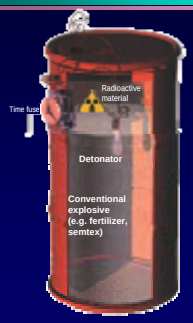
The Nature of Radiological Terrorism



David J. Brenner, Ph.D., D.Sc.,
Center for Radiological Research
Columbia University Medical Center
djb3@columbia.edu

Goiânia, Brazil, 1987
Population 1.3 million

Abandoned medical clinic in Goiânia contained 1,400 Curie radioactive cesium sources

The radioactive sources were stolen, broken open, and dispersed

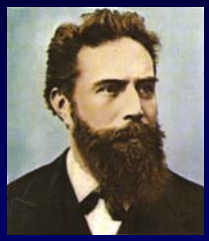
Goiânia incident: Equivalent to a large dirty-bomb scenario in Manhattan

- 130,000 people (10% of population) came to ER / temporary screening locations
- 250 (0.2%) were contaminated
- 20 (0.01%) required treatment

Topics that we will cover

- ✓ What is radioactivity?
- ✓ What is radiation?
- ✓ Radiation threat scenarios
- ✓ Response issues
- ✓ Will it happen?
- ✓ Further resources

1895: X rays discovered
1896: Radioactivity discovered



Wilhelm Roëntgen

Henri Becquerel and Marie Curie

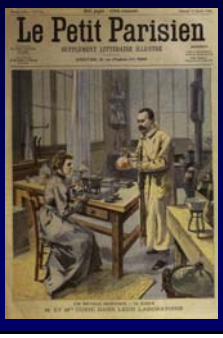
X rays were immediately big news in New York

"The College of Physicians and Surgeons is using x-rays to reflect diagrams directly on to the students' brains, making a more enduring impression than the normal method of learning"

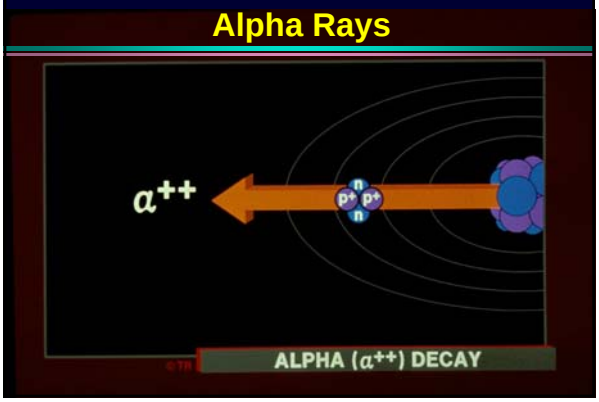
New York Morning Journal, 1896

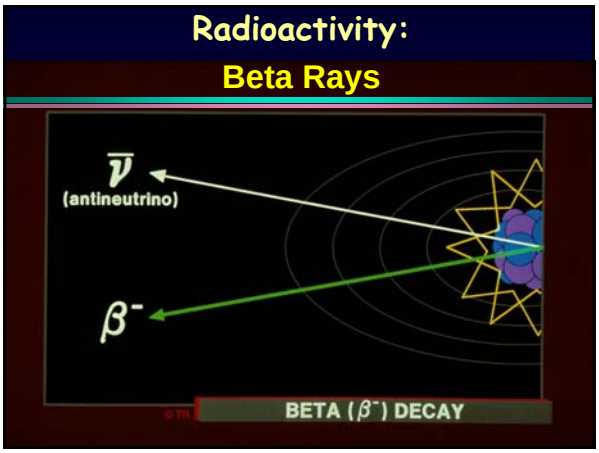
Radioactivity

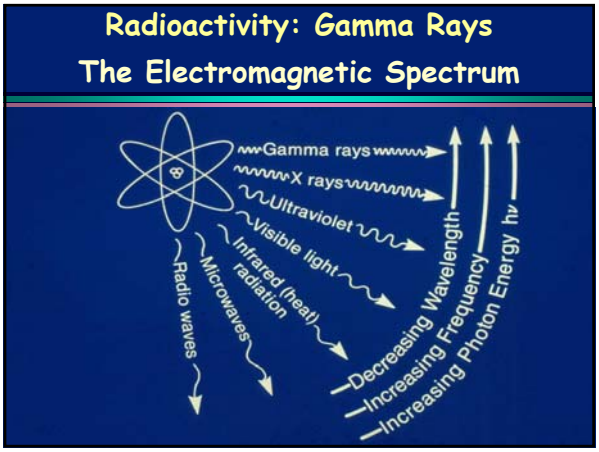
The spontaneous emission of radiations: alpha rays, beta rays, gamma rays, from radioactive materials

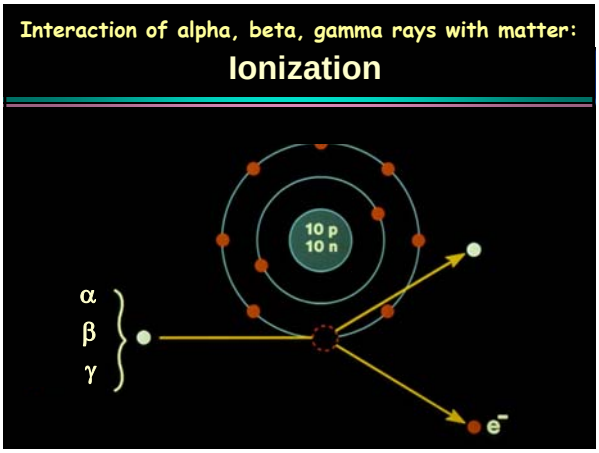


Radioactivity: Alpha Rays

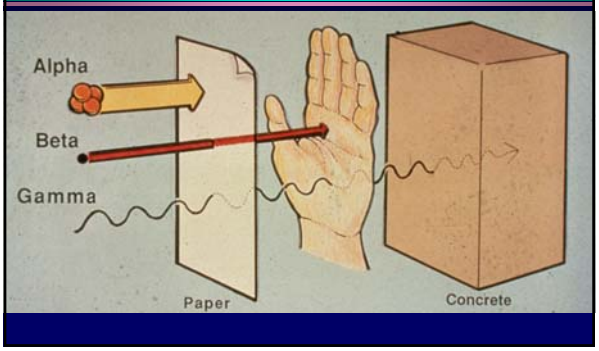



Radioactivity:
Beta Rays
$\bar{\nu}$
(antineutrino)
β^-
BETA (β^-) DECAY


Radioactivity: Gamma Rays
The Electromagnetic Spectrum
Gamma rays
X rays
Ultraviolet
Visible light
Infrared (heat) radiation
Microwaves
Radio waves
Decreasing Wavelength
Increasing Frequency
Increasing Photon Energy hν


Interaction of alpha, beta, gamma rays with matter:
Ionization
10 p
10 n
α
β
γ
e⁻

Alpha, beta and gamma rays



Radiation *vs.* Radioactive Materials

- **Radiation:** energy transported in the form of particles or waves (alpha, beta, gamma, neutrons)
- **Radioactive Materials:** material that contains atoms that emit radiation spontaneously

Exposure *vs.* Contamination

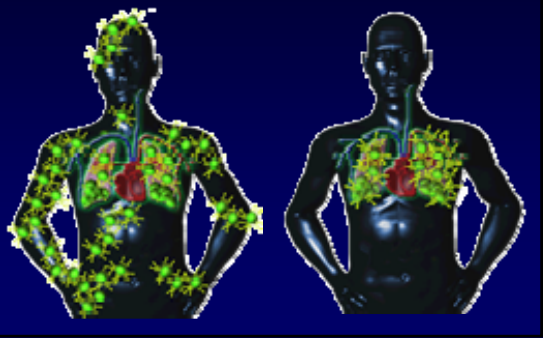
External Exposure: irradiation of the body from external source

Contamination: radioactive material on patient (external) or within patient (internal)

External Contamination

- Radioactive material (usually in the form of dust particles) on the body surface and / or clothing
- 80-90% typically removed by removing clothing

Removing internal contamination is more problematic



Radiation Dose

- Measured in Gray (Gy) or milli-Gray (mGy)
- Equivalent dose is measured in milli-Sievert (mSv)
- For our purposes, 1 mGy = 1 mSv

- Old dose units are the rad and the rem
- 1 rad = 10 mGy; 1 rem = 10 mSv

- Average background radiation dose is 3 mSv / year
- A mammogram produces about 0.01 mSv
- A CT scan produces about 10 mSv.

Radioactivity

- The activity (strength) of a radioactive source is measured in Curies (Ci) or Becquerels (Bq)

- 1 Bq = 1 radioactive disintegrations / sec
- 1 Ci = 37 GBq
  = 37 billion disintegrations / sec

The Principal Medical Hazards of Ionizing Radiation

Early (days / weeks) effects of high doses

- Damage to the blood forming and gastro intestinal organs

Later effects of high and low doses

- Cancer risks
- Hereditary risks
- Effects on the developing embryo / fetus

Long-Term Radiation Risks

Teratogenic risks

order of magnitude larger than

Carcinogenic risks

order of magnitude larger than

Hereditary risks

Radiation Threat Scenarios

- Nuclear accident
- Nuclear device
- Attack on nuclear power plant
- Dirty bomb

Nuclear Accident

Risk
- Fallout of fission products

Outcome
- Long term carcinogenesis

Likelihood
- Fairly small
  - Chernobyl
  - Windscale
  - Three Mile Island

Nuclear Device

Risk
- Exposure to γ rays and neutrons
- Fallout of fission products

Outcome
- Large number of acute deaths
- Long term carcinogenesis

Likelihood
- Remote

Attack on a nuclear power plant

Risk

- Attack on the reactor itself
- Attack on stored used fuel elements

Release of fission products: I-131, Cs-137, etc

Outcome

- Unlikely to involve acute deaths
- Long-term carcinogenesis

Likelihood

- Extremely unlikely

Dirty Bombs (Radioactive dispersal devices, RDD)

Risk

- Release of radioactive cesium, cobalt or americium
- Small number of contaminated people
- Large number of very slightly contaminated people
- Psychological chaos (many frightened people)

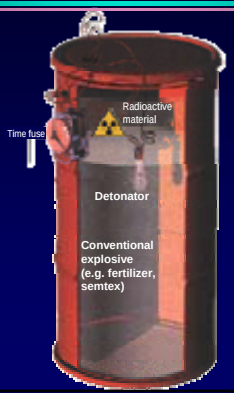
Outcome

- Unlikely to result in acute deaths
- Risk of long-term carcinogenesis

Likelihood

- Likely

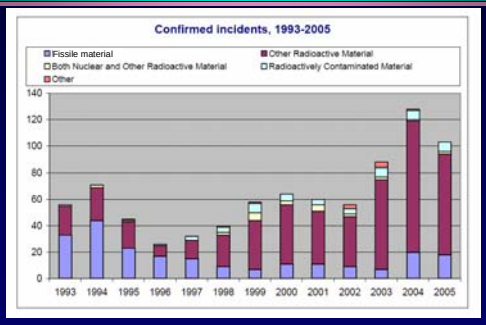
Radioactive Dispersal Device (RDD)



Dirty Bombs

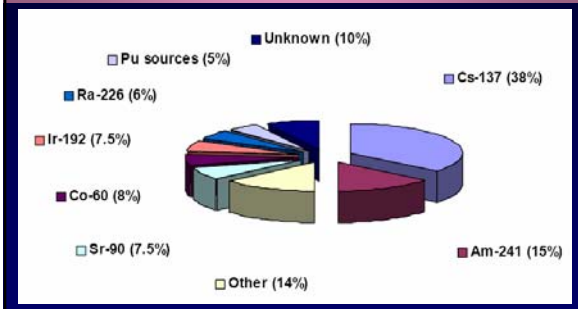
How available are the radioactive materials?

Smuggling of potential dirty bomb ingredients is increasing



IAEA 2006

Types of radioisotopes involved in smuggling incidents, 1993-2005



IAEA 2006

November 1995

Moscow, Russia -- A group of Chechen rebels contacts a Russian TV station to claim that they have buried a cache of radiological materials in Moscow's Ismailovsky Park.

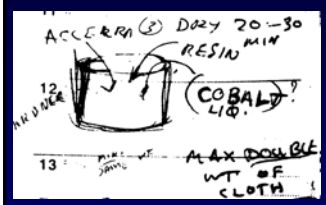
There, the authorities find a partially buried container of radioactive cesium.

December 1998

Argun, Chechnya – A container filled with radioactive materials found attached to an explosive mine hidden near a railway line. It is safely defused.

The location is Argun, where a Chechen group, led by Shamil Basayev, operated an explosives workshop.

January 2003



Herat, Afghanistan -- Based on evidence uncovered in Herat, including detailed diagrams and computer files, British intelligence agents conclude that Al Qaeda has succeeded in constructing a small dirty bomb, though the device has not been found.

November 2006

London: **Dhiren Barot sentenced to life imprisonment**

His "radiation dirty bomb project" was based on an incident in France when a truck carrying 900 smoke detectors caught fire, provoking concern about the radiation exposure.

Barot wrote: *"If something so small and simple such as 900 burning smoke detectors could cause so much havoc, then by increasing the amount used, the possibilities are good"*

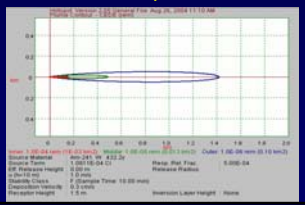
"The radiation project should use around 10,000 smoke detectors and either set them alight or place them on top of an explosive device."

"The burning has the potential to affect around 500 people... as soon as we realised this... we concluded that it deserved to be an independent project in its own right."

November 2006

London: **Dhiren Barot sentenced to life imprisonment**

His "radiation dirty bomb project" was based on an incident in France when a truck carrying 900 smoke detectors caught fire, provoking concern about the radiation exposure.



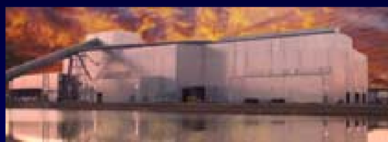
March 1998

Cesium tubes similar to the ones missing from Greensboro

Greensboro, North Carolina -- Nineteen small tubes of cesium are taken from a locked safe in Moses Cone Hospital. The total activity was 22 Gbq (0.6 Ci).

Each tube was three-quarters of an inch long by one-eighth of an inch wide and were used in the treatment of cervical cancer. The cesium is never recovered.

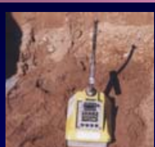
March 2002
Nucor Steel Mill, Hertford, NC

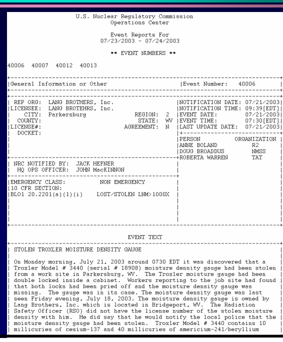


- 2 Ci cesium industrial gauge found on scrap metal conveyer belt
- Traced back to a batch of four belonging to a bankrupt Baltimore chemical company. Three have been located....

Moisture Density Gauges, contain small quantities of americium-241 and cesium-137

About 22,000 in use in the US.
About 50 per year reported as missing





U.S. Nuclear Regulatory Commission
Operations Center

Event Reports For
07/23/2003 - 07/24/2003

** EVENT NUMBERS **

40006 40007 40012 40013

General Information or Other | Event Number: 40006

REP ORG: LANG BROTHERS, Inc.
LICENSEE: LANG BROTEHRS, Inc.
CITY: Parkersburg REGION: 2
COUNTY: STATE: WV
LICENSE#: AGREEMENT: N
DOCKET:

NOTIFICATION DATE: 07/21/2003
NOTIFICATION TIME: 09:39[EDT]
EVENT DATE: 07/21/2003
EVENT TIME: 07:30[EDT]
LAST UPDATE DATE: 07/21/2003

PERSON	ORGANIZATION
ANNE BOLAND	R2
DOUG BROADDUS	NMSS
ROBERTA WARREN	TAT

NRC NOTIFIED BY: JACK HEFNER
HQ OPS OFFICER: JOHN MacKINNON

EMERGENCY CLASS: NON EMERGENCY
10 CFR SECTION:
BLO1 20.2201(a)(1)(i) LOST/STOLEN LNM>1000X

EVENT TEXT

STOLEN TROXLER MOISTURE DENSITY GAUGE

On Monday morning, July 21, 2003 around 0730 EDT it was discovered that a Troxler Model # 3440 (serial # 18908) moisture density gauge had been stolen from a work site in Parkersburg, WV. The Troxler moisture gauge had been double locked inside a cabinet. Workers reporting to the job site had found that both locks had been pried off and the moisture density gauge was missing. The gauge was in its case. The moisture density gauge was last seen Friday evening, July 18, 2003. The moisture density gauge is owned by Lang Brothers, Inc. which is located in Bridgeport, WV. The Radiation Safety Officer (RSO) did not have the license number of the stolen moisture density with him. He did say that he would notify the local police that the moisture density gauge had been stolen. Troxler Model # 3440 contains 10 millicuries of cesium-137 and 40 millicuries of americium-241/beryllium

Small and large dirty bombs (RDD: Radioactive dispersal device)

- **Small RDD:**
  High explosives dispersing 0.1 to 10 Curies
- **Intermediate RDD**
  High explosives dispersing 10 to 1,000 Ci
- **Large RDD:**
  High explosive dispersing 1,000 to 10,000 Ci

Small Dirty Bomb (RDD): 2 Ci cesium source + 10 lb TNT

Inner Ring: One cancer death per 100 people due to remaining radiation (typical dose 25 cGy)

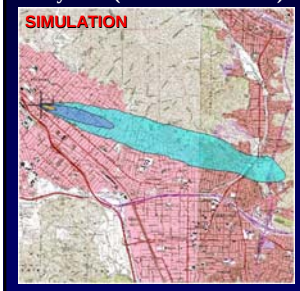
Middle Ring: One cancer death per 1,000 people due to remaining radiation (typical dose 2 cGy)

Outer Ring: One cancer death per 10,000 people due to remaining radiation (typical dose 0.2 cGy)

EPA suggests decontamination

Large RDD: 1,300 Ci Cs-137 source released in Los Angeles

4-day dose (internal + external)



Release: 1.3 kCi Cs-137 RDD with 5 lbs high explosive

	Dose (rem)	Area (km^2)	Description
	1	0.03	Consider evacuation. Shelter in place if no evacuation.
	0.1	0.4	
	0.01	3.8	

- Release location: Burbank Police Department 34 10' 60"N, 118 18' 31"W
- 100% Aerosolized release fraction
- Normal summertime west-northwest winds, 10-12 mph.
- Map size: 6 x 6 km

From B. Buddemeier, UCRL-PRES-149903 (2007)

Large RDD: 1,300 Ci Cs-137 source released in San Francisco

Deposited Contamination

Release: 1.3 kCi Cs-137 RDD with 5 lbs high explosive

	Level ($\mu Ci/m^2$)	Area (km^2)	Description
	20	5	Take measures to prevent cross contamination.
	2	59	
	0.2	409	

- Release location: San Francisco Police Department, 850 Bryant
- 37° 46' 31" N 122° 24' 15" W
- 100% Aerosolized release fraction
- Strong afternoon west winds 18-25 mph.
- Map size: 25 x 25 km

From B. Buddemeier, UCRL-PRES-149903 (2007)

Health-Care Provider Response to a Radiological Event

Almost all the individual presenting at ER / clinic will not require treatment

- 1987 radiation incident in Goiânia, Brazil, a city with about the same population as Manhattan.
- In the first few days after the incident became known, 130,000 people (10% of the population) came for screening, of whom 20 required treatment.

The Need for High-Throughput Radiation Screening

After a radiol… large, ten… need to be… exposure..

"A frenzy can fade if the public believes government is being honest"

New York Times, March 26, 2006

a) because of th… …ce- driven need for triage

b) beca… …e reassurance measures are an effective means of reducing mass panic

Center for High-Throughput Minimally-Invasive Radiation Biodosimetry

- Columbia University
- Arizona State University
- Georgetown University
- Translation Genomics (TGen)
- University of Pittsburgh
- National Cancer Institute
- Sionex Corporation
- NYC Department of Health
- University of Bern

www.cmcr.columbia.edu

RABIT: Rapid Automated BIodosimetry Tool

- Fully automated ultra high-speed robotic biodosimetry workstation.
- Automates two well-established manual assays, γ-H2AX and micronucleus
- One fingerstick of blood
- No human intervention

- Phase I (2008): 6,000 samples/day
- Phase II (2010): 30,000 samples/day

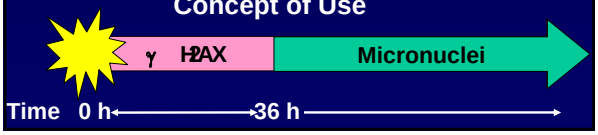
The main technical innovations are:

1) Use of smaller samples – single drop of blood from a capillary finger stick
2) Complete automation of biology and imaging in multi-well plates
3) Innovations in high-speed imaging

γ-H2AX vs. Micronuclei

γ-H2AX	Micronuclei
☺ Same day processing	☹ 70 hour processing
☺ Highly linear with dose	☺ Slightly non linear with dose
☹ Signal lasts only ~36 h	☺ Signal stable for years
☺ Amenable to high-throughput automation	☺ Amenable to high-throughput automation

Concept of Use



An RDD in a big city: Will it happen?

"Many experts tell us the question is not whether, but how soon ... we will see, for example, a 'dirty bomb' detonated in central London, or some other major capital"

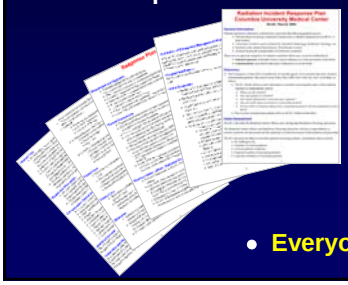
Kofi Annan, UN Secretary General, London, Feb 2005

Bottom line

In the event of a radiological event, medical centers in major cities need to be able to quickly assemble a competent team of health care providers, physicists and administrators / communicators

We need to be prepared for a radiological incident

- **Facilities should plan in advance and include procedures in their Disaster Plan**



2002 AHA Survey

46% of hospitals did not have radiological terrorism in their disaster plan....

- **Everyone needs training!**

Selected further information

CDC and OSHA have very good starting websites:
www.bt.cdc.gov/radiation/dirtybombs.asp
www.osha.gov/SLTC/emergencypreparedness/rdd_tech.html

Documents:
American College of Radiology / ASTRO:
"Disaster Preparedness for Radiology Professionals"
www.astro.org/GovernmentRelations/RadiationDisasterManagement

NCRP Report #138, 2001
"Management of Terrorist Events Involving Radioactive Material"

The real bottom line

- ✓ The threat of radiological terror is real
- ✓ Most scenarios will present major organizational challenges

The real bottom line

- ✓ The threat of radiological terror is real
- ✓ Most scenarios will present major organizational challenges
- ✓ The answer: