NORM Waste Strategy Consultation: Supporting Document

Detailed Overview of NORM Waste Management in Each of the UK NORM industry Sectors

January 2014
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1. **Executive Summary**

1.1 The UK Government and the Devolved Administrations of Scotland, Wales and Northern Ireland, are developing a strategy to manage NORM waste arisings. As part of that strategy, a data collection exercise was undertaken to obtain information how NORM wastes are produced and managed in the UK. This data collection exercise included engagement with NORM waste producers and treatment/disposal providers; summaries of this engagement are provided in this document in the form of ‘pen portraits’.

1.2 Pen portraits are included for 14 NORM industry sectors that are known to be “active” in the UK in that they produce or manage NORM waste. The pen portraits summarise information obtained during various discussions and face-to-face meetings between the UK environmental regulators and each of the NORM industry sectors.

1.3 For each NORM industry, the pen portrait gives details of typical volumes and radioactivity levels for the solid, liquid and gaseous NORM wastes produced. Background information is included about the manufacturing or production processes and how NORM and other wastes are produced, treated and disposed of. The pen portraits conclude with a summary of current and impending NORM waste management issues for each NORM industry.

1.4 The pen portrait for the production and use of Thorium and Uranium metals and compounds identifies a number of uses for these compounds. Disposal of solid NORM waste from this NORM industry should be possible under exemptions allowed by the UK radioactive substances legislation. However, the waste may also be classified as hazardous and its management needs to take due account of these hazardous properties. Some producers highlighted difficulties in indentifying cost effective waste disposal routes.

1.5 The pen portrait for UK oil and gas production notes that the majority oil and gas production is carried out in the offshore environment. Most of the NORM waste produced by the offshore oil and gas industry is produced water, with the majority of this disposed directly to sea under permits controlling the discharge of radioactive substances granted by the environment agencies. Solid NORM scale produced offshore can be disposed by re-injection where suitable facilities exist or can be discharged direct discharge to sea; again to comply with the conditions imposed by the environment agencies in any radioactive substances permit. For onshore oil and gas production, more NORM scale is treated before disposal to landfill.

1.6 Decommissioning of oil and gas installations will create NORM waste. However, limited data on solid and liquid NORM waste arisings from such decommissioning is available at present. Hence, it has not been not possible to determine whether decommissioning activities will cause a NORM waste management issue in the future.
Ways to get better data on decommissioning of onshore and offshore installations are highlighted in the consultation document.

1.7 The pen portrait for the Titanium Dioxide industry notes that a filter cake is the main solid NORM waste stream produced. Depending on the concentration of NORM radionuclides in the feedstock, this NORM waste may be disposed of under exemptions allowed under the UK radioactive substances legislation. Most filter cake is currently disposed of to a suitable landfill. Most filter cloths have higher NORM radionuclide concentrations and are disposed to the landfill operated by LLWR Ltd. Filter cake is approximately 50% water, so clarity has been requested by those operating in the Titanium Dioxide industry whether exemption limits apply to dry mass or mass as disposed. Government intends to clarify this issue during the consultation process. Liquid wastes produced during Titanium Dioxide manufacture are disposed either directly to the Humber Estuary or to a suitable liquid waste treatment facility.

1.8 NORM waste produced by the Iron and Steel industry is substantially influenced by the quality and the availability of iron ore and its original source. NORM waste in the form of sludges and filter cakes are blended to produce a residue which is used in the cement industry. Rotary Hearth furnaces could be used to further concentrate waste from the steel industry, however, doing so may produce a waste which is both hazardous and radioactive, and has no current UK use.

1.9 NORM waste data for coal mine dewatering is limited, however, available data suggests that the radioactive properties of the waste will be out of scope of UK regulations.

1.10 The China Clay industry produces NORM waste in the form of solid scales. These scales are treated by adding cement to solidify the NORM waste which results in a waste that does not need to be regulated (ie is out of scope) under UK radioactive substances legislation. The China Clay industry is seeking clarification that the way they process NORM waste is not considered to be a practice that is deliberate “dilution”. Confirmation is sought that the resultant waste falls outside the scope of UK radioactive substances legislation.

1.11 The majority of NORM waste generated by the contaminated land industry is as a result of sites where, previously, radium luminising was carried out. This practice has stopped, but there are some sites in the UK where there is a legacy associated with NORM wastes that have to be managed in the future. Those who have to manage this legacy (including the Ministry of Defence) are seeking clarification from UK safety and environmental regulators as to the degree of remediation which these sites must undergo. The extent of remediation and any proposed changes in site use have a significant impact on the NORM waste volumes that have to be managed.
1.12 High pressure water jetting and dry shot blasting are the two most common techniques used in the UK to descale various items of equipment that have been contaminated with NORM scale. During oil and gas extraction, solid NORM scale deposits and builds-up on the inside of plant and equipment. This scale needs to be removed to allow continued use of the equipment. Descaling activities can also be undertaken as a treatment prior to disposal. Following descaling, some NORM wastes have hazardous properties (eg contain oils or heavy metals) which may cause problems how they are ultimately disposed of.

1.13 Incineration of NORM waste is possible and is currently carried out at 3 different facilities in England. At present, none of the incinerators are using their full radioactive capacity, therefore, some contingency capacity exists. Under the radioactive substances exemption legislation, there is no legal requirement for NORM waste producers to notify incinerators that their waste contains NORM. Some incinerator operators have cited that this issue may cause a breach of the discharge limits in their permits issued by the Environment Agency.

1.14 The final disposal option for many solid radioactive wastes is burial. There are five facilities that are regulated by the environment agencies to dispose of NORM waste by burial in the UK. Other landfill sites can dispose of NORM waste, however, these facilities do not require regulation to control the radioactive properties of the NORM waste. The majority of NORM waste disposed in the UK is to landfills that are exempt from radioactive substances regulation.

1.15 The East Northants Resource management Facility operated by Augean is the only UK facility permitted to dispose of hazardous NORM wastes.

1.16 Various issues were raised by those landfill operators contacted during the data collection exercise. A common issue raised was the uncertainties as to the volumes of NORM waste requiring disposal, in particular from decommissioning oil and gas facilities.
2. Introduction and Background

2.1 A review of the long term management of the UK’s solid Low Level Waste (LLW), held by the UK Government and the Devolved Administrations of Scotland, Wales and Northern Ireland (referred to as Government in the rest of this document), led to a revised policy statement published on 26th March 2007. The policy required the creation of strategies for the management of LLW from the nuclear industry, as well as radioactive waste arising from the non-nuclear industry, including small users producing relatively low volumes of radioactive waste from anthropogenic sources, and high volume arisings of Naturally Occurring Radioactive Materials (NORM). This document supports the development of the latter Strategy.

2.2 In order to produce a worthwhile and effective NORM Strategy, Government asked the Scottish Environment Protection Agency (SEPA), the Environment Agency (EA) and Atkins to work together to co-ordinate the collection of relevant data from industries that produce NORM waste, or provide waste treatment and/or disposal services for NORM containing wastes.

2.3 The aim of the NORM Strategy is to ensure that there are safe, sustainable and resilient NORM waste management arrangements in place in the UK. The NORM Strategy will also identify and take steps to overcome any obstacles preventing those managing NORM waste from contributing to sustainable economic growth.

2.4 In the UK, legislation came into force in 2011 controlling the management of radioactive substances from NORM waste producing industrial sectors. However, not all NORM industrial sectors are represented in the UK, e.g. there is no phosphate manufacturing industry in the UK. Pen portraits are included in Section 5 of this document for each of the 14 NORM industrial sectors in the UK as listed below.

- Production and use of Thorium or Thorium compounds.
- Production and use of Uranium or Uranium compounds.
- Extraction and production/use of rare earth elements.
- Mining and processing of ores other than Uranium.
- Production of oil and gas.
- The removal and management of scales and precipitates.
- Use of phosphate ore.
- Titanium dioxide manufacturers.
- Extractions and manufacturing of zirconium.
- China Clay extraction.
- Coal mine dewatering.
- Water treatment for drinking water.
- Refining and converting ore to metal covering tin, copper, aluminium, zinc, lead, iron and steel.
- Remediation of NORM contaminated land (including site investigation and remediation of contaminated land).
3. Production and use of uranium and thorium or their compounds, and the production of products where uranium, thorium or their compounds are added

Introduction

3.1 Uranium and thorium metal and uranium and thorium compounds have historically been used and continue to be used for their physical and chemical properties rather than their radioactive properties, e.g. incandescence (gas mantles), density (shielding and weights), refractive properties (optics).

3.2 Thorium compounds are also used in schools, e.g. as a radon generator, to demonstrate properties of radioactivity and radioactive decay. In this case, the thorium compounds are being used for their radioactive properties and strictly speaking should not be considered as being part of a NORM industrial activity. However, as the compounds used are the same or similar to those used for their non-radioactive properties and a single exemption\(^1\) applies to all such compounds, they have been included in this summary as users will face the same issues managing those compounds as those using them for their non-radioactive properties.

Overview of the uranium and thorium “industry” in the UK

3.3 There is not a single thorium and uranium industry; rather it is a diverse collection of producers and users depending on the uses to which the thorium and uranium is being put. This section has been divided into three main sections in order to address the distinct parts of this NORM industrial activity:

- Production of uranium and thorium and uranium and thorium containing compounds
- Manufacture of products containing uranium and thorium and uranium and thorium compounds
- Use of uranium, thorium, their compounds and use of products which contain uranium, thorium or their compounds

3.4 Production of uranium and thorium and uranium, and thorium compounds

3.5 With the exception of nuclear fuel cycle activities (which are outside the scope of this strategy), uranium and thorium metals and uranium and thorium compounds are not currently manufactured in the UK.

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\(^1\) Exemption or exempt is used throughout this document to mean that the radioactive properties in the NORM waste do not require to be regulated under radioactive substances legislation
Manufacture Of Products Containing Uranium And Thorium And Uranium And Thorium Compounds

3.6 There is only one type of type of product currently being manufactured in the UK where uranium or thorium is deliberately added. This is the manufacture of thorium coated optical lenses, carried out by Umicore in Dundee

Use of Uranium, Thorium and Their Compounds and Use of Products Which Contain Uranium, Thorium or Their Compounds

3.7 The majority of uses of uranium, thorium, and their compounds and products containing uranium, thorium, and their compounds can be undertaken under the provision of an exemption therefore it is difficult to state how widespread the use of these materials is. However, Table 1 below specifies the known uses and indicates how widespread their use is.

Table 1. Uses of Uranium, Thorium and Their Compounds, and Use of Products which Contain Uranium, Thorium or Their Compounds

<table>
<thead>
<tr>
<th>Use</th>
<th>Current or historic use</th>
<th>How widespread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic use</td>
<td>Current</td>
<td>Many universities and some schools</td>
</tr>
<tr>
<td>Addition of thorium to electrodes of high performance lamps</td>
<td>Current</td>
<td>Used in many commercial and industrial lights</td>
</tr>
<tr>
<td>Use of depleted uranium as radioactive source shielding containers</td>
<td>Current</td>
<td>Common</td>
</tr>
<tr>
<td>Use of depleted uranium as ballast and counterweights due to high density (aircraft and engineering equipment)</td>
<td>Historic</td>
<td>Some still in use (no new production)</td>
</tr>
<tr>
<td>Use of uranium in ceramic tiles and glass (for colouration)</td>
<td>Historic</td>
<td>Uncommon</td>
</tr>
<tr>
<td>Thoriated welding rods</td>
<td>Historic</td>
<td>Largely replaced by non-radioactive alternative</td>
</tr>
<tr>
<td>Use of thorium in gas mantles</td>
<td>Historic</td>
<td>Largely replaced by non-radioactive alternative</td>
</tr>
<tr>
<td>As of thorium in hardener alloys</td>
<td>Historic</td>
<td></td>
</tr>
</tbody>
</table>
Incorporation of thorium into optical lenses  
Historic  
Largely replaced by non-radioactive alternative

Use of thorium as optical coatings
Current  
Specialist

Melting of magnesium thorium alloys to recover magnesium
Current  
Specialist

### NORM Wastes Generated from Uranium and Thorium Users

#### 3.8
The production of thorium coated lenses generates a solid waste containing $\text{ThF}_4$. The waste is composed of glass beads, aluminium foils, paper, and vinyl gloves, vacuum filters and shot blast filter with the thorium being distributed throughout the waste. The waste also contains ~ 3% zinc selenide, depending on the exact concentration this may mean the waste would be classed as hazardous and would be regulated under hazardous substances legislation.

#### 3.9
Based on information from 2008-2012, up to 1000 kg of waste can be generated per year containing up to 50 MBq of Th-232. The specific activity is variable but is typically less than 50 Bq/g.

#### 3.10
Melting of magnesium thorium alloys (ZT1, TZ6) generates a solid waste in the form of magnesium dross. This waste is <0.4% Th-232. This is sent to landfill. This waste stream is likely to decrease in the future as magnesium castings containing less than 4% Th-232 are now classed as exempt waste.

### Academic Uses of Uranium and Thorium Compounds

#### 3.11
Academic uses of uranium and thorium may generate small quantities of solid or liquid waste. For example, solid wastes containing a few hundred grams of uranium and thorium from various studies or disposal of redundant stock or liquid wastes from electron microscopy that contain a few grams of uranium.

#### 3.12
Solid wastes can usually be disposed of under exemption. However, they may also be categorised as hazardous due to the chemical toxicity of the compounds. Users have reported confusion as to how such wastes should be properly consigned and, therefore, asked for clarity as to when the hazardous waste regulations apply and how the landfill regulations apply.

#### 3.13
Some users have also reported difficulties disposing of such wastes as some waste management companies (e.g. landfill operators) are reluctant to accept wastes which are both hazardous and radioactive; those that do can charge expensive fees, e.g. there are reports of
several thousand pounds being charged for the disposal of a few 100g of uranium conditioned in concrete to landfill.

3.14 Liquid wastes may be disposed of to sewer under exemption providing any other requirements imposed by a trade effluent consent (issued by water companies) are complied with.

Depleted uranium shielding, counterweights etc

3.15 Depleted uranium is commonly used as radioactive source containers. Keeping and use of such material requires a permit granted by the environment agencies. When no longer required, such containers are typically sent overseas for recycling.

Use in high performance lamps

3.16 The mass of thorium used in such devices is very small and the keeping use and disposal of these devices are usually exempt from regulation. Further information regarding the quantities and uses of radioactive substances in lamps can be can be found in a report on the radiological impact of the recycling and disposal of light bulbs.\(^2\)

Summary of issues for uranium and thorium users

- A lack of clarity regarding the interpretation of hazardous waste and landfill regulations
- Difficulty in finding affordable waste management options

4. Production of Oil and Gas

Introduction

4.1 During the process of extracting oil and gas, other naturally occurring substances are also extracted; these include various heavy metals and some natural radionuclides (NORM). Solid, liquid and gaseous NORM waste streams are produced as a result of oil and gas production. There are various published documents\(^3\),\(^4\) that provide further information regarding NORM waste production and its management in the oil and gas industry.

Overview of the Oil and Gas Industry in the UK

4.2 The majority of oil and gas produced in the UK is currently extracted offshore. Recent figures published on the gov.uk website\(^5\),\(^6\) show that offshore oil and gas production accounts for \(\sim 98\%\) of the UK’s oil production and \(\sim 99.9\%\) of gas production. There are approximately 280 oil and gas production platforms and a large number of subsea installations operating in the UK sectors of the North Sea and Irish Sea (\(\sim 100\) oil and \(\sim 180\) gas) extracting oil and gas from approximately 370 fields.

4.3 In 2012, there were 29 onshore oil fields and 7 onshore gas fields listed as producing hydrocarbons on the gov.uk website. These oil and gas fields are listed in Table 2 along with their reported oil and gas production and the operating companies\(^7\). Wytch Farm is the most significant onshore oil field accounting for \(\sim 80\%\) of onshore oil production.

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\(^3\) IAEA (2004), Safety Reports Series No. 34 Radiation Protection and the Management of Radioactive Waste in the Oil and Gas Industry
\(^4\) SNIFFER (2005), UKRSR07 Identification and assessment of alternative disposal options for radioactive oilfield wastes – Technical Summary Report
\(^5\) Oil production since 1975 (gov.uk website – last accessed 14 August 2013)
\(^6\) Gross gas production since 1991 (gov.uk website – last accessed 14 August 2013)
\(^7\) Operating companies assumed to be those granted the PEDL as shown on the onshore licensing map (1 August 2013) published by DECC
<table>
<thead>
<tr>
<th>Type</th>
<th>Field Name</th>
<th>Operator</th>
<th>Hydrocarbon Production</th>
<th>Produced Water Generated (m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oil Production / Tonnes</td>
<td>2008</td>
</tr>
<tr>
<td>Gas</td>
<td>Elswick</td>
<td>Cuadrilla</td>
<td>n/a</td>
<td>348</td>
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<tr>
<td>Gas</td>
<td>Misperton</td>
<td>Viking</td>
<td>n/a</td>
<td>4,914</td>
</tr>
<tr>
<td>Gas</td>
<td>Kirkleatham</td>
<td>Egdon</td>
<td>n/a</td>
<td>454</td>
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<tr>
<td>Gas</td>
<td>Malton</td>
<td>Viking</td>
<td>n/a</td>
<td>1,256</td>
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<td>Gas</td>
<td>Marishes</td>
<td>Viking</td>
<td>n/a</td>
<td>409</td>
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<td>Gas</td>
<td>Pickering</td>
<td>Viking</td>
<td>n/a</td>
<td>4,077</td>
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<td>Gas</td>
<td>Saltfleetby</td>
<td>Wingas</td>
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<td>Avington</td>
<td>Igas Island</td>
<td>2,840</td>
<td>8</td>
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<td>Herriard</td>
<td>Gas</td>
<td>443</td>
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<td>Lidsey</td>
<td>Key</td>
<td>780</td>
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<td>Beckingham</td>
<td>Igas</td>
<td>226</td>
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<td>Key</td>
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<td>Igas</td>
<td>1,799</td>
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<td>Oil</td>
<td>Crosby East</td>
<td>Europa</td>
<td>1,839</td>
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<td>Type</td>
<td>Field Name</td>
<td>Operator</td>
<td>Hydrocarbon Production</td>
<td>Produced Water Generated (m³)</td>
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<td>-------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Oil Production / Tonnes</td>
<td>Gas Production / Ksm³</td>
</tr>
<tr>
<td>Oil</td>
<td>Farleys Wood</td>
<td>Onshore</td>
<td>412</td>
<td>-</td>
</tr>
<tr>
<td>Oil</td>
<td>Airfield</td>
<td>cirque</td>
<td>3,694</td>
<td>-</td>
</tr>
<tr>
<td>Oil</td>
<td>Goodworth</td>
<td>igas</td>
<td>962</td>
<td>-</td>
</tr>
<tr>
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<td>Horndean</td>
<td>igas</td>
<td>7,710</td>
<td>255</td>
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<td>Oil</td>
<td>Humby Grove</td>
<td>Petronas</td>
<td>10,985</td>
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<td>Keddington</td>
<td>Egdon</td>
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<td>4,380</td>
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<tr>
<td>Oil</td>
<td>Kirklington</td>
<td>Egdon</td>
<td>89</td>
<td>-</td>
</tr>
<tr>
<td>Oil</td>
<td>Long Clawson</td>
<td>igas</td>
<td>4,362</td>
<td>-</td>
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<tr>
<td>Oil</td>
<td>Nettleham</td>
<td>igas</td>
<td>104</td>
<td>72</td>
</tr>
<tr>
<td>Oil</td>
<td>Scampton</td>
<td></td>
<td>3,165</td>
<td>390</td>
</tr>
<tr>
<td>Oil</td>
<td>Scampton North</td>
<td></td>
<td>6,081</td>
<td>283</td>
</tr>
<tr>
<td>Oil</td>
<td>Singleton</td>
<td>igas</td>
<td>24,042</td>
<td>8,113</td>
</tr>
<tr>
<td>Oil</td>
<td>Stainton</td>
<td>igas</td>
<td>515</td>
<td>2</td>
</tr>
<tr>
<td>Oil</td>
<td>Stockbridge</td>
<td>igas</td>
<td>22,376</td>
<td>82</td>
</tr>
<tr>
<td>Oil</td>
<td>Storrington</td>
<td>igas</td>
<td>2,220</td>
<td>569</td>
</tr>
<tr>
<td>Type</td>
<td>Field Name</td>
<td>Operator</td>
<td>Oil Production / Tonnes</td>
<td>Gas Production / Ksm³</td>
</tr>
<tr>
<td>------</td>
<td>----------------</td>
<td>----------</td>
<td>-------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>Oil</td>
<td>Wareham</td>
<td>Perenco</td>
<td>478</td>
<td>-</td>
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<tr>
<td>Oil</td>
<td>Welton</td>
<td>Igas</td>
<td>34,491</td>
<td>2,140</td>
</tr>
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<td>Oil</td>
<td>West Firsby</td>
<td>Europa</td>
<td>5,278</td>
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<tr>
<td>Oil</td>
<td>Wytch Farm</td>
<td>Perenco</td>
<td>688,074</td>
<td>34,073</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>832,340</td>
<td>113,180</td>
</tr>
</tbody>
</table>
4.4 The latest version of the onshore licensing map (1 August 2013) published by DECC indicates that there are 3 licensed coal bed methane fields. Only one (the Airth development near Falkirk) has reported production of gas, although it is understood that this was part of the exploration phase and production has now stopped pending a decision on planning permission.

4.5 Whilst there are several operators actively pursuing shale gas extraction, no such extraction is currently in operation. This method of gas extraction could expand significantly in the near future, especially in light of the recent UK Government announcement regarding fiscal incentives to boost the shale gas industry.

4.6 There is great deal more information available on the oil and gas industry at the oil and gas field data page of the gov.uk website\(^8\).

4.7 NORM wastes generated from the production of oil and gas

4.8 The origins and types of NORM containing waste that may be generated as a result of oil and gas production are described in UKRSR07\(^4\) and IAEA SRS34\(^3\). The principal waste types are reproduced in Table 3.

**Table 3. Principal NORM waste types generated by the oil and gas industry**

<table>
<thead>
<tr>
<th>Type</th>
<th>Nuclides</th>
<th>Characteristics</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale</td>
<td>(^{226})Ra, (^{228})Ra and decay products</td>
<td>Hard deposits of barium and strontium sulphates and much lower activity carbonates</td>
<td>Wet parts of oil production installations; well completions, water treatment plant</td>
</tr>
<tr>
<td>Sands and sludges</td>
<td>(^{226})Ra, (^{228})Ra and decay products</td>
<td>Sand, clay, paraffin, heavy metals, waxes and sludges</td>
<td>Separators, skimmer tanks, Water treatment equipment and water/product storage vessels</td>
</tr>
<tr>
<td>LSA films</td>
<td>(^{226})Ra, (^{228})Ra, (^{210})Pb and decay products</td>
<td>Thin films, thin scale deposits</td>
<td>Wet parts of gas production and processing installations; well completions</td>
</tr>
<tr>
<td>Gas deposits</td>
<td>(^{210})Pb and decay</td>
<td>Very thin films</td>
<td>Gas treatment and</td>
</tr>
</tbody>
</table>

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The regulatory regime controlling radioactive wastes does not categorise the waste types as listed in the table, rather it considers the physical state of the waste, its radionuclide concentration and any hazardous properties. With this in mind the rest of the document considers two main waste streams:

- Liquid wastes containing NORM, including produced water, and
- Solid wastes containing NORM

**Liquid wastes containing NORM**

This section of this pen portrait describes the different types of liquid wastes containing NORM that may arise as a result of oil and gas extraction, explains the available disposal routes and presents the available data on the different waste types.

**Description of liquid wastes**

4.9 Water is a natural constituent of hydrocarbon bearing geological reservoirs and is extracted along with oil and gas and is often referred to as produced water. The composition of such produced water varies and is dependent on the reservoir characteristics. Constituents of produced water include NORM at low concentrations. All oil extracted from producing installations contains some produced water; typically the water content is of the order of 1% by volume. This entrained water is usually separated and disposed of at onshore processing facilities.

4.12 There is a separate waste stream that is likely to arise if hydraulic fracturing is used onshore to assist with the extraction of gas, i.e. in shale gas extraction. The fracturing fluids that flow back to the surface (flow back fluids) are anticipated to contain NORM in
concentrations that will require a permit to be issued by the environment agencies regulating controls on its radioactive properties.

4.13 Produced water generated by the oil and gas industry usually contains concentration of the natural radionuclides Radium-226 and Radium-228 that exceed the values specified in the radioactive waste regulatory regime that classify it as radioactive waste. Typical activity concentrations observed in produced water from different origins are detailed in Table 4.

Table 4. Activity Concentrations Observed in Produced Water from Oil and Gas Industry

<table>
<thead>
<tr>
<th>Source of produced water</th>
<th>Ra-226</th>
<th>Ra-228</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore oil and gas</td>
<td>~1 Bq/l</td>
<td>~ 1 Bq/l</td>
</tr>
<tr>
<td></td>
<td>~ 95 % of reported values are less than 10 Bq/l</td>
<td>~ 95 % of reported values are less than 10 Bq/l</td>
</tr>
<tr>
<td>Coal bed methane (based on limited samples from two sites)</td>
<td>0.16 – 2 Bq/l</td>
<td>0.5 – 3 Bq/l</td>
</tr>
<tr>
<td>Shale gas (based on limited samples from one site⁹)</td>
<td>14-90 Bq/l</td>
<td>1.4-12 Bq/l</td>
</tr>
</tbody>
</table>

Disposal routes for liquid wastes

4.14 The disposal options for liquid waste containing NORM are:

- disposal by re-injection,
- disposal to sea or estuarine waters,
- disposal of to inland water,
- disposal of to sewer, and
- transfer to be treated elsewhere.

4.15 The preferred disposal route for produced water is re-injection. This is only possible where installations have appropriate facilities and

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equipment, and where the geological properties of the formation allow. Where re-injection is not possible, one of the alternative management options identified must be used. Offshore, this is typically by disposal directly to sea, providing that limits imposed by DECC on oil concentration in the water and limits on radionuclide activity imposed by the environment agencies can be complied with. For onshore operations, disposal directly to sea is often not an available option so alternative disposal routes must be pursued.

Summary of available data on produced water – offshore industry

4.16 There is a good data set available regarding the quantities of produced water discharged and the concentrations of radionuclides in produced water from the offshore industry. Details of the produced water disposed of via re-injection are presented in Table 5, with details of disposal directly to sea presented in Table 6. The vast majority of produced water is disposed of directly to sea.

Table 5. Quantities of produced water generated offshore disposed of by re-injection (radionuclide data not available prior to 2009)

<table>
<thead>
<tr>
<th></th>
<th>Volume (m³)</th>
<th>Pb-210 (TBq)</th>
<th>Ra-226 (TBq)</th>
<th>Ra-228 (TBq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>30,700,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2007</td>
<td>40,000,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2008</td>
<td>39,000,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2009</td>
<td>40,430,915</td>
<td>0.026</td>
<td>0.048</td>
<td>0.034</td>
</tr>
<tr>
<td>2010</td>
<td>22,628,061</td>
<td>0.005</td>
<td>0.009</td>
<td>0.091</td>
</tr>
<tr>
<td>2011</td>
<td>37,779,504</td>
<td>0.008</td>
<td>0.055</td>
<td>0.038</td>
</tr>
</tbody>
</table>
Table 6. Quantities of produced water generated offshore disposed of directly to sea

<table>
<thead>
<tr>
<th>Year</th>
<th>Volume (m$^3$)</th>
<th>Pb-210 (TBq)</th>
<th>Ra-226 (TBq)</th>
<th>Ra-228 (TBq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>201,143,831</td>
<td>0.031</td>
<td>0.163</td>
<td>0.126</td>
</tr>
<tr>
<td>2007</td>
<td>200,649,040</td>
<td>0.029</td>
<td>0.238</td>
<td>0.200</td>
</tr>
<tr>
<td>2008</td>
<td>197,688,091</td>
<td>0.051</td>
<td>0.216</td>
<td>0.153</td>
</tr>
<tr>
<td>2009</td>
<td>195,689,502</td>
<td>0.104</td>
<td>0.300</td>
<td>0.199</td>
</tr>
<tr>
<td>2010</td>
<td>196,472,057</td>
<td>0.037</td>
<td>0.364</td>
<td>0.133</td>
</tr>
<tr>
<td>2011</td>
<td>180,655,586</td>
<td>0.039</td>
<td>0.323</td>
<td>0.219</td>
</tr>
</tbody>
</table>

4.17 Some liquid wastes may have properties (e.g. oil content is too high) that mean that they cannot be discharged directly to sea. Such wastes must be sent onshore for treatment and subsequent disposal. From discussions with offshore operators, it appears that the treatment and disposal of these wastes is currently causing the industry some difficulties. Anecdotal evidence indicates that there is a lack of onshore permitted treatment sites.

Summary of available data on produced water– onshore industry

4.18 In total, 34 onshore fields reported generating produced water in 2012. Annex 1 presents how much produced water has been reported to DECC as being generated by onshore oil and gas fields over the last 5 years. Wytch Farm in Dorset generates the most produced water (~95% of total generated onshore). Produced water is disposed of at Wytch Farm by re-injection; this is permitted by the Environment Agency. With the exception of Wytch Farm, no information is currently available on how produced water is disposed of from the onshore industry.

Future liquid waste estimates and management

4.19 Indications are that the future quantities, radionuclide content, and chemical content of liquid wastes produced by the oil and gas industry will be substantially the same as those proposed at present. Similarly, we are not aware of any impending change in current management practice or other management options available.
Solid NORM wastes

4.20 Solid wastes containing NORM originate from two main sources:

- Solid NORM accumulates as a hard, insoluble scale inside process pipework, equipment and valves. Solid scale must be removed as it can significantly reduce the performance of the equipment. Removal takes place during routine cleanout and descaling operations.

- Solid NORM also occurs as a mixture of sand, sludge and other sediments deposited inside vessels and are, typically, filtered and removed during shutdowns. Normally this waste is treated to remove any hydrocarbon contamination and is macerated prior to discharge or re-injection under a permit granted by the appropriate environmental regulatory body.

4.21 Drill cuttings and associated drilling fluids and chemicals are another solid by-product produced during drilling but, generally, do not contain NORM.

Offshore Treatment of NORM Scale

4.22 Most NORM scale is disposed either by direct discharge to the sea or by reinjection.

4.23 Reinjection of NORM scale is encouraged by the environment agencies and is carried out on installations that have appropriate facilities and equipment, and where geological properties allow. It may be possible to send wastes from installations that do not have re-injection capability to installations that do (either in the same or a different field). Offshore operators have requested clarity on whether or not these types of movement are permissible, in particular are they consistent with the requirements of the OSPAR Convention?

Onshore Treatment and Disposal of NORM

4.24 Some equipment containing deposits of NORM scale is treated onshore. This may be for practical reasons (e.g. insufficient space, lack of facilities or because of health and safety considerations), or for legal reasons, (i.e. international treaties prohibit waste generated onshore from being sent offshore for disposal). Over the last few years, several companies have invested in facilities where NORM scale can be treated (usually by high pressure water jetting). Following treatment, most NORM waste is then landfilled.

4.25 Indications are that there are sufficient facilities in the UK to treat and dispose solid NORM wastes

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10 Operators take steps to limit solid scale production through the injection of chemicals but this does not wholly avoid the need to physically clean and decontaminate equipment to maintain performance.
Solid Operational wastes – offshore industry

4.26 The average mass of scale generated by the offshore oil and gas industry between 2006 and 2011 was ~ 800 tonnes per year containing on average 6.4 GBq Radium-226 (data for Radium-226 from 2009-2011).

4.27 Figure 0-1 shows the mass of scale disposed of both onshore and offshore from UK offshore installations for the years 2006 – 2011. Figure 0-2 shows the total quantity of Radium-226 disposed onshore and offshore for the years 2009-2011.

Figure 0-1  Mass of Scale Generated by the Offshore Industry and How Much was Disposed of Onshore or Offshore
Figure 0-2  Total quantity of radium-226 generated by the offshore industry and how much was disposed of onshore or offshore

Solid Operational wastes – onshore industry

4.28  It is anticipated that the quantities of solid NORM waste generated from the onshore industry will be very much less than those produced by the offshore industry. This due to their being fewer fields and the much lower hydrocarbon production. However, other than for Wytch Farm, we have no information on how much solid NORM waste is generated by the onshore oil and gas industry or how it is managed. Solid waste will also be generated by oil and gas terminals and refineries although we have no reliable data as yet.

Decommissioning wastes

4.29  There is limited information on the quantities of NORM waste generated during decommissioning of oil and gas installations, due largely to the fact that only a limited number of installations have been decommissioned to date. Also, it is only recently that data on disposals has distinguished whether an installation is operational or is being decommissioned.

4.30  The DECC database (Environmental and Emissions Monitoring System) collects data from decommissioning installations. However, to date, only one entry has been reported under this category, in 2009. The reported quantities of scale disposed to sea were 28.73 tonnes with an associated Radium-226 activity of 0.93 GBq (which gives an average activity of ~ 33 Bq/g). This scale was disposed of to sea.
4.31 There is also some data available in the SNIFFER report (and is summarised in Table 7), however, the report acknowledges that it was difficult to source documentary evidence of the data. The data reported in the SNIFFER report relate to quantities disposed of to land based facilities.

Table 7. Quantity of Decommissioning Waste Disposed to Land Based Facilities

<table>
<thead>
<tr>
<th>Facility</th>
<th>Mass of Non-exempt LLW</th>
<th>Estimated activity</th>
<th>Mass of exempt LLW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conoco Viking</td>
<td>-</td>
<td></td>
<td>&lt; 1 tonne</td>
</tr>
<tr>
<td>Shell Brent Spar</td>
<td>12 tonnes</td>
<td>52.8 MBq (Radium-226) 586 MBq (total)</td>
<td>Unknown</td>
</tr>
<tr>
<td>Phillips Maureen</td>
<td>2.8 tonnes</td>
<td>302 MBq (total)</td>
<td>~ 80 tonnes</td>
</tr>
<tr>
<td>BP North West Hutton</td>
<td>2.5 tonnes</td>
<td>133 MBq (total)</td>
<td>Unknown</td>
</tr>
<tr>
<td>Odin</td>
<td>No waste with activity &gt; 10 Bq/g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tommeliten</td>
<td>No waste with activity &gt; 10 Bq/g</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ekofisk</td>
<td>No waste with activity &gt; 10 Bq/g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.32 We have little information whether or not decommissioning wastes will be an issue at the end of life of onshore oil and gas extraction operations. It may be, for some operations, that this is the only point at which solid NORM waste is generated.

Decommissioning wastes – disposal routes

4.33 Current practice on decommissioning offshore installations is to remove as much scale from the installation as possible and dispose of the waste directly to sea. Only scales that are inaccessible or cannot be disposed of to sea, due to other chemical or physical properties, are brought to shore for treatment.

Decommissioning wastes – conclusion

4.34 In conclusion, there is insufficient data to provide a good estimate of how much waste will be produced from decommissioning installations as the timing when installations will be decommissioned is uncertain.

4.35 A summary of issues for the oil and gas industry follows.
General issues

- There is sufficient treatment and disposal capacity in the UK to manage the volumes of solid waste expected from normal operations and expected arisings from decommissioning of offshore platforms. However, the oil and gas industry rely on a limited number of treatment and disposal facilities, in particular there are very few landfills that can accept waste that is both radioactive and hazardous. Any change to the availability of such facilities could cause problems.

- Data on solid waste generated by the oil and gas industry is uncertain; both DECC and the environment agencies collect data, but the information is fragmented and needs better coordination.

- Decommissioning arisings are uncertain and, to date, only few facilities have been decommissioned.

- Clarity is needed on the transfronteir shipment of waste requirements (e.g., if a platform is to be decommissioned overseas or if a storage vessel containing produced water can be sent overseas for treatment). The oil and gas industry are seeking clarity which regulations apply and whether UK policy requires any NORM wastes to be returned to the UK for disposal here.

- There are considerable uncertainties associated with the estimates of NORM waste that will require disposal in the future and the availability of disposal facilities in the medium to long term. Therefore, we consider that it is necessary to put in place arrangements to collect data from all NORM industries on both operational and decommissioning waste arisings along with monitoring the availability of disposal and management facilities to ensure that any potential constraints on NORM waste disposal are identified as soon as possible, in advance of a problem arising.

Offshore specific issues

- Some liquid wastes generated offshore have properties (e.g. oil content too high) that mean that they cannot be discharged direct to sea, but there are very few onshore facilities permitted to treat these wastes.

- There is also a lack of clarity whether produced water can be managed as a relevant liquid (i.e. it can be disposed of akin to a solid waste as allowed by the UK exemption order regulations).

- A clear position on the acceptability of offshore inter-field and intra-field transfers for the purpose of disposal by reinjection would be helpful.
Onshore specific issues

- For onshore oil and conventional gas drilling, we have very little data on waste arisings. For example, other than Wytch Farm, we do not know how other onshore operators dispose of their solid waste or produced water.

- To date, a number of the smaller onshore oil and gas facilities have not been regulated and clarity is needed as to what constitutes proportionate regulation.
5. Manufacture of Titanium Dioxide Pigments

Introduction

5.1 Titanium dioxide (TiO$_2$) is a simple inorganic compound produced as a pure white powder. It is commonly available in two main crystal forms, anatase and rutile and is typically supplied to the market in a range of package sizes or in bulk.

5.2 It has a very high refractive index which gives whiteness and opacity to a vast range of everyday products from coatings and plastics, to inks and cosmetics. It absorbs UV light and so protects either the substrate when used in a paint or protecting against polymer degradation when incorporated into such systems. Much smaller quantities of TiO$_2$ are produced as specialist ultrafine grades which provide UV protection in sunscreens and catalytic properties in DeNOX applications.

5.3 TiO$_2$ is extracted from titanium bearing minerals (ilmenite, rutile and some slag feedstocks) that also contain low levels of naturally occurring radioactive material. The extraction process and associated residue treatment can generate NORM wastes.

5.4 There are two commercial processes used to produce TiO$_2$, the ‘chloride’ and ‘sulphate’ process routes:

- The chloride process is run as a continuous process with the main stages being conversion of titanium bearing ores into a chloride form; separation of titanium chloride (TiCl$_4$) from the unwanted chlorides, mainly iron; and oxidation of TiCl$_4$ to TiO$_2$,

- The sulphate process is run as a batch process with the three main stages being dissolving the ore, hydrolysis of the resulting titanium oxysulphate forming hydrated TiO$_2$ and drying to produce anhydrous TiO$_2$.

5.5 Further information on the TiO$_2$ industry, the extraction processes and associated wastes is available in an IAEA safety report.$^{11}$

Overview of titanium dioxide manufacturing industry in the UK

5.6 There are two main producers of TiO$_2$ in the UK, Huntsman (Tioxide Europe Ltd), located in Greatham, Hartlepool and Cristal located in Stallingborough, Immingham. Both of these companies use the chloride process. Both responded to questionnaires that were sent to obtain information about their NORM waste arisings.

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$^{11}$ IAEA (2012) Safety Reports Series No. 76: Radiation Protection and NORM Residue Management in the Titanium Dioxide and Related Industries
5.7 Information on NORM wastes generated from the manufacture of TiO₂ follows.

Solid Waste

5.8 TiO₂ manufacturers reported that they routinely produce 2 relevant solid waste streams, filter cake and filter cloths. Internal deposition of radium scales in areas other than the filter cloths was also noted.

Filter cake

5.9 Filter cake is the main solid waste generated by TiO₂ production. It is produced when unwanted chlorides which have been separated from titanium tetrachloride are treated. The unwanted chlorides are slurried in water to produce an acidic sluice liquor which is neutralised, typically with lime, to precipitate the metals as insoluble hydroxides. These insoluble hydroxides are removed from solution by settling and pressure filters which produce a solid filter cake.

5.10 The concentration of radionuclides (Uranium-238 sec and Thorium-232 sec) in the filter cake is dependent on the concentration of radionuclides in the original ore. Generally, the radionuclide concentrations in the filter cake are close to the out of scope values. Currently, one of the companies produces filter cake which is in scope of radioactive substances regulation whilst the other produces filter cake which is out of scope. The filter cake has no hazardous properties that require consideration.

5.11 The company producing in scope waste disposes of it to a landfill site as exempt radioactive waste based on the results of a bespoke radiological impact assessment in accordance with the provisions of the EPR 2010 exemption regulations. The other company also use a landfill facility to dispose of their waste.

5.12 The total quantity of filter cake generated is of the order of 200,000 tonnes per year. Both companies have reported the influence that the quality of the feedstock has on the both the quantity of filter cake produced and the radionuclide concentration that it will contain. Currently, where possible, ores are sourced with high titanium content and low concentrations of natural radionuclides, as these feedstocks become more difficult to source, ores with less titanium and/or more radionuclides may have to be sourced. Depending on the specific characteristics of the feedstock it may result in either higher radionuclide content in the filter cake or a higher quantity of filter cake being generated (possibly with lower radionuclide content).

Filter Cloths

5.13 Filter cloths are used on the pressure filters. The main radionuclides associated with the filter cloths are Radium-226 and Radium-228. The activity concentration will depend on the operational lifetime of
the cloths and varies between the coarse and fine cloths used but typically radium activity concentrations of the order of 100s of Bq/g and 50Bq/g are seen respectively. This material is considered non-hazardous and is currently disposed either to the LLWR repository, to the SITA landfill near Preston or as exempt material depending on measured activity concentration. Only one of the companies reported generating this waste stream. The reported average quantities were up to 10 tonnes per year.

5.14 This material is considered non-hazardous and is currently disposed of to the LLWR repository. Discussions are ongoing to consider other options for disposal of cloths with activity concentration <200Bq/g.

5.15 Only one of the companies reported generating this waste stream. The reported average quantities were up to 10 tonnes per year.

Radium Scales

5.16 One company noted that radium containing scales can build up in pipework and vessels especially those which are rubber- and brick-lined. This scale is classed as low level radioactive waste and will need to be disposed of to a permitted landfill facility. No further information on the quantities of this waste produced was provided however such waste only arises on an irregular basis typically linked to decommissioning of plant equipment.

Liquid Waste

5.17 Essentially all the radioactive content for Huntsman is removed to the solid waste by neutralisation and filtration leaving a liquid waste stream with a radioactivity content below routine levels of detection and out of scope from a NORM legislative perspective. Cristal report that they generate two relevant liquid waste streams, these are liquid effluent and sluice liquor.

Liquid effluent

5.18 Liquid effluent arises from the various processes involved in the chemical processing of the original ore. The Cristal effluent is an aqueous effluent that typically contains low levels of Uranium-238sec and Thorium-232sec along with trace levels of heavy metals and some organics. The radioactivity content of this effluent is permitted for discharge into the Humber Estuary.

Sluice/Acidic Liquor

5.19 As described above sluice/acidic liquor is treated at the neutralisation plant to form solid waste filter cake. However for operational reasons it is sometimes necessary for Cristal to send some of the liquor off-site for treatment. The waste is sent to a radioactive substance
permitted treatment facility but is classed as exempt from radioactive substances legislation.

Summary of Issues for the Titanium Dioxide Manufacturing industry

- The availability and quality of raw ores has a significant influence on both the quantity and NORM content of waste generated. It is likely that the characteristics of waste generated by the UK TiO2 industry will change in the future as it becomes necessary to source lower quality ores.

- The legislation places restrictions on when the “assessed landfill” exemption may be used related to other permits held. The titanium dioxide industry, with agreement from the environment agencies, does not believe that the current restriction is appropriate. It would be helpful to review and clarify what restriction if any need to be in place.

- The titanium dioxide industry relies on local landfills accepting their waste. Should the local landfills have to close, not be granted planning permission or decide not to take exempt NORM waste, alternatives would need to be found. These landfills may need to be assessed in accordance with the exemption order legislation, although this is responsibility for the waste producer. Some disposal facilities may not wish to be associated with such an assessment.

- Filter cloths are currently disposed of to the LLWR repository. If LLWR stopped accepting NORM derived waste, another disposal route would have to be found for these wastes.

- Out of scope and exemption limits have been applied on the basis of waste as it is disposed of, rather than on a dry mass basis. Confirmation that this is the correct interpretation is requested since filter cake is approximately 50% water so if the interpretation was different it could have major implications for the industry.

- The UK regulatory regime for NORM waste management only applies to those industries listed in the legislation. The question then arises as to whether NORM materials or articles imported/purchased by a listed industry and then discarded would need to be regulated even if the listed industry has not processed the material or article in any way to affect its radioactive content. Examples could be Zirconia grinding media or unused feedstock.
6. **Extraction and Refining of Zircon and Manufacture of Zirconium Compounds**

**Introduction**

6.1 Zircon is the raw material in the manufacture of steel refractory materials, in glazes, glasses and ceramics. Refractory bricks for steel and glass furnaces are made by fusing zircon sand with alumina and sodium carbonate.

6.2 Zircon mineral contains trace amounts of uranium and thorium. Because zircon is used directly in the manufacture of refractory materials and glazes, the products will contain similar amounts of radioactivity. In the fusion of zircon, the more volatile radionuclides, for example Lead-210 and Polonium-201, may be concentrated in dust and fumes within the plant.

6.3 Further information on the zircon and zirconium industry, the extraction processes and associated wastes is available in an IAEA safety report\(^\text{12}\).

6.4 Overview of the Zircon Industry in the UK

6.5 There were a number of companies that processed and produced zircon and zirconia in the UK that produced waste with high NORM content, however, these have now closed. The industry that remains in the UK is set out below.

**Chemical manufacture**

6.6 Magnesium Electron (chemicals) Limited, based in Manchester, manufactures zirconia and zirconium compounds. It is understood that they produce NORM waste. The company has recently been contacted for further information.

**Zirconia milling operations**

6.7 It is understood that there are a small number of companies that mill zirconia. At present we have no information suggesting that this process generates NORM waste in the UK.

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\(^\text{12}\) IAEA (2007) Safety Reports Series No. 51: Radiation Protection and NORM Residue Management in the Zircon and Zirconia Industries
Foundries

6.8 Zircon sands are commonly used in foundries for mould making; it is understood that most users in the UK use small quantities. At present we have no information suggesting that this process generates NORM waste in the UK. One larger scale user has been contacted for further information.
7. Production of Iron and Steel

Introduction

7.1 There are two main processes for producing steel; (1) basic oxygen steelmaking (BOS) and (2) the electric arc furnace process. The two processes have very different requirements in terms of raw material used, as outlined below.

- The integrated steelmaking route, based on the blast furnace (BF) and basic oxygen furnace (BOF), uses raw materials including iron ore, coal, limestone and recycled steel. On average, this route uses approximately 1,400 kg of iron ore, 770 kg of coal, 150 kg of limestone, and between 120-300 kg of recycled ferrous materials, including steel scrap, to produce a tonne of crude steel.

- The electric arc furnace (EAF) route, uses primarily steel scrap and/or direct reduced iron (DRI) and electricity. On average, the recycled steel-EAF route uses 880 kg of recycled steel, 150 kg of coal and 43 kg of limestone to produce a tonne of crude steel.

7.2 It is the integrated steelmaking process that is of potential concern from a NORM perspective due to the significant quantities of raw materials used, particularly iron ore, which contains naturally occurring radionuclides. These naturally occurring radionuclides can be concentrated or released to the environment during the iron and steelmaking process.

7.3 Overview of the steel industry in the UK

7.4 There are 3 integrated steelworks in the UK, all of which produce steel using the basic oxygen steelmaking process (BOS). The locations and operators are listed in Table 8.

Table 8. Locations and operators of integrated steelworks in the UK

<table>
<thead>
<tr>
<th>Location</th>
<th>Operator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scunthorpe</td>
<td>Tata Steel</td>
</tr>
<tr>
<td>Port Talbot</td>
<td>Tata Steel</td>
</tr>
<tr>
<td>Redcar</td>
<td>SSI</td>
</tr>
</tbody>
</table>

NORM wastes generated by the iron and steel making industry

7.5 Due to the high temperatures used in the steelmaking process, the volatile radionuclides Polonium-210 and Lead-210 are partly emitted to atmosphere. The volatile radionuclides may also be concentrated in sludges that are generated as a result of the various gas cleaning and abatement technologies used. Such sludges may contain
concentrations of radionuclides, particularly Pb-210 that exceed the out of scope values in the legislation that controls radioactive wastes.

7.6 In summary there are two NORM waste/residue streams from steel making industry

- Gaseous emissions containing Polonium-210 and Lead-210
- Sludges and filter cakes (arising from gas cleaning) containing Polonium-210 and Lead-210

Influence of raw material on NORM waste

7.7 The main raw materials used in the iron and steel making processes; iron ore, limestone and coke, all contain some naturally occurring radionuclides. The concentrations of naturally occurring radioactive nuclides in the various raw materials are variable and are dependent on where the raw materials are sourced. For example, South American iron ore tends to contain more radionuclides than Australian iron ores. Worldwide competition for iron ore has increased markedly over the past 20 years and in particular there is a high level of demand from China. This has resulted in steelmakers in the UK and the rest of Europe having to source increasing amounts of their ores from non-Australian sources, including South America. This Brazilian ore tends to contain higher concentrations of NORM impurities which results in higher quantities of radioactivity discharged to the environment and higher concentrations of radionuclides in the process residues.

7.8 The UK environment agencies have accepted that there is little that can be done to minimise the quantities of radionuclides in raw materials and that UK businesses must compete in a global marketplace. However, the regulators do expect the steel industry to have due regard to the impact that different raw material have on radioactive discharges and on the generation of radioactive wastes and to have appropriate arrangements in place to manage all wastes (both radioactive and non-radioactive) from the iron and steel making process.

Gaseous effluents

7.9 All three UK steel works have been issued with a permit by the Environment Agency to allow them to make gaseous discharges of Polonium-210 and Lead-210. For gaseous wastes, no issues have been identified that require addressing by the NORM strategy.

Sludges and filter cakes

7.10 There are various plants in the steel making process where hot, particulate laden gases are treated, resulting in the generation of sludges and filter cakes etc. These include the sinter plant, the blast furnace and the BOS plant. In general, gas cleaning systems are
used in all of these processes to recover/re-use as much raw material as possible into the steel making process, thereby avoiding generating waste. They also minimise atmospheric emissions.

7.11 Where materials are re-used in the onsite steel making process, no NORM waste management issues arise as the recovered materials are not considered waste. However, some residues cannot be completely used in this way as they contain concentrations of certain metals (e.g. zinc) that are detrimental to the steelmaking process. One such example is residues arising from blast furnace gas cleaning.

7.12 Dust is removed from blast furnace gases by a wet scrubber (a system that removes dusts entrained in the hot gas by capturing them in a liquid). The particulates are then removed from the liquid scrubber waste and either fed back into the steel making process or disposed of as waste if it contains high levels of zinc and other heavy metals, which interfere with the steel making process.

7.13 However, the liquid scrubber waste can be treated through a hydrocyclone, which separates the dust into two fractions known as the underflow and the overflow. The underflow (~70% of total solids) can be fed back into the steelmaking process. The overflow (~30 of total solids) contains the majority of the zinc and is unsuitable for re-use in the process. The use of the hydro-cyclone also results in Lead-210 concentrating in the overflow fraction at concentrations which could exceed the out of scope levels in the radioactive substances legislation. It should also be noted that the zinc oxide content of these residues means that they are classified and managed as hazardous waste.

7.14 Hydro-cyclones are not currently installed at all 3 UK integrated steel-making sites, however this technology is considered to be BAT. Some overseas installations have multiple hydrocyclones which generate wastes with higher radionuclide content. Table 9 indicates which sites have hydrocyclones installed on their blast furnaces and estimates typical quantities of waste generated and Lead-210 concentrations.

<table>
<thead>
<tr>
<th>Site</th>
<th>Hydro-cyclone</th>
<th>Annual quantity of “overflow”</th>
<th>Typical Lead-210 activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scunthorpe</td>
<td>Yes</td>
<td>~ 10 000 tonnes</td>
<td>5.4-12.8 Bq/g</td>
</tr>
<tr>
<td>Port Talbot</td>
<td>No</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Redcar</td>
<td>Yes</td>
<td>??</td>
<td>??</td>
</tr>
</tbody>
</table>
7.15 The management of these wastes as radioactive waste has only recently become an issue. This is due to a combination of an increase in the Lead-210 concentration in the waste as a result of the changes in international iron ore consumption patterns described above and changes in the radioactive substances regulatory regime. Prior to 2011 these wastes could have been used or disposed of without any regulatory oversight relating to the radioactive properties under the phosphatic substances and rare earths exemption order.

7.16 Current management arrangements for NORM waste generated by the steel industry

**Scunthorpe**

7.17 Only a small percentage of solid radioactive material is disposed of from the Scunthorpe site. A fraction of the BF filter cake is blended with other on site materials (BOS Filter cake) to produce a residue that can be sold to the cement industry. All of the residues sold to the cement industry are “out of scope”. The remaining BF filter cake is currently being accumulated on site pending a decision regarding the most appropriate material management option. In recent years, a high proportion of BF filter cake arisings have been blended for use in the cement sector but material management strategies are, by their very nature, dynamic and it has to be recognised that up to 10,000 tonnes per annum may need to be accumulated, in a worse-case scenario.

**Port Talbot**

7.18 The Port Talbot site does not currently generate solid radioactive material. This would be likely to change should hydro-cyclone technology be installed at the site. Hydro-cyclones are being seriously considered for the Port Talbot site but any decision is complicated by the multitude of technical and legal considerations surrounding each option.

**Redcar**

7.19 Data to be included during the consultation process.

**Management options for Sludges and filter cakes**

7.20 There are three main management options available for the blast furnace hydro-cyclone overflow residues.

- Disposal to landfill
- Use in cement making process
- Further iron recovery using a rotary hearth furnace or equivalent technology
Dispose to landfill

7.21 The residues can only be disposed of to a landfill which is permitted to dispose of both hazardous waste and radioactive waste. There is only one such facility (excluding LLWR) in the UK.

7.22 This option is also undesirable as it results in valuable material being disposed of and replacement raw materials being sourced from outside the UK. It also contains significant cost implications compared to the other options. Compared to use in the cement making process it would result in loss of revenue from the sale of residues to the cement sector and would incur additional landfill disposal costs. It is anticipated that the net cost to the steel industry would be in the order of millions of pounds per year.

7.23 It is worth noting that the relatively short half-life of lead-210 (22.3 years) combined with the typical concentrations in the waste should make it a relatively straight forward process to demonstrate that the disposal by landfill does not pose any long term risks, therefore it may be appropriate to consider facilities other than those already permitted.

Use in cement making process

7.24 The residues generated by the steel sector have properties that are desirable in the cement making process (i.e. high iron content). The cement industry has specifications that material must meet in order for it to be used in the cement making process, e.g. moisture content, various trace elements and heavy metals content. The steel operators blend various waste streams (including BF filter cake) in order to produce a residue that is acceptable and can be sold to the cement sector. If the cement sector did not have access to this material it would have to source raw materials from elsewhere.

7.25 None of the waste currently used by the cement sector exceeds the out of scope concentrations. The BF filter cake that exceeds the in scope values is technically suitable for use by the cement industry, however if the residue is considered to be a radioactive waste, then transfer to the cement sector would be considered to be a disposal and this “transfer” from the steel to the cement industry would require permitting. It is likely that the cement industry would be unwilling to accept waste that was associated with a radioactive substances permitting requirement due to public perception issues.

Summary of issues for the Steel Industry

- Currently, the steel industry blends the solid residues it generates with other out of scope residues to ensure that the resultant residue is all out of scope. The steel industry worries that this practice may be construed as “deliberate dilution” to produce a material that they can sell to the cement industry.
• If the steel industry cannot use the above blending process, their sludge and filter cake waste will need an EPR permit and be managed as radioactive waste.

• This blending process appears to be compatible with the provision of the draft Basic Safety Standards Directive (March 2013) which would allow the regulatory authorities to authorise the mixing of radioactive and non-radioactive materials in specific situations (building residues are cited in the draft BSS).

• The steel industry is considering investing in new technology (a rotary hearth furnace) which will further concentrate their waste; especially the zinc concentration. The steel industry is seeking clarification whether high-zinc material can be sent overseas and what are (i) the TFS requirements for zinc which is radioactive and hazardous (Conventional and RS) and (ii) the UK policy or returning wastes following overseas treatment. If export is not allowed, there are no zinc manufacturers in the UK and this would leave the steel industry with a waste which is classed as hazardous and radioactive.

• It is unclear to the steel producers what the regulatory and policy framework relating to the mixing (and therefore dilution) of radioactive waste is and have requested that if mixing with the intention of dilution is allowed, any criteria that need to be satisfied are clearly set out.

• The NORM strategy will need to assess whether steel waste:
  - Can be diluted and managed as exempt waste;
  - Needs a specific exemption;
  - Needs to be permitted.
8. **Coal Mine Dewatering**

**Introduction**

8.1 When coal is extracted from underground it is necessary to de-water the mine to ensure the continued safe operation of the mine. Following cessation of mining it may also be necessary to keep de-watering abandoned coal mines for environmental protection purposes, i.e. uncontrolled discharges may have a detrimental impact on water quality.

8.2 Like any other water abstraction from underground there is the possibility that the water may contain levels of NORM which are above those found in surface waters and which exceed the relevant out of scope levels.

**Overview of coal mine dewatering industry in the UK**

8.3 During 2012 there were 49 operational coal mines that produced ~ 16 million tonnes of coal. Of these 49 sites, 33 were surface sites and 16 were underground. Up to date statistics are available from The Coal Authority\(^{13}\).

8.4 The Coal Authority also currently operates a number of mine water treatment schemes in order to remediate existing discharges and prevent new discharges from coal mine workings (29 in England, 13 in Scotland and 10 in Wales). Further detail is available on the Coal Authority website.

**NORM wastes from coal mine de-watering and mine water treatment**

8.5 There is very little data available regarding the concentration of NORM in waters discharged as a result of coal mine de-watering or the solids that are associated with the treatment of mine-waters. The Coal Authority recently analysed liquids and solids from three different mine water treatment schemes; all of the samples contained radionuclides at concentrations less than the out of scope values in the UK radioactive substances legislation. However, some former coal mines may produce wastewater that would require to be regulated and discussion with the Coal Authority are continuing.

8.6 It is also useful to be aware of the limited amount of data associated with waters sampled as part of exploration and development of coal bed methane extraction. The limited data available show that the concentration of NORM (namely, Radium-226 and Radium-228) exceed the out of scope value in the legislation so would need to be regulated if they are discharged into the environment.

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\(^{13}\) [http://coal.decc.gov.uk/](http://coal.decc.gov.uk/)
Summary of issues for coal mine de-watering

- There is very little data regarding the concentration of NORM in coal mine de-watering wastes. Recent data suggests such wastes will be out of scope. However, data from coal bed methane developments suggests that it is possible that some waters could fall within scope of the radioactive substances legislation.

- A proportionate approach will be adopted if it is deemed necessary to collect further information about regulation of NORM wastes from coal mine dewatering activities. This approach takes due account of the fact that many de-watering facilities are operated to improve or prevent degradation of the environment.
9. China Clay Extraction

Introduction

9.1 Kaolin is a fine white clay often referred to as China Clay. The primary China Clay deposits of south west England are regarded as world class and the UK is the world’s third largest producer of China Clay.

9.2 China Clay products have a range of industrial applications which are grouped into three main market areas:

- Paper - demand is dominated by the paper industry. China Clay performs 2 quite separate functions in the manufacture of paper; as a filler, it is incorporated into the paper sheet (web), both reducing its cost and improving its printing characteristics. It is also used as a coating pigment, enhancing the surface properties of the paper.

- Ceramics - the main markets are Europe, Middle East and Asia with the China Clay being used for the manufacture of sanitary ware, wall tiles, electrical porcelain and glazes

- Speciality Applications - speciality applications use China Clay as fillers in paint, rubber, plastics, adhesives & sealants and pharmaceuticals. Other uses include the manufacture of animal feed, white cement and glass fibre.

The formation of China Clay

9.3 The kaolin reserves of south west England are regarded as typical primary deposits. These deposits are formed from high-heat-flow granites rich in radiogenic elements such as Uranium, Thorium and Potassium. High temperature and hydrothermal circulation associated with a relatively early phase of mineralisation is thought to have increased the permeability of the granite and reduced its iron content. Over time, a process known as kaolinisation resulted in the formation of kaolinised zones which are funnel or trough shaped, narrowing downwards.

Socio-Economic

9.4 China Clay is a mineral of national and international importance and for many years it has been Britain’s most important mineral export after hydrocarbons; with in excess of 85% of the China Clay produced being exported. The UK China Clay operations generate significant economic benefits both locally and nationally.

9.5 For example, in 2012 Imerys Minerals Ltd had expenditure, in excess of £100m, with approximately 1500 UK based organisations. At the end of 2012 Imerys Minerals Ltd directly employed approximately 1150 people of which just under 1000 were based in Cornwall.
9.6 Responses from China Clay manufacturers indicate that extensive China Clay deposits remain in Cornwall and Devon and reserves are sufficient to last for many decades at current mining rates.

Overview of industry

9.7 There are two producers of China Clay in the UK; Imerys Minerals Ltd (including the recent acquisition of Goonvean Ltd’s Kaolin operations) and Sibelco. China Clay operations are centred on the Mid Cornwall area to the north of St. Austell and in Devon on the south west edge of Dartmoor, near Plymouth.

China Clay Production

9.8 The production of China Clay can be a complicated process which can be split into three distinct sections - opencast mining, refining and drying

9.9 Once the clay is exposed by excavation and blasting, the most common method of mining is best described as a hydraulic mining process (essentially high pressure water jetting). This liberates China Clay from the quarry face together with sand and mica. This material runs in slurry form to the lowest part of the pit, known as the sink, where it is lifted by centrifugal pumps to mechanical sand classifiers and hydrocyclones, where the more coarse sand elements are removed. The clay suspension is then transported by underground pipeline to the refineries.

9.10 The refining process is highly automated and computerised. A series of mineral processing techniques are used to engineer the size, shape and brightness of the China Clay particles to create a range of different products, each with differing physical and chemical properties.

9.11 Once refined, the China Clay products are pumped again via underground pipelines to drying complexes which are often located near ports and railway sidings. The China Clay slurry is dewatered and thickened before entering a mechanical dryer for final treatment. The final clay product is then transported to the customers in the United Kingdom or overseas, by road, rail or sea transport.

NORM waste in the China Clay industry

9.12 NORM occurs naturally in the granite that forms much of Cornwall and Devon. During the refining of the China Clay, certain processes can encourage small particles of radioactive material to collect and concentrate on the surfaces of processing equipment and other infrastructure. Although this does not directly impact on the production process, it does add to the complexity and cost of
maintenance and decommissioning activities; those carrying out the work activities need to be appropriately trained and competent and the NORM contamination has to be removed from the surfaces of the processing equipment before being repaired and put back into service or scrapped / recycled.

9.13 Imerys is the majority shareholder of ReClaym Ltd which operates a plant designed and built specifically to remove NORM contamination.

9.14 ReClaym uses an ultra high pressure water jetting technique to remove surface NORM contamination. This technique has been developed for cleaning items of equipment that need to be cleaned and put back into service and is common throughout the oil and gas industry.

9.15 As an alternative, some of the heavier materials that are no longer required by operations are prepared at ReClaym and sent to Studsvik UK located in Cumbria. Studsvik have recently designed and built a largely automated plant that uses shot blasting processes to remove contamination. This is an efficient but aggressive cleaning process that renders the equipment being cleaned as unserviceable and consequently, any equipment cleaned by this method is then sent to a scrap metal merchant for recycling.

9.16 Imerys is in the process of decommissioning a number of closed China Clay production sites and although it is very difficult to quantify, NORM contamination could potentially lead to significant NORM waste volumes and activity concentrations.

Issues for the China Clay Industry

- Surfaces can become NORM contaminated if they have been regularly exposed to China Clay slurry; typically, however, it is only the internal surfaces of plant and equipment that are affected. Therefore, the extent of contamination throughout a plant cannot be determined until all items have been dismantled and intrusive monitoring carried out.

- Similar to other NORM industries, NORM waste is cemented prior to disposal and clarification is sought how the environment agencies regulate this practice in a consistent manner.

- Imerys raised the issue that if they wanted to send waste to an assessed landfill, they would not be able to do so as they have a permit from the Environment Agency and the exemption order regime says that an operator cannot makes use of the assessed landfill disposal route where a permit granted by the Environment Agency is already in place.
10. **Extraction and Production/Use of Rare Earth Elements**

10.1 The extraction and production or use of rare earth elements has potential to create NORM waste that has to be regulated by the environment agencies. However, it has been identified that no operations of this type are undertaken in the UK at this time and, therefore, no further consideration of this waste stream is made.

11. **Mining and Processing of Ores other than Uranium**

11.1 Mining and processing of ores has potential to create NORM waste that has to be regulated by the environment agencies. It has been identified that, in the UK, where ores other than uranium are mined, "regulated" NORM waste is not created at this time and, therefore, no further consideration of this waste stream is made.

12. **Any Industrial Activity Utilising Phosphate Ore**

12.1 Utilisation of Phosphate Ore has the potential to create in scope NORM waste, however, it has been identified that no operations of this type are undertaken in the UK at this time. Therefore, no further consideration of this waste stream is made.

13. **NORM wastes generated from the Extraction and refining of zircon and manufacture of zirconium compounds**

13.1 Information will be added during the consultation process.

14. **Summary of issues for the zircon and zirconium compound industry**

14.1 Information will be added during the consultation process.

15. **Production of Tin**

15.1 Primary tin production does not currently take place in the UK.

16. **Production of Copper**

16.1 The main waste materials arising from the copper separation and refining are the tailings from the flotation stage and the furnace slags from the smelting stage. Partitioning of lead-210 and polonium-210 from uranium occurs into the copper concentrate during the smelting process. These radionuclides are vaporised at the smelting stage and may accumulate in dusts collected from off gases. Primary copper production is not currently taking place in the UK.

16.2 Manufacture of copper products does take pace in the UK. This is not known to produce any NORM wastes.
17. **Production of Aluminium**

17.1 The main mineral source of aluminium is bauxite, which contains 30 to 50% hydrated aluminium oxide. When bauxite is refined into aluminium oxide (alumina) the naturally occurring radionuclides present are concentrated in the waste product which is known as "red mud". This process does not currently take place in the UK.

17.2 In 2009, the UK produced approximately 800,000 tonnes of aluminium. This was produced by the smelting of imported alumina in facilities such as that operated by Alcan near Fort William. This process does not produce NORM waste.

18. **Production of Zinc**

18.1 Primary zinc production does not currently take place in the UK. However, it is possible that this may change in the future as a mining company has commenced a zinc exploration initiative in the North Pennines.

19. **Production of Lead**

19.1 Lead is usually extracted from lead ore in a blast furnace (a lead smelter). This process produces lead bullion that requires further refining. Similar to other metal production it is the ore processing and smelting that give rise to NORM wastes.

19.2 Britannia Refined Metal in Northfleet, Gravesend is Europe’s biggest producer of lead. This company does not operate a lead smelter, it refines lead that has been smelted in other countries. This company is not known to produce any NORM wastes,; this will be checked during the consultation process.

20. **Water Treatment for Drinking Water**

20.1 Water treatment for drinking water has the potential to create NORM waste that requires to be regulated. It has been identified that, in the UK, where water is treated for drinking, in-scope (ie regulated) NORM waste is not created at this time and, therefore, no further consideration of this waste stream is made.

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14 Source Aluminium Federation website
21. Management of NORM Contaminated Land

Introduction

21.1 The occurrences of land contamination reflect a legacy of historical use of radioactive materials by a range of organisations (both civil and military) at times when there were no or very few statutory controls on the use and disposal of such material.

Overview of Contaminated land likely to have enhanced levels of NORM

21.2 Land that is contaminated with radioactivity or other materials is not in itself ‘waste’ but rather ‘contaminated property’. Controls over the management of the risks associated with any contamination are required in accordance with the land use and development controls associated with Town and Country Planning. Where Town and Country Planning controls are not triggered then Part IIA of the Environmental Protection Act 1990 otherwise known as the Contaminated Land Regime applies. Both advocates a risk based suitable for use approach. As a consequence there is considerable uncertainty over the quantities and timing of any NORM wastes that may be generated from land remediation activities at such sites.

21.3 The bulk of the NORM activities likely to have generated land contamination were undertaken in support of both civil and defence activities with 37 luminising factories in operation in the late 1950s. The organisations registered in the UK under the Luminescing Regulations 1947 ranged from the producers of radium powders and paints through distributors to instrument and watchmakers and repairers. In addition to which historically gas mantles were manufactured using thorium within the UK and the presence of radioactive contamination associated with waste disposal (commercial and medical) and salvage activities pre 1974 can not be discounted.

21.4 The 2006 DEFRA Report; “Industrial Activities which have used material containing radioactivity”\(^\text{15}\), discusses the various land uses and the likely occurrence the UK in more detail.

21.5 The scale of defence activities across the UK in the first half of the 20\(^{th}\) century was considerably greater than today. Whilst it falls to SEPA in Scotland and local authorities across the rest of the UK to identify land affected by radioactive contamination, the MOD continues to manage a programme of land quality assessment across the current defence estate to ensure it is ‘suitable for use’ and where appropriate take action to bring land back into beneficial use and

protect human health and the environment. In addition sites are assessed either prior to sale or the surrender of the respective lease. To-date this has resulted in the clean-up of a number of sites which were contaminated, as well as the characterisation and sale of other areas of land ensuring that the information and knowledge relating to any residual contamination is transferred to the new owner for subsequent management and control.

**Ministry of Defence Land**

**Background**

21.6 Across the UK a number of sites are known to have land that has been contaminated as a result of legacy NORM activities. These circumstances of contamination are associated in particular with radium luminising activities, including both development of radium luminised items as well as their maintenance and disposal. Other activities that have resulted in contamination include the use of radium, thorium and uranium in teaching, electronic valves, thoriated alloys. The predominant NORM waste stream is Ra-226 from the maintenance and disposal of luminised instruments pre 1969.

21.7 By the end of the 1960s, the UK ceased to use radium for luminising and in 1969, the MOD issued instructions to withdraw all radium containing instruments. On a number of defence sites redundant luminised instruments and paint were disposed of by burning and burial (as was common practice at the time) leading to localised soil contamination. Many of these localised areas have now been remediated. In general, the remediation has involved the excavation of the radium contaminated areas and disposal of the resultant waste materials as either radioactive or exempt waste. Where appropriate, and within the control of MOD, radioactive land contamination has been left *in-situ* with the residual risk being managed through the use of suitable and sufficient institutional controls.

**Socio-Economic**

21.8 The MOD is charged to protect the security, independence and interests of the UK at home and abroad. The Defence Infrastructure Organisation (DIO) was formed on 1 April 2011 to bring together property and infrastructure functions from across the Ministry of Defence. DIO manages the MOD’s property infrastructure and ensures strategic management of the defence estate as a whole, optimising investment and providing the best support possible to the military. DIO has adopted a risk based approach to the management and remediation of radioactive and non-radioactive land contamination as set out in national legislation, statutory guidance and supporting Contaminated Land Reports (CLR).
Overview of waste arisings

21.9 The principal NORM containing waste types associated with land remediation are summarised in Table 10 below:

Table 10. Principle Waste Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Nuclides</th>
<th>Characteristics</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>$^{226}$Ra, and decay products</td>
<td>Primary contaminant is radium sulphate (&lt;1%wt) with &gt;99%wt of waste comprising: soil, ash, concrete, cement, sand, glass/ceramics, scrap and rubble containing trace elements of organic material and occasionally asbestos (predominantly chrysotile). Density is approximate and may change from site to site but, generally reflects soil densities.</td>
<td>Localised soil contamination associated with luminising and waste disposal activities.</td>
</tr>
<tr>
<td>Discrete artefacts</td>
<td>$^{226}$Ra, and decay products</td>
<td>Discrete items such as dials with remnants of radium luminised paint.</td>
<td>Localised and associated with luminising and waste disposal activities</td>
</tr>
<tr>
<td>Ash and clinker</td>
<td>$^{226}$Ra, and decay products</td>
<td>Layers of intermixed ash and clinker.</td>
<td>Localised and associated with burning and waste disposal activities</td>
</tr>
</tbody>
</table>
tonnes per cubic metre. Free liquid comprising natural soil moisture content will be present, probably in the order of 20-35% by wet weight. Domestic waste (such as glass, ceramics, wood and cloth), construction materials (such as concrete, brick and principally chrysotile asbestos) and metals used in the construction of instruments (such as steel, brass and copper) may sometimes be present. A complicating factor for waste estimation is that the composition of the matrix has been found to vary and must be determined on a case by case basis.

21.11 The radium sources vary in size from grains to physically large lumps with dimensions of tens of centimetres and there is no correlation between particle size and activity. In the natural environment the radium decay products have an equilibrium value of about 60 – 70% of the parent Ra-226. Enclosing the waste in an airtight container causes the equilibrium value to rise to near 100%.

Future solid waste estimates and management

21.12 Obtaining a forecast of future waste arisings involves the assessment and collation of anticipated arisings based on the findings of the MOD Land Quality Assessment Programme. The prioritisation of the latter has to consider a range of potential contaminants some of which are more mobile and depending upon the circumstances present a more immediate risk than Ra-226. Further, decisions on if and when to remove and dispose of radioactive land contamination are taken on a case by case basis taking account of the risks posed to human health and the environment for current and any planned change of use. The low solubility and mobility of Ra-226 combined with the principle decay mode being alpha radiation and level of shielding afforded by disposal through burial lends itself to the effective use of institutional management controls. As a result historical data is not a reliable predictor of future waste volumes. Similarly the level of conservatism inherent in radiological surveys as applied to land contamination means that there is a high degree of uncertainty in any forecast. On the basis of land quality surveys carried out before May 2013, the worst case volume estimate for radioactively contaminated land potentially requiring future remedial work was estimated to be less than 400m³.

Future liquid waste estimates and management

21.13 There is no reasonably foreseeable risk of MOD having liquid waste arisings from this source because of the known insolubility of radium luminising material and its combustion products. Water sampling at radium contaminated sites supports this conclusion. As mentioned previously, free liquid comprising natural soil moisture content is likely to be present in radium contaminated soil, probably in the order of 20-35% by wet weight.
Site Decommissioning wastes

21.14  NORM contaminated building wastes are very unlikely to arise because of historic monitoring programmes carried out by MOD and predecessor organisations and because the vast majority of affected facilities have been remediated, demolished and/or redeveloped.

Site Decommissioning and Land Remediation wastes – disposal routes

21.15  In the unlikely event NORM contaminated decommissioning wastes arise, they would be subject to waste minimisation and disposal by an appropriate route. Past experience indicates that the activity concentrations would allow disposal to a suitable landfill (as either radioactive or exempt waste).

21.16  Waste arising from land remediation will be subject to accumulation and disposal under the relevant permit/authorisation and will be monitored with hand held instrumentation and carefully removed with the emphasis on manual segregation of the material to prevent mixing and cross contamination. This will minimise the volume of waste generated and ensure high activity sources and/or contaminated soils are accumulated together to minimise the disposal volume (in accordance with the waste management hierarchy). All the waste will be assayed using dose rate measurements and suitable dose rate/activity Models with confirmatory gamma spectrometry. The waste will then be sentenced according to whether it is exempt (disposal to landfill) or requires authorised disposal (LLWR or a suitably permitted landfill).

Decommissioning and Land Remediation wastes – conclusion

21.17  Any future NORM waste arisings from decommissioning is expected to be negligible as the risk of MOD locating any further contaminated facilities is very low and only very small volumes and low activity concentrations have been found in the past.

21.18  As with the management of land that may be contaminated with other non-radioactive substances, the need for land remediation and thus the volume of NORM waste arisings depends upon the use of the site in question and any proposed changes in use. The aim of this approach is to ensure that the risks posed by any contamination at the site remain appropriate for the current and intended land use, thereby avoiding the unnecessary generation of wastes. Any residual risks associated with land contamination are managed using suitable and sufficient institutional controls. This approach is both possible and effective for land contaminated as a result of NORM activities because the contaminant of most concern, radium-226, is essentially insoluble and buried at depths at which it does not present a risk to human health. Where radioactive material is known or suspected to be present at shallow depths, the nature of MOD’s activities means
that access restrictions are relatively simple to implement and enforce without affecting MOD operations.

21.19 In the event of remediation, there will be a high degree of uncertainty regarding the actual volume and characteristics of NORM waste that will be created due to the limitations of radiological surveys as applied to land contamination.

Summary of issues for contaminated land giving rise to NORM wastes

- Environmental legislation is a devolved matter and there are differences in the regulation of land contamination and waste management across the UK. Differences in regulation of land contaminated with radioactivity and the regulation of NORM wastes has implications for the amount of NORM waste generated.

- The overarching objectives of the policy on contaminated land and the Part 2A regime are:
  - To identify and remove unacceptable risks to human health and the environment.
  - To seek to ensure that contaminated land is made suitable for its current use.
  - To ensure that the burdens faced by individuals, companies and society as a whole are proportionate, manageable and compatible with the principles of sustainable development.

- To deliver the above objectives legislation has been enacted around risk based principles. While following the criteria set out in the statutory guidance in relation to radioactive land contamination the MOD has engaged with members of the Radiation Protection Advisor community and wider public who do not feel that the risk based approach provides sufficient protection to human health and that ALARP principles should be adopted. As a result, there is an expectation amongst some that radioactive land contamination must be remediated through excavation and off-site disposal irrespective of the risk and effectiveness of institutional controls. This is implications for the generation of NORM wastes.

- Use of NORM is only one source of historic land contamination. National strategies need to take a holistic view in addressing the risks posed by land contamination in accordance with the objectives behind the Land Contamination Regime.

- MOD’s radioactively contaminated land represents the legacy of MOD’s and its predecessor organisations use of radioactive materials at times when there were no or very few statutory controls on the use and disposal of such material. This situation is not unique to MOD and there is often a paucity of historical records.
• The methods used to characterise, segregate and sentence radium waste will also impact on waste management arrangements.

• The end use of the site and the land use and environmental regulatory requirements will also make a significant impact on the volume of waste needing treatment and/or disposal. Decisions on “how clean” the site should be after remediation and opportunities for in-situ waste disposal are paramount.

• Like other NORM waste producers, guidance from the regulators is needed as to waste sentencing and averaging.
22. **Removal and Management of Radioactive Scales and Precipitates from Equipment Associated with Industrial Activities**

**Introduction**

22.1 Descaling involves the removal of NORM scale from contaminated pipes, equipment and machinery before it is returned for continued usage, or disposed of. The NORM scale removed is then treated and disposed of.

22.2 The two primary means of descaling in the UK are high pressure water jetting and dry tumble blasting/shot blasting.

**Overview of the descaling industry in the UK**

22.3 There are 4 operators permitted by the environment agencies to treat NORM waste by descaling. These include:

- **Scotoil**, Aberdeen - High pressure water jetting.
- **NORM solutions**, Aberdeen – High pressure water jetting.
- **NSNL**, Aberdeen – High pressure water jetting.
- **Studsvik**, Lillyhall – Dry tumble blasting/shot blasting.

22.4 It has been noted that waste being sent to descalers is likely to increase in the future as decommissioning of offshore platforms intensifies.

**NORM wastes accepted by descalers**

**Scotoil**

22.5 Scotoil accept waste for treatment from the oil and gas industry. They accept contaminated equipment for descaling using high pressure water jetting, and sands and sludges for consolidation and repackaging. Almost all of the waste being treated contains hazardous properties such as heavy metals (eg. mercury) and hydrocarbons.

22.6 The capacity for the plant is 1000 tonnes per annum, with their highest throughput to date being 90 tonnes per annum.

22.7 The NORM waste produced from the treatment process is stabilised. Waste exempt from regulation under radioactive substances legislation is sent to a hazardous landfill, whereas waste that requires to be regulated is sent to a permitted hazardous landfill or for incineration. Most NORM waste disposed of by Scotoil is exempt from radioactive substances regulation.
NORM solutions

22.8 NORM Solutions accept waste for treatment from the oil and gas industry. They accept contaminated equipment for descaling using high pressure water jetting, and sands and sludges for consolidation and repackaging. Almost all the waste being treated contains hazardous properties such as heavy metals (eg. mercury) and hydrocarbons.

22.9 The waste produced from the descaling process is stabilised and disposed of to a hazardous landfill that is permitted by the environment agencies to accept radioactive waste or to a hazardous waste incinerator permitted to accept radioactive waste.

22.10 The sands and sludges are sent to a hazardous waste incinerator permitted by the Environment Agency to accept radioactive waste for disposal.

Studsvik

22.11 The Studsvik site in Cumbria is a nuclear licensed site; they primarily accept LLW from the nuclear industry, but have treated contaminated equipment from the China Clay industry.

22.12 They accept contaminated metallic components which are size reduced and decontaminated by shot blasting. Due to the treatment being a ‘dry’ process they are limited to dry, solid residues. Typically, this waste does not contain any other hazardous properties. Should they wish to take NORM waste from other sectors they would need to address the ‘stickiness’ of residues.

22.13 The waste produced from the descaling process are stabilised and sent to landfill.

Summary of issues for the descaling industry

- Operators requested clarity how transfronteir shipments of NORM waste are to be regulated.
- The need to submit a Euratom Treaty Article 37 submission was seen as a major issue for the industry; they requested clarity on the issue.
- Descalers gave anecdotal evidence that there were oil and gas wastes which had high levels of mercury that we not suitable for disposal to a conventional landfill. This issue looks to have been resolved by the installation of new mercury abatement technology in the Tradebe incinerator, however, this technology is still in the assessment phase. Should this new technology provide sufficient capability to deal with NORM wastes containing mercury it would be the only treatment route available.
- Some descalers are limited to the size of articles they can accept for treatment.
There is anecdotal evidence that some descalers may be deliberately diluting their NORM waste to ensure its activity concentrations are below the limits where it would require to be regulated or to meet landfill limits in respect of the hazardous properties of the NORM waste.

Some descalers asked what level of conditioning is appropriate?
23. NORM Waste Management Route – Incineration

Introduction

23.1 High temperature incinerators can accept a range of combustible and non-combustible, solid, liquid and gaseous wastes.

Overview of incinerators in the UK

23.2 There are 10 hazardous waste incinerators in the UK, these take a range of hazardous wastes including clinical waste, chemicals, solvents, petrochemicals, and small items from schools, university’s and research and development establishments.

23.3 Of these, 3 incinerators are permitted by the Environment Agency to accept radioactive waste;

- **Veolia Ellesmere Port** – This is a water cooled rotary kiln incinerator. It can accept bulked and drummed liquids, oily sludges, contaminated soils and powders, pharmaceutical products, contaminated packaging and material and highly toxic, reactive or malodorous liquids or gases and bulk powders. This has recently been permitted to accept low level radioactive waste.

- **Tradebe Fawley** – This is a rotary kiln incinerator. It can accept solid, liquid, and gaseous NORM waste including oily sludges. They have recently installed a new mercury abatement process which allows them to accept NORM waste with high levels of mercury.

- **Grundon Slough** – This is a stepped hearth incinerator primarily dedicated to clinical waste. It can accept combustible, solid NORM wastes in small quantities.

NORM wastes accepted by incinerators

Veolia Ellesmere Port

23.4 Veolia Environmental Services (UK) High Temperature Incinerator (HTI) at Ellesmere Port in Merseyside was permitted to treat solid, sludges liquid and gaseous low level radioactive waste in April 2013.

23.5 They have implemented a phased reception of radioactive waste, with the intention that NORM waste will be received in IBC’s or 205l drums and processed via their shredding, mixing and pumping system and automated drum feed system respectively.

23.6 Veolia’s HTI is permitted to receive 100,000 tonnes per annum, and anticipate an annual throughput of approximately 1,000 tonnes of LLW, although they are restrained by their permit limits. NORM radionuclides permit limits are 720MBq per day, 7.2GBq per month, 4MBq per individual package and 320MBq per consignment.
23.7 They are trialling a new mercury abatement process. This technology is currently in the assessment stage.

23.8 All waste produced from the HTI system is classified as Very Low Level Waste (VLLW). The ash is put back through the system, and slag, sludge from the mercury abatement process, filter cakes and filter cloths are sent to landfill. If any of these waste streams are above VLLW they will be processed through the HTI.

**Tradebe Fawley**

23.9 The Fawley HTI is permitted to process 45,000 tonnes per year of waste in total. The proportion of NORM is controlled by a permit issued by the Environment Agency which imposes an annual activity limit of 12GBq per isotope.

23.10 Fawley HTI can treat liquid, solid and gaseous NORM waste including oily sludges so long as each package is less than one tonne in weight and the activity per isotope is <10MBq, in accordance with their Conditions for Acceptance.

23.11 In the past 5 years the Fawley HTI has never used its full annual activity limit, and waste has been accepted from industries:

- Producing and using of Thorium and Thorium compounds;
- Producing and using of Uranium and Uranium compounds;
- Producing oil and gas;
- Managing scales and precipitates;
- Manufacturing TiO2; and
- Extracting china clay.

23.12 The installation of a new mercury abatement process allows them to accept NORM waste with high levels of mercury. This technology is currently in the assessment stage.

23.13 The ash resulting from the HTI process is <5Bq/g and is disposed of as exempt radioactive waste to landfill.

**Grundon Slough**

23.14 The Grundon HTI is primarily dedicated to treat clinical waste. It can also accept solid, combustible NORM waste, including wastes originating from the oil and gas industry, the production and use of thorium and uranium compounds, contaminated soils.

23.15 They are restricted on the size of packages they can accept due to the layout of the incinerator, and they cannot accept liquids or volatile alphas or metals as they will contaminate the equipment.
23.16 The ash resulting from the HTI process is <5Bq/g and is disposed of as exempt waste to landfill.

Summary of issues for incinerators

- At present, none of the incinerators contacted are using their full capacity for radioactive waste, and have no problems with disposal. However, it was noted that the continued availability of landfill disposal routes for their exempt waste is fragile due to the, often poor, public perception about disposing radioactive wastes.

- Incinerators noted that the UK radioactive substances exemption regime does not require waste producers to notify them when they send their waste for treatment. This means treatment/disposal providers may be unknowingly accepting exempt waste. This becomes a particular problem when the treatment process concentrates the activity (such as high temperature incineration), and could lead to operators unwittingly breaching their permitted limits. At present, incinerators are relying on a contractual obligation for consigners to notify them if the NORM waste is exempt.

- There was anecdotal evidence that ‘sham disposal’ or deliberate dilution of NORM waste to bring it below exemption limits or landfill limits for hazardous properties is taking place. This is allowing waste to go to landfill without treating potential hazardous properties beforehand.

- Operators requested clarity on how transfrontier shipments of NORM waste are to be regulated.

- There are currently no hazardous waste incinerators permitted to accept radioactive waste in Scotland, thus all waste from Scotland (including waste from the oil and gas industry) is having to be treated in England. This does not align with the proximity principle in Governments’ 2007 LLW Policy.
24. NORM Waste Management Route - Landfill

Introduction

24.1 The final disposal option for many solid radioactive wastes is burial. There are five facilities that are permitted to dispose of NORM waste by burial in the UK. Other landfill sites can dispose of exempt NORM waste, however, these facilities do not require a permit issued by the environment agencies to control the radioactive properties of the NORM waste.

Stoneyhill facility operated by Sita

24.2 In 2012, the Sita facility near Peterhead was granted a RSA 93 authorisation by SEPA to dispose of NORM waste. The facility is located close to a descaling facility operated by Sita Nuvia where equipment from oil and gas installations has the NORM scale removed using high pressure water jetting. The NORM waste following descaling is grouted in 200 litre drums and sent to the Sita facility for disposal by controlled burial where the NORM waste drums are co-disposed with other non-radioactive waste.

24.3 Stoneyhill can accept up to 200 tonnes of NORM waste annually. However, SEPA has included limits in the RSA 93 authorisation granted to Sita that restricts the concentration of NORM wastes disposed in each active cell as specified below:

<table>
<thead>
<tr>
<th>Cell or Phase</th>
<th>Lead-210 (MBq)</th>
<th>Radium-226 (MBq)</th>
<th>Radium-228 (MBq)</th>
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<tr>
<td>3A</td>
<td>650</td>
<td>10150</td>
<td>4120</td>
</tr>
<tr>
<td>3B</td>
<td>385</td>
<td>6010</td>
<td>2440</td>
</tr>
<tr>
<td>3C</td>
<td>685</td>
<td>10640</td>
<td>4320</td>
</tr>
<tr>
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<td>860</td>
<td>13420</td>
<td>5450</td>
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<tr>
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<td>490</td>
<td>7635</td>
<td>3100</td>
</tr>
<tr>
<td>4</td>
<td>430</td>
<td>6735</td>
<td>2735</td>
</tr>
<tr>
<td>5</td>
<td>370</td>
<td>5800</td>
<td>2350</td>
</tr>
<tr>
<td>6</td>
<td>245</td>
<td>3800</td>
<td>1540</td>
</tr>
</tbody>
</table>
Lillyhall facility operated by waste Recycling Group Ltd

24.4 The Lillyhall facility is both a non-hazardous and a stable non-reactive hazardous landfill situated 22 miles from the LLWR repository and 16 miles from Sellafield, on the West Coast of Cumbria.

24.5 The site is underlain by clays which provide an effective natural barrier to the migration of radionuclides.

24.6 The site is permitted by the Environment Agency to dispose radioactive waste whose total activity levels do not exceed 4 MBq/tonne except for wastes containing tritium only in which case the total activity allowed is 40 MBq/tonne. Waste that is exempt from permitting is also disposed at the Lillyhall site.

24.7 The site has a remaining disposal capacity of about 1.5 million m$^3$; with radioactive waste accounting for less than 2% of the total annual disposal volume.

24.8 Government understands that the facility operators have submitted an application to the Environment agency to vary its permit to accept higher concentrations of radioactive waste for disposal.

Clifton Marsh facility operated by Sita

24.9 Clifton Marsh can dispose of radioactive waste with a concentration limit of 200 Bq/g. Smaller quantities (<10 tonnes) can be disposed of where the activity concentration is less than 1000 Bq/g.

24.10 The majority of LLW disposed of at Clifton Marsh is from the Springfields nuclear site, however, the permit and planning permission has recently been varied to allow receipt of LLW from other UK sites.

24.11 The permit also places restrictions on the volumes of waste that can be received for disposal from waste outwith the north-west planning region.

East Northants Resource Management Facility (ENRMF), Kings Cliffe, operated by Augean

24.12 Recently, the Secretary of State granted planning permission to extend the life of the East Northants Resource Management Facility (ENRMF aka Kings Cliffe) to year 2026. A condition of the planning decision is that 20% of the total capacity (1.2 million m$^3$) will be allocated to the disposal of radioactive waste.
24.13 Augean operates 3 facilities for disposal of radioactive and hazardous wastes:

- ENRMF which takes radioactive and hazardous wastes. The permit allows disposals of up to 200Bq/g
- Thornhaugh near Peterborough which takes exempt, non-hazardous and stable non-reactive hazardous wastes
- Port Clarence which takes exempt, non-hazardous and hazardous wastes

24.14 At Port Clarence and ENRMF, hazardous waste is mixed with Air Pollution Control (APC) residues. Exempt NORM wastes are also stabilised with APC residues at Port Clarence. The radiological Permit granted by the Environment Agency at Port Clarence allows stabilisation of radioactive NORM waste.

24.15 Augean also operate a high temperatures incinerator in East Kent – this incinerator is permitted by the Environment Agency to take radioactive pharmaceutical waste. Augean hopes that the incinerator will be capable of taking combustible NORM waste if its application to vary the current permit is accepted by the Environment Agency.

24.16 At Port Clarence, Augean have a thermal desorption process that they use to treat drilling muds and oily sludges. This process distils oils. It is permitted to process NORM wastes. The main radioactivity is transferred to the solid fraction which can then be disposed of to landfill and the oil recovered.

24.17 Augean are looking at a thermal desorption process that will recover the mercury from oily NORM and have sent some samples overseas for preliminary trials of the technology.

24.18 Most NORM waste deal with by Augean is disposed of as exempt radioactive waste at their Port Clarence facility. In contrast, most waste from the nuclear industry is sent for disposal at the Kings Cliffe facility.

24.19 Augean can dispose of large, bulky items, but the decision to do so is on a case by case basis.

Low Level Waste Repository (LLWR), near Drigg in Cumbria operated by LLWR Ltd

24.20 The LLWR is the national repository for LLW in the UK, and is owned by the Nuclear Decommissioning Authority, the body with the responsibility for decommissioning civil nuclear liabilities in Britain.

24.21 Near surface disposal of solid Low Level Waste is permitted to Vault 8 where the activity of alpha emitting radionuclides does not exceed 4 GBq per tonne or where the activity of all other radionuclides does
not exceed 12 GBq per tonne. The current permit allows only for storage of LLW in Vault 9.

24.22 Specific annual limits are also in place for groups or individual radionuclides: including U-238 and U-235 at 0.3 TBq, and Ra-226 and Tho-232 at 0.03 TBq.

24.23 The Repository aims to take much of the LLW from the decommissioning of nuclear installations, but has limited capacity for LLW from other sources. Following a recent review of the Environmental Safety Case for the LLWR the Environment Agency has received an application from the site operator for a variation to its current permit in order to dispose of LLW in Vault 9. The outcome of this is not yet known, and may result in constraints in the types and quantities of radionuclides (including long-lived radionuclides such as radium which are common constituents of many NORM wastes). Included in the permit application is that the waste acceptance conditions will specify that an “active particle” can be disposed to the LLWR if its size range is 0.6 to 2.0 mm of high-specific activity material such that a single particle could bear of the order of 0.01 MBq or more of radium-226.

24.24 The LLWR’s potential future site capacity is already heavily oversubscribed and primarily reserved for supporting the NDA’s clean-up and decommissioning activities across its sites.

Summary of issues for Landfill operators

- The 6% total organic content (TOC) limit imposed by the Landfill Directive limits the volumes of organic waste that can be disposed of.
- The ENRMF facility is the only UK facility permitted to dispose of hazardous NORM wastes
-Volumes of NORM waste from decommissioning oil and gas facilities are uncertain and are highly dependent on the economic viability of oil and gas production
- The volumes of exempt NORM waste disposed of are uncertain and there is no organisation tasked with obtaining such data
- Guidance on sentencing and averaging of NORM waste would be welcome
- Guidance is also welcome on how to conduct a radiological risk assessment and how this influences landfill radiological capacity.
- Transfrontier shipment of NORM waste is an issue and some landfill operators would welcome clarification whether NORM wastes require a TFS authorisation and to clarify the UK Government policy on import/export of waste for treatment (and overseas disposal).