

REUSE AND RECYCLE OF NATURALLY OCCURRING RADIOACTIVE MATERIALS (NORM) RESIDUES

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Abstract. In Malaysia, the Naturally Occurring Radioactive Materials (NORM) are subjected to regulatory control under the Atomic Energy Licensing Act 1984 (Act 203). The control limit for radionuclides in NORM are 1Bq/g for U-238 and Th-232 respectively and 10 Bq/g for K-40. Industries involving with NORM include the rare earth extraction plant, tin smelting activities as well as the oil and gas industries. The rare earth industries using mineral such as monazite as input in chemical process to produce rare earth elements and generated NORM residues, tin smelting activities generated tin slag and the oil and gas industries generated oil scales and sludge as the byproducts or wastes. Formerly, Malaysia has been one of the major oil exploration and tin mining countries and the tin smelting activities are still carried out. Rare earth extraction plants in Malaysia started since 1980's where the local monazite ore were used as input material, but now the input materials for rare earths extraction were imported. The main issues dealing with rare earth extraction plant, tin smelting activities and oil and gas industries is the waste management. Amount of wastes generated in large volume with the low level of radionuclides such as U-238, Th-232 and K-40 that have a long half-life required proper management and large areas for storage. Management options for NORM wastes including the reuse and recycle are stated in the current Regulations but not implemented. In oil and gas industries, the sludge and scales are sent to the licensed incineration facility to incinerate and the final concentrated ash are disposed in the secured landfill. For the rare earth industry, research being carried out to recycle and reuse the residues in other commercial products such as soil conditioner in agriculture and road base materials. Since the use of NORM wastes is to mix with other materials in order to convert the wastes to bricks or soil conditioner, another issue arises, that is dilution of wastes. There are no specific guidelines, whether the dilution principle is allowed in management the NORM waste as it will increase the amount of the wastes. Therefore, international best practices to reuse or recycle the NORM wastes and international guidance or standards are required.

1. INTRODUCTION

Naturally Occurring Radioactive Materials (NORM) is control as radioactive materials in Malaysia. The control limit is 1 Bq/g for radionuclide of U-238 and Th-232 and 10 Bq/g for the K-40. Any material contain NORM exceed these limit is considered as radioactive materials. The rare earth that industries using NORM materials as input in chemical process to produce rare earth elements and also generated NORM residues or wastes. This NORM activity is called milling of radioactive material; therefore, it is control under the Atomic Energy Licensing Act 1984 (Act 304). The regulatory body is the Atomic Energy Licensing Board (AELB).

2. LEGAL REQUIREMENTS

The Atomic Energy Licensing Act 1984 (Act 304) is the main Act to provide for the regulation and control of atomic energy, for the establishment of standards on liability for nuclear damage and for matters connected therewith or related thereto. The Atomic Energy Licensing Board (AELB) was than established under Section 3 of the Act 304 on 1 February 1985 to enforce the Act. AELB has adopted and enforced several Regulations and Order under the Act 304 such as:

- Radiation Protection (Licensing) Regulations 1986
- Radiation Protection (Transport) Regulations 1989
- Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010
- Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011
- Radiation Protection (Low activity radioactive sources) (Exemption) Order 2020

2.1 Radioactive Waste Management

In Malaysia, the radioactive waste management was made in accordance to the Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011. In the Second schedule of the Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011, the activity and activity concentration of the radionuclides below the clearance level are release from regulatory control. This regulation is made in accordance to the IAEA standards documents, Basic Safety Standards 115 (1996). However, the latest IAEA standards documents, *Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, GSR Part 3* (2014) had also being taken into account for the formulation of implementation policy.

Table 1 shown the control limit for the licensing of activities involving with NORM. For the milling and disposal of material containing NORM above the stated limit, is subjected to the regulatory control, licensed and approved by the Board.

Table 1: Control limit (licensing) for the activity concentration of raw material and waste containing NORM

Radionuclide	Activity Concentration (Bq/g)
^{40}K	10
Each radionuclide in the chain of Uranium and Thorium decay	1

For the disposal of NORM waste, there are options used such as:

- Near surface disposal facility – for NORM waste from monazite cracking (Th-232 activity concentration exceed 200 Bq/g)
- Landfilling – for tin slag, tin tailing from tin mining activities and NORM wastes from ilmenite processing (U-238 and Th-232 decay series activity exceed 1 Bq/g)
- Incineration - for oil and gas sludge, concentrated ash from the incineration activity will be dispose in secured landfill (U-238 and Th-232 decay series activity concentration more than 1 Bq/g)

3. NORM WASTE MANAGEMENT

The main issues occur from NORM activities is the waste management. The wastes generated from mining industries and mineral processing plants were in a large amount and normally contain low level of naturally occurring radionuclides. Malaysia implemented 1 Bq g⁻¹ as the clearance limit for naturally occurring radionuclides from series of uranium and thorium, as stipulated in the Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011. Processing of mineral and disposal of waste containing naturally occurring radionuclides below the activity concentration of 1 Bq/g were exempted from regulatory control.

The whole process for milling of mineral containing NORM involve the importation/ mining of raw material, transportation to the plant, storage of the raw material, processing of the raw material to produce products and generate by-products (waste). Some of the by-products are potentially reuse and recycle to another material used in another industry, but some are dispose of as a radioactive waste. Environmental issues pertaining to the waste disposal is the major consent of the public. The treatment of the by-products containing activity concentration of Uranium and Thorium to below permissible limit is required before the by-products can be reused and recycled.



• Oil scale



• Tin slag

6. REFERENCES

- Atomic Energy Licensing Act 1984, Atomic Energy Licensing Board (AELB), Kuala Lumpur (1984).
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- International Atomic Energy Agency (IAEA) Safety Series No. 111-F, Principles of Radioactive Waste Management Safety Fundamentals, Vienna: Austria (1995).
- International Atomic Energy Agency (IAEA) GSR Part 5: Pre-Disposal Management of Radioactive waste. Vienna: Austria (2009).
- International Atomic Energy Agency (IAEA) GSG-1: Classification of Radioactive waste. Vienna: Austria (2009).

3.1 Rare Earth Extraction Plant

In Malaysia, the rare earth extraction activities starting in 1980s. As Malaysia formerly is one of the largest tin mining industry, the raw materials came from the local mine. But nowadays, most of the natural resources already finished, the rare earth extraction plant in operation using raw material that imported from overseas such as Australia. Under the Act 304, the licence for rare earth extraction activities are divided into 3 phases;

- Siting Licence phase
- Construction Licence phase
- Operating Licence phase -The Operating License phase are divided into 2 stages, which is Temporary Operating Licence and Full Operating Licence

One rare earth extraction plant in operation, using lanthanide concentrate from Western Australia as input material. The raw material contains of Th-232 of 6 Bq/g which is exceed the control limit of 1 Bq/g under the Act 304, therefore this activity is licenced by the regulator.

The residues generated consider as radioactive residues as the concentration for the activity concentration of Th-232 in its residue less than 10 Bq/g. The residue generated is temporally stored in the storage facility in the plant site. The residue is considered as NORM residue and with huge amount of waste generated yearly, large area are required to store the waste.

3.2 Tin smelting activities

As Malaysia formerly is one of the largest tin mining industry, the mining activities produced tin ore and tin tailings. Tin ore were undergone smelting process to get the tin ingot and the byproduct generated is tin slag. The slag contains trace amount of Th-232 and U-238 radionuclides and slightly higher than the control limit, therefore dealing with tin slag required a license under the Act 304. Currently the slag was stored temporarily in the smelting plant.

3.3 Oil and gas industries

Oil and gas industries contribute mostly for the energy used in Malaysia. Oil and gas exploration generated wastes that is classified as NORM wastes which are the oil sludge and after some times, the scales deposited in the piping materials, vessels, tank etc. These NORM wastes are incinerated and the concentrated ash from the incineration activity will be disposed in secured landfill, where the radiological monitoring and environmental sampling are required.

4. REUSE AND RECYCLE OR NORM RESIDUES

The main issue that the industry is facing is to manage the waste generated from the rare earth production and tin smelting activities. As huge amount of very low level waste (less than 10 Bq/g) containing NORM generated during the operational of the plant. The control limit of radioactive waste is 1 Bq/g, the industries are facing with radioactive waste disposal issues. Currently the waste generated is stored in the plant facilities and the huge amount occupied a large area of the plant. The industry is studying to recycle and reuse the residues in other commercial products. Research and development (R&D) is being carried out in collaboration with local research centre and higher education institutions. As provided in the IAEA document, GSR Part 5 (2009), pre-treatment disposal of radioactive wastes includes three principles:

- Delay and decay
- Dilute and disperse
- Concentrate and contain

For the rare earth industry, research being carried out to recycle and reuse the residues in other commercial products such as soil conditioner in agriculture and road base materials. Since the use of NORM wastes is to mix with other materials in order to convert the wastes to bricks or soil conditioner, another issue arises, that is dilution of wastes. There are no specific guidelines, whether the dilution principle is allowed in management the NORM waste as it will increase the amount of the wastes. Therefore, international best practices to reuse or recycle the NORM wastes and international guidance or standards are required.

NORM wastes also contain minerals such as, Magnesium that is valuable for agriculture. Study had been carried out to re-use this NORM wastes as soil conditioner or as construction and road based materials.

By mixing with the normal soil to the residue to ensure the final concentration of NORM radionuclides such as U-238 and Th-232 in the dilution are below the control limit (1 Bq/g). This material can be reused or recycled as soil conditioner or road base construction materials. However, a reference level should be established. Since clearance level of 1 Bq/g is too low and the dilution required a large amount of normal soil (or other non-radioactive materials), a reference level established could help in safe management of NORM wastes.

According to the IAEA General Safety Guides (GSG-1) for the Classification of radioactive wastes, the NORM wastes from 1-100 Bq/g are classified as Very Low Level Waste (VLLW) and the disposal facility recommended was the landfill type. Therefore, consideration should be given to reuse the NORM residues as road based materials.

5. CONCLUSION

NORM wastes generated from the rare earth industry is huge amount. The clearance level as recommended in the GSR Part 3 (2014), that is 1 Bq/g for each of U-238, Th-232 and decay series nuclides. Referring to the IAEA waste classification of radioactive waste which consider NORM wastes as Very Low Level Waste (VLLW), the reference level for the reuse and recycle or disposal of NORM waste should be established within the VLLW classification. The dilution process should be considered provided that the reference level is not exceeded. Above the reference level, this NORM waste are recommended to be disposed of in the secured landfill.

