobilize the contaminants. These trenches and small impoundments were not designed as permanent storage, yet most of them remain to this day. *[Possible image – trenches around Chernobyl or a generic trench and piles of debris to illustrate concept.*

]

After the fires were extinguished~~cleaning the blast area~~, a structure known as the sarcophagus was constructed of concrete, steel plates and beams to isolate the most contaminated wastes and the reactor. The sarcophagus was constructed between May and November 1986 under very hazardous working conditions. *[Images of the Chernobyl sarcophagus.]* The structure was hastily designed and erected and has been exposed to the elements and infiltrated by moisture for more than 20 years. A new safer confinement structure is currently being designed to address the shortcomings of the sarcophagus and to further isolate the reactor core and the most contaminated wastes for the next 100 years. *[Image: New safe confinement structure image is on cover of IAEA report: Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience.]*

5. Living in the Aftermath of Chernobyl—Lessons from the Recovery

The accident at Chernobyl resulted in unprecedented radiological contamination of a densely inhabited area. It caused major economic, social and psychological hardships to those living in the region. Local and national authorities were not prepared for an incident of such size and severity. How did people in the region react and what measures did they take to cope after the accident? How did the cleanup of the area proceed and what was life like in the affected areas?

The reports of two women with first-hand, personal experiences living in the aftermath of Chernobyl help to answer these questions. The first is Larisa Leonova, a chemist with the U.S. Environmental Protection Agency who was one of the early responders to the Chernobyl event. At the time of the accident, she was managing a laboratory in Moscow on a part-time basis while earning her PhD in chemistry. Larissa volunteered to help with the response and traveled to Kiev several weeks after the incident. She worked in the area around Pripyat, trying to convince local residents to leave the area.

> *[Image – LL8 3:51:54 – 3:52:21 "My Name is Larisa Leanova and I live in United States oh, it's my twentieth years. And um, back when Chernobyl happened I was ah, twenty-eight years old and four years is graduated from ah, university. And I was working as a chemist, basically part time a lab manager and part time doing my PhD research work. Back when the Chernobyl happened I was in Moscow, I always lived in Moscow."]*

> *[Image—LL8 4:00.44--?? "So, I basically ah, set up the vacation time and I called to my uncle in the Kiev and I said like you know me and another group of ah, chemists we are ready to provide whatever the type of the help we can."]*

Vira Yakusha is a computer scientist with a consulting firm in Washington DC. At the time of the accident, Vira was a resident of Kiev and a recent graduate of Kiev University. Vira was pregnant with her first child, and she brings the perspective of an expectant mother and member of the general public reacting to the events occurring around her.

> *[Image – VY4 2:33:03 – 2:34:00 "My name is Vira Yakusha and ah, I was born in Kiev. And ah, I lived there for my entire life. And I loved the city a lot. And ah, I was there as a just a member of general population when Chernobyl tragedy struck. And so my perspective is a perspective of a lay person who is not professionally involved in the nuclear, in the nuclear industry, but who was, whose*

life was directly affected by what happened. And ah, my story is a story of person who is trying to comprehend what's going on and trying to do the best, what is best for my family, for health of my family and ah, trying to live my life as ah, as simple as possible if it's possible in the difficult circumstance."]

Using the first-hand accounts of Larissa and Vira, we will look at several key aspects of the recovery from a radiological event: countermeasures to reduce exposure to the radiation released during the incident, coping with contamination of the food supply, and the special health concerns for pregnant women and their children associated with the accident.

5.1 Limiting Exposure and Cleaning Up

Once the pressing issues of putting out the fires, evacuating the immediate area, removing debris and isolating the reactor were taken care of, attention turned to the impact of the accident on the broader area. Radioactive dust and dirt were a major source of contamination in both agricultural and urban areas.

Because of the magnitude of the accident, local and national authorities were initially uncertain how to proceed. Larissa Leonova, a chemist who now works for the U.S. EPA, volunteered to travel to Kiev in the first weeks after the accident to lend a hand.

> *[LL4:01:56- 4:02:35 "our group of volunteers were basically invited by um, some sort of the organization which were created back there and basically consist um, of very strange group of people who -- represented by Army and by some ah, local officials which were not scientists. They were just the politicians and they were trying, trying to create some sort of the response. And um, again you know first couple of weeks it was basically you know not enough data or no information about plume or no information which territory it's more affected."]*

> *[LL4:03:03 – 4:03:14 "we were among of the first, to my knowledge, volunteer group who went there and who got um, ah, who were involved in ah, um, some sort of the response."]*

One of the first assignments of the group of volunteers was to provide the local populace with some basic guidance about how to limit their exposure to the radioisotopes released by the plant.

> *[LL4:05:05 – 4:05:25 "that's the season when everybody in the Ukraine um, pick up the strawberries. And Ukraine, it's very high in the strawberries and actually you know like um, everybody over there -- middle of the May and June the strawberries is the best place -- taste unbelievably good and everybody has a strawberry growing in their backyards and garden."]*

[LY4:05:40 – 4:05:51 "So, the first advice which we wrote was very silly, we're saying like do not eat the strawberries if they are you know like right besides the dripping line um, from your roof."]

[LL4:06:00 –4:06:15 "The other thing was we were basically advising that ah, try to have at least a bucket of water near the entrance of your door and before -- after you

coming from the street to your house, wash you um, shoes and remove your shoes, try to not bring the additional dust."]

Once the authorities began to realize the significance of the accident, they began to issue further guidance on ways to reduce exposure to contaminated dust:

[VY1 01:34:00 - 01:34:30 "First Monday after, uh, after Easter so it was May -- May 5th, and the May 5th was the first day when, uh, when authorities, uh, Soviet authorities officially on the radio started to say well, things are, um, under control, but, um, for, just for personal precautions please shower regularly, try to keep dust out of the rooms, and, uh, keep your clothes laundered often, and cover the food and bread if you buy something so, uh, it's, uh, to prevent dust from, uh, coming on the food. Uh, so there were first official guidelines for general population to minimize, uh, the exposure."

VY3 02:25:56 - 02:26:32 "After that first announcement, ah, they say that you should wash ah, take shower often, wash your ah, clothing often. Ah, try to prevent dust from setting on your household items. Ah, there was more information. And ah, it will become more and more detailed and instructions more elaborate this time. Then they were not that afraid to accept or admit that something wrong is going on. And, ah, we were doing this religiously. Our family. We were trying to follow everything and some more."

VY3 02:14:21- 02:14:18"my family just tried to keep everything as clean as possible. Free from dust, from dirt. But ah, the thing is that you cannot be 100% sure, of course. And later on, of course, it was not about the surfaces, of your living space, but more about the food that you are getting and ah, and ah, probably some accidental contamination that, for example, like there, rooftops for um, perceived to be very dirty. And they were in fact. So we were told or people were telling the children were told to avoid the downpours from the, from the roof, for example. If ah, water is pouring from the roof, it' probably, if it goes and fills in your overcoat, you don't want to have your overcoat to get dirty and to get rid of it later on."]

As we can see from these examples, one of the primary ways people are exposed to radioactivity after a radiological event is through contaminated dust and soil that adheres to hair, skin, clothing, and shoes. One effective way to reduce this exposure is to shower frequently, launder clothing frequently, remove shoes and outer clothing before entering living areas, and practice general good housekeeping to reduce dust and dirt indoors.

These hygiene precautions were successful in areas like Kiev after the Chernobyl accident, and they are also recommended by Centers for Disease Control and others.

The decontamination activities performed after Chernobyl gives us an idea of what techniques are most effective to reduce the dose received from exposures to radiation. In the days following the accident, the area around the Chernobyl plant and the most contaminated areas in the exclusion zone were sprayed with organic solutions to create a thin film that would immobilize dust. Buildings, vehicles, and city streets were washed frequently and sprayed with water to suppress dust. *[Image: workers spraying water on trucks, buildings, and streets.]*

Much of the radioactivity from the accident was concentrated in surface soil, plants, on asphalt and concrete, and to a lesser extent on roofs and walls. Streets in Kiev were washed daily in the weeks following the accident. In surrounding areas, roads and buildings were washed, residential areas were cleaned, contaminated soils were removed--especially along drip lines next to buildings--and sediments were removed from the bottom of reservoirs. *[Image: men peeling back sod (42-15785116).]* Decontamination activities concentrated on schools, hospitals and other high-use buildings. Overall, tens of thousands of public buildings and residences were treated in about 1000 cities and towns.

According to the International Atomic Energy Agency (*IAEA Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience)*, street cleaning, removing trees and shrubs, and plowing soils in yards to bury the surface soils were efficient and inexpensive means of achieving significant reductions of dose. Roofs and walls also contribute to dose, but they are costly and difficult to clean and thus present a more difficult issue in the event of a radiological emergency in an urban setting. [*Images for this section could be a montage of people scrubbing, plowing, and spraying the streets, buildings, and yards.]*

> *VY4 02:45:17 – 2:45-31 "I've heard from people who stayed there that um, street washing was much more frequent during that memorable summer that there is. When much more often than usual and they were doing a good job of keeping the city clean after all."*
>
> *VY4 2:58:48 – 2:59:05 "In my understanding and my feeling that ah, in the long term during that summer, during consequent months, government did a lot. I mean what they could at this given time. Given level of technology. To clean up what they could."*
>
> *VY4 02:57:04 – 2:57:12 "Not really humanly possible ah, to get things 100% clean as they were before. Ah, you had to really invent a time machine for that."*
>
> *VY4 2:57:19 – ? "For example contaminated soil could be put out of agricultural use. Some things could be thrown away but you cannot make clean everything.*

> *You just, it's impossible. Period. And this what ah, was um, a perception that government did what they could do."*

In 2008, the International Commission on Radiological Protection issued a report that provided guidance on the protection of people living in areas that had been contaminated on a long-term basis from a radiological event. The report identifies numerous actions and strategies that can be used to reduce exposures, improve living conditions and rehabilitate the affected areas. Among the actions identified in the report that should be implemented by authorities are "…clean-up of buildings, remediation of soils and vegetation, changes in animal husbandry, monitoring of the environment and produce, provision of clean foodstuffs, managing of waste..., health surveillance…" and public information. The report also identifies actions that can be taken by the inhabitants of the area, including monitoring the radiological quality of their living areas and food, and the radiation exposure of themselves and their children. *(Reference: ICRP Publication 111, October, 2008, page 12.)*

The following websites also provide good information on actions that can be taken to limit exposure after a radiological incident. [*Images: CDC rad website and address www.bt.cdc.gov/radiation, image of DHS Ready.gov rad website and address http://www.ready.gov/america/beinformed/radiation.html.*

There's also a not-so-great quality but understandable image of a silhouette guy showering off yellow dots at http://www.remm.nlm.gov/deconimage.htm]

5.2 Managing the Food Supply

The massive amount of radioactive fallout from Chernobyl also had far-reaching consequences for the food supply in the contaminated area. As noted by the International Commission on Radiological Protection, "the management of contaminated foodstuffs and other commodities produced in areas affected by a nuclear accident or a radiation emergency…presents a particularly difficult problem because of issues of market acceptance." *(Reference: ICRP Publication 104, 2007.)* While external exposures are likely to dominate radiation doses, iInternal exposure to radiological contaminants through consumption of contaminated food and water can be a very significant exposure concern. Early responders were advised not to eat locally grown food, and surprisingly, to drink red wine instead of water:

> *[LL8: 4:20:00 – 4:20:06 "We were ordered -- we were basically -- that was our order to drink red wine, not drink water. So, that was our liquid consumption. "and LY8 04:27:54 – 4:28:08 "We were not given anything besides red wine. We were strictly advised not drink water or milk. And we were advised do not eat any um, grown -- locally grown product -- produce, nothing, no vegetables, no fruit, nothing."]*

Many locals used common sense and avoided eating locally grown foods that were probably contaminated:

[LY8 4:14:29 - 4:14:45 "We found the people who were very educated and um, they were not eating any fresh food since the accident, since the first they heard about the accident. They were trying to eat canned food only."

Local authorities prohibited animal feeding with pasture grasses in the affected areas and rejected milk based on radiological monitoring. Many thousands of agricultural and domestic animals were slaughtered immediately, and the remainder evacuated. *[Images – pigs and cows being screened with radioactivity meters by a worker in a moon suit (ex: 42-15882699 and* 0000316032-056*), images of dead fish on the shore near the reactor(I suggest no using an image of dead fish because their death was not caused by radiation which some may be led to believe by using it in this context. These fish were likely killed due to the contaminated water from efforts to put the fires out – not the radiation in the water.)]*

People living in the area tried to obtain imported food as much as possible, but this was often difficult. Vira Yakusha explains her dietary habits when she returned to Kiev with a young baby in the months following the accident:

[VY3 02:27:15 – 2:27:43 Well first concern ah, at that point was the food. And ah, food and again official line was that all food is carefully screened. Sources of food that contaminated milk or other ah, ah, necessities are discarded and thrown away and so you don't have worry about that. But of course we did worry. And of course we, we will try to buy imported food. As much as it was possible. But it was not that readily available.

VY3 2:22:18 – 2:24:00 "…if there is a cereal made in Hungary, probably there is less ah, a less chance that it's radiologically contaminated than the sour cream made on the local factory. Because God knows where this local factory gets their milk from. And in the first couple of weeks we were so ardent about it that I even didn't eat any bread because bread was definitely make over, made of local grains. And again, local grains could be contaminated. But after a couple of weeks without bread, I said you know what? I'm going to eat bread. Because I cannot. I need to eat something, right?"
[VY3 02:28:35 – 2:28:51 "So there are very, there are always efforts. There are always efforts to make sure your food sources are clear. But it is almost impossible. So you have to accept at some point that you have to, continue with your life or otherwise you will just go mad."

VY3 2:27:43– 2:28:12 "And of course, ah, ah, we will try to buy imported food. As, as much as it was possible. But it was not that readily available. And again, there were um, ah, some things that you cannot buy imported. For example, like your greens, your apples. And ah, sometimes you will come across imported apples with big luck. I remember my husband bought five kilos of ah, ah, a golden ah, golden delicious which is a common brand in America and they were ah, grown somewhere ah, from north of imported apples. And we were very happy. We were feeding our baby these apples for quite a long time while they lasted."

According to the International Atomic Energy Agency, some of the most effective countermeasures were treating the soil; removing some areas from agricultural production altogether based on radiological screening; switching animals to clean fodder from uncontaminated areas; and providing dietary supplements such as cesium binders to help the radio nuclides pass through the animals without being incorporated in food products. *[Images: workers in suits walking through a field (42-15800571), a man with a rotor tiller (*42-15784775*), peasant gardeners (DWF15-682237), and a fallow field with a rad sign in front of it (42-15784775)]*.

The countermeasures described above went a long way to reducing the radiological contamination of foods from the areas affected by the Chernobyl accident. However, the long half life of some of the contaminants, particularly Cesium-137, and the economic hardships following the fall of the Soviet Union, resulted in continued barriers to agricultural restoration in the affected area.

5.3 Coping with Health Concerns

Exposure of humans to radiation can cause health problems, depending on the type of radiation, the amount of radiation exposure, and the individual's general health and susceptibility to illness. For the people affected by Chernobyl, the potential impact of the accident on their health was a major concern.

Vira Yakusha was living in Kiev and pregnant with her first child at the time of the accident. Upon learning of the disaster, she tried to leave Kiev as soon as she was able, to try to put as much distance between her baby and the radiation emergency as she could. Unfortunately, many people were trying to do the same, and Vira was unable to buy a train or plane ticket *[image –we could show a few generic Russian-looking group queued up at a ticket booth, as Vira spoke about the crush of people waiting to purchase airline or train tickets.]*

Vira discussed this situation urgently with her husband and her family:

> *VY1 1:29:20 - 01:29:27 "I was really determined, uh, to keep my baby healthy and, uh, as far as harm's way was possible."*
>
> *VY1 1:50:49 "I don't know what to do, it's impossible to buy tickets for -- for a plane, it's impossible to buy tickets for a train, but we need to get you out. And we were sitting in the kitchen and trying to figure out what kind of plan that could work"*
>
> *VY2 01:51:36 – 1:51:41 "And so we were thinking about this and that, and there is suddenly, um, uh, a buzz on the door …"*
>
> *VY2 1:51:54 – 1:52:44 "I opened the door and this is, uh, again my friend, uh, Yenna, who, uh, head of the family who were taking me to Karnyov, and he sort of looks grim, and he said you know what, I made a decision, uh, I take my, uh, girls*

away to Mosc -- I'm taking my girls away to Moscow because I want to get my kids out of here as soon as possible. And his, his thinking was pretty much the same that if the government admits so much that, uh, it's dangerous, then it's really, really dangerous. Yeah, and he said, um, okay, so my car is downstairs, uh, waiting for you, um, my wife and my kids are in the car, and we have still one place left in this car, this is for Vira. If you want to go with us you have 40 minutes to pack yourself."

[Images – Possibly a man standing next to an old, Soviet-style car? A family around a table talking about something obviously upsetting or pressing.]

Vira left Kiev that night, and four months later in Moscow she gave birth to Doreena, a healthy baby girl. We can't say whether getting out of Kiev, about 70 miles from the disaster, in the weeks after the accident helped her give birth to a healthy child. Her child may very well have been fine had she continued to live in Kiev.

VY1 01:32:46 – 1:33:18 "Doreena, and she is, uh, 21 years old right now, and, uh, I never had any, uh, uh, health problems with her that I should, could attribute to potential exposure. But unfortunately, uh, my understanding of the nature of the whole thing is that you never can, if you have some sort of health problem you can never be 100 percent sure if it was the result of, uh, your exposure to the radioactivity at some point or it's just your particular body type or, uh, other factors that were contributing."

Reflecting on her actions many years later, Vira feels that she made the right choice given the information that she had:

VY4 02:42:38 – 2:43:38 "My personal feeling is the health of your children or your child is the first priority, because this is something that you are ulta, ultimately responsible for. So I would say what I said to myself. Put as many miles as you can between the source of radiation and yourself and your baby and try to get as much information as much reliable information as you can. And try to… I mean panic is never a good helper or a good advisor. So probably understanding is our best weapon and to know how things work and what is real danger and what is imagined danger. It is a real important difference. And the more you understand, the better your choices are, the better your behavior is. At least you're choosing between least, least possible evils. And ah, it's impossible to be in a perfect world. But in our imperfect world, you have to make your own choices. And it's better to be based on the, on the ways of reason."

Pregnant women and their unborn babies are particularly vulnerable to the effects of radiation. However, termination of a pregnancy is rarely justified unless the dose absorbed by the pregnant woman or unborn child is very very high. According to the International Atomic Energy Agency ~~and the Centers for Disease Control~~, the potential health risks associated with radiation exposure are highest when a baby is in its early stages of development--during weeks 2 through 15 of the pregnancy. Exposure to large doses of radiation during this time could result in severe health effects such as birth defects, stunted growth, and brain damage.

The risks associated with radiation exposure are somewhat lower during the second and third trimesters of pregnancy. During weeks 16 to 25 of a pregnancy, unborn babies exposed to radiation may experience health consequences, but only if the doses of radiation are very very high, such as those large enough to cause radiation sickness in the mother. After the 26th week of pregnancy, the risks to the unborn baby are lowest since the baby's organs have already been formed. Exposure to radiation from any source during pregnancy can cause significant anxiety and fear, and pregnant women should consult with their doctors about their concerns.
More information about the special health concerns associated with exposure to radiation during pregnancy can be found on the Centers for Disease Control Website *[Image – CDC web site and fact sheet at http://www.bt.cdc.gov/radiation/prenatal.asp*

Coping with uncertain future health risks to people of any age is a significant challenge following a radiological incident. Widespread fear after the Chernobyl accident caused many people to attribute their subsequent health problems to the effects of the accident, even though these problems may have developed anyway.

Vira Yakusha helps us understand: [NOTE: *This is based on statements from Vira but we do not have video of it so we have to discuss how best to portray: (why don't we have video? I remember this story being taped.]*

> *" It was my best friend, Nadia, and her husband who helped me leave Kiev and took me with them in their car to Moscow because of our concerns about contamination levels following the accident. Nadia and I were classmates at the university. I never in my life met a more energetic, bright and sunny person than Nadia.*
>
> *"On the drive to Moscow, we took a detour—in part to avoid the roadblocks already established on the main roads between Kiev and Moscow, and in part to help Nadia's relatives plant potatoes. The crop from their vegetable patch was a main source of their food in the winter. We ended up on a little field near Kanev city, and Nadia and her husband were planting potatoes. It was a sunny, very bright spring day. We all had this feeling then that the danger was all around us, and the fact that we could not see, smell or feel it made it even more menacing. But I felt that we were out of danger at that moment—we were already far away from Kiev and even further away from Chernobyl, after all. I just feel very uncomfortable that they were working very hard physically while I was just sitting under a shade tree due to my pregnancy.*
>
> *"Only a month later, information that had been previously suppressed became more or less public, and we learned that the wind had moved the invisible cloud*

of radioactive dust southward, so the idyllic countryside with the potato patch was exactly underneath it. I was never able to get more specific information, and I don't even know if it really exists, but when we learned in 1994 that Nadia had been diagnosed with breast cancer, the thought of that perfect sunny day came to my mind immediately. I don't think there is any way to prove the link scientifically, but in the mind of everyone involved there is no doubt about the "cause and effect" between the exposure and her illness."

Since the Chernobyl accident, much knowledge has been gained about its effect on the health of the people who were exposed to radioactive contamination in the areas surrounding the plant. Between 2003 and 2006, the World Health Organization (WHO) conducted a series of expert meeting to review all the scientific evidence and evaluate the health impacts of Chernobyl. The WHO expert group reported in April 2006 that the main cancer consequence observed as of that date was the significant increase in thyroid cancer among young people who had lived in the most contaminated areas of Belarus, the Russian Federation and the Ukraine. These cancers occurred primarily among children and adolescents who drank milk contaminated with radioactive iodine immediately after the accident.

The WHO expert group also reported that "The Chernobyl accident led to extensive relocation of people, loss of economic stability, and long-term threats to health in current and possibly future generations…High levels of stress, anxiety and medically unexplained physical symptoms continue to be reported among those affected by the accident…Designation of the affected population as "victims" rather than "survivors" has led to feelings of helplessness and lack of control over their future. This has resulted in excessive health concerns or reckless behavior…"
(Source: "Health Effects of the Chernobyl Accident and Special Health Care Programmes: Report of the UN Chernobyl Forum Health Expert Group," Editors Burton Bennett, Michael Repacholi and Zhanat Carr, World Health Organization, Geneva, 2006.)

The WHO expert group concluded overall that "…the large increase in thyroid cancer incidence among those exposed in childhood and adolescence continues; fortunately, few of these have been fatal. In contrast, at this time, no clearly demonstrated increase in the incidence of other cancers can be attributed to radiation exposure from the accident." However, the report went on to note that this did not mean that the longer-term cancer risk of those who were exposed had not increased. Based on the experience of other populations exposed to ionizing radiation, the WHO experts predicted that "…a small increase in the relative risk of cancer is expected, even at the low to moderate doses received" and said that further studies are required to understand the full health effects of the accident. *(Source: Journal of Radiological Protection 26 (2006) 127-140, Cancer consequences of the Chernobyl accident: 20 years on).*

Vira Yakusha shares her thoughts on the question of whether or not she perceives herself more as a "victim" or as a "survivor" of Chernobyl: [NOTE: *This is based on statements* *from Vira but we do not have video of it so we have to discuss how best to portray: I know we have video of this.]*

"The distinction is more like the difference between having a positive versus a negative attitude towards life. Based on my experience and my communications with fellow denizens of Kiev, there is no way to tell exactly who is a victim and who is a survivor. I guess everyone's attitude fluctuated between those two poles, depending the weather, the mood etc. But I would agree that people with a prevailing "survivor" attitude had better outcomes in fighting the consequences of Chernobyl. It is impossible to know if they have a "survivor" attitude because they are stronger, or if they are stronger because of their "survivor" attitude." These were not the same responses she gave during the interview. We can definitely use this statement but I would also like to find the original video response to this question.

6.0 What if it happens here? (NOTE TO KIRK: Please double check the noted video times in this section as I was working from the transcript, not the DVD.)

One of the biggest problems with the Soviet response to the Chernobyl disaster was a lack of credible information about the accident and its effects on the population. Due to the closed nature of Soviet society, Soviet authorities either did not fully understand the severity of the accident, or they intentionally downplayed it.

The first public notice of the accident came on April 27, 1986 from Sweden when workers at the Forsmark Nuclear Power Plant (about 700 miles away) detected elevated levels of radioactivity that were not from local sources. *[image – map showing Forsmark plant on the east central coast of Sweden and Chernobyl/Kiev, perhaps with a scale showing distance between them.]*

Almost a week after the accident, the major Soviet newspapers were still not discussing the ongoing nuclear disaster that was contaminating much of the USSR and Europe. *[Images of soviet newspapers and political figures; some possible footage at www.encyclomedia.com, "The Chernobyl Nuclear Disaster," September 15, 2006.]* Soviet premier Mikhail Gorbachev did not appear on television to discuss the incident until May 14, 1986, several weeks after the event. As a result, citizens were forced to turn to informal news channels, networks of associates and whatever international news they could find on short-wave radios. The lack of reliable information about the accident and its effects created uncertainty, inefficiency and suspicion that the incident was far worse than was being reported.

Larisa Leanova and Vira Yukasha describe the situation.

(Possible quotes in order of preference here; how many depends on time)

> *[LY8 3:52:26 – 3:53:33 "we didn't get any information about Chernobyl um, officially — almost like a week after the accident happened. When I first time*

heard about it — it was the first day ah, first working day basically it was a Monday, I believe it was 27th or 28 of the April. I came to work and one of my co-workers told me, "Did you hear the news that BBC's announcing"? And I said, "No, I basically was very busy this weekend, I didn't listen to any BBC". And we all had the habit to listen one of them ah, for a radio station and um, early morning Monday exchange the news. What really was get — what we were getting from the abroad and what was um, broadcast in the Russian radio stations. So, my co-worker told me that he heard that something happen in the Ukraine and Sweden is picking up ah, increased radioactivity levels. And I said, "I haven't heard of that".]

[VY1 1:29:29 – 1:29:41 "Because nobody was giving you any, uh, hard information at this point, assumption was that, uh, probably things are much, much worse than officials would tell you. And, uh, so the first week, uh, we were living our life more or less our life as usual."]
[VY1 1:23:21 – 1:23:36 "we were very skeptical about official sources of information per usual, uh, so we turned onto the, uh, Radio Free, uh, uh, what was that, what was commonly called The Voices From Abroad, and, uh, there were several radio stations that they were broadcasting towards the Soviet territory, and one of them was Voice of America, another was Radio Free Europe and one of them was BBC and such. And they were all, um, the Soviet, uh, government tried to jam them, and so you had intelligence or people who were curious about what was going on and wanted to have more information that was officially available, they were trying to find the Voices on the short wave bands."]

[VY2 1:58:10 – 1:58:50 "I am sitting in the back seat of the car, and, uh, our radio is on, and the radio is official so it's radio and there's a news report and oh, everything is, uh, contained in Chernobyl, everything is fine, in Kiev there is no danger at all in Kiev, I mean, the population should not worry. And I'm thinking yeah, that's, it's an interesting twist because here I am from Kiev, and, uh, I'm too dirty to enter Moscow but in Kiev everything is fine. Yeah, and, um, it was a surreal moment"]
VY2 02:05:28 – 2:05:37 "There is a difference between, uh, questioning authorities or expecting answers to a question. So I was, uh, very aware that authorities are not telling the whole truth. But I never expected to, uh, get answers, truthful answers, if — if I would start questioning."

Vira later observed:

"…my personal observations are not at all scientific, but it seems that people who were critical and distrustful of then-Soviet government information had much better chances to avoid the negative consequences of radioactive contamination. My own story is an example of it because I decided to move away from Kiev in order to protect my baby, even when official sources told the population that there was no real danger in the city. I would caution against applying this 'rule of thumb' to U.S. realities because, in my opinion, here there are many mechanisms

that will allow better and more truthful information to reach the general population in the case of a negative event." [NOTE: we have to decide how to best include this quote since it is not on video—either tape her saying it or use her voice here?] *I don't understand why we are missing the video.*

If a similar incident were to happen in the U.S., we can in fact expect a much more open flow of information. Not only would the major news media cover the disaster, but the U.S. Department of Homeland Security, the Centers for Disease Control, the U.S. Environmental Protection Agency and other agencies would post information on what do.

[VY4 2:41:07 — 2:42:14 "This is such a society where ah, different ah, groups of people have their say. So there is always a balance of forces. And the result of this balance, ah there is a much better possibility that the real information, the scientific information will come out and be available and be widely available and with the internet, it's, it's, it's even, it's even better now. Because I remember how I was just raking my mind trying to remember what I was taught about levels of radiation. And now I fully expect it to be available, this information to be available on the web. And probably guidelines that I will have from authorities. I will be more willing to trust them and to follow their recommendation, because I um, understand that it's much more reliable and much more better grounded reality than it used to be on the Soviet. So it's a different story."]

6.1 Being Prepared

The U.S. Environmental Protection Agency works closely with other civilian and military federal agencies as well as state and local governments to develop radiological emergency response plans and procedures. These plans specify how emergency response organizations will work together and what will actually happen during an emergency response operation. In addition to planning activities, EPA provides training and guidance to first responders, and conducts and participates in exercises that simulate radiological emergencies. *(Source: EPA Radiation Website.)*

Jim Mitchell is an On-Scene Coordinator for the U.S. Environmental Protection Agency. On-Scene Coordinators are responsible for coordinating response activities carried out by federal, state and local officials after a significant incident. Jim describes one of their exercises, called TOP OFF, as an example of how the U.S. is preparing at every level for a possible radiological attack:

[JM6 3:24:05-3:24:37 "…Top Off was an, was an exercise, uh, that took place about four years ago and it took place in Seattle where there was a, uh, a radiological dirty bomb, a device that was set off in Seattle. Now numerous federal, um, uh, the local, you know, the local city was Seattle and also local communities, you know, took part in responding to this exercise. And it was specifically to look at how the federal government, the federal, state and local governments would respond and outline the issues, uh, that were surrounding their response, identify gaps and try to find ways to fill those gaps."]

[JM7 3:42:27 – 3:43:20 "…we're working towards, um, a level of preparedness that we haven't seen in the past. An, and, um, you know, as a, as, as a part of the region and as part of our, our, um, uh, response experts, uh, for responding to these types of incidents, we're working there. Uh, we need to continually develop exercises and training not only from On Scene Coordinators and, and our own responders, both regionally and nationally, but we need to, we need to, uh, to integrate our plans and procedures with the locals, with state and local, um, plans, with other federal agencies. So we clearly have a defined role and we have a, a developed, uh, a working path so if something like this happens, we're not, you know, we're not arguing over who's doing what or who's responsible for what. That we, that we continue to achieve a level of preparedness, um, you know, everyday. It's, it's an ongoing process."]

[JM7 3:43:27 – 3:43:42 "We cannot anticipate all the conditions, um, or the, or the, or the impacts from something like this. We can take the knowledge that we, that we have to develop through exercises, through training, um, through research from our national laboratories and try to bring it to a level of preparedness that we have not seen in the past. And we're working towards that on a daily basis."]

Public education is another essential element in preparing for a possible incident.

[LV10 4:49:00 – 4:50:56 "…So, my message will be prepare yourself as much as you can, read the literature which is advising you how you have to act in case of the um, pandemic flu, in case of the emergency evacuations, what you have to keep in your home in case of the first couple of days of survival you know like in the case of the accident. Meaning you have to trust your government but you have to trust yourself also because it's so many of us, it's only one government. So if you will not help yourself in the very few first moments after the accident your government may be too late when it finally—government will be helping you. So you have to give the government opportunity to save you. And to do that basically educate yourself what you can do for yourself and you know take the responsible action."

Dr. John Cardarelli of the U.S. Environmental Protection Agency discusses some of the information resources available to the public:

> *[JC2 5:08:32 - 5:09:42 "There's a lot of resources available to folks to learn more about long-term recovery and the types of information that they — that's going to be concerned or they're going to be interested on. I would recommend a lot of folks visit uh, vetted, scientific, internet websites. Uh, for example, usepa.gov uh, the cdc.gov for public health inquiries, there's a nice website that's available by various professional societies, the Health/Physics Society, which is hps.org. Um, the National Commission for Radiological Protection is also another good website uh, the ncrp.com and there's various international uh, websites as well.*
>
> *I.A.E.A, that stands for the International Atomic Energy Association, as well as*

the I.C.R.P., the International Commission for Radiological Protection. These are all scientifically valid, vetted information that can provide a lot of information to folks that are concerned about the public health issues, environmental issues and some of the socio-economic aspects of why certain things and clean, cleanup levels have been set the way they have."]

[JC 5:10:00 – 5: 10:36 "You're going to have a large variety of professional folks, subject matter experts, some who will say, any amount of radiation is not good for you. Others will say, you can take X amount and it's not going to hurt you at all. The truth probably is somewhere in between and what's more important is that folks understand that and they have to come to, to a conclusion themselves. The best way to do that is to educate yourself on what the risks are to you, your family, your friends, your loved ones um, and do that by educating yourself at these various websites."]

Examples of good internet sites for information on how to respond to a radiological incident are: the Department of Health and Human Services' Radiation Event Medical Management site *[Show a screen shot and the web address: www.remm.nlm.gov];* U.S. EPA's Radiation Protection program page *[show screen shot and address: www.epa.gov/radiation];* and the U.S. Department of Homeland Security's Ready America Radiation Threat site *[Screen shot and www.ready.gov/america/beinformed/radiation.html]*.

7.0 Conclusion

As frightening as the possibility of a "dirty Bomb" or other radiological incident may seem, we know from experience that we can recover safely from such an event. And, the United States is better prepared than ever before to cope with such an eventuality.

In this film, we have reviewed the incident at the Chernobyl power plant—the worst nuclear accident in history and which released much more radiation than would be expected from a dirty bomb or radiological attack. We learned that there are many effective ways to limit the exposure of people to radiation and live safely in long-term contaminated areas.
Let's recap the main points:

- Although we can forecast the potential types of radiological threats might we face, we cannot forecast with precision the exact facts that will accompany any specific incident. However, a dirty bomb or other radiological attack is not likely to release nearly as much radiation as was released from the Chernobyl accident.

- If radioactive materials are used in a terrorist attack, living things could be exposed to higher than normal levels of radiation that could harm them and contaminate their surroundings.

- Exposure to radiation can cause health problems. The possible health risks vary widely depending on the type of radiation, the amount of exposure and the individual's general health.

- Pregnant women should recognize that exposure to small doses of radiation during pregnancy is not likely to increase the risk of birth defects. However, each situation must be evaluated carefully and people with special health concerns should seek advice from their doctor.

- A radiological incident will cause real fear and anxiety among people in the affected area. Being prepared and relying on sound, accurate scientific information can help people to make better-informed decisions and allay these fears.

- People can reduce their exposure to harmful radiation by shielding themselves from the source, removing contaminated dust from their skin and clothing, and cleaning or temporarily leaving the area.

- Governmental authorities can employ a number of effective counter measures after a release, including cleaning-up buildings, remediating soils and vegetation, monitoring the environment and establishing health surveillance programs. They also play an important role in restoring supplies of safe water and food to those in the affected area.

- Radioactivity decays with time. The "half-life" of many radioactive elements is relatively short, but others with much longer half-lives will cause areas to remain contaminated on a long-term basis. Even though such areas may have a higher than background level of radiation, they can be cleaned to a level that allows people to live in them safely.

- Recovering from a large-scale radiological incident may require long periods of time to heal the environment, repair damage to the local economy and mitigate the psychosocial impacts on the population.

- There are many high quality sources of public information about the health, environmental and socio-economic issues associated with radiation exposure. If a radiological emergency were to occur in the United States, government and news sources would provide additional information to guide those being affected.

We have learned much about how to cope and recover from a major radiological release since the Chernobyl accident. This knowledge will help us to effectively respond to a future possible incident. The best way for citizens to prepare is to educate themselves about the possible scenarios that could occur and the risks they pose. We hope this film has helped you begin this process.

Chernobyl Straw-Man Outline

The Chernobyl Incident – Experiences, Recovery, and Lessons Learned

Introduction (3 min) – State the purpose of the documentary: In an age of growing incidence and awareness of terrorism aimed at mass casualties and disruption, the U.S. faces a risk of experiencing a "dirty bomb" or even an improvised nuclear device. EPA has been preparing for such an eventuality, and is ready to respond, if necessary.

A dirty bomb or improvised nuclear device would be likely to detonate with little or no warning and contaminate a large, densely inhabited area. To address the key issues that would confront the U.S. and in such an event, this discussion will examine an event that forced the USSR to confront some of the same issues: response and recovery from the Chernobyl nuclear incident. The Chernobyl incident was the uncontrolled meltdown of one of the core reactors of the Chernobyl nuclear power plant in 1986 near what is now Kiev, Ukraine. In this documentary, we'll examine how recovery from that that incident was managed, focusing on effective countermeasures in the aftermath of the disaster and eventual restoration and recovery of the area. We will enhance our discussion of the response and recovery from that incident with direct, first-hand, personal perspectives of an early responder who provided technical assistance in the early phase of recovery, and of a resident of Kiev, who was a young mother in Ukraine at the time of the disaster. [More detailed resumes when they first appear on screen]

Outline of what's to come (1 min) – road map of where we're going: Definition of terms, description of incident, immediate response, long-term response, and discussion of U.S. preparedness for such an event.

Definition of terms (3 min) – A primer on radioactivity is in order. Before we begin talking about radioisotopes, we need to define a few key technical ideas to frame the discussion: [There's a nice discussion from CDC] Radioactivity is measured by the number of atoms disintegrating per unit time. A **becquerel** (Bq) is 1 disintegration per second. A **curie** (Ci) is disintegrations per second of 1 gram of radium (37 billion disintegrations per second). Radiation can take the form of a beta particle, an alpha particle, a gamma ray, or some combination of all these. Introduce the variability of half life, physical properties of particles (density, sorption coefficient) that affect transport, perhaps a discussion about what type of radioisotopes are produced by nuclear fission, which ones were troublesome at Chernobyl (biologically mobile radionuclides: ^{131}I, ^{137}Cs, ^{90}Sr). Could also introduce idea of overall dose of gamma vs. beta discussed by Hinton et. al. (p. 429 – 430) to demonstrate relevance to Chernobyl.

The Incident (10 min) – Discussion of what transpired. Explanation of why they had a meltdown in the first place, how the disaster unfolded, and what happened as a result. The focus of this section is what happened up to the evacuation of Pripyat. There will be good footage here that should give the viewer an idea of the magnitude of the disaster and it'll set the stage for the recovery. Also discuss fallout, what it is, heavy (hot) particles close, lighter particles far, control of wind, precipitation.

This is a good place to introduce the types of incidents we might face and draw a distinction between the similarities and differences between a nuclear power plant meltdown and an RDD or improvised nuclear device.

Radioactive dispersal device (RDD):

- An RDD is a conventional bomb that contains radioactive materials and scatters those materials and other debris over a small area when it detonates. This type of weapon may use medical or industrial nuclear materials, but the materials do not undergo a nuclear reaction.
- An RDD would likely involve contamination over a densely populated area, initial confusion/lack of information, and an improvised response (by that I mean flying blind), but would differ from Chernobyl in that the contaminated area would be significantly smaller and the amount and intensity of radioactivity released would likely be orders of magnitude lower.
- *CDC FAQ: Although a dirty bomb could cause serious injuries from the explosion, it most likely would not have enough radioactive material in a form that would cause serious radiation sickness among large numbers of people.*

Improvised Nuclear Device (IND): <*Note – This may be insufficiently constrained to even discuss – perhaps touch on it and move on. I spoke with Jim Mitchell about an IND, and we determined that there is probably too much variability to draw any meaningful generalities other than mass casualties and large area, but not as big as Chernobyl. INDs range from rogue nukes from the former USSRs to amateur nuclear bombs, which open the possibility of incomplete reaction and thus long lived radioisotopes].*

- An IND is a small nuclear bomb where materials undergo a nuclear reaction.
- An IND would be catastrophic. The contaminated area would be big but still smaller that Chernobyl and there would likely be mass casualties. *[*

The Immediate Response (15 min) – Here we can talk about the liquidators (and touch on the construction of the sarcophagus and the new safe confinement, in passing). We'll certainly be able to identify some good footage/photos of this part, then we can get into the more meaty and meaningful information in the Health Physics articles. We can also discuss the fallout pattern and how it was highly variable based on precipitation (Balinov, p. 385), and what fell out where (short-lived and long-lived isotopes). We could introduce the concept of distance, time, and shielding here - Dose rates decreased by three orders of magnitude in the 3 km from the plant to Pripyat (Hinton et. al. p.430).

Balanov mentions evacuation, distribution of stable iodine tablets to Pripyat (but not the surrounding area), and restriction of the food supply as the most effective immediate measures. For the immediate affected area, outline the basic measures – establishment of 30 km exclusion zone, evacuation, nuclear waste repositories. For the larger (and more populous) area, outline other measures - bathing, clothing, hygiene … We can discuss these systematically, and we can follow each with CDC/REMM/DHS recommendations. I like that approach because we can tie together history, first-hand anecdotes, and current recommendations:

Clothing and hygiene: *Exposure to radiological contaminants through fallout is an important mechanism of exposure in the early phase of a radiological incident. Contamination refers to particles of radioactive material that are deposited* *anywhere that they are not supposed to be, such as on an object or on a person's skin. Internal contamination refers to radioactive material that is taken into the body through breathing, eating, or drinking. One effective way to reduce exposure is to remove clothing where particles may lodge and to shower to remove particles from skin and hair.*

CDC recommendations for dirty bomb:

- *To keep radioactive dust or powder from getting inside, shut all windows, outside doors, and fireplace dampers. Turn off fans and heating and air-conditioning systems that bring in air from the outside. It is not necessary to put duct tape or plastic around doors or windows.*
- *If you must go outside, be sure to cover your nose and mouth with a cloth to reduce the risk of breathing in radioactive dust or smoke.*
- *Take off your outer layer of clothing and seal it in a plastic bag if available. Put the cloth you used to cover your mouth in the bag, too. Removing outer clothes may get rid of up to 90% of radioactive dust.*
- *Put the plastic bag where others will not touch it and keep it until authorities tell you what to do with it.*
- *Shower or wash with soap and water. Be sure to wash your hair. Washing will remove any remaining dust.*

a. Clothing – Larissa's story about the lead-lined boxes in Kiev.

b. Hygiene – Vira and Larisa recollections about official recommendations and what people actually did

Food: *Internal exposure to radiological contaminants through consumption of food and water is a very significant exposure mechanism, more so for a nuclear power plant disaster of nuclear explosion than for a dirty bomb. One of the most significant effects of the Chernobyl accident was an increase in thyroid cancer in children through ingestion of milk contaminated with ^{131}I. 20,000 agricultural and domestic animals slaughtered immediately, the remainder evacuated. Due to lack of forage and animal care infrastructure, and additional 120,000 animals were slaughtered from May to June 1986.*

CDC recommendations – immediate:

- *Food and water supplies most likely will remain safe. However, any unpackaged food or water that was out in the open and close to the incident may have radioactive dust on it. Therefore, do not consume water or food that was out in the open.*
- *Food inside cans and other sealed containers will be safe to eat. Wash the outside of the container before opening it.*

c. Food –Most effective countermeasures were restriction of geographically based pasture grasses from animal diets, rejection of milk based on radiological monitoring. Short-term effectiveness was hindered by lack of timely information and an economic issue for private farmers. Larissa has stories about how even uneducated people were smart enough to eat pre-event canned goods rather than fresh food bought in stores.

Dietary additives:

Potassium Iodide (KI): *As noted above, thyroid cancer was one of the primary issues in the immediate aftermath of the Chernobyl incident. Mikhail Balinov of the IAEA* *lists provision of KI to residents of Pripyat as one of the key successes of the initial response to the disaster. KI was not provided to surrounding areas.*

CDC recommendations:
In the case of internal contamination with radioactive iodine, the thyroid gland quickly absorbs this chemical which can then injure the gland. Iodine in non-radioactive KI blocks radioactive iodine from being absorbed by the thyroid gland.

Iodized table salt also contains iodine, but table salt does not contain enough iodine to block radioactive iodine from getting into your thyroid gland. You should not use table salt as a substitute for KI.

Where can I get KI? KI is available without a prescription. You should talk to your pharmacist to get KI and for directions about how to take it correctly. Your pharmacist can sell you KI brands that have been approved by the FDA.

***Prussian blue** Prussian blue traps radioactive cesium and thallium in the intestines and keeps them from being re-absorbed by the body. CDC has included Prussian blue in the Strategic National Stockpile, a special collection of drugs and medical supplies that CDC keeps to treat people in an emergency. [Note – I can't get to that site to find out what-all they have there. Would be a good idea to mention some details of this as a way to demonstrate some preparation for such incidents.]*

d. Dietary additives – Larisa and Vira may well have recollections about what sort of things people did in addition to avoiding certain foods. There was a tale about using vodka to flush radioisotopes from the body. *I don't know if it would work, but it would certainly make you feel better!*

***Children/pregnancy**: **We can touch this, but will have to treat this hot-button topic sensitively to avoid offense. My gut tells me that we have plenty of material, and should probably drop this controversial bit, unless Vira and/or Larisa feel strongly. We could tie this in with the general lack of reliable information and lack of trust.** Pregnant women, babies, and infants are highly sensitive to environmental contaminants. We now know that many individuals terminated pregnancies in the aftermath of the disaster, either as their own decision or under the advice of physicians.*

CDC: Unborn babies are particularly sensitive to ionizing radiation during their early development, between weeks 2 and 15 of pregnancy. The health consequences can be severe, even at radiation doses too low to make the mother sick. Such consequences can include stunted growth, deformities, abnormal brain function, or cancer that may develop sometime later in life.

e. Children\Pregnancy – Larisa and perhaps Vira have recollections of how a large number of pregnant women chose to terminate pregnancies to avoid perceived problems for babies, sometimes on the advice of physicians.

The Long-term Response (15 min) – This section should discuss the longer-term mitigation actions after the evacuation was complete, the fires were out, and things were settling down to a new state of normalcy. We could restate the distance, time, and shielding mantra here: 80% of total dose was received within 3 mo of incident (Hinton et. al. p.430). We can discuss the radioisotopes that are most problematic – ^{137}Cs, ^{90}Sr. ^{131}I is mostly gone by now.

a. Food supply – Greatest long-term problem is radiological contamination of milk and meat (Balinov p.388) *[Note that rural food supply in Soviet Union made local sourcing more prevalent than in U.S. today. Our centralized food system would* *make isolating affected foodstuff a lot easier.]* "Effects of the disaster were profound and long-lasting. As recently as 2001, 9% of the milk supply in the affected areas did not meet the standards for ^{137}Cs (Alexakhin et. al. p. 422)"

Here are techniques used in the long-term (post-1987)

- *Withdrawal of areas from agricultural use based on radiological surveys,*
- *Soil treatment to reduce Cs and Sr uptake,*
- *Cesium binder dietary supplements to animal feed*
- *intensive fertilizer use to dilute plant radioactivity*
- *change in fodder crops to species that uptake less Cs and SR (ex: rapeseed)*
- *clean feeding – substitute fodder from uncontaminated areas before slaughter and milking.*

Most effective long-term countermeasures treatment of fodder land, clean animal feed, intro of cesium binders (Prussian blue) into animal feed (Balinov p. 388). Other countermeasures included application of organic and mineral fertilizers and agroameliorants, ferrocyanide compounds in farm animals, preslaughter cattle feed w/ clean feedstock, storage of milk in dried or condensed forms to allow ^{131}I decay (Alexahkin et. al p. 421). Disintegration of USSR and accompanying economic hardship reduced effectiveness.

Questions: Ask if Larisa and Vira have recollections about restrictions on food supplies, stories about economic hardship for local farmers and their response, etc.

b. **Forests** – Not given much attention initially. Long-term countermeasures include restrictions on access and use of forest products (mushrooms, berries, and wild game harvesting, firewood), suppression of forest fires to avoid secondary deposition (IAEA p. 87), and alteration of hunting practices (seasonal harvesting) (Balinov p. 388).

Questions: I'm sure that Larissa and Vira have many stories to tell about this proud Russian tradition.

c. **Aquatic systems** – divided into drinking water and contaminated aquatic foods.

Drinking water - Weeks after accident, Kiev drinking water supply switched from Dnieper River to Desna River via a pipeline; Water treatment is designed to remove particulates, but Kiev added activated charcoal and zeolites to treatment system as polishing step. Initial release of water from Kiev reservoir to allow room to contain contaminated runoff; standard soil erosion countermeasures were implemented, but not completely effective because Cs and Sr were in dissolved phase. Countermeasures to prevent transfer of radionuclides from soil to water generally expensive and ineffective. Most effective: Early restriction of drinking water and alternate water supplies (groundwater?). (Balinov) Other countermeasures – Dikes & channel barriers to reduce sediment mobility, addition of sorbents to water (Alexahkin et. al p. 423).

Aquatic foods – similar to forest management; Fish advisories still in place and effective in Scandinavia and Germany, but perhaps not in Russia, Belarus, and Ukraine because of economic motivations to harvest fish (i.e. they're free). Cooking methods (remove skin and bones because of Cs concentrations)

Questions: Similar to above – recollections of concerns about drinking water and aquatic foods, any thoughts on effectiveness of restrictions?

d. **Radiation-induced effects on plants and animals** – *Suggest we skip this, as we have plenty of other material.* Balinov has a nice discussion (p. 389). Alexakhin talks about pine mortality and forest succession (p. 423). Hinton et. al. talks about albino barn swallows (p. 433) Could touch on the "after we're gone" business about how the wildlife has rebounded in the exclusion zone since people are no longer hunting and competing for resources, but ecosystem effects seem peripheral to our story.

e. **Decontaminating Urban infrastructure** – We state up front (and we believe) that an urban area will be target of RDD, so we need to devote some time to this discussion. *An intentional detonation of a nuclear device is likely to take place in an urban area, and is thus quite different from the rural environment surrounding the Chernobyl plant. One of the most significant affects of the Chernobyl accident was contamination of locally grown food, which is unlikely to be a significant concern in a modern American city. Nevertheless, the Chernobyl disaster contaminated several urban areas (including Kiev), and lessons from the urban decontamination effort following Chernobyl are relevant for a dirty bomb scenario in the U.S.*

Large scale decontamination of urban areas was carried out during the first years after the disaster, and was usually carried out by military personnel. In the early period after the incident, inhalation of dust particles was of particular concern, and the CEZ and power plant areas were sprayed with organic solutions to create a thin film that would immobilize dust in the most contaminated areas. In addition, city streets were washed frequently and sprayed with water, which had the effect of suppressing dust and concentrating radionuclides in sewer system. Streets in Kiev were washed daily following the accident

In surrounding areas, activities included washing buildings and roads with special solutions, removing contaminated soils (especially along drip lines next to buildings), and decontamination of reservoirs. The activities focused on schools, hospitals and other buildings with high numbers of people. About 1000 settlements were treated and tens of thousands of public buildings and residences

From this extensive urban decontamination experience, we can discuss the most effective techniques to reduce contamination. A significant fraction of dose was concentrated in soil, on coated surfaces such as asphalt and concrete, and to a lesser extent on roofs and walls. Street cleaning, removal of trees and shrubs, and plowing soils in yards are efficient and inexpensive means of achieving significant reductions of dose (according to IAEA). Roofs and walls also contribute to dose, but are costly and difficult to clean.

Based on accumulated experience, IAEA recommends:

- *Removal of the upper 5–10 cm layer in front of residential buildings, around public buildings, schools and kindergartens, and from roadsides inside a settlement. The removed, most contaminated, layer of soil should be placed into holes specially dug on the territory of a private homestead or on the territory of a settlement. The clean soil from the holes should be used to cover the decontaminated areas. Such a technology excludes the formation of special burial sites for radioactive waste.*
- *Private gardens should be treated by deep plowing or removal of the upper 5-10 cm layer of soil. By now, vegetable gardens have been ploughed many times, and the activity distribution in soil will be uniform in a layer 20–30 cm deep.*
- *Covering the decontaminated parts of courtyards, etc., with a layer of clean sand, or, where possible, with a layer of gravel to attenuate residual radiation.*
- *Cleaning or replacement of roofs.*

Questions: Similar to above – We can discuss washing down buildings, porous materials like brick, and so forth. Larissa has recollections about this in Kiev.

Epilogue: U.S. response to a similar incident (5 min) – A reassuring message that EPA/NDT has been considering responding to such incidents and has plans in place to avoid major pitfalls experienced at Chernobyl. We have technologies here that they didn't have, and have preparation that they did not (ex: stockpiles of KI, cesium binders; organizational structure to transmit info). *[John is knowledgeable about this material, and I assume has great ideas about what this message needs to be.]*

Chernobyl Straw-Man Outline

The Chernobyl Incident – Experiences, Recovery, and Lessons Learned

Introduction (3 min) – State the purpose of the documentary: In an age of growing incidence and awareness of terrorism aimed at mass casualties and disruption, the U.S. faces a risk of experiencing a "dirty bomb" or even an improvised nuclear device. EPA has been preparing for such an eventuality, and is ready to respond, if necessary.

A dirty bomb or improvised nuclear device would be likely to detonate with little or no warning and contaminate a large, densely inhabited area. To address the key issues that would confront the U.S. and in such an event, this discussion will examine an event that forced the USSR to confront some of the same issues: response and recovery from the Chernobyl nuclear incident. The Chernobyl incident was the uncontrolled meltdown of one of the core reactors of the Chernobyl nuclear power plant in 1986 near what is now Kiev, Ukraine. In this documentary, we'll examine how recovery from that that incident was managed, focusing on effective countermeasures in the aftermath of the disaster and eventual restoration and recovery of the area. We will enhance our discussion of the response and recovery from that incident with direct, first-hand, personal perspectives of an early responder who provided technical assistance in the early phase of recovery, and of a resident of Kiev, who was a young mother in Ukraine at the time of the disaster. [More detailed resumes when they first appear on screen]

This is a good place to introduce the types of incidents we might face and draw a distinction between the similarities and differences between a nuclear power plant meltdown and an RDD or improvised nuclear device.

Draw on the differences between RDD, IND, and a nuclear power plant (NPP) disaster. The common theme to draw from these events is a potential for a radiological contamination of a wide-area. We will use the Chernobyl experience to discuss the issues involved with recovery from wide-scale radiological event.

Radioactive dispersal device (RDD):

- An RDD is a conventional bomb that contains radioactive materials and scatters those materials and other debris over a small area when it detonates. This type of weapon may use medical or industrial nuclear materials, but the materials do not undergo a nuclear reaction. *Iodine 131 is not likely to be a constituent of this device, so potassium iodine tablets would not be necessary because Iodine-131 is created by a nuclear reaction.* ***<Define nuclear reaction in layman's terms [make consistent with C:\Documents and Settings\jcardare\My Documents\Reference Materials\REMM\rdd.htm]***

- An RDD would likely involve contamination over a densely populated area, initial confusion/lack of information, and an improvised response (by that I mean flying blind), but would differ from Chernobyl in that the contaminated area would be significantly smaller and the amount and intensity of radioactivity released would likely be orders of magnitude lower.

- *CDC FAQ: Although a dirty bomb could cause serious injuries from the explosion, it most likely would not have enough radioactive material in a form that would cause serious radiation sickness among large numbers of people.*

Improvised Nuclear Device (IND): An IND is a small nuclear bomb where materials undergo a nuclear reaction. An IND would be catastrophic. The contaminated area would be big but amount of contaminated land would still be smaller than Chernobyl and there would likely be mass casualties. ***[Include language about fission products, specifically I-131 which will require KI distribution to the public.] Make sure this is consistent with the REMM site.***

Nuclear Power Plant disaster – Chernobyl, three mile island.
We may want to provide a brief description on the difference between Chernobyl and TMI. John will draft this language. Why is Chernobyl not likely to happen in America?

Outline of what's to come (1 min) – road map of where we're going: Definition of terms, description of incident, immediate response, long-term response, and discussion of U.S. preparedness for such an event.

The Incident (5 min) – Discussion of what transpired. Explanation of why they had a meltdown in the first place, how the disaster unfolded, and what happened as a result. The focus of this section is what happened up to the evacuation of Pripyat. There will be good footage here that should give the viewer an idea of the magnitude of the disaster and it'll set the stage for the recovery. Also discuss fallout, what it is, heavy (hot) particles close, lighter particles far, control of wind, precipitation. ***[Note that the reactor burned for ten days, spewing radiation across 100,000s acres covering most of western Europe.]***

The Immediate Response (15 min) – Here we can talk about the liquidators (and touch on the construction of the sarcophagus and the new safe confinement, in passing). We'll certainly be able to identify some good footage/photos of this part, ***<IAEA photo library may be useful*** then we can get into the more meaty and meaningful information in the Health Physics articles. We can also discuss the fallout pattern and how it was highly variable based on precipitation (Balinov, p. 385), and what fell out where (short-lived and long-lived isotopes (nuclear reactions) ***<define these terms.*** We could introduce the concept of distance, time, and shielding here - Dose rates decreased by three orders of magnitude in the 3 km from the plant to Pripyat (Hinton et. al. p.430).

Balanov mentions evacuation, distribution of stable iodine KI tablets to Pripyat (but not the surrounding area), and restriction of the food supply as the most effective immediate measures. For the immediate affected area, outline the basic measures – establishment of 30 km exclusion zone, evacuation, nuclear waste repositories. For the larger (and more populous) area, outline other measures - bathing, clothing, hygiene … We can discuss these systematically, and we can follow each with CDC/REMM/DHS recommendations. I like that approach because we can tie together history, first-hand anecdotes, and current recommendations:

Clothing and hygiene: *Exposure to radiological contaminants through fallout is an important mechanism of exposure in the early phase of a radiological incident. Contamination refers to particles of radioactive material that are deposited anywhere that they are not supposed to be, such as on an object or on a person's skin. Internal contamination refers to radioactive material that is taken into the body through breathing, eating, or drinking. One effective way to reduce exposure is to remove clothing where particles may lodge and to shower to remove particles from skin and hair.* ***We should consider including the miniature videos of these concepts from the REMM site. We should consider dedicating a minute to describe the REMM website.***

CDC recommendations for dirty bomb: ***I prefer to reference the viewer to the REMM website for these details and spend more time presenting the environmental consequence and recovery aspects of the event.***

- *To keep radioactive dust or powder from getting inside, shut all windows, outside doors, and fireplace dampers. Turn off fans and heating and air-conditioning systems that bring in air from the outside. It is not necessary to put duct tape or plastic around doors or windows.*
- *If you must go outside, be sure to cover your nose and mouth with a cloth to reduce the risk of breathing in radioactive dust or smoke.*
- *Take off your outer layer of clothing and seal it in a plastic bag if available. Put the cloth you used to cover your mouth in the bag, too. Removing outer clothes may get rid of up to 90% of radioactive dust.*
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- *Shower or wash with soap and water. Be sure to wash your hair. Washing will remove any remaining dust.*

a. Clothing – Larissa's story about the lead-lined boxes in Kiev.

b. Hygiene – Vira and Larisa recollections about official recommendations and what people actually did ***We may be able to use information from the Chernobyl documentary I viewed this weekend from the Google site.***

Food: *Internal exposure to radiological contaminants through consumption of food and water is a very significant exposure mechanism, more so for a nuclear power plant disaster of nuclear explosion than for a dirty bomb. One of the most significant effects of the Chernobyl accident was an increase in thyroid cancer in children through ingestion of milk contaminated with* ^{131}I. *20,000 agricultural and domestic animals slaughtered immediately, the remainder evacuated. Due to lack of forage and animal care infrastructure, and additional 120,000 animals were slaughtered from May to June 1986.* ***Discuss the EPA Protection Action Guidelines for food and water and soil. Also compare and contrast the guidance provided by the ICRP following the Chernobyl incident.***

Subtle message is that there is not one right answer. That international standards may vary from US and that state and local standards may vary even more.

Need to discuss the DHS Optimization process as well as the recent ICRP optimization document – compare and contrast – even think about the CERCLA process.

CDC recommendations – immediate: ***Stay away from providing recommendation. Simply refer to the site for guidance.***

- *Food and water supplies most likely will remain safe. However, any unpackaged food or water that was out in the open and close to the incident may have radioactive dust on it. Therefore, do not consume water or food that was out in the open.*
- *Food inside cans and other sealed containers will be safe to eat. Wash the outside of the container before opening it.*

c. Food –Most effective countermeasures were restriction of geographically based pasture grasses from animal diets, rejection of milk based on radiological monitoring. Short-term effectiveness was hindered by lack of timely information and an economic issue for private farmers. Larissa has stories about how even uneducated people were smart enough to eat pre-event canned goods rather than fresh food bought in stores.

Dietary additives:

Potassium Iodide (KI): *As noted above, thyroid cancer was one of the primary issues in the immediate aftermath of the Chernobyl incident. Mikhail Balinov of the IAEA lists provision of KI to residents of Pripyat as one of the key successes of the initial response to the disaster. KI was not provided to surrounding areas.* ***KI is most likely to be needed following a NPP or IND incident because it is created in nuclear reaction.***
An RDD does not contain nuclear reactions. This is not an issue for long-term recovery since its half-life is only 8 days.
Virtually all is gone with 80 days. Long-term recovery is concerned mostly about the longer lived radionuclides like cesium-137 or strontium-90.

CDC recommendations:
In the case of internal contamination with radioactive iodine, the thyroid gland quickly absorbs this chemical which can then injure the gland. Iodine in non-radioactive KI blocks radioactive iodine from being absorbed by the thyroid gland.

Iodized table salt also contains iodine, but table salt does not contain enough iodine to block radioactive iodine from getting into your thyroid gland. You should not use table salt as a substitute for KI.

Where can I get KI? KI is available without a prescription. You should talk to your pharmacist to get KI and for directions about how to take it correctly. Your pharmacist can sell you KI brands that have been approved by the FDA.

Prussian blue *Prussian blue traps radioactive cesium and thallium in the intestines and keeps them from being re-absorbed by the body. CDC has included Prussian blue in the Strategic National Stockpile, a special collection of drugs and medical supplies that CDC keeps to treat people in an emergency. [Note – I can't get to that site to find out what-all they have there. Would be a good idea to mention some details of this as a way to demonstrate some preparation for such incidents]* ***Why PB for long-term recovery? This was used on animals and people to increase excretion of the Cs in the bodies. Hence, meat concentration were low, human doses were lower, etc. so PB has a potential for long-term recovery. See CDC website for proper application following a cesium event.***

d. Dietary additives – Larisa and Vira may well have recollections about what sort of things people did in addition to avoiding certain foods. There was a tale about using vodka to flush radioisotopes from the body. *I don't know if it would work, but it would certainly make you feel better!*

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What is EPA's role here? National Response Framework language.

1. ***Environment***
    a. ***Urban areas***
    b. ***Agriculture (FDA)***
    c.

a. Food supply – Greatest long-term problem is radiological contamination of milk and meat (Balinov p.388) *[Note that rural food supply in Soviet Union made local sourcing more prevalent than in U.S. today. Our centralized food system would make isolating affected foodstuff a lot easier.]* "Effects of the disaster were profound and long-lasting. As recently as 2001, 9% of the milk supply in the affected areas did not meet the standards for ^{137}Cs (Alexakhin et. al. p. *422)"* ***We should have a small presentation on the isotopes of concern:Cs – binds quickly with concrete, Sr –, Po-***

Here are techniques used in the long-term (post-1987)

- *Withdrawal of areas from agricultural use based on radiological surveys,*
- *Soil treatment to reduce Cs and Sr uptake,*
- *Cesium binder dietary supplements to animal feed*

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Questions: Ask if Larisa and Vira have recollections about restrictions on food supplies, stories about economic hardship for local farmers and their response, etc.

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Questions: I'm sure that Larissa and Vira have many stories to tell about this proud Russian tradition.

c. **Aquatic systems** – divided into drinking water and contaminated aquatic foods.

Drinking water - Weeks after accident, Kiev drinking water supply switched from Dnieper River to Desna River via a pipeline; Water treatment is designed to remove particulates, but Kiev added activated charcoal and zeolites to treatment system as polishing step. Initial release of water from Kiev reservoir to allow room to contain contaminated runoff; standard soil erosion countermeasures were implemented, but not completely effective because Cs and Sr were in dissolved phase. Countermeasures to prevent transfer of radionuclides from soil to water generally expensive and ineffective. Most effective: Early restriction of drinking water and alternate water supplies (groundwater?). (Balinov) Other countermeasures – Dikes & channel barriers to reduce sediment mobility, addition of sorbents to water (Alexahkin et. al p. 423).

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Questions: Similar to above – recollections of concerns about drinking water and aquatic foods, any thoughts on effectiveness of restrictions?

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From this extensive urban decontamination experience, we can discuss the most effective techniques to reduce contamination. A significant fraction of dose was concentrated in soil, on coated surfaces such as asphalt and concrete, and to a lesser extent on roofs and walls. Street cleaning, removal of trees and shrubs, and plowing soils in yards are efficient and inexpensive means of achieving significant reductions of dose (according to IAEA). Roofs and walls also contribute to dose, but are costly and difficult to clean.

Based on accumulated experience, IAEA recommends:

- *Removal of the upper 5–10 cm layer in front of residential buildings, around public buildings, schools and kindergartens, and from roadsides inside a settlement. The removed, most contaminated, layer of soil should be placed into holes specially dug on the territory of a private homestead or on the territory of a settlement. The clean soil from the holes should be used to cover the decontaminated areas. Such a technology excludes the formation of special burial sites for radioactive waste.*

- *Private gardens should be treated by deep plowing or removal of the upper 5-10 cm layer of soil. By now, vegetable gardens have been ploughed many times, and the activity distribution in soil will be uniform in a layer 20–30 cm deep.*

- *Covering the decontaminated parts of courtyards, etc., with a layer of clean sand, or, where possible, with a layer of gravel to attenuate residual radiation.*

- *Cleaning or replacement of roofs.*

Questions: Similar to above – We can discuss washing down buildings, porous materials like brick, and so forth. Larissa has recollections about this in Kiev.

Epilogue: U.S. response to a similar incident (5 min) – A reassuring message that EPA/NDT has been considering responding to such incidents and has plans in place to avoid major pitfalls experienced at Chernobyl. We have technologies here that they didn't have, and have preparation that they did not (ex: stockpiles of KI, cesium binders; organizational structure to transmit info). *[John is knowledgeable about this material, and I assume has great ideas about what this message needs to be.]*

The most relevant ICRP guidance [4.10] recommended some generic two level criteria for intervention in the early accident phase — for sheltering, 5–50 mSv of whole body dose or 0–500 mSv to particular organs; for administration of stable iodine aimed at thyroid protection against intake of radioiodines, 50–500 mSv to the thyroid; for evacuation, 50–500 mSv of whole body dose or 500–5000 mSv to particular organs. For the intermediate accident phase, the generic criteria of 5– 50 mSv of whole body dose or 50–500 mSv to particular organs were recommended for control of foodstuff contamination with radionuclides, and 50–500 mSv of whole body dose for relocation.

Recommendations	EPA PAGs	ICRP (reference 4.10)
Sheltering		50 mSv WB
		500 mSv Org
Iodine Protection		500 mSv Thy
Evacuation		500 mSv WB
Intermediate Phase		
Control Food		10 mSv/a
Relocation		1000 mSv

The annual limits of exposure were substantially (by a factor of 2.5–5) reduced and established equal to 20 mSv for workers and 1 mSv for members of the general public [4.13]. The latter value is currently perceived as a safe level of human exposure.

The ICRP discarded the previous two level intervention criteria and recommended instead some intervention levels (in terms of averted effective dose) — 50 mSv for sheltering, 500 mSv (thyroid dose) for administration of stable iodine, 500 mSv for evacuation, 1000 mSv (lifetime dose) for relocation and 10 mSv/a for the control of foodstuffs.

it proposes the value of the 'existing annual dose', including external and internal doses from natural and human-made radionuclides, of 10 mSv as the generic dose below which intervention is not usually expedient. This does not exclude intervention at lower doses if site specific optimization analysis proves it to be expedient. Inter alia, the ICRP recommended a generic intervention exemption level for radionuclides in commodities dominating human exposure equal to 1 mSv/a.

Interview footage

Major topic	subtopic	location			duration
Definitions					
Need to add	Definitions - RDD, IDD, IND, isotope, 1/2 life, fallout, hot particles, etc.				
Intro					
Complete				**Total >**	**0:03:37**
	Intro - Who is Larissa	LL8	3:51:54	3:52:21	0:00:27
	Intro - Who is Vira	VY4	2:33:03	2:34:00	0:00:57
	Intro - Who is John	JC1	5:00:07	5:00:17	0:00:10
	Intro - Who is Jim	JM6	3:08:22	3:08:50	0:00:28
	Intent of documentary	JC1	5:00:24	5:00:41	0:00:17
	Why Chernobyl	JC1	5:00:50	5:01:24	0:00:34
	focus on long-term response	JC1	5:01:30	5:02:14	0:00:44
Technical issues					
	nuclear reaction - difficulties of obtaining fissile material - good discussion				
	RDD definition, types of radioisotopes, impact	JM7	3:40:17	3:41:13	0:00:56
	nuclear reaction - short-lived 1/2 lives - touched on in Chernobyl/Hisorshima discussion				
	300 decay products Hiroshima	JM7	3:35:56	3:36:31	0:00:35
	Hiroshima vs Chernobyl	JM7	3:36:32	3:37:06	0:00:34
	Johns disc. of chernobyl/hiroshima differences	JM7	3:37:24	3:38:35	0:01:11
	Jim- restatement of Chern/hiroshima	JM7	3:39:00	3:39:47	0:00:47
Incident					
	Set the stage				
	springtime in Kiev	VY1	1:15:52	1:16:48	0:00:56
narrator - need text	What happened				
narrator - need text	Why it happened				
narrator - need text	When it happened				
	Initial reactions			**Total >**	**0:04:35**
	First heard of accident	VY1	1:17:49	1:18:29	0:00:40
	Info from Sweden, initial react	VY1	1:25:20	1:26:10	0:00:50
	More dangerous than let on	VY1	1:33:34	1:33:53	0:00:19
	First heard of event	LL8	3:51:22	3:53:32	0:02:10
	magnitude of event, no official media info	LL8	3:54:14	3:54:37	0:00:23
	we have to get you out	VY2	1:50:49	1:51:02	0:00:13
Immediate Response					
	liquidators			**Total >**	**0:03:28**
	First responders - army	LL8	3:59:28	3:59:49	0:00:21
	First responder training	LL8	3:59:56	4:00:39	0:00:43
	responders not monitored, no remed in Kiev	LL8	4:08:36	4:09:29	0:00:53
	responder team - LL, doctor, soldier	LL8	4:09:49	4:10:18	0:00:29
	responder dosage, sent home after 12 days	LL8	4:18:14	4:19:16	0:01:02
	Old/new sarcophagus				
	limited funds for sarcophagus	VY4	3:02:57	3:03:27	0:00:30

narrator - need text	*Fallout pattern*				
narrator - need text	*Evacuation of Pripyat*				
	Distribution of KI				
	Prussian blue, KI, red wine	LL8	4:27:48	4:28:08	0:00:20
	Clothing				
	no info aside from bedspread				
	Hygiene			**Total >**	**0:02:23**
	Official precautions - hygiene	VY1	1:33:58	1:34:53	0:00:55
	windowsill was hot	VY3	2:11:35	2:11:47	0:00:12
	Bedspread	VY3	2:11:54	2:12:14	0:00:20
	Guidance on cleanliness, threw out bedsprd	VY3	2:12:46	2:13:13	0:00:27
	Wash shoes before entering	LL8	4:05:58	4:06:27	0:00:29
	stopping all cars, too dirty	VY2	1:57:29	1:58:02	0:00:33
	Food			**Total >**	**0:07:45**
	Family tried to keep things clean, food	VY3	2:14:24	2:14:58	0:00:34
	Apply logic to diet, don't eat local	VY3	2:22:13	2:22:51	0:00:38
	Food scarce, less worry	VY4	2:37:50	2:38:12	0:00:22
	strawberries and drip lines	LL8	4:05:22	4:05:51	0:00:29
	Food scarce, less worry	VY4	2:37:50	2:38:12	0:00:22
	Concerns about milk	VY4	2:48:05	2:48:48	0:00:43
	Wood for picnic barbecues	VY4	2:55:38	2:56:33	0:00:55
	Drinking water	VY4	3:01:29	3:02:04	0:00:35
	Poor people have to grow their food	VY4	3:04:53	3:05:19	0:00:26
	locals eating canned food	LL8	4:14:29	4:15:31	0:01:02
	turning in metal pots and pans	LL8	4:13:47	4:14:29	0:00:42
	Dietary additives				
	Red Wine	LL8	4:19:44	4:20:21	0:00:37
	Prussian blue, KI, red wine	LL8	4:27:48	4:28:08	0:00:20
	Children/ pregnancy				
	Pregnancy	VY1	1:14:58	1:15:25	0:00:27
	Keep baby healthy	VY1	1:29:14	1:29:27	0:00:13
	Health effects of rad on child	VY1	1:32:46	1:33:26	0:00:40
	advice to mothers	VY4	2:42:38	2:43:58	0:01:20
	Windowsill decon, babies	VY4	2:51:18	2:52:30	0:01:12
	Other				
	no cars going towards Kiev	LL8	4:03:33	4:04:21	0:00:48
Long-term Response					
	Hygiene				
	street cleaning	VY4	2:45:04	2:45:49	0:00:45
	6-mo gov't recommendations	VY3	2:25:56	2:26:36	0:00:40

	Food				
	8-month concerns - food, imported apples	VY3	2:27:18	2:28:35	0:01:17
	Gardens, rainbow of responses	VY4	2:45:50	2:48:04	0:02:14
	Forests				
	Red Forests	VY4	2:59:12	2:59:46	0:00:34
	Aquatic systems				
	Nothing				
	Decon of urban infrastructure				
	Home soil remediation	LL8	4:26:33	4:27:00	0:00:27

Other topics on tape but not in outline

Emotional effects/different coping strategies
Ambiance
--> good stuff about plague city, surreal empty streets, everything is fine in Kiev, baby playing in clean dirt…
Government Information sources
--> abundant info on lack of trust in official communcation, JC's web sources of info
Health Effects, real or percieved
--> Both VY and LL noted respiratory issues, good observations on human nature
Variation in U.S. and USSR response
--> U.S. is more ready 6 yrs after 9/11
--> VY and LL perspective on veracity of USSR gov't vs U.S. gov't
Acceptance of cleanup above background
U.S. response to a similar incident
--> JM's administrative info
Advice
--> JM's advice to OSCs
--> LL's and Vira's advice to others in similar situation

Protecting babies	Pregnancy	VY1	1:14:58	1:15:25	0:00:27
ambiance	springtime in Kiev	VY1	1:15:52	1:16:48	0:00:56
initial reactions	First heard of accident	VY1	1:17:49	1:18:29	0:00:40
initial reactions	Info from Sweden, initial react	VY1	1:25:20	1:26:10	0:00:50
Protecting babies	Keep baby healthy	VY1	1:29:14	1:29:27	0:00:13
Protecting babies	Health effects of rad on child	VY1	1:32:46	1:33:26	0:00:40
initial reactions	More dangerous than let on	VY1	1:33:34	1:33:53	0:00:19
Official precautions	Official precautions - hygiene	VY1	1:33:58	1:34:53	0:00:55
ambiance	Leave granted - official sympathy	VY1	1:36:09	1:36:44	0:00:35
Emotional effects	aviod panic	VY1	1:37:02	1:37:37	0:00:35
ambiance	Sureeal - empty streets	VY1	1:41:13	1:41:54	0:00:41
initial reactions	we have to get you out	VY2	1:50:49	1:51:02	0:00:13
Official information	if govt admits its dangerous …	VY2	1:52:19	1:52:25	0:00:06
Official precautions	stopping all cars, too dirty	VY2	1:57:29	1:58:02	0:00:33
Official information	Everything is fine in Kiev	VY2	1:58:16	1:58:48	0:00:32
ambiance	plague city	VY2	2:00:21	2:00:55	0:00:34
Health effects	People in clinic have thyroid issues	VY2	2:01:10	2:01:56	0:00:46
Health effects	Have to accept "you're OK"	VY2	2:01:58	2:02:31	0:00:33
Official information	questioning authority vs expecting answers	VY2	2:05:26	2:05:48	0:00:22

Official information	Gov't gives you all the info you need	VY3	2:09:48	2:10:13	0:00:25
remediation	windowsill was hot	VY3	2:11:35	2:11:47	0:00:12
remediation	Bedspread	VY3	2:11:54	2:12:14	0:00:20
Official precautions	Guidance on cleanliness, threw out bedsprd	VY3	2:12:46	2:13:13	0:00:27
food/water	Family tried to keep things clean, food	VY3	2:14:24	2:14:58	0:00:34
Official information	don't trust those guys, stay away	VY3	2:16:06	2:16:25	0:00:19
food/water	Apply logic to diet, don't eat local	VY3	2:22:13	2:22:51	0:00:38
Official precautions	6-mo gov't recommendations	VY3	2:25:56	2:26:36	0:00:40
food/water	8-month concerns - food, imported apples	VY3	2:27:18	2:28:35	0:01:17
Emotional effects	do your best or else you will go mad	VY3	2:28:36	2:28:51	0:00:15
Health effects	Tendancy to blame poor health on Chernobyl	VY3	2:28:53	2:29:10	0:00:17
Emotional effects	Many people feel depressed, doomed	VY3	2:29:26	2:29:34	0:00:08
Emotional effects	survivor/bystander	VY3	2:31:56	2:32:41	0:00:45
character/advice	Intro - Who is Vira	VY4	2:33:03	2:34:00	0:00:57
Emotional effects	lived through acceptance and denial, food	VY4	2:36:58	2:37:47	0:00:49
food/water	Food scarce, less worry	VY4	2:37:50	2:38:12	0:00:22
ambiance	dirty means radioactive to us	VY4	2:38:15	2:38:39	0:00:24
Emotional effects	I get cranky, terrible unseen danger	VY4	2:39:00	2:39:45	0:00:45
Official information	more willing to trust authorities in U.S.	VY4	2:41:28	2:42:22	0:00:54
Protecting babies	advice to mothers	VY4	2:42:38	2:43:58	0:01:20
remediation	street cleaning	VY4	2:45:04	2:45:49	0:00:45
Range of responses	Gardens, rainbow of responses	VY4	2:45:50	2:48:04	0:02:14
food/water	Concerns about milk	VY4	2:48:05	2:48:48	0:00:43
Health effects	people get sick all the time	VY4	2:48:51	2:49:34	0:00:43
Health effects	continual health problems	VY4	2:49:37	2:50:18	0:00:41
Protecting babies	Windowsill decon, babies	VY4	2:51:18	2:52:30	0:01:12
food/water	Wood for picnic barbecues	VY4	2:55:38	2:56:33	0:00:55
cleanup > Bckgd	Impossible decon, gov't did what they could	VY4	2:57:00	2:57:50	0:00:50
ambiance	Red Forests	VY4	2:59:12	2:59:46	0:00:34
food/water	Drinking water	VY4	3:01:29	3:02:04	0:00:35
economics	limited funds for sarcophagus	VY4	3:02:57	3:03:27	0:00:30
food/water	Poor people have to grow their food	VY4	3:04:53	3:05:19	0:00:26
character/advice	glad if info can help others	VY4	3:06:57	3:07:06	0:00:09
character/advice	Intro	LL8	3:51:54	3:52:21	0:00:27
initial reactions	First heard of event	LL8	3:51:22	3:53:32	0:02:10
initial reactions	magnitude of event, no official media info	LL8	3:54:14	3:54:37	0:00:23
Official information	info sources - librarian	LL8	3:57:36	3:58:20	0:00:44
ambiance	University friends wanted to help	LL8	3:57:19	3:57:30	0:00:11
Official information	First responders - army	LL8	3:59:28	3:59:49	0:00:21
Official information	First responder training	LL8	3:59:56	4:00:39	0:00:43
ambiance	no cars going towards Kiev	LL8	4:03:33	4:04:21	0:00:48
Official precautions	strawberries and drip lines	LL8	4:05:22	4:05:51	0:00:29
Official precautions	Wash shoes before entering	LL8	4:05:58	4:06:27	0:00:29
ambiance	responders not monitored, no remed in Kiev	LL8	4:08:36	4:09:29	0:00:53
Official information	responder team - LL, doctor, soldier	LL8	4:09:49	4:10:18	0:00:29
Official precautions	turning in metal pots and pans	LL8	4:13:47	4:14:29	0:00:42
food/water	locals eating canned food	LL8	4:14:29	4:15:31	0:01:02
Official information	Responders told locals about rad particles	LL8	4:16:21	4:16:36	0:00:15
Range of responses	uncooperative owners threaten to sick dogs	LL8	4:17:30	4:17:55	0:00:25

Health effects	responder dosage, sent home after 12 days	LL8	4:18:14	4:19:16	0:01:02
Official information	Russian army says what they are told to say	LL8	4:19:23	4:19:28	0:00:05
Official precautions	Red Wine	LL8	4:19:44	4:20:21	0:00:37
Health effects	Aftereffects - bronchitis	LL8	4:21:04	4:21:23	0:00:19
Official precautions	Home soil remediation	LL8	4:26:33	4:27:00	0:00:27
food/water	Prussian blue, KI, red wine	LL8	4:27:48	4:28:08	0:00:20
Emotional effects	Anger over no info to protect self, betrayal	LL8	4:29:29	4:29:50	0:00:21
cleanup > Bckgd	never get to zero	LL8	4:30:49	4:31:23	0:00:34
character/advice	I believe in my mission	LL8	4:34:22	4:34:36	0:00:14
economics	Russian culture, no gov't assistance	LL8	4:35:57	4:36:38	0:00:41
character/advice	Made choice to return - no other option	LL8	4:40:10	4:40:25	0:00:15
U.S. Preparation	Difference in U.S. response 1	LL8	4:40:26	4:40:40	0:00:14
U.S. Preparation	Difference in U.S. response 2	LL10	4:48:11	4:48:33	0:00:22
character/advice	trust govt but trust yourself	LL10	4:48:49	4:49:57	0:01:08
character/advice	don't be concerned about your posessions	LL10	4:50:11	4:50:29	0:00:18
character/advice	Gov't has to trust people	LL10	4:50:50	4:51:04	0:00:14
character/advice	Don't be an ostrich	LL10	4:52:54	4:53:27	0:00:33
character/advice	Death on the end of the couch	LL10	4:53:38	4:54:13	0:00:35
character/advice	Intro - John	JC1	5:00:07	5:00:17	0:00:10
	Intent of documentary	JC1	5:00:24	5:00:41	0:00:17
	Why Chernobyl	JC1	5:00:50	5:01:24	0:00:34
	focus on long-term response	JC1	5:01:30	5:02:14	0:00:44
U.S. Preparation	role of EPA in long-term recovery	JC1	5:04:38	5:05:17	0:00:39
cleanup > Bckgd	determine cleanup levels	JC1	5:05:25	5:06:14	0:00:49
Official information	can't turn back the clock, tell the truth	JC1	5:06:25	5:07:33	0:01:08
Official information	Good sources of info	JC2	5:08:31	5:09:40	0:01:09
Official information	experts have different opinions, use judgemer	JC2	5:09:52	5:10:36	0:00:44
U.S. Preparation	U.S. better prepared	JC2	5:10:53	5:13:12	0:02:19
U.S. Preparation	exercises	JC2	5:12:07	5:12:26	0:00:19
U.S. Preparation	Topoff 4, long-term recovery	JC2	5:12:43	5:13:25	0:00:42
character/advice	Intro - Jim	JM6	3:08:22	3:08:50	0:00:28
administrative	OSC role in response	JM6	3:10:54	3:11:26	0:00:32
administrative	EPA doesn't respond to NPPs	JM6	3:11:26	3:12:05	0:00:39
administrative	EPA provides mobile rad labs, risk assess	JM6	3:12:33	3:13:04	0:00:31
administrative	OSC rad release actions	JM6	3:14:13	3:14:49	0:00:36
administrative	EPA and DOE under FRMAC	JM6	3:15:21	3:16:02	0:00:41
administrative	dirty bomb under NCP	JM6	3:16:13	3:16:37	0:00:24
administrative	lead agency role in long-term cleanup	JM6	3:17:20	3:17:42	0:00:22
cleanup > Bckgd	Optimization process - different cleanup levels	JM7	3:19:45	3:20:16	0:00:31
cleanup > Bckgd	Optimization process stakeholders	JM7	3:20:41	3:21:33	0:00:52
cleanup > Bckgd	work together for Acceptable Cleanup levels	JM7	3:22:41	3:22:52	0:00:11
administrative	Predefined roles, responsibilities	JM7	3:23:14	3:23:33	0:00:19
U.S. Preparation	Topoff lessons	JM7	3:24:06	3:26:07	0:02:01
U.S. Preparation	Purpose of exercises	JM7	3:26:17	3:26:49	0:00:32
cleanup > Bckgd	factors that affect decontamination	JM7	3:27:44	3:28:09	0:00:25
Technical	Waste disposal - licensed vs RCRA-type	JM7	3:20:28	3:31:22	0:10:54
U.S. Preparation	EPA rad emergency response teams	JM7	3:33:01	3:33:32	0:00:31

U.S. Preparation	NDT support for OSCs	JM7	3:33:33	3:34:00	0:00:27
U.S. Preparation	ATSDR support for public health guidance	JM7	3:34:16	3:35:03	0:00:47
Technical	300 decay products Hiroshima	JM7	3:35:56	3:36:31	0:00:35
Technical	Hiroshima vs Chernobyl	JM7	3:36:32	3:37:06	0:00:34
Technical	Johns disc. of chernobyl/hiroshima differences	JM7	3:37:24	3:38:35	0:01:11
Technical	Jim- restatement of Chern/hiroshima	JM7	3:39:00	3:39:47	0:00:47
Technical	RDD definition, types of radioisotopes, impact	JM7	3:40:17	3:41:13	0:00:56
U.S. Preparation	Are we ready?	JM7	3:42:28	3:43:53	0:01:25
U.S. Preparation	training, devices, advice for local responders	JM7	3:45:58	3:46:44	0:00:46
U.S. Preparation	practical advice for OSCs	JM7	3:46:44	3:48:26	0:01:42
				total>	**1:30:38**

<good intro

<strong, reassuring

<good, technical discussion
<good background, no footage

<two extremes of reaction

<good dietary advice

<good
<nice gesture

<good dietary advice

<very solid, this is a keeper
<self decon, concerns about baby

<good perspective

<risks to cleanup workers

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Chernobyl - Status of images:

Corbis – primary image source and basis of earlier quote. Corbis has changed prices since original quote in11/07, and now wants $180/photo (as opposed to $155 in quote), and now is releasing 2-year rights-managed photos rather than rights managed forever. Cost varies depending on pictures, but is generally around $180 for 2-yrs and $300 for 5-yrs.

Getty Images – A second big source of photos stock – they have some photos of the Chernobyl incident. We are waiting on pricing.

Thoughtequity – capture stills from video, videos are all recent "what's it like now" images of Pripyat and such. Still capture from videos for $130 each, $750 (6 images) minimum.

ElenaFilatova.com – good videos and images, free as long as photos are attributed

BBC archives – no still photos, video mostly marginal newscast and so forth

REMM website – all images are public domain, lots of good general renderings of radioactivity concepts that we can use, dirty bomb exploding and scattering blue glowing stuff we used in the intro is from this source. We have contacted them and confirmed that we can use these images.

IAEA – We can use images from their photobank so long as the images are properly credited. The photobank images are good, but limited in number. We will use what we can.

Summary – public domain images are out there, and we can lean heavily on the free ones but we'll still need to spend some money on images

Date:
Contract No.: EP-W-06-089 DATS
Contractor: Dynamac Corporation
TO X: NAME
TDD:

SUMMARY

CLIN	CLIN DESCRIPTION	TOTAL	
Various	Labor	$	53,508.40
2001	Travel	$	26,031.25
3001	Equipment/Specialized Labor/Subcontracts/Misc. ODCs	$	26,000.00
TOTAL COST ESTIMATE FOR TDD No. ###		**$**	**105,539.65**

PERIOD OF PERFORMANCE IS XXX CALENDAR DAYS FROM THE TDD ISSUE DATE

NOTES:

Expect travel to Chicago and Washington DC to interview

ASSUMPTIONS:

EPA contractor will have to develop/create or purchase props for the interview set

Paper

THIRD ANNUAL WARREN K. SINCLAIR KEYNOTE ADDRESS: RETROSPECTIVE ANALYSIS OF IMPACTS OF THE CHERNOBYL ACCIDENT

Mikhail Balonov*

***Abstract*—The accident at the Chernobyl Nuclear Power Plant in 1986 was the most severe in the history of the nuclear industry, causing a huge release of radionuclides over large areas of Europe. The recently completed Chernobyl Forum concluded that after a number of years, along with reduction of radiation levels and accumulation of humanitarian consequences, severe social and economic depression of the affected regions and associated psychological problems of the general public and the workers had become the most significant problem to be addressed by the authorities. The majority of the >600,000 emergency and recovery operation workers and five million residents of the contaminated areas in Belarus, Russia, and Ukraine received relatively minor radiation doses which are comparable with the natural background levels. An exception is a cohort of several hundred emergency workers who received high radiation doses and of whom 28 persons died in 1986 due to acute radiation sickness. Apart from the dramatic increase in thyroid cancer incidence among those exposed to radioiodine at a young age and some increase of leukemia in the most exposed workers, there is no clearly demonstrated increase in the somatic diseases due to radiation. There was, however, an increase in psychological problems among the affected population, compounded by the social disruption that followed the break-up of the Soviet Union. Despite the unprecedented scale of the Chernobyl accident, its consequences on the health of people are far less severe than those of the atomic bombings of the cities of Hiroshima and Nagasaki. Studying the consequences of the Chernobyl accident has made an invaluable scientific contribution to the development of nuclear safety, radioecology, radiation medicine and protection, and also the social sciences. The Chernobyl accident initiated the global nuclear and radiation safety regime.**
Health Phys. 93(5):383–409; 2007

Key words: National Council on Radiation Protection and Measurements; Chernobyl; dose, population; health effects

INTRODUCTION

THE CHERNOBYL accident was the most severe in the history of the nuclear industry. At 01:23 on the night of 26 April 1986, Unit 4 of the Chernobyl Nuclear Power Plant (CNPP), located 130 km to the north-east of Kiev, the capital of Ukraine,† was destroyed by two powerful explosions in the reactor core. The CNPP was equipped with four large power channel-type reactors with a graphite moderator, a thermal power of 3,200 MW, and an electrical power of 1,000 MW each; another two units of the same type were under construction. The explosions were caused by gross breaches of the operating procedures by staff and technical inadequacies in the safety systems (INSAG 1986, 1993). As a result of the explosions, the reactor closure head was lifted and the core exposed. Air entering caused the hot graphite to ignite, and it burned for 10 d. As a result of the explosions, highly radioactive core fragments were ejected onto the site and the roof of the building.

Over the course of 10 d, radioactive substances in the form of gases, vapors, aerosols, and so-called "hot particles" were ejected from the burning reactor. Wind currents under changing weather conditions spread the radioactive substances over Europe, principally Belarus, Ukraine, and Russia—the CNPP is situated in the vicinity of the common border of those countries. No more than 20% of the radioactive discharge spread beyond Europe (De Cort et al. 1998).

An estimated 350,000 emergency and recovery operation workers, including army, power plant staff, local police and fire services, were initially involved in containing and cleaning up the accident in 1986–1987. Later, the number of registered "liquidators" rose to about 600,000.

About five million people live in areas of Belarus, Russia, and Ukraine that are contaminated with radionuclides due to the Chernobyl accident (~37 kBq m^{-2} or 1 Ci km^{-2} of ^{137}Cs).‡ Amongst them, about 400,000 people

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† Up until 1991, Belarus, Russia, and Ukraine were part of the USSR.

‡ In mapping of the deposition, ^{137}Cs was chosen because it is an easy to measure long-lived radionuclide, and it is of radiological significance.

lived in more contaminated areas—classified at the time by Soviet authorities as areas of strict radiation control (>555 kBq m^{-2} or 15 Ci km^{-2} of ^{137}Cs). Of this population, 116,000 people were evacuated in the spring and summer of 1986 from the area surrounding the CNPP (designated the "Exclusion Zone") to noncontaminated areas. Another 220,000 people were relocated in subsequent years (UNSCEAR 2000).

The response of the authorities to the accident and the public information on the related risks and the application of protective measures were based on national and international radiological standards and on the assessments of the consequences of the accident. The first national prediction of the medical consequences of the Chernobyl accident was made in the autumn of 1986 and subsequently published (Ilyin and Buldakov 1987). The consequences of the Chernobyl accident were also widely discussed at the Kiev conference in 1988 (IAEA 1989), pursuant to the results of the International Atomic Energy Agency's (IAEA) Chernobyl project (IAC 1991), and at the many conferences marking its 10th (IAEA 1996a; Karaoglou et al. 1996) and 15th anniversaries (International Conference 2001). The health consequences were analyzed comprehensively and in depth by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) in its 1988 and 2000 reports (UNSCEAR 1988, 2000).

Though the divergences in the assessment of the radiological consequences of the accident were not substantial on the whole among specialists with significant work experience in the radiation protection field, this socially important issue continues to attract the attention of the public and the press. This is due both to the unprecedented scale of the accident and the radioactive discharges it caused, and to the associations with the serious consequences of the atomic bombings of Hiroshima and Nagasaki in 1945. Moreover, in the most affected country, the USSR, the accident and the related countermeasures had complex psychological, social, and economic consequences for the populace, which coincided in time with, and in many ways contributed to the disintegration of, one of the largest States of the 20th century, the USSR, involving an unavoidable and difficult transitional period.

As substantial contradictions in the interpretation of the Chernobyl accident consequences existed between the scientific community and the general public, and also amongst United Nations organizations involved, the IAEA initiated in early 2003 establishment of the Chernobyl Forum aiming to retrospectively assess the environmental and health consequences of the accident and to advise the governments of Belarus, the Russian Federation, and Ukraine on future actions, such as environmental remediation and special health care as well as research activities (Chernobyl Forum 2003). Comprehensive analysis of the accident consequences was considered timely not only because of its approaching 20th anniversary but also because it was felt that almost 20 y are sufficient to carefully study long-term effects both in the environment and in human health.

The Forum participants were eight United Nations organizations [IAEA, the World Health Organization (WHO), the United Nations Development Programme (UNDP), the Food and Agriculture Organization (FAO), the United Nations Environment Programme, the United Nations Office for the Coordination of Humanitarian Affairs, UNSCEAR, and the World Bank] as well as the competent authorities of the three more affected countries, i.e., Belarus, Russia, and Ukraine. The Forum was created as a contribution to the United Nations' 10 y strategy for Chernobyl, launched in 2002 with the publication of *Human Consequences of the Chernobyl Nuclear Accident—A Strategy for Recovery* (UNDP/UNICEF 2002). The Chernobyl Forum and subsequent conference were chaired by Dr. Burton Bennett, Radiation Effects Research Foundation (RERF), Japan.

To provide a basis for achieving the goal of the Forum, IAEA convened an expert working group chaired by Dr. Lynn Anspaugh, United States, to summarize the environmental effects, and the WHO convened an expert group to summarize the health effects of the accident. The working group on health was co-chaired by Dr. Geoff Howe, United States (thyroid studies); Dr. Elisabeth Cardis, France (solid cancers/leukemia studies); and Dr. Fred Mettler, United States (noncancer outcomes and health-care programs). In total, >80 recognized experts from 12 countries, including Belarus, Russia, and Ukraine, and six relevant international organizations participated in the 11 expert meetings that produced two technical reports on environmental (IAEA 2006a) and health issues (WHO 2006). In addition, UNDP has drawn on the work of eminent economists and policy specialists to assess the socio-economic impact of the Chernobyl accident, based largely on the 2002 UNDP and the United Nations Children's Fund study (UNDP/UNICEF 2002).

Both technical reports and the summary report, *Chernobyl's Legacy: Health, Environmental and Socio-economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine,* were considered in detail and approved by consensus at the last Forum meeting in April 2005 (Chernobyl Forum 2003). The reports were also presented and discussed during the International Conference entitled *Chernobyl: Looking Back* *to Go Forwards,* organized by IAEA on behalf of the Chernobyl Forum, in Vienna in September 2005.

In November 2005, the United Nations General Assembly considered a report of the Secretary-General (UN 2005a) on efforts to promote recovery in areas affected by the Chernobyl legacy that included findings of the Chernobyl Forum. The General Assembly also adopted a resolution (UN 2005b) encouraging the international community to redouble its efforts to mitigate the consequences of the accident in which, *inter alia*:

- noted consensus reached among members of the Chernobyl Forum regarding assessment of the accident consequences and future actions;
- noted the necessity to widely disseminate the Forum's findings and recommendations; and
- requested to organize further studies consistent with the recommendations of the Chernobyl Forum.

This paper presents a review of the findings and recommendations of the Chernobyl Forum for which the author served as scientific secretary since its inception. The scientific secretary for health issues was Dr. Michael Repacholi of WHO, and for socio-economic issues, Ms. Louisa Vinton of UNDP. The paper also includes some of the author's considerations of the radiation protection practices applied after the Chernobyl accident and of assessment of its consequences based on his own involvement, as well as evaluation of the accident's influence on radiological research and development of international nuclear safety and radiation protection policy.

FINDINGS OF THE CHERNOBYL FORUM—ENVIRONMENTAL CONSEQUENCES (CHERNOBYL FORUM 2006; IAEA 2006a)

The report of the Forum's expert group on environment covers the issues of radioactive release and deposition, radionuclide transfers and bioaccumulation, application of countermeasures, radiation-induced effects on plants and animals as well as dismantlement of the Shelter and radioactive waste management in the Chernobyl Exclusion Zone (IAEA 2006a).

Release and deposits of radioactive material

Major releases of radionuclides from Unit 4 of the Chernobyl reactor continued for 10 d following the 26 April explosion. These included radioactive gases, condensed aerosols and a large amount of fuel particles. The total release of radioactive substances was about 14 EBq, including 1.8 EBq of ^{131}I, 0.085 EBq of ^{137}Cs, 0.01 EBq of ^{90}Sr, and 0.003 EBq of plutonium radioisotopes. The noble gases contributed about 50% of the total release.

More than 200,000 square kilometers of Europe received levels of ^{137}Cs above 37 kBq m^{-2} (Fig. 1) (De Cort et al. 1998). Over 70% of this area was in the three most affected countries, Belarus, Russia, and Ukraine. The deposition was extremely varied, as it was enhanced in areas where it was raining when the contaminated air masses passed. Most of the strontium and plutonium radioisotopes were deposited within 100 km of the destroyed reactor due to larger particle sizes.

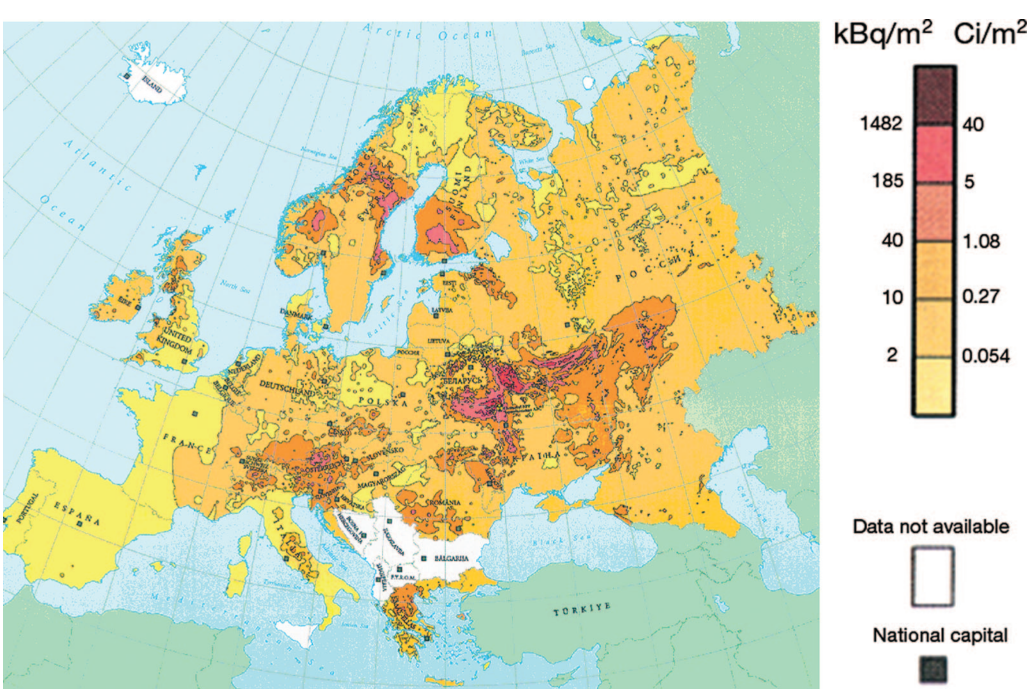

Fig. 1. Deposition of ^{137}Cs throughout Europe as a result of the Chernobyl accident (De Cort et al. 1998).

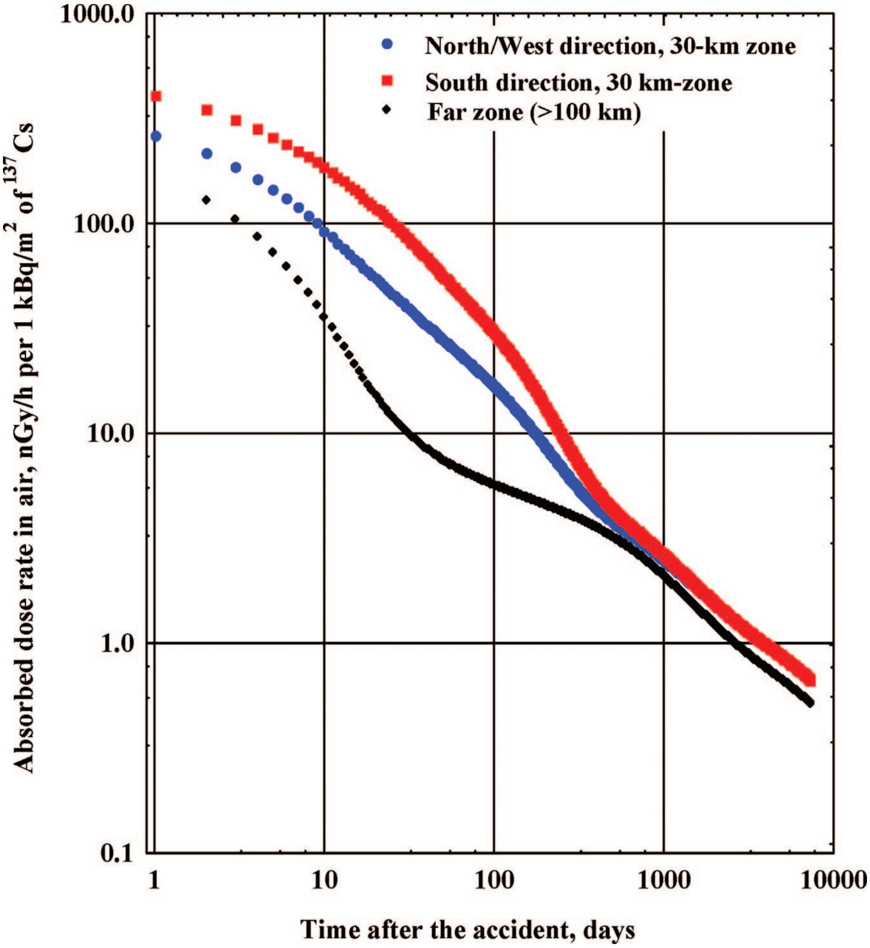

Fig. 2. Dynamics of standardized dose rate in air over undisturbed soil after the Chernobyl accident in different geographical areas (Personal communication to the Chernobyl Forum, Golikov VYu, 2004).

Many of the most significant radionuclides have decayed away. The releases of radioactive iodines caused great concern immediately after the accident. For the decades to come ^{137}Cs will continue to be of greatest importance, with secondary attention to ^{90}Sr. Over the longer term (hundreds to thousands of years) the plutonium radioisotopes and ^{241}Am will remain, although at levels not significant radiologically.

Scope of urban contamination

Radionuclides deposited most heavily on open surfaces in urban areas, such as lawns, parks, streets, roads, town squares, building roofs, and walls. Under dry conditions, trees, bushes, lawns, and roofs initially had the highest levels, whereas under wet conditions horizontal surfaces, such as soil plots and lawns, received the highest levels. Enhanced ^{137}Cs concentrations were found around houses where the rain had transported the radioactive material from the roofs to the ground.

The deposition in urban areas in the nearest city of Pripyat and surrounding settlements could have initially given rise to a substantial external dose. However, this was to a large extent averted by the timely evacuation of residents. Due to radioactive decay, wind, rain, and human activities, including traffic, street washing and cleanup, surface contamination by radioactive materials and air dose rate have been reduced significantly in inhabited and recreational areas during 1986 and afterwards (Fig. 2). One of the consequences of these processes has been secondary contamination of sewage systems and sludge storage.

At present, in most of the settlements subjected to radioactive contamination as a result of Chernobyl, the air dose rate above solid surfaces has returned to the background level predating the accident. But the air dose rate remains elevated above undisturbed soil in gardens and parks in some settlements of Belarus, Russia, and Ukraine.

Radioactive contamination of agricultural products

In the early months after the accident, the radionuclide levels of agricultural plants and plant-consuming animals were dominated by surface deposits. The deposition of ^{131}I caused the most immediate concern, but the problem was confined to the first 2 mo after the accident because of ^{131}I decay with half-life of 8 d. The radioiodine was rapidly absorbed into milk at a high rate leading to significant thyroid doses to people consuming milk, especially children in Belarus, Russia, and Ukraine. In the rest of Europe increased levels of ^{131}I in milk were observed in some southern areas where dairy animals were kept outdoors.

After the early phase of direct deposition, uptake of radionuclides through plant roots from soil became increasingly important. Radioisotopes of cesium (^{137}Cs with half-life of 30 y and ^{134}Cs with half-life of 2.1 y) led to the largest problems. The radiocesium content in foodstuffs was influenced not only by deposition levels but also by types of ecosystem and soil as well as by management practices. In addition, ^{90}Sr could cause problems in areas close to the reactor, but at greater distances its deposition levels were low. Other radionuclides such as plutonium isotopes and ^{241}Am did not cause real problems in agriculture, either because they were present at low deposition levels, or were poorly available for root uptake from soil.

In general, there was a substantial reduction in the transfer of radionuclides to vegetation and animals in intensive agricultural systems in the first few years after deposition, as would be expected due to weathering, physical decay, migration of radionuclides down the soil, reductions in bioavailability in soil and due to countermeasures (Fig. 3). However, in the last decade there has been little further obvious decline, by 3–7% y^{-1}.

Currently, ^{137}Cs activity concentrations in agricultural food products are generally below national and international action levels. However, in some limited areas with high radionuclide deposition (parts of the Gomel and Mogilev regions in Belarus and the Bryansk region in Russia) or poor organic soils (the Zhytomir and Rovno regions in the Ukraine) milk may still be produced with ^{137}Cs activity concentrations that exceed the national action level of 100 Bq kg^{-1}. In these areas countermeasures and environmental remediation may still be warranted.

Radioactive contamination of forest

Following the accident, vegetation and animals in forests and mountain areas have shown particularly high uptake of radiocesium, with the highest recorded ^{137}Cs levels found in forest food products. This is due to the persistent recycling of radiocesium particularly in forest ecosystems.

Particularly high ^{137}Cs activity concentrations have been found in mushrooms, berries, and game and these high levels have persisted for two decades. Thus, while the magnitude of human internal exposure through agricultural products has experienced a general decline, high ^{137}Cs levels of forest food products still exceed permissible levels in some countries. In some areas of Belarus, Russia, and Ukraine, consumption of forest foods with ^{137}Cs dominates internal exposure. This can be expected to continue for several decades.

The high transfer of radiocesium in the pathway lichen-to-reindeer meat-to-humans has been demonstrated again after the Chernobyl accident in the Arctic and sub-Arctic areas of Europe. The Chernobyl accident led to high levels of ^{137}Cs in reindeer meat from Finland, Norway, Russia, and Sweden and caused significant economic difficulties for the indigenous Sami people.

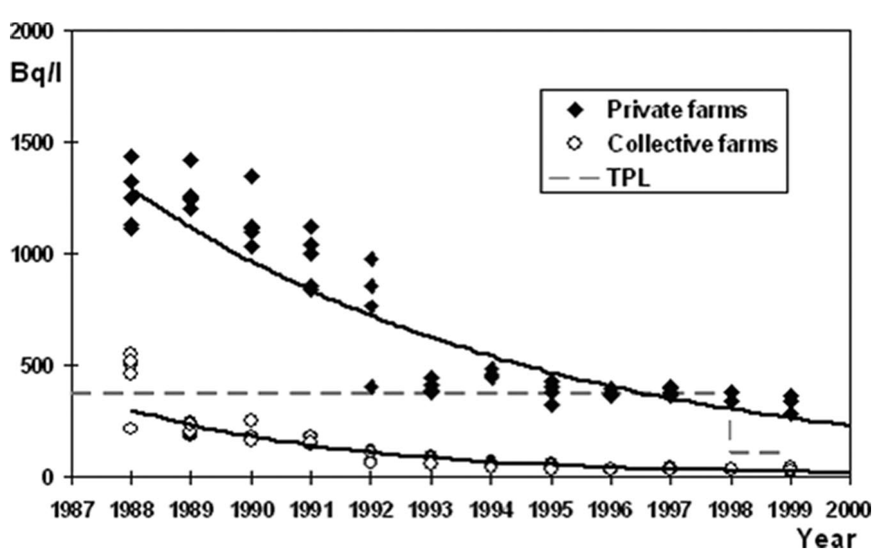

Fig. 3. Reduction with time of ^{137}Cs activity concentration in milk produced in private and collective farms of the Rovno region of Ukraine with a comparison to the temporary permissible levels [Temporary permissible levels for various radionuclides (^{131}I, $^{134+137}$Cs, ^{137}Cs, ^{90}Sr) in food products were established for particular time periods in order to prevent internal exposure of the public above reference levels] (Prister 1998).

Activity in aquatic systems

The initial levels of radionuclides in surface water systems in areas close to the reactor site and in many other parts of Europe were due primarily to direct deposition on the surface of rivers and lakes. In the first few weeks after the accident, high activity concentrations of ^{131}I in drinking water from the Kiev Reservoir were of particular concern.

Levels in water bodies fell rapidly during the weeks after fallout through dilution, physical decay, and absorption of radionuclides to catchment soils. Bed sediments are an important long-term sink for activity.

Bioaccumulation of radiocesium in the aquatic food chain led to significant activity concentrations in fish in the most affected areas, and in some lakes as far away as Scandinavia and Germany. Because of generally lower fallout and lower bioaccumulation, ^{90}Sr levels in fish were not significant for human doses.

Although secondary input by run-off of long-lived ^{137}Cs and ^{90}Sr from soil continues in the long term (at a much lower level), ^{137}Cs levels in fish have reduced by an order of magnitude during a decade since the time of the accident. At the present time, activity concentrations both in surface waters and in fish are low. Therefore, irrigation with surface water is not considered to be a hazard.

While ^{137}Cs and ^{90}Sr levels in water and fish of rivers, open lakes and reservoirs are currently low, in some "closed" lakes with no out-flowing streams in Belarus, Russia, and Ukraine both water and fish will remain contaminated with ^{137}Cs for decades to come. For some people living next to "closed" lakes, consumption of fish has dominated their total ^{137}Cs ingestion.

Owing to the large distance of the Black and Baltic Seas from Chernobyl, and the dilution in these systems, activity concentrations in seawater were much lower than in freshwater. The low water radionuclide levels combined with low bioaccumulation of radiocesium in marine biota has led to ^{137}Cs levels in marine fish that are not of concern.

Environmental countermeasures and remediation

The Soviet authorities introduced a wide range of short- and long-term environmental countermeasures to mitigate the accident's negative consequences. The countermeasures involved huge human, financial, and scientific resources.

Decontamination of settlements in the affected regions of the USSR during the first years after the Chernobyl accident was successful in reducing the external dose when its implementation was preceded by proper remediation assessment. However, the decontamination has produced a disposal problem due to the considerable amount of low-level radioactive waste that was created.

The most effective agricultural countermeasures in the early phase were exclusion of contaminated pasture grasses from animal diets and rejection of milk based on radiation monitoring data. Feeding animals with "clean" fodder was effectively performed in some affected countries. However, these countermeasures were only partially effective in reducing radioiodine intake via milk because of the lack of timely information about the accident and necessary responses, particularly for private farmers.

The greatest long-term problem has been radiocesium contamination of milk and meat. In the USSR and later in the Commonwealth of Independent Study (CIS) countries, this has been addressed by the treatment of land used for fodder crops, clean feeding, and application of cesium binders, such as Prussian blue, to animals that enabled most farming practices to continue in affected areas and resulted in a large dose reduction.

Application of agricultural countermeasures in the affected CIS countries substantially decreased since the middle of 1990's because of economic problems. In a short time, this resulted in an increase of radionuclide content in plant and animal agricultural products.

In Western Europe, because of the high and prolonged uptake of radiocesium in the affected extensive systems, a range of countermeasures are still being used for animal products from uplands and forests.

The following forest-related restrictions widely applied in the USSR and in Scandinavia have reduced human exposure due to residence in radioactively contaminated forests and use of forest products:

- restrictions on public and forest worker access as a countermeasure against external exposure;
- restricted harvesting of food products such as game, berries, and mushrooms by the public, which contributed to reduction of internal doses;
- restricted collection of firewood by the public to prevent exposures in the home and garden when the wood is burned and the ash is disposed of or used as a fertilizer; and
- alteration of hunting practices aiming to avoid consumption of meat with high seasonal levels of radiocesium.

Numerous countermeasures put in place in the months and years after the accident to protect water systems from transfers of radionuclides from contaminated soils were generally ineffective and expensive. The most effective countermeasure was the early restriction of drinking water and changing to alternative supplies. Restrictions on consumption of freshwater fish have also proved effective in Scandinavia and Germany, though in Belarus, Russia, and Ukraine such restrictions may not always have been adhered to for various reasons including economic ones.

Radiation-induced effects on plants and animals

Radionuclides released from the accident caused numerous acute adverse effects on the plants and animals living in the higher exposure areas, i.e., in localized sites at distances up to 30 km from the release point. Outside the Chernobyl Exclusion Zone, no acute radiation-induced effects in plants and animals have been reported.

The response of the natural environment to the accident was a complex interaction between radiation dose, radiosensitivity and recovery of the different plants and animals. Both individual and population effects caused by radiation-induced cell death have been observed in biota inside the Exclusion Zone as follows:

- increased mortality of coniferous plants, soil invertebrates, and mammals; and
- reproductive losses in plants and animals.

Following the natural reduction of exposure levels due to radionuclide decay and migration, biological populations have been recovering from acute radiation effects. As soon as by the next growing season following the accident, population viability of plants and animals had substantially recovered as a result of the combined effects of reparation and repopulation from less affected areas. A few years were needed for recovery from major radiation-induced adverse effects in plants and animals.

Genetic effects of radiation, in both somatic and germ cells, have been observed in plants and animals of the Exclusion Zone during the first few years after the Chernobyl accident. Both in the Exclusion Zone, and beyond, different cytogenetic anomalies attributable to radiation continue to be reported from experimental studies. Whether the observed cytogenetic anomalies in somatic cells have any detrimental biological significance is not known.

The recovery of affected biota in the Exclusion Zone has been facilitated by the removal of human activities, e.g., termination of agricultural and industrial activities. As a result, populations of many plants and animals have expanded, and the present environmental conditions have had a positive impact on the biota in the Exclusion Zone. Indeed, the Exclusion Zone has paradoxically become a unique sanctuary for biodiversity.

Environmental aspects of dismantlement of the Shelter and of radioactive waste management

The accidental destruction of Chernobyl's Unit 4 reactor resulted in an extensive spreading of radioactive material and a large amount of radioactive waste in the Unit, at the plant site, and in the surrounding area.

Construction of the Shelter between May and November 1986, aiming at environmental containment of the damaged reactor, reduced radiation levels on-site and prevented further release of radionuclides off-site. The Shelter was erected in a short period under severe radiation conditions. Measures taken to save construction time led to imperfections in the Shelter as well as to lack of comprehensive data on the stability of the damaged Unit 4 structures. In addition, structural elements of the Shelter have degraded due to moisture-induced corrosion during the two decades since it was erected. The main potential hazard of the Shelter is a possible collapse of its top structures and release of radioactive dust into the environment.

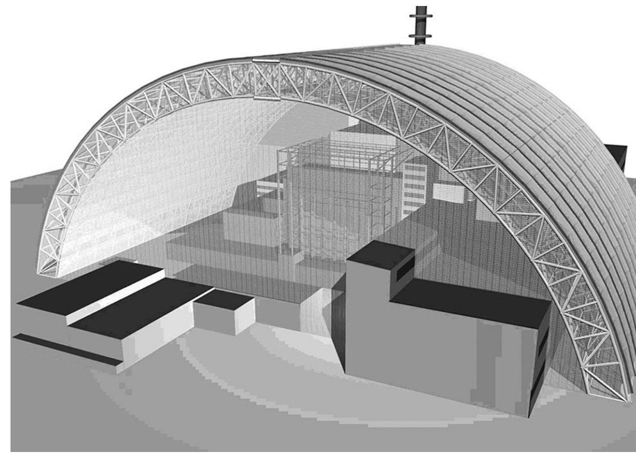

Fig. 4. Planned NSC over the destroyed Chernobyl reactor.

To avoid the potential collapse of the Shelter, measures are implemented to strengthen unstable structures. In addition, a New Safe Confinement (NSC) that should provide >100 y service life is planned as a cover over the existing Shelter (Fig. 4). The construction of the NSC is expected to allow for the dismantlement of the current Shelter, removal of highly radioactive fuel-containing mass from Unit 4, and eventual decommissioning of the damaged reactor.

In the course of remediation activities both at the CNPP site and in its vicinity, large volumes of radioactive waste were generated and placed in temporary near-surface waste storage and disposal facilities. These facilities were established without proper design documentation and engineered barriers and do not meet contemporary waste disposal safety requirements.

During the years following the accident, large resources were expended to provide a systematic analysis and an acceptable strategy for management of existing radioactive waste. However, to date a broadly accepted strategy for radioactive waste management at the CNPP site and the Exclusion Zone, and especially for high-level and long-lived waste, has not yet been developed.

More radioactive waste is potentially expected to be generated in Ukraine in the years to come during NSC construction, possible Shelter dismantling, fuel-containing mass removal and decommissioning of Unit 4. This waste should be properly disposed of.

The future of the Chernobyl Exclusion Zone

The overall plan for the long-term development of the Exclusion Zone in Ukraine is to recover the affected areas, redefine the Exclusion Zone, and make the less affected areas available for limited economic use. This will require well defined administrative controls on the nature of activities that may be performed in the particular areas. In some of them, restriction of crop planting and cattle grazing, and use of only clean feed for cattle still may be needed for decades to come for radiological reasons. Accordingly, these resettled areas are best suited for an industrial use rather than an agricultural or residential uses.

FINDINGS OF THE CHERNOBYL FORUM—HEALTH CONSEQUENCES (CHERNOBYL FORUM 2006; WHO 2006)

The report of the Forum's Expert Group provides a summary on health consequences of the accident on Belarus, the Russian Federation, and Ukraine (WHO 2006).

Human radiation doses (Chernobyl Forum 2006; IAEA 2006a; WHO 2006)

Three population categories who were exposed from the Chernobyl accident:

- emergency and recovery operation workers who worked at the CNPP and in the Exclusion Zone after the accident;
- inhabitants evacuated from contaminated areas; and
- inhabitants of contaminated areas who were not evacuated.

With the exception of the on-site reactor personnel and the emergency workers who were present near the destroyed reactor during the time of the accident and shortly afterwards, most of recovery operation workers and people living in the contaminated territories received relatively low whole-body radiation doses, comparable to background radiation levels accumulated over the 20-y period since the accident (Table 1).

The highest doses were received by emergency workers and on-site personnel, in total about 1,000 people, during the first days of the accident, ranging up to 20 Gy, which was fatal for some of the workers. The doses received by recovery operation workers who worked for short periods during 4 y following the accident ranged up to >500 mSv with an average of ~100 mSv, according to the State Registries of Belarus, Russia, and Ukraine.

Table 1. Summary of average accumulated doses to affected populations from Chernobyl fallout.

Population category	Number	Average dose (mSv)
Liquidators (1986–1989)	600,000	~100
Evacuees from highly-contaminated zone (1986)	116,000	33
Residents of "strict-control" zones (1986–2005)	270,000	~70
Residents of other "contaminated" areas (1986–2005)	5,000,000	10–20

Effective doses to the persons evacuated from the Chernobyl accident area in the spring and summer of 1986 were estimated to be of the order of 33 mSv on average, mostly from external gamma radiation, with the highest dose of the order of several hundred millisieverts.

Ingestion of food contaminated with radioactive iodine did result in significant doses to the thyroids of inhabitants of the contaminated areas of Belarus, Russia, and Ukraine. The thyroid doses varied in a wide range, according to age, level of ground contamination with ^{131}I, and milk consumption rate. Reported individual thyroid doses ranged up to ~50 Gy, with average doses in contaminated areas being ~0.03 to a few gray, depending on the region where people lived and on their age. The thyroid doses to residents of Pripyat city, located in the vicinity of the CNPP, were substantially reduced by timely distribution of stable iodine tablets. Drinking milk from cows that ate contaminated grass immediately after the accident was one of the main reasons for the high doses to the thyroids of children, and why so many children subsequently developed thyroid cancer.

The general public has been exposed during the past 20 y after the accident both from external sources (^{137}Cs on soil, etc.) and via intake of radionuclides (mainly, ^{137}Cs, ^{134}Cs, and, to less extent, ^{90}Sr) with food, water, and air. Both external and internal exposure by cesium radionuclides result in uniform body irradiation whereas intake of ^{90}Sr leads to exposure of bone tissue, including bone marrow. Depending on environmental conditions (soil type, etc.) and countermeasures, contribution of internal dose to total dose constituted from 10–70%.

The average effective doses for the general population of "contaminated" areas accumulated in 1986–2005 were estimated to be between 10 and 30 mSv in various administrative regions of Belarus, Russia, and Ukraine. In the areas of strict radiological control, the average accumulated dose was >50 mSv. Some residents received up to several hundred millisieverts.

The vast majority of about five million people residing in contaminated areas of Belarus, Russia, and

Ukraine currently receive annual effective doses from the Chernobyl fallout of <1 mSv in addition to the natural background doses. However, ~100,000 residents of the more contaminated areas still receive >1 mSv annually from the Chernobyl fallout. Although future reduction of exposure levels is expected to be rather slow, i.e., of about 3–5% y^{-1}, the great majority of dose from the accident has already been accumulated.

The Chernobyl Forum assessment agrees with that of the UNSCEAR (2000) Report in terms of the individual and collective doses received by the populations of the three most affected countries: Belarus, Russia, and Ukraine.

Radiation-induced death

The number of deaths attributable to the Chernobyl accident has been of paramount societal interest. Claims have been made that tens or even hundreds of thousands of persons have died since 1986 as a result of the accident whereas in fact they have died of diverse natural causes that are not attributable to radiation. However, widespread expectations of ill health and a tendency to attribute all health problems to radiation exposure have led to the assumption that Chernobyl-related fatalities were very high.

Acute radiation sickness mortality. The number of deaths due to acute radiation sickness (ARS) during the first year following the accident is well documented. According to UNSCEAR (2000), ARS was diagnosed in 134 emergency workers. In many cases the ARS was complicated by extensive beta radiation skin burns and sepsis. Among these workers, 28 persons died in 1986 due to ARS. Two more persons had died at Unit 4 from injuries unrelated to radiation. Nineteen more died in 1987–2004 of various causes, however their deaths are not necessarily attributable to radiation exposure. Among the general population exposed to the Chernobyl radioactive fallout, however, the radiation doses were relatively low, and ARS and associated fatalities did not occur.

Cancer mortality: epidemiological data. It is impossible to derive reliably numbers of fatal cancers caused by generally low radiation exposure due to the Chernobyl accident from epidemiological studies of all affected general public or workers because radiation-induced cancers are at present indistinguishable from those due to other causes. So far, epidemiological studies of residents of affected areas in Belarus, Russia, and Ukraine have not provided clear and convincing evidence for a radiation-induced increase in general population mortality, and in particular, for fatalities caused by leukemia, solid cancers (other than thyroid cancer), and noncancer diseases.

However, among the >4,000 thyroid cancer cases diagnosed in 1992–2002 in persons who were children or adolescents at the time of the accident, 15 deaths related to the progression of the disease have been documented.

Some radiation-induced increases in fatal leukemia, solid cancers, and circulatory system diseases have been reported in Russian emergency and recovery operation workers (Ivanov et al. 2001, 2004). These findings, however, should be considered as preliminary and need confirmation in better-designed studies with careful individual dose reconstruction.

Cancer mortality: biostatistical projection. An international expert group has made projections to provide a rough estimate of the possible fatal impacts of the accident and to help plan the future allocation of public health resources (Cardis et al. 1996; WHO 2006). These predictions were based on the experience of other populations exposed to radiation that have been studied for many decades, such as the survivors of the atomic bombings in Hiroshima and Nagasaki. The predictions should be treated with great caution, especially when the additional doses above natural background radiation are small.

The expert group predicted that among the 600,000 persons receiving more significant exposures (liquidators working in 1986–1987, evacuees, and residents of the most "contaminated" areas), the possible increase in cancer mortality due to this radiation exposure might be up to a few percent. Among the five million persons residing in other "contaminated" areas of Belarus, Russia and Ukraine, the doses are much lower and any projected increases are more speculative, but are expected to make a difference of <1% in cancer mortality.

Such increases would be very difficult to detect with available epidemiological tools, given the normal variation in cancer mortality rates.

The diseases attributable to the Chernobyl radiation exposure

Thyroid cancer in children. One of the principal radionuclides released by the Chernobyl accident was ^{131}I, which was significant for the first few months. Children were found to be the most vulnerable population with regard of internal thyroid exposure due to ingestion of foodstuffs, especially milk, containing high levels of radioiodine, and a substantial increase in thyroid cancer among those exposed as children was recorded subsequent to the accident.

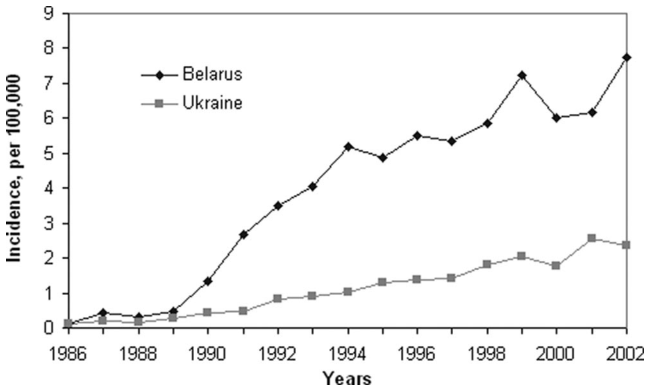

Fig. 5. Incidence rate of thyroid cancer in children and adolescents exposed to ^{131}I as a result of the Chernobyl accident (Jacob et al. 2006).

From 1992–2002 in Belarus, Russia, and Ukraine >4,000 cases of thyroid cancer were diagnosed among those who were children and adolescents (0–18 y) at the time of the accident, the age group 0–14 y being most affected (Fig. 5). The majority of these cases were treated with favorable prognosis for their lives. Given the rarity of thyroid cancer in young people, the large population with high thyroid doses, and the known radiation risk estimates, it is most likely that a large fraction of thyroid cancers observed to date is attributable to radiation exposure from the accident. It is expected that the increase in thyroid cancer incidence from Chernobyl will continue for many more years, although the long-term magnitude of risk is difficult to estimate.

It should be noted that early mitigation measures taken by the national authorities helped to minimize the health consequences of the accident. Intake of stable iodine tablets during the first 6–30 h after the accident reduced the thyroid dose of the residents of Pripyat city by a factor of six on average (Balonov et al. 2003). Pripyat was the largest city nearest to the CNPP and ~50,000 residents were evacuated within 40 h after the accident. More than 100,000 people were evacuated within a few weeks after the accident from the most contaminated areas of Ukraine and Belarus. These actions reduced radiation related health impacts of the accident.

Leukemia, solid cancers, and circulatory diseases. Given the level of doses received, it is likely that studies of the general population will lack statistical power to identify radiation-induced risk of leukemia, although for higher exposed emergency and recovery operation workers an increase may be detectable. The most recent studies suggest a twofold increase in the incidence of leukemia between 1986 and 1996 in Russian emergency and recovery operation workers exposed to external doses of >150 mGy. Since the risk of radiation-induced leukemia decreases few decades after exposure, its contribution to morbidity and mortality is likely to become less significant as time progresses.

There have been many post-Chernobyl studies of leukemia and cancer morbidity in the populations of "contaminated" areas in the three countries. So far, there is no convincing evidence that the incidence of leukemia or cancer (other than thyroid) has increased in children, those exposed in utero, or adult residents of the "contaminated" areas. It is thought, however, that for most solid cancers the minimum latent period is of the order of 10 y or more—and it may be too early to evaluate the full radiological impact of the accident.

There appears to be some recent increase in morbidity and mortality of Russian emergency and recovery operation workers caused by circulatory system diseases. Incidence of circulatory system diseases should be interpreted with special care because of the possible indirect influence of confounding factors, such as stress and lifestyle (smoking, alcohol consumption, etc.).

Cataracts. Examinations of eyes of emergency and recovery operation workers clearly show that cataracts may develop in association with exposure to radiation from the Chernobyl accident. The data from studies of emergency and recovery workers suggest that exposures to radiation somewhat lower than previously experienced may be cataractogenic.

Continued eye follow-up studies of the Chernobyl populations will allow confirmation and greater predictive capability of the risk of radiation cataract onset and, more importantly, provide the data necessary to be able to assess the likelihood of any resulting visual dysfunction.

Inherited and reproductive effects

Because of the relatively low dose levels to which the population of the Chernobyl-affected regions were exposed, there is no evidence or any likelihood of observing decreased fertility among males or females in the general population as a direct result of radiation exposure. These doses are also unlikely to have any major effect on the number of stillbirths, adverse pregnancy outcomes or delivery complications, or the overall health of children.

No discernable increase in hereditary effects caused by radiation is expected based on the low risk coefficients estimated by UNSCEAR (2001) or in previous reports on Chernobyl health effects (UNSCEAR 2000). There has been a modest but steady increase in reported congenital malformations in both "contaminated" and "uncontaminated" areas of Belarus since 1986 (Fig. 6).

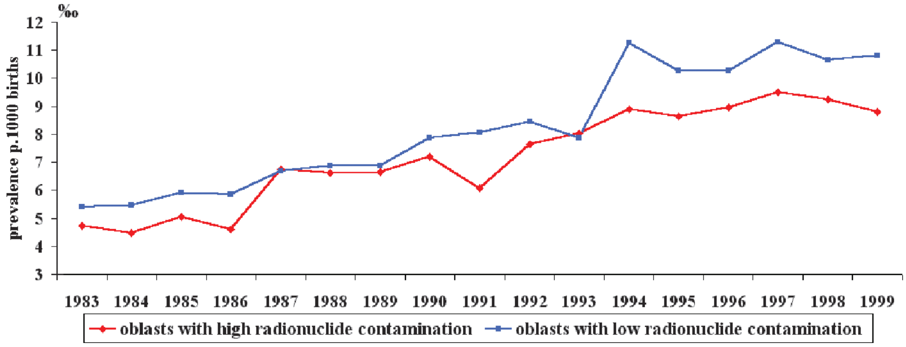

Fig. 6. Prevalence at birth of congenital malformations in four oblasts of Belarus with high and low levels of radionuclide contamination (Lazjuk et al. 2003).

This does not appear to be radiation-related and may be the result of increased registration.

Psychological and mental health problems

Stress symptoms, depression, anxiety (including post-traumatic stress symptoms), and medically unexplained physical symptoms have been reported in Chernobyl-exposed populations. The studies also found that exposed populations were more likely to report subjective poor health than were unaffected control groups. In general, the context in which the Chernobyl accident occurred makes the findings difficult to interpret because of the complicated series of events unleashed by the accident, the multiple extreme stresses and culture-specific ways of expressing distress.

In addition, individuals in the affected populations were officially categorized as "sufferers," and came to be known colloquially as "Chernobyl victims." This label, along with the extensive government benefits, had the effect of encouraging individuals to think of themselves fatalistically as invalids. Thus, rather than perceiving themselves as "survivors," many of those people have come to think of themselves as helpless, weak, and lacking control over their future.

FINDINGS OF THE CHERNOBYL FORUM—THE SOCIO-ECONOMIC IMPACT (UNDP/UNICEF 2002; WORLD BANK 2002; CHERNOBYL FORUM 2006)

The economic cost

The huge costs of the Chernobyl nuclear accident borne by the Soviet Union and three successor countries, Belarus, Russia, and Ukraine, can only be calculated with a high degree of estimation, given the non-market conditions prevailing at the time of the disaster and the high inflation and volatile exchange rates of the transition period that followed the break-up of the Soviet Union in 1991. However, the magnitude of the impact is clear from a variety of government estimates from the 1990's, which put the cost of the accident, over two decades, at hundreds of billions of dollars.

The scale of the burden is clear from the wide range of costs incurred, both direct and indirect:

- direct damage caused by the accident;
- expenditures related to:
  1. actions to seal off the reactor and mitigate the consequences in the Exclusion Zone;
  2. resettlement of people and construction of new housing and infrastructure to accommodate them;
  3. social protection and health care provided to the affected population;
  4. research on environment, health, and production of clean food;
  5. radiation monitoring of the environment;
  6. radioecological improvement of settlements and disposal of radioactive waste;
- indirect losses relating to the opportunity cost of removing agricultural land and forests from use and the closure of agricultural and industrial facilities; and
- opportunity costs, including the additional costs of energy resulting from the loss of power from the CNPP and the cancellation of Belarus's nuclear power program.

Coping with the impact of the disaster has placed a huge burden on national budgets. In Belarus and Ukraine, 5–7% of government spending each year is still devoted to Chernobyl-related benefits and programs. This massive expenditure has created an unsustainable fiscal burden, especially in the form of social benefits for as many as seven million recipients in the three countries. With limited resources, governments thus face the task of streamlining Chernobyl programs to provide more focused and targeted assistance.

Consequences of Chernobyl for the local economy

The affected territories are mostly rural. Industry was mainly fairly unsophisticated, concentrated in food processing or wood products. This profile has remained largely the same after the accident. The agricultural sector was worst hit by the effects of the accident. A total of 0.8 million hectares of agricultural land were removed from service in the three countries, and timber production was halted for a total of 0.7 million hectares of forest. Restrictions on agricultural production crippled the market for foodstuffs and other products from the affected areas. “Clean food” production has remained possible in many areas thanks to remediation efforts, but this has entailed higher costs in the form of fertilizers, additives, and special cultivation processes.

Wages tend to be lower and unemployment higher in the affected areas than they are elsewhere. This is in part the result of the accident and its aftermath, which forced the closure of many businesses, imposed limitations on agricultural production, added costs to product manufacture (particularly the need for monitoring), and hurt marketing efforts. The proportion of small- and medium-sized enterprises is far lower in the affected regions than elsewhere. This is partly because many skilled and educated workers, especially the younger ones, have left the region. The result of these trends is that the affected regions face a higher risk of poverty than elsewhere.

Impact of Chernobyl on local communities

Since the Chernobyl accident, >330,000 people have been relocated away from the more affected areas. One-hundred and sixteen thousand of them were evacuated immediately after the accident, whereas a larger number were resettled several years later, when the benefits of relocation were less evident.

Communities in the affected areas suffer from a highly distorted demographic structure. As a result of resettlement and voluntary migration, the percentage of elderly individuals in affected areas is abnormally high. A large proportion of skilled, educated, and entrepreneurial people have also left the region, hampering the chances for economic recovery and raising the risk of poverty.

Impact on individuals

As noted in the Chernobyl Forum report on health issues (WHO 2006), “the mental health impact of Chernobyl is the largest public health problem unleashed by the accident to date.” Psychological distress arising from the accident and its aftermath has had a profound impact on individual and community behavior. Populations in the affected areas exhibit strongly negative attitudes in self-assessments of health and well-being and a strong sense of lack of control over their own lives. Associated with these perceptions is an exaggerated sense of the dangers to health of exposure to radiation. Such fatalism is also linked to a loss of initiative to solve the problems of sustaining an income and to dependency on assistance from the State.

Anxiety over the effects of radiation on health shows no sign of diminishing. While attributing a wide variety of medical complaints to Chernobyl, many residents of the affected areas neglect the role of personal behavior in maintaining health. This applies not only to radiation risks such as the consumption of mushrooms and berries from contaminated forests, but also to areas where individual behavior is decisive, such as misuse of alcohol and tobacco.

The main causes of death in the Chernobyl-affected region are the same as those nationwide—cardiovascular diseases, injuries, and poisonings—rather than any radiation-related illnesses. The most pressing health concerns for the affected areas thus lie in poor diet and lifestyle factors such as alcohol and tobacco use, as well as poverty and limited access to health care.

Added to exaggerated or misplaced health fears, a sense of victimization and dependency created by government social protection policies is widespread in the affected areas. The dependency culture that has developed over the past two decades is a major barrier to the region’s recovery.

Response of the governments to the challenges of Chernobyl

The Soviet Union undertook far-reaching measures in response to the Chernobyl nuclear accident. The government adopted a low threshold with regard to the level of radioactive contamination that was considered acceptable for inhabited areas. The same caution applied to the zoning principles that were defined by the Soviet government in the wake of the accident, and that were subsequently reinforced by national legislation after the dissolution of the Soviet Union in 1991.

In the wake of the accident, rehabilitation actions were undertaken on a huge scale (Table 2). To accommodate the resettled populations, large investments were made in the construction of housing, schools, and hospitals, and also in physical infrastructure such as roads,

Table 2. Chernobyl-related construction in 1986–2000 (UNDP/UNICEF 2002).

	Belarus	Russia	Ukraine	Total
	(thousands)			
Houses and flats	65	37	29	131
Schools (number of places)	44	18	49	111
Kindergartens (number of places)	18	4	11	33
Outpatient health centers (visits per day)	21	8	10	39
Hospitals (beds)	4	3	4	11

water and electricity supply, and sewerage. Many villages were provided with access to gas supplies for heating and cooking. This involved laying down a total of 9,000 km of gas pipeline in the three countries. Large sums were also spent to develop methods to cultivate "clean food" in the less contaminated areas where farming was allowed.

An extensive benefits system was established for the populations that were seen to have suffered as a result of the Chernobyl accident, through either exposure to radiation or resettlement. Benefits were offered to very broad categories of Chernobyl victims, defined as people who:

- fell ill with radiation sickness or became invalids due to the consequences of the accident;
- took part in cleanup activities at the Chernobyl site and in the evacuation zones in 1986–1987 (known colloquially as "liquidators");
- participated in cleanup activities in 1988–1989;
- continued to live in areas designated as contaminated; or
- were evacuated, or resettled, or left the affected areas on their own initiative.

Some seven million people are now receiving special allowances, pensions, and health-care privileges as a result of being categorized as in some way affected by Chernobyl. In effect, these benefits compensate risk rather than actual injury. In the absence of alternative sources of income, the Chernobyl benefits became the key to survival for many whose livelihoods were wiped out by the accident. And the health-care system detected and treated thousands of cases of thyroid cancer that developed among children who were exposed to radioiodine in the weeks following the accident.

However, government efforts also contained the seeds of later problems. First, the zones delineated for social protection of the public in the early aftermath of the accident have become radiologically unjustified with time passage because of radiation declination. Continued limitations on commercial activities and infrastructure development in the less affected areas became more of a burden than a safeguard. Zoning adjustments need to be done in light of new research.

Second, the massive investment programs initiated to serve resettlement communities proved unsustainable, particularly under market economic conditions. Funding for Chernobyl programs has declined steadily over time, leaving many projects half completed.

Third, the selective and restrictive information provided by the Soviet government, particularly in the immediate aftermath of the accident, left a legacy of mistrust surrounding official statements on radiation, and this has hindered efforts to provide information to the public in the following decades.

The enormous scale of the effort currently being made by the three governments means that even small improvements in efficiency can significantly increase the resources available for those in need. Resources now committed to Chernobyl health-care benefits should be targeted to high-risk groups (e.g., emergency workers) and those with demonstrated health conditions, or be shifted into a mainstream health-care system. Such changes take political courage, as reallocating resources faces strong resistance from vested interests.

Risk perception in the affected regions

Two decades after the Chernobyl accident, residents of affected areas still lack the information they need to lead healthy, productive lives, according to recent sociological studies. Although accurate information is accessible, misconceptions and myths about the threat of radiation persist, promoting a paralyzing fatalism among residents.

These findings were most recently confirmed by three country-specific reports prepared as part of the United Nations initiative, i.e., International Chernobyl Research and Information Network. Surveys and focus group meetings in 2003–2004 showed that people living in the areas affected by the Chernobyl accident express deep confusion and uncertainty about the impact of radiation on their health and surroundings. Awareness is low of what practical steps to take to lead a healthy life in the region.

Overcoming mistrust of information provided on Chernobyl remains a major challenge, owing to the early secrecy with which Soviet authorities treated the accident, the use of conflicting data by different institutions, the unresolved controversies surrounding the impact of low-dose radiation on health, and the often complex scientific language in which information is presented.

The International Chernobyl Research and Information Network country studies confirm that Chernobyl-affected populations need unambiguous and comprehensible answers to a range of questions, as well as fresh policies that would focus on promoting the region's economic development. The Chernobyl Forum findings should provide authoritative source material for creative dissemination to the affected populations, helping them to both lead healthier lives and overcome a paralyzing legacy of worry and fear.

People who need direct assistance in coping with the consequences of Chernobyl

Current scientific knowledge suggests that a small but important minority, numbering between 100–200 thousand people, is caught in a downward spiral of isolation, poor health, and poverty; these people need substantial material assistance to rebuild their lives. This group includes those who continue to live in severely affected areas and are unable to support themselves, unemployed resettlers, and those whose health is most at risk, including patients with thyroid cancer and other malignant cancers, and those with psychosomatic disorders. Resources should be focused on resolving their needs and on helping them to take control of their lives in the circumstances that have resulted from the accident.

A second group, numbering several hundreds of thousands of individuals, consists of those whose lives have been directly and significantly affected by the consequences of the accident but who are already in a position to support themselves. This group includes resettlers who have found employment and many of the former cleanup workers. The priority here should be to help these people to normalize their lives as quickly and as far as is possible.

A third group consists of a much larger number of people, totaling several million in the three countries, whose lives have been influenced by the accident primarily in that they perceive themselves as actual or potential victims of Chernobyl. Here the main need is for full, truthful, and accurate information on the effects of the accident based on internationally recognized research, coupled with access to good quality health-care and social services, and to employment.

The approach of defining the most serious problems and addressing them with special measures, while pursuing an overall policy of promoting a return to normality, should apply to the affected territories as well as to the affected individuals and communities. This combination of measures—focusing resources on those most in need, while actively promoting integration with mainstream provisions wherever possible—is really the only alternative to the current unsustainable policy.

CHERNOBYL FORUM RECOMMENDATIONS TO THE GOVERNMENTS OF BELARUS, RUSSIA, AND UKRAINE

The recommendations requested by the representatives of Belarus, Russia, and Ukraine were initially prepared by the Forum Secretariat based on those presented in the Forum's technical reports. In addition, UNDP has contributed recommendations for economic and social policies based largely on the 2002 United Nations study (UNDP/UNICEF 2002) as well as on the World Bank's *Belarus: Chernobyl Review* (World Bank 2002). The recommendations were circulated among the Forum's participants and eventually accepted by consensus.

This paper contains mostly generic advice for the governments of the three affected countries; more detailed recommendations can be found in the respective technical reports and in the summary report (Chernobyl Forum 2006). With regard to radiation protection of the public and the environment, the recommendations are based on current concepts of the International Commission on Radiological Protection (ICRP) and international safety standards developed by IAEA.

Recommendations on environmental monitoring, research, and remediation (Chernobyl Forum 2006; IAEA 2006a)

- Various ecosystems considered in the present report have been intensively monitored and studied during the years after Chernobyl, and environmental transfer and bioaccumulation of the most important long-term contaminants, ^{137}Cs and ^{90}Sr, are now generally well understood. There is, therefore, no need for major new research programs on radioactivity; but it is of use to continue limited targeted monitoring and study of some specific areas;
- It is important to inform the public on persistent high contamination of wild food products (fungi, game, berries, etc.) and on simple cooking procedures aimed at reducing internal exposure;
- As activity concentrations in environmental compartments are now in quasi-equilibrium and change slowly, the number and frequency of routine sampling and measurements can be substantially reduced;
- To further develop the system of environmental protection against radiation, the long-term impact of radiation on plant and animal populations should be further investigated in the highly affected Chernobyl Exclusion Zone; this is a globally unique area for radioecological and radiobiological research in an otherwise natural setting;
- The general public, along with the authorities, should be particularly informed about existing radiation risk factors and methods to reduce them in the long term via remediation and regular use of countermeasures, and involved in discussion and decision making;
- Particular attention must be given to the production on private farms in several hundred settlements and about 50 intensive farms in Belarus, Russia, and Ukraine where radionuclide concentrations in milk still exceed national action levels;
- Remediation measures remain efficient mainly in areas with poor (sandy and peaty) soils where there is a high radiocesium transfer from soil to plants;
- Technologically based remediation measures applied to forests and surface waters will not be practicable on a large scale;
- There is nothing that can be done to remedy the radiological conditions for plants and animals residing in the Exclusion Zone of the CNPP that would not have an adverse impact on plants and animals;

- Experience with protection of the public after the Chernobyl accident has clearly shown the need for further international harmonization of appropriate radiological criteria and safety standards applicable to remediation of areas contaminated with radionuclides;
- During the preparation and construction of the NSC and soil removal, it is important to maintain and improve environmental monitoring strategies, methods, equipment and staff qualification.
- Development of an integrated radioactive waste management program based on existing programs for the Shelter, the CNPP site and the Exclusion Zone is needed to ensure application of consistent management approaches, and sufficient facility capacity for all waste types; and
- Return of the Chernobyl Exclusion Zone to limited economic use will require well-defined administrative controls as to the nature of activities that may be performed in particular areas. The re-used areas are best suited for an industrial site rather than an agricultural or residential area.

Recommendations on health care and research (Chernobyl Forum 2006; WHO 2006)

- Medical care and annual examinations of the workers who recovered from ARS and other highly-exposed emergency workers should continue;
- Current follow-up programs for those persons with whole-body exposures of <1 Gy should be reconsidered relative to necessity and cost-effectiveness. From previous knowledge, these follow-up programs are unlikely to be cost-effective or beneficial to individuals. Resources might more profitably be directed towards general health care;
- Screening for thyroid cancer of those who were children and adolescents and resided in 1986 in the areas with radioactive fallout should continue. However, the screening should be evaluated periodically for cost/benefit;
- Registries of exposed persons should continue as well as studies of morbidity and mortality. These are typically for documentation or research purposes and usually will not be of direct medical benefit to individuals;
- Continued eye follow-up studies of the Chernobyl populations will allow greater predictive capability of risk of radiation cataract onset and more importantly provide the data necessary to assess the likelihood of a resulting visual dysfunction;
- The local registers on reproductive health outcomes should be based on standard protocols for such conditions as congenital malformations and genetic disorders. It should be understood that such registers are unlikely to provide useful scientific information on radiation effects, however they may provide reassurance to the local population;
- Renewed efforts at risk communication should be undertaken, providing the public and key professionals with accurate information about the physical and mental health consequences of the disaster; and
- Elevated radiation-induced morbidity and mortality from solid cancers of both emergency workers and populations of areas contaminated with radionuclides still might occur during decades to come and requires careful research to evaluate.

Recommendations for economic and social policy (UNDP/UNICEF 2002; World Bank 2002; Chernobyl Forum 2006)

Current scientific knowledge about the impact of the disaster suggests that five general principles should underlie any approach to tackling the consequences of the accident:

- Chernobyl-related needs should be addressed in the framework of a holistic view of the needs of the individuals and communities concerned and, increasingly, of the needs of society as a whole;
- Moving away from a dependency culture in the affected areas, the aim must be to help individuals to take control of their own lives and communities to take control of their own futures;
- Efficient use of resources means focusing on the most affected people and communities. The response must take into account the limited budgetary resources at government disposal;
- The new approach should seek changes that are sustainable and long-term, and based on a developmental approach; and
- The international effort can only be effective if it supports, amplifies and acts as a lever for change in the far larger efforts made by local and national government agencies and the voluntary sector in the three countries.

In order to follow the principles as above, the following specific recommendations should be implemented:

- Find new ways to inform the public, embracing a comprehensive approach to promoting healthy lifestyles, and not simply focus on radiation hazards;
- Focus attention on highly affected areas, revisit the classification of zones. Governments also need to clarify to the public that many areas previously considered to be at risk are in fact safe for habitation and cultivation;
- Streamline and refocus government programs on Chernobyl in order to meet the objectives of reducing the population's exposure to radiation and providing support to those who have been directly affected by the accident;
- Improve benefits targeting, limit benefits to those who indeed suffered from the accident. Where not already

done, eliminate benefits for individuals living in areas with mild contamination. Those who need State assistance on poverty grounds should be covered by a nationwide targeted and means-tested system of social assistance;

- Improve primary health care, including psychological support. This should include promotion of healthy lifestyles; improvement in access and quality of reproductive health care, and provision of psychological support and diagnosis and treatment of mental diseases, especially depression;
- Rethink health recuperation programs. Both government and charitable recuperation programs should ensure that travel outside the region is provided in a way that does not exaggerate the danger of living in Chernobyl-affected areas; and
- Encourage safe food production. A cost-benefit analysis is essential in propagating mitigation measures, as the costs of producing "clean food" may exceed any reasonable market value.

Adopt a new approach to economic development of the affected regions:

- Put economic development aiming to make the affected communities economically and socially viable in the medium and long term at the center of strategies to address the effects of Chernobyl. Give the individuals and communities concerned control over their own futures;
- Improve the business climate, encourage investment and support private sector development;
- Support initiatives to promote inward investment, both domestic and international, at the regional level, to promote employment and create a positive image for the areas concerned;
- Encourage the creation and growth of small- and medium-size enterprises in the affected areas and in the adjacent towns and cities;
- Adapt examples of good practice in the three countries and abroad, including community based solutions such as credit unions and producer and consumer cooperatives, to the special circumstances that apply in the affected areas;
- Promote the rebuilding of community structures to replace those that were lost in the process of evacuation and as a result of the break up of the Soviet Union; and
- Explore the possibilities for promoting specialized ecological tourism and for maximizing the contribution that these areas can make to the preservation of international biodiversity.

DISCUSSION

Effectiveness of radiation protection of the public

The application of radiation protection measures for the public both during the early and the recovery phase of the Chernobyl accident, and both in the USSR and in other European countries, constitutes a unique experience which must be comprehensively and critically analyzed. Attempts have already been made to do this at international and national levels (IAC 1991; Lochard and Belyaev 1996; IAEA 1996a, 2001), but much still remains to be done. Of interest here are not only the radiological analysis of the effectiveness of the protective measures and the combination thereof, particularly in terms of the dose avoided by residents, but also their cost and the way they were received by the public, taking into account social factors and cultural traditions. Here we do not examine issues relating to radiation protection of the emergency workers, which have been covered in detail in other publications (IAEA 1990; IAC 1991).

The radiation protection principles adopted during the Chernobyl accident in the most affected country, the USSR, differed significantly from the international principles introduced in ICRP Publication 26 (ICRP 1977a) and subsequent publications of ICRP and adopted in many countries in the world. Thus, in the USSR at this time, radiation protection was based on a system of dose limits assuming a threshold with respect to the dose-effect dependence (USSR Ministry of Health 1977). For nuclear reactor accidents, special dose limits were established with the goal of preventing radiation sickness and radiation damage to the thyroid, and corresponding two-stage action levels were defined with respect to radiation levels and the concentration of radionuclides in the environment (USSR Ministry of Health 1983). The radiation protection optimization principle was not included in these guidelines.

Potential acute radiation effects among the public and substantial increase of cancer risk due to radiation were successfully avoided through the timely evacuation in April–June 1986 of 116,000 residents from the accident zone, where doses over the first year could exceed a few hundred millisieverts and over 70 y could be as high as 1 Sv or more. Subsequently, these residents were not able to return to their homes so evacuation became relocation.

The subsequent relocation in 1988–1990 of another 220,000 residents from other heavily contaminated areas was justified rather by social and psychological than by radiological rationales. By the time of relocation about half of the lifetime dose of less than few hundred millisieverts was already received by the residents and, therefore, only another half (about a hundred millisieverts) could be averted. This is an order of magnitude below the international criterion recommended for permanent relocation by ICRP and IAEA (ICRP 1993; FAO et al. 1996).

Intensive application of radiation protection measures (decontamination of settlements, provision of "clean food" products and agricultural countermeasures) started shortly after the accident at large scale and significantly reduced the exposure levels (up to a factor of 2–3) and the corresponding risk of stochastic health effects among the public, i.e., leukemia and solid cancers.

One exception is protection against uptake of radioactive iodine in the thyroid. Only in Pripyat city, where the staff of the CNPP lived, was the medical service ready to distribute stable iodine tablets and it did so during the 1–1.5 d following the accident. Over 60% of the residents received tablets (Likhtarev et al. 1994; Balonov et al. 2003), which reduced the dose to the thyroid from inhalation of ^{131}I by a factor of 6–10 on average (Goulko et al. 1996; Balonov et al. 2003). They were evacuated 1.5 d after the accident.

The danger of ^{131}I uptake with food existed in all the areas contaminated with radionuclides during the first month after the accident and had practically disappeared by June 1986. Only in a small part of the contaminated areas in the USSR did it prove possible to protect the public in an effective and timely manner by stopping the use of contaminated milk and green vegetables. The thyroid exposure levels among people living in Belarus, Russia, and Ukraine, in particular children and adolescents, were certainly substantial, causing several thousand cases of thyroid cancer in 20 y among those who were children and adolescents in 1986. Other countries in Europe managed to avoid these effects thanks to the timely prevention of use of contaminated milk.

It should be noted that, though the radiation protection optimization theory based on cost-benefit analysis was well developed at the time of the Chernobyl accident, the vast majority of decisions were taken on the basis of the dose limitation principle. Optimization analysis was often carried out retrospectively. This applies not only to the early measures—evacuation, distribution of stable iodine, restriction of the radionuclide content in food—but also to the recovery period after the Chernobyl accident both in the USSR and in other European countries. In the USSR, standards for dose and the radionuclide content in food products did not remain the same but were gradually reduced for the various post-accident periods on the basis of what standards could actually be met. This approach, in essence, is similar to the optimization recommended by the ICRP for intervention.

Prognosis of health consequences

At various times after the Chernobyl accident, several groups of Soviet and international experts have given prognoses of its somatic radiogenic consequences (Ilyin and Buldakov 1987; Anspaugh et al. 1988; Cardis et al. 1996; WHO 2006). It should be borne in mind that these prognoses are not aimed at substantiating measures for radiation protection of the public and workers, since radiation protection is based on more practical dose criteria. Rather, these prognoses are important for planning special health-care measures (constructing or restructuring clinics, arranging diagnosis and treatment), and also for informing the public and the authorities. Considering the time required to set up a health-care system for large-scale operation, medical prognosis is more valuable the earlier it is done.

The first prognosis of the medical consequences of the Chernobyl accident was prepared by a group of Soviet specialists at the request of the authorities in autumn 1986, discussed at a symposium in Moscow in June 1987 and published in the collected proceedings of the symposium (Ilyin and Buldakov 1987), classified until 1989. The prognosis was presented in the form of two articles, based on information known at the time on the doses to the public, and the linear no-threshold (LNT) theory on the dependence of the probability of radiogenic cancers on the dose with parameters from UNSCEAR and ICRP publications (ICRP 1977a, 1977b, 1986; UNSCEAR 1982). The morbidity prognosis for the "liquidators" was not examined in these articles.

One article, prepared by the Institute of Biophysics, Moscow, was about the medical prognoses for inhabitants of the areas in Belarus, Russia, and Ukraine with the highest levels of radioactive fallout (Buldakov et al. 1987). Amongst the 1.1 million inhabitants of these areas, it was predicted that the cancer death rate in the 70 y following the accident would increase on average by 3.3%, and that there would be ~7,500 cases of thyroid cancer, including ~1,000 cases in children below the age of seven (at the time of the accident).

The second article, prepared by the Institute of Radiation Hygiene, Leningrad, examined separately the expected effects on the Russian population (Ramzaev et al. 1987). For the 600,000 inhabitants of the most contaminated areas in four oblasts, the predicted increase in the cancer death rate was 3.5%, while for the 60 million inhabitants of the European part of Russia it was 0.2%. Moreover, 1,400 cases of thyroid cancer were predicted in the four oblasts, including >300 cases in children below the age of seven (at the time of the accident), and up to 9,000 cases (3,000 of them in children) in the European part of Russia. Overall, these studies yielded three important conclusions:

1. The increase in radiogenic cancers in the population would not be significant from the point of view of organizing health care, although the carcinogenic effects of the Chernobyl accident on individual population groups at specific periods of time could be detected using scientific methods;
2. A considerable increase in the incidence of radiogenic thyroid cancer should be expected, particularly among children; and
3. Psychological trauma caused by the accident would affect millions of people.

In 1988, the recognized U.S. experts published the first assessment of the global impact of the Chernobyl accident (Anspaugh et al. 1988). Based on monitoring data collected by IAEA, WHO, and UNSCEAR and on available environmental models, they estimated lifetime collective dose commitment in the population of the northern hemisphere of ~900,000 person-Gy and its distribution among countries of Europe (97%), Asia, and North America. Using LNT radiation risk models of that time they also projected 2–17 thousand radiation-caused cancer deaths in the USSR (40%) and non-USSR Europe (60%). The corresponding average increase of population cancer mortality would be negligible, i.e., 0.02% in the USSR and 0.01% in Europe. The authors also noted huge economic and social effects of the accident.

Ten years after the accident an international group of specialists who had participated actively in post-Chernobyl epidemiological studies gave a more detailed prognosis of the carcinogenic consequences of the Chernobyl accident based on more accurate effective doses and the radiation risk factors in the previous LNT assumption (Table 3) (Cardis et al. 1996). Populations were divided into the 600,000 more exposed people (liquidators working in 1986–1987, the evacuees, and the residents of the strict control zone) and around seven million residents of other radionuclide-contaminated territories.

According to the 1996 prognosis, ~4,000 premature deaths from radiation-induced cancer (solid cancer and leukemia) were estimated to occur over the lifetime of the more exposed populations (600,000) and a further 5,000 cases among the other 7 million residents. The predicted average increase in the frequency of radiation-induced solid cancers over a lifetime was 3.3% among the more exposed population and 0.6% in the other residents. With regard to leukemia, these indicators were 12 and 1.5%, respectively.

There is clearly reasonable agreement between the prognoses of 1986, 1988, and 1996. From Table 3 it is also evident that in large cohorts the incidence of radiogenic cancer is scarcely noticeable. However, in individual population groups at specific periods of time after the Chernobyl accident, and particularly in terms of increased frequency of leukemia in the "liquidators" in the first decade, the radiogenic effects can be detected using scientific methods. At the time the article was written (Cardis et al. 1996) these effects were not yet apparent.

Thyroid cancer caused by internal exposure to radioiodine was not examined in this article as it was not considered by Anspaugh et al. (1988). At the time it was written, the incidence of radiogenic thyroid cancer among children and adolescents who were living in areas affected by radioactive fallout in spring 1986 was already widely recognized (Kazakov et al. 1992; Likhtarev et al. 1995) and efforts were focused upon analyzing the surveillance data.

The issues regarding prognosis of the carcinogenic consequences of the accident and comparison with 20 y of surveillance were examined by the Chernobyl Forum in 2003–2005 (Chernobyl Forum 2006; WHO 2006). By

Table 3. Predictions of background and excess deaths from solid cancers and leukemia in populations exposed as a result of the Chernobyl accident (Cardis et al. 1996).

Population	Population size/average dose	Cancer type	Period	Background number of cancer deaths	Predicted excess cancer deaths	AF[a] (%)
Liquidators, 1986–1987	200,000	Solid cancers	Lifetime (95 y)	41,500	2,000	5
	100 mSv	Leukemia	Lifetime (95 y)	800	200	20
			First 10 y	40	150	79
Evacuees from 30-km zone	135,000	Solid cancers	Lifetime (95 y)	21,500	150	0.7[b]
	10 mSv	Leukemia	Lifetime (95 y)	500	10	2
			First 10 y	65	5	7
Residents of SCZs	270,000	Solid cancers	Lifetime (95 y)	43,500	1,500	3
	50 mSv	Leukemia	Lifetime (95 y)	1,000	100	9
			First 10 y	130	60	32
Residents of other "contaminated" areas	6,800,000	Solid cancers	Lifetime (95 y)	800,000	4,600	0.6
	7 mSv	Leukemia	Lifetime (95 y)	24,000	370	1.5
			First 10 y	3,300	190	5.5

[a] AF: attributable fraction = (excess deaths/total death from the same cause) × 100.
[b] A misprint has been corrected which appeared in Cardis et al. (1996) and in WHO (2006).

that time the number of cases of thyroid cancer in those who had been children or adolescents at the time of the accident exceeded 4,000, the doses had been reliably reconstructed (Gavrilin et al. 1999; Balonov and Zvonova 2002; Kruk et al. 2004; Likhtarev et al. 2005) allowing determination of the radiation risk factors and their dependence on sex and age at the level of environmental (Jacob et al. 1999, 2006) and analytical (e.g., Davis et al. 2004) studies. Although the new evaluations of the radiation risk factors among children were noticeably higher than among adults, the overall number of radiogenic thyroid cancers was in reasonable agreement with the prognoses made in 1986 (see above).

Experts from the Forum also acknowledged that there was a statistically significant increase in the incidence of leukemia in 1986–1998 in Russian "liquidators" with doses >150 mSv from the study cohort of 72,000 persons (Ivanov et al. 2004). The noted increase is in reasonable agreement with the 1996 prognosis (Cardis et al. 1996). As expected, no carcinogenic effect of exposure was detected in any of the studies on the population of contaminated areas [except for thyroid cancer, see above] (e.g., Fig. 7) (Ivanov et al. 2004).

Based on these data, the Forum experts deemed it inappropriate to review the prognosis of Cardis et al. and it was adopted as a whole by the Forum (Chernobyl Forum 2006; WHO 2006) despite several differences in the demographic and dosimetric data (compare Tables 1 and 3).

In the author's opinion, with today's level of knowledge about the radiobiology of humans and mammals in general, prognoses of cancer morbidity and mortality merit attention only in cohorts of individuals with an average dose of the order of 100 mSv or at least some tens of millisieverts and above. As we know, neither the most informative Life-Span Study (LSS) on the Japanese cohort of individuals exposed to the atomic bombings of 1945 nor any other studies have provided reliable evidence of the carcinogenic effects of radiation at smaller doses. This was examined specifically with respect to the LSS in an article by Heidenreich et al. (1997) who showed convincingly that there is an increase in incidence of solid cancer morbidity and mortality only in groups with a dose >200 mSv. With respect to radiation-induced leukemias, a similar conclusion can be drawn from the LSS data by Pierce et al. (1996). Very generally speaking, this is the position formulated by UNSCEAR in its report (UNSCEAR 2000, Annex G): "There is substantial and convincing scientific evidence for health risks at high dose. Current summarized data, which represent international consensus, show that radiation induced cancer cases (excess above background cases) could be observed in humans at effective doses in excess of 0.1 Sv delivered at high dose rates."

Since prognoses of health consequences are not directly intended for substantiating necessary radiation protection measures, they do not have to be based on a cautious approach but rather on firmly established scientific facts. In the dose range <0.1 Sv, because of absence of proper experimental evidence, the dependence of adverse radiation effects on dose can be assessed only by means of biophysical models among which the LNT models are the most popular ones (Brenner et al. 2003; UNSCEAR 2000). However, there are also many others, including superlinear and threshold ones, and even the models accounting for hormesis effect. In the author's view, prior to experimental resolution of contradiction among the models they should not be used in a unappealable way for practical purposes, including public information, because of unacceptable prediction uncertainty.

Therefore, the prognosis by Cardis et al. (1996), adopted by the Chernobyl Forum in 2003–2005, with regard to the 600,000 most exposed persons with average group doses of at least several tens of millisieverts (Tables 1 and 3), viz. around 4,000 cases of premature death from radiogenic cancer, can be considered justified at today's level of scientific knowledge.

Two important features of this prognosis should be noted. Firstly, the specific markers of radiogenic cancer are not yet known. This means that in terms of specific individuals it is impossible to determine whether their cancer is due to the effects of radiation or other causes or, moreover, whether it is due to Chernobyl or background radiation. Taking into account the individual dose, it is possible only to estimate the probability of the corresponding cause-effect link. Secondly, it is important to understand the considerable statistical uncertainty of this

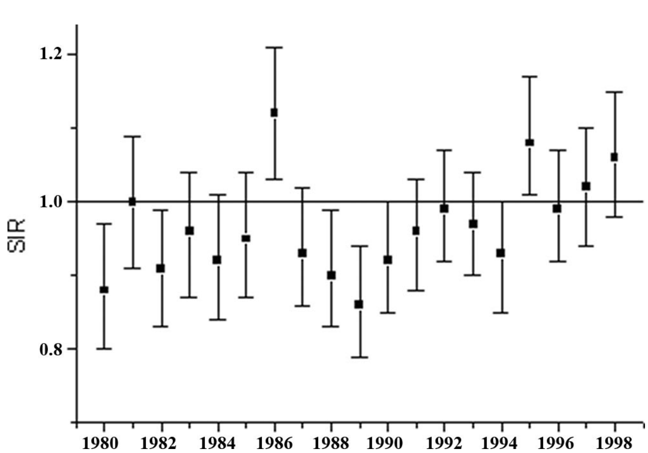

Fig. 7. Dynamics of solid cancer incidence among residents of five contaminated rayons of the Bryansk oblast standardized to incidence in other rayons (Ivanov et al. 2004).

prognosis, which lends itself rather to estimation within an order of magnitude.

For cohorts of the residents of the less contaminated areas of Belarus, Russia, Ukraine and other countries in Europe with average doses of <30 mSv over 20 y, there are today no experimental data for predicting radiogenic morbidity and mortality with reasonable certainty. At the same time, we cannot rule out that adequate epidemiological data on low-dose human exposure will be obtained as further progress is made in global radiobiology of man and other mammals. This may provide in the future the scientific basis for evaluating the health consequences of the Chernobyl accident among residents of areas with low radiation levels.

It should be stressed that the approach outlined in no way contradicts the application of the LNT theory for the purposes of radiation protection, where a cautious approach is conventionally and consciously applied to decision-making regarding human protection (ICRP 1991; FAO et al. 1996).

Comparison with the nuclear bombings of Japanese cities in 1945 and with weapons testing

Many attempts have been made to compare the radiological consequences of the Chernobyl accident with the consequences of other major nuclear events. They have been compared primarily with the consequences of the nuclear bombings of Hiroshima and Nagasaki in 1945 and the series of atmospheric nuclear weapons tests in 1950–1960, and sometimes also with other events, like the discharge of radioactive waste into the Techa River in 1949–1951 and the accidents at Kyshtym and Windscale in 1957. Depending on the comparison criteria chosen, authors have reached different, sometimes paradoxical, conclusions. The opinion has often been expressed that the Chernobyl accident has had considerably more severe consequences than the bombings of Hiroshima and Nagasaki, since a far greater amount of radionuclides, in particular the relatively long-lived ^{137}Cs, were released into the environment during the accident. At the same time, the activity released into the biosphere as a result of the nuclear tests was incomparably greater than the release from the Chernobyl accident. In this paper we will limit ourselves to an examination of only the former three major events, which have attracted the most public attention.

As a specialist in human radiation protection, the author considers the most valid approach to be comparison of the consequences of these events in terms of damage to the health of the exposed population, viz. the number of cases of premature death. It is natural to take into account not only the number of cases of early death but also the cases of established or predicted death from radiation-induced cancer. In so doing, it should be understood that the latter cases are different in that (1) they cannot be identified amongst the overall number of deaths from cancer, and (2) the loss of years of life in this group is on average 10–15 y less than in the case of early death due to the latent period and the development period of the illness.

Data regarding acute effects leading to death, i.e., explosive and thermal impact, as well as cases of ARS, are usually documented. As proposed in the previous section, we will estimate roughly the number of expected deaths from radiation-induced cancer in the three populations in question as the product of the collective dose in people with individual or average group doses >0.1 Sv and the corresponding radiation risk coefficients:

$$N = RC \times CD\,(>0.1\ \mathrm{Sv}) = RC \times \sum_i D_\mathrm{i},\ \text{cases}, \tag{1}$$

where RC is radiation risk coefficient (Sv^{-1}), CD (>0.1 Sv) is the collective dose for dose values above 0.1 Sv, and D_i is individual or average group dose ($D_\mathrm{i} > 0.1$ Sv).

For rough estimation, the risk factors for death from radiation-induced cancer can be taken from ICRP Publication 60 (ICRP 1991), equal to 0.1 Sv^{-1} for acute exposure and 0.05 Sv^{-1} for prolonged exposure.

Specific demographic and dosimetric data relating to the atomic bombings of Hiroshima and Nagasaki in 1945 were taken from RERF (www.rerf.or.jp) and Preston et al. (2003), the data on global fallout were taken from UNSCEAR (2000), and the data on the Chernobyl accident from the Chernobyl Forum report (IAEA 2006a). For atomic-bomb survivors, the author roughly extended collective dose from LSS cohort to ~280,000 officially registered persons. For the Chernobyl accident, the author roughly extended collective effective dose (without thyroid dose caused by intake of radioiodine) from population of areas with ^{137}Cs soil deposition >37 kBq m^{-2} in Belarus, Russia, and Ukraine, to the whole of Europe (see also Cardis et al. 2006). The collective dose both in workers and general public was taken into account. The results are presented in Table 4; the author's own estimations using data from the aforementioned publications are given in parentheses.

From Table 4 it follows that, of the events examined, the greatest number of fatalities (~200,000) was undoubtedly caused by the atomic bombings of the Japanese cities, with cases of premature death from various types of impact (mechanical, thermal, and radiation) predominating. The contribution of long-term mortality from radiation-induced cancer in survivors of the bombing is of the order of 1%. The release of

Table 4. Major consequences of the atomic bombings of Japanese cities in 1945, global radioactive fallout from nuclear weapons testing since 1950's and the Chernobyl accident in 1986.

Event, year	Number of casualties	Collective dose in survivors (10^3 person-Sv)		Number of projected deaths	^{137}Cs release (PBq)	Economic damage	Social disruption
		Total	$D_i > 0.1$ Sv				
Bombing of Hiroshima and Nagasaki cities, 1945	150,000–220,000	(~30)	(~20)	(~2,000)	0.2	Large	Large
Global fallout, since 1950's	—	~5,000	—	—	~1,000	Small	None
Chernobyl accident, 1986	30	(200–300)	(~80)	4,000	85	Large	Large

radionuclides into the environment, particularly ^{137}Cs, was the smallest of the three events examined.

In second place in terms of medical consequences is the Chernobyl accident, with 4,000 of the 600,000 most exposed persons predicted to die from radiation-induced cancer. Here, on the other hand, the contribution of early death from radiation sickness and from the consequences of the explosion are only of the order of 1%. The release of ^{137}Cs was 400 times greater than during the nuclear bombings of 1945, but an order of magnitude lower than during the nuclear tests carried out for many years afterwards.

And, finally, the global fallout of radioactive products from nuclear tests caused small individual doses to the world population, which were on average noticeably <0.1 Sv, above which harmful effects of radiation on human health have been definitely observed. Therefore, despite the huge fallout of ^{137}Cs onto the surface of both hemispheres, particularly the northern hemisphere, and the corresponding collective doses, in general we do not think it is possible to predict their carcinogenic consequences owing to the lack of direct epidemiological or even experimental data for such small doses. An exception is the small population groups in the Arctic engaged in reindeer breeding, where the long-term internal doses of ^{137}Cs entering the body with reindeer meat since the beginning of the 1960's are estimated to be tens of millisieverts (Strand et al. 2002). These doses could have been taken into account in a prognosis of carcinogenic consequences, but this specific problem is not dealt with in this paper. Nor are the social and economic consequences of these events dealt with in detail here. For the sake of completeness, they are characterized only qualitatively in Table 4.

Thus, the damage to the health of the population from the impact of the Chernobyl accident in 1986 was approximately two orders of magnitude less than that of the atomic bombing of the Japanese cities in 1945, even though it released many times more radionuclides.

Chernobyl studies as a source of new knowledge

The Chernobyl accident has inevitably given rise to an enormous number of studies in the fields of nuclear technology and safety, radioecology, radiation medicine and protection, and also the social sciences.

Studies on the operational management of different types of reactors, on the development physical and chemical mechanisms of severe nuclear accidents and their modeling and prevention, and on the role of the human factor have been intensified. Numerous measures have been drawn up and promptly brought into practice with a view to substantially enhancing the safety of RBMK type reactors operating in Russia, Ukraine, and Lithuania (Birkhofer 1996; INSAG 1993). The experience gained through the accidents at Three Mile Island in 1979, and at Chernobyl, have stimulated the development of conceptually new fourth generation nuclear power reactors with strengthened internal safety systems.

The Chernobyl accident has provided a very strong incentive to the study of radioecology for at least two reasons. Firstly, because of the need for scientific substantiation of measures for radiation protection of the population and rehabilitation of contaminated areas and, secondly, as a unique short-term radioactive marker of atmospheric, hydrological, geochemical and biological processes in the environment. The range of the studies, most of which have been carried out in Europe, including the USSR and its successor States, is characterized by the publication over a period of 20 y of >20,000 scientific articles, according to data from the IAEA (2007). One of the leading radioecologists of the twentieth century, Dane A. Aarkrog, singled out the post-Chernobyl period as one of the four main developmental periods for radioecology (Aarkrog 1994).

Data from radioecological studies have allowed current estimates to be made of the radiation doses received by the populations of contaminated areas in the past and at the present time, and predictions to be made for the future. The contributions to the human radiation dose from different exposure pathways (external exposure from the plume and from radioactive fallout, internal exposure by means of inhalation and ingestion of radionuclides from food and drinking water) have been studied carefully, as have been the contributions of different ecosystems (urban, agricultural, forest, and water). The natural laws governing the transfer parameters of a number of radiologically important man-made radionuclides (iodine, cesium, strontium, transuranium, and others) among the components of terrestrial and water ecosystems have been investigated and determined, and the body of information obtained has been compared with all the information from the pre-Chernobyl period (Alexakhin and Korneev 1991; SCOPE 1993; Dahlgaard 1994; Karaoglou et al. 1996).

The experience gained in applying radiation protection measures in the environment is invaluable (Alexakhin et al. 2007). It has *inter alia* been used as the basis for protecting the populations of contaminated areas over the last 20 y. As a result of the implementation of a number of international projects, the IAEA and also the European Commission in cooperation with CIS countries have developed detailed guidelines for radiation protection of the public in the event of possible future nuclear or radiological accidents involving radionuclide releases into the environment (IAEA 1994; Karaoglou et al. 1996). They include procedures and codes for radiological evaluation (COSYMA, RODOS), as well as practical recommendations on technologies for protection and rehabilitation measures (e.g., EC project STRATEGY).

UNSCEAR (1996) and IAEA (2006a) reports have shown that high doses in the vicinity of the Chernobyl accident site (up to 10–30 km) have led to many biological effects in animals and plants (Hinton et al. 2007). The radiation effects in the terrestrial and water biota in natural conditions are of paramount interest not only for general radiobiology but also for validating a biota radiation protection system, which is currently under active development (ICRP 2003; IAEA 2005). Unfortunately, only a few results of experimental studies in the Chernobyl accident area can be quantitatively correlated with the dose and transferred to other conditions, since the doses in the biota in the post-accident period were not determined accurately. This situation is not hopeless provided sufficient efforts are made to reconstruct the dose in different biota species, particularly the surface beta radiation dose in the early period.

In the field of radiation medicine, we can identify two clusters of new knowledge linked to the Chernobyl accident. The first is related to methods of treating ARS, especially when there is a combination of whole-body exposure and local radiation burns. Here, a great measure of success has been achieved, enabling the lives of the majority of the emergency workers who received life-threatening radiation doses to be saved and allowing them to return to normal life (UNSCEAR 1988; Gusev et al. 2001).

The second area of highly productive investigation is radiation epidemiology of the long-term radiation effects on workers and the public. UNSCEAR (2000) and WHO (2006) reports showed that studies on thyroid cancer in people who were children or adolescents in 1986 have today proved to be most informative. Owing to the low spontaneous incidence rate at a young age and as a result of high doses in the thyroid gland of hundreds of thousands young people caused by the intake of ^{131}I with milk, this effect was detected at the start of the 1990's and since then has been studied thoroughly with respect to the dependence of radiation risk factors on sex and age, the contribution of short-lived iodine radioisotopes, the influence of stable iodine prophylaxis, etc. This information is already being used to plan countermeasures during nuclear accidents.

As regards other types of radiogenic cancer (leukemia, solid cancers), the results of the post-Chernobyl studies should be examined in the context of validation the prognoses of the radiological consequences of the accident, rather than as a source of independent estimations of radiation risk factors.

Thus, in the 20 y since the Chernobyl accident, a huge amount of new knowledge has been gained in a number of branches of science and the scientific potential of its study is put to great use. However, as pointed out by the Chernobyl Forum (2006), continued study of some targeted long-term consequences on the environment, as well as on the health of man and society, remains crucial.

Influence of the Chernobyl accident on nuclear safety and radiation protection

The vast experience gained in responding to the Chernobyl accident and particularly protecting the population from radionuclides in the environment has had a radical influence on the development of nuclear safety and radiation protection at both international and national levels. This marked the origin of the global nuclear and radiation safety regime, the global sharing of common visions and objectives (Taniguchi in press).

The first of several binding international documents to appear as a result of the Chernobyl accident were two important conventions aimed at cooperation in the event of serious accidents potentially involving the transboundary transfer of released radioactive material. The Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency were prepared by the IAEA in 1986 shortly after the Chernobyl accident and entered into force in early 1987 (IAEA 1987a, 1987b). Currently, around 100 IAEA Member States are party to them.

Later on, the Convention on Nuclear Safety was developed (IAEA 1996b) and ratified by all countries with nuclear power plants and additional countries neighboring countries with nuclear installations. The Convention seeks to enhance nuclear safety through peer review. The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (IAEA 1997) and the Code of Conduct on the Safety of Research Reactors (IAEA 2006b) provide similar functions at other nuclear facilities.

In early post-Chernobyl period, technology improvements made to the RBMK reactors to ensure further safe reactor operation were of primary importance. The most important of them were elimination of the positive power coefficient and improvements to the shutdown system. Other safety improvements have been made, including increasing the Design Basis Accident criteria for overpressure protection and pipe breaks. These design changes increase the reliability of the core cooling system and lessen the chance of a radioactive release.

An important step in developing the philosophy of radiation protection was the elaboration by the ICRP of principles of intervention in the event of a nuclear or radiological accident, namely principles for the justification and optimization of intervention (ICRP 1991). These general principles were soon converted into specific radiological criteria for intervention at both the early and the recovery stages of accidents (ICRP 1993). Based on the experience gained in protecting the population after the Chernobyl accident, the ICRP renounced the previous two-level system of intervention criteria (ICRP 1984) and recommended single intervention levels (ICRP 1993). Later still, partially in response to long-term Chernobyl problems, the ICRP developed recommendations on the protection of the population in conditions of prolonged exposure (ICRP 2000). In this last document, in developing the principle of optimization, new generalized criteria were proposed for making decisions on the application of protection and rehabilitation measures.

The IAEA, in cooperation with other international organizations, converted the ICRP recommendations into international safety standards, at first in the form of general requirements (FAO et al. 1996) and then also in the form of special requirements on preparedness and response for a nuclear or radiological emergency (FAO et al. 2002) and on remediation of areas contaminated by radionuclides as a result of past accidents (IAEA 2003). In introducing these and other safety standards, IAEA has organized cooperation among a number of international organizations to develop the means for adequate response to radiation accidents. Through its technical cooperation system, IAEA carries out ongoing regional and national projects to improve the preparedness of its Member States for such situations.

More generally, the series of International Safety Standards, which were developed and promulgated throughout the nuclear industry by the IAEA in the post-Chernobyl period, provide guidance for maintaining safety management. These Standards have become accepted by the international community and are the basis for assessing nuclear safety in all stages of existence, at all types of nuclear installations.

Before the Chernobyl accident there were no international standards for permissible levels of radionuclides in food products. Already by May 1986, however, in response to the threat of internal exposure of the inhabitants of many European countries, such standards had been rapidly developed and entered into force in the USSR and the European Union, firstly for ^{131}I, and then for radionuclides of cesium (^{134}Cs and ^{137}Cs) and also ^{90}Sr. In 1989, in response to international demand, the Codex Alimentarius Commission established *Guidelines on Levels for Radionuclides in Food for Use in International Trade* (CAC 1991). These guidelines have recently been updated.

Since 1986, IAEA has been operating an emergency response center, which is an international focal point for collecting data on accidents that have occurred around the world, and a body for organizing assistance upon the request of States.

Influenced by Chernobyl lessons, assistance of experts from countries with substantial radiological experience, including treatment of radiation injuries, has become common international practice in case of emergencies that happen from time to time in some regions of the world. As for emergency preparedness and response, the preventive protective actions for the public in case of a developing nuclear emergency suggested by IAEA are now accepted in many countries.

The Chernobyl accident revealed a need for the preventive development of environmental countermeasure technologies which can be applied to different ecosystems, above all urban and agricultural ecosystems. Many such technologies were known in the USSR as a result of the experience gained in the Kyshtym accident (IAEA 1990; EC 1991); others have been developed and applied ad hoc. Later, pursuant to the results of analysis of the effectiveness of the protective technologies applied in the Chernobyl accident area, international and regional guidelines were developed for radiation protection in the event of serious accidents involving the release of radioactive substances into the environment (EC projects RECLAIM; STRATEGY).

After the Chernobyl accident, a number of countries established national radiation emergency centers. Aiming to provide technical support for their operation, the countries developed and put in operation automatic early warning systems for detection of elevated levels of airborne activity as well as assessment tools for evaluation of possible radiological consequences and decision support regarding protection actions.

This very short list of innovations shows that it is difficult to overestimate the influence the Chernobyl experience has had on the continuing development of an international system for nuclear safety and radiation protection.

CONCLUSION

The accident at the CNPP in 1986 was the most severe in the history of the nuclear power industry, causing a huge release of radionuclides over large areas of Europe. The accident was a human tragedy and had significant environmental, public health, and socio-economic impacts.

Radiation levels in the environment have reduced by a factor of several hundred since 1986 due to natural processes and countermeasures. Therefore, the majority of the land that was previously contaminated with radionuclides is now safe for life and economic activities. However, in the Chernobyl Exclusion Zone and in some limited areas of Belarus, Russia, and Ukraine some restrictions on land use should be retained for decades to come.

The majority of the >600,000 emergency and recovery operation workers and five million residents of the contaminated areas in Belarus, Russia, and Ukraine received relatively minor radiation doses which are comparable with the natural background levels; this level of exposure did not result in any observable radiation-induced health effects. The mitigation measures taken by the authorities, including evacuation of people from the most contaminated areas, substantially reduced radiation exposures and the radiation-related health impacts of the accident.

An exception is a cohort of several hundred emergency and recovery operation workers who received high radiation doses; of whom 134 persons developed ARS and 28 died in 1986. Nineteen more ARS survivors died from 1987–2004 from various reasons.

Another cohort affected by radiation are children and adolescents who in 1986 received substantial radiation doses in the thyroid mainly due to the consumption of milk containing radioiodine. In total, about 4,000 thyroid cancer cases have been detected in this cohort during 1992–2002; >99% of them were successfully treated. Many of those cases were caused by radiation and more are expected in the future.

According to biostatistical prognosis, among the 600,000 persons receiving more significant exposures (liquidators working in 1986–1987, evacuees, and residents of the most "contaminated" areas), the possible increase in cancer mortality due to radiation exposure might be up to a few percent. Among the five million persons residing in other "contaminated" areas of Belarus, Russia, and Ukraine, the doses are much lower and any projected increases are more speculative, but are expected to make a difference of <1% in cancer mortality.

Apart from the dramatic increase in thyroid cancer incidence among those exposed at a young age and some increase of leukemia in the most exposed Russian workers, there is no clearly demonstrated increase in the cancer incidence due to radiation in the most affected populations. There was, however, an increase in psychological problems among the affected population, compounded by insufficient communication about radiation effects and by the social disruption and economic depression that followed the break-up of the Soviet Union.

The governments took many successful countermeasures to address the accident's consequences. However, recent research shows that the direction of current efforts should be changed. Social and economic restoration of the affected Belarusian, Russian, and Ukrainian regions, as well as the elimination of the psychological burden on the general public and emergency workers, must be a priority. Additional priorities for Ukraine are to decommission the destroyed Chernobyl Unit 4 and gradually remediate the Chernobyl Exclusion Zone, including safely managing radioactive waste.

Despite the unprecedented scale and character of the Chernobyl accident, its consequences on the health and lives of people are far less severe than those of the atomic bombings of the cities of Hiroshima and Nagasaki.

Studying the consequences of the Chernobyl accident in terms of nuclear technology and safety, radioecology, radiation medicine and protection, and also the social sciences has made an invaluable scientific contribution to the development of these disciplines. Targeted research of some long-term environmental, health, and social consequences of the Chernobyl accident should be continued for decades to come.

The Chernobyl accident initiated the global nuclear and radiation safety regime. Since the Chernobyl accident, our world has become more cautious with regard of use of nuclear energy and radiation sources and, therefore, much safer. However, diligence is required to make certain that the lessons learned from Chernobyl are not forgotten.

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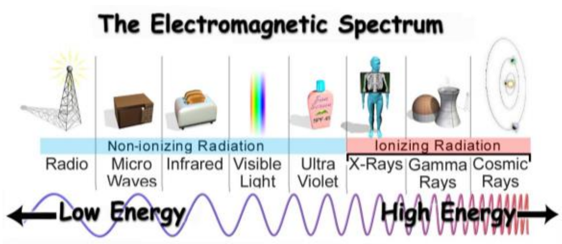
Chernobyl Documentary
Radiation Primer

To understand some of the concepts we will present in this documentary, it is important to first review some basic radiation terminology and characteristics.

The word 'radiation' has many meanings. There are different types of radiation, many which are not harmful at all. *[Graphic - electromagnetic spectrum]* Television waves, radio waves, and radar are all examples of radiation, and none of these cause harm to living organisms. These types of radiation do not have enough energy to cause damage to living tissue, and are called *non-ionizing radiation.*



The other general category of radiation is called *ionizing radiation* which does have enough energy to cause damage to living tissue. Ionization is a destructive process that causes atoms or molecules to lose electrons. X-rays, cosmic rays, and nuclear radiation are types of ionizing radiation.

Many radioactive materials occur naturally. For example, granite contains remnant radioactive isotopes from the formation of the earth, and when granite erodes, these radioisotopes are carried away as sand and clay that form the soil around us – there are beaches in Brazil with such high natural radiation levels that they have restricted access. Sand and clay are also used to make building materials such as brick and concrete, which may emit very low levels of radioactivity. Other naturally occurring radioactive isotopes are created when cosmic rays interact with atoms in the atmosphere. We are also exposed to manmade radioactive materials that have been released into the environment. Nuclear weapons testing has contributed to a slight increase in background radiation. You may also be exposed to radiation through medical procedures such as x-rays. You are exposed to radiation, known as background radiation, every day, and the amount of background radiation you are exposed to depends on where you live.

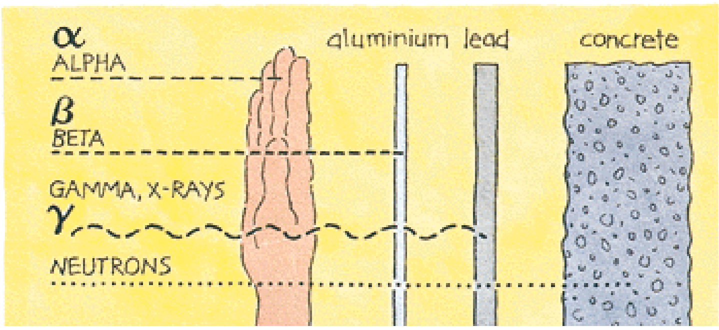
Nuclear radiation, which comes from the nucleus of an atom, is the type of radiation that most people think of when discussing radioactivity, and our discussion will focus on nuclear radiation. Remember that an atom is made of neutrons and protons that form the nucleus and electrons that orbit around the nucleus. *[show atom structure graphic]* There are over100 different types of atoms and each has a specific number of protons that identifies the atom as an *element*, such as oxygen or iron. For example, the element uranium always has 92 protons. However, the number of neutrons can vary. Elements with the same number of protons but different numbers of neutrons are called *isotopes*. For example, uranium can have 138 neutrons or 146 neutrons. Uranium with 146 neutrons is known as the isotope U-238.

[Graphic: table of uranium isotopes]

Radionuclide	**Protons**	**Neutrons**
Uranium 230	92	138
Uranium 235	92	143

Uranium 238	92	146

Certain isotopes are unstable because they have too many protons or neutrons. They essentially have too much energy and they release that extra energy to become more stable. This happens spontaneously and is called *radioactive decay*. These isotopes are radioactive. Radioactive isotopes release energy primarily as four types of radiation: alpha particles, beta particles, gamma rays, and neutrons. Each type of radiation has different ability to penetrate materials *[see graphic]*.



Nuclear radiation is measured in several different ways. When we talk about the amount of radioactive material, we don't use weigh or volume because it does not have much meaning. Instead, we talk about the amount of radiation emitted from the material, or *activity* of the material.

[NOTE – We could potentially lose this whole alpha, beta, gamma, neutron breakdown, as there isn't a place later in the documentary where we go into the types of radiation given off by Chernobyl]

They release energy primarily as four types of radiation: alpha, beta, gamma, and neutrons. We will discuss the characteristics of each.

Alpha particles are two protons and two neutrons ejected from the nucleus of a radioactive atom. *[graphic - animation of alpha decay]* They have lots of energy but can only travel up to an inch or two in air and are easily stopped by a piece of paper. They are also easily stopped by the outer layer of your skin which is made of several layers of dead skin cells. However, serious damage can occur if you inhale or ingest an alpha emitter. In fact, internal alpha radiation exposure is the most damaging type of radiation. An unfortunate example is the former Russian KGB officer Alexander Litvinenko who ingested a lethal quantity of the rare alpha emitter polonium-210. Exposure to alpha particles can mostly be eliminated by wearing a respirator.

Beta particles are electrons ejected from the nucleus. Beta radiation can travel several feet in air and can penetrate up to a half inch into human tissue. It takes thick plastic or metal to stop beta radiation. A respirator will protect a responder from inhaling beta emitters and protective suits will provide some protection from beta radiation by preventing contamination of bare skin. *[show animation of beta decay]*

Gamma rays are electromagnetic energy (not particles) that comes from the nucleus, usually at the same time alpha or beta particles are emitted. They travel many yards in air and penetrate right through the human body. Gamma rays are the most serious external exposure hazard and there is no practical protective suit that will stop gamma radiation. It takes about a foot of lead or several feet of concrete to stop all gamma radiation. A respirator is still beneficial to prevent ingesting gamma emitters. Although gamma is hard to stop, it is easy to detect. Based on the amount detected, responders can take actions to protect themselves, for example, by limiting the time they are exposed. *[graphic - animation of gamma decay]*

The last type of ionizing radiation is neutron radiation. This comes from the nucleus but is rarely emitted spontaneously. Instead neutron radiation is created by nuclear reactions such as those in a power plant or detonation of a nuclear bomb. Neutrons can travel very far in air, up to a mile and can penetrate through the human body. They are not easily stopped or detected. It takes many feet of concrete to stop neutrons. There is no protective equipment for neutron radiation.

This illustration summarizes the penetrating power of the four types of ionizing radiation that we have discussed. {show graphic}

Activity is usually measured in *curies,* which is the amount of radiation emitted by one gram of radium. A curie is equal to 37 billion disintegrations per second, or 37 billion gamma rays, alpha particles, or beta particles per second. The physical amount of material to make one curie could be one gram of radium or thousands of kilograms of some other radioactive material. That is why the amount of material is not important but the activity of the material is!

The activity of a radioactive material is closely related to the material's *half-life,* or is the amount of time it takes for the radioactivity of the material to decrease by half. For example, if the half life on isotope is one day, then after one day, half of the material will have decayed. The remaining half is still radioactive, so after another day half of this portion will have decayed. The decay process continues until no more radioactive material remains. Depending on the starting amount, it takes about 7 to 10 half-lives before the radioactivity is near background levels of radiation.

Each radioactive isotope has a unique half-life. *[graphic - half life table]* Half-lives of some isotopes are billions of years; other isotopes have half-lives of just a few seconds. Isotopes with shorter half-lives have higher activity, and tend to pose more serious health threats. This makes sense because a short half life means a material is emitting a lot of radiation in a short time.

Isotope	**Half-Life**	**Origin**	**Uses**
Uranium-238	4.5 billion years	Naturally occurring	Armor-piercing projectiles
Carbon-14	5,730 years	Naturally occurring	Carbon dating fossils
Cesium-137	30 years	Manmade	Geiger counters
Iodine-131	8 days	Manmade	Treat thyroid cancer
Technetium-99m	6 hours	Manmade	Medical imaging
Strontium-97	9 seconds	Manmade	None

Half-life is also important from the perspective of environmental cleanup. If a material with a long half-life is released then it will take a long time to decay to a harmless level. Cesium-137, one of the isotopes released by the Chernobyl accident, has a half life of 30 years. Cesium-137 continues to this day to be the primary contaminant of concern in most of the areas affected by the Chernobyl accident. After 32 years, almost half of the Cesium-137 released by the accident remains. On the other hand, one of the other major isotopes released by the accident (Iodine-131) has a half-life of 8 days. Iodine-131 was a major health concern shortly after the accident, but essentially all of it has decayed away by now and it is no longer a problem.

We need to cover one more topic before we go back to our story about Chernobyl*: nuclear reactions*. A nuclear reaction is one where the nucleus of an atom is changed, releasing incredible amounts of energy. At Hiroshima and Nagasaki, *uncontrolled* nuclear reactions occurred in a split second, releasing huge amounts of energy and radioactive isotopes with short half-lives. Most of these short half-life isotopes have decayed away, and the cities of Hiroshima and Nagasaki are now vibrant urban centers. *Controlled* nuclear reactions such as those used at nuclear power plants, on the other hand, take place over longer periods and create more isotopes with long half-lives. Both controlled and uncontrolled nuclear reactions create long and short half-life radioactive isotopes, but a controlled nuclear reaction creates a much higher proportion of long half-life isotopes. This is a fundamental reason that Hiroshima and Nagasaki are active urban centers with large populations, but the exclusion zone around the Chernobyl plant is expected to be uninhabitable for 1,000 years.

[NOTE – We may need to get into the discussion of dose later in the documentary, especially when we kick into the residual levels of contamination that are left. At this point, we've defined too many new terms, yet hit the highlights – isotopes are created by reactions, and they can be radioactive.

The short half-life isotopes are the problem because they release a lot of energy fast. The longer half lives are an ongoing problem because they really don't go away.

In a similar vein, we may want to introduce the idea of fallout and hot particles here in the primer rather than later. I chose to put that later in the story, as this is a long section with a lot of new terms and it's pretty dry – best to keep it short and focused if we can.]

Note the last radionuclide in the table, uranium-235. This is an important radionuclide in our story about Chernobyl. Although it has a very long half-life and is not very radioactive, uranium-235 is a fissile material. This means it can undergo fission which is when a nucleus is split releases lots of energy in the process. Uranium-235 is made into fuel for a nuclear power plant or an atomic bomb. The uranium-235 used in an atomic bomb undergoes an uncontrolled reaction releasing incredible amounts of energy in a split second for destructive purposes. Nuclear reactor fuel undergoes fission in a controlled manner and the energy released is harnessed to make electricity.

As the nuclei of uranium-235 fission they are turned into numerous other radionuclides, like cesium-137 and strontium-90. These radionuclides have much shorter half-lives than uranium-235, thus are much more radioactive and potentially dangerous to us. Cesium-137 we mentioned previously as the primary contaminant of concern from the Chernobyl accident because it is persistent with a half-life of 30 years. Many more radionuclides with much shorter half-lives were released from the accident and have since decayed to background levels.

Before we get into the other units of measurement we should review the difference between exposure and dose. Radioactive materials emit radiation in all directions which creates a "radiation field." If the radiation is gamma then the radiation field can extend over a large area. Exposure is when you are in a radiation field, basically, the radiation is bombarding your body. As the radiation interacts with your cells damage will occur. The damage is called dose. Dose is cumulative, so the more radiation that interacts with your body the higher your dose. Now how is the radiation field and dose measured?

The radiation field is measured using various field portable instruments with very sensitive detectors. There are detectors for all types of radiation. Detectors that measure gamma typically provide readings in roentgen [note to narrator: pronounced ran-'kin]. The technical definition is not important, however, it is only applicable to measurement of gamma radiation. Many instruments measure the radiation field over time and readings are in roentgen per hour. However, because these instruments are so sensitive they can detect background levels of radiation. Background radiation is at very low levels of radiation. It is so low that we have to measure micro amounts. Remember that micro means one millionth. Thus, these instruments measure in the microroentgen per hour levels. As we stated before, background is different everywhere but in most areas in the United States background gamma radiation is typically between 10 and 30 microroentgen per hour. To put these measurements into perspective, we are usually not concerned about our immediate health and safety until levels are in the milliroentgen per hour range or about a thousand times higher. And we don't become really concerned until levels are over a million times higher than background!

Dose is measured in units of roentgen equivalent man or rem. Rem is related to the amount of damage to the human body so it does not work for animals or plants, which by the way, are usually much more resilient to radiation than human beings. The international version of a rem is the sievert and just like the becquerel, only the United States and Russia use the rem. But the conversion is easy because there are 100 rem in one sievert. For a frame of reference, the average person in the United States receives about 360 millirem per year from background radiation. This is a very low dose and as far as we know not harmful to us.

Let's put the various measurement altogether. {show Units Illustrated animation slide} The amount of radioactivity of a material is measured in curies. It emits a radiation field that can be measured with a radiation instrument in roentgen. The damage to human is measures in rem.

{show Exposure and Dose animation slide} We consider all radiation to have a harmful affect on us and there is an accumulated affect. The more radiation absorbed by your body the higher the dose. Dose is accumulated as long as we are exposed to the radiation field. We like to reduce our dose as much as possible, both short and long term exposures. [do we want to talk about ALARA? – probably not]

Background - however, we do not start to see immediate biological changes in our bodies until a dose of 25 rem or nearly 70 times our yearly background dose. At this dose there will be some temporary changes in our white blood cell counts but that is about it. The long term consequences of a 25 rem dose are essentially unknown. However, we do know that there is an increased chance of getting cancer and increase chance of dying from the cancer due to radiation exposure. In the United States, there is about a 20 percent change that you will die from cancer. If you receive one rem of dose then your chance of dying from cancer increases by about seven hundredth of a percent. Thus, a 25 rem dose increases our chance of dying from cancer by less than two percent. {show Cancer Statistic table}

Exposure	**Chance of Dying from Cancer**
Background	20%
1 rem	20.07%
25 rem	21.8%
100 rem	27%

It is important to understand that a dose of 25 rem is extraordinary. Occupational limits are set at 5 rem per year and very few workers that work with radiological materials reach that level in a year, most don't reach that level in their entire work career. [do we want to discuss guidance levels for emergency responders which is 25 rem to save lives and greater than 25 rem by volunteer only according to EPA?]

We looked at the half lives of a few naturally occurring and manmade radioactive materials. There are many more of each with the manmade radionuclides usually made for useful purposes. Most of the manmade radionuclides have a fairly high activity and in sufficient quantities can be deadly. Examples are cobalt-60 with a five year half life used for various industrial and medical purposes, like cancer treatment. {show table of Radionuclide Uses in the United States}

Radionuclide	**Half-Life**	**Uses**
Americium 241	433 years	Smoke detectors
Cobalt 60	5 years	Cancer treatment
Gallium 67	3 days	Medical diagnosis
Hydrogen 3	12 years	Luminous exit signs
Iridium 192	74 days	Test integrity of pipe welds
Uranium 235	704,000,000 years	Nuclear power plant fuel

More information to add to primer:
Hot particle
Fallout
Environmental damage—fate and transport *radioisotope dispersal patterns and persistence in the environment*

SUMMARY AND DISCUSSION OF MAJOR FINDINGS FROM CHERNOBYL

Lynn R. Anspaugh,* Elena Buglova,† John D. Boice, Jr.,‡ Lars-Erik Holm,§ Ralph L. Andersen,** and Thomas S. Tenforde††

In the final session of the 42nd Annual Meeting of the National Council on Radiation Protection and Measurements (NCRP), the chairpersons of the five earlier scientific sessions presented their views on the highlights and major conclusions of talks given in their sessions. The following is a brief summary of the statements by the session chairs. The moderator of this panel discussion was Dr. Thomas S. Tenforde, President of the NCRP.

Dr. Lynn R. Anspaugh: Chair of session on "Environmental Impacts and Mitigation of Residual Radiation"

Key points are as follows:

- The Chernobyl accident was a result of a poorly conceived reactor safety experiment and had enormous consequences;
- The outcome demonstrated a need for improved fail-safe mechanisms to be integrated into future reactor designs;
- The emergency response was not well organized for several hours, but proceeded rapidly once it was underway; a total of 116,000 people from the region near Chernobyl were evacuated within days after the accident, and 350,000 were ultimately relocated;
- Radioactive releases from the damaged reactor were mapped relatively quickly and milk and dairy products were monitored and diverted from public use; cleanup and agricultural countermeasures were undertaken; studies of Chernobyl radiation effects on exposed humans and natural biota have been informative and are continuing;
- Initial efforts by the USSR to conceal the magnitude of the accident and the release and dispersal of radionuclides through much of Europe and worldwide were inappropriate and created global concerns;
- Conclusions of the 2005 Chernobyl Forum and earlier reports of the United Nations Scientific Committee on Effects of Atomic Radiation were helpful and endorsed by the United Nations General Assembly;
- Efforts are continuing to secure the highly radioactive structure of the damaged Chernobyl reactor and store radioactive waste materials in an ecologically safe confinement system; and
- A continuing challenge is to ensure that all possible measures be implemented to respond more effectively to a future major accident in nuclear facilities worldwide.

Dr. Elena Buglova: Chair of session on "Dosimetry and Health Effects in Emergency Responders and Cleanup Workers"

Major conclusions are as follows:

- Radiation exposures of liquidators were variable and consistent dosimetry procedures were not employed; dosimetry records exist for only about one-half of the liquidators and there has been a need for retrospective dosimetry assessments for epidemiological studies and health risk evaluation; efforts have been made to assess doses to liquidators using biological measures including electron paramagnetic resonance analysis of tooth enamel, cytogenetic endpoints, and fluorescence in situ hybridization analysis of gene and chromosome damage;
- Acute health effects among liquidators were well characterized, and 134 cases of acute radiation syndrome were confirmed;

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0017-9078/07/0

- Among these 134 liquidators, 28 persons who received a combination of high external doses of gamma radiation and skin burns due to beta irradiation died in 1986 due to acute radiation syndrome (95% of short-term deaths occurred after whole-body doses ≥6.5 Gy, and bone marrow depression was the main cause of early death); 19 more died in 1987–2004 from other causes;
- Application of bone marrow transplantation for treatment of highly exposed individuals was generally unsuccessful;
- Skin doses from beta irradiation were large compared to doses resulting from internal contamination and doses to bone marrow resulting from whole-body gamma irradiation;
- The Ministry of Health Care of the Russian Federation has maintained a large registry of liquidators (~186,000) and residents of four contaminated regions located near Chernobyl (~368,000) to study the incidence of late health effects, including both cancer and noncancer effects;
- Some, but not all, studies of liquidators have reported increased risks of leukemia 10 y after the Chernobyl accident following doses >150 mSv; a small elevation in risk of cerebrovascular diseases (≤20%) was reported among workers who had been in the 30-km exclusion zone and received doses greater than 150 mSv in <6 wk, which will require further confirmation; and
- Exposures of about 1,500 workers involved in stabilizing the sarcophagus of the Chernobyl reactor where the 1986 accident occurred are being closely monitored by external dosimeters and biodosimetry methods; respiratory protection and other exposure controls have been implemented as protective measures for these workers.

Dr. John D. Boice, Jr.: Chair of session on "Population Exposures and Health Effects"

Highlights are as follows:

- Extensive dosimetry measurements have been made on exposed individuals and ^{137}Cs in foodstuffs and deposited on the ground;
- In the exposed population the average thyroid dose in adults was ~300 mGy and in the most exposed infants was 1,000 mGy or more; whole-body doses from external or internal irradiation were mainly due to ^{137}Cs and, on average, were ≤2% of the thyroid doses;
- Excess thyroid cancer risk has been and continues to be observed in the more highly exposed population of children exposed at age <20 y;
- Thyroid cancer risk decreased with increasing age at exposure, was higher among women, iodine deficiency (from food sources) enhanced risk of thyroid cancer, and iodine prophylaxis (KI supplements) significantly decreased risk of thyroid cancer even if given months after exposure, suggesting that thyroid function in areas of endemic goiter could enhance the effectiveness of radioiodines to cause thyroid cancer;
- Several classes of chronic disease, including leukemia, breast cancer, and autoimmune thyroiditis, have been studied in the exposed population using relatively weak epidemiological methods; some evidence has been found for an increase in the risk of autoimmune thyroiditis based on antibody measurements but not clinical symptoms;
- Although not well designed, epidemiological studies have demonstrated an increase in mental health effects such as stress-related psychological symptoms among exposed populations, especially surviving liquidators; and
- No direct brain effects have been documented among liquidators or members of the exposed population, including those exposed as infants.

Dr. Lars-Erik Holm: Chair of session on "Lessons Learned from Chernobyl"

Major conclusions are as follows:

- A major project, designated as the ETHOS Project, has been implemented by the European Commission to rehabilitate the territories in the Belarus Republic that were heavily contaminated as a result of the Chernobyl accident; this program addresses both technical and social aspects of problems posed by radioactive contamination in Belarus villages, with the goal of improving the living conditions of the inhabitants;
- The International Atomic Energy Agency has studied the Chernobyl accident and other radiological incidents that adversely affected human health and the environment, and formulated a set of general principles that serve as a foundation for international guidance and standards related to the operation of nuclear reactor facilities; these principles describe emergency preparedness and countermeasures to be taken in the event of a nuclear accident, even if the probability of an accident is low;
- Efforts must be made to provide accurate and easily understood information to exposed members of the public, and to provide long-term health monitoring and early disease detection and treatment to the affected population;
- Apart from the large increase in thyroid cancer incidence in young people, there are at present no clearly demonstrated radiation-related increases in cancer risk in the population exposed to radiation from the Chernobyl accident; reports of increased leukemia risk

among liquidators and of breast cancer among premenopausal women are noteworthy, but will require confirmation in additional studies; and

- Predictions of the long-term cancer burden related to radiation exposure from Chernobyl are uncertain, especially because the applicability of risk estimates from other populations with different genetic and environmental backgrounds exposed in many cases to higher doses and dose rates and to different types of radiation is unclear; there is a need for continued monitoring of the exposed population and analysis of the results using carefully designed, large-scale epidemiological studies.

***Mr. Ralph L. Andersen*: Chair of session on "International Perspectives on the Future of Nuclear Science, Technology and Power Sources"**

Highlights are as follows:

- Nuclear power is expected to grow worldwide over the coming decades and the new generation of advanced reactors that are being designed must demonstrate enhanced safety and system reliability, sustainable system designs with minimal environmental impact, and competitiveness in the cost of energy production;
- Generation-IV reactors, for which six design concepts are under active consideration, have four major technology goals: sustainability (decreased nuclear wastes and improved resource utilization); economy (decreased reactor construction and power production costs); safety and security (inherent reactor safety features and minimal accident consequences); and nonproliferation features (physical protection of nuclear materials and limitation of plutonium use);
- New reactor designs are facing challenges in the area of radiological risk management, including the evolving social demand for increased stakeholder involvement in decisions related to public, worker, and environmental health and safety issues;
- Carbon dioxide emissions and other greenhouse gases must be dramatically reduced (~10-fold) in the coming decades to control the projected increase in global temperatures and associated climate changes; this goal can only be met by low- and no-carbon alternatives for producing energy, including the nuclear option;
- Enlightened national and international policies and regulations must be developed and enforced in order to promote the increased use of nuclear power as an alternative power source; and
- Major reviews of the effects of the Chernobyl accident reported in the Chernobyl Forum and discussed at an international conference in Vienna in September 2005 have led to a general consensus that the health and environmental consequences of the accident, although large and unprecedented, should not be viewed as an impediment to future increases in the use of nuclear power.

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U.S. ENVIRONMENTAL PROTECTION AGENCY

NATIONAL DECONTAMINATION TEAM

DECONTAMINATION ANALYTICAL AND TECHNICAL SERVICES (DATS) CONTRACT

CONTRACT NUMBER: EP-W-06-089
TDD No. TO-01-07-10-0017

REVISED COST ESTIMATE TO PROVIDE
Interview Documentary

December 31, 2007

Dynamac Technical POC:
Thomas Kouris, DATS Program Manager

Dynamac Corporation
4900 Olympic Boulevard
Erlanger, KY 41018

Technical Direction Document TO-02-07-10-0017
Interview Documentary

1. Objective and Statement of Work

The objective of this technical direction document (TDD) is to prepare a professional digital video disc (DVD) of an interview with a Chernobyl scientist and a resident of Kiev, Ukraine, describing the decontamination of the Chernobyl area following the incident. The overall intent of the documentary is to present a brief description of the facts associated with the incident, the Russian government's response to the incident and the approach for decontaminating and restoring the area, and the public perception of the response and decontamination/restoration effort. The documentary will serve as medium to transmit lessons learned from the Chernobyl incident with particular emphasis on public perceptions of the government's response associated with recovery issues.

A single technical task, Prepare Documentary of Chernobyl Interviews, has been identified in this cost estimate. This task will include the following subtasks:

WORK TASK	DESCRIPTION OF WORK
Task 1.1	**Prepare Documentary of Chernobyl Interviews**
Subtask 1.1.1	**Prepare and submit background materials and interview questions**
Subtask 1.1.2	**Obtain still photographs and videotapes of Chernobyl disaster to enhance interview**
Subtask 1.1.3	**Videotape interviews**
Subtask 1.1.4	**Prepare script detailing how visual aids will be used to enhance interview**
Subtask 1.1.5	**Edit interviews, and prepare draft and final DVDs of documentary**
Subtask 1.1.6	**Produce ten 2-minute stand alone video clips highlighting aspects of response.**

In addition to the assigned technical task listed above, routine project management activities are required to support the task, including development of this cost estimate. The project management activities are identified as Task 2.1.

2. Technical Approach

The documentary is anticipated to be 40 to 45 minutes in length, and will begin with a brief (3 to 4 minute) introduction giving the historical framework of the incident and introducing the interviewer (Dr. John Cardarelli II, U.S. EPA Health Physicist) and the two to three persons being interviewed (Ms. Larisa Leonova, U.S. EPA Waste, Pesticides, and Toxics Division Quality Assurance Officer Coordinator; Ms. Vira Yakusha, Dynamac Inc., local resident at the time of the incident; and other persons to be determined by Dr. Cardarelli). The visual images will consist of about 20 to 25 minutes of images of the interview, which will be filmed in a rented studio, and about 20 to 25 minutes of video and still images of the Chernobyl incident and conditions in Ukraine at the time of the incident. The documentary will close with a brief discussion by Dr. Cardarelli, summarizing the lessons of the Chernobyl decontamination/ restoration effort. The documentary will be professionally edited and produced.

The technical approach to each of the subtasks listed above will be accomplished using the following technical approach:

Subtask 1.1.1 Prepare and submit background materials and interview questions

The documentary will begin with a brief (3 to 4 minute) introduction giving the historical framework of the incident and introducing the interviewer (Dr. John Cardarelli II, U.S. EPA health physicist) and the persons being interviewed (Ms. Larisa Leonova, U.S. EPA Waste, Pesticides, and Toxics Division Quality Assurance Officer Coordinator; Ms. Vira Yakusha, Dynamac Inc., local resident at the time of the incident; and other persons to be identified by Dr. Cardarelli). DATS will prepare the text of the brief introduction, and all parties will prepare and submit approximately 20 questions to be discussed during the interview. Ms. Leonova, Ms. Yakusha, and a third person will be interviewed separately or collectively during a single day. Other persons in may also participate in the interview. The day before the interview, all parties will meet for about 4 hours to discuss the interview and select questions to be asked during the interview.

Subtask 1.1.2 Obtain still photographs and video images of Chernobyl disaster to enhance interview

The documentary will include approximately 20 to 25 minutes of video and still images of the Chernobyl incident and decontamination efforts. These images will be obtained from commercial sources, and the still and video images will be purchased rights managed and royalty free with no broadcast restrictions, so the documentary may be shown or broadcast as required, without incurring ongoing royalty obligations. Obtaining the images will require research to determine what footage is available. DATS anticipates that obtaining the images will require two episodes of research – an initial phase to obtain general images of the incident and decontamination/restoration efforts, and a second episode to obtain images of any particular topics that the interviewers focus on during the interview. The general images will be available before the interview and will be reviewed during the initial meeting to discuss the interview questions.

Subtask 1.1.3 Videotape interviews

DATS will rent a studio venue to record the interviews, and will provide sound, lighting, backdrops, video recording equipment and personnel to operate such equipment and record the interviews. DATS will record images of the interviews in Standard Definition in an accessible and editable digital format using a Canon XL1, a professional 3CCD chip digital video camera in MiniDVD format. Lavier Wireless Microphones and ultra high frequency (UHF) receivers will be used to capture speakers' voices, eliminating unwanted location noise and producing a clean and audible voice capture. The interviews will be transcribed using a commercial transcription service for ease of selecting sections of the interviews for inclusion in the documentary.

Subtask 1.1.4 Prepare script detailing how visual aids will be used to enhance interview

After the interviews are concluded, NDT, DATS, and the video editor/engineer will confer and discuss which aspects of the interviews will be emphasized and included in the documentary, and how the documentary will be linked together into a cohesive narrative. The group will also discuss linking available images of the incident with the interview and needs for other images, as appropriate. Following this meeting, DATS will prepare a script detailing which sections of the interview will be included and the sequencing of the interview questions and images to be included in the documentary and will submit this script to Dr. Cardarelli for comment. The script will be modified as appropriate and resubmitted for comment and approval. The group will discuss which additional images, if any, will be obtained for inclusion in the documentary, based on the focus of the questions and the flow of the discussion.

Subtask 1.1.5 Edit videotapes and prepare draft and final DVDs of documentary.

DATS will prepare a draft documentary based on the approved script. This task includes all editing and merging of images and includes a voice-over narrator to read the introductory sections and any necessary linking narratives during the documentary. Video will be digitized in real-time into an editing bay and graphics will include periodic title slates to introduce persons on screen. Stock music will be incorporated to enhance the documentary as needed. DATS will prepare five DVD copies of the draft documentary and will submit the copies to Dr. Cardarelli for comment. DATS will meet with Dr. Cardarelli for one day to review the documentary and identify any necessary changes. The final draft will be modified as necessary to accommodate Dr. Cardarelli's comments. DATS will submit ten DVD copies of the final documentary and the transcript of the entire interview as the final deliverables for the project.

Subtask 1.1.6 Produce ten 2-minute stand alone video clips highlighting aspects of response.

The DATS PM will work with Dr. Cardarelli to identify ten sections of the documentary to be broken out into stand-alone video clips of the interview that highlight specific aspects of the response and associated activities. Each stand-alone video clip will have duration of about 2 minutes, and will include title graphics; subtitle graphics identifying speaker, topic, or other relevant information; video or still images of the response (if appropriate); and an ending graphic identifying the location where the entire interview can be viewed. DATS has assumed that the 2-minute clips will be extracted from the documentary and will involve video footage that is included in the documentary rather than other video images from the interviews. The 2-minute video clips are expected to include shorter sections of the documentary edited together to form a continuous 2-minute segment.

Task 2.1 Routine project management activities.

Routine project management activities include preparation of the cost estimate, and project initiation/close-out.

3. Work Schedule

The schedule proposed for completion of this TDD is provided in Attachment 1.

4. Project Staffing

Rik Lantz, DATS Scientist/Engineer III, will serve as Project Manager (PM) under this TDD. Tom Kouris, DATS Program Manager will provide oversight of the work. Vira Yakusha, DATS IT Specialist will participate in the interview and provide research about the disaster. The cost estimate was prepared by Rik Lantz and Tom Kouris.

The level of effort associated with this project staff is listed below:

Work Element	Labor (hours)
Task 1.1 Prepare Documentary of Chernobyl Interviews	**166**
Task 2.1 Routine Project Management	**29**
Totals	**195**

5. Estimated Costs

A summary of the estimated costs for this TDD is listed below by Contract Line Item Number (CLIN):

CLIN	CLIN DESCRIPTION	TOTAL
Various	Labor	$ 25,532.10
2001	Travel	$ 3,504.55
3001	Equipment/Specialized Labor/Subcontracts/Misc. ODCs	$ 35,208.93
TOTAL COST ESTIMATE FOR TDD No. TO-01-07-10-0017		**$ 64,245.58**

A spreadsheet showing all CLINs that comprise the summary is located in Attachment 2.

The basis for the level of effort for Task 1.1 is as follows:

<u>Subtask 1.1.1 – Prepare and submit background materials and interview questions</u>: The DATS PM will spend approximately 8 hours to research the Chernobyl incident and prepare an introductory text for the documentary. Both the DATS PM and DATS IT Specialist will spend approximately 4 hours each to prepare questions for the interview. The DATS PM and DATS IT Specialist will spend approximately 4 hours at a meeting to discuss the project, to select interview questions, and to prepare for the interview.

Subtask 1.1.2 - Obtain still photographs and videotapes of Chernobyl disaster to enhance interview: The DATS PM will spend approximately 4 hours working with video editor/engineer to obtain and select images to include with documentary, and to coordinate receipt and payment for images. The DATS IT Specialist will review a subset of images for inclusion in the documentary for approximately 2 hours.

Subtask 1.1.3: Videotape interviews: DATS has assumed that the DATS IT Specialist and an additional person to be identified by Dr. Cardarelli will travel to Chicago to participate in the interview. The DATS IT Specialist will travel to Chicago from Washington DC and an additional person to be identified by Dr. Cardarelli will travel to Chicago from Cincinnati. Each person will require approximately 6 hours for travel time each way, and will spend one and one half 8-hour days participating in the interview and related logistics. Other persons may participate in the interview. DATS has included labor and travel costs for participation of the DATS IT Specialist. DATS only included travel costs for one additional person from Cincinnati; no labor costs are included in the estimate. The DATS PM will spend 4 hours on interview logistics and will be present during the entire interview to observe discussion and select comments and issues to be included in documentary. The entire text of each interview will be transcribed and estimated transcription costs are included under this task.

Subtask 1.1.4 - Prepare script detailing how visual aids will be used to enhance interview: The DATS PM will review interview footage and work with the video editor/engineer to select images and portions of interviews that will be used in the documentary, and will prepare a draft script including a timeline including short description of interview remarks, the location in transcript where the complete remarks can be found, and a description of video images that will accompany remarks. The description of video images will include copies of still photos or screen shots of video images to assist in evaluation of the appropriateness of the images that accompany the text. DATS has assumed that the PM will require 20 hours to prepare a draft script of the documentary. The DATS PM and DATS IT Specialist will review and comment on the script, and the DATS PM will modify the script to address comments on the draft script. The DATS Program Manager will require two hours to review and comment on the script, the DATS IT Specialist will require four hours to review and comment on the script, and the DATS PM will require 16 hours to modify the script to address comments.

Subtask 1.1.5 - Edit interviews, and prepare draft and final DVDs of the documentary: The DATS PM will submit the approved transcript to video editor/engineer and work with the video editor/engineer to prepare the draft documentary. DATS has assumed that this task will primarily be accomplished by the video editor/engineer, and preparing the draft DVD will require the PM to spend approximately 8 hours on logistics, coordination, and question resolution. The draft DVD will be submitted to Dr. Cardarelli and the interviewees for comment and a revised version will be prepared based on comments on the draft. DATS PM will meet with Dr. Cardarelli for one day in Cincinnati to review the draft documentary and identify requested changes. DATS has assumed that the DATS PM will review the draft documentary for 2 hours before the meeting and will work with Dr. Cardarelli for 8 hours to review the documentary and identify requested changes. The DATS PM will travel to Cincinnati and will require approximately 5 hours for travel time each way. DATS has assumed that addressing comments and preparing the final DVD will primarily be accomplished by the video editor/engineer with guidance and assistance from the DATS PM. DATS has assumed that the DATS IT Specialist will require 2 hours to review and comment on the draft DVD, and the PM will require 12 hours to incorporate comments and coordinate preparation of the final DVD.

Subtask 1.1.6 - Produce ten 2-minute stand alone video clips highlighting aspects of response: The DATS PM will work with Dr. Cardarelli to identify ten 2-minute sections of the documentary to be broken out into stand-alone video clips during the one day meeting described in Subtask 1.1.5. DATS has assumed that to identify the individual video clips will require approximately 4 hours. DATS PM will work with the video editor/engineer to produce the clips. DATS has assumed that this task will be accomplished in the video editor/engineer workspace, and interaction with the video editor/engineer will require 8 hours.

The basis for the level of effort for Task 2.1 is as follows:

Approximately 19 hours is budgeted for preparation of the initial and revised cost estimates, including time to define the scope of work and to obtain bids for non-traditional support services (videotaping interview, editing video, and creating DVD). A total of 10 hours are budgeted for routine project management, oversight, and TDD close-out by the DATS PM and DATS Program Manager.

6. Deliverables

Within 4 months following approval of the cost estimate, the following deliverables will be submitted:

- Background material for 3 to 4 minute voice-over narrative to introduce documentary
- Proposed interview questions
- Draft script indicating which sections of interview will be included and detailing how visual aids will be integrated with interview
- Final script indicating included portions of interview and associated graphic images
- Draft DVD of documentary (5 copies)
- Final DVD of documentary (10 copies), incorporating comments on draft
- Electronic files of ten 2-minute stand alone video clips

7. Points of Contact

The DATS points of contact for this TDD will be Mr. Tom Kouris, DATS Program Manager, and Rik Lantz, DATS Project Manager. Contact information for these individuals is listed below.

DATS Program Manager:

Tom Kouris
Dynamac Corporation
4900 Olympic Boulevard
Erlanger KY 41018
(219) 916-1949 cell
tkouris@dynamac.com

DATS Project Manager:

Rik Lantz
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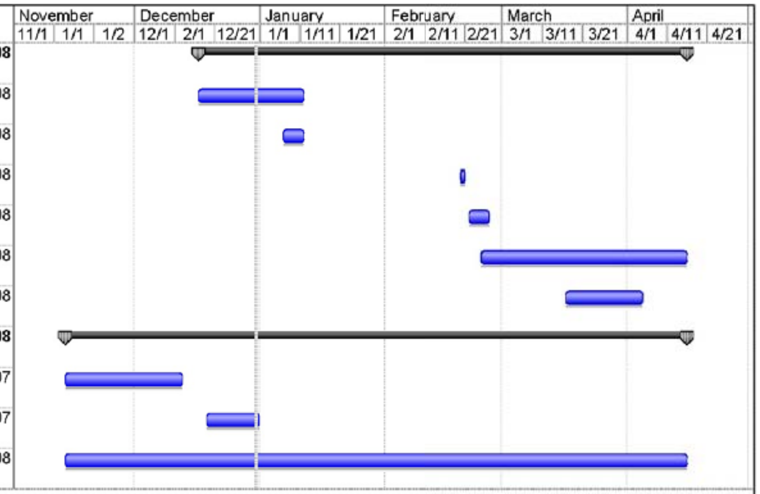
20 North Wacker, Suite 1210
Chicago, IL 60606
(773) 633-7008
RikLantz3737@earthlink.net

Attachment 1

Schedule

ID		Task Name	Start	Finish
1		**T1.0 Prepare DVD of Chernobyl Interview**	**Mon 12/17/07**	**Tue 4/15/08**
2		T1.0.1 Prepare background Materials	Mon 12/17/07	Fri 1/11/08
3		T1.0.2 Obtain Photographs/Videotapes	Mon 1/7/08	Fri 1/11/08
4		T1.0.3 Videotape Interviews	Wed 2/20/08	Wed 2/20/08
5		T1.0.4 Prepare Script/Integrate Aids	Fri 2/22/08	Tue 2/26/08
6		T1.0.5 Edit Interview/Prepare Documentary	Mon 2/25/08	Tue 4/15/08
7		T1.0.6 Prepare 10 2-minute stand alone clips	Mon 3/17/08	Fri 4/4/08
8		**T2.1 Project Management**	**Wed 11/14/07**	**Tue 4/15/08**
9		Develop Work Plan	Wed 11/14/07	Wed 12/12/07
10		Revise Work Plan	Wed 12/19/07	Mon 12/31/07
11		Routine Project Management	Wed 11/14/07	Tue 4/15/08



Project: TO-01-07-10-0017
Date: Mon 12/31/07

Subtask | Milestone ◆ | Task

Attachment 2

Cost Estimate

TDD # **TDD Number TO-01-07-10-0017**

Labor Basis of Estimate
CLIN 10xx

CLIN	CLIN DESCRIPTION	UNIT of ISSUE	CONTRACT UNIT PRICE	QTY	PRICE
0001	Program Manager	HR	$ 153.58	13	$ 1,996.54
0002	Clinical Microbiology & Infectious Diseases	HR	$ 168.25	-	$ -
0003	Toxicology	HR	$ 257.65	-	$ -
0004	HVAC Engineer	HR	$ 146.60	-	$ -
0005	Operations Analysis, Planning and Policies	HR	$ 198.15		$ -
0006	Health Physicist	HR	$ 124.65	-	$ -
0007	Chemist	HR	$ 132.60	-	$ -
0008	Certified Industrial Hygienist	HR	$ 80.53	-	$ -
0009	Transportation Specialist	HR	$ 73.45	-	$ -
0010	Environmental Health, Sampling & Monitoring Specialist	HR	$ 127.13	-	$ -
0011	Principal Professional	HR	$ 190.34	-	$ -
0012	Scientist/Engineer I	HR	$ 47.59	-	$ -
0013	Scientist/Engineer II	HR	$ 79.62	-	$ -
0014	Scientist/Engineer III	HR	$ 133.98	142	$ 19,025.16
0015	IT Specialist	HR	$ 112.76	40	$ 4,510.40
0016	Administrative Assistant	HR	$ 43.49	-	$ -
			LABOR SUBTOTAL	195	$ 25,532.10

Travel Basis of Estimate
CLIN 2001

	Rate	No. of Persons	No. of Trips	No. of Days	No. of Miles	Total Price
Airfare: Washington DC to Chicago	$500.00	1	1			$ 500.00
Airfare: Cincinnati to Chicago	$550.00	1	1			$ 350.00
Lodging:	$ 149.00	2	2	2		$ 298.00
M&IE:	$ 64.00	2	1	2.75		$ 352.00
Transportation: Home to Airport and Airport to Hotel	$ 35.00	2	4			$ 280.00
Airport Parking:	$ 20.00	2	2	2		$ 180.00
POV	0.485	1	4		25	$ 48.50
Airfare: Chicago to Cincinatti	$550.00	1	1			$ 350.00
Lodging:	$ 104.00	1	1	2		$ 298.00
M&IE:	$ 54.00	1	1	2.75		$ 148.50
Transportation: Home to Airport and Airport to Hotel	$ 35.00	1	4			$ 140.00
				TRAVEL SUBTOTAL		$ 2,945.00
				G&A	19%	$ 559.55
				TRAVEL SUBTOTAL		$ 3,504.55

Equipment/Specialized Labor/Subcontracts/Misc. ODCs Basis of Estimate
CLIN 3001

CLIN	CLIN DESCRIPTION	UNIT of ISSUE	CONTRACT UNIT PRICE	QTY	PRICE
3001	In-Frame Productions subcontract	Lot	$ 31,755.00	1	$ 31,755.00
3001	Federal Express	Lot	$ 150.00	1	$ 150.00
3001	Transcription services	Lot	$ 1,200.00	1	$ 960.00
			TOTAL SUB		$ 32,865.00
			G&A	7.132%	$ 2,343.93
			CLIN 3001 SUBTOTAL		$ 35,208.93

CLIN 100x - Labor	$ 25,532.10
CLIN 2001 - Travel	$ 3,504.55
CLIN 3001 - Equipment/Specialized Labor/Subcontracts/Misc. ODCs	$ 35,208.93
TOTAL COST ESTIMATE TDD No. TO-01-07-10-0017	$ 64,245.58

Technical Direction Document ## - Chernobyl Interviews
Task Order 1 – Technical Information Services
Performance Work Statement (PWS)

The contractor shall supply the personnel, equipment, and supplies to complete the tasks described below. This Technical Direction Document (TDD) does not constitute an assignment of additional work outside the general scope of the Contract or the Task Order; does not constitute a change as identified in FAR clause 52.243-2 entitled "Changes" nor in any manner causes an increase or decrease in performance or changes any expressed terms, conditions or specifications of the Contract or Task Order.

1.0 TASKS TO BE PERFORMED

Under DATS SOW B.2.c, the Contractor shall provide the personnel, equipment, materials, and supplies necessary to support and prepare a professional videotape of interview of Chernobyl scientists.

Task 1.1

The contractor shall prepare a professional videotape of interviews with EPA selected people who were involved with Chernobyl. Specific activities include the following:

- Prepare and submit a list of suggested questions to be used by EPA in advance of the interview
- Gather various media to include photographs and videotape that can be used to enhance the interview presentation/final product for the viewers
- Present a script to NDT as to how this media can be used to support the interview
- Arrange for, and or perform videotaping of the interviews, editing of the tapes, and production of draft and final DVDs

Interviews will be conducted in Chicago.

2.0 DELIVERABLES

The contractor shall submit deliverables in electronic and hard copy formats (where applicable). Draft and final deliverables shall be in ~~Microsoft Word, Microsoft Excel, Microsoft Project, and/or Adobe PDF Format and the Final Technical Report shall be provided in Microsoft Word and/or Adobe PDF format.~~
an appropriate video format (digital) so the product can be digitally edited and incorporated into Microsoft Powerpoint presentations.

- Provide suggested interview questions within 4 weeks following approval of the cost estimate
- Present script and media within 2 weeks following finalization of the interview questions
- Provide 3 copies draft DVD within 3 weeks following the last interview
- Provide 10 copies of the final DVD within 2 weeks following receipt of comments

3.0 PERIOD OF PERFORMANCE

The period of performance (POP) of this TDD is 4 months from the issuance of the TDD.

4.0 GOVERNMENT FURNISHED INFORMATION

There will not be any information provided

5.0 POINTS OF CONTACT

Contracting Officer Representative:

John Cardarelli II, PhD, CHP, CIH, PE
CDR USPHS
Environmental Protection Agency
National Decontamination Team
26 W. Martin Luther King Drive (MS 271)
Cincinnati, Ohio 45268
(513) 487-2423 w
(513) 675-4745 c
(513) 487-2537 f
cardarelli.john@epa.gov

Alternate Contracting Officer Representative:

Natalie Koch
Environmental Protection Agency
National Decontamination Team
26 W. Martin Luther King Dr. (MS 271)
Cincinnati, Ohio 45268
513.487.2422 (Office)
513.675.4741 (Cell)
Koch.natalie@epa.gov

The following was taken from the email sent by Vira to John. It was copy protected so I had to re-type the message.

==

John, I could not wait, and I've finished watching the film right now.

I must congratulate you (and your team) on the job well done.

Your film makes a coherent and valuable statement, and you even managed to make my own musings somehow relevant and interesting.

I have only two points of concern:

First, when you talk about the first response to the Chernobyl disaster (firefighters extinquishing fire on the roof etc.) you talk about inadequacy and haphazard nature of this response. This is true, but at least on phrase must be said about the heroism of the people who sacrificed their lives to avoid the worst outcome. One sentence should be enough, but we owe at least that much to their memory.

Second, my baby was not born in Moscow, but in Krasnodar, Russia. I know it is not of real importance to anyone except my immediate family, but still it is important for many reasons. If it is too technically costly to make another voice recording, could you at least cut the word "Moscow" out of this phrase? I hope it is not too difficult.

Other than that, I have no complaints, only praises! Great job! Of course there could be some improvements, but there is always room for improvements in this world. It is very presentable as it stands right now…

Again, thank you for making me a participant in this project.

Warmest,

Vira Yakusha