Derivation of radionuclide levels in remediation waste that are appropriate for disposal on landfills

Gerhard Proehl, Gerard Bruno, Jagos Raicevic

Agenda Item 4.3

40th Meeting of the Waste Safety Standards Committee (WASCC)
Topical Session: Remediation Strategies after an Emergency
2-3 November 2015, Vienna
Background of the work

• Remediation
  • Reduction of public exposure due to contamination of farmland, residential areas, forests, surface waters
    • Removal /immobilization of radionuclides
    • Modification of exposures pathways

• Removal of contaminated soil, grass, rubble, vegetation may generate enormous amounts of material
  • Usually activity levels are relative low

• Safe handling, processing, treatment, storage and disposal is necessary
  • Avoid undue exposures to the public and workers
  • Avoid a secondary dispersion in the environment
    • Wind and water erosion
  • Avoid use for construction purposes and preparing organic fertilizers
Waste classification scheme in IAEA GSG-1

- HLW: High level waste (deep geological disposal)
- ILW: Intermediate level waste (intermediate depth disposal)
- LLW: Low level waste (near surface disposal)
- VSLW: Very short lived waste (decay storage)
- VLLW: Very low level waste (landfill disposal)
- EW: Exempt waste (exemption/clearance)
Definitions from GSG-1

**Exempt waste (EW)**
- Waste that meets the criteria for clearance, exemption or exclusion from regulatory control for radiation protection purposes as described in IAEA RS-G 1.7

**Very low level waste (VLLW)**
- Waste that does not necessarily meet the criteria of EW, but that does not need a high level of containment and isolation
- Suitable for disposal in near surface landfill type facilities with limited regulatory control. Such landfill type facilities may also contain other hazardous waste.
- Typical waste in this class includes soil and rubble with low levels of activity concentration.
- Concentrations of longer lived radionuclides in VLLW are generally very limited.
Clearance and exemption  (IAEA Safety Glossary)

Exemption

- The determination by a regulatory body that a source or practice need not be subject to some or all aspects of regulatory control on the basis
  - that the exposure and the potential exposure due to the source or practice are too small to warrant the application of those aspects or
  - that this is the optimum option for protection irrespective of the actual level of the doses or risks.

Clearance

- The removal of regulatory control by the regulatory body from radioactive material or radioactive objects within notified or authorized practices.
  - Removal of control in this context refers to control applied for radiation protection purposes.
Exemption and clearance in IAEA documents
Clearance and exemption levels
(GSR Part 3, IAEA Safety Glossary)

Clearance level
- A value, established by a regulatory body
- and expressed in terms of activity concentration,
- at or below which regulatory control may be removed from a source of radiation within a notified or authorized practice.

Exemption level
- A value, established by a regulatory body and expressed in terms of activity concentration, total activity, dose rate or radiation energy,
- at or below which a source of radiation need not be subject to some or all aspects of regulatory control.
Radiation risks arising from the practice or a source within a practice are sufficiently low

— as not to warrant regulatory control,

— with no appreciable likelihood of situations that could lead to a failure to meet the general criterion for exemption; or

Regulatory control of the practice or the source would yield no net benefit,

— in that no reasonable control measures would achieve a worthwhile return in terms of reduction of individual doses or of health risks.
Radiological criteria

- A **practice** or a source within a practice **may be exempted**, material **may be cleared** without further consideration provided that ....
  - the **effective dose** ..... owing..
    - to the exempted practice or the exempted source within the practice,
    - to the cleared material
      - is of the order of 10 $\mu$Sv or less in a year.

- To take into account **low probability scenarios** ..... the effective dose expected to
  - .... **any member of the public** for such low probability scenarios
  - does **not exceed 1 mSv in a year**.
Derivation of clearance and exemption levels

Clearance levels in the IAEA-BSS

- Determined that the cleared material may be used without any further restrictions
- Based on IAEA SRS-44

IAEA-BSS – Footnote 65

... specific clearance levels may be developed for metals, rubble from buildings and waste for disposal in landfill sites: “Conditional clearance levels”
Approach in SRS-44

- **Includes all types of solid material**
  - containing man-made and natural radionuclides
  - Not for foodstuffs and drinking water

- **Derived on the basis of several scenarios and assumptions**
  - Including external irradiation, dust inhalation and ingestion
  - Encompass all typical exposure situations for all material types.
  - Relate activity concentration to individual doses

- **To cover various uses of material, more than one scenario has been considered for each pathway**
  - Reflect the range of material characteristics and exposed individuals
  - Each scenario contains a set of parameter values
  - Each scenario represents a range of exposure situations
Scenarios considered in SRS-44

**Workers**
- On landfill
- In foundry
- Other worker (e.g. truck driver)

**Residents**
- Near landfill or other facility
- Near foundry
- In house / near place constructed of contaminated material
- Using water from private well
  - landfill -> groundwater -> well
- Consuming fish from contaminated river
Derivation of clearance levels in SRS-44

Consideration of 2 cases

- Realistic scenario
- Low probability scenario

Estimating for each scenario

- Activity concentration in material that lead to an effective dose of
  - 10 µSv/a for the realistic scenario
  - 1 mSv/a for the low probability scenario
- Selection of the scenario with the lowest activity concentration for derivation of the radionuclide-specific clearance level
- Rounding to the next order of magnitude
- Consider the mixture of radionuclides (man-made or natural)
Comparison of activity levels for different scenarios (IAEA-SRS 44)

<table>
<thead>
<tr>
<th>Radio-nuclide</th>
<th>Clearance level RS-G 1.7/ SRS-44 (Bq/g)</th>
<th>Limiting scenarios</th>
<th>Activity level in material derived for scenario Landfill -&gt; groundwater -&gt; well (Bq/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-60</td>
<td>0.1</td>
<td>“Residents in houses constructed with building material”</td>
<td>100</td>
</tr>
<tr>
<td>Cs-134</td>
<td>0.1</td>
<td>“Worker on landfill”</td>
<td>1000</td>
</tr>
<tr>
<td>Cs-137</td>
<td>0.1</td>
<td></td>
<td>1000</td>
</tr>
<tr>
<td>Sr-90</td>
<td>1</td>
<td>Resident near landfill</td>
<td>10</td>
</tr>
</tbody>
</table>
Findings

- **For gamma-emitters**, the clearance level is in general **limited by external exposure**

- Derived activity levels for the “landfill -> groundwater -> well” may be much higher
  - Long migration times landfill -> well
  - Short half-lives compared to the migration times
  - Strong sorption of caesium
Revisit the “Water Pathway Calculations” in SRS-44

- Check assumptions, models and parameters
- Impact of additional engineered barriers, e.g.
  - Liners
  - Bottom clay layers
- Discuss influence of modification of radiological criteria for landfill workers
  - Public vs occupational exposure
Revisit the “Water Pathway Calculations” in SRS-44

- For those modified assumptions:
  - Derive activity levels in material that would be suitable for disposal on conventional landfills
  - Address sensitivity and uncertainties to ensure a cautious derivation of such activity levels.

- Such levels may be considered as:
  - **Specific clearance levels** for the disposal of material with residual amounts of radionuclides on landfill sites
Key components and processes

• **Characteristics of the material to be disposed**
  - Soil, rubble, vegetation with residual activities
  - Ratio of material containing residual activities to other waste

• **Landfill characteristics**
  - Capacity of the landfill
  - Annual precipitation, evaporation and infiltration
  - Engineering characteristics: bottom sealing, drainage, disposal cover

• **Radionuclide characteristics**
  - Physical half-life and chemical form
Key components and processes (cont.)

• Processes in the landfill
  • Sorption of radionuclides to the disposed material
  • Migration of radionuclides in the landfill with infiltration water
  • Sorption of radionuclides to the bottom sealing

• Results
  • Exposure to public and workers arising
  • Identification of critical exposure pathways and critical groups
  • Discharge of radioactivity with the drainage water as function of time
  • Possible exposure to the public from use of such groundwater
Activities

- **Consultancy meeting in June 2015**
  - Revisit SRS 44
  - Modify underlying model to estimate radionuclide behaviour in landfills
  - Preliminary calculation

- **Next steps**
  - Review parameters and models in SRS-44
  - Address sensitivity and uncertainties
  - Calculations
  - Derive specific clearance levels for disposal in landfills
Possible next steps

- Update of SRS-44
- Interaction with review of RS-G 1.7
- Discussion of the application of specific clearance levels
  - Remediation
  - Decommissioning
  - Waste management
  - Embedment into the regulatory processes
Thank you