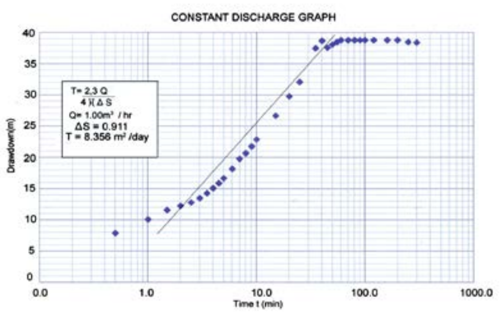
SAND2018-2727C

International Implementation of IAEA's Borehole Disposal Concept for Sealed Radioactive Sources 18545



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Exceptional service in the national interest

John R. Cochran *jrcochr@sandia.gov*

David G. Bennett - International Atomic Energy Agency, Waste Safety

Paul Degnan - Catalystra, Australia

Chris Grout - Global Affairs Canada

Gert Liebenberg - International Atomic Energy Agency, Nuclear Safety & Security

Richard Little - Quintessa Limited, United Kingdom

Jack Ramsey – U.S. Nuclear Regulatory Commission

Japie van Blerk - Aquisim Consulting Limited, South Africa

Philippe Van Marcke - International Atomic Energy Agency, Waste Technology

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What works? teamwork

- 9 authors – but 100's have contributed
- Special thanks to Nora Zakaria (Nuklear Malaysia) and Eric Glover (Ghana Atomic Energy Commission)
- Success because of <u>international teamwork</u>

Contents

- Disused Sealed Radioactive Sources
- Safety and Security Threats from DSRSs
- Options for Management of DSRSs
- IAEA’s Borehole Disposal Concept
- Implementation in Ghana and Malaysia
- Concluding Words

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What is a Sealed Radioactive Source?

- A small container of radioactive material that is sealed to contain the radioactive material, but not the radiation
- Most < 15 cc and largest < 280 cc
- Most are ~ low activity, but some intensely-radioactive
- Used widely in beneficial applications
- In all countries
- Millions manufactured

Low Energy Gamma SRSs
(Photo credit: QSA Global)

What are Disused Sealed Radioactive Sources?

- They are - radioactive sources which are no longer used, and not intended to be used again, for their original purpose
- Disused because:
  - Radioactive decay
  - Source equipment becomes obsolete, or worn-out or damaged
- *May be several million DSRSs in the world*

Source Devices Containing DSRSs

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Safety and Security Threat

- DSRSs Safety Threat
  - Visually appear harmless
  - Human senses cannot detect radiation
  - Name is misleading; if sealed, then must be safe
  - Fatal accidents from poorly-controlled sources

- DSRSs Security Threat
  - Radiological dispersal device or so-called “dirty-bomb””
  - Weapon of mass disruption

Goiânia Incident

- Accident (safety) occurred in Goiânia, Brazil 1987
  - 50-TBq (1350 Ci) Cs-137 source stolen & cut open
  - Acute anxiety ensued, *112,000 people* sought medical attention
  - 4 died
  - Several years to decontaminate and cleanup
  - Discrimination against people and goods
- Analogue for dirty bomb (security) incident

Goiânia Incident

- 3,500 m3 radioactive wastes from 15 cc of Cs-137

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Management Options

1. Decay in storage
2. Reuse or Recycling
3. Return to the vendor/repatriation
4. Storage and
5. Disposal.

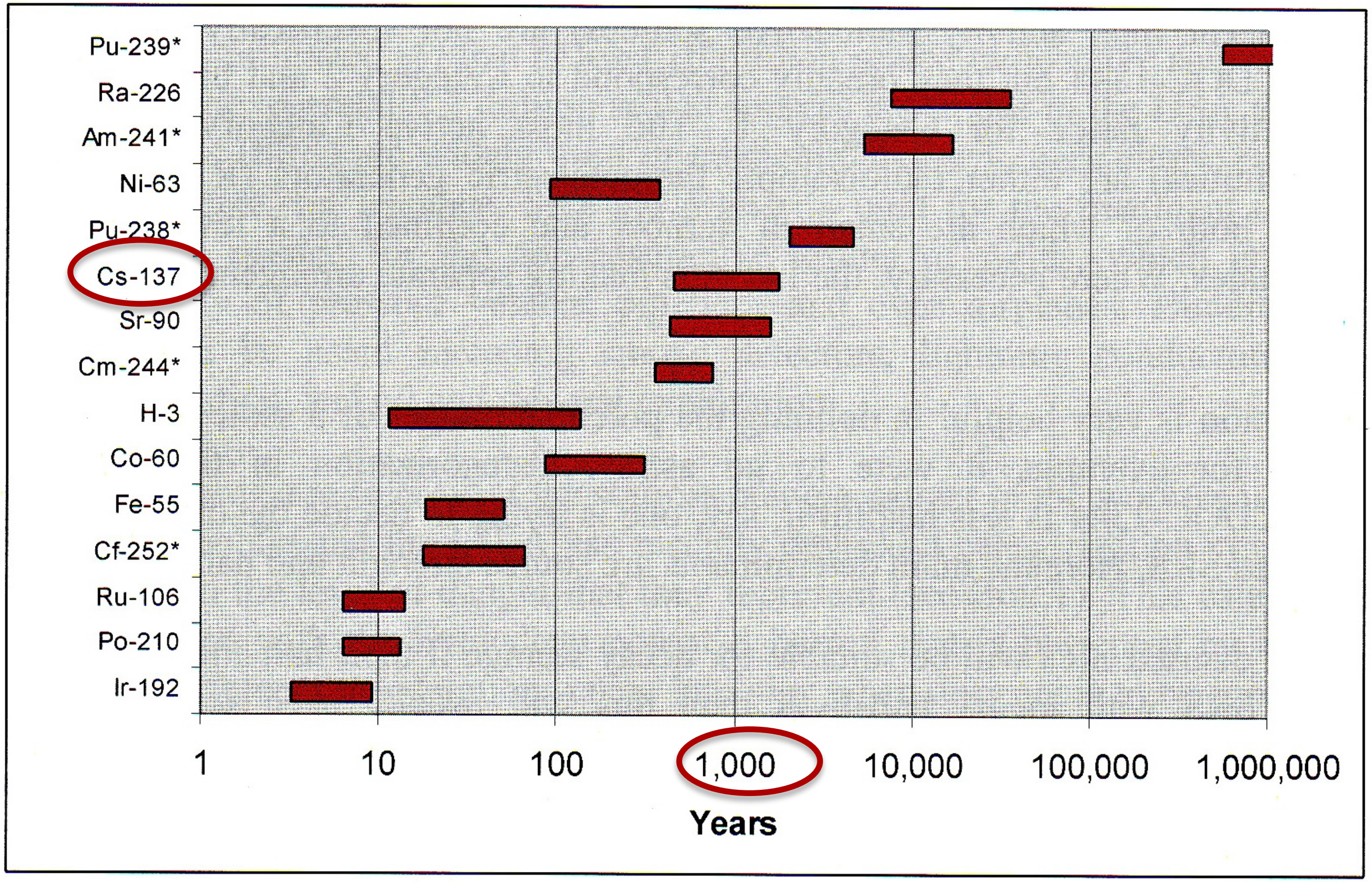
Management Options

1. Decay in storage → OK for small percentage
2. Reuse or Recycling → economical for small percentage
3. Return to the vendor/repatriation → limited
   a. Manufacturers out of business
   b. No "special form" certificate for shipping
   c. Shipping too costly
   d. Cheaper to use new materials
   e. Repatriation very expensive
4. Storage and
5. Disposal.

Repatriation of Sources to the U.S.

Photo: LANL's Off-Site Source Recovery

Long-Term Storage & Time to Decay



Time Required for Nuclides in DSRSs to Decay to the IAEA's Exemption Levels
(Asterisk Indicates Nuclides Where Progeny Are Longer-Lived than the Parent Nuclide)

Disposal

- Disposal is the *only long-term exit strategy* for most DSRSs
- Disposal is also difficult
  - No disposal facilities for DSRSs in Africa or Middle East – all held in storage
  - Nuclear-power countries have some disposal capacity for DSRS
  - For example - in U.S. several disposal facilities that accept DSRSs, but – 4.8 TBq (130 Ci) limit for Cs-137 sources, far below the 50 TBq (1350 Ci) source in Goiânia incident

Contents

IAEA's Integrated Program Manage DSRSs

- *IAEA developed integrated program* that supports the efforts of Member States to manage and dispose of DSRSs
- Program began early 1990's with conditioning of radium needles in African countries
- IAEA's main implementing contractor is South African Nuclear Energy Corporation (NECSA)

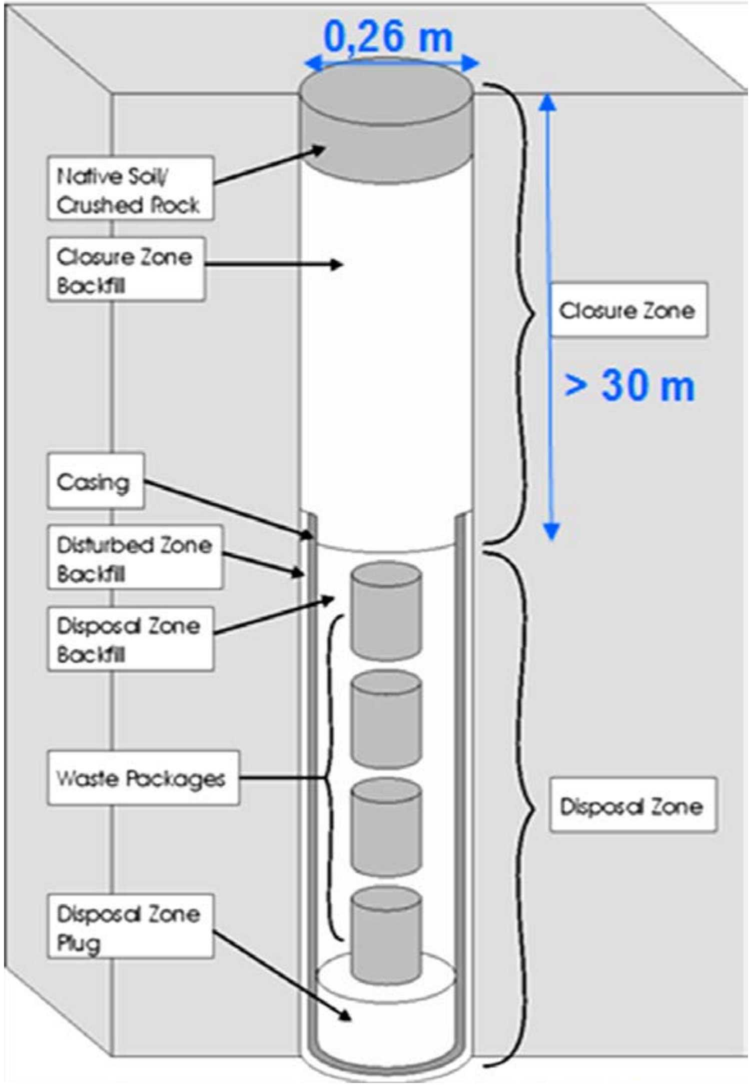
IAEA's Integrated Program to Manage DSRSs

- Collection of DSRSs
- Characterization
- Conditioning for storage
- Interim storage & inventory control
- Analysis of long-term management options
- Analysis of disposal options
- Disposal site selection process
- Design of the BDC
- Development of the safety case for the BDC
- Licensing the BDC disposal facility
- Disposal (construction / condition for disposal / transport / emplacement / closure) and
- Post-closure monitoring.

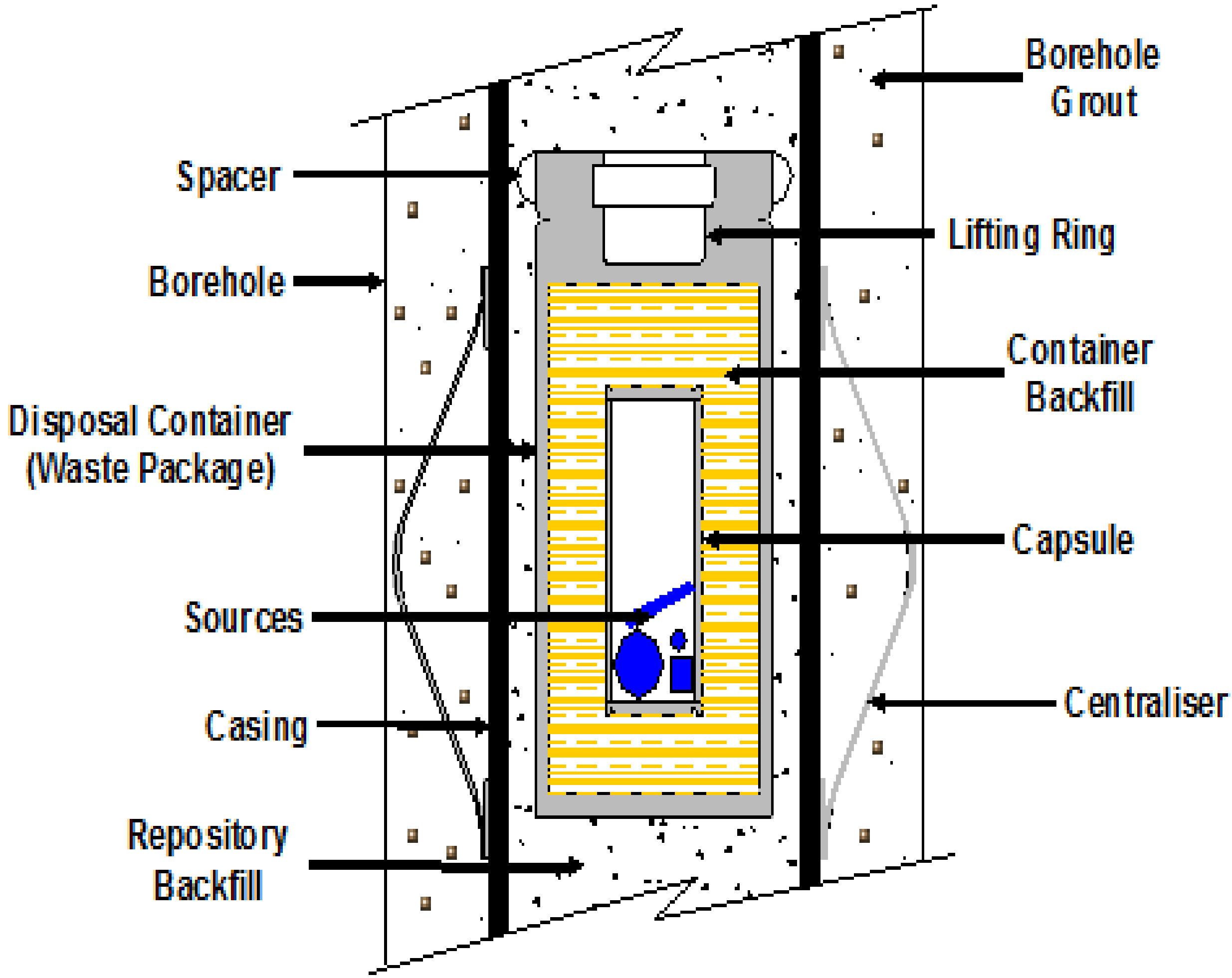
IAEA's Borehole Disposal Concept (BDC)

- Multi-barrier disposal system for DSRSs that uses:
  - Stainless steel capsules to hold the DSRSs
  - Stainless steel containers to hold the capsules
  - Cement barriers
  - Disposal in a borehole, at depths > 30 m

System View of BDC



Close-up View of BDC



BDC - Container and Capsule

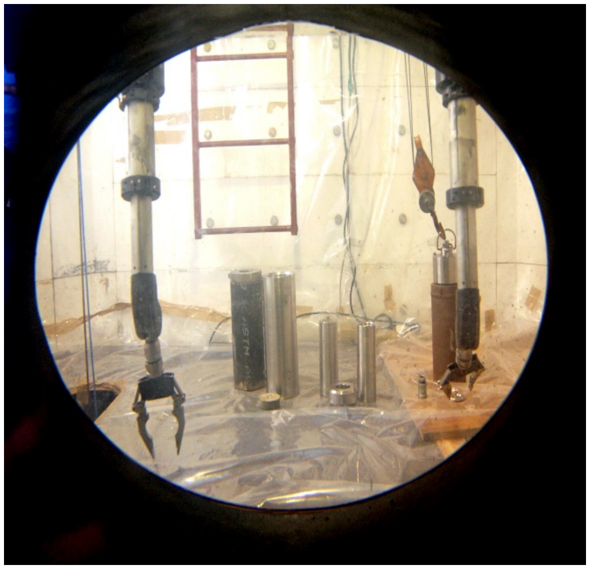
Why the BDC is Safe

- Multi-barrier system (doesn't rely on any single barrier)
- Completely passive (e.g., no leachate-collection)
- Uses materials with well understood properties:
  - Stainless steel resists corrosion commonly available geochemical conditions
  - Cement with high alkalinity reduces corrosion rates stainless
  - Cement sorbs nuclides and limits advection
- Small footprint & depths > 30 m greatly limits the likelihood:
  - Inadvertent human intrusion (safety) and
  - Deliberate human (security)
- Relatively simple

IAEA’s Mobile Hot Cell

- Hot cell required transfer higher-activity DSRSs from their “source devices” to an interim storage or disposal capsules
- Many countries lack access to hot cell
- IAEA/NECSA build “mobile hot cell” fitting in 2 ISO sea-land containers
- Double-walled steel box, with master-slave manipulators & 1.5-m thick window
- Fill cavity between walls with river sand
- Safe up to 37 TBq (1000 Ci) Co-60

IAEA’s Mobile Hot Cell



Contents

Implementation of the IAEA's BDC

- Canada provided $2.5 million USD grant through Weapons of Mass Destruction Threat Reduction Program to IAEA to demonstrate the BDC in Ghana, Philippines and Malaysia
- Part of Canada's international security commitments made in the context of the Global Partnership
- Ghana and Malaysia moving forward, and Philippines scaled-back

Implementation in Ghana & Malaysia

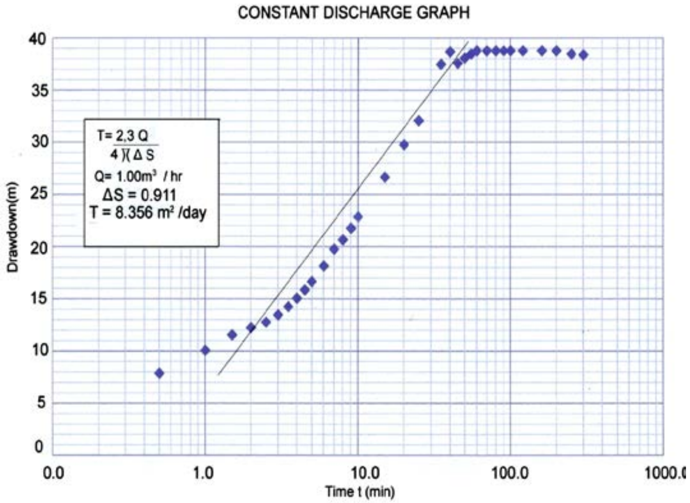
- Many similarities
  - Tropical climate
  - Sited the BDC at Research Facilities
  - Fractured bedrock with shallow groundwater

- Many Differences
  - Malaysia self-funded many activities
  - Ghana - 256 DSRSs with total activity ~33 TBq (~900 Ci)
  - Ghana – 13 waste packages <u>137- 150 m deep</u>

  - Malaysia - 12,928 DSRSs with a total activity of ~ 1 TBq (~32 Ci)
  - Malaysia - 60 waste packages <u>117 m to 177 m deep</u>

Proposed Disposal Site - Malaysia

Site Characterization Malaysia & Ghana



Safety Case for the BDC

- The safety case integrates the evidence and arguments that support, justify and quantify safety
- Qualitative confidence-building
- Quantitative dose-assessment
  - Site characterization data + inventory data + BDC design + evaluation of features, events and processes = scenarios
  - Mathematical and computer models of the scenarios to assess hypothetical doses

Safety Case for Malaysia and Ghana

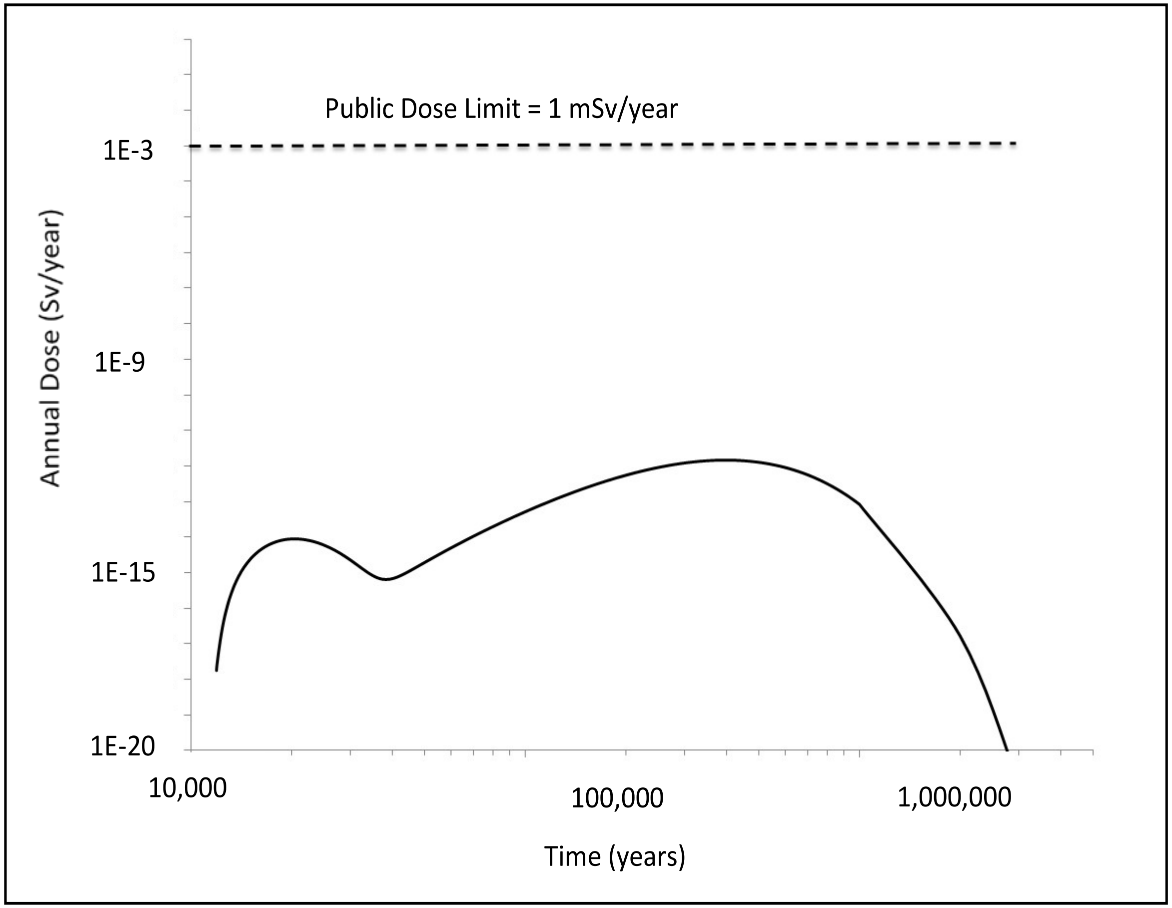
- Nuklear Malaysia and Ghana Atomic Energy Commission (GAEC) each led Safety Case development
- “Heavy-lift”
  - Little precedence (no template to follow)
  - In-country team of experts not always available

Nuklear Malaysia's SC Report

TABLE OF CONTENT

Nuklear Malaysia's SC Report

Dose Results - Malaysia



Calculated Annual Dose to Resident Farmer, for the Expected Performance Design Scenario, with Peak Dose being ~ 6 x 10^{-10} mSv/yr

Status in Malaysia & Ghana

- Malaysia - submitted their license application (with Safety Case) in fall 2017 , in licensing process
- Ghana – revising Safety Case for submission summer of 2018

Contents

Concluding Remarks

- Storage is not long-term option for majority DSRSs
- Disposal is only exit strategy majority of DSRS
- IAEA developed the multi-barrier BDC
- Malaysia and Ghana are implementing BDC with support from Canada, the IAEA, the U.S. NRC, and many others
- The inventory of DSRSs will likely be safely disposed in-country; permanently eliminating the safety and security liabilities of these sources, and
- These programs are providing a template for other countries to safely dispose of their DSRSs.

Thank You

and “thanks” to the US Nuclear Regulatory Commission’s Office of International Program for funding preparation of this presentation