Public Health Implications Associated with the December 2013 Radioactive Source Theft Event in Mexico

Robert Emery, DrPH, CHP, CIH, CBSP, CSP, CHMM, CPP, ARM
Vice President for Safety, Health, Environment & Risk Management
The University of Texas Health Science Center at Houston
Professor of Occupational Health
The University of Texas School of Public Health
Learning Objectives

- Describe the events associated with the theft of a high activity radioactive source in Mexico

- Specifically discuss the radiological threat associated with exposure to Cobalt 60

- Describe the public health response implications of a radiological event such as this (what happened and what could have happened?)

- Identify how research conducted at the UT School of Public Health is directly related to this event

- Discuss possible means of prevention that could be applied in this situation to prevent its recurrence
2 December 2013, a truck transporting a 3,000 Curie (Ci) Co-60 teletherapy source from a hospital in Tijuana to a radioactive waste storage facility in Santa Maria Maquixco was stolen in Tepojaco, a town near Mexico City.
Teletherapy Units

- Use the radiation emissions from a source of radioactive material for cancer treatment, typically Co-60.

- When the radioactive source decays to a level where it is no longer effective for treatment purposes, it is removed and can be replaced with a new source.

- The depleted source still represents a health risk and must be stored and disposed of properly.

- When the source is in its shielded position the device is quite safe. When in an unshielded configuration can be very dangerous.

Figure 3. Basic head design of a cobalt radiotherapy unit.
Device being loaded into transport crate 27 November 2013 in Tijuana

Crate on back of transport truck leaving Tijuana 27 November 2013

Event Description (Day 1)

- Given the long drive, the driver and assistant pulled into a gas station to rest

- At around 1 a.m. Monday 2 December 2103, a man armed with a handgun knocked on the passenger window and demanded the keys to the vehicle.

- Both the driver and assistant were taken to an empty lot where they were bound and told not to move. They heard one of the assailants use a walkie-talkie type device or phone to tell someone, "It's done"

Source: http://www.cnn.com/2013/12/06/world/americas/mexico-radioactive-theft/
The thieves drove off in the white 2007 Volkswagen Worker truck, labeled “Transportes Ortiz” on the sides, license plate 726-DT-8.

The driver was eventually able to free himself and notified authorities of the theft.

Mexican authorities initiated a search and issued press releases to alert the public (Day 2).

On 4 December 2013 Mexico's "Comisión Nacional de Seguridad Nuclear y Salvaguardias (CNSNS) informed the IAEA's Incident and Emergency Centre (IEC) of the theft of the truck (Day 3).

Responsibility as part of the member state Code of Conduct.
Why the Concern?

- The 3,000 Co-60 Ci source is considered Category 1 by the IAEA.

- IAEA defines a Category 1 source as “extremely dangerous to the person.”
  - “If not safely managed or securely protected, the source would be likely to cause permanent injury to a person who handled it or who was otherwise in contact with it for more than a few minutes.”
  - “It would probably be fatal to be close to this amount of unshielded radioactive material for a period in the range of a few minutes to an hour.”

- Or the source could possibly be used in a radiological dispersal device, commonly referred to as a “dirty bomb”
Radiological Aspects of Co-60

- Cobalt 60 (Co-60 or $^{60}\text{Co}$)
  - Half life: 5.27 years
  - 2 high energy gamma emissions: $1.17 \text{ MeV} + 1.33 \text{ MeV} = 2.5 \text{ MeV}$
- To estimate the exposure rate at 1 foot from an unshielded point source:
  - $\dot{X} = 6CE$, where
    - $\dot{X} = $ exposure rate in Roentgen/hr (R/hr) at 1 foot
    - $C = $ activity in Ci
    - $E = $ total gamma energy in MeV
  - $(6) (3,000 \text{ Ci}) (2.5 \text{ MeV}) = 45,000 \text{ R/hr}$ at 1 foot from source

The LD$_{50}$ for whole body irradiation is equivalent to about 450 R, an amount that would be reached in about 30 seconds!
Radiological Aspects of Co-60

- Another way to estimate exposure rate that can account for the attenuation caused by the source container and holder:
  - The target Co-60 teletherapy exposure for a 5,000 Ci source is 100 Rmm (R/min at 1 meter)
  - Adjusting for reported the 3,000 Ci would be (0.6)(100 Rmm) = 60 Rmm
    - Converting to R/hr = 3,600 R/hr at 1 meter
    - 1 foot = 30.48 cm. 1 meter = 100 cm, a 3.3 fold difference
    - So the exposure rate at 1 foot would be (3,600 R/hr)(3.3)^2 = 36,324 R/hr
      - Within 20% of 6CE estimation
### What are the Plausible Scenarios at This Point?

<table>
<thead>
<tr>
<th>Source in shield</th>
<th>Source Sealed</th>
<th>Source Breached</th>
</tr>
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<tbody>
<tr>
<td>Best case scenario, low population exposure potential, no contamination, but harder to detect</td>
<td>A portion of the source could be shielded, with perhaps some contamination reaching outside of unit, likely low population risk</td>
<td></td>
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<td>Serious exposure potential for those in proximity of source, situation akin to a Radiological Exposure Device (RED), but makes detection easier. Contamination screening not necessary, but estimating radiation doses becomes an issue</td>
<td>Depending upon amount of dispersal, there would be both an exposure and contamination concern. Situation akin to or could be a Radiological Dispersal Device (RDD). Both contamination screening and dose estimation becomes a concern</td>
<td></td>
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</table>
When radiation emissions from source pass into a body, a person is considered “exposed”, just like when a person has an x-ray. Radiation emissions deposit energy and can cause damage but do not make the body radioactive or contaminated. Thus, after an exposure occurs, there is nothing to detect with a radiation meter.

If a source of radioactive material becomes dispersible, then contamination can occur, where small bits of radioactive materials get on the body. The contaminants can be detected by a radiation meter.

Contaminants can also be ingested or inhaled. Internal contamination can also be detected, typically through bioassay techniques.

Source: http://www.bt.cdc.gov/radiation/contamination.asp
When (and if) the Source is Found, the Key Consideration: is the Source Intact?

- When a sealed source is intact, the primary concern is exposure to the radiation emissions from the source.

- If the integrity of the source is compromised, in addition to the radiation emissions, the issue of radioactive contamination must now be considered.

- So once the source is located, a primary concern will be to determine if the sealed source is intact.

http://www.orau.org/ptp/collection/Sources/teletherapy.htm
Terrorism Potential

- If the thieves were primarily focused on stealing the truck and do not know what the device is, they might be considering the scrap value of the metal (lead).

- If the thieves realize what they have and its potential value to certain “interested parties”, they might try to sell the device.

  - Given the presence of systemic criminal elements associated with drug dealing and human trafficking, the risk of the device falling into the wrong hands and serving as a component of a “dirty bomb” is significant.
Radionuclide Theft and Diversions: 1992 - 2003
Incidents and Suspected Smuggling Routes

Legend
- Origin
- Interdiction
- Destination
- Waypoint
- Suspected Smuggling Routes

Produced by Argonne National Laboratory: 2 December, 2003
Washington Post report, 6 December 2013:

Reported radioactive material theft and seizures 2003 to 2013
Biological Effects

Exposure to ionizing radiation can produce both acute (immediate) and chronic (long term) effects.

- **Acute effects**
  - <100 rem
    - no immediate effects
  - 100-200 rem
    - Mild nausea, vomiting
    - Loss of appetite
    - Malaise, fatigue
  - 200-400 rem
    - Nausea universal
    - Hair loss
    - Diarrhea, fatigue
    - Hemorrhages in mouth, subcutaneous tissues, kidneys
Biological Effects

- Acute effects (con’t)
  - 400-600 rem
    - Mortality probability 50%
  - 600-1,000 rem
    - Bone marrow destroyed
    - GI tract affected
    - Internal bleeding
    - Survival dependent upon prompt medical intervention
  - >1,000 rem
    - Rapid cell death
    - Internal bleeding, fluid loss
    - Cardiovascular collapse
    - Death likely within hours
Biological Effects

- Chronic effects
  - Possible effects on immune system
  - Possible increased risk of cancer (estimates vary with rate of delivery of dose. For acutely delivered doses, $1 \times 10^{-3}$ increased cancer fatalities per rem)
  - Possible damage to reproductive systems can result in mutations passed on to subsequent generations
- Psychological effects
Progression of Acute Radiation Syndrome (ARS)

- Depends on the dose delivered, but starting at whole body doses at about 70 R
  - Prodromal stage
    - Nausea, vomiting, anorexia, diarrhea, minutes to days after exposure
  - Latent stage
    - In this stage patient looks and feels generally healthy, for hours to a few weeks. But stem cells in bone marrow and cells lining GI tract are dying
  - Manifest illness stage
    - Malaise, anorexia, diarrhea, fever, dehydration and electrolyte imbalance. Death can be due to infection, dehydration, and electrolyte imbalance. At higher doses, convulsions and coma

- Also consider skin burns if in direct contact with the source
Examples of Previous Co-60 Events

- 1983 Ciudad Juarez, Mexico. Abandoned Co-60 teletherapy device melted in scrap yard. Metal used to make rebar and table legs. Only detected when a truck took a wrong turn and drove towards Los Alamos National Labs setting off area radiation detectors. 10 people significantly exposed, 1 died, 21 contaminated zones, 109 homes had to be demolished.

- 2000 Thailand. 420 Ci Co-60 unit abandoned, wound up at scrap yard. 3 died, 10 hospitalized, 1,872 significantly exposed.

- 2010 Mayapuri, India. Orphaned Co-60 unit winds up in scrap yard, 1 died, 8 hospitalized
On 4 December 2013 CNSNS reports that law enforcement authorities found the truck abandoned about 25 miles from where it was stolen. The teletherapy head had been taken off of the truck bed and the source rod had been removed from the teletherapy head.

The source rod was located about a half mile from the truck in a corn field.

An exclusion zone of about 500 meters was established – likely at the 2 mr/hr zone.

Mexican authorities began assessing potential radiation exposures to persons who may have been close to the unshielded source, and hospitals were alerted to watch for symptoms of such exposure.
Event Description (Day 5)

- On 6 December 2013 Mexican media reports that the six individuals were admitted to the general hospital in the city of Pachuca and may have been exposed to the stolen source.

- All males, ranging in age from 16 to 38. Unclear whether the thieves were among these individuals.

- They all tested “negative for radiation poisoning” and were released to law enforcement officials for questioning.
  - The actual testing performed not included in reports.
  - Asking about symptoms? Lymphocyte count? Chromosome dicentrics?

- In the meantime, specialized robotic equipment being assembled for source recovery by Mexican authorities.
Public Health Considerations for This Type of Event

- Medical community notified of event – increase awareness about individuals possibly arriving exhibiting certain symptoms

- Establish system for screening patients prior to entry to avoid possible contamination
  - Techniques for sorting between externally contaminated, internally contaminated or both

- Set up decontamination stations

- Availability of appropriate decorporation agent (DTPA)

- Possible surge capacity needs to monitor large numbers of concerned citizens

- Providing factual and appropriate information through the mass media
Educating the Medical Community: Presentation of Burns with No Knowledge of Cause

The hallmark diagnostic question: *How did you get these burns?*

http://web.princeton.edu/sites/ehs/radiation/Xraytraining/RigakuMiniflexPrism.htm\#Incidents
Other Considerations

- Had contamination occurred (due to breached source or explosion):
  - If malicious, law enforcement involvement, security controls, evidence collection, intensive media coverage
  - Demands for screening passengers arriving from affected area via car, plane, or boat
  - Demands for screening of products (food, livestock and materials) coming from affected area
  - Employers, travelers concerns about travel to affected areas
**Other Public Health Consideration**

- The **case definition**: the method by which public health professionals define who is included as a *case* in an outbreak investigation, (i.e. a person considered directly affected by an outbreak)

- A **case definition** defines a case in terms of time, person, and place.

- Case definitions may also be categorized into **suspect**, **probable** and **confirmed** cases.

- Example:

  **Suspect Clinically Significant Radiation Exposure Case**: All residents of Hueypoxtla with onset of symptoms such as nausea, dizziness, vomiting, or diarrhea between December 2, 2013 and December 11, 2013.

  **Probable Clinically Significant Radiation Exposure Case**: Meet the suspect case definition plus presence of skin reddening or burns of unknown origin after December 2, 2013.

  **Confirmed Clinically Significant Radiation Exposure Case**: Meet the probable case definition plus have exposure confirmed by serial lymphocyte count and/or skin reddening or burns of unknown origin.


Work at UT School of Public Health

Emery RJ, Sprau DD, Morecook RC. Risk communication considerations to facilitate the screening of mass populations for potential contamination with radioactive materials. Health Phys 95(Suppl 5):S168-S174; 2008.


Tools Developed at UT SPH

- Nomograms developed for rapid estimation of dose and assignment of clinical category for sources commonly involved in accidents

- Comprehensive chart addressing clinical care steps using three means of estimating dose
  - By direct measurement in US or SI units and subunits
  - By serial lymphocyte count
  - By “time to onset” of symptoms

- Summary chart for decorporation agents and estimated external exposure rates
Prevention (Research Opportunities?)

- Possible measures to prevent the recurrence of an event such as this:
  - Transport only in enclosed vehicle?
  - Stop at only pre-identified rest stops?
  - Specified travel times?
  - Include guards during transport?
  - Install intrusion delay or deterrents on device head prior to transport?
  - GPS locator on truck and source?
  - Lessons from other industries, such as armored cars?

- Where did the teletherapy unit originally come from? are sources being transferred to places with inadequate infrastructure?
On 11 December 2013 Mexican officials report that robot retrieval of source successful. Source now in transport container and on way to waste storage facility.

Press reports: a farmer in the cornfield where the source was found has been hospitalized. He reportedly handled the source and became ill soon after.

A federal judge has ordered the detention of 5 individuals suspected of being involved in the theft. Their health status not reported.
“Recovering a source of that level of intensity is not making enchiladas,” Juan Eibenschutz, executive director of the Nuclear Security and Safeguard Commission
On 12 December 2013 IAEA press release on website reporting successful recovery of source, and:

- “One member of the public is undergoing medical assessment in Mexico City after presenting himself with skin damage indicating overexposure to the source by carrying it over one shoulder .... A further 60-70 people have presented themselves for testing but have not shown signs of overexposure.”

- 12 December 2013 press report: “For Mexican Town, Fears Linger Over Theft of Radioactive Cobalt-60”
  - Article cites examples of poor risk communications to village townspeople.
  - Public apparently didn’t understand mixed message:
    - “It’s safe, but stay away”
  - Mistrust of authorities, confusion about exposure versus contamination
Summary

- Theft events involving radioactive materials are relatively rare, so a review of this case provides a useful public health educational experience to answer the questions:
  - “could we have responded to this?” and
  - “what would have been my involvement in the response?”

- All of the facts of the case described here have not yet been assembled, so the final public health impact of the event has not yet been determined

- Thankfully the source was found, apparently was not leaking, and has been recovered

- The event also serves as the basis for an important discussion about “what else could have happened”

- Several possible means of prevention exist that could help in reducing the probability of recurrence or improving emergency response and risk communications
UTHealth
The University of Texas Health Science Center at Houston
School of Public Health