LEGISLATION AND BEST PRACTICE IN THE EMERGING EUROPEAN RARE EARTH ELEMENT INDUSTRY

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Abstract

This paper explores the environmental legislation and best available technique reference documents in place in the European Union to support the emerging European rare earth element (REE) industry. One of the issues for REE mining, beneficiation and processing is the radioactivity that can be associated with the ores, arising from the presence of elevated U and/or Th and their daughter products. Therefore, workers may need to be protected from radiation during the exploitation of REE resources, and the public protected by suitable disposal of the radioactive wastes produced. Potential regulatory gaps and best practices are identified, based on the experience of countries with a REE industry.

Introduction

Rare Earth Element (REE) mining, processing and exploitation are large scale industries that use a wide range of chemical substances and generate significant quantities of waste. Additionally, the ores contain variable amounts of impurities such as non-target toxic metals, fluorine and radionuclides that may be released from the ore during processing into the product or waste streams, and/or represent safety issues to the workers. The most significant environmental impact of mining is often on the surface- and groundwater quality as seen at Bayan Obo, China[1], Mountain Pass, USA[2], and a processing plant in Sichuan, China[1]. The large volumes of tailings that are generated during hard rock mining are a source of waterborne contamination. Tailings are also a major environmental hazard if the tailings impoundment dam fails.

Dust and gaseous emissions are also important vectors for both environmental contamination and the exposure of workers to toxic substances. For example, processing at Bayan Obo has led to the release of fluoride, dust and waste gases containing HF and SO_2[1].

Past REE mining and processing has therefore led to significant environmental impacts in several non-EU countries, including Brazil, China, Malaysia and the USA. In addition to the environmental damage caused, remediation of contaminated sites can be expensive. For

example, the estimated cost of remediating the Mitsubishi REE processing site in Bukit Merah, Malaysia is $100 million[3]. It is therefore important to ensure that the regulatory framework in the EU will support the development of a well managed REE industry with acceptably low environmental impacts. Since mining and industrial processing are established industries in the EU, there is a body of relevant legislation that could be expected to cover the REE industry. Best practice is described in best available technique reference documents (BREF) for the management of tailings and waste-rock in mining activities[4] and the non ferrous metals industries[5]. However, although generic environmental protection methodologies are included in these BREF, specific issues relating to REE tailings and processing are not considered specifically. Therefore, in this paper, we explore the EU legislation and guidelines that are in place to support this emerging industry and identify potential gaps.

Naturally Occurring Radioactive Materials (NORM)

REE ores often contain sufficient natural radioactivity to be considered naturally occurring radioactive materials (NORM). The radioactivity arises from U and/or Th and their daughter products (Figure 1) that are either co-mineralised with the REE or present in other minerals within the ore. It is therefore a safety issue at mining sites and during processing: a significant relationship has been found between the inhalation of Th-containing dusts and lung cancer in miners in a 20 year study at Bayan Obo[6]; two REE processing plants and a waste facility in Brazil became contaminated with Th and its daughters[7]; and workers have received elevated doses in the REE industry worldwide[8].

The separation of the different radionuclides in the decay chain from the REE during beneficiation and processing occurs at a point determined by the chemistry and physicochemical associations in the ore. Given that there are 8 elements within the ^{238}U decay chain (Figure 1) and 8 in the ^{232}Th chain, their separation during processing is not simple and it is important to ensure that the final REE products are below the NORM activity level (1 Bq/g of a single radionuclide in the decay chain). Examples of radionuclide partitioning during REE processing are given by the IAEA[8].

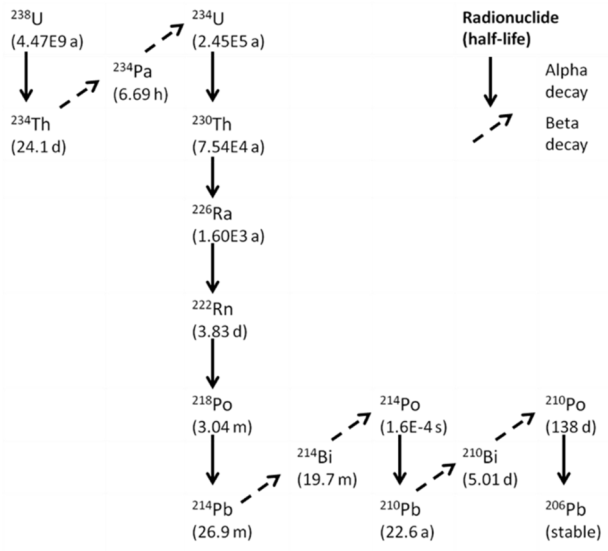

Figure 1: Radioactive decay chain of ^{238}U (a = years; d = days, h = hours, m = minutes, s = seconds)

Analysis of the Regulation of the REE Industry

In this section, EU legislation is compared with legislation in states with an existing REE industry or experience with NORM, focussing on USA and Western Australia.

Regulatory Framework

Environmental regulation and implementation of the regulations are clearly important for any potentially polluting industry, but are not without their challenges. The 11 km^2 tailings impoundment at Bayan Obo, China has contaminated the surrounding area[1], and provides an extreme example of the environmental consequences of an unregulated REE industry. Introducing regulation in China has also been difficult because of the large number of small companies and a significant level of illegal mining. Forced mergers have consolidated the industry, but the system is still reliant on a level of self-regulation. Similarly, although Russia's legislation in many cases meets or exceeds commonly accepted international standards, its enforcement has been uneven[9]. India has also experienced challenges trying to eliminate illegal mining, in this case due to easy access to REE-containing beach sands. Europe's existing mining industries mean that legislation is in place and in use. The Mining Waste Directive (2006/21/EC) is a key piece of legislation, and links with the Water Framework (2000/60/EC) and Groundwater (2006/118/EC) Directives for the management of mine water. The Industrial Emissions Directive (IED; 2010/75/EU) applies to the beneficiation and processing of the REE ores, and also ties in with the Water Framework Directive and Groundwater Directive. Additionally, processing wastes are controlled by the Waste Framework Directive (2008/98/EC) and Landfill Directive (1999/31/EC). The Basic Safety Standards (2013/59/EURATOM) address the management of NORM.

Penalties are needed for non-compliance with the regulations and the "polluter pays" principle is embedded in legislation in the EU (Environmental Liability Directive (2004/35/EC)), in the USA (Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)) and Western Australia (Contaminated Sites Act (2003)). The Contaminated Sites Act (2003) also states the penalties associated with non-compliance, including a daily penalty to discourage delay. Environmental quality standards also support industrial regulation. In the EU, the Water Framework and Groundwater Directives require threshold values to be set for only a limited list of substances, with only some relevance to the REE industry. The threshold values set also differ between member states. In 2011, China brought in specific pollutant discharge standards for the rare earth industry[10].

Environmental Impact Assessment (EIA)

Environmental impact assessment prior to the onset of activities is an important process for minimising the environmental risks associated with mining. The Environmental Impact Assessment Directive (2011/92/EU) applies to for EU mine sites with a surface area greater than 25 hectares. There is also a need for appropriate EIA if a proposed mine may impact a Natura 2000 site, as defined by the Habitats Directive (Directive 92/43/EEC) and Birds Directive (2009/147/EC). The definition of when an EIA is required varies between countries,

but EIA is needed in the USA, Russia and Western Australia. Additionally, China is introducing an environmental risk assessment system for the REE industry[10].

Tailings management legislation

The tailings arising from REE mining are large-scale wastes with a significant pollution potential. The Mining Waste Directive (2006/21/EC) requires all EU waste facilities to have a permit, and the application for this includes a waste management plan for minimizing environmental impacts. Facilities with a significant accident hazard also require an emergency plan to be drawn up by the competent authority. Additionally, the operator must provide a financial guarantee before operations start to provide a resource for restoring the waste facilities. The operator must maintain the site until the competent authority approves site restoration and closure, and then the operator must maintain and monitor the site for as long as the competent authority considers necessary. This is similar to legislation in Western Australia and the USA. In the USA, wastes that are "uniquely associated" with mining and processing are excluded from being regulated as hazardous wastes (Bevill amendment), and these are instead treated as non hazardous solid wastes. The Contaminated Sites Act (2003) in Western Australia introduces the full life-cycle costs principle, which ensures that the cost of effective waste disposal is included in the cost of the products. Western Australia also has specific guidelines on safe design and operating standards for tailings storage[11], which play a similar role to the BREF for the management of tailings and waste rock in mining activities in the EU[4]. However, Western Australia also provides specific guidelines for the handling of the NORM mining waste[12], which is not the case in the EU.

NORM legislation

The explicit inclusion of NORM in the latest versions of the IAEA Basic Safety Standards (2011) and the EU Basic Safety Standards (2013/59/EURATOM) will support more consistent regulation of NORM. However, the actual regulation of the handling and disposal of NORM wastes differ between countries and EU member states. The EU Basic Safety Standards state that "activities in industries processing materials with naturally occurring radionuclides, or activities related to such processing" are within its scope, suggesting that REE mining and processing are relevant. This is already the case in the UK, where REE mining and processing are specifically identified as a NORM industry that falls under their national regulations. The new BSS also address worker exposure to radon explicitly, which will be important for both worker exposure and waste management in the REE industry.

Countries with large scale NORM industries have developed their regulations of NORM wastes to a higher level than others, often taking lead from the UN, ICRP and IAEA. Norway has integrated its legislation for activities that involve or may involve radioactive pollution or radioactive waste management into its 2011 Pollution Control Act, which controls their permit system[13]. A repository has also been built for the disposal of NORM wastes from the oil industry with > 10 Bq g^{-1} of ^{226}Ra, ^{228}Ra or ^{210}Po. The repository is operated by a private company, and the owners are required to have a fund for closure and remediation. The state has also guaranteed to manage the site if the company is no longer able.

In Australia, radioactivity is regulated by the Radiation Protection and Control (Ionising Radiation) Regulations (2000). However, since these regulations define 'radioactive ores' as

those with a specific activity greater than 35 Bq g^{-1}, the mining, processing and waste disposal of lower activity ores are regulated through state-level environmental and mining laws. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) provides The Code of Practice and Safety Guide: Radiation Protection and Radioactive Waste Management in Mining and Minerals Processing[14] to support the legislation, and this gives prescriptive practice-specific radiation safety requirements. Additionally, Western Australia has extensive guidelines for managing NORM in the mining and processing industry[12]. A Radiation Management Plan and a Radioactive Waste Management Plan must be written and approved prior to any work taking place that involves NORM[14]. The depth and level of detail of the Radioactive Waste Management Plan should reflect the amount and activity of the wastes, as well as the degree of processing, as this can affect the ease with which radionuclides leach. The dilution of NORM tailings (prior to any chemical treatment that breaks secular equilibrium) with lower activity waste from the same site is encouraged to reduce the overall activity concentration to below the regulatory limit. Dilution is also allowed for materials to be used in other activities such as road building[12]. Potentially valuable tailings can be stored in tailings dams if adequate safeguards are in place[12].

Management of the mine site

As well as requiring management during operation, mines also require stabilisation and monitoring during idle periods, which typically occur when the market price of the commodity falls, and long term post closure management. Failure to stabilise sites effectively can lead to unauthorised discharges, as seen at the Pea Ridge mine and the South Maybe Canyon mine site, USA[2], both of which have REE-rich ores. The EU does not have direct legislation for mining, but uses a variety of legislation including the Mining Waste Directive (2006/21/EC) discussed above. This influences mining permits since tailings are often disposed of at the mine site. It is strengthened by Seveso III (96/82/EC), which addresses operator responsibility to prevent major accidents, with disused mines as well as disused and operational tailings disposal facilities being within the scope of the directive. However, given the legislative approach in the EU, aspects of mine management are not addressed explicitly and, as a result, there are differences between the regulations in different member states. A different legislative approach in the USA (Surface Mining and Control Act of 1977) gives more direct control of the mine, including idle periods and post closure. The waste rock piles, the tailings ponds, and other mine areas must be stabilized and managed during idle periods, and restored to its previous condition on closure.

Site management in the case of bankruptcy is another important issue, given the large sums of money involved in waste management and site remediation. The USA has a “superfund” (legislated in CERCLA) generated by a tax on chemical and oil companies, which can pay for the Environmental Protection Agency to clean up hazardous abandoned sites and respond to short term emergencies. In Western Australia, the Director of an insolvent company may be liable for the costs of remediation if the insolvency is linked to avoidance of responsibility for site remediation. Ultimately, if the director is also bankrupt or not judged to be liable, the state takes responsibility.

There is currently a discussion of a disaster risk-sharing fund in the EU to cover large scale industrial accidents (damage exceeding €100 million), funded by a mandatory insurance

premium of a percentage of the annual net sales. A report prepared for the EC[15] raises questions relating to this. The fund could not subsidise operators or it would be in breach of the polluter pays principle, but if the funds are to be re-paid, there is the question of whether liability should be capped. Different industries have different levels of risk and there are differences in the extent to which environ-mental damage is covered by existing private insurance in different member states.

The Non-Extractive Industry Panel suggests that the fund is unnecessary in the EU, given the stringency of the Environmental Impact Assessment, Mining Waste, Seveso III, and Environmental Liability Directives, and the financial controls they define[16]. They argue that adherence to the EU law should make the fund unnecessary, and that the fund may encourage low standards in industry. However, environmental protection against large scale accidents does need consideration, as does the management of sites and contaminated land that are no longer under ownership. One issue here is licensing of subsidiaries, whose financial losses are not covered by the parent company. Equally, the financial guarantees associated with the Mining Waste Directive may only cover a relatively small part of the overall costs.

Conclusions

The regulations to support REE mining and processing industries in Europe generally compare favourably with international standards. The main issues that have been identified here are:

- several different pieces of environmental legislation control aspects of REE exploitation in the EU, which emphasizes the need for focused guidance documents
- the next updates of the relevant BREF documents[4,5] should therefore include REE-specific information, including the management of NORM
- the current environmental quality standards should be reviewed to encompass the main hazards associated with REE mining and processing
- there is a lack of direct legislation for mine management, which may lead to differences between the regulations in different member states
- REE NORM waste management regulation is likely to differ between member states
- the question of funding for remediation of abandoned sites is relevant to REE mining

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