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Radioactive Material Production, Transportation, Use, and Possible Misuse

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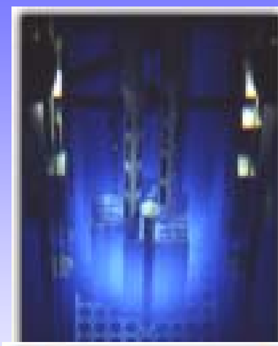
Radioactive Material Production, Transportation, and Use

Radioactive Material Production, Transportation, and Use

- The creation, shipping, and use of radioactive material is **highly regulated** (IAEA, NRC, DOT, etc.).
- High Activity Sources can **only** be produced by sophisticated methods (e.g. reactors & accelerators).
- High activity sources can only be obtained after special licensing to ensure their <u>safe use</u> and their <u>security</u>.
- Similar regulations exist in other countries were radioactive material is produced or used.



1/14/2003 *UCRL-PRES-149904; Radioactive Material Production, Transportation, Use, and Possible Misuse 3

Emphasize that:

1) **High activity sources are difficult to obtain**
2) **Once obtained, measures are taken to ensure the <u>safety</u> and <u>security</u> of the source.**
3) **The Regulatory agencies continually check up on the users to make sure they follow the requirements**.

4) Pictured above is the Cherenkov radiation produced at University of Missouri-Rolla campus, the UMR Nuclear Reactor (UMRR)
5) Also picture is The Fast Flux Test Facility (FFTF) is a 400-megawatt (thermal) liquid-metal (sodium) cooled fast neutron flux nuclear test reactor owned by the U.S. Department of Energy (DOE). The facility is located in the 400 Area of DOE's Hanford Site in southeastern Washington State. Currently, the FFTF is being deactivated. This reactor produces many unique isotopes.

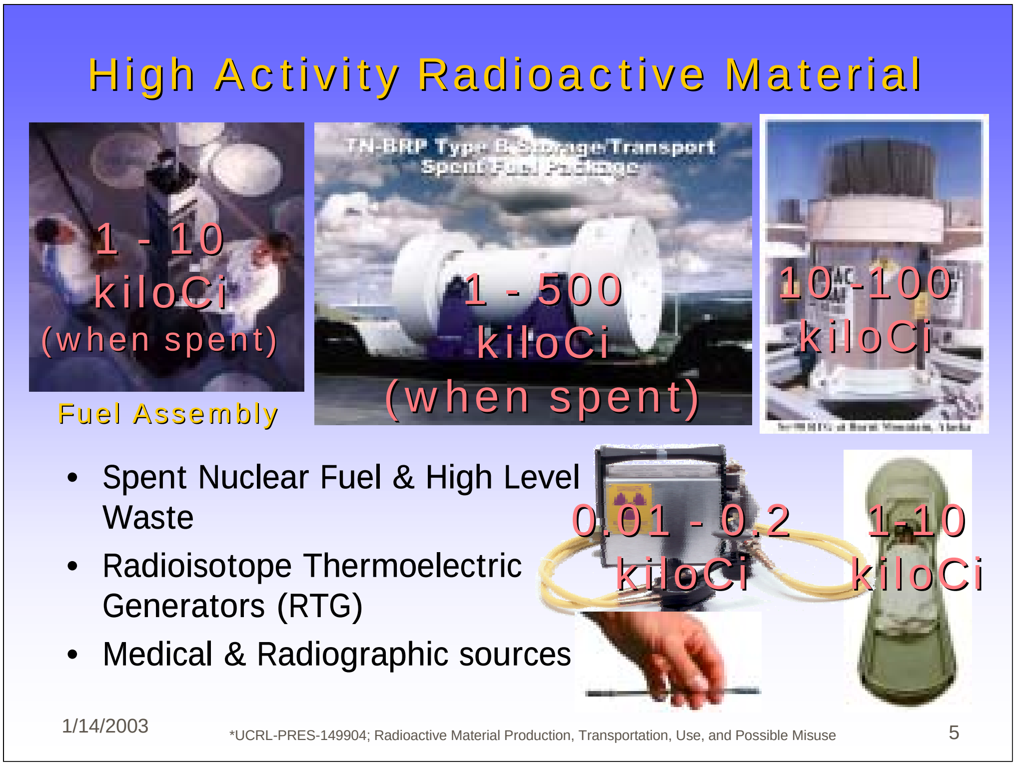
Shielding Requirements Limit Portability

- For gamma sources: the higher the activity, the more shielding you require to transport the source.

Small radiography sources:
- typically 0.1 Ci to 200 Ci.
- 30 – 50 Lbs

Medium radiography sources:
- Hundreds of Ci
- 200 - 400 Lbs

Large industrial source:
- 9,000 Ci
- 3 tons of shielding



•Radioisotope Thermoelectric Generators (RTG)

The picture shown is of some Sr-90 RTGs up in Alaska, these range from 2 – 5 feet in height. RTGs use the heat generated by the decaying radioactive material to generate electricity. They make about 500watts (enough to light 5 100 watt light bulbs) but are extremely reliable and maintenance free for decades of operation in remote areas (like space or deep ocean). These generally have very radioactive sources of (4 to 500 kCi) in order to make the heat. The source resides at the center of the generator as is about the size of a large soup can. *Typically the radioactive material itself is in a chemically inert form (I.e. ceramic) and then placed in a double welled steel capsule. These sources undergo extensive testing (I.e. vibration, crushing, fire, cold, etc..) to ensure the don't break open in an accident.*

These sources are very robust and the RTG is designed to meet Type-B shipping container requirements, including surface dose rates below 200 mrem/hr on contact.

1 year after being removed, spent fuel activity is ~ 1Tbq/kg [27 ci/kg] (source Finland radiation and nuc authority)

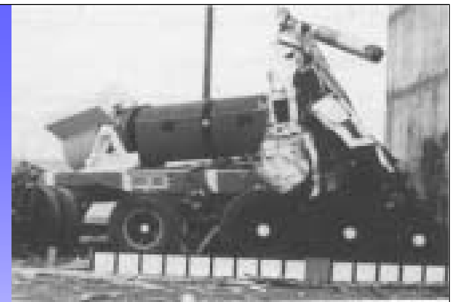
•Nuclear fuels and Spent nuclear fuels. **Emphasize that unused nuclear reactor fuel is not highly radioactive. After use however, the fission products build up and make the waste very radioactive.** They are an external hazard and can not be handled directly. If dispersed they will be and internal and external hazard.

•Pressed into ceramic pellets and clad in special metals capable of withstanding the harsh conditions inside a reactor core. When spent fuel is transported, it is placed into shipping container that are able to withstand the most heinous accident conditions. ***If appropriate, show the shipping cask trials (locomotive hitting cask) video.***

•Medical & Radiographic Sources

Small (in size, but not activity) sources intended for industrial or medial use. These sources are

Spent Fuel



- Currently stored "onsite" at locations throughout the country.
- Spent Fuel containers extremely rugged and made to withstand extreme accident conditions.
- For thirty years, > 5,000 highly-radioactive fuel assemblies have been shipped without radiation release (despite several accidents).
- Security measures are taken.

Source: ***NUCLEAR TECHNOLOGY & INFORMATION ON REACTOR SAFETY***
http://www.geocities.com/ntirs/index.html

For over thirty years, spent fuel shipments have traversed our nation's highways and, over that time, over five thousand highly-radioactive fuel assemblies have been transported. Even with all of this experience and history, there has not been one single radiation release of any kind despite a few serious traffic accidents. This excellent safety record is due to the design, engineering, planning, and regulation related to the dry casks used for the transportation of spent fuel.

A variety of casks have been designed and tested and are being used. Lighter casks, from 25 to 40 tons are designed to hold up to 7 fuel assemblies. Heavier casks, up to 120 tons, are designed to carry up to 36 assemblies. These heavier casks may be transported by rail. In general, the casks are cylindrical with multiple walls and shields that give the casks their extreme strength and radiation shielding characteristics. In one such design, shown below, the spent fuel is sealed in a water-filled stainless steel cylinder with walls 1/2 inch thick and clad with 4 inches of a heavy metal (usually lead) for radiation shielding. This container is surrounded by 5 inches of water and encased in a corrugated stainless steel outer package. Another cask, designed by the Babcox & Wilcox Company and designation "BR-100" is also shown.

Source: ***NRC*** *http://www.nrc.gov/waste/spent-fuel-transp.html**Safety Requirements***

Safety in the shipment of nuclear material is achieved by a combination of factors, including the physical properties of the nuclear material itself, the ruggedness of the container, and the operating procedures applicable to both the transportation package and the vehicle transporting the package.

Materials Shipping Requirements

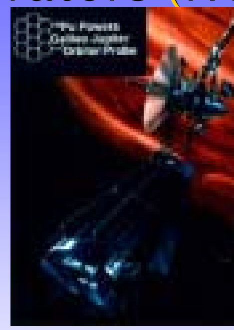
NRC performs inspections to determine whether transportation package users have taken the appropriate package measurements to ensure radiation levels are not exceeded. NRC inspections also focus on whether casks have been properly inspected for certain specific criteria, such as leak-tightness, that bolts and other equipment are intact, and that the packages are safe for transport.

Safeguards (Security) Requirements

For transportation of spent fuel, NRC performs inspections to determine that the spent fuel is physically protected against radiological sabotage.

Radioisotope Thermoelectric Generators (RTG)

Self heated
Plutonium 238



- **The heat generated by the radioactive decay is used to generate electricity**
- **Used when maintenance free power is need for decades (satellites, ocean bottom, and arctic applications)**
- **RTGs most often made from Sr-90 (0.46 kW/kg) or Pu-238 (0.54 kW/kg).**

Plutonium 238

Plutonium 238 is a non-fissile, alpha emitting isotope with a half life of 87 years. A sample of pure material would produce approximately 0.54 kilowatts/kilogram of thermal power. In some configurations, the surface temperature of a Pu-238 fuel element can reach 1050 degrees C.

These characteristics make Pu-238 the most capable heat generating isotope. It will outlast most customers; even after 20 years a Pu-238 based power source will produce 85% of its initial power output. It has a high energy density, allowing power system mass and volume to be minimized. It is also easy to shield and its emissions will not interfere with sensitive instrumentation.

Unfortunately, Pu-238 is difficult to manufacture, making it extremely expensive. An accurate price is difficult to determine because of the lack of an open market, but the recent estimates by experts in the field indicate that the material costs several thousand dollars per gram in kilogram sized lots Ð if it is available at all. Since RTG conversion efficiency is on the order of six to eight percent, this puts the price of a 50 W power supply at close to a million dollars.

There is also the public relations problem associated with the word plutonium. Frequent readers of Atomic Energy Insights might understand that plutonium is not as dangerous as Ralph Nader says it is, but that realization has not yet permeated the general public's consciousness. Most political decision makers are also not knowledgeable enough about nuclear physics to understand that Pu-238 cannot be used to produce a nuclear weapon; it has the wrong number of nucleons to be a fissile isotope.

Strontium 90

Sr-90 is a beta emitter with a 28.1 year half life. A pure sample will supply 0.46 kilowatts/kilogram of thermal power when new, or about 15 percent less than a similar mass of Pu-238. Additionally, an Sr-90 based RTG will deteriorate about three times as fast as one based on Pu-238; a 20 year old power supply will produce only 61 percent of the initial power output.

Because of the lower energy density, a Sr-90 fuel rod will not get as hot as a Pu-238 rod. A new rod, depending on configuration, might be able to achieve a surface temperature of only 700 to 800 degrees C. This is important because a lower temperature available to the hot junction of a thermocouple will reduce the thermoelectric conversion efficiency of the RTG. Because of these characteristics, a Sr-90 RTG will be about 50 to 100 percent heavier than a Pu-238 RTG of the same power output. For space based applications, where every payload gram is carefully controlled, this mass difference makes it uneconomical to consider Sr-90.

Strontium, however, has some advantages over plutonium. It is a fission product with a high yield; about five percent of all fission reactions produce Sr-90. Since Sr-90 has a long half life compared to the time that reactor fuel spends in a core, it is quite feasible to mine Sr-90 from spent nuclear fuel. Sr-90 is considered by most of its current owners to be an expensive waste problem; perhaps some of them would pay to get rid of it.

Strontium is not associated with nuclear weapons and has never been called the most deadly element known to man. There is a precedence in the United States for widely licensing small quantities of sealed Sr-90; it is used in some aircraft ice detection systems.

There is also a precedent for its use in earth based RTGs; most of the Soviet ocean bottom and Arctic devices used SR-90 heat sources. (Chmielewski)

Portable Radiography Sources

- “Top strength” industrial radiography sources can burn fingers and cause radiation sickness within a few minutes.
- Effects drop off dramatically with distance. Outside of 3 meters, acute effects rare even after hours of exposure.
- Sources are constructed to meet rigorous testing standards. A typical source is encapsulated in two (2) TIG welded Stainless Steel Capsules.
- Source Material itself is often metal (Cobalt or Iridium) or embedded on non-soluble ceramics or “microspheres” to prevent inhalation of radioactive material if the source encapsulation is breached.

Metals are difficult to disperse

“Top strength” industrial radiography sources can be ~100 Curies and produce ~ 2 R/min @ 1m

Strong Radiography Sources

~2 R/min @ 1 meter

Facility Sources:

Stronger sources exist in facility based system Produce 200 R/min at 1m

Co-60 Sources: 1.32 R/hr @ 1m per 1 Ci

Therefore: 13,200 R/hr **(200 R/min)** @ 1m per 10,000 Ci

or 150,000 R/hr **(2,000 R/min)** @ 1 ft per 10,000 Ci

or 20 R/hr @ **25 meter** per 10,000 Ci

Facility Based Irradiators

- These sources can have 10 to 100 times more radioactivity than radiography sources
- Found in food irradiators, medical sterilizers, etc.
- The shielded enclosures that hold the sources weigh more than a ton.
- Difficult to remove source from the facility or equipment.

Irradiating blood is recognized as the most effective way of reducing the risk of Graft-Versus-Host Disease (GVHD). This disease most commonly occurs in patients

with severely weakened immune systems, and is recognized as a risk associated with blood transfusions. Transfusion-Associated GVHD (TA-GVHD) has become a

major concern in current transfusion practices for immunodeficient and immunosuppressed patients because of the associated high mortality rate. Immunosuppressive

therapies have not proven effective for TA-GVHD.

The unit pictured above Weighs 1150 kg (2,535 lb.) or 1479 kg (3,260 lb.)

And uses a 650, 1450 or 2900 Ci Cs-137 Source.

If time permits, the TEPP movie on source testing can be very valuable.

Conclusion:

Radioactive Material Production, Transportation, and Use

- High Activity Radioactive Material is highly regulated.
- Industrial Sources are very robust and made not to leak.
- When dangerous quantities are shipped, the material is put a a container capable of withstanding harsh accident conditions.
- Very high activity industrial/medical sources are facility based and difficult to remove.

Expose people to an external source of radiation.

Sources could be placed in areas of high population (subways, stadiums, etc..) and expose passersby.

*** Only a few individuals might be injured before the threat is discovered**

*** medically detectable effects from available sources not likely (Time, Distance, Shielding)**

*** Source easily found one threat is known**

Disperse radioactive material using conventional means.

•Requires putting the radioactive material in a dispersible form (I.e. fine powder or liquid)

•If there is enough activity to be a threat once dispersed, then performing the prerequisite chemistry can be lethal to the chemist.

**** Even without a lot of radioactivity, public hysteria to being “sprayed” can be a major issue. Remember the “med fly” spraying, (for those of us in California).***

Detonate a radioactive dispersal device (a ‘dirty bomb’)

Combining Radioactive sources with explosives

•Satisfying “bang” to announce event

•Radiation Exposure unlikely to produce health effects, but..

•Contamination will greatly complicate emergency response effort.

*** Like above, commercial high activity sources may not easily be distributed, even with an explosion.**

*** Source easily found once threat is known**

Detonate an improvised nuclear device
very hard to do...

WHAT IS A 'DIRTY BOMB'?

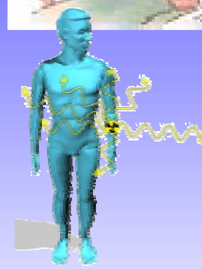
- A "Dirty Bomb" is conventional explosives combined with radioactive material with the intention of spreading the radioactive material over a relatively large area.
- This is **NOT** a nuclear explosion, the radioactive material does not enhance the explosion.
- Very few deaths would be expected from acute radiological exposure (the greatest hazard would likely be from the effects of the conventional explosives).
- The contamination will hamper emergency response efforts and can delay hospital treatment.
- Widespread contamination can deny the use of facilities and areas and have a significant psychological impact on the exposed population.

If it comes up, the older (cold war) definition of a 'Dirty Bomb' was used for nuclear weapons that created an excessive amount of fallout. However, the term currently used in the news media is the slang term defined above.

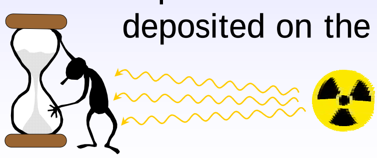
But this is NOT the current definition

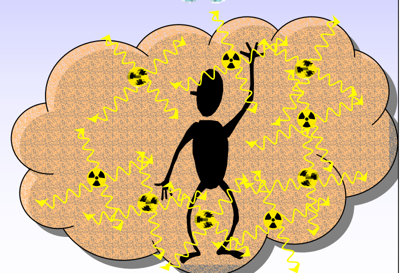
External Exposures

- Focused radiation or localized contamination can result in radiation effect to specific areas on the body



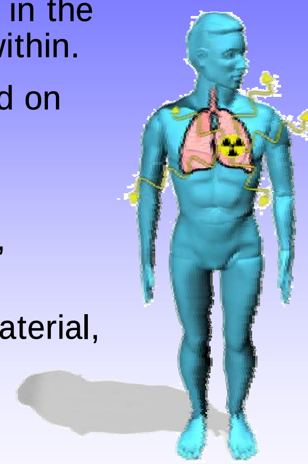
- Whole body exposure can result from:
  - A passing radioactive cloud or smoke
  - A large, distant point source
  - Exposure from contamination deposited on the ground





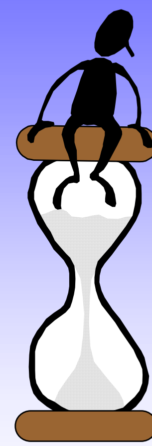
Internal Exposures

- Once radioactive material is deposited in the body, it can expose the person from within.
- The magnitude of the dose will depend on many factors:
  - How much material was deposited,
  - How it got into the body (ingestion, inhalation, absorption, or injection)
  - Chemical form of the radioactive material,
  - the radiation it produces,
  - How quickly it decays, and
  - How quickly the body eliminates the material

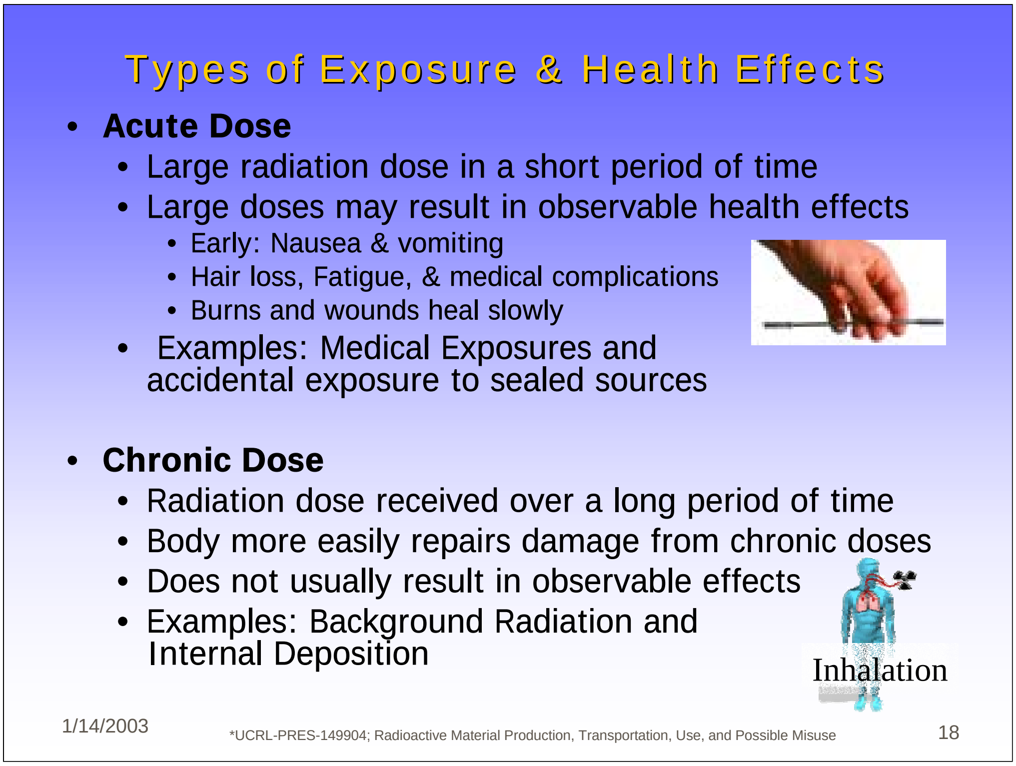


Internal Exposures

- Dose from <u>internal depositions</u> are usually expressed by **summing dose that will be received over the next 50 years from a one time internal deposition**.
  - Referred to as Committed Effective Dose Equivalent (CEDE).
  - This dose calculation/estimate takes into account factors on the previous slide.
  - Even with a large CEDE, there may or may not be acute effects from the exposure.



Do not use internal doses to predict acute exposure effects like nausea and vomiting.



These slides were included in case the “BB1 Understanding Radiation” was not presented prior to these slides.

Early: Nausea & vomiting => Usually happens within a few hours of large (> 100 rad) exposures. The higher the dose, the sooner and more severe the symptom.

Burns and wounds heal slowly => For localized exposures, burns and tissue necrosis.

Hair loss, Fatigue, & medical complications =>

Dose (rads) **Effects**

25-50 First sign of physical effects

(drop in white blood cell count)

100 Threshold for vomiting

(within a few hours of exposure)

320 - 360 ~ 50% die within 60 days

(with minimal supportive care)

480 - 540 ~50 % die within 60 days

(with supportive medical care)

1,000 ~ 100% die within 30 days

A good example of this is the use of a large (> 1 Ci) Cs-137 or similar amounts of spent fuel.

Radiological injury or death is more likely to occur from an intact source as it irradiates nearby people. Once dispersed, the acute external radiation becomes less of a hazard and reducing the chronic exposure from internal deposition becomes the primary health concern. Of course the financial/civil burden of denial of facility/area use is also a significant factor.

Internal dose is Measured as CEDE = Committed Effective Dose Equivalent. This is equal to the total dose received by an individual <u>over the next 50 years</u> from an internal deposition. In addition to radiological decay, all radioactive material has a “biological half life” which describes how our bodies eliminate the radioactive material.

The Human Factor

- Concerns about radiation and contamination often produce an exaggerated emotional response.
  - Can't detect it with our 5 senses
  - Associated with cancer
  - Reminiscent of "cold war" fears
  - Science difficult to understand
  - Out of our control

- Possible results may be...
  - Unexposed people saturating the medical community
  - Health and economic effects from long term anxiety or depression in the community

Narrative:

Experiences from Chernobyl and Goiana have shown that radioactive contamination can have profound psychological effects on a community involved in a radiological contamination event

Why? Well…

Read first major sub-bullets

{click}

There can be both short and long term effects from this…

1) Many people who are not contaminated or exposed to the event may go to the hospital anyway… just to be sure. This can have a significant impact on the medical communities ability to manage the event

2) Long term economic and health effects may also be present from anxiety or depression in the community.

{Note: if you are giving the First Responder presentation, you can mention that you will be providing more detail later on}

.

Conclusion:
Misuse of Radioactive Material

- High activity sources can cause health effects, but only to those in close proximity.
- Acute health effects from distributed radioactive material unlikely without prolonged, high-concentration exposure.
- Radiation or contamination will hinder response efforts.
- Denial of facilities and areas will have a major cost effect
- Public anxiety and it's effects may be the primary lasting health effect.

1/14/2003 *UCRL-PRES-149904; Radioactive Material Production, Transportation, Use, and Possible Misuse 20

I have been reviewing extensive materials on this subject and performing my own analysis. The general consensus about RDDs can be summed up by the following points.

1) The primary ***radiological health*** concern from an RDD is from dispersal and internal uptake of radioactive material. If there was enough to be of an external exposure concern for folks out of the "blast zone", then it would have been a very lethal point source to begin with and would have been difficult for the terrorist to set up & transport without keeling over before setting it off. However, it should be noted that a real exposure concern may be from source fragments at the scene.

2) Internal Exposures cause chronic long term doses that ***generally*** do not produce acute effects, even if they exceed dose levels that would have caused death or injury for an acute exposure. The primary concern for the internally exposed population is the long term increased rick of cancer. [The exception to this would inhaling enough material to "burn" the inside of your lungs resulting in pulmonary edema, though this would require extended breathing of the "smoke"]

3) Increased risk of cancer is not an "injury." The definition of Injury should be limited to Acute Radiation Syndrome (ACS) and Acute Cutaneous Syndrome (ACS) (burns caused by high levels of skin contamination with high energy beta emitters).

4) The ***primary*** issues surrounding the radiological aspect of an RDD are not additional deaths or injuries, but:

a) Physically injured personnel receive a delay in treatment due to fear of

References

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Copyright © 1994-1997 Baylor College of Medicine, All rights reserved.
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