Permanent Risk Reduction: A Roadmap for Replacing High-Risk Radioactive Sources and Materials

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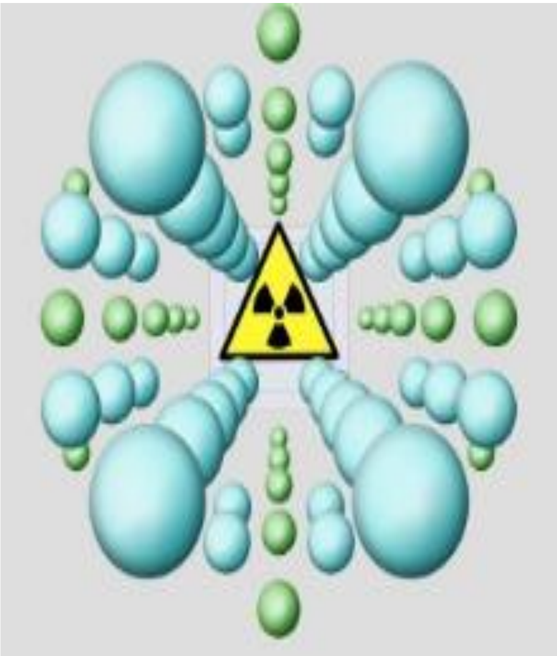
Overview

- CNS Workshops and Studies
- Materials of Security Concern
- Uses of Current High-Risk Materials
    - Medicine
    - Oil and gas industry
- Strategy for Replacing High Activity Sources
- Replacement Priority
- Encouraging Replacement: Actions
- Conclusions



CNS Workshops and Studies

Since 2008, CNS has led a series of workshops and studies:

- Alternatives to High-Risk Radiological Sources: The Case of Cesium Chloride in Blood Irradiation (2014)
- Permanent Risk Reduction: A Roadmap for Replacing High-Risk Radioactive Sources and Materials (2015)
- Treatment Not Terror: Strategies to Enhance External Beam Cancer Therapy in Developing Countries While Permanently Reducing the Risk of Radiological Terrorism (2016)
- Additional material since: for NYC, NTI, and IAEA ICONS, draft language for 2016 NSS

CNS

Important Current Uses for High-Risk Materials, Existing Alternatives and Challenges, and Suggested Next Steps

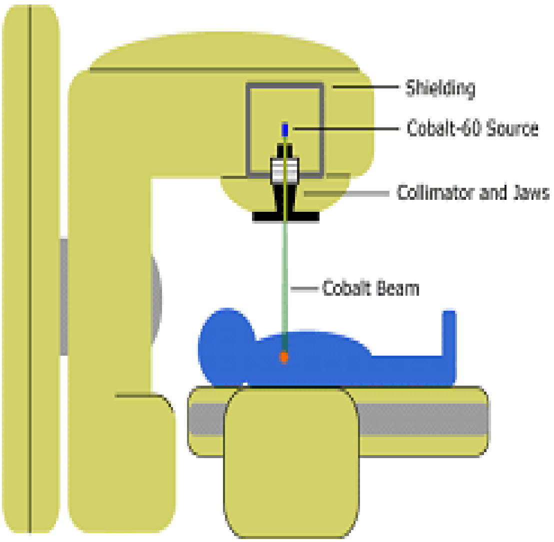
High-Risk Sources

- A task force report by the NRC listed 16 radionuclides as those of principal concern when considering the problems they would cause if used in a radiological dispersion device (RDD)
- Considered an immediate danger only when found in large enough amounts to threaten life or cause severe damage (IAEA Category 1 and 2)
  - Categories 1 and 2 as well as some from Category 3 are those for which replacement is most warranted
- Radionuclides highlighted in blue are in widespread commercial use around the world and those with highest risk

1. Americium-241 (Am-241)
2. Am-241/Beryllium (Be)
3. Californium-252 (Cf-252)
4. Cesium-137 (Cs-137)
5. Cobalt-60 (Co-60)
6. Curium-244 (Cm-244)
7. Gadolinium-153 (Gd-153)
8. Iridium-192 (Ir-192)
9. Promethium-147 (Pm-147)
10. Plutonium-238 (Pu-238)
11. Pu-239/Be
12. Radium-226 (Ra-226)
13. Selenium-75 (Se-75)
14. Strontium-90 (Sr-90)/Yttrium-90 (Y-90)
15. Thulium-170 (Tm-170)
16. Ytterbium-169 (Yb-169)

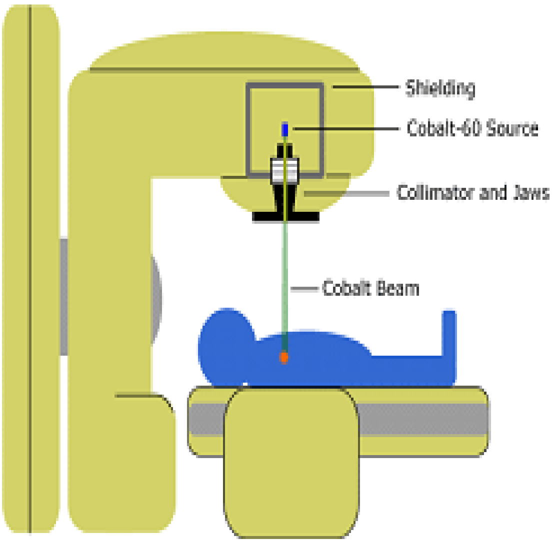
Cancer Treatment: External Radiation

- LINACs and radiotherapy machines that employ Co-60 and Cs-137 sources can treat cancer
- In high- and middle- income countries, radiotherapy machines have been replaced with LINACs
  - Better cancer care:
    - Can hit deep seated cancers, target tumors more precisely and spare more healthy tissue
- LINAC use less widespread in LMICs because of higher costs, complexity and need for stable power sources
  - Use of LINACS varies directly with GDP/capita
  - Widespread use HMIC, medium LMIC, less LIC



Cancer Treatment: External Radiation

- Cancer rates are growing in developing states: Meeting need with Co-60/Cs-137 would create security threats in areas where security is weakest
- Governments should encourage replacement where feasible and training and education in LINACs through groups such as International Cancer Expert Corps
- Companies and governments should support development of LINACs more suitable for challenging environments

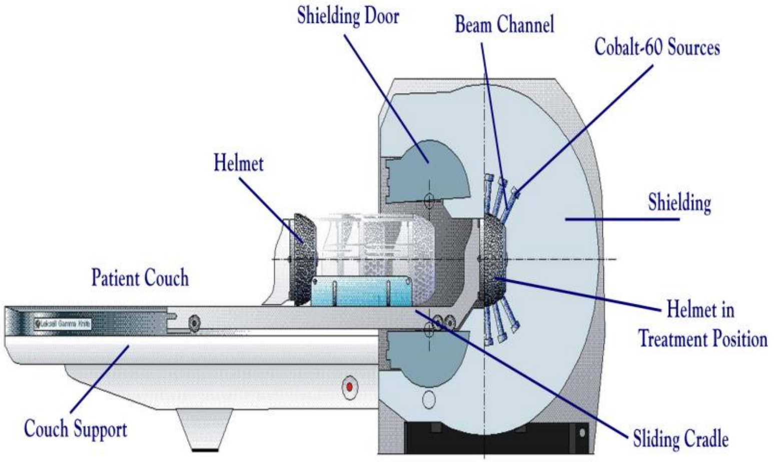


Cancer Treatment: Internal Radiation

- Brachytherapy involves placing radioactive material into the body where it provides localized doses to, for example, destroy tumors
- Doubtful that radionuclides in this case can be replaced
  - This method is superior to external radiation in cases where external radiation would cause too much damage
- Investment in screening and prevention programs to lessen late stage presentation of disease can reduce need for radiation

Cancer Treatment: Radiosurgery

- **Radiosurgery uses multiple collimated Co-60 sources, the so-called Gamma Knife—particularly for brain tumors**
- **Primarily used in developing countries**
- **Other technologies have emerged: CyberKnife technology, which uses LINAC, is the most accepted**
- **Both types have some support among doctors. Depends on:**
  - **Range and Type of Treatment**
  - **Doctor preferences**
  - **Costs**
- **Additional clinical experience needed to determine the degree to which alternatives can replace Gamma Knife**



Blood Irradiation

- Cs-137 in the form of cesium chloride is commonly used for blood irradiation prior to blood transfusions to prevent Graft-Versus-Host-Disease
- 2008 NAS Report: Replacement of Cs-137 highest priority for implementing use of alternative technologies
  - Danger of Cs-137 for "Dirty Bombs"
  - 1/3 of irradiators replaced in US under CIRP
  - France, Norway, Japan no Cs-137
- X-ray units (and to some extent Photovoltaics) and LINACs are equivalent in cost and quality

Irradiation: Medical Research

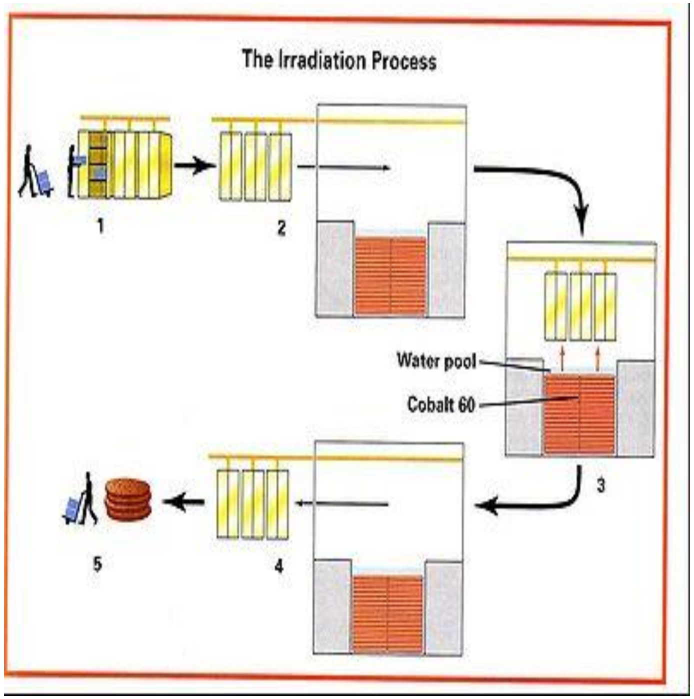
- Medical research uses of radioactive sources involve tagging and tracing biological activities
- Like cancer treatment, alternatives include x-ray machines or small accelerators
- Some energies can only be reached through Cs-137
- Concern about replicating and comparing results.
- Focus on new researchers, calibration/correlation, and consultations to ensure quality of continued research (U-California)

Irradiation: Medical Equipment (Sterilization)

- Represents 80% of 420 million curies of Co-60 used worldwide
- Primary Med sterilization modality is chemical (ethylene oxide)
- For gamma irradiation: Co-60 or e-beam or x-ray
  - Co-60 penetrates packages more effectively
  - But e-beam faster- may be equivalent
- Historical practice and regulatory requirements slow replacement
  - if producer changes method has to undergo through expensive testing and validation process
  - Should government provide support?

Food Industry: Irradiation

- Massive amounts of high-activity radioactive material, Cs-137 and Co-60, are used in large facilities for food sterilization and preservation.
  - Often used to kill pests like fruit flies
- Irradiation has been growing 10% a year
  - Other chemical alternatives increasingly restricted
- E-beam based x-ray technologically equivalent-Gamma
  - In fact greater flexibility and faster processing time
  - Real difference is in cost– x-rays better above a certain volume because of sunk costs in electricity
  - Trend toward E-beam
    - In China, # of cobalt-60 facilities dropped from 153 to 140 in 2017; # of e-beam facilities increased from 369 to 500
    - Analyst: "Unless economics is overwhelmingly in favor of Gamma Irradiators, Accelerator-based systems are bound to prevail"
- Leave to market forces or help accelerate the accelerators?



Oil and Gas: Downhole Applications

- Oil and gas industry uses two types of radioactive sources downhole: neutron and gamma ray sources.
- Useful in analyzing minerology mapping, measuring density and porosity, and making inter-well measurements
  - Density and Lithology are usually determined by cesium-137 gamma source that is well below category 2 threshold
  - Lithology and Porosity are typically determined by stronger Am-241/Beryllium neutron sources---some older sources category 2
- Materials usually double-encapsulated, but security often breached due to negligence, portability a challenge
- Replacement by the use of Deuterium-Tritium (DT) generators not as good:
  - Much lower porosity sensitivity
  - Current research into D-D, D-Li7 and Dense Plasma Focus Accelerators—good performance; some other trade-offs
  - Other alternatives– acoustic sources and Nuclear Magnetic Resonance also have challenges
- If replaced, need to find means of comparing historic data

Sterile Insect Technique: Electronic Alternatives

- SIT used to suppress or eradicate a harmful pest that damages agriculture or causes disease in humans
  - Use radiation to sterilize males who mate with females and don't reproduce. Ultimately can control population.
- Large gamma devices with large amounts of material: 24 Co-60 and 10 cesium-137 dedicated units worldwide
- Electronic alternatives:
  - X-rays: Generally lower dose rate and less effective penetration so lower throughput and longer processing time (which leads to less time for mating)
    - But similar results for some diseases—mosquitos with dengue fever; and some agricultural applications; Orangeworm (tree nuts), hive beetles (honey)
    - And safer and more secure and better able to obtain replacements
  - E-beams: rarely used, but technically greater potential with future improvements

Sterile Insect Technique: Biological and Chemical Alternatives

- Wolbachia
  - Leveraging endemic bacteria that can lead to sterility (introducing it to other insects in lab that then reproduce)
- Genetic Engineering
  - Release of Insects Carrying Dominant Lethals– lethal genes suppressed in lab but when they are released gene kills offspring before reach maturity
  - Gene drives-- emerging technology used to increase the spread of particular mutations among population
    - experiments with malaria mosquitos, i.e. female sterility or insuring male offspring
- Chemosterilization
  - Renewed interest after problems with DDT
  - Some new candidates

Nondestructive Testing: Radiography

- NDT employs radioactive sources (Ir-192) in fieldwork where x-ray units cannot be used to inspect quality and safety of solid and welded systems
- Radiographing uses a portable radiographic camera housing Category 2 or 3 amounts of radionuclides
- Often left unattended in vehicles and subject to theft
- Camera systems high risk but easier to use in fairly inaccessible places, x-ray units too bulky and require power sources,
- Ultrasonic Testing is highly effective and some ways superior
  - Only need access to one side of a material to search for defects
  - Far fewer safety/secure risks –no need for radiation exclusion zone

Strategy for Replacing High Activity Sources

- Replacing radionuclides in high-activity devices should be driven by need to mitigate risk that materials will be come available for criminal or unauthorized acts
- Replacement superior to radiological security efforts- permanent threat reduction
- As a rule of thumb, *before substituting an alternative non-isotopic device or material for a high risk radionuclide, the alternative should be at least roughly equivalent in cost and utility for carrying out the intended use as the high-risk radionuclide it would replace.*

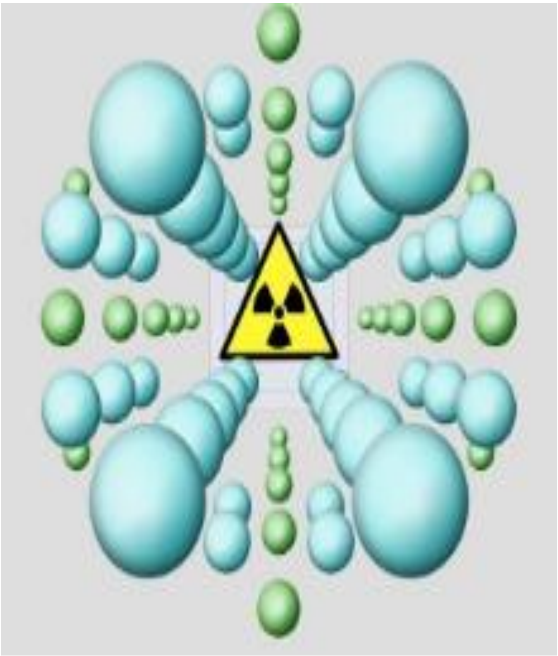
Replacement Priority

- Level of risk of material should be determined on case by case basis:
  - Where is it located—i.e. security environment?
  - How dangerous is radionuclide?
  - How much is needed for device or task?
  - Will physical characteristic of material have impact on how easily it may be used for criminal/unintended activities?
  - How essential is the material?
- Certain fundamental replacement priorities such as seeking to replace category 1 and 2 sources
  - particularly Cs-137

Encouraging Replacement: Actions

- Government encouragement
  - Goal and Norm Setting: Broad Mandates
  - Softer approaches such as financial assistance, tax breaks
  - Justification Principle and Financial Assurance
- Leveraging Market forces
  - Lack of knowledge about liability risks
- International coalition
  - Awareness raising, generation of global strategy for alternative technologies
  - Should involve industry and professional society groups, scientific and policy research communities, government policy makers and regulators

Conclusions



- Replacement of high-activity radionuclides is a critical element of permanent threat reduction
- Technical successes follow political commitment (HEU–LEU conversion)
- An objective numerical scale needs to be developed to establish replacement priorities
- Much of the data is available, but organizing and verifying data and creating useful databases will require technical expertise and oversight