ENVIRONMENTAL RADIOLOGICAL MONITORING METHODS IN TENORM FACILITIES AND ITS RELEVANCE

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ABSTRACT

In Malaysia, mineral processing plant is one of the Naturally Occurring Radioactive Material (NORM) processing industries controlled by the Atomic Energy Licensing Board (AELB) through the enforcement of Atomic Energy Licensing Act 1984 (Act 304). The activities generated waste which is called as TENORM wastes. TENORM wastes are mainly found in thorium hydroxide from the processing of xenotime and monazite, and iron oxide and red gypsum from the processing of ilmenite. Other TENORM wastes are scales and sludges from the oil and gas industries, tin slag produced from the smelting of tin, and ilmenite, zircon, and monazite produced from the processing of tin tailing (amang). The environmental and radiological monitoring program is needed to ensure that the TENORM activities did not caused any contamination to the environment. The program activities vary in the types of samples, parameters of analysis as well as the frequency of monitoring based on license's conditions issued by the AELB. The main objective of this study is to assess the suitability of license's condition and the monitoring program required in oil and gas, and mineral processing industries. Study was done by assessing the data submitted to the AELB in order to comply with the licensing requirement. This study had found out that there are a few of license's conditions that need to be reviewed accordingly based on the processing activity.

ABSTRAK

Di Malaysia, kilang pemprosesan mineral yang mengandungi bahan radioaktif tabii (NORM) adalah merupakan salah satu industri pemprosesan yang dikawal oleh Lembaga Perlesenan Tenaga Atom (AELB) melalui peruntukan Akta Perlesenan Tenaga Atom, 1984 (Akta 304). Aktiviti-aktiviti pemprosesan mineral ini menghasilkan sisa yang dipanggil sisa TENORM. Sisa TENORM dijumpai terutamanya dalam torium hidroksida hasil daripada pemprosesan xenotim dan monazit, dan besi oksida dan gipsum hasil daripada pemprosesan ilmenit. Sisa TENORM lain adalah skel dan enapcemar minyak daripada industri petroleum dan gas, sanga timah daripada proses peleburan bijih timah dan ilmenit, zircon, struverit dan monazit hasil

daripada pemprosesan tahi bijih (amang). Program pemonitoran alam sekitar dan radiologi perlu dijalankan dalam setiap aktiviti TENORM bagi memastikan ianya tidak mencemarkan alam sekitar. Program ini berbeza dari segi jenis sampel, parameter yang perlu dianalisis dan juga kekerapan pemonitoran, bergantung kepada syarat lesen yang ditetapkan oleh AELB. Objektif utama kajian ini adalah untuk melihat kesesuaian syarat lesen dan aktiviti pemonitoran dalam industri petroleum dan gas, serta pemprosesan mineral yang mengandungi NORM. Kajian dilakukan dengan menganalisis data yang dikemukakan kepada AELB bagi menepati keperluan lesen. Hasil kajian mendapati terdapat beberapa syarat lesen yang perlu dinilai semula kesesuaiannya berdasarkan kepada aktiviti pemprosesan yang dilakukan.

Keywords: TENORM, environmental monitoring, limit

INTRODUCTION

In Malaysia, Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) are mainly found in scales and sludge from the oil and gas industries, thorium hydroxide from the processing of xenotime and monazite, and iron oxide and red gypsum from the processing of ilmenite. Other TENORM are tin slag produced from the smelting of tin, and ilmenite, zircon, and monazite produced from the processing of tin tailing (generically termed amang). These unwanted materials containing TENORM have subsequently been called TENORM wastes. These activities are regulated and controlled by the Atomic Energy Licensing Act, 1984 (Act 304). The licensing authority of the Act 304 is the Atomic Energy Licensing Board (AELB). AELB enforces the TENORM activities including oil and gas industries, milling activity involving minerals containing NORM and its waste management through its licensing procedure and conditions of license issued to the licensees. During operation, the mineral processing plant is given Class A license for milling. Class G license is issued to allow the storage and disposal of radioactive waste. Class H license is for the services including consultancies, environmental and radiological monitoring, treatment and wastes disposal etc.

There are variations on the license conditions based on the activities. For example, the minerals processing activities with class A license and TENORM waste disposal activities from oil and gas industries with class G license are summarized below:

i. The ilmenite processing activities (sulphate process) are required to carry out the monitoring for external radiation, activity concentration of radon and thoron daughter progenies and activity concentration of Ra-226 and Ra-228 in the air on site and up to 5km radius from the premise 3 times a year, activity concentration of Ra-226 and Ra-228 in underground, pond and sea water 3 times a year, activity concentration of Ra-226 and Ra-228 in soil and sediment 6 times a year and activity concentration of Ra-226 and Ra-228 in TENORM waste once a year.
ii. The ilmenite processing activities (chloride process) are required to carry out the monitoring for external radiation, activity concentration of radon and thoron

daughter progenies and activity concentration of Ra-226, Ra-228, Th-232 and U-238 in the air on site and up to 10km radius from the premise 2 times a year, activity concentration of Ra-226 and Ra-228 in underground, pond and sea water 6 times a year, activity concentration of Ra-226, Ra-228, Th-232 and U-238 in soil 4 times a year and activity concentration of Ra-226 and Ra-228 in TENORM waste once a year.

iii. The disposal activities for TENORM wastes from oil and gas industry are required to carry out the monitoring for external radiation and the activity concentration of radionuclides in ground water and soil, onsite and offsite the disposal site during the disposal/ once a year.

Regulatory Control of NORM

Different regulatory bodies from different countries have proposed different dose criteria and screening levels related to regulatory control of NORM. ICRP 60 recommends an annual limit of 1 mSv yr^{-1} to members of the public and waste disposal dose criteria of 10 μSv yr^{-1} (IAEA 1996). In Malaysia any activities related to TENORM handling, such as the treatment, reuse and disposal, resulting in a total dose exceeding 0.3 mSv yr^{-1} shall be licensed.

Licensing and environmental monitoring program

In Malaysia, atomic energy activities license's application procedures is spelt out in the Radiation Protection (Licensing) Regulations, 1986 (AELA, 1984b) and Radiation Protection (Basic Safety Standard), 1988 (AELA, 1984c) explained the procedures on radiation protection as well as the occupational health and safety. Below are some of the important aspects:

i. Regulation 4 (AELA, 1984b) - Class A license in respect of milling of materials containing or associated with radioactive materials or in respect of a waste treatment facility for radioactive materials shall be in three parts namely, sitting, construction and operation. The operation part of a Class A license in respect of the milling materials containing or associated with radioactive materials or in respect of a waste treatment facility for radioactive materials shall be issued in two stages, temporary operation and full operation.

ii. Regulation 10 (AELA, 1984b) - Class G license is a license to store and dispose of radioactive materials or wastes and also to decommission a milling installation.

iii. Regulation 23 (AELA, 1984b) - Information required for application to site, construct and operate a milling installation shall contain the information including the emergency monitoring and removal of released tailings.

iv. Regulation 51 (AELA, 1984c) – A released limit shall be specified by the regulator, by taking into consideration of the result of pre-operational environmental monitoring conducted for a period of not less than twelve months, the critical pathways and critical group of the population. The licensees shall complement effluent monitoring by environmental monitoring as approved by the regulator.

Processing of minerals containing NORM

Any activity dealing with milling of minerals containing naturally occurring radioactive materials (NORM), required the class A license. Prior to obtain the license, various documents need to be approved by the AELB, including the Radiological Impact Assessment (RIA), Radiation Protection Program and the Environmental Monitoring Program. This monitoring program include the location of sampling on site and off site, the type of environmental samples, the parameter of analysis as well as the frequency of monitoring. In the first stage of operation (which is called pre-operational), the licensees are required to carry out the environmental monitoring for a period of not less than 12 months (baseline data). For the temporary operation license (normally 2 years), the licensee are required to carry out the environmental monitoring according to the program approved by the AELB. If the results of monitoring did not exceed the limit imposed by the law, renewal of license can be given for the period of 1-3 years based on the performance of the licensee in compliance the atomic energy legislations. This is called full license operation for milling of mineral containing or associated with radioactive materials.

During full license operation, environmental and radiological monitoring program are enclosed in the license's conditions. Normally, the monitoring program including the following item:

i. Sampling location – onsite and offsite (up to 1km, 5km, 10 km radius)
ii. Type of environmental samples – soil, sediment, air, radon and thoron gaseous, water (pond and river nearby), underground water, flora, fauna etc.
iii. Parameters for analysis – radionuclides in the U-238 and Th-232 series and K-40.
iv. Frequency of the monitoring – normally monitoring to be carry out in every 2 months but in some cases, the licensee can ask to reduce the monitoring frequency to quarterly and so on based on the previous monitoring results.
v. External radiation monitoring at workplace was done by direct monitoring (in-situ) using survey meter or using TLD dosimeters (TLD 100H Harshaw).

Oil and gas industry

A class G license is required to store and dispose of TENORM wastes in oil and gas industry. Normally, oil sludge are treated and stored in landfill. Prior to obtain the class G license, the Radiological Impact assessment (RIA) program should be approved by the AELB. Routine environmental monitoring are required to be carried out at least once a year and specific monitoring during workover, maintenance and cleaning of equipments (AELA, 1996d; AELA, 2009e). The parameters of monitoring include the external gamma radiation, surface contamination and monitoring of the air.

Enforcement and approved limit

On site routine inspection is carried out by the regulatory body to ensure the compliance with all the regulatory body requirements. The inspection also provide a clear picture on environmental radiological monitoring program implemented by the licensees. Advises will be given or orders can also be issued in order to correct any unwanted situation. In some cases, the AELB will also randomly collect the environmental samples such as soil, water and TENORM wastes to validate the result from monitoring provided by the licensee.

In ensuring that no TENORM activities will contaminate the environment, the monitoring program data submitted by the licensees is compared with the approved/ permissible limit as specified in the Atomic Energy Licensing Act, 1984 and the legislative made thereunder. In some cases, world reference, such as UNSCEAR reports, ICRP and IAEA recommendations are also taken into account. If the results of monitoring exceed the approved/ permissible limit, the licensees are required to take mitigation measures to ensure that the approved/ permissible limit is not exceed in the future.

Radiation Protection (Basic Safety Standards), 1988 (AELA, 1984c) required the licensee to carry out the pre-operational environmental for a period of not less than 12 months. During operation, license's condition will specified the radiation and environmental monitoring program to be complied by the licensees. As stated by the BSS, annual dos limit for members of public is 1 mSv yr^{-1}. The approved limit for effluent and other water samples before can be discharged to the environment is 1 Bq L^{-1} for Ra-226 and the limit for radon and thoron gas and their progenies are 0.4WL and 1.2WL respectively. In oil and gas industry, AELB guideline, LEM/TEK/30 1996 (AELA, 1984d) defines that a surface is considered to be contaminated if for alpha emitters it exceeds 0.04 Bq cm^{-2} and 0.4 Bq $cm^{-2}$for beta and gamma emitters. For airborne contamination monitoring, the activity concentration shall not exceed 0.01 Bq m^3 for uranium and 0.001 Bq m^3 for thorium dust. The Total Activity Concentration (TAC) for oil sludge is 3 Bq g^{-1} (AELA, 1984e). Other limit that can be used as guidance to the licensees is the average of radionuclides in normal soil of Malaysia reported by UNSCEAR (2000). The AELB also implemented the policy of if not applicable in the Act 304, IAEA recommendation is applicable.

Based on the various Regulations, Orders, license's conditions, etc that need to be complied by the licensees, the objective of this study is to assess the suitability of license's condition and monitoring program in oil and gas and mineral processing industries.

METHODS

Study is done by assessing and analyzing the data submitted to the AELB by various industries as prescribe in the licensing requirement. Seven industries involved in this study. Type of TENORM activities and data assessed are shown in the Table 1:

Table 1: Summary of type of TENORM activities and data assessed

TENORM activities	**Number of licensees assessed**	**Type of data assessed**	**References**
1. Operator of oil and gas industries	2	Routine and specific monitoring data	AELB's document: - LEM/TEK/58(2009) - LEM/TEK/30 (1996)
2. Operator of mineral processing industries	3	Routine environmental and radiological monitoring data	License's conditions of the licensees
3. Consultant of envinronmental and radiological monitoring for TENORM activities	2	- Monitoring parameters & location - Type of equipments used - Radiosensitivity of the equipments - Method of mesurements	- Environmental Monitoring Program - Radiation Protection Program

RESULTS AND DISCUSSION

Table 2 summarized the requirement for the environmental monitoring, location, monitoring sample and method of measurement.

Table 2: Summary of the requirement for environmental monitoring, location, monitoring sample and methods of measurement

TENORM activities	**Requirement**	**Location of monitoring**	**Monitoring Samples**	**Methods of measurement**
1. Oil & gas industry	LEM/TEK/30 LEM/TEK/58 (Routine Radiological Monitoring)	On shore/ Off shore/ Sludge farm	Soil, sediment, sludge, scales	Activity concentration of radionuclides (Ra-226, Ac-228) using Multi-channel analyzer coupled with Hyperpure GeLi detectors
			Water	Activity concentration of radionuclides (Ra-226, Ac-228) using Liquid scintillation counter
			Radon/ thoron daughter progenies	A few hours continuous monitoring using Radon thoron detector
			Airborne contamination	Filter paper in the Personal Air Sampler
			Surface contamination	Contamination survey meter and Wipe test
			External radiation	Survey meter / TLD 100H
	LEM/TEK/30 LEM/TEK/58 (Specific Radiological Monitoring)	Maintenance/ Cleaning/ Workover	Sludge, scale, sediment	Activity concentration of radionuclides (Ra-226, Ac-228) using Multi-channel analyzer coupled with Hyperpure GeLi detectors
			External radiation	Survey meter
			Surface contamination	Contamination survey meter and Wipe test
			Airborne contamination	Filter paper in the Personal Air Sampler

2. Mineral processing plant	License's conditions	On site/ Off site/ Disposal Site	Soil, sediment, flora/fauna	Activity concentration of radionuclides (Ra-226, Ra-228) using Multi-channel analyzer coupled with Hyperpure GeLi detectors
			Water	Activity concentration of radionuclides (Ra-226, Ra-228) using Liquid scintillation counter
			Radon/ thoron daughter progenies	A few hours continuous monitoring using Radon thoron detector
			Airborne contamination	Filter paper in the Personal Air Sampler
			External radiation	Survey meter/ TLD 100H

The oil and gas industries are required comply with the AELB guidelines called LEM/TEK/30 (AELA, 1984d) and also LEM/TEK/58 (AELA, 1984e), meanwhile the mineral processing industries are required to comply with the monitoring program as specified in the license's conditions. As shown in the Table 2, there are some similarities on methods of monitoring in TENORM facilities. However the amount and the number of samples taken in each location, varied, such as, 2 or 3 samples per location, 1L or 5L for liquid samples, 1 kg or 5 kg for solid samples. Other observation needed an information on the location of monitoring, for example, TLD chips are placed on the fence or entrance gate of monitoring area such disposal site, radon and thoron gas monitored at the platform etc. As at the platform, the wind speed is high, therefore it is not recommended to monitor for activity concentration of radon and thoron gas and airborne contamination. Radon and thoron gas are normally found with high concentration at the close workplace areas without proper ventilation system. Parameters of analyzing also need to be reviewed. Most of TENORM wastes, the concentration of Ra-226 and Ra-228 in soils and sediment samples are required to be monitored. However, for other cases, the concentration of U-238 and Th-232 are also required.

Thus, in order to standardize the methods of monitoring, the suitability and relevancies of the environmental and radiological monitoring methods are recommended below:

i. Location of monitoring should represent the actual working area, if nobody work or stay at the place, therefore no monitoring are required.

ii. External radiation monitoring using TLD dosimeters should be monitoring at the working area (i.e. at the middle of sludge farm/ disposal site) and TLD chips should be placed at 1m above ground.
iii. Survey meters used for external gamma radiation monitoring should have wide range and calibrated for environmental use.
iv. Open workplace area and area with ventilation (or high speed of air) such as offshore did not suitable to monitor air contamination and activity concentration of radon/ thoron and progenies. Radon and thoron are suggested to be monitored in the closed area.
v. Activity concentration of radon/ thoron and their daughter progenies should be monitored continuously for at least 24 hours to have the clear picture on the trend of activity concentration of radon, thoron and their progenies.
vi. Wipe test for surface contamination should be started from the outside to the inside of monitored area of 10cm x 10cm grid wipe in circle.
vii. The activity concentration of at least radionuclides U-238, Th-232, Ra-226, Ra-228, K-40 should be analyzed in all environmental and TENORM samples. This is to enable for the calculation of the radiological risk parameters such as Total Activity Concentration (TAC), Radiological hazards indices (I_{yr}), Radium Equivalent (Ra_{eq}), Effective Doses, etc.
viii. During pre-operational, it is justified to carry out the environmental monitoring in a frequency of 3 mthly in the period of 12 months calendar. Because during pre-operational there are no minerals containing NORM processing yet, thus it is expected that there are no contamination caused by TENORM.

CONCLUSION

Environmental and radiological monitoring program is part of the license's conditions and should be carried out in proper manner as the monitoring result will represent that the TENORM activities carried out by the licensee are safe and do not pose radiological hazards to the members of public and do not contaminate the environment. This study had found out that, there are a few of license's conditions that need to be reviewed accordingly based on the processing activity.

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