

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

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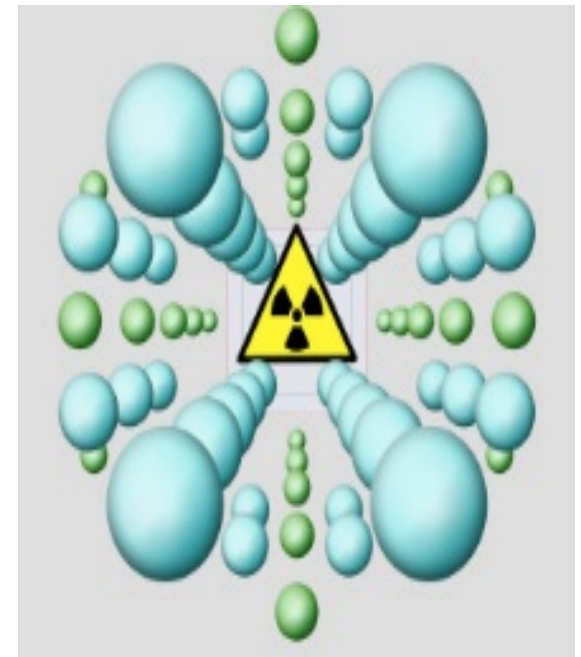
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Radioactive Sources: Applications and Alternative Technologies Meeting

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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**



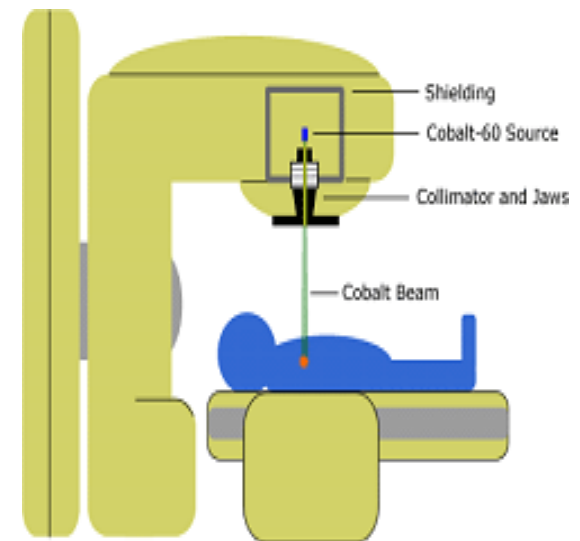
Important Current Uses for High-Risk Materials, Existing Alternatives and Challenges, and Suggested Next Steps

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)

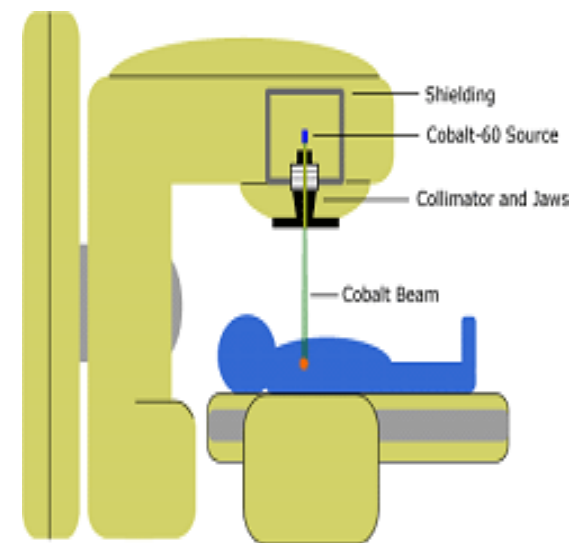
Cancer Treatment: External Radiation

- 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

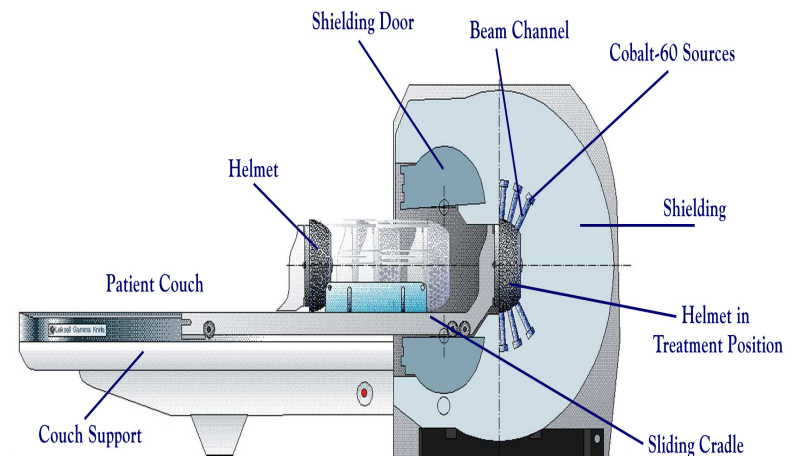


Cancer Treatment: Internal Radiation

- 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)**

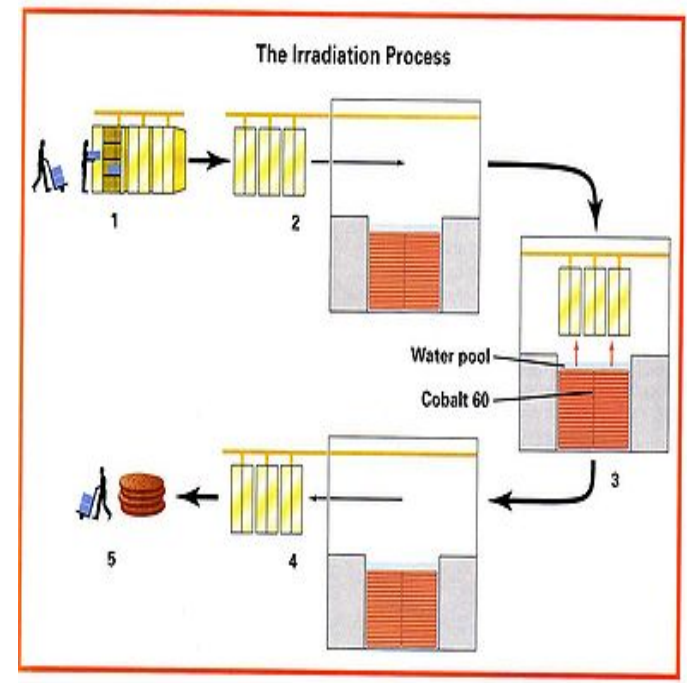
Irradiation: Medical Equipment (Sterilization)

- 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 mineralogy 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

