Refresher course: Environmental Remediation from site characterisation to the end state

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Learning objectives

- Acquire systematic knowledge on the stages of environmental remediation;
- Become familiar with the process of site characterisation including historical site information;
- Develop awareness of the time required for proper implementation of the various stages of environmental remediation;
- Learn which radiological and non-radiological factors may be used to justify remediation;
- Understand the drivers and constraints that are relevant in determining the site end state;
- Appreciate the need for interim states in environmental remediation.

Refresher… What is "environmental remediation", and what is it not?

- Remediation is conducted to reduce or avoid exposure of humans [or the environment] to unacceptable exposures
- Apart from radioactivity, there are more reasons to remediate sites (see next slide)
- Terms such as *restoration*, *rehabilitation*, *reclamation*, *clean-up* may be misleading – Why?
- "Remediation" does not necessarily imply complete removal of all hazards or achieve "zero risk"
- Decommissioning is closely related to ER, but is often treated separately

Remediation: definition (examples)

- IAEA Safety Glossary: “Any measures that may be carried out to reduce the radiation exposure from existing contamination of land areas through actions applied to the contamination itself (the source) or to the exposure pathways to humans.”
- EU Extractive Waste Directive: “restore the land **to a satisfactory state**, with particular regard to soil quality, wild life, natural habitats, freshwater systems, landscape and appropriate beneficial uses”
- In a nutshell: remediation shall make a site “safe enough”, enable after use or ensure access control

Reasons for contaminated sites to exist?

- Inadequate operating or closure practice,
- Missing regulations/enforcement/control
- Nuclear or radiological accidents
- Any other situations?

For which reasons may remediation be required?

- Radiation safety
- Geotechnical stability (dams, slopes)
- Erosion of contaminated material
- Non-radiological factors (e.g., toxic pollutants)
- Community safety (e.g., unsafe mine shafts)
- Regional development, availability of land
- Visual impact
- Risk perception
- It is often a combination of the above factors.

Who is responsible for ER?

- Governments define a policy and strategic framework for ER
  - This includes a radioactive waste management policy
- Site operator/owner or legal successor is responsible for remediation planning and implementation
  - In case of accidents: government to define responsibilities for remediation
- Regulatory authorities are responsible for
  - Establishing a regulatory system
  - Regulatory control of environmental remediation activities (including review of plans and permitting)

Policy and strategy background (1)

- What are policies for?
- Develop inventory of sites to remediate
- Set priorities of remediation sites
- Define organisational structures for ER
- Make sufficient financial and other resources available
- Define general funding mechanisms
- Policies must be based on RP principles

Policy and strategy background (2)

- What are strategies for?
- Describe how policies are implemented
  - e.g., in case of an emergency, to maintain sufficient level of preparedness
- Procedures for defining general or site-specific reference levels
  - level above which it is not appropriate to allow exposures to occur
- Identify applicable technologies and technical approaches
- Define site release criteria
- Define framework for stakeholder engagement

ER flowchart

Preliminary site assessment → Identification of **priority** sites or objects

Detailed **site characterisation** and **risk assessment**
Including historic site assessment
Include all risks (radiological, geotechnical, toxic, perceptions)

Reference level (dose), other requirements (e.g., geotech, water)

Justification of remediation and development of ER approach, **end state**

↓

Optimisation of remediation planning, feasibility study, engineering design

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Permitting, implementation and success control (observe **dose limits)**

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Post-remediation management (maintenance, after-care

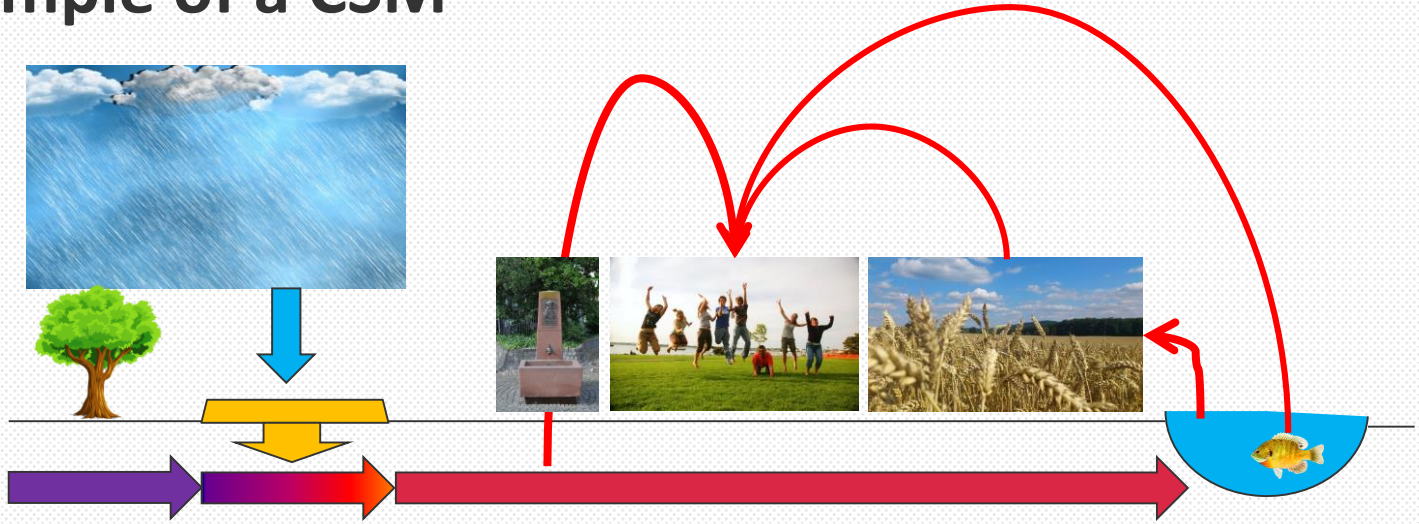
“Reference level”

- **International BSS, Requirement 48**: Justification for protective actions and optimization of protection and safety:
- All reasonable steps shall be taken to prevent doses from remaining above the reference levels. Reference levels shall typically be expressed as an annual effective dose to the representative person in the range of 1–20 mSv or other corresponding quantity, the actual value depending on the feasibility of controlling the situation and on experience in managing similar situations in the past.

Conceptual Site Models (CSM)

- To develop a conceptual understanding of a site, a CSM should be created at the outset of a project to capture
  - what is initially known about a site
  - including critical data gaps
  - and then be periodically revised as investigation activities provide additional information
- Examples of information in CSM
  - Total inventory of activity of relevant nuclides and release rate
  - Important dispersion mechanism and parameters (e.g., dilution factors
  - Receptors and key exposure pathways leading the highest contributions to the effective dose

Example of a CSM



Groundwater flow
Precipitation
Percolation
Mobilisation rates
Dilution ratio

Abstraction rates
Consumption rates
Transfer factors
Dose conversion factors
Effective dose

What does this mean for site characterisation?

- Site inventory (use site history information)
- Mobilisation properties
- Hydrogeology, hydrology, meteorology
- Population density (proximity to site)
- Living habits, consumption rates
- Expectations, (after-) use scenarios
- Perceptions
- Site characterisation is a long process (1.5 years or more!)

End state (ES)

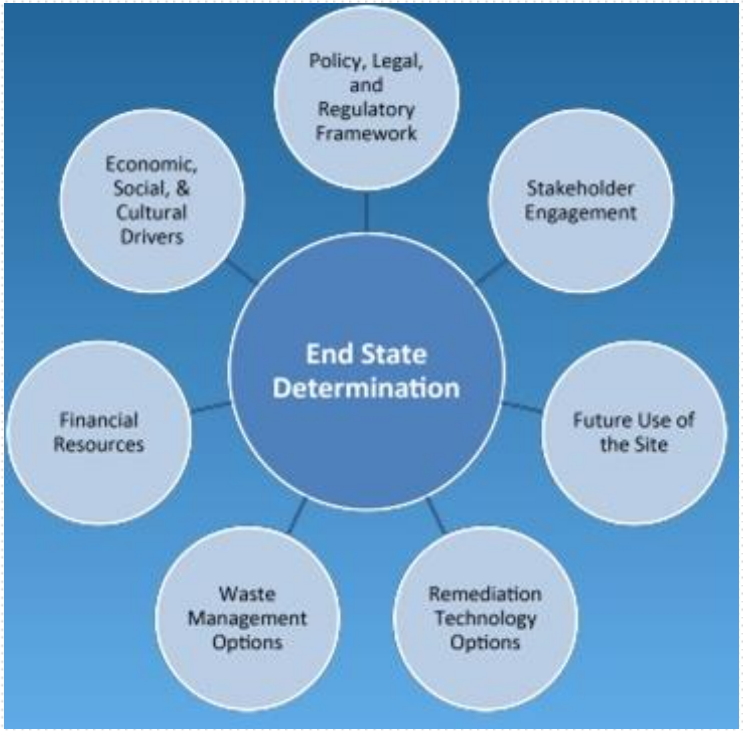
- The ES "describes the physical conditions to be achieved that make the intended future use of the site possible and are appropriately protective of people and the environment."
- ES is what we are trying to achieve. How safe is safe enough?
- Determination of ES encompasses conditions on
  - Residual contamination level
  - Site appearance, landscape, landform
  - Physical structures and their safety
  - Exposure pathways and/or site access control

Notes on ES

- Reaching the ES does not necessarily coincide with release of the site for unrestricted use, or release from regulatory control
- End states: unrestricted or restricted use, no use/access (next slide)

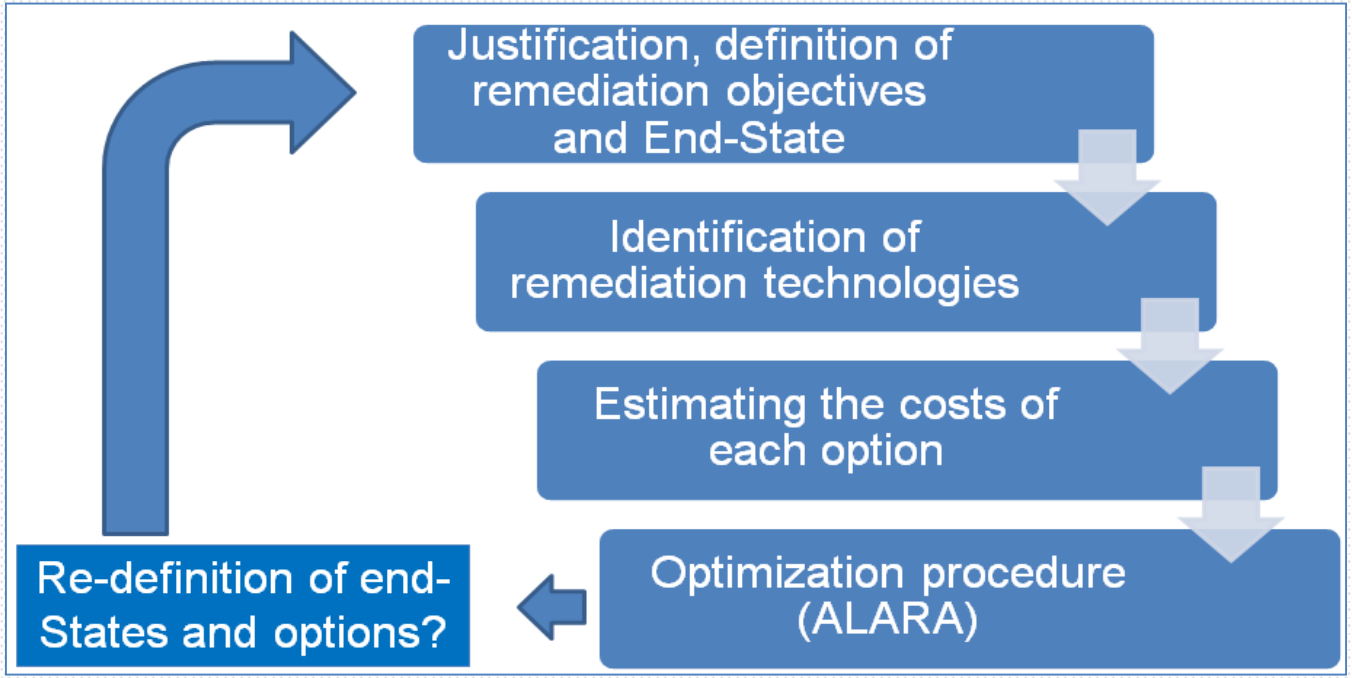
No access, no use

What are the drivers of end state determination?



Adapted from IAEA NW-T-3.4

End state determination is an iterative process



This process may take years!

Principal methods of ER

- Removal of contamination
- Breaking the link between source and receptor
  - Restricted access to contamination or source of hazard
  - Isolation, encapsulation
  - Minimisation of contaminant release from source
- Natural attenuation
- Or a combination of the above

Various notes on ER

- Think of waste management options
  - On-site vs. off-site
  - Pre-treatment/conditioning
- Sustainability: sensitivity of remediation success to failure of institutional control and post-closure maintenance
  - Preference of low or no maintenance solutions
- Use ecological engineering to the extent possible
- Economic redevelopment of a remediated site may partly offset the cost of remediation
- Define quality management standards (including ongoing quality control and verification) – how do you measure success

Interim (End) States

- "Interim States" may be required as a temporary solution due to critical constraints such as
  - availability of funding
  - radioactive waste management
  - additional infrastructure needs
- Interim State may hinder the achievement of an overall end state
- Confusion may arise over why the overall agreed end state is not being achieved (or may not be achievable at all)

Stakeholders of ER projects

- Definition: Any person or group that has a direct or indirect interest in the remediation project
- Key stakeholder groups
  - Communities affected by the site
  - Civil society, pressure groups, NGOs
  - Funding organisations
  - Potential investors
  - Regulatory authorities
  - Site owner/operator

Record keeping in ER projects

- Keep records of all data and decisions for future reference
- Examples:
  - Historic site information
  - Site characterisation record (drilling, samples, photos, interviews)
  - Stakeholder engagement records (minutes of meetings and public hearings, letters received and responses)
  - Decision records, reasons for key decisions taken
  - Permits and correspondence between owner, consultants, works contractors and regulator(s)
  - Waste management records (disposal, waste transfer sheets

Record keeping in ER projects (cont'd)

…continued from previous slide

- Implementation records, any accidents or deviations from remediation plan
- Site take-over records, verification of remediation success
- OHS records, dose records, monitoring records
- Photos of works, site diaries
- Records of external reviews and inspections
- Post-remediation monitoring and maintenance records

- Store in electronic format or as hardcopy
- Make sure it can be easily located and retrieved

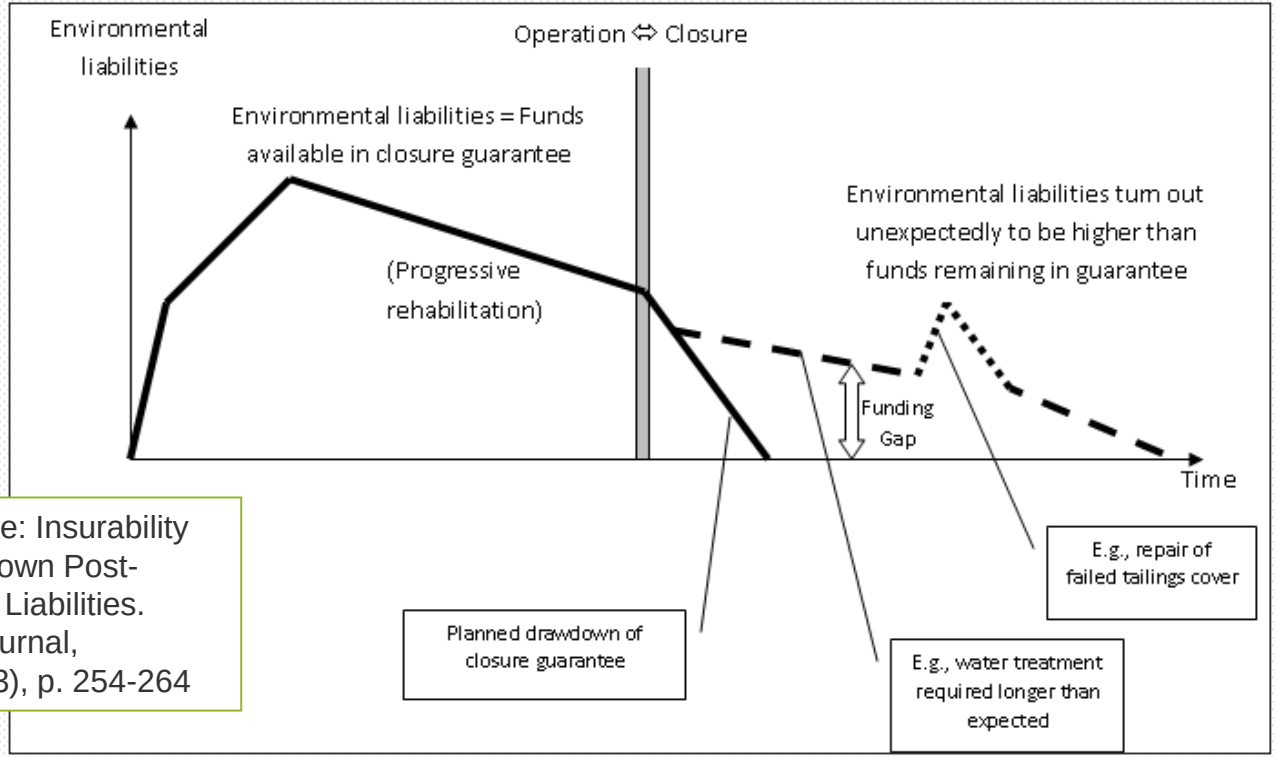
Cost estimate of ER projects

- Capital cost ("one off")
- Recurring cost
- Examples
  - Monitoring, sampling and analytics
  - Inspections,
  - Maintenance (clean out diversion channels)
  - Repair (covers, treatment plants, pumps)
  - Reporting
- Recurring cost may need to be covered over a long period of time

Notes on cost estimates

- Cost estimates may be very uncertain initially (strategic stage) and are gradually reduced as planning and implementation progress
- Experience has repeatedly shown that contingency is used up and new contingency margin must be added (only for this to happen again)
- Be aware of unplanned costs in the after-care phase

Funding gap in post-remediation cost



C. Kunze: Insurability of Unknown Post-Closure Liabilities. (CIM Journal, Q4/2013), p. 254-264

Recommended reading (1)

- NEA Report No. 7290 “Strategic Considerations for the Sustainable Remediation of Nuclear Installations”, OECD, 2016
- Nuclear Energy Series NW-G-3.1 “Policy and Strategies for Environmental Remediation”, IAEA, 2015
- WS-R-3 “Remediation of Areas Contaminated by Past Activities and Accidents”, IAEA, 2003
- WS-G-3.1 “Remediation Process for Areas Affected by Past Activities and Accidents”, IAEA, 2007
  - DS468 – Draft Safety Guide, https://www-ns.iaea.org/standards/documents/dsnumber-list.asp?s=11&l=86

Recommended reading (2)

- TRS 475, “Guidelines for Remediation Strategies to Reduce the Radiological Consequences of Environmental Contamination”, IAEA, 2012
- NW-T-3.4, “Overcoming barriers in the implementation of environmental remediation projects”, IAEA, 2013
- NW-T-3.5, “Lessons Learned from Environmental Remediation Programmes”, IAEA , 2014
- E-Learning Course on Planning for Environmental Remediation, IAEA, 2017, http://elearning.iaea.org/m2/course/view.php?id=500

1. Policy & Strategy
2. Project Management & Planning Basics
3. Cost Estimation Basics
4. End State and Future Use Determination

Questions? Want to discuss further?

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