IAEA
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Management of Bulk NORM Residues and Waste (Part 2)

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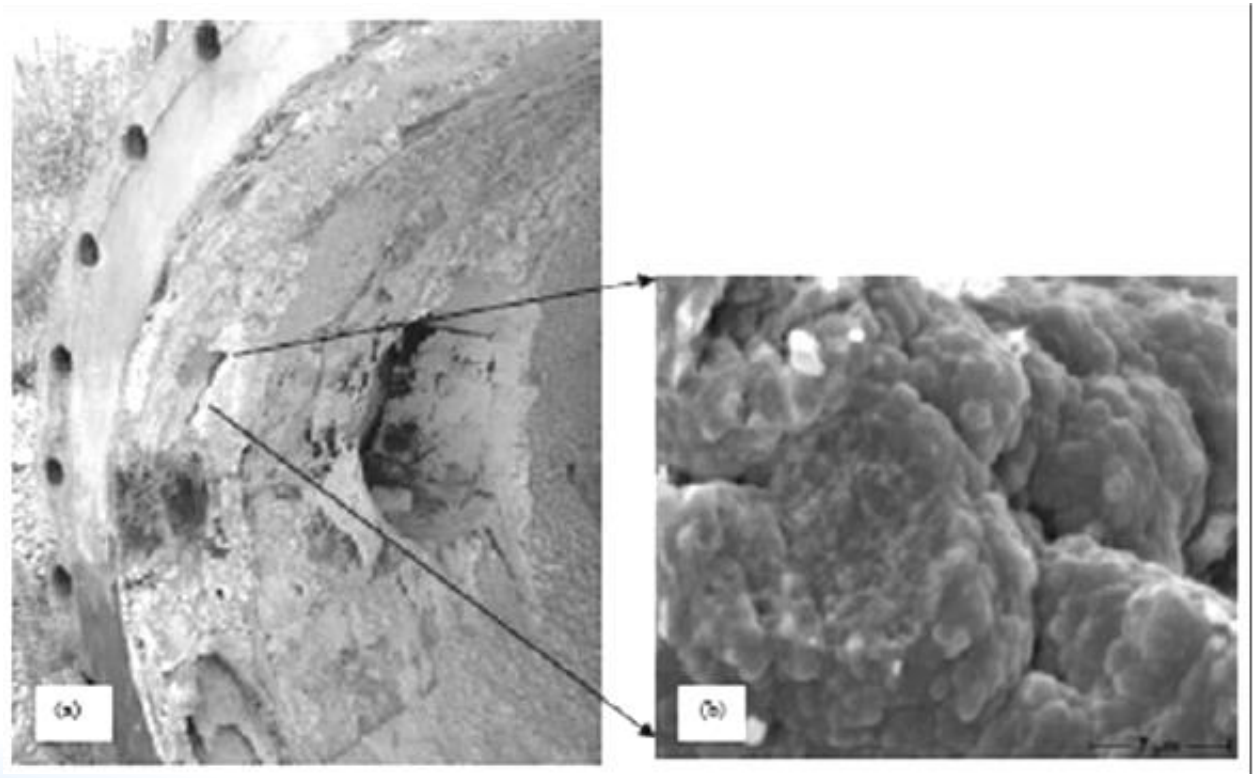
Scale

- Scale containing elevated activity concentrations forms inside pipes, valves, pumps, vessels and filtration systems

Process	Radionuclide	Activity concentration (Bq/g)
Oil and gas production	^{226}Ra	0.1 – 15 000
Phosphoric acid production	^{226}Ra	0.03 – 4000
Titanium dioxide pigment production	^{226}Ra	<1 – 1600
Chemical processing of zircon	^{226}Ra	>5000
Coal fired steam generation	^{210}Pb	Can exceed 100
Coal mining, Ra-rich inflow water	^{226}Ra, ^{228}Ra	Up to 200

Scale

- Pipe scale in a phosphoric acid plant

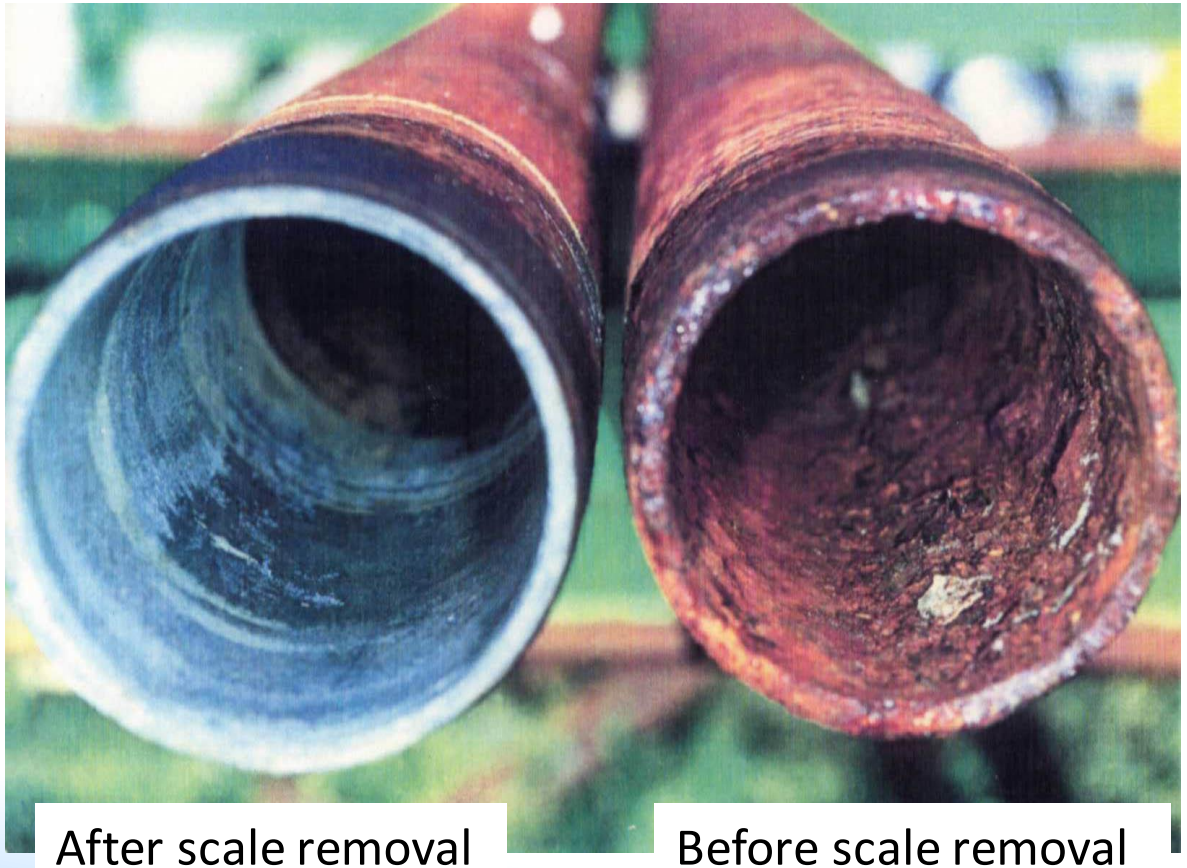


Photographic image

SEM image

Scale

- Oil and gas production ‘tubulars’



Scale

- In most NORM scale, ^{226}Ra is the predominant radionuclide
  - Sometimes ^{228}Ra from the ^{232}Th decay series as well
- Some scale may contain elevated levels of ^{210}Pb
- The presence of high activity concentrations may require special radiation protection precautions when equipment is opened for maintenance
- Scale may be difficult to remove, and various methods need to be considered:
  - Mechanical, e.g. boring, reaming
  - Chemical
  - Abrasive, including high pressure water jetting
  - Melting as scrap

Scale removal

- Scale removal may itself create radiological hazards to workers
- Scale removal creates NORM waste in solid or liquid form
  - This waste has to be disposed of in an acceptable manner
- Outside companies performing decontamination or scrap melting may have to be authorized by the regulatory body

Scale removal in oil and gas production

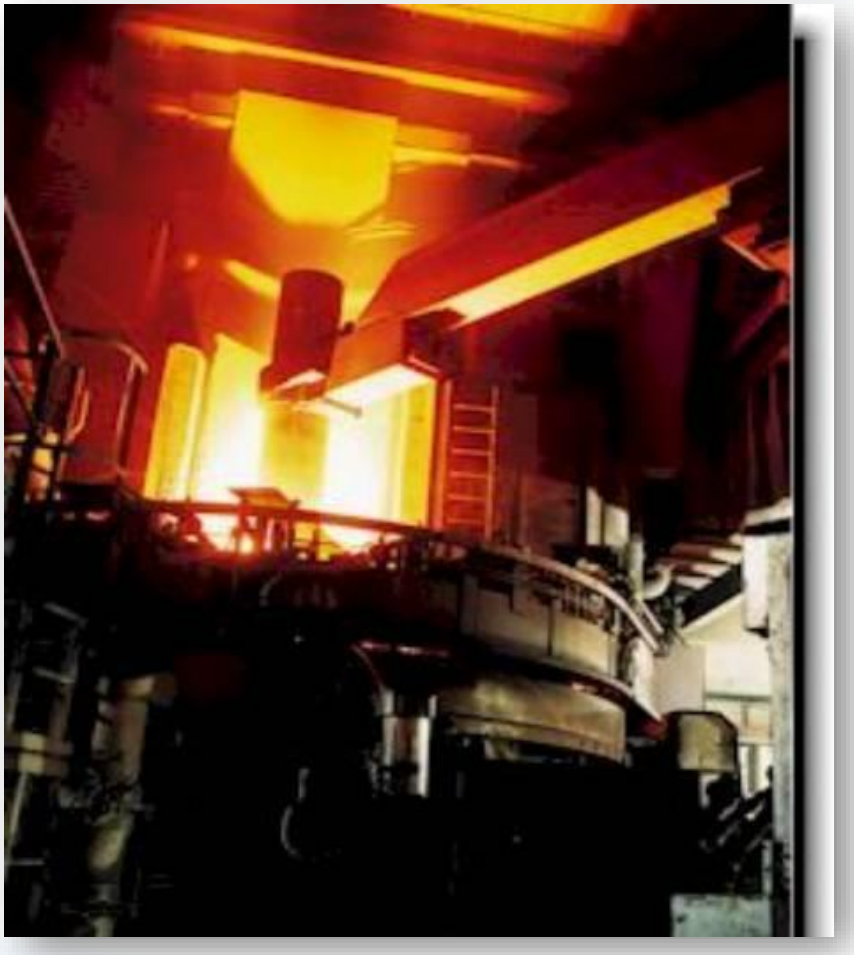
Scale removal using high pressure water jet

Dry drilling of tubulars with closed extractor system

Melting facility for NORM contaminated scarp

- The radionuclides migrate to the slag, leaving the steel free of radioactivity

- Mixing with larger amounts of non-contaminated scrap can reduce activity concentrations and exposures to levels below radiological concern



Options for management of scale after removal

- Reintroduction to the process to recover residual minerals of value
- Burial at the site (where the site will be under institutional control after closure – e.g. mine sites)
- Disposal at a hazardous waste disposal facility
- Disposal at a low/intermediate level radioactive waste facility
- Indefinite storage in drums at controlled storage facilities

- The oil and gas industry has some additional options:
  - Discharge from offshore rigs into marine waters
  - Injection into well field formations
  - Disposal in abandoned wells
- In all cases, an appropriate risk assessment is necessary

Sediments and sludges

Process	Radionuclide	Activity concentration (Bq/g)
Rare earth extraction	^{228}Ra	0.6 – 10 000
Oil and gas production	^{226}Ra	0.05 – 800
Niobium extraction	^{226}Ra, ^{228}Ra	200 – 500
Zircon chlorination	^{226}Ra	0.3 – 48
Titanium dioxide pigment production	^{232}Th	0.02 – 24
Iron smelting	^{210}Pb	12 – 100
Water treatment	^{226}Ra	0.1 – 14
Phosphate fertilizer production	^{226}Ra	1.3 – 4.3

Sediments and sludges

- Activity concentrations vary over a wide range
- Depending on the activity concentration, some sediments and sludges have to be treated in a similar manner to high activity scale
  - In many cases, engineered shallow ground burial in earthen trenches or concrete silos is the preferred option
- Lower activity sediments and sludges (of the order of 10 Bq/g or less) are generally suitable for disposal at normal industrial waste or hazardous waste facilities

Slag

Process	Radionuclide	Activity concentration (Bq/g)
Niobium extraction from pyrochlore	^{232}Th	20 – 120
Tin smelting	^{232}Th	0.07 – 15
Copper smelting	^{226}Ra	0.4 – 2
Thermal phosphorus production	^{238}U	1

Slag

- There are many opportunities for using slag as a by-product ;
  - as a construction material (or component of construction material)
  - Resource for extraction of contained metals
- Slag with higher activity (from steel, niobium, tin, copper etc. production) may need to be restricted
  - A detailed assessment is necessary
- Slag with lower activity concentration, e.g. thermal phosphorus slag, can be used in the construction of roads, dams, etc.
  - Its use in house construction may need to be subject to certain conditions

Furnace dust

Process	Radionuclide	Activity concentration (Bq/g)
Extraction of niobium from pyrochlore	^{210}Pb, ^{210}Pb	100 – 500
Fusion of zircon	^{210}Po	600
Thermal phosphorus production	^{210}Pb	1,000
Tin smelting	^{210}Pb, ^{210}Pb	Up to 200

Furnace dust

- Furnace dusts contain volatile radionuclides (lead and polonium)
- Can have high activity concentrations
- Usually requires disposal in a regulated facility
- Consider worker exposure during scrubber and incinerator maintenance (or where dusts may accumulate)

Liquid residues

- Can involve large volumes (e.g.; Mine water)
- Excess water from tailings dams, phosphogypsum stacks, etc.
- Recirculated process water and contaminated rainwater
- Used process water streams:
  - Water separated from slurry streams
  - Wash water
  - Flotation water
  - Spent leach solutions
  - Gas scrubbing water
- Water from decontamination of equipment
- Spent solvents
- 'Produced water' from oil and gas production
  - Formation water and injection water

Liquid residues-management options

- Recycle to the process
  - By far the most widely used option
  - Can be used for aqueous residues and spent solvents
- Treatment + discharge
  - Neutralization — neutralizing agents, mixing acidic & alkaline streams
  - Settling, precipitation, filtration — can remove up to 90% of ^{226}Ra etc.
  - Treatment for compliance with (non-radiological) effluent treatment standards in terms of environmental regulation is usually adequate also for radionuclides
  - Treatment generates solid waste (sludge, filter cake)
- Evaporation and seepage ponds
  - Subsequent land remediation and management of solid waste
- Slurry with sand and return to mining void
- Direct discharge to large water bodies, e.g. marine waters

Liquid residues – oil and gas

- Management options for 'produced water' from oil and gas extraction:
  - Can be generated in very large volumes
    - Oilfields: 2400 – 40 000 m^3/day
    - Gas fields: 1.5 – 30 m^3/day
  - Wide range of activity concentrations
    - 0.002 – 1200 Bq/L ^{226}Ra
  - Options:
    - Discharge to marine waters (mainly for offshore facilities)
    - Reinject into reservoir
    - Pump to seepage/evaporation ponds
      - Subsequent land rehabilitation and disposal of solid waste

Gaseous emission

- Gaseous emissions arise from furnaces, chemical processes and ventilation systems
- Sources of exposure:
  - U and/or Th series radionuclides in airborne dust particles
  - Radon
- Emission standards in terms of environmental regulation:
  - Reduced emission of hazardous constituents, including radionuclides
  - Improved atmospheric dispersion, e.g. stack height
- Emission controls:
  - Dust filters and precipitators
  - Gas scrubbers
- Emission control generates solid and liquid NORM residues:
  - Captured dust particles
  - Scrubber liquids — water, NaOH

Monitoring and surveillance

- The facility operator is responsible for the design and implementation of a suitable monitoring and surveillance programme
- Monitoring:
  - Monitoring of discharges
  - Monitoring of materials and equipment before removal from the facility for scrap or repair
  - Environmental monitoring
- Surveillance:
  - Physical inspection to verify the integrity of waste management systems including structures and components

Discharge monitoring

- The purpose of discharge monitoring is to verify that the amounts of activity being discharged are within the discharge limits established for the facility
  - This in turn helps to ensure that the optimization process is being implemented as intended and that doses received by members of the public are within the dose limit

- All liquid and gaseous discharges, including entrained dust particles, should be monitored

Monitoring residual materials/ equipment prior to removal from site

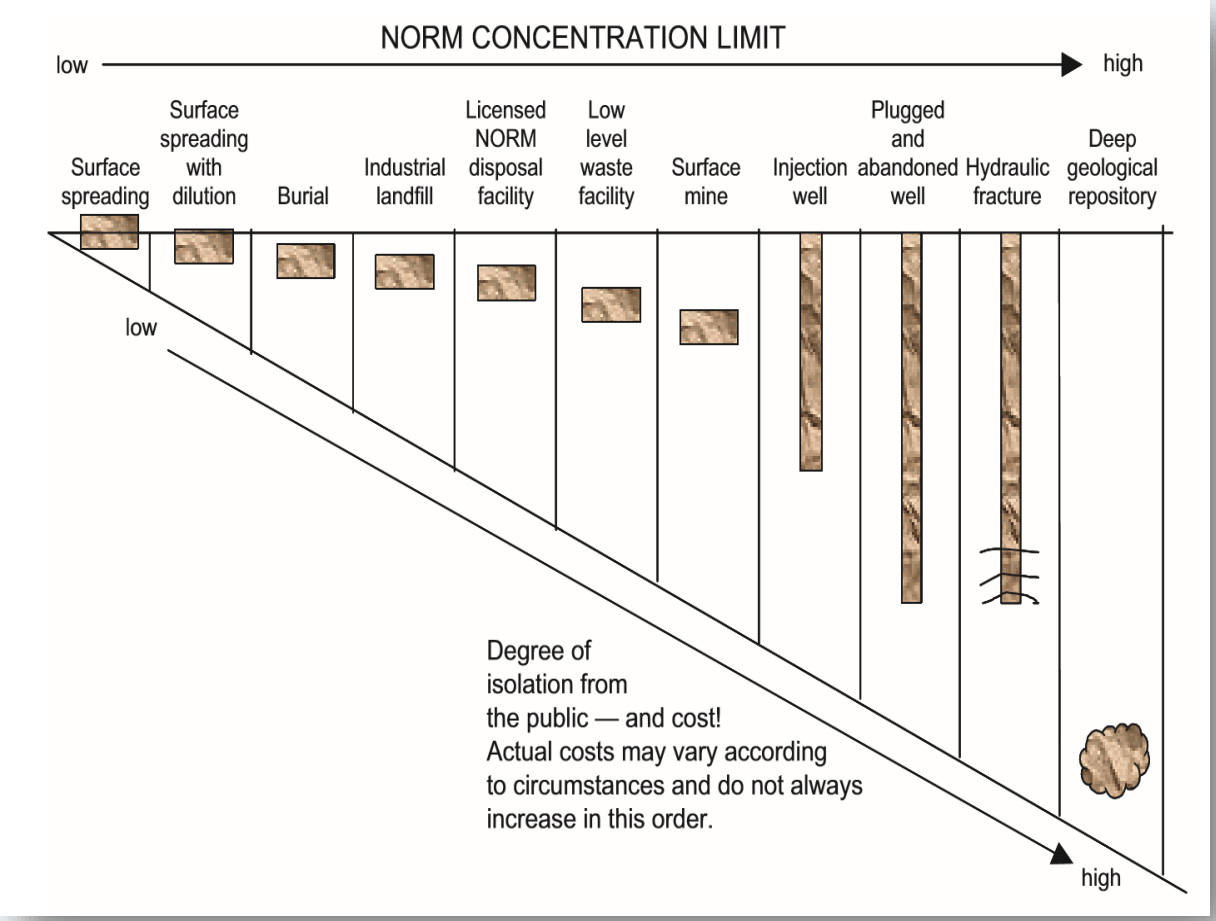
- For purposes of clearance (removal from regulatory control), monitoring is necessary for verifying compliance with NORM clearance criteria:

- For removal from the site for disposal, recycling or repair, monitoring is necessary for:
  - Verifying compliance with the Transport Regulations, where applicable
  - Verifying compliance with the acceptance criteria of the receiving facility

Environmental monitoring

- The purpose of environmental monitoring is:
  - To evaluate the effectiveness of the waste management control measures
  - To assess doses received by members of the public
  - To assess the environmental impacts
- Environmental regulation will also require the monitoring of non-radiological components
- Monitoring programme:
  - Frequency
  - Environmental media to be considered:
  - Radionuclides to be considered

Potential Disposal Options



Disposal alternatives for NORM wastes. Disposal of more concentrated wastes requires greater isolation of waste from the general public (from IAEA TRS49)

Public doses from NORM facilities

- **Annual dose to the representative person (µSv):**
  - Uranium tailings, Germany: <1000
  - Uranium tailings, Brazil: 350
  - Uranium residues, Romania: 51
  - Gold mine tailings, South Africa: 30 (1.5 – 140)
  - Mining and beneficiation of rare earth ores: 0 – 44
  - Extraction and purification of rare earths: 0 – 30
  - Zircon and zirconia production: 0.01 – 37
  - Mining and beneficiation of phosphate rock: <10 – 27
  - Phosphoric acid production: Trivial
  - Phosphate fertilizer production: 0 – 4
  - Phosphate animal feed production: 11 – 30
  - Thermal phosphorus production: 1
  - Titanium dioxide pigment production: Trivial

Key messages

- Doses arising from solid, liquid and gaseous NORM residues are generally very low
- Small to moderate quantities of solids with higher activity concentrations
- Larger volumes of liquids
- Can be regarded as potential resources
- Appropriate protection is achievable through different management options