FNCA

Forum for Nuclear Cooperation in Asia

FNCA Consolidated Report on NORM and TENORM

March 2024

Radiation Safety and Radioactive Waste Management Group, Forum for Nuclear Cooperation in Asia (FNCA)

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PREFACE

Various radionuclides exist in nature, and materials containing them are called naturally occurring radioactive materials (NORM). Most natural radiation has been excluded from regulation by the International Commission on Radiological Protection (ICRP) because it is impossible or difficult to control the source and exposure.

However, in 1990, ICRP Publ.60 Recommendation stated that even natural radiation can be subject to radiation protection if exposure can be controlled. Among them, NORM in which radioactivity or radiation levels have been artificially increased is called TENORM (Technologically Enhanced NORM), and requires even higher monitoring.

According to ICRP, examples of exposure to artificially increased radiation include ①cosmic radiation exposure from jet aircraft use, ②cosmic radiation exposure from spaceflight, and ③radon exposure due to changes in housing structure and lifestyle, ④ handling of materials containing significant amounts of natural radioactive materials (NORM) (phosphoric acid fertilizers, etc.) .

This project focused on NORM&TENORM, where radiation exposure is sometimes a problem, and investigated and considered the current situation in each FNCA country. In recent years, international standards regarding the regulation of naturally occurring radioactive substances are being considered. Related information was also collected. This report collects NORM&TENORM data and presents the discussed results based on task group work in the Radioactive Waste Management (RWM) project within the framework of FNCA (Forum for Nuclear Cooperation in Asia).

This report has the following structure.

Preface
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＜Part I General＞
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  2.1 Sources of NORM&TENORM
  2.2 Management of NORM&TENORM
  2.3 Regulatory Base or Framework
  2.4 Issues related to NORM&TENORM

Such information exchange and discussion based on peer review through on-site fact-finding observations between neighboring countries will support the strengthening of efforts to formulate harmonious international agreements through the IAEA and other organizations.

March 1, 2024
Project Leader of Japan
KOSAKO Toshiso
(Professor Emeritus, The University of Tokyo)

Framework of Regional Cooperation under FNCA

1. What is FNCA?

The 1st International Conference for Nuclear Cooperation in Asia (ICNCA) was held by the Atomic Energy Commission in March 1990 to promote cooperation in the field of nuclear energy with neighboring Asian countries more efficiently. Since then, the Atomic Energy Commission of Japan has held many ICNCAs where the ministers in charge of development and utilization of nuclear energy exchanged frank views on how to proceed with regional cooperation, and has carried out practical cooperation on specified subjects as well. At the 10th International Conference for Nuclear Cooperation in Asia held in March 1999, it was agreed to move to a new framework, "Forum for Nuclear Cooperation in Asia" (including Coordinator and Project Leader System) with a view and information to shifting to more effective and organized cooperation activities. Under this framework, view and information exchanges are made on the following fields: (1) Radiation Utilization Development (Industrial Utilization/Environmental Utilization, and Healthcare Utilization), (2) Research Reactor Utilization Development, (3) Nuclear Safety Strengthening, and (4) Nuclear Infrastructure Strengthening.

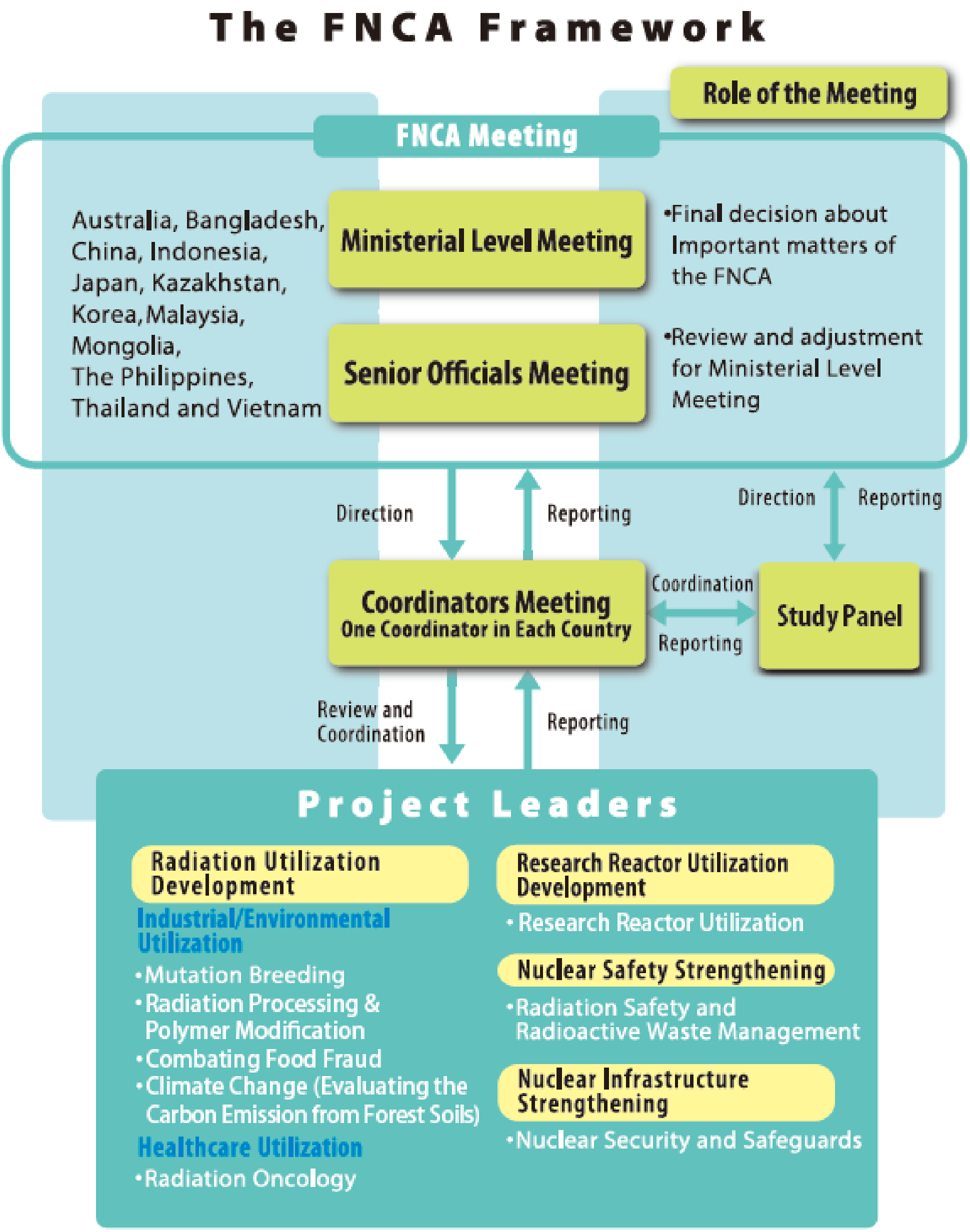
2. Participating Countries

Australia, Bangladesh, China, Indonesia, Japan, Kazakhstan, Republic of Korea, Malaysia, Mongolia, Philippines, Thailand and Vietnam

3. Framework

The basic framework of cooperation consists of the following three (See the figure on the next page). :

- **Forum meeting**
  Discussion on cooperation measures and nuclear-energy policies.
  Forum meeting is comprised of a ministerial level meeting and a senior official level one.
- **Coordinators meeting**
  Discussion on the introduction, revision and abolishment, adjustment, and evaluation of cooperation projects by an appointed coordinator from each country.
- **Cooperation activities for each project**



4. FNCA Radiation Safety and Radioactive Waste Management Project

This project superseded Radioactive Waste Management Project and started in 2008 with the aims of sharing information and experiences in the area of Radiation Safety & Radioactive Waste Management (RS&RWM) processes and regulatory issues as well as facilitating safety improvement and understanding of RS&RWM to public perception in nuclear society.

In each member country, the use of radiation in industry, agriculture, medical treatment, and various other fields is rapidly increasing, and at the same time, several countries are looking into introducing nuclear power plants. In consideration of such tendency, member countries have been discussing how to promote the standardization (calibration) on personnel dosimeter, focusing on appropriate radiation exposure management.

The accumulated results acquired through these activities over ten years were published as a serried of FNCA Consolidated Report on RS&RWM. These reports are available on the FNCA Website.

[URL: https://www.fnca.mext.go.jp/english/rwm/e_projectreview.html]

Part I General International Radiation Protection Concept for NORM

1. International Radiation Protection Concept for NORM

International organizations have been worked on NORM&TENORM. Items in below are important actions for radiation protection from NORM&TENORM.

ICRP published Publication 142, 'Radiological Protection from Naturally Occurring Radioactive Material (NORM) in Industrial Processes[1]' in 2019. It was well summarized in MAIN POINTS of this publication what this document describes, as below.

MAIN POINTS

- ***Exposures resulting from industrial activities involving naturally occurring radioactive material (NORM) are controllable, with protection achieved through justification of taking protective actions and optimisation of protection.***
- ***NORM presents no real prospect of a radiological emergency leading to tissue reactions or immediate danger to life; actions to protect workers and the public should consider long-term external exposure, intake of radioactive material, and radon or thoron inhalation.***
- ***An integrated and graded approach is recommended for the protection of workers, the public, and the environment, including characterisation of the exposure situation, and optimisation of radiological protective actions to complement the protection strategy already in place or planned to manage other hazards.***
- ***Reference levels (excluding exposure to radon and thoron) for the protection of workers should reflect the distribution of exposures and would, in the majority of cases, be less than a few mSv annual effective dose. Very rarely would it be expected that a value exceeding 10 mSv annual effective dose would be necessary.***
- ***Reference levels for protection of the public should reflect the distribution of exposures, and would generally be less than a few mSv annual effective dose.***
- ***Radon and thoron exposures should be managed using a graded approach, first relying on radon prevention and mitigation measures in the building, as recommended in Publication 126 (ICRP, 2014b).***

(Referred from ICRP Publication. 142[1])

Paragraph 1.3 of ICRP Publ.142[1] summarizes the contents of this publication itself.

1.3. Structure of this publication

(20) Section 2 presents the characteristics of NORM exposure, an overview of the industries and practices where NORM exposure can occur, and elements related to the NORM cycle. Section 3 describes the Commission's system of radiological protection

applied to NORM exposure, including the type of exposure situation, the category of exposure concerned, and the basic principles to be applied. Section 4 provides guidance on implementation of the system of radiological protection using an integrated and graded approach for the various exposed workers, the public, and the environment. Conclusions are provided in Section 5. Annex A provides more details about activities that may involve NORM exposure.

(Referred from ICRP Publication. 142[1])

IAEA held international conference 'Management of naturally occurring radioactive material (NORM) in industry' in 2020. Proceedings[2] was issued in 2022. Many actions made by many countries ware introduces and discussed. It looks it contributed to make the specific safety guide No. SSG-60 'Management of Residues containing naturally occurring radioactive material from uranium production and other activities[3]' in 2021. It was based on the safety report No.49 'Assessing the need for radiation protection measures in work involving minerals and raw materials[4]' in 2006.

The structure of the IAEA specific safety guide No. SSG-60[3] is listed below.

- Section 2; Overview of NORM activities and NORM residues
- Section 3; Recommendations on the governmental, legal and regulatory framework for the safe management of NORM residues
- Section 4; Recommendations on the protection of people and the environment
- Section 5; Recommendations on the regulatory control process
- Section 6; Recommendations on strategies for NORM residue management
- Section 7; Recommendations on the development of a safety case and supporting safety assessment
- Section 8; Full lifetime of facilities for the long term management of NORM residues

European Commission (EC) published documents for radiation protection from TENORM. In 1999. EC established reference levels for regulatory control of work places effected with TENORM. In Radiation Protection 95 'Reference levels for workplaces processing materials with enhanced levels of naturally occurring radionuclides[5],' classification of regulatory control for radiation protection on NORM was introduced. (See. Fig.1) In Radiation Protection 107 'Establishment of reference levels for regulatory control of workplaces where materials are processed which contain enhanced levels of naturally-occurring radionuclides[6],' the classification was sophisticated as five classes with detailed reference levels. (See Fig.2) It also describes the methodology for evaluation of dose exposure from NORM to worker and public using normal and unlikely scenarios, exposure pathways and parameters.

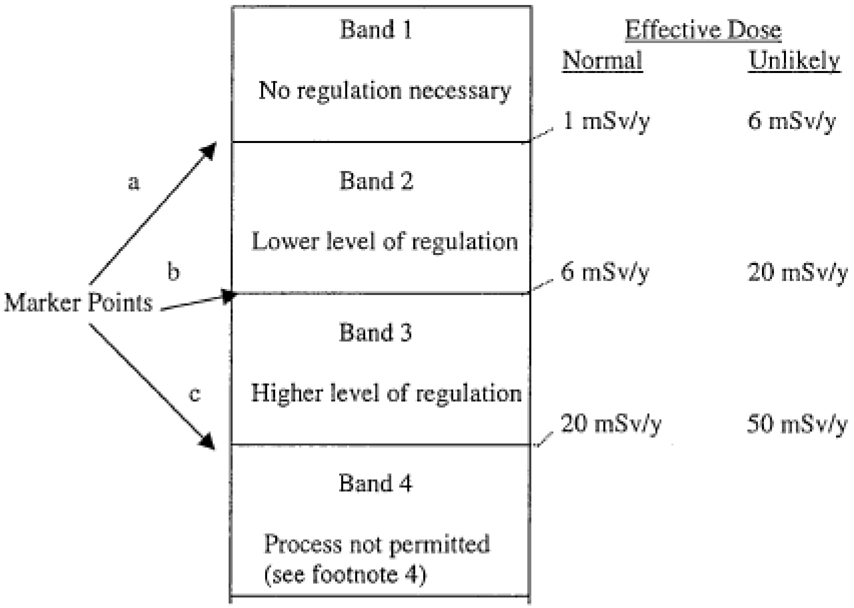
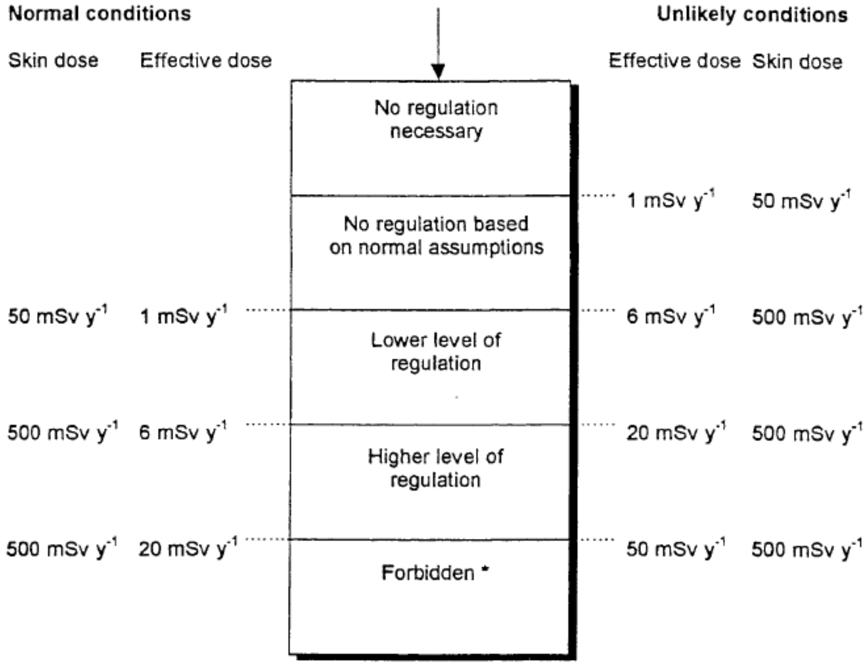


Fig. 1. Radiation protection classes for NORM from Radiation protection No.95, EC[5)]



Note:
* A thorough review of the working practices is necessary to obtain detailed dose assessments. If these doses are above the worker dose limits, the practice must cease.

Fig.2. Radiation protection classes for NORM from Radiation protection No.107, EC[6)]

EURATOM conducts RadoNorm[7)] project which aims at managing risk from radon and

NORM exposures from 2020 to 2025. Scope of this project has 9 work packages, which includes not only exposure, dosimetry, mitigation, management, but even social aspects, education, and ethics. Current actions for radiation protection from NORM in EU region can be observed.

United States Environmental Protection Agency (USEPA) published information about TENORM in USA in USEPA Radiation Protection information website[8]. They show the introduction about TENORM and list the major TENORM industries and sources in USA. Some actions for TENORM are also described.

World Nuclear Association (WNA) has a NORM information webpage[9] in their website 'Information Library/ Safety and Security/ Radiation and Health.' In this webpage, NORM information around the world is summarized.

National Institutes for Quantum and Radiological Science and Technology (QST) of Japan published NORM database website[10]. It contains NORM data related to Japanese trade. The database also contains dose calculation tool for NORM in some typical situation.

The foundation of these actions are data from the science report of the Scientific Committee on the Effects of Atomic Radiation of United Nations (UNSCEAR). UNSCEAR consolidated and periodically updated the world-wide data on NORM&TENORM from 1977. The reports tagged with 'NORM(TENORM)' in UNSCEAR website are listed as below.

- UNSCEAR 1972 Report Annex D: Miscellaneous sources of ionizing radiation[11]
- UNSCEAR 1977 Report Annex B: Natural sources of radiation[12]
- UNSCEAR 1977 Report Annex E: Doses from occupational exposure[13]
- UNSCEAR 1982 Report Annex C: Technologically modified exposures to natural radiation[14]
- UNSCEAR 1982 Report Annex H: Occupational exposures[15]
- UNSCEAR 1988 Report Annex A: Exposures from natural sources of radiation[16]
- UNSCEAR 1993 Report Annex A: Exposures from natural sources of radiation[17]
- UNSCEAR 1993 Report Annex D: Occupational radiation exposures[18]
- UNSCEAR 2000 Report Annex B: Exposures from natural radiation sources[19]
- UNSCEAR 2000 Report Annex E: Occupational radiation exposures[20]
- UNSCEAR 2008 Report Annex B: Exposures of the public and workers from various sources of radiation[21]

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8) USEPA, TENORM Website, （Last updated on July 2022）
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9) WNA, Naturally-Occurring Radioactive Materials (NORM), (Updated April 2020)
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Part II Present status of NORM&TENORM in FNCA countries

1 AUSTRALIA

1.1 Introduction

Australia is a very large and very resource rich country. There are mineral deposits of every type and these are exploited to supply domestic and international demands for the minerals. The mining industry is 11% of Australia's revenue, (about 50% of international trade) and the industry is valued at $220,000,000,000 per annum.

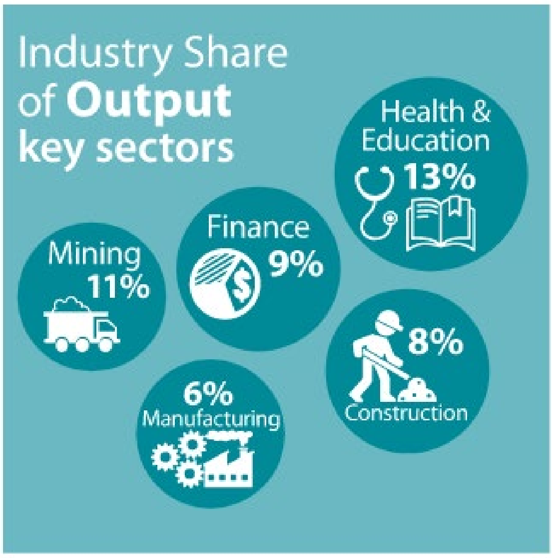

Figure 1. Australian industry (from industry.gov.au)

With all this mining, milling and refining in Australia comes the associated challenge of managing the naturally occurring radioactive material (NORM) that is found in the ore. Only material which is modified by humans is regulated within Australia, and these are regulated by the local authorities (9 radiation protection regulators, plus other specialised regulators such Oil and Gas regulator, Environmental Protection Agencies).

In the mining and refining process the material is well controlled, however when the NORM is separated from the product special controls need to be put in place. NORMs are managed by setting an exemption criteria, typically around 1 Bq/g, with material above that monitored by regulators.

1.2 Sources of NORM&TENORM

Mining and processing of minerals result in increased concentrations of naturally occurring radioactive materials (NORM) in products and/or process wastes. This phenomenon of technologically enhanced NORM (TENORM) may bring the majority of the minerals industry operations into the limelight of regulatory focus worldwide. Technologically enhanced naturally occurring radioactive materials (TENORM) arise in many industries. TENORM is the enhancement of the possibility of exposure to people or to the environment from naturally occurring radioactivity, when material containing naturally occurring radioactivity is disturbed, handled or processed. The process can be as simple as the transport of ore to the surface resulting in the mobilisation of contained radioactivity or the dispersal associated with a dust problem. TENORM does not necessarily imply concentration of radionuclides, but that the materials are in a condition where there is potentially an increased dose to the workforce or public through one or more pathways.

The awareness of TENORM in relation to the non-uranium industry is increasing in Australia, where the issue is predominantly seen as belonging to the mining industry. Many of the mining products potentially contain radioactivity due to the presence of uranium and thorium and their progeny in the ore. In the petroleum production and processing industry and the heavy minerals industry, this awareness has progressed to the drafting of new guidelines and regulations in regard to the disposal of wastes containing NORM. However, in other industries, the awareness is principally related to limitations placed on the level of radioactivity in exported products. In recent times the mining industry has become more conscious of TENORM in its own waste products. These might be solids, liquid or gaseous emissions.

TENORM is now widely recognised in Australia in the heavy minerals, petroleum, base (primarily Cu) and precious metals, refractory metals (Ta/Nb), tin, alumina and many other industries. A major driver for a better understanding of TENORM in mining industry processing has been the adverse effect the presence of radioactivity has on the marketability of products on the international market. Australia has consequently become a world leader in process development for the removal of radioactivity during mineral processing and extractive metallurgy. The other major driver is the risk associated with the presence of NORM and the fear of litigation due to excessive exposure of the workforce or public.

The occupational health issue of specific relevance to the mineral sands industry is radiation. Western Australian mineral sands deposits contain up to 10% heavy minerals, of which 1-3% is monazite. This in turn typically contains 5-7% of radioactive thorium and 0.1 - 0.3% of uranium, which is barely radioactive.

In ore, or general heavy mineral concentrate, the radiation levels are too low for radioactive classifications. However, when the radioactive material is concentrated in the process of separation and production of monazite the radiation levels are increased, creating the need for special controls to protect some "designated" employees in dry separation plants.

In the past, occupational exposure to radiation levels of 50 mSv/yr, then the limit, were not uncommon.

Dust control is the most important objective in radiation safety for the titanium minerals industry. The most significant potential radiation problem is inhaled thorium in mineral sands dust.

This contrasts with other industries where the focus for radiation protection has been direct gamma radiation from materials in rock. Exposure to gamma radiation still needs to be controlled in the mineral sands industry, due principally to uranium and thorium in zircon. However, safety programs are targeting alpha radiation arising from airborne dust which may be inhaled.

The more precise identification of airborne radiation in mineral sands dry separation plants led to the introduction of voluntary codes of practice in 1980. These codes were incorporated into protective legislation in 1982. The method of calculating permissible exposure levels was changed in 1984 and again in 1986. The result was an effective six-fold reduction in radiation exposure limits.

The industry responded with two major initiatives:

- Engineering programs to reduce airborne dust in the dry separation plant.
- Research programs to improve industry and community knowledge about airborne radiation.

This paper focuses on the problems in dealing with TENORM waste. The amount of TENORM waste varies from small quantities of higher radioactivity content to very large quantities of very low concentration of radioactivity. The complexity of the deportment of radioactivity through industrial plants means that there are diverse waste streams, which contain significant amounts of TENORM.

Types of TENORM Occurring in Australia

Uranium

The largest source of TENORM waste arises from uranium mining. In Australia, over 10 million tonnes of uranium mill tailings are produced each year.

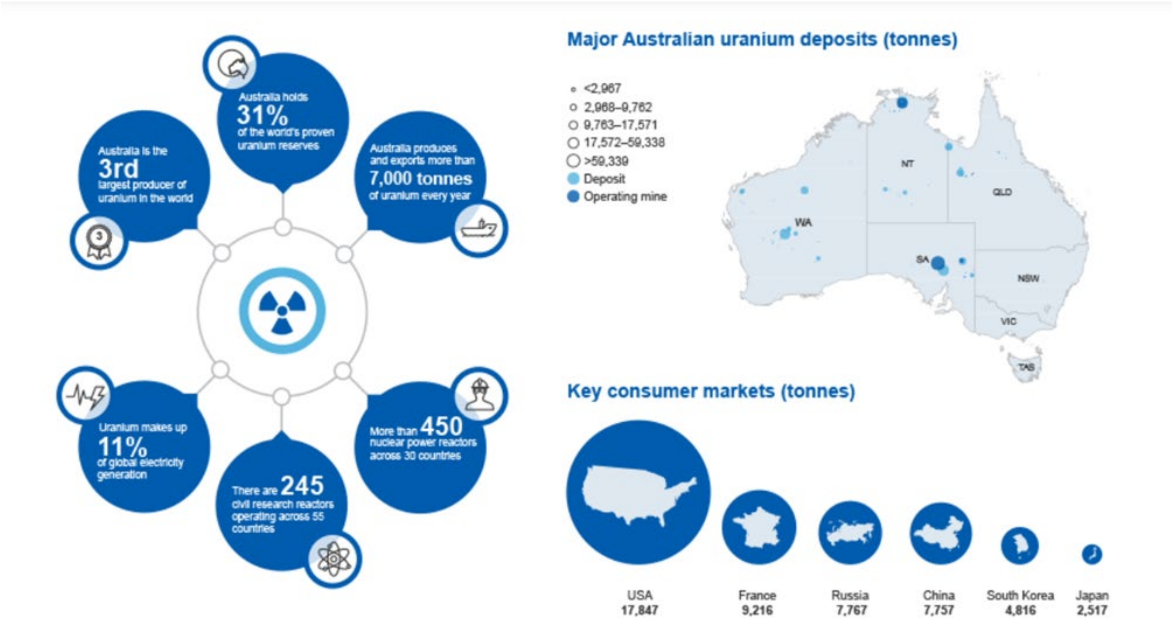

Figure 2. Australian Uranium Industry (from industry.gov.au report)

The tailings from a uranium mill contain over 99 percent of the ore mass and about 70% of the radioactivity originally present in the ore. The tailings from milling 0.2% U3O8 ore typically contain 21 Bq/g 226Ra, 84 Bq/g beta-activity and 130 Bq/g alpha-activity (including 226Ra and 222Rn progeny). As well as tailings, many other waste streams at uranium mines contain TENORM. For example, the scale in process water lines can contain significant amounts of radioactivity.

Iron and steel

The presence of small concentrations of uranium in the feedstocks (iron ore, coke etc) to iron making can result [BHP 2000] in enhanced levels of 210Po and 210Pb in recirculated sinter plant off-gas cleaning dust. The concentrations of these radionuclides in the collected dust can be such that any bleed-off dust is difficult to dispose of in normal waste disposal facilities. The other uranium progeny occur at lower concentrations (as they do not accumulate) in blast furnace slags and gas cleaning sludges. Although the concentrations in the slags are low, they may be a TENORM issue if such products are subsequently used by other industries, such as in cement manufacture, if the workforce is exposed to a dusty workplace.

Heavy minerals

Australia is a major world producer of heavy minerals, which frequently contain elevated concentrations of thorium and uranium. Some of the radioactivity is separated and disposed of as part of mineral processing to produce the heavy mineral concentrates. These TENORM wastes, frequently including monazite, must be managed in accordance with local licence conditions [Western Australian Chamber of Minerals and Energy 2000]. The mineral concentrates ilmenite, rutile and zircon can contain radioactivity. Zircon is mostly used without further processing and its use must be accompanied by practices, which minimise the potential to inhale dusts. The further processing of zircon or ilmenite to either remove a portion of the contained radioactivity to meet specified concentrations or to produce higher grade intermediates, such as synthetic rutile and TiO2 pigment, and at the same time remove some radioactivity, can result in enhanced levels of radioactivity in fumes from thermal processing and/or wastes that are enhanced in radioactivity. The appropriate disposal of refractories manufactured using zircon is an issue in Australia. [Hartley et al 1991]

Copper

Some operations in Australia either mine uranium in association with copper minerals [Thomas 1996] or have to manage low concentrations of uranium and its decay progeny in their copper treatment processes. The copper metal product can be contaminated with radioactivity. By-products such as gold and silver in slimes may contain elevated levels of radioactivity, and there can be 210Po and 210Pb in smelter off-gases. Dust in sulphur dioxide off-gases from these operations can contain TENORM. There is now considerable experience in the appropriate management of these issues.

Phosphate

Uranium and thorium frequently occur in phosphate deposits. Although the presence of radioactivity in the fertiliser products is normally not an issue, the radium, or more specifically the emanating radon, in the phosphogypsum product must be taken into consideration in operation and in designing the method of closure of such facilities.

Tantalum, niobium and tin

These generally have TENORM associated with them and again, there can be TENORM issues in the end use and disposal of slags.

Oil and Gas processing

Processing of oil and gas in Australia generates scales containing elevated concentrations of 226Ra. Radium is brought to the surface in formation water and can precipitate out in sludges and as scale on internal surfaces of oil and gas production facilities. The scale from pipework can require disposal as a radioactive material. Some of this material has been disposed of at the Mt Walton East Intractable Waste Facility in Western Australia and disposal at sea is permitted on a case by case evaluation basis [Western Australian Department of Minerals and Energy 2000].

When natural gas and oil are processed, radon tends to concentrate in ethane and propane fractions, due to the fact that the boiling point of 222Rn is between those of ethane and propane.

While radon is virtually non-reactive, its short-lived progeny are chemically active and subject to deposition on internal surfaces of processing equipment. The short-lived progeny, in turn, quickly decay to 210Pb, which has a half-life of 22.6 years.

Coal combustion

Coal fired power stations are the major source of electricity in Australia and produce fine ashes containing TENORM [Zahorowski et al 1994]. Issues are dust in emissions and storage of dusts/ashes without mobilisation of pollutants including radionuclides.

1.3 Regulatory Base or Framework

Australia has a federal system of government and the regulation of TENORM radioactive waste management and disposal comes under both Commonwealth (Federal) and State/Territory regulation. There are nine jurisdictions within Australia.

Nuclear activities of the Commonwealth Government are regulated by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). However, most TENORM issues arise from industrial or mining activities and the regulation of these industries is mainly a state responsibility. Uranium mining and milling is a special case, involving both state regulators and approval by commonwealth agencies.

In the States and Territories, the use of radiation and radioactivity are regulated by Environmental Protection Authorities and Health Departments in each state. In addition, mines are also regulated by Departments of Mines or equivalent in States and territories. In Australia TENORM is regulated either under mining regulation or under radiation health regulations. In general, TENORM arising from mining and milling activities is managed at mine sites as part of the site environmental management plan.

There is a large degree of inconsistency in the definitions of clearance and exemption levels in regulations in the different States in Australia. These inconsistencies include the actual levels and also how these are specified. There is a national effort lead by ARPANSA to develop consistency through the National Directory for Radiation Protection. For the nuclear industry and radioactivity used in industry, research and medicine, the IAEA GSR Part 3 exemption values for both exemption and clearance of 1 Bq/g is used. However, there is still discussion about applying a graded approach to regulation, particularly when it is not being released for unrestricted use, but is destined for a specified use or disposal method. At present in Australia, the TENORM waste is dealt with on a case-by-case basis.

・Guidance

Every regulator issues guidance on how to meet the expectations in the documents that are supplied. Guidance from ARPANSA (Commonwealth); Western Australia Department of Mines, Industry, Regulation and Safety; NSW Resources Regulator; and the Queensland

Department of Natural Resources and Mines were used in the writing of this report, and are listed in the references at the end of the document.

1.4 Management of NORM&TENORM

Management on site

The majority of NORM facilities in Australia are part of the extraction industries – mining and oil and gas industries. For all facilities which have a NORM hazard require a Safety Case to Construct and Operate the facility. These are supplied to the regulator and is what is used by the regulator in their inspections through the life of the facility. The Safety Case is a suite of documents which describe all the safety systems and what is required. In general, the following documents are expected:

- Safety Management Plan
    - This is a requirement of all facilities and describes how work health and safety will be managed at the facility. This includes in Australia psychosocial hazards (psychological and social hazards like bullying, exclusion, work demands and others) and the expectation is that all the various ways to keep things safe are part of the one holistic implementation plan.
- NORM Management Plan
    - See more detail below.
- Radiation Protection Plan
    - This is the plan for how radiation exposure and contamination will be minimised and monitored. This is the same template as used for the IAEA in general.
- Radioactive Waste Management Plan
    - The plan which describes how radioactive material will be managed when it is no longer useful. This covers airborne, liquid and solid wastes and may involve disposal if that option is available.
- Environmental Monitoring Plan
    - The plan which describes how the facility will be monitored during the production phase; what will be monitored, how often and how it will be reported.
- Decommissioning Plan
    - The plan which details what actions are being taken to reduce radiation exposure and optimise safety when the facility is being decontaminated and dismantled. The expectation is that this plan is continually revised during the life of the facility and gets more detailed as the years go by.

- Rehabilitation Plan
    - See more detail below.
- Quality Plan
    - The plan which demonstrates that the organisation can keep producing the same material reliably and repeatedly. There are ways to report matters which can be used to identify problems and rectify or mitigate the issue. This includes calibrations, maintenance, documentation of procedures (which can be videos) and reporting systems.
- Security Plan
    - The plan which details how members of the public are protected from accidental access to radioactive material, and how the organisation protects the NORM from intentional access.

All of these plans are graded based on the level of hazard and risk present at the site. There has to be a risk assessment which is conducted covering all safety and environmental aspects which forms the basis for all the plans above. The outcome of the risk assessment will be used by the regulator to determine the level of information which is required for a site (graded approach). For a site with a small amount of NORM, the regulator may decide that the NORM management plan can be used to cover both the radiation protection plan, environmental protection plan, quality plan and the radioactive waste plan.

NORM Management Plan

The NORM management plan is a document based on a risk assessment which sets out how the company will manage the NORM hazard on the site. It will have the following sections:

Description of the NORM and level of potential radiation

This section identifies the type of NORM hazards at the site, and identify the physical, chemical and radiological characterisation of the materials all through the processing facility. The risk to people will be identified and the justification for why the activity is taking place.

Scope of activities

This section describes what the actual site to be licenced actually does and what it will not do. It will include a brief description of the site, the major equipment and how people will interact with the NORM hazard.

Organisational arrangements for managing NORM

This section is to demonstrate to the regulator that the company / organisation which is applying for the licence has the capacity and resources to do the work properly. There are sufficient numbers of people employed in defined positions – using an organisation chart showing chains of command and including safety positions – to ensure that the work is done safely. The organisation has the financial capacity to fund all the facilities, tasks and processes described so that the people and environment are safe, including rehabilitation and decommissioning of the facility. The organisation can comply with all regulatory expectations and can maintain effective control of the hazard.

Workforce arrangements

This section includes how the workforce will be managed and arranged to ensure that everyone is safe. This includes the psychosocial hazards such as boredom, fatigue, work stress and loud or cramped working environments. The roster arrangements (hours on shift, how many people on shift, how many teams) and total hours per year are to be supplied to assist the dose assessment.

Routes and risk of exposure to radiation

This section discusses the sources and magnitude of NORM; including the possible modes of exposure (inhalation, absorption, invasion and ingestion); and the identification of transfer or storage areas for NORM (stockpiles and hoppers).

Engineering control of radiation

This section lists the engineering controls, for all routes and identified areas of exposure, implemented to reduce exposure to an acceptable level. Some examples of engineering controls which can be claimed are:

- Mine and process plant design
    - Examples are having the control rooms a safe distance from the plant
    - Building the site to minimise dust spread by the prevailing winds and rain
    - Having access paths (on the surface and below the surface) in areas with lower levels of NORM
    - Minimising stockpiles on the site
- Dust suppression and extraction
    - Effective dust suppression and extraction will reduce exposure to alpha emitters through inhalation. It is important to identify all areas of dust generation and some controls which can be used are
    - watering roads, stockpiles, faces and points that generate dust
    - controlling spillage and cleaning up as soon as practicable
    - installing dust suppression on crushing, screening and conveyor systems at appropriate locations
    - enclosed local extraction ventilation containment systems fitted to control dust generated during operations
- Ventilation
    - Ventilation is the primary control for managing alpha-emitting dust and radon in an underground mine. It has to be assessed in processing facilities for worker and environmental safety reasons.

- Enclosed operator cabins
    - Enclosed cabins may provide protection to operators inside the cabin from NORM.
- Maintenance
    - An effective maintenance strategy can reduce the type and amount of NORM exposure. Exposure of maintenance personnel to NORM should be considered when risk assessing maintenance activities.
- Separation of workers from NORM
    - Separation distance will directly affect the exposure to gamma radiation. Some strategies include using remote operated or autonomous equipment
    - locating non-critical plant and infrastructure such as administration in areas of low background exposure
    - locating control rooms outside of the process plant
- Shielding and sealing surfaces
    - storing known 'hot' core in the middle of other core sample trays and pallets of core
    - concrete walled bunkers may provide some protection for stockpiles
    - coating underground development with an appropriate thickness of shotcrete may reduce gamma shine

Administrative control of radiation

In addition to the engineering controls there are also administrative controls which can be used. Some of these controls are:

- pre-start checks to ensure that the dust control, suppression, extraction and ventilation systems are operating and effective
- hygiene standards, rules and practices
- clean-in/clean-out facilities and procedures
- housekeeping standards
- decontamination of equipment prior to leaving site or being maintained
- capturing exposure history completely and accurately
- exclusion or limiting work time of persons from high dose areas
- sample handling, transfer and storage procedures
- product storage and transport practices and procedures
- waste management procedures
- removing muck from drives and development headings as soon as possible

Education, training and competency

The most important administrative control is the training of staff. The organisation has an obligation to train workers so that they are competent to perform their duties where there are risks from NORM. This will include both appropriate induction training with periodic assessment of knowledge of risk management for NORM and any other relevant and appropriate training with periodic assessment required to effectively and safety do the tasks required. This training will include a matrix showing which workers need which training and why that training is required.

The training must cover radiation terminology, hazards, risks, exposure pathways and monitoring. The worker must understand the controls and how to use the equipment and controls which are there to make them safe.

Radiation monitoring program

In the context of NORM, monitoring may include:

- the use of TLD badges
- personal exposure dust monitoring
- environmental dust monitoring
- radon measurement
- gamma shine measurements
- surface contamination monitoring
- ensuring there is compliance with work procedures and work practices.

Results of the monitoring program must be reported regularly to the workers and others as required.

Dose assessment

This should include the calculations (based on the NORM source term in the first section, the exposure times in the workforce section and any credit from the engineering controls) to demonstrate that the facility has an acceptable level of exposure to workers. All assumptions need to be listed and explanations of how information from the monitoring program is used in the assumptions.

Monitoring records and reporting

In this section it will describe the records kept, how they are reported and what happens when there is a variance from the expected results. Overviews of previous years results will also be included here are part of the regular reviews.

Management of product (if NORM)

Describe how a NORM product will be managed, including all temporary storage, transport and handling in addition to the process. This includes packaging and labelling.

Management of waste

Details of the handling, storage and disposal methods of NORM waste including residues on site

Emergency response plan interaction

As the facility should have an emergency response plan, this section is an explanation of the impact NORM may have on the mine's emergency response procedures and capabilities. It is not meant to be the only emergency plan.

Review and audit

Procedures for periodic review, audit and continuous improvement of the NORM management plan.

Rehabilitation plan

When the site, or a section of the site, is to be no longer used or processed, the organisation must make good on the site and return the area to a state where it can be used for other activities. The owner can sell the land to others and it can be used for another unforeseen site. In general (with mines) the land is returned to a semi-natural state with soil and plants covering the site to allow it to return to the same environment that it was before the mine was built.

Operational History

This section has a summary of significant surface disturbing activities, including mining operations, ancillary mining activities and exploration, carried out on the mining area. Describe if there have been rehabilitation activities undertaken since commencement of mining operations including decommissioning or demolition of built infrastructure. This section must include a history of the ownership of the land, the companies involved and the regulatory approvals on the site.

Final Land use Options and Analysis

This section describes what options were considered, the consultation process employed, the stakeholders consulted and the outcomes of the consultation. The final land use option should be identified with consideration of the surrounding environment and land uses in the area (will it be farmland, native vegetation of an industrial site).

Areas which must be analysed include: soils and materials; fauna; flora; overburden (mined waste rock) placement; waste management; geology and geochemistry; erosion and sediment control; biological resources (grasses, trees, bushes); mine subsidence and management of cultural and heritage issues.

Rehabilitation Risk Assessment and Objectives

A specific risk assessment has to be conducted for the rehabilitation phase of the site. This will be informed on the Final Land use option. The outcomes of this risk assessment are to be listed here including the controls which are to be put into place. This section must include the criteria for determining when the Final Land use option has been reached, and what monitoring will be used to assist in that decision.

Rehabilitation Implementation Plan

This section will outline the schedule, activities and monitoring of the rehabilitation project. It will reference detailed drawings of the final site and important milestones. The general methodologies for rehabilitation will be outlined and a clear link to the risk assessment identified. The phases of the rehabilitation from active site to abandoned site will be included in the schedule.

Decommissioning activities are included in this section.

Quality Assurance Program

This section must describe how the rehabilitation quality assurance process will be formally integrated into the day-to-day mine planning process, including:

- the responsibilities for implementation
- how the process will be formally documented and recorded (e.g. inspection test plans)
- how the process will be reviewed and refined over time to promote continuous improvement.

Monitoring Program

The company / organisation should select the most appropriate indicators and monitoring methods that:

- align the monitoring program with the rehabilitation objectives and rehabilitation completion criteria
- are relatively simple to measure and are reproducible
- are effective for tracking rehabilitation progress, or regression and potential risks

The frequency of monitoring will depend on site-specific circumstances and the selected monitoring methodology. As a guide, the frequency of monitoring will be more intense immediately following rehabilitation until such time that there is adequate ground cover or adequate species establishment.

Research, models and trials

The company should proactively seek to improve rehabilitation methodologies using a range of resources including:

- rehabilitation trials at existing rehabilitation areas
- undertaking literature reviews to assess the suitability of various rehabilitation techniques and identify industry best practices
- partnering with research institutions to undertake research programs that address specific knowledge gaps
- undertaking modelling to improve rehabilitation methodologies (e.g. landform evolution modelling to address any long-term erosion and stability risks).

Review and revision

This section must describe the triggers for reviewing and revising the rehabilitation management plan and the process for document management. Triggers may be regulatory (from an inspection); incidents which cause a change (e.g. drought, fire, flood, company or land having new owners); as the project moves into a different phase of rehabilitation; or be time based.

Disposal

There are reuse and recycling options of NORMs which include:

- soil conditioning additive in agriculture, with particular reference to phosphate binding;
- substitute for clay, or as a clay additive, in the manufacture of construction materials such as bricks and tiles;
- road base construction material;
- substitute for natural gypsum in the manufacture of plaster wall board;
- filler in the production of rubbers and PVC.

The disposal options for NORMs include:

- into the ocean in the case of offshore facilities at a dilute level
- Landfill for slags and other processing wastes
- Placed back into the mine when the extraction has completed
- Capping tailings dams

The Sandy Ridge Facility for the disposal of hazardous waste will be used as an example. This facility is a clay mine which will also be used for the disposal of hazardous waste when the mine is complete.

Figure 2. Tellus site (from website)

The NORM Management Plan for Sandy Ridge had to describe the waste, including nature of material (chemical, physical and radiological), contaminants, and quantities and rate of production. They also had to describe the environment into which the waste will be disposed, including the social and cultural heritage; and present and potential land use. The system for waste management including the facilities and procedures involved in the handling, treatment, storage and disposal of radioactive waste and the resultant predictions of environmental concentrations of radionuclides and radiation doses to the public.

NORM Management Plan for disposal

As discussed above, there is a requirement for NORM management plan and there are some slight differences for a disposal facility to an operational facility. Differences from the above are outlined below with the sections above being referenced below.

Figure 3. Tellus operations (from website)

1. An outline of the processes generating waste.
2. A description of waste including nature of material (chemical, physical and radiological), contaminants, and quantities and rate of production.
3. A description of the environment into which the waste will be discharged or disposed (climate, terrain, soils, vegetation, hydrology), including the baseline radiological characteristics.
4. Heritage (social and cultural) and land use (present and potential).
5. A description of the proposed system for waste management including the facilities and procedures involved in the handling, treatment, storage and disposal of radioactive waste.
6. Predictions of environmental concentrations of radionuclides and radiation doses to the public from the proposed waste management practice, including demonstration that the statutory radiation protection requirements will be met both now and in the future.
7. A program for monitoring the concentration of radionuclides in the environment and assessment of radiation doses to members of the public arising from the waste management practices.
8. Contingency plans for dealing with accidental releases and the circumstances which might lead to uncontrolled releases of radioactive waste in the environment.
9. Contingency plan to cover cases of early shutdown or temporary suspension of operations.
10. A schedule for reporting on the waste disposal operation and results of monitoring and assessments.
11. A plan for the decommissioning of the operation and associated waste management facilities, and for the rehabilitation of the site.
12. A system of periodic assessment and review of the adequacy and effectiveness of the Radioactive Waste Management Plan to take account of potential improvements consistent with best practicable technology

The NORM management plant had to include a program for monitoring the concentration of radionuclides in the environment and assessment of radiation doses to members of the public. Contingency plans were developed for dealing with accidental releases of radioactive waste in the environment, or early shutdown of operations. There had to be regular reporting on the waste disposal operation and results of monitoring and assessments. It also has to include a plan for the decommissioning of the operation and associated waste management facilities, and for the rehabilitation of the site.

During the operational stage, the appropriate authority must be notified of any changes to the operation which may alter the nature or quantity of waste generated; any proposal to change the waste containment system; and any unanticipated circumstances that may lead to a variation in performance of the approved Radioactive Waste Management Plan.

By following all the requirements Sandy Ridge was given an approval to operate and dispose of NORM.

Sandy Ridge NORM Operations

Immobilisation treatment involves locking the waste into a cementitious matrix and/or adsorbing it into a suitable material.

NORM wastes that do not require immobilisation, such as contaminated equipment, will be disposed according to the appropriate procedure, which may include grouting of any void spaces in equipment pieces (e.g. pipes)

Monitoring during Operations

During operations the regulator and other stakeholders are provided reports on the monitoring of the site. This report includes details of:

- The level of effluent control achieved and the extent to which environmental pollution and degradation are prevented in similar mining and mineral processing operations elsewhere in the world.
- The total cost of the application or adoption of the technology relative to the environmental protection to be achieved by its application or adoption.
- Evidence of detriment, or lack of detriment, to the environment after the commencement of the waste management/disposal operation.
- The physical location of the operation.
- The age of equipment and facilities and their relative effectiveness in reducing environmental pollution and degradation.

Rehabilitation Plan

As described above there will need to be a rehabilitation plan for the site, with the difference here being the intention to have more NORM and other hazardous wastes stored in the facility than were there before. This changes the scale and type of risk assessment which is the basis for all the other rehabilitation plans.

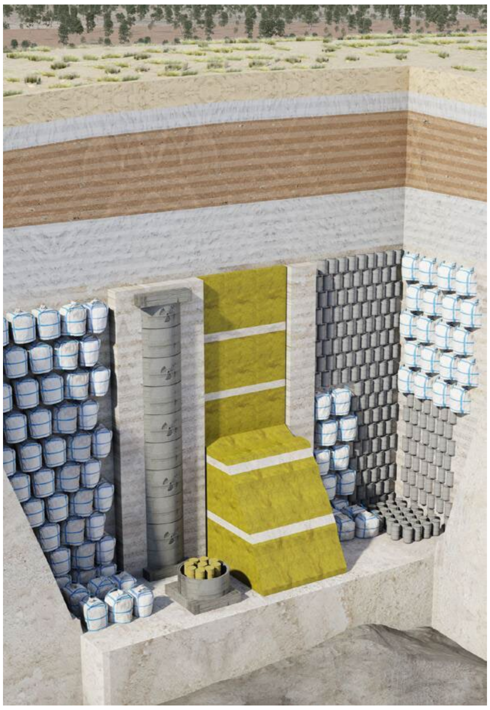

Figure 4. Tellus final state (from website)

The condition of the site to be rehabilitated, including the facilities and waste to be rehabilitated, levels of contamination, and quantities of waste are a primary focus of the plan. This includes the Waste Acceptance Criteria which was used during the facility operations, the packaging and barriers emplaced to contain the material and geology encapsulating the disposed material. This is the source term and barriers in the environmental safety case.

The rehabilitation will also include:

- Details of rehabilitation measures to be undertaken.
- Management of waste generated during rehabilitation.
- The anticipated final state of the site after rehabilitation, including estimates of the levels of residual contamination.
- Details on ongoing monitoring and surveillance that will be required after rehabilitation.
- Contingency plans and plans for remediation of any defects in the rehabilitation that may become apparent.

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2 BANGLADESH

2.1 Sources of NORM&TENORM

Bangladesh has not comprehensive nation-wide investigation/survey data on NORM &TENORM inventory. The locations and extents of the NORM&TENORM have never been studied and this should be one of national problems on controlling of NORM&TENORM. Most of the ongoing activities for NORM in the country is research based and deals with natural background radiation.

The probable NORM&TENORM industry/sources in Bangladesh

NORM&TENORM industry/sources	Number of facilities	Remarks
Natural gas field	28	Till now, 8 gas field do not come into operation -- product/by-products are: crude oil, condensate, HSD, MS, NGL, produced waters, sludge, scale etc.
Oil and Gas Exploration	3	In operation. Major waste: Sludge, scale, sediment, produced waters etc.
Water treatment and purification plant	4	In operation. Major waste: Sludge, scale, spent reign, spent filter media, spent membrane, concentrate, backwash water, rinse water, brine etc.
Coal mines	2	1 is in operation 1 decision pending Major waste: rock, slag, coal tailings, waste material, rock bank,

		culm, boney, or gob, heavy metals etc.
Coal fired power plant	2	1 plant is in operation. 1 plant is in trial for operation. Major waste: Fly ash, bottom ash, produced water, boiler slags etc.
Beach sand deposits	18 deposits	Product/by-products: heavy minerals,
Hard rock	1	Major waste: Waste rock, tailings, slag, wash slimes etc.
Fertilizer (natural) industry particularly phosphate	10	2 is phosphate based Product/by-products: Phosphogypsum, Phosphate slag, liquid and solid effluents, produced water, etc.
Cement production	43	Product/by-products: Cement kiln dust, debris, sludge, lignite fly ash, etc.
Ship breaking and metal recycling	179	Major waste: Sludge, scale, muck & debris, scrap, effluent, oil, grease and other refuses from ships

These industries may produce Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) at different radioactivity levels.

2.2 Management of NORM&TENORM

In Bangladesh, NORMs/TENORMs subject to human driven technological processing are yet to come under proper regulations to guide or enforce the industrial facilities generating NORM&TENORM. However, they are under occasional monitoring. Some case study with regards to NORM&TENORM are discussed below:

Case-1. NORM management of a scrap ship of ship breaking and metal recycling yard

End-of-life ship (dead) that was used as an oil and gas floating production storage and offloading (FPSO) vessel at an offshore oil field in the North Sea was imported and beached at the ship breaking and metal recycling yard. As per the reports of different national and international media, the vessel is likely to contain large amounts of residues that are contaminated by NORM and sulphur in addition to the various other hazardous materials in its structure and tanks. Therefore, radiation monitoring/survey was conducted for possible contamination and detection of radioactive materials present in the ship. High level of gamma doses was measured in the sludge filled oil pipes and collected sludges (Table 1). During the inspection, ^{226}Ra was detected by isotope identifier at the dismantle pipes storage area (sludge), indicating the presence of NORM in the sludges of pipe. The gamma analysis of the collected samples indicates that only naturally occurring radionuclides (^{238}U and ^{232}Th decay series and non-series ^{40}K) were present in the sludge samples with high activity (Table 2). Al the Sludge filled cargo oil pipes (also other pipes) were segregated from the ship, the open ends of each pipe were closed by metal jackets and transported on the yard with crane. Sludge filled cargo oil pipes were clean-up and stored in heavy duty plastic drum. 320 kilograms of sludges were stored in two drums and radiation levels were measured (Table 3). The clothing materials (e.g., masks, PPE, gloves, plastics, polyethylene etc.) were stored (30 kg)) in separate drum. Again, radiation levels were measured on the cleaned pipes as well as other pipes, oil tanks and different areas on the ship (Table 1).

Table 1. Dose rate and surface activity.

Location	Dose rate (μSv/hr.)	Surface activity (Bq/cm^2)
Different areas on the Ship	0.01–0.16	0.07–0.43
Sludge filled cargo oil pipes before cleaning the sludge	0.1–**8.54**	0.32–**3.88**
Cargo oil pipes after cleaning the sludge	0.02–0.15	0.22–0.66
Cargo oil pipes without having sludge (water pipe)	0.03–0.23	0.17–0.59
Oil tank (vessel)	0.10 - 0.17	0.17–0.54
Sludge filled pipe cleaning area on the shipping yard.	0.03 – 0.07	0.16-0.25

Table2. Activity concentration of the radionuclides present in the sludge samples of scrap ship

Sampling location	Sample ID	Activity concentration (Bq kg^{-1})		
		^{226}Ra (^{238}U)	^{232}Th	^{40}K

Concentrated sludge	CS-1 (Sludge)	10860.73±0.24	1460.33±0.30	145.25±1.60
	CS-2 (Sludge)	15845.10±0.24	2510.94±0.30	321.01±1.60
Oil pipe	OPS-3 (Sludge)	14975.62±0.24	1933.70±0.30	
	OPS -4 (Sludge)	15283.45±0.24	1960.54±0.30	
Oil tank	OTS-5 (Sludge))	2497.38±0.24	305.63±0.30	
	OTS -6 (Sludge)	414.08±0.24	67.37±0.12	
	OTS -7 (Sludge)	244.62±0.25	25.59±0.14	
	OTS -8 (Sludge)	1326±0.24	166.95±0.39	72.89±1.59
	OTS -9 (Sludge)	2588.45±0.24	285.84±0.31	
	OTS -10 (Sludge)	34.61±0.29	23.76±0.16	
	OTS -11 (Sludge)	16.71±0.29	3.18±0.19	

Table 3. Dose rate and surface activity of sludge filled drum.

Drum – 1 Weight = 120 kg	Reading position	Dose rate (μSv/hr.)	Surface activity (Bq/cm^2)
	Top	1.07	0.76
	Middle	2.80	4.30
	Bottom	3.30	4.25
	1 meter distance	0.22	0.50
Drum – 2 Weight = 200 kg	Top	2.90	2.90
	Middle	3.70	4.05
	Bottom	2.85	3.50
	1 meter distance	0.40	0.90
Drum –3 (CW) Weight = 30 kg	Top	0.11	0.34
	Middle	0.32	0.39
	Bottom	0.59	0.50
	1 meter distance	0.12	0.27

The sludge and clothing materials filled drums were sealed and temporarily stored in a room on the ship breaking yard and also sealed the room. Radiation levels of the sludge storage room was recorded (Table 4).

Table 4. Dose rate and surface activity of temporary storage room of sludge.

Reading place	Reading position	Dose rate (μSv/hr.)	Surface activity (Bq/cm^2)
Closed door of the storage room	Top	0.13	0.33
	Middle	0.13	0.52

	Bottom	0.15	0.31
	50 cm	0.11	0.30
	1 meter distance	0.08	0.28
Entry boundary of the storage room		0.06	0.18

After ending the cleaning work, radiation/contamination levels (dose rate and surface activity) of all the areas of the ship, such as ship base, side walls, oil tanks, oil pipes, scrap materials, cleaning areas, ship yard etc. were measured due to NORM contamination. The measured dose rate and surface activity are ranging from 0.01 – 0.17 µSv/h and 0.07 – 0.66 Bq/Cm^2, respectively which is comparable to the background level. The results show that all the monitored areas of the ship are considered free of NORM contamination and do not pose external radiation hazard to the people and the environment.

Case-2. NORM management of scraps of stainless steel

- A container containing scraps of stainless-steel including steel pipes (being exported) was seized by custom authority of sea port due to radiation alarm in their detection system.
- Therefore, radiation survey/monitoring around the detained container was performed.
- The maximum radiation dose rate of the suspected container was measured as 9.0 µSv/hr, which confirm the presence of radioactive material inside it.
- The scraps were unloaded and checked for dose and contamination levels.
- A total of 20 pieces of contaminated (with scale and sludge) steel pipes were recovered.
- The maximum dose and surface activity levels on the surface of the recovered materials were measured as 21.90 µSv/hr and 31.03 Bq/cm^2, respectively.
- The radioisotope identifier identified the presence of NORM (^{226}Ra and ^{232}Th).

The recovered contaminated (with scale and sludge) steel pipes were sealed in a box with proper shielding and transported to Central Radioactive Waste Processing and Storage Facility (CWPSF) for interim storage and further processing (Cleaning, characterization etc.).

1. NORM&TENORM characterization of some NORM producing industries/sources

The gamma analysis of raw materials, final products, by-products, solid and liquid waste generated from some NORM industries/sources indicate the presence of naturally occurring radionuclides (NORM) of ^{238}U(^{226}Ra) and ^{232}Th decay series and non-series ^{40}K with a relatively high activity in some cases (Table 5). Radioactivity may be concentrated and enriched in products, by-products, or wastes during the processing cycle of NORM industries.

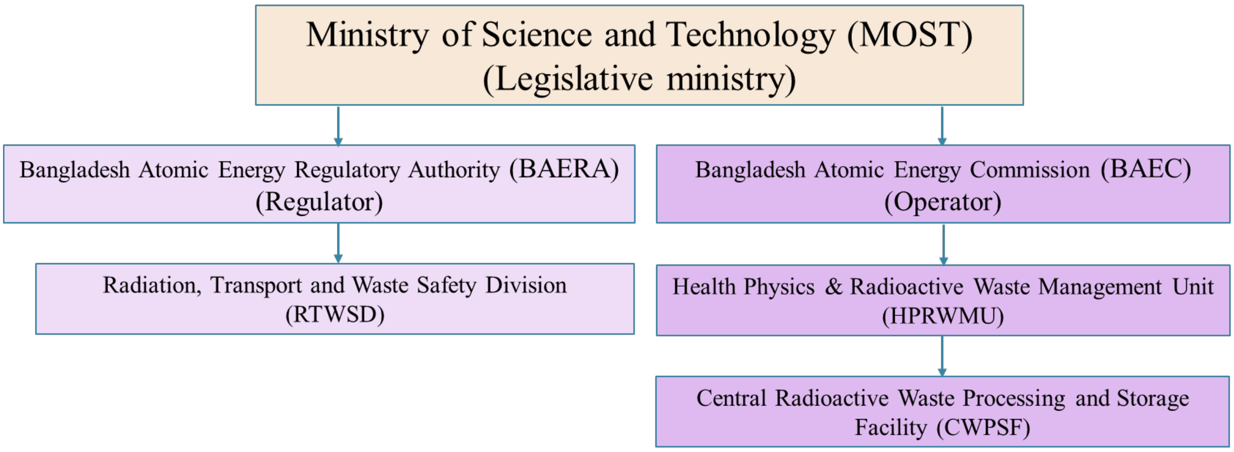
Table 5. Activity concentrations of radionuclides in raw material, final product, by-product and other wastes generated from some NORM industries/sources.

NORM industry/sources	Type of sample	Activity concentration (Bq kg^{-1})		
		^{238}U (^{226}Ra)	^{232}Th	^{40}K
Coal-fired power plant	Raw (bulk/core) coal	32.3 - 103.7	16.4 - 95.8	13.9 - 544.0
	Fly ash	203.9 - 329.5	231.2 - 263.7	260.2 - 277.8
	Bottom ash	149.3 - 190.2	157.7 - 188.1	183.9 - 187.0
	Pond ash	158.8	167.7	253.4
	Soil	33.0–118.0	43.0–182.0	318.3–743.4
Triple Superphosphate (TSP) fertilizer factory	Phosphate rock	772.78 - 906.60	9.33 - 36.13	29.60 - 99.79
	Phosphate fertilizer	197.52 - 221.70	35.05 - 47.48	ND
	Phosphogypsum	271 – 328	45.09 – 94.74	248.83 – 341.90
	Liquid waste	4.82 – 7.67	6.93 – 12.78	ND
	Waste-mixed river water	3.26 – 4.16	3.77 – 6.44	ND
	Soil	4.45 - 12.55	38.60 - 75.09	619.88 - 787.00
Beach sand mineral deposits	Raw sand	2400-2500	3300 - 4300	80 - 260
	Fractionated sand (processed)	7500-63300	14700-152,000	640-6200
	Zircon sand	6900–11700	1400 –19400	210–920
Building materials	Cement	41.0-82.8	58.8-75.4	915.4-1033.3
	Clinker	46.4-52.7	68.8-81.5	833.7-871.8
	Gypsum	53.9-63.8	89.6-93.9	1087.8-1113.9
	Brick	41.4-74.4	64.9–87.6	986.5–1156.8
	White sand	33.3 –63.3	60.8–82.5	832.4–1046.1
	Red sand	46.0–70.6	65.6–94.6	889.3–1136.2
	Tiles	7.23–65.04	67.12–75.72	969.64–1051.71
	Limestone	55.85 – 60.2	60.8 – 70.41	668.77– 928
	Lime powder	68.0 - 101.69	00.74 - 107	1012.83-1660
	Mosaic stone	36.32-73.44	48.01-61.49	893.52-1127.01
	Granite	37.05–93.18	50.40–120.06	891.70–1239.90

2.3 Legal and regulatory framework

The Legal basis for the safe management of radioactive wastes is Bangladesh Atomic Energy Regulatory Authority (BAERA) Act-2012, Nuclear Safety and Radiation Control (NSRC) Rules-1997 and National Policy for the Management of Radioactive Waste and Spent Nuclear Fuel-2019 (NPMRW&SNF-2019) based closely on the BSS apply to regulate activities that involve sources of ionizing radiation and management of radioactive waste. These rules and regulation cover the requirements for the inventory, storage and disposal of wastes arising from the usage of radioactive materials/sources and nuclear installation. But, in these rules and acts, there is no appropriate regulations to guide, control or enforce the industrial facilities generating NORM&TENORM.

National organization for radioactive waste management



Bangladesh Atomic Energy Commission (BAEC), a statutory body, was formed by the Presidential Order No. 15 of 1973 and worked as an operator in all radiological and nuclear activities in the country. To continue the functions of the Bangladesh Atomic Energy Commission established under the Bangladesh Atomic Energy Commission Order, 1973 (P.O. No. 15 of 1973 and re-enact the Act in updated form for the peaceful use, Research & development and promotion of atomic energy in Bangladesh, and execution of development projects involving nuclear power stations according to the international rules and regulations, nuclear and radioactive waste management and for matter incidental thereto; Bangladesh Atomic Energy Commission Act 2017 was formulated.

According to Bangladesh Atomic Energy Regulatory Act-2012 (BAER Act 2012) chapter-V and section no. 38 (Management of Radioactive Waste and Spent Fuel), the originator of the radioactive waste shall be responsible for the safe management of radioactive waste and security from its generation prior to their receipt at the radioactive waste management facility. The authorized person or facility shall ensure the availability of qualified staff and adequate financial resources. The details concerning regulatory requirements for management of radioactive waste, provide guidance, formulation of necessary regulations is the responsibility of regulatory authority.

The operator is responsible for the development of management procedures of waste, all activities involved in the handling, transportation, pre-treatment, treatment, conditioning, storage and disposal of radioactive waste in accordance with national strategy, in compliance with the regulatory requirements and within the legal and regulatory infrastructure. According to BAER Act 2012 chapter-V and section no. 38, radioactive waste shall be managed in the following way:

(a) to maintain sub-criticality;
(b) to ensure removal of residual heat;
(c) to reduce the effects of ionizing radiation on the radiation worker, people and the environment;
(d) to take into account properties influencing nuclear safety such as toxicity, flammability, explosiveness, and other hazardous properties.

NSRC rules 1997 describe the general requirements for radioactive waste management. The applicable standards, code and guide for Radioactive Waste Management program are IAEA Safety series nos. 53, 63, 79, 11-SF, 111-S1, 111-G1.1, G3.1 and other IAEA RADWASS publication. According to NSRC rules 1997, chapter-X and article. 87 (radioactive Waste Management), the licensee -

(1) shall comply with the following requirements for radioactive waste management: -

- the requirements of the applicable safety series published under the IAEA RADWASS Program.
- activity and volume of any radioactive waste that results they are responsible be kept to the minimum practicable.
- the waste be collected, transported, stored and disposed of in accordance with the requirements of the applicable standards.
- segregate, and treat separately if appropriate, different types of radioactive waste were warranted by differences in factor, such as radionuclide content, half-life, concentration, volume and physical and chemical properties, taking into account the available options for waste disposal.

(2) shall not dispose of licensed material without the approval of the regulatory authority.

According to the NSRC rules 1997 (Schedule-II), exemption level of NORM radionuclides activity concentration is as follows:

Radionuclides	Activity concentrations (Bq g^{-1})	Activity (Bq)
^{238}U	1×10^1	1×10^4
^{235}U	1×10^1	1×10^4
^{226}Ra	1×10^1	1×10^4
^{232}Th	1×10^0	1×10^3
^{40}K	1×10^2	1×10^6

Recently, National Policy for the Management of Radioactive Waste and Spent Nuclear Fuel-2019 has been approved by the government to support a sustainable and successful implementation of nuclear energy program in Bangladesh. The purpose of this policy relates to all types of radioactive wastes (RW) including Disused Sealed Radioactive Sources (DSRS), Spent Nuclear Fuel (SNF) and Naturally Occurring Radioactive Materials (NORM) generated in Bangladesh at present as well as to be generated in future. The main objective of this National Policy is to set up the goals and requirements for the safe and efficient management of RW, SNF, DSRS and NORM in a manner that protects human health and the environment now and in the future.

According to the national policy-2019, article 5.4 of section 5.0, disposal of RW in dedicated facilities duly licensed will be the ultimate end-point for the safe and sustainable management of any type of RW with the exception of exempted waste as per BAERA Act, 2012, NSRC RULES-1997, international laws, rules and regulations.

According to this national policy-2019, article 7.6.1 of section 7.6, a Waste Management Company (RWMC) will be established under Bangladesh Atomic Energy Commission (BAEC). Until a separate WMC is formed “BAEC” will be responsible for the management of RW generated from activities other than operation and maintenance of NPP.

As per article 13.1 of Section 13.0 (Management of NORM) and article 5.5 of section 5.0 (National obligations), NORM shall not be addressed as RW if otherwise not specified by the BAERA/Government and in-situ (on site) disposition will be the final option for NORM management in the country.

2.4 Issues related to NORM&TENORM

There is yet issues and challenges particularly in establishing national inventories and defining strategies to manage NORM wastes and residues including sampling & characterization and remediation (clean up) of the contaminated sites. The NORM industry has still not been defined. The regulatory area is not clear i.e., which industries should be regulated. One crucial problem in this area is the lack of consensus among the NORM industries, workers and the public with regards to radiation protection and safety. NORM wastes, and their management still proceed like those of ordinary production wastes. The technologies for disposal, recycling, and reuse of NORM&TENORM wastes and residues need to be developed.

3 CHINA

3.1 Sources of NORM&TENORM

In China, NORM mine refers to non-uranium mines containing relatively high concentrations of natural radionuclides (e.g. rare earth mines and phosphate mines, etc.). Radioactivity will probably be concentrated and enriched in products, by-products or wastes in the process ofprocessing, smelting and utilizing of NORM mines.

NORM&TENORM ubiquitous existing in rare earth, phosphate and non-ferrous metal industries has been paid attention for long term in China. Some regulatory requirements have been established and enacted.

“List of Radiation Environment Supervision and Management for the Exploitation and Utilization of Mineral Resources” (Announcement No. 54 of the Ministry of Ecology and Environment 2020) lists the types of minerals and corresponding industrial activities that need to be supervised and managed by radiation environment (see Table 1).

Table 1. List of radiation environment supervision and management for the exploitation and utilization of mineral resources

Serial number	Mineral category	Industrial activity
1	Rare earth	Mining, mineral processing and smelting of various rare earth minerals (including cerium fluoride, yttrium phosphorite and ionic rare earth ore); Mineral processing and smelting of monazite
2	Zirconium and zirconia, niobium/tantalum, Tin, aluminum, lead/zinc, copper, iron, vanadium, molybdenum, nickel, germanium, titanium, gold	Mining, mineral processing and smelting
3	phosphates	Mining, beneficiation and processing activities directly from phosphate ore
4	coal	Mining，beneficiation

3.2 Management of NORM&TENORM

Since the 1970s, China began to pay attention to the radiation environment management of NORM industrial activities, mainly focusing on the management of associated radioactive mine tailings and waste residues. Since the 1980s, under the leadership of the National Environmental Protection Department, several large-scale investigation activities have been carried out, including NORM waste. These include the national survey of natural radioactivity levels conducted from 1983 to 1990, the first national survey of pollution sources conducted from 2006 to 2009, and the second national survey of pollution sources conducted from 2017 to 2019. In addition, in the past ten years, with the support of the nuclear and radiation safety supervision project of the Ministry of Ecology and Environment, some scientific research institutions and universities have carried out radiation level investigations and impact assessments of some typical NORM enterprises. Among them, the second national survey of pollution sources has the most recent time and the most extensive coverage, screening nearly 29,700 enterprises in 15 categories of industries across the country, and determining a total of 464 NORM enterprises. The monitoring items for solid waste in the second national survey of pollution sources included the activity concentrations of ^{238}U, ^{226}Ra and ^{232}Th in tailings and waste residues.

The results of the second national survey of pollution sources on the radioactive level of mineral resources development and utilization industry show that by the end of 2017, the cumulative storage capacity of NORM waste (more than 1 Bq/g) is about 2 billion tons, of which the solid waste with a radioactive activity concentration of more than 10 Bq/g is mainly rare earth, niobium/tantalum, zircon and zirconia, lead/zinc, germanium/titanium, iron and other minerals. The total amount is about 2.25 million tons. The industry with the largest cumulative storage volume of NORM solid waste is the iron and steel industry, accounting for more than 99%, and other minerals with large storage volumes include coal, aluminum, rare earth and so on. The radioactive levels of rare earth, niobium/tantalum, lead/zinc, zircon, zirconia, germanium/titanium, tin and other NORM solid wastes are high. Among them, the average activity concentration of ^{238}U in niobium/tantalum solid waste is the largest, about 19 Bq/g, followed by phosphate, copper and rare earth, about 3-4 Bq/g. The average activity concentration of ^{232}Th in rare earth NORM solid waste is the highest, which is about 50 Bq/g. The average activity concentration of ^{226}Ra in niobium/tantalum solid waste is the highest, about 20 Bq/g.

At present, China's NORM waste management focuses on storage and disposal, and the most concerned waste types are all kinds of tailings and smelting waste. The main management methods include tailings wet storage, underground discharge, temporary storage in storage, near-surface landfill disposal, rock cave disposal, and so on.

In addition to a very small part of the tailings is used, most of the tailings are stored in the tailings pond. According to statistics, there are more than 10,000 tailings ponds in China, of which

80% are metallurgical and non-ferrous metal industries. Wet storage of metal mine tailings is the main disposal method at present.

In all kinds of industries involving NORM, due to the high level of radioactivity in rare earth mines, more attention has been paid to radiation regulation in the early stage. In China, the waste rock and tailings generated by Baiyun Ebo bastnaesite-monazite mine are mainly used to backfill the gob, and the monazite concentrate that is expected to recover rare earth or thorium is temporarily stored in the form of tailing ponds/tailings DAMS, and certain covering measures are usually taken. The Baiyun Ebo bastnaesite-monazite mine has tried to carry out recycling methods such as using blast furnace slag for making building materials and recovering iron.

Temporary storage, as part of NORM waste management, provides time for radionuclides to decay until approved for recycling, reuse, or clearance.

A small percentage of NORM waste is currently recycled or reused after treatment. This may involve waste from some industries being used as raw materials in other industries, such as for making new products such as building materials. This practice helps to reduce the amount of waste while creating some economic value; However, in some cases, it may also lead to radiation effects on workers, the public and the environment.

The main purpose of NORM waste recycling is to recover the metals in it. This is because the tailings or waste residues usually contain a certain amount of target metals or other metals, among which iron is the most common, as well as copper, aluminum, zinc, vanadium, thorium, rare earth elements, scattered metals, etc. When these metals reach a certain grade, they have the value of further recovery. In addition to metals, it is possible to recover other useful ingredients such as salt and sodium sulfide. Common processes are leaching, oxidation, reduction, electrolysis and so on.

At present, the common way of NORM waste reuse is to make basic building materials or super-performance building materials, such as cement additives, roadbed materials, tailings composite ceramics, etc. It is also expected that it may be used as special functional materials, such as glass-ceramics, snow melting agents, passivating agents for repairing contaminated soil, etc.

3.3 Regulatory Base or Framework

Currently, China still has not specific regulation directly control of NORM&TENORM but NORM&TENORM management has been involved in other legislative documents.

Legislation system in nuclear safety and radiation safety composed of 5 hierarchy, i.e. law, regulation, department rule, standard and technical guideline.

a) Law

“Law on the Prevention and Control of Radioactive Contamination” went into force on 2003-10-01 is the first law on radioactive waste management. This law set up specific chapter for NORM&TENORM, i.e. Chapter V: Prevention and control of radioactive contamination during the operation of uranium, thorium mines and mines accompanying natural occurring radioactivity material (NORM).

The law states:

·units exploiting and utilizing mines with NORM shall, before applying for a mining license, draw up an environmental impact report and report to the competent environmental protection administration department of the people’s government at provincial level and higher for examination and approval;

·radioactive contamination prevention and control facilities integrated with structural units at uranium, thorium and NORM mines shall be designed, constructed and put into operation at the same time as the main part of the project;

·radioactive contamination prevention and control facilities shall be checked and accepted at the same time as the main part of the project; only after checking and accepting that the standards have been met the main part of the project be put into production or operation; and

·tailing repositories shall be constructed for the storage and disposal of tailings produced during the operation of uranium, thorium and NORM mines; tailing repositories shall conform to radioactive contamination prevention and control requirements.

b) Department Rule

In “List of Radiation Environment Supervision and Management for the Exploitation and Utilization of Mineral Resources” (Announcement No. 54 of the Ministry of Ecology and Environment 2020), the construction enterprises related to mineral resource development and utilization activities listed by the Ministry of Ecology and Environment are required to give a conclusion on whether the activity concentration of uranium (thorium) series single nuclide in raw ore, intermediate products, tailings, tailing slags or other residues exceeds 1 Bq/g in the environmental impact statement (list). For more than 1 Bq/g, the construction unit shall organize the preparation of radiation environmental impact assessment, and incorporate the environmental impact statement (list) for approval; When the construction unit completes the acceptance of environmental protection, it shall organize the acceptance of the radiation environmental protection facilities built in support of the construction, organize the preparation of radiation environmental protection acceptance monitoring reports and incorporate them into the acceptance monitoring reports.The above requirements correspond to the regulatory documents "Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises Engaged in the Exploitation and Utilization of Associated Radioactive Mines (Trial Implementation)" (2018) and

"Format and Content of Special Paper on Environmental Impact Assessment of Radiation in the Exploitation and Utilization of Mineral Resources (Trial implementation)" (2015).

c) Standard and Technical Guideline

Due to the large number of NORM industries, our country has not set up a special standard widely used in the regulation of NORM industry radioactivity, and there are some national standards and industry standards related to NORM management.

“Basic standards for protection against ionizing radiation and for the safety of radiation sources” (GB 18871-2002) provides radiation dose limits and corresponding nuclide exemption levels.

The “Regulations on Radioactive Waste Management (GB 14500-2002)” is the comprehensive standard on radioactive waste. The specific chapter on NORM&TENORM is set up in the standard. The standard stipulates basic requirements on NORM&TENORM waste management, which can be summarized as the followings: waste generators are responsible for taking effective measurements to manage NORM&TENORM waste; necessary facilities for waste management shall be set up;discharging of gaseous and liquid effluents should not exceed the limitation approved by regulatory bodies; environmental impact assessment files should be submitted and approved before constructing disposal facilities of NORM&TENORM solid waste; for NORM&TENORM solid waste or residues already existed, remediation measurements should betaken; status of radioactivity in the environment should be assessed before closure and decommissioning of waste generating facilities; and reuse and recycle of NORM&TENORM waste shall be reviewed and approved by regulatory bodies.

“Activity concentration for material not requiring radiological regulation” (GB 27742-2011) stipulates that activities involving natural radionuclides in materials with an activity concentration of less than or equal to 1Bq/g are generally not subject to radiation protection regulation, provided that the legitimacy of the declared activity is confirmed.

In March 2020, the Ministry of Ecology and Environment issued the “Technical specifications of radiation environmental protection for other radioactive material’s storage and solid waste’s landfill (Trial)”(HJ 1114-2020). To specify the radiation environmental protection principles and general technical requirements to be observed by the waste landfills of rare earth, niobium/tantalum, zirconium and zirconia, tin, lead/zinc, copper and other NORM industrial activities. Among them, for the disposal of uranium (thorium) series single nuclide activity concentration greater than 400 Bq/g NORM waste, more stringent environmental protection measures should be taken according to the actual situation.

Other standards include “Format and content of acceptane monitoring report of radiation environmental protection for completion of development and utilization project of other radioactive mines"(HJ1148-2020), "Limit standards for ^{226}Ra in phosphate fertilizer and its compound fertilizer"(GB8921-2011), "Emission standards of pollutants from rare earths industry"(GB26451-2011), "Limits of radionuclides in building materials"(GB6566-2010), and "Limitation concentration of natural radioactivity in non-ferrous metal ores and concentrates products"(GB20664-2006).

3.4 Issues related to NORM&TENORM

Although China has been concerned about the radiation effects of NORM activities and NORM waste for nearly 40 years, and has carried out the investigation of radioactivity levels and the construction of regulations and standards, there are still various issues that need to be addressed, mainly including:

(1) The source item of waste is unclear, and there are difficulties in classification of storage and disposal. Because NORM waste involves many industries, a wide range, and the composition and level of nuclide are not fixed, although China has carried out a large number of investigations, including the first national survey of pollution sources, the second national survey of pollution sources and other special investigations, but at present, it is not completely accurate and clear to grasp the key indicators of waste distribution, quantity, type, and level of nuclide, which causes difficulties in management. Due to the large amount of NORM waste and the extremely long half-life of the major nuclides it contains, disposal policies and technologies are still in the research stage. The cost of sending radioactive solid waste disposal sites is high, and the waste is difficult to dispose in time. At present, the main outlet of NORM waste is: return to the raw material, disposal in the tailings pond or pile up, open stacking, etc., there are great security risks.

(2) Lack of risk assessment method, hierarchical management system has not been established. NORM waste mainly contains natural radionuclides, considering its inherent safety, poor accessibility to personnel, and predictable way and frequency of exposure to the public, according to international requirements and practices, such waste disposal should be implemented on a risk-based level management. Hierarchical management can be applied to the level of detail in radiation regulation methods, disposal routes and safety assessments. From the perspective of regulatory methods, it is divided into exemption, notification, filing and licensing. From the perspective of disposal route, it can be divided into exemption, unconditional clearance, landfill disposal of general waste, NORM waste special disposal facility, radioactive waste disposal facility, etc. From the point of view of safety evaluation, generally, modular parameters, scenarios and models can be used to carry out evaluation, and the complexity of evaluation methods should match the degree of risks. At present, the technical foundation of radioactive waste disposal risk assessment in China is weak, the lack of relevant practice and consensus, the hierarchical management system can not be established, it is difficult to improve the economy of disposal on

the premise of ensuring safety, and the timely disposal of NORM waste has brought adverse effects.

4 INDONESIA

4.1 Sources of NORM&TENORM

All minerals and raw materials contain radionuclides of natural origin (decay series of U-238, Th-232, and K-40). Material giving rise to significantly enhanced exposures has become known as naturally occurring radioactive material (NORM).

Indonesia has 2 terms related to the NORM, i.e., NORM and TENORM. NORM comes from nature without technology, and TENORM (Technologically Enhanced Naturally Occurring Radioactive Materials) comes from industrial activities.

In this report, we present the current status of TENORM in Indonesia.

Some sources of TENORM in Indonesia are coming from :

a. Metal Extraction and Processing: Tin (No. 2 in the world), Nickel (No.2 in the world), Copper (No. 4 in the world)
b. Oil and Gas Industry
c. Coal Electricity Generation
d. The phosphate industry
e. Water Treatment
f. Geothermal Energy Generation
g. Iron and Steel Production
h. Scrap Metal Recycling
i. Alumina Production
j. The zircon and zirconia industries

The TENORM data are primarily from metal extraction and processing, the oil and gas industry, and coal electricity generation. The Tin industry of Indonesia is the second largest production of tin in the world.

Table 1. TENORM inventory of tin industry in Bangka Island.

No.	Material Name	Estimated Production (tons/year)	Radionuclide concentration (Bq/kg)		
			Ra-226	Th-232	K-40
1.	Refined tin	64,000	< LLD	< LLD	< LLD
2.	Slag	31,500	3,364 – 6,123	1,585 – 16,431	3,602 – 8,714
3.	Zircon	17,000	4,675 – 12,641	1,280 – 12,958	101 – 942
4.	Ilmenite	67,000	4,450 – 5,629	3,313 – 15,513	220 – 570

5.	Monazite	17,000	14,568 – 31,027	23,214 – 152,639	1,705 – 9,687
6.	Waste of tin tailing industry	33,000	3,390 – 6,004	5,451 – 10,144	390 – 663

From the inventory, it concluded that the TENORM concentration in tin mining/processing is very high (>> 1 Bg/g)

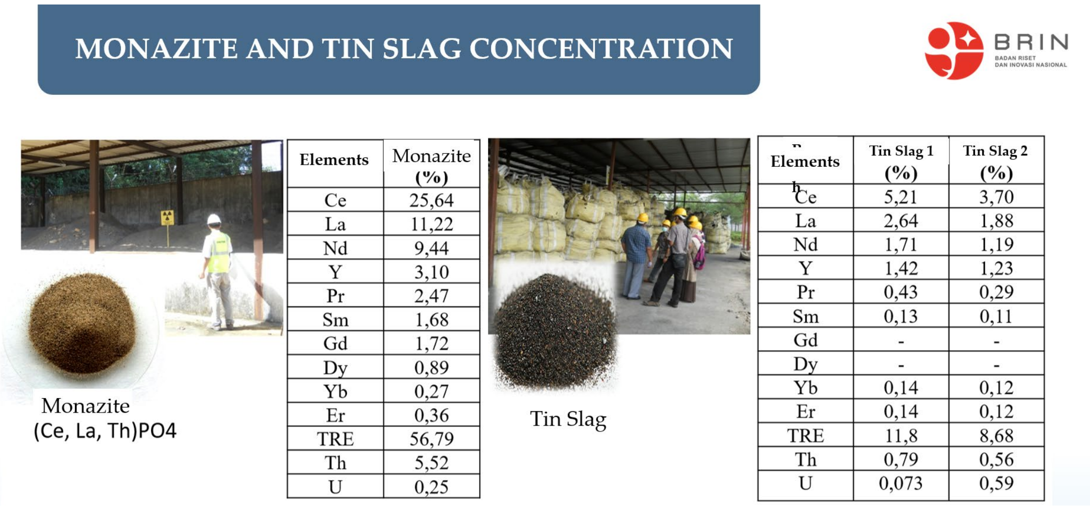


Figure 1. Elements concentration of TENORM residue from post-tin mining/processing

The elements concentration of post-tin mining/processing as TENORM residue in the form of monazite and tin slag contains uranium, thorium, and critical elements, which are still of high value (Figure 1). The content of elements that have economic value is still in the effort as research material for their extraction to achieve a circular economy.

Figure 2. Pilot Plant of Separation Uranium, Thorium and Rare Earth (BRIN) and RE concentrate product (insert)

The development of monazite processing technology using the alkaline method has been carried out on a pilot scale with the establishment of a pilot plant for processing monazite into REE hydroxide at KST GA Siwabessy – BRIN, Lebak Bulus, South Jakarta (Figure 2). This pilot plant has a processing capacity of 50 kg monazite/batch. A series of experiments can produce REE hydroxide/carbonate products with a content of 80% and a radioactive content of less than 100 ppm.

To downstream monazite processing results, REE hydroxide concentrate processing technology has also been developed to separate REE elements. R&D activities carried out at KSE Baiquni – BRIN Babarsari, Yogyakarta, have produced summary process technology for the elements cerium (Ce), Lanthanum (La), and Neodymium (Nd). The summary technology for the three REE elements has also been carried out on a pilot scale with a processing capacity of 10 kg REE hydroxide/batch. The products produced are cerium oxide (CeO_2) 96%, lanthanum oxide (La_2O_3) 96%, and Nd hydroxide concentrate ($Nd(OH)_3$) 58%.

4.2 Management of TENORM

The procedures of TENORM Management in Indonesia, in general, the company generated TENORM should conduct a radiological study to know what kind of radiation protection should be applied. If there are any contaminated sites, they will ask to make a clean-up for these sites. The TENORM residues/wastes would be stored at their interim storage.

4.2.1 Radiological Assessment

Oil and gas companies that have been surveyed for TENORM in Indonesia are commonly in the big island of Indonesia archipelago such as Sumatera Island, Java Island, Borneo Island and Papua Island. The oil and gas companies that have been surveyed are domestic companies and also foreign companies. A map of the locations of oil and gas companies that have been surveyed for TENORM can be seen in Figure 3.

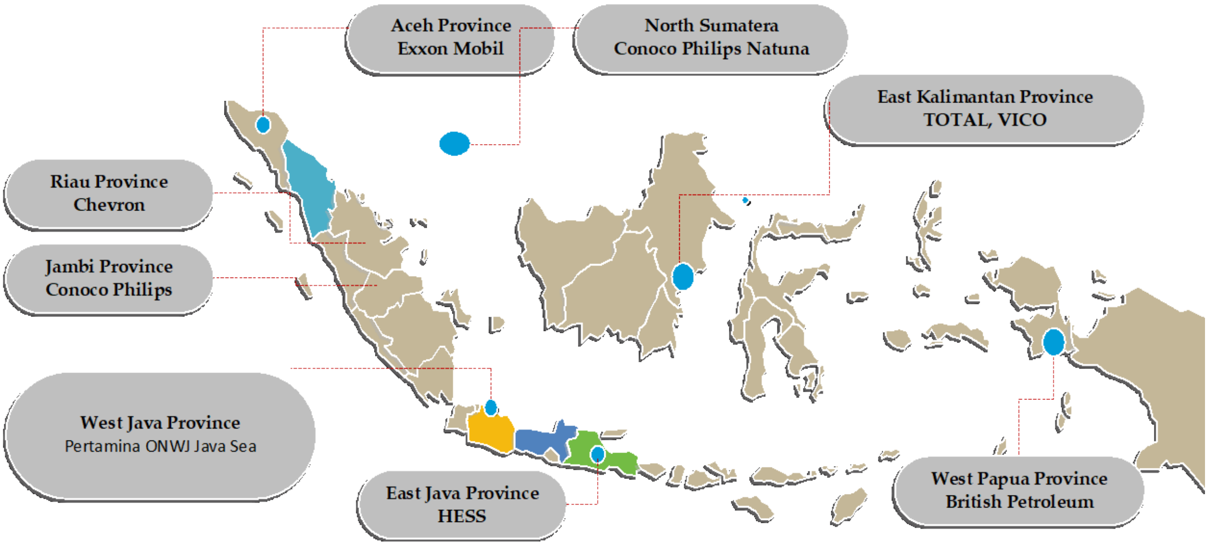


Figure 3. Oil and gas companies that have been surveyed for TENORM.

A radiological assessment is then carried out in the surveyed area by measuring the total level of radiation dose, both internal and external. An example of estimated total dose from external and internal radiation at one oil and gas company is presented in the Table 2.

Table 2. Total Effective Dose

No.	Site	Area	Location	Total Effective Dose (μSv/a)
1.	CPU	PWT	Tank T-5310, T-5320, T-5330	371 – 1901
2.	CPU	Bunker	Bunker 1	883
3.	CPA	PWT	Tank T-760	59 – 235
4.	Handil	HTS	External cleaning box	943 – 1887
5.	Handil	PWT	Front Mushola Tank T-2, T-3, T-5	255 – 1050
6.	BSP	TPA	Decreasing boot Around V-2700	197 – 1181
7.	BSP	TLA	Tank T-960, T-970, T-980, T-990, T-2070	498 – 4609

Decision making then conducted after the radiological assessment. The company make decision to clean up the site according to the international regulation on the management of TENORM.

Below is the map of the Coal Power Plant (CPP) surveyed by TENORM for a site clean-up.

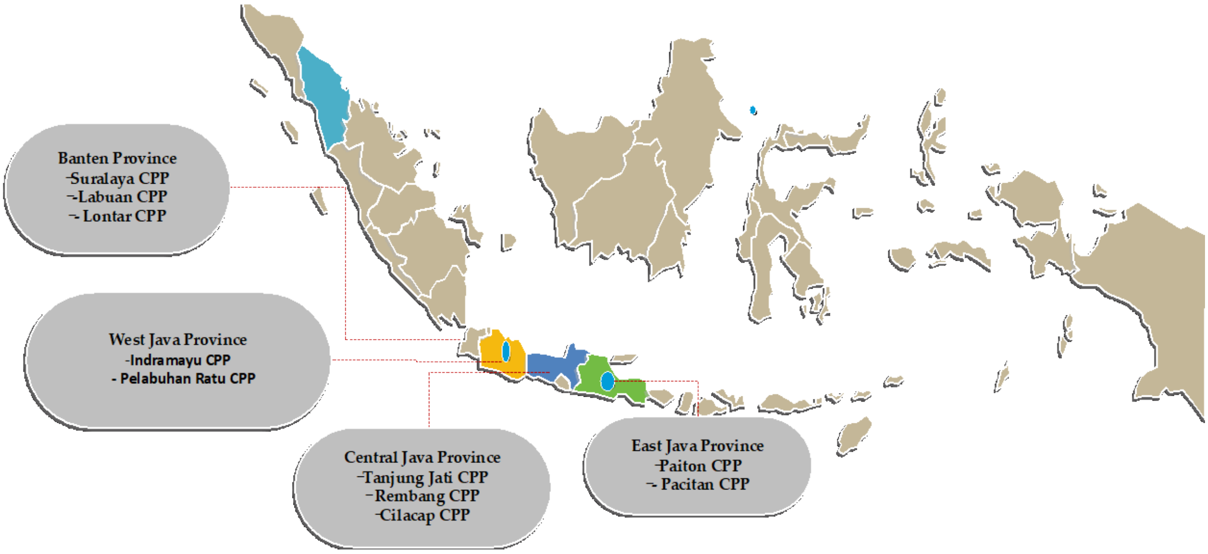


Figure 4. Coal Power Plant (CPP) that have been surveyed TENORM.

After radiological mapping was carried out, the TENORM concentration content was measured. TENORM concentration in fly ash are presented in the Table 3.

Table 3. TENORM concentration in fly ash.

Sources	Concentration (Bq/kg)		
	Ra-226	Th-232	U-238
PLN, Paiton, East Java	42.62 ± 4.32	38.62 ± 3.92	17.14 ± 1.80
PLN, South Sulawesi	75.61 ± 7.86	44.28 ± 4.99	<1.00
PLN, North Sumatera	88.25 ± 8.95	88.39 ± 8.95	30.56 ± 3.55
PLN, Tj. Jati, Central Java	51.31 ± 5.12	56.83 ± 5.61	30.22 ± 3.24
KPC, East Kalimantan	50.11 ± 5.33	46.02 ± 4.90	21.72 ± 2.18

Radiological Assessment of Tin Industry:

- Radiological assessment at TIMAH Inc. and KOBATIN Inc.;
- Radiological assessment at some tin smelters;
- Radiological assessment in conventional Mining and industries;

- TENORM characterization at tin sand, tin residue, monazite, zircon, ilmenite, tin slag, and waste.

Radiological assessment in other industries:
- TENORM characterization and radiological assessment at phosphate industry in Gresik, East Java;
- TENORM characterization and radiological assessment at incandescent gas mantle (*Welsbach mantle*) industry in Tangerang
- TENORM Characterization in the Drinking Water Industry
- TENORM Characterization in Geothermal Energy Generation

4.2.2 Clean Up / Remediation

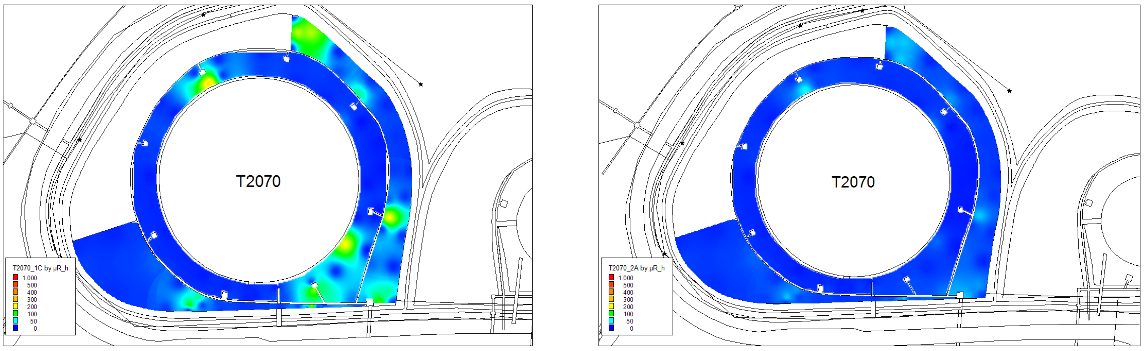
Clean up / remediation for the contaminated area in Indonesia:

- Clean Up of TENORM contaminated area at incandescent gas mantle (Welsbach mantle) factory at Tangerang, Java Island.
- Clean Up of TENORM contaminated area at Chevron oil and gas company at Jambi Area, Sumatera Island.
- Clean Up of TENORM contaminated area at Total Indonesie oil and gas company at Senipah Area, East Kalimantan.
- Clean Up of TENORM contaminated area at Phosphate Industry at Gresik, East Java.
- Clean Up of TENORM at Pertamina ONWJ, Java Sea

Experience in the clean up in the oil and gas company

- Stripping areas around Tank T-2070. TENORM may come from the sandblasting activities to cleaning the tank as it used upper slag. The upper slag has a higher radioactive content.
- Found some sacks containing TENORM. Some sacks are still intact, and they are already destroyed.
- There is a TENORM depth of more than 75 cm.

Figure 5. Clean up activities in the contaminate site of the oil and gas company.



(a) (b)

Figure 6. Radiological map of the clean-up site. (a) before clean up; (b) after clean up.

4.2.3 Management of TENORM Residue

1) TENORM Residue from the incandescent gas mantle (*Welsbach mantle*) has been put at Interim Storage in the Center for Radioactive Waste Technology – BATAN
2) TENORM Residue from remediation at Total Indonesie Oil and Gas Company has been put in Interim Storage.
3) TENORM Residue from remediation at Chevron Jambi has been put in the BATAN area as the TENORM laboratory.
4) TENORM-contaminated pipes have been put in field storage with Radiation Sign.

5) TENORM Residue from the Phosphate Industry has been put in Interim Storage in the Center for Radioactive Waste Technology – BATAN.
6) The Tin Industry has residues with high radionuclide concentrations. Some technologies have separated the residues to get Monazite, Zircon, Ilmenite, etc. Zircon and ilmenite could be sold in the market, and monazite with high concentrations of thorium, uranium, and rare earth elements (REE) becomes the strategy materials.

BATAN (now BRIN) has the facility to separate thorium, uranium, and rare earth concentrate (RE hidroxide/carbonate). RE concentrate would be separated into elements such as Lanthanum, Cerium, Praseodymium, Neodymium, etc., in different pilot plant.

4.2.4 Management of TENORM Waste

Based on Indonesian government regulations related to TENORM waste management, TENORM waste is included in the hazardous waste category which contains radioactivity. The final management for this waste is landfill or disposal and a minimum of landfill class II. BATAN (now BRIN) is currently researching the prospective sites and design for TENORM waste disposal in Bangka and Belitung Island.

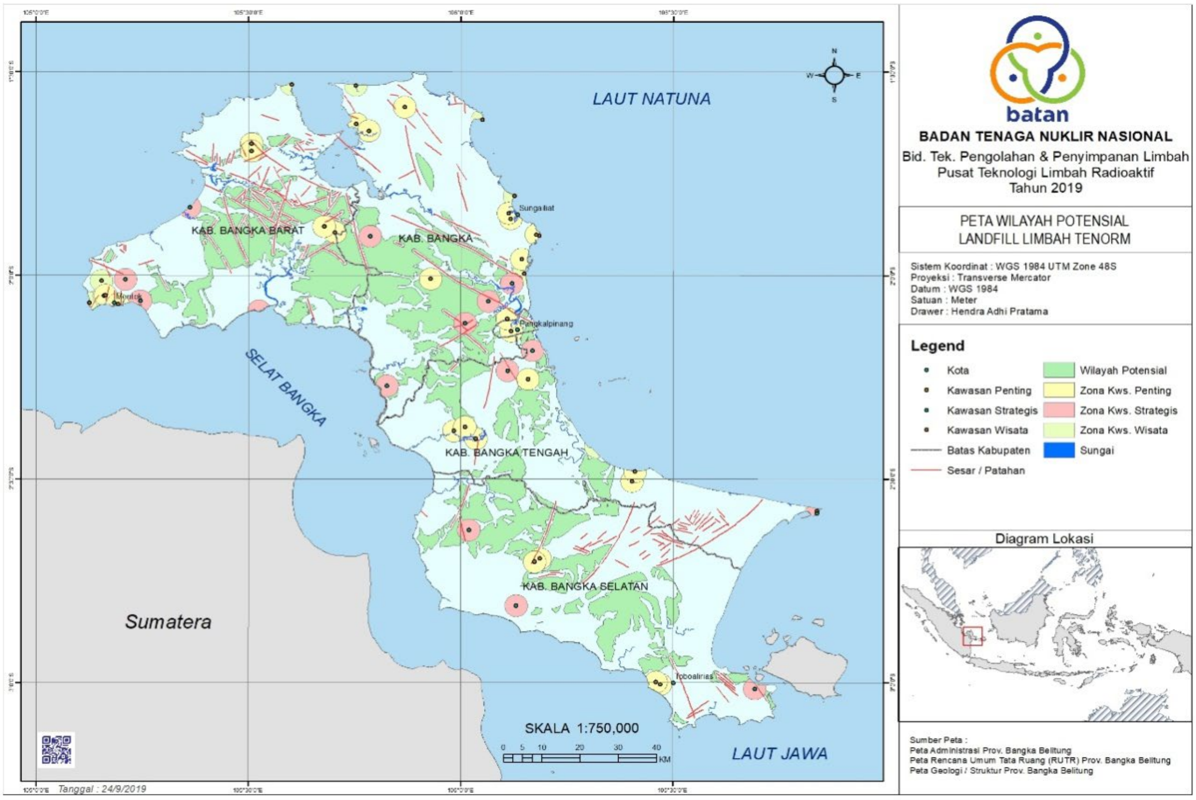


Figure 7. A potential area for Tenorm landfill in Bangka Island.

4.3 Regulatory Base or Framework

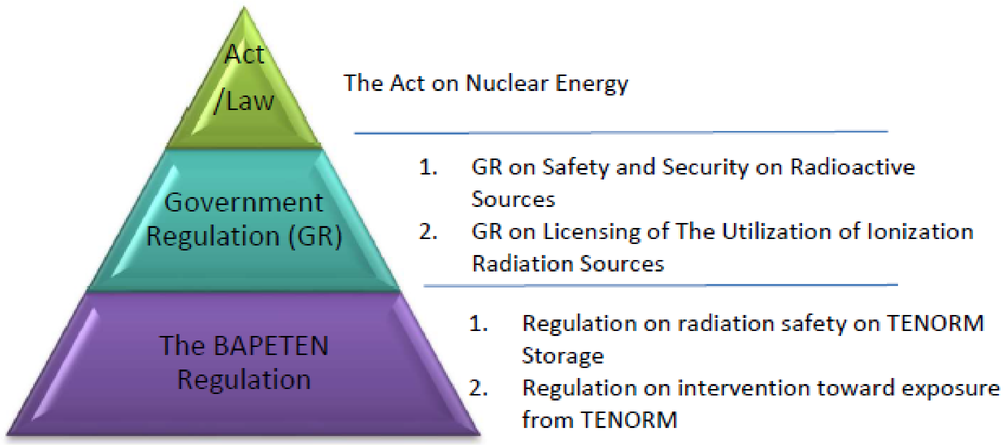


Figure 8. Hierarchy of TENORM legislation in Indonesia.

- Interventional Level in Indonesia could be expressed in terms of:
  a. The amount or quantity of TENORM is at least 2 tons and
  b. Contamination level equal to or more than 1 Bq / cm^2; and /or activity concentration of:
    - 1 Bq/gr for each radionuclide in the uranium and thorium series or
    - 10 Bq/gr for potassium.

- The TENORM producer should perform a radiation safety analysis of TENORM.
- The radiation safety analysis for TENORM includes at least the following:
  a. types and processes of activities carried out;
  b. TENORM quantity;
  c. types and concentration levels of radionuclides; and
  d. Highest radiation exposure and/or contamination on the TENORM surface.
- Radiation safety analysis would be assessed by the Regulatory Body (BAPETEN). If the assessment shows the Intervention Level is exceeded, the TENORM Producer should implement the interventional measures.

4.4 Issues related to TENORM

The issues related to TENORM in Indonesia are:

1) Regulation. Due to the conflicting and inconsistent norms in some regulations in Indonesia, coordination among authorities is necessary to establish the national system of TENORM management in Indonesia. Moreover, the considerable amount of TENORM that comes from activities in the past and the national geographical location of Indonesia as an archipelagic country also give more challenges to control the TENORM. Besides that, new regulations on TENORM should be based on a graded approach;
2) Radiation Protection. Workers in industry-generated TENORM still have low knowledge of radiation protection;
3) Decontamination. Techniques for decontamination of TENORM-contaminated goods or equipment;
4) Circular Economy. Circular economy of TENORM residues;
5) Interim Storage. Interim storage of TENORM residue/waste has a minimal area with poor quality;
6) Disposal. Indonesia has no final disposal for TENORM waste.

5 JAPAN

5.1 Sources of NORM&TENORM

The information in this chapter is extracted from the document "Exemption from regulation of natural radioactive substances" [Radiation Council MEXT Japan, 2003], which is related to NORM sources.

5.1.1 Overview

The UNSCEAR 2000 Report and RP-122 provide information on radioactivity levels for minerals and other materials containing natural radioactive materials.

According to RP-122, it has been shown that not only those with originally high radioactivity levels that may exceed the BSS exemption level, but also those with low radioactivity levels may unintentionally increase the ratio of uranium and thorium in the residues and by-products produced in the process of extracting useful materials, resulting in concentrations that exceed the BSS exemption level. It is believed that the resulting concentrations may exceed the BSS exemption levels. In addition, many of these minerals and other materials are present in the living environment as general consumer goods (products) after being chemically and physically processed.

Therefore, a survey was conducted by the Nuclear Safety Division (Nuclear Regulation Office and Radiation Regulation Office) of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) on operations and general consumer goods that handle materials containing naturally radioactive materials. This survey was conducted for the purpose of preparing basic data for considering policies for regulatory exemptions.

5.1.2 Industrial use

(1) Overview

Japan is dependent on imports from overseas for raw materials used in its industrial activities, with the largest imports amounting to over 100 million tons per year. These industrial activities have a long history. The survey covered monazite, phosphate, titanium ore, bastnaesite, and zircon, which are considered to have relatively high concentrations of natural radioactive materials among the ores used in industry, as well as coal, which is imported in large quantities, and samarium oxide, whose concentration as a single metal exceeds the BSS exemption level.

Air radiation dose rates were measured using a NaI(Tl) scintillation survey meter . The radioactivity concentrations of uranium, thorium, and samarium in the collected samples were measured using an inductively coupled plasma mass spectrometer (ICP-MS), and the specific activities of U-238, Th-232, and Sm-147 were determined by multiplying the specific activity of each nuclide. The doses from those containing uranium and thorium were calculated from the air radiation dose rate, etc., and those containing samarium were calculated from the radioactivity concentration in the air, etc.

(2) Results of the survey

As a result of the investigation, if 1 Bq/g, which is the BSS exemption level for Th-232 series nuclides and U-238 series nuclides (as Th-232 and U-238, respectively) and 0.5 Bq/g for RP-122 are assumed as reference values for the radioactivity concentration of raw ore, those exceeding these values were found in monazite, phosphate ore, zircon and samples collected from the Bastnesite plant. Only samples from Jordan and Morocco exceeded the reference value for phosphate. This indicates that there are differences in radioactivity concentrations depending on the producing country. Monazite, zircon, and bastnaesite are not chemically treated, so the chemical composition of the raw materials remains unchanged, or they are mixed with other substances and sold as products on the market. The waste generated in the process of each ore is treated as industrial waste, but none of the waste was found to exceed the guideline values due to dilution in the process.

As a result of the measurement of the air radiation dose rate, even if the radioactivity concentration of the raw ore was low, there were cases where the radiation dose rate was relatively high, such as several μSv/h at a distance of 1 m from the object due to the adhesion of can stones (scale)f during the process. However, the maximum annual external radiation dose to workers is about 0.40 mSv/year at the product storage area at the Bastone site, considering the actual working hours. It is estimated that the inhalation of dust is small because workers wear masks for dust control when handling powdered materials such as raw material powder. In addition, the air radiation dose rate at the site boundary is equivalent to the national natural radiation dose rate of 0.004 to 0.11 μSv/h (excluding cosmic rays), and is not considered to pose a particular safety problem to the general public.

Samarium oxide is imported from China, France, and other countries at a rate of about 100 tons per year. Some of it is processed into ceramics materials, and the remainder is metallized to form alloys with cobalt and other materials to be used as raw materials for magnets. Magnets are used in various fields. Samarium contains Sm-147, a naturally occurring radionuclide that emits only alpha rays, so internal exposure must be considered. During the production process of alloys and magnets, there are processes that generate dust, such as crushing and sintering. Therefore, the airborne concentration in the work area in each process was measured and the effective dose due to samarium was calculated. As a result, the annual effective dose due to samarium was about 10-380 μSv when the particle size of the dust was between 1-50 μm, assuming a breathing rate of 1.2 m^3/hour and an annual work time of 2,000 hours. This is calculated based on conservative assumptions, and the dose would be even lower if an assessment is made taking into account the wearing of masks (protection factor of masks: and actual working hours, etc. For these reasons, it is unlikely that the annual dose will exceed 1 mSv.

Table 1 shows the results of the survey on the actual utilization of ores containing uranium and thorium. The monazite listed in this table is regulated as a nuclear raw material by the Law Concerning Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (hereinafter referred to as “Nuclear Reactor Regulation Law”). The monazite listed in this table is subject to regulation under the Law Concerning Regulation of Nuclear Source Materials, Nuclear Fuel Materials and Reactors (hereinafter referred to as “Nuclear Reactor Regulation Law”). Table 2 shows the actual usage of samarium and the results of exposure assessment.

Although some of the plants had experience in conducting nuclide analysis of raw materials, etc. in the past, with the exception of titanium ore, no facility response or continuous analysis based on the assumption that naturally radioactive materials are contained has been conducted.

Table 1. Results of a survey on the actual utilization of ores containing uranium and thorium

Minerals	Annual imports (producing country)	Product (by-product)	Processes	Nuclide analysis [*1] Samples	Concentrations（Bq/g） U-238	Th-232	Ambient dose rate[*2](μSv/h)		Exposure dose assessment (mSv/y)
Monazite	10 t c.a. (Vietnam, Malaysia)	Spa bath elements, paints	Sandy monazite is crushed and processed, and used as raw material for health products, paints and spa bath elements	Monazite	40 c.a.	300[*3] c.a.	Monazite warehouse	Surface: 100 (Th 7% concentration)	0.3 (at product manufacturing site) (annual working hours: 360 h c.a., dose rate[*4] at workplace: 0.75 μSv/h)
							Product manufacturing site	1 m: 0.8	
Phosphate ore	0.9 Mt c.a. (China, Morocco, Jordan, South Africa, etc.)	Ammonium phosphate (gypsum, fluorite, sodium silicofluoride)	Phosphate ore is decomposed with sulfuric acid to obtain phosphoric acid and gypsum. Ammonia is reacted with this phosphoric acid to produce ammonium phosphate.	Phosphate ore (Jordan)	0.74	0.0078	Phosphate ore warehouse	Surface: 0.32-0.46 1 m: 0.19-0.22	0.3 (at phosphate ore warehouse) (annual working hours: 1600 h c.a., dose rate[*4] at workplace: 0.18 μSv/h)
				Phosphate ore (Morocco)	1.2	0.0084			
				Phosphate ore (China)	0.10	0.0019	Phosphate ore storage	Floor surface: 0.26 1 m: 0.17	
				Concentrated phosphoric acid	0.8	0.0038	Phosphate liquid factory tanks	Surface: 4.6	
				Ammonium phosphate	0.73	0.0044	Product warehouse	Surface：0.05 1 m: 0.05	
Titanium ore	0.4 Mt c.a. (South Africa, India, Vietnam, Australia, Canada, etc.)	Titanium dioxide (Gypsum, iron oxide)	Titanium ore is decomposed by adding sulfuric acid. After this, titanium dioxide is produced through processes such as standing, filtration, calcination, and drying.	Titanium ore (South Africa)	0.074 ～ 0.44	0.13 ～0.16	Raw ore yard (South Africa)	Surface：0.20～0.40 1m：0.15～0.25	0.27 (at raw ore yard) (annual working hours: 1400 h c.a., dose rate[*4] at workplace: 0.19 μSv/h)
				Titanium dioxide products	0.018	0.0013	Static tank	Surface：0.30 1m：0.15	
				Industrial waste	0.21	0.23	Industrial waste yard	Surface：0.30 1m：0.15	
Bastnesite	2-3 kt c.a. (USA)	Abrasive materials	Bastnesite is crushed in a wet grinder, then filtered, dried, roasted, crushed, and classified to produce the abrasive.	Bastnesite raw material	1.1	5.8	Raw material storage area	Surface：1.9 1m：0.6	0.40 (at product storage area) (annual working hours: 480 h c.a., dose rate[*4] at workplace: 0.84 μSv/h)
				Separated solids from filtration	1.0	4.9	Raw material hopper	Surface：2.0 1m：0.10	
				Abrasive products	1.4	7.1	Product storage area	Surface：3.6 1m：0.88	
Zircon	70 kt c.a. (South Africa,	Refractory	Zircon is weighed, kneaded,	Raw material (zircon sand)	4.2	0.77	Raw material yard (zircon flour for	Surface：2.7 1m：1.0	0.14 (at product storage area)

	Australia, etc.)		molded, dried, and fired to produce refractory bricks				refractory bricks)		(annual working hours: 120 h c.a., dose rate*4 at workplace: 1.13 μSv/h)
				Refractory bricks (100% zircon)	3.5	0.81	Zircon content 80% refractory	Surface：1.8 1m：1.2	
				Dust collection for temporary waste storage	0.17	0.037	Temporary waste storage area	1m：0.15	
Coal	0.155 Gt c.a. (Australia, China, Indonesia, Canada, etc.)	Fly ash, clinker	Coal is burned in a boiler and clinker is recovered from the bottom of the boiler and fly ash from the dust collector.	Coal (China)	0.015	0.018	Coal storage area	Surface：0.03 1m：0.03	0.13 (at clinker warehouse) (annual working hours: 1100 h c.a., dose rate*4 at workplace: 0.12 μSv/h)
				Clinker	0.097	0.072	Clinker warehouse	Surface：0.15 1m：0.15	
				Fly ash	0.095	0.091	Ash dumping area	Surface：0.15 1m：0.10	

(Survey by the Nuclear Regulation Office, Nuclear Safety Division, Ministry of Education, Culture, Sports, Science and Technology, 2003)

*1: Samples with relatively high radioactivity concentrations in the ore-by-ore survey are listed as representative.

*2: The locations where relatively high air radiation dose rates were measured in the ore-by-ore survey were represented. The "1 m" indicates the air radiation dose rate at a distance of 1 m from the object.

*3: The concentration of thorium exceeds 370 Bq/g and the quantity exceeds 900 g, and is therefore subject to the regulation.

*4: The value obtained by subtracting the background (measured value at the site boundary) from the air radiation dose rate at a distance of 1 m from the object.

Table 2. Samarium usage and exposure assessment results

Substance	Import quantity (Country of origin)	Products	Process	Airborne concentration		Internal exposure assessment (μSv/y)			
						Particle size 1μm		Particle size 50μm	
						Without mask	With mask	Without mask	With mask
Samarium	100 t c.a. (China, France)	Magnets, ceramics	Samarium is used to produce ceramic materials from samarium oxide and to make alloys with cobalt and other metals from samarium metal to produce magnets	Alloy production site	Airborne concentration：3.1×10^{-9} Bq/cm^3	67	6.7	10	1.0
				magnet manufacturing site	Airborne concentration：1.7×10^{-8} Bq/cm^3	380	5.9	59	

(Survey by the Nuclear Regulation Office, Nuclear Safety Division, Ministry of Education, Culture, Sports, Science and Technology, 2003)

5.1.3 General consumer goods

(1) Overview

Minerals containing naturally radioactive materials are chemically or physically processed and used in many living environments as general consumer goodsg. Their uses are diverse, ranging from those that we do not come into contact with in our daily lives, such as ship-bottom paints and catalysts for automobile mufflers, to those that we come into physical contact with in our daily lives, such as clothing and bedding. In terms of external exposure, there are items such as wallpapers and paints, which have a high radioactivity concentration per unit weight but a low dose per unit area when applied to walls, etc., and items such as decorative items, which have a low radioactivity concentration but local exposure should be considered. Therefore, a sample analysis survey was conducted for the main items among these general consumer goods, and exposure assessments under normal use were conducted for some of them.

(2) Results of the survey

The radioactivity concentrations of Th-232 and U-238 were determined by measuring the uranium and thorium content of the samples using an inductively coupled plasma mass spectrometer (ICP-MS) and multiplying by the specific activity of each nuclide. As a result of the analytical investigation, some general consumer goods were found to exceed the BSS exemption level. The external doses for the users were calculated using a calculation code based on a model of the normal conditions of use of the consumer goods, the time of use, and the sources.

As a result of the exposure assessment, the external exposure doses for users are 110 μSv/year for radon hot spring bath elements, 220 μSv/year for underwear, 90 μSv/year for bedding, and 10 μSv/year for wallpaper, and the external exposure doses for users are not considered to exceed or to be close to 1 mSv/year. However, if a user uses several general consumer goods at the same time, the user may receive a dose of several hundred μSv/year.

The results of the analysis of radioactivity concentrations in general consumer goods are shown in Table 3.

Table 3. Analysis results of radioactivity concentration in general consumer goods

Samples	Analysis results（radioactivity concentrations :Bq/g）	
	U-238	Th-232
Radon Hot Spring Bath Element A	34	270
Ship Bottom Paint	12	81
Radon hot spring bath element B	10	81
Bracelets and necklaces (ceramic)	1.7-8.8	12-71
Health appliances (powdered)	5.4	34
Refractory materials, refractory bricks	2.9-3.5	0.49-0.57
Muffler catalyst	3.3	210
Clothing (kneaded into fiber)	1	8.8
Supporters, wristbands (kneaded into fibers)	0.011-0.94	0.093-8.5
Deodorant paint	0.4-0.82	2.9-5.5
Socks (kneaded into fiber)	0.7	6.2
Sheets (kneaded into fibers)	0.67	5.4
Shoe insoles (powder incorporated)	0.085-0.42	0.63-6.2
Bedding (kneaded into fiber)	0.043-0.26	0.01-2.3
Abrasives	0.2	0.7

Phosphate fertilizer	0.038-0.073	0.0014-0.0015
Sinter	0.00084-0.012	0.00081-0.029

(Survey by Nuclear Safety Technology Center and others, 2002)

5.2 Management of NORM&TENORM

The information in this chapter is extracted from the document " Guideline for Ensuring Safety of Raw Materials and Products Containing Uranium or Thorium" [MEXT, 2009], which is related to NORM management.

5.2.1 Position and outline of guidelines

(1) Purpose of guidelines

To reduce the health risk of getting exposed to unnecessary radiation at the time of handling raw materials and products that contain uranium or thorium, the manufacturers and importers who are required to conduct self management and measures to be taken by them are specified concerning the following matters:

(i) Ensure safety by reducing unnecessary radiation exposure of workers at production establishments and residents living in the vicinity.

(ii) Ensure safety by reducing unnecessary radiation exposure of users from consumer goods.

(2) Self management by manufacturers and importers

MEXT's Subcommittee on Safety Regulations for Research Reactors, etc. made discussions about a desirable safety management concerning the use of NORM in the future, and a report was prepared by the Subcommittee concerning "Desirable Safety Regulations for Test and Research Reactor Facilities, etc." in January 2005. The report suggested, concerning the safety management involved in the use of NORM, that it should be appropriate to develop guidelines with reference to the General Administrative Group Report and opinions of knowledgeable persons, rather than immediately introducing regulation under the law, and then to require manufacturers and importers who handle NORM to conduct self management based on the guidelines.

For these reasons, those companies and industries that handle raw materials and products that contain uranium or thorium, among NORM, are expected to make effective use of the guidelines for ensuring safety, including reduction in exposure to unnecessary radiation.

(3) Description of guidelines

The guidelines are composed of the six steps mentioned below, including the identification of targeted manufacturers and importers, provision of information and recording (see Table 4).

Description (1) presents the measures to be taken by targeted manufacturers engaged in the manufacturing industry, and Description (2) presents the measures to be taken by targeted manufacturers and importers of consumer goods. The details of respective descriptions are mentioned in sections 2.2.2 and 2.2.3. The manufacturers that produce consumer goods are required to take the measures prescribed in both Description (1) and Description (2).

Moreover, among those who have permission to use nuclear fuel materials and those who made notification to use nuclear raw materials, the manufacturers that produce consumer goods or industrial products are subject to the guidelines, and they are required to take the measures prescribed in Description (1) or Description (2), in addition to the obligations prescribed by the Reactor Regulation Law.

Table 4. Respective steps mentioned in the guidelines

	Description (1)	**Description (2)**
	Measures to be taken by targeted manufacturers engaged in the manufacturing industry (See 2.2.2 and 2.2.3 for further details)	Measures to be taken by targeted manufacturers and importers of consumer goods (See 2.2.2 and 2.2.4 for further details)
Purpose	Ensure safety by reducing unnecessary radiation exposure of workers at production establishments and residents living in the vicinity.	Ensure safety by reducing unnecessary radiation exposure of users at the time of use of consumer goods (excluding interim products, etc.).
Step 1	[Identification of targeted manufacturers] Identify targeted manufacturers based on the information about the types of raw materials to be used in processing and the radioactivity concentration of uranium or thorium.	[Identification of targeted manufacturers and importers] Identify targeted manufacturers and importers based on the information about the types of raw materials contained in products and the radioactivity concentration and quantity of uranium or thorium, and on how products are used.
Step 2	[Measurement of radiation dose rate] The targeted manufacturers identified by Step 1 should measure radiation dose rates of their work environments (raw materials, wastes, products, etc.) by using survey meters.	[Measurement of radiation dose rate] The targeted manufacturers and importers identified by Step 1 should measure the radiation dose rates of consumer goods by using survey meters.
Step 3	[Evaluation of exposure dose] Calculate the exposure doses of workers and residents in the vicinity based on the results of measurement of radiation dose rates as prescribed in Step 2.	[Evaluation of exposure dose] Calculate the exposure doses of users based on the results of measurement of radiation dose rates as prescribed in Step 2.
Step 4	[Measures to reduce radiation exposure]	[Measures to reduce radiation exposure]

	Take necessary measures to reduce exposure doses if radiation exposure is estimated to exceed 1 mSv/year.	Take necessary measures to reduce exposure doses if radiation exposure is estimated to exceed 1 mSv/year.
Step 5	[Provision of information] Provide information to the destination to which interim products, etc. are shipped.	[Provision of information] Provide and present information to consumer goods users.
Step 6	[Production of records and education] Produce and save necessary records and conduct necessary education programs.	[Production of records] Produce and save necessary records.

5.2.2 Manufacturers and importers subject to guidelines

Of the details of the guidelines as mentioned in 2.2 1(3) “Description of guidelines”, Step 1 “Identification of targeted manufacturers and importers” in Table 4 is explained in this section. The flow chart to identify targeted manufacturers and importers is shown in Figs. 2 and 3.

It should be noted, however, that the concentration and quantity of radioactivity mentioned in this section serve as indicative values to guarantee that exposure doses are kept at 1 mSv/year8 or lower and strict application thereof is not necessarily required.

(1) Targeted manufacturers engaged in the manufacturing industry

The targeted manufacturers engaged in the manufacturing industry should be those manufacturers (including individuals) who possess the production establishments that satisfy Conditions 1 and 2 as described below:

Condition 1: Production establishments where specified raw materials are used as raw materials and processed into interim products, etc. or consumer goods, or where interim products, etc. that are processed by using specified raw materials are used as raw materials and processed into other interim products, etc. or consumer goods

Condition 2: Production establishments where specified raw materials or interim products, etc., of which the radioactivity concentration of natural uranium or thorium may exceed 1 Bq/g or that of refined uranium or thorium may exceed 10 Bq/g, are used as raw materials and processed

* “Specified raw materials” are defined in (5) of section 2.4 “Definition of terms and commentary”, “interim products, etc.” are defined in (8) of the same section, and “consumer goods” are defined in (9) of the same section.

(i) Condition 1

The typical flows of specified raw materials and interim products, etc. are shown in Fig. 1.

Those manufacturers who process specified raw materials and interim products, etc. process specified raw materials themselves as raw materials (primary processing) in one case and process interim products, etc. that are processed by using specified raw materials as raw materials (n-th processing) in other case. The guidelines cover both of the two cases.

Interim products, etc. should include those that are recycled from wastes produced at the time of processing and reused for other processing. Manufacturers who process imported specified raw materials and imported interim products, etc. are, of course, subject to the guidelines.

(ii) Condition 2

As mentioned in (8) of section 2.4 “Definition of terms and commentary”, the specified raw materials and interim products, etc., which contain natural uranium or thorium and of which the radioactivity concentration of uranium or thorium is 1 Bq/g or lower, and which contain refined uranium or thorium and of which the radioactivity concentration is 10 Bq/g or lower, are not subject to the guidelines.

It is desirable for each of the industrial associations concerned to specify the raw materials that are used in respective industries concerned and have a possibility of exceeding these radioactivity concentrations, and provide such information to their member companies.

(iii) Others

Those manufacturers who use the materials that contain uranium or thorium, of which the radioactivity concentration and quantity require notification and permission under the Reactor Regulation Law, become subject to the Act, and are required to take measures based on laws and regulations as a necessary premise. Those manufacturers subject to the Act are also required to implement the matters mentioned in the guidelines together with the measures based on laws and regulations.

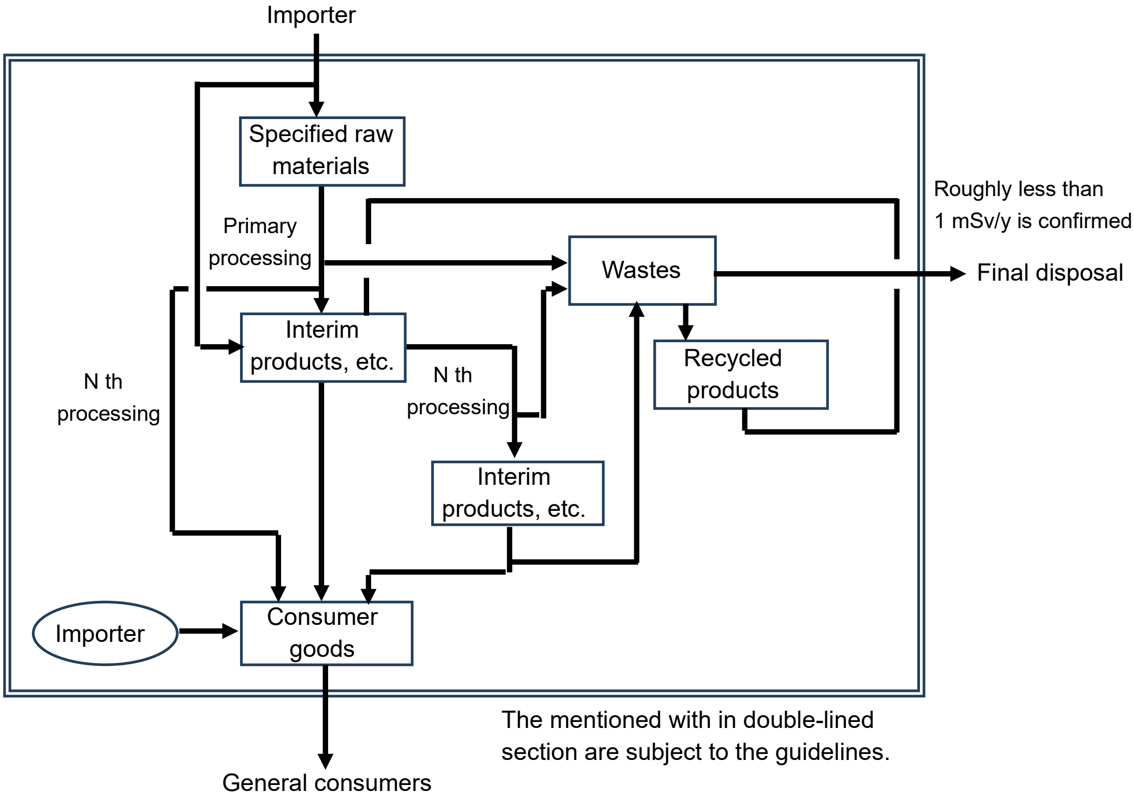


Fig. 1. Flow of specified raw materials and interim products, etc. (pattern diagram)

5.2.3 Targeted manufacturers and importers of consumer goods

The targeted manufacturers and importers of consumer goods (excluding interim products, etc.) are those (including individuals) who manufacture or import those consumer goods that satisfy Conditions 1 and 2 as described below:

Condition 1: Those consumer goods that are manufactured from specified raw materials or interim products, etc. that are processed by using specified raw materials or that are imported, and that are used in contact with or close (within one meter) to human bodies

Condition 2: In the case of consumer goods that contain natural uranium or thorium, those consumer goods whose radioactivity concentration of uranium or thorium may exceed 1 Bq/g and whose quantity thereof may exceed 8,000 Bq. In the case of consumer goods that contain refined uranium or thorium, those consumer goods whose radioactivity concentration may exceed 10 Bq/g and whose quantity thereof may exceed 80,000 Bq.

* “Specified raw materials” are defined in (5) of section 2.4 “Definition of terms and commentary”, “interim products, etc.” are
defined in (8) of section 2.4, and “consumer goods” are defined in (9) of section 2.4.

(i) Condition 1

As for consumer goods, as there is almost no possibility of radiation exposure of more than 1 mSv/year, except for the case where such goods are used in contact with or close to human bodies, only those consumer goods that are used in contact with or close to human bodies are made subject to the guidelines.

(ii) Condition 2

The quantity of uranium or thorium contained in consumer goods is much smaller than that of specified raw materials and interim products, etc. handled in large quantities on an industrial scale. Therefore, if it is obvious that the quantity of uranium or thorium is less than a certain quantity, it is considered reasonable to make such consumer goods not subject to the guidelines.

For consumer goods, therefore, the standards for the quantity of radioactivity should be stipulated, as is the case with (1) of this section, in addition to the standards for radioactivity concentration.

The concentration and quantity of radioactivity of consumer goods should be measured and analyzed in the shapes they are used in ordinary households.

(iii) Others

Those consumer goods that contain uranium or thorium, of which the radioactivity concentration and quantity require notification and permission under the Reactor Regulation Law, become subject to the Act, and measures based on laws and regulations should be taken as a necessary premise. Even in the case of consumer goods subject to the Act, the matters mentioned in the guidelines should be implemented together with the measures based on laws and regulations.

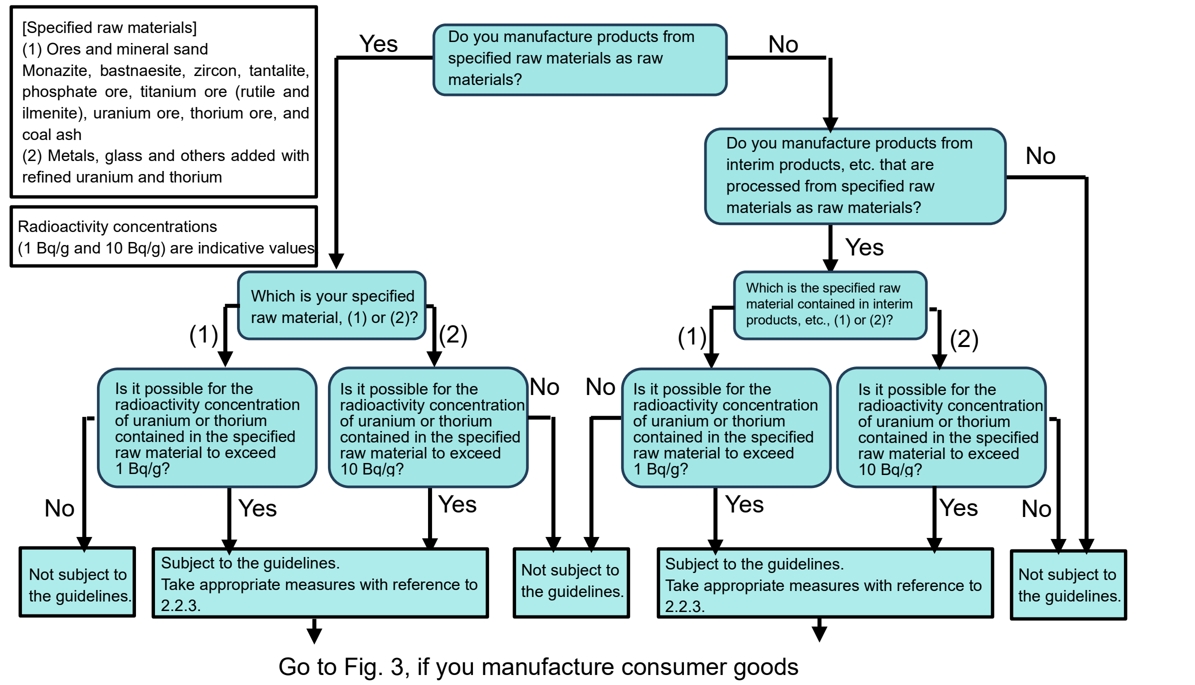


Fig. 2. Flow chart to identify targeted manufacturers engaged in the manufacturing industry

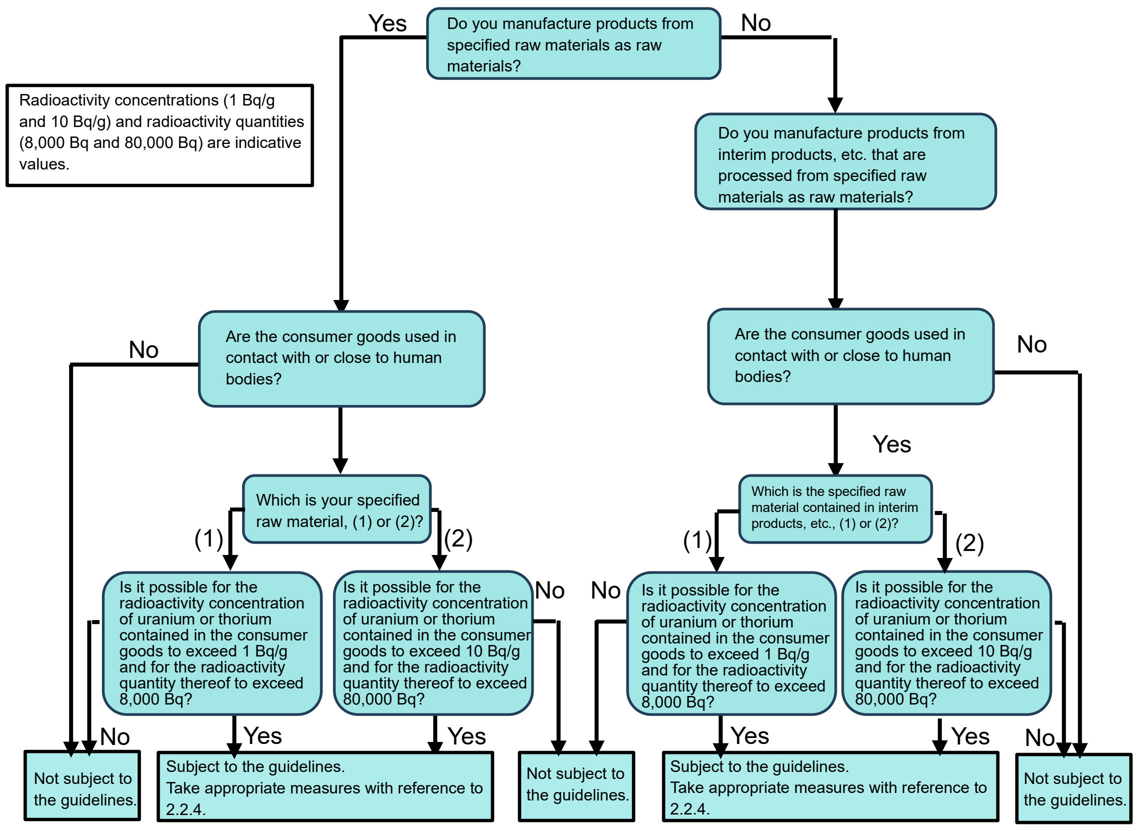


Fig. 3. Flow chart to identify targeted manufacturers and importers of consumer goods

5.2.4 Measurement of radiation dose rates at production establishments, evaluation of exposure doses and measures for improvement

This section explains the measurement of radiation dose rates which is conducted by the targeted manufacturers engaged in the manufacturing industry outside the boarders of production establishments that handle specified raw materials or interim products, etc. that are processed by using specified raw materials (hereinafter referred to as “specified raw materials and others” in this section and the following sections), as well as evaluation of exposure doses and necessary measures for improvement.

Specified materials and others should be handled at places where sufficient ventilation can be provided. Particularly in the case where dust can be generated, such measures as wearing appropriate protective equipment such as masks and gloves should be taken.

(1) Measurement of radiation dose rates and evaluation of exposure doses
(Step 2 and Step 3 in Table 4)

Targeted manufactures should conduct the measurement of radiation dose rates and evaluation of exposure doses with reference to “Appendix 1: Measurement method of radiation dose rates” and “Appendix 2: Evaluation of exposure doses.”

(i) Evaluation of exposure doses of workers at production establishments
Conduct the measurement of radiation dose rates at workplaces (including waste storage places) and calculate one-year exposure doses of workers in consideration of their working hours.

(ii) Evaluation of exposure doses of residents living in the vicinities of production Establishments
Conduct the measurement of radiation dose rates on the borders of production establishments and calculate one-year exposure doses of residents living in the vicinities thereof.

(iii) Frequency of measurement of radiation dose rates and evaluation of exposure doses
The frequency of measurement is once a year in principle. In the following cases, however, unscheduled measurement should be additionally conducted because of a possibility of increase in exposure doses:

A) Increase in the total amount of specified raw materials and others

B) Change in types, places of origin and suppliers of specified raw materials and others
C) Change in processes and specifications of equipment or products
D) Change in operating hours, workplaces or storage places of specified raw materials and others
E) Change in borders of production establishments
F) Changes in method of handling wastes, including specified raw materials and others

(2) Measures for improvement to reduce exposure doses
(Step 4 in Table 4)

In response to the results of evaluation of exposure doses as prescribed in (1) of this section, the targeted manufacturers should take the following measures to reduce exposure doses:

(i) In the case where the exposure doses of workers are estimated to exceed 1 mSv/year, the following measures should be taken to keep their exposure doses at 1 mSv/year or lower:
A) Reduce the amount of specified raw materials and others or products in storage
B) Store wastes at several places rather than at one place
C) Shorten the time of being engaged in works
D) Build shields

(ii) In the case where the exposure doses of residents living in and around the borders of production establishments are estimated to exceed 1 mSv/year, the following measures should be taken to keep their exposure doses at 1 mSv/year or lower:
A) Reduce the amount of specified raw materials and others or products in storage at production establishments
B) Keep places of storage or use away from the borders of production establishments
C) Build shields

(3) Provision of information
(Step 5 in Table 4)

(i) The targeted manufacturers should provide the destinations to which interim products, etc. are shipped with the following pieces of information about uranium or thorium contained in the interim products, etc. for evaluation of exposure doses and safe handling:
A) Names of products and manufacturers

B) Types of specified raw materials and others and places of origin (or places of processing)
C) Concentration and quantity of radioactivity of uranium or thorium contained in products
D) Physicochemical properties of uranium or thorium
E) Cautions about handling and storage
F) Other necessary matters

(ii) When the targeted manufacturers deliver wastes under their control to third parties to dispose of them in landfills (including the case where wastes go through intermediate treatment), they should confirm that the exposure doses at such third parties do not exceed roughly 1 mSv/year9. In the case where the exposure doses at such third parties are estimated to exceed 1 mSv/year or cannot be evaluated, wastes should not be delivered to them.

(3) As for the time that is used to evaluate exposure doses, it is allowed to set a realistic access time and the period of 8,760 hours (24 hours x 365 days) does not need to be used at all time.

(4) Production of records and education
(Step 6 in Table 4)

The targeted manufacturers should produce the following records and save them:

(i) Records of measurement and evaluation

The records of measurement and evaluation should be saved with written information about the date of measurement, name of the person who made the measurement, results of measurement, and the method and results of evaluation. The records should be saved for five years.

(ii) Records of education

In the case where the exposure doses of workers are estimated to exceed 1 mSv/year and the measures prescribed in (2) of this section are taken, the education programs should be provided concerning the conditions of individual exposure, methods of reduction in exposure and the handling of matters that contain uranium or thorium, and the records of education should be saved. The records should be saved for three years.

5.2.5 Measurement of radiation dose rates at the time of use of consumer goods, evaluation of exposure doses and measures for improvement

This section discusses the measurement of radiation dose rates at the time of use of consumer goods (excluding interim products, etc.), evaluation of exposure doses, and necessary measures for improvement, which are conducted by the targeted manufacturers and importers.

(1) Measurement of radiation dose rates and evaluation of exposure doses
(Step 2 and Step 3 in Table 4)

(i) Evaluation of exposure doses of users

The targeted manufacturers and importers measure radiation dose rates at the positions where consumer goods are used and calculate one-year exposure doses of users in consideration of duration of use of consumer goods in a year. If radioactivity analysis values are available, exposure doses may be evaluated by using the results of such analysis.

If consumer goods are in the form of powder and there is a possibility that such powder be inhaled, the exposure doses of inhaled powder should also be evaluated.

As for the specific methods of measurement of radiation dose rates and evaluation of exposure doses.

(ii) Frequency of measurement of radiation dose rates and evaluation of exposure doses

In the following cases, however, unscheduled measurement should be additionally conducted because of possible increase in exposure doses:

A) Change in types of specified raw materials and others used as raw materials, and
places of origin and suppliers thereof
B) Change in composition of specified raw materials and others
C) Change in utilization methods of consumer goods

(2) Measures for improvement to reduce exposure doses
(Step 4 in Table 4)

In the case where the result of evaluation of exposure doses of consumer goods users are estimated to exceed 1 mSv/year in normal usage, the targeted manufacturers and importers should take the following measures to reduce exposure doses of consumer goods and keep exposure doses at 1 mSv/year or lower in normal usage. Even if exposure doses do not exceed

1 mSv/year, it is recommended to take such measures, when exposure doses can be reasonably and easily reduced.

(i) Reduce the amount of specified raw materials and others that are used per unit of consumer goods
(ii) Make improvements to limit the usage of consumer goods not to allow them to be used in contact with or close to human bodies for a long period of time.

(3) Provision of information
(Step 5 in Table 4)

In the case where the results of evaluation of exposure doses of consumer goods users are estimated to exceed 1 mSv/year because of inappropriate usage such as the use thereof in excess of appropriate time, the cautions and other information prescribed below should be indicated on or attached to consumer goods. Attentions should be paid not to allow such indications to be dropped off or unreadable at the time of use. However, as for those consumer goods for which such cautions cannot be indicated, information should be appropriately known by other methods.

(i) The fact that consumer goods contain uranium or thorium
(ii) The exposure dose per hour of use
(iii) Cautions about handling to reduce exposure doses of users, etc. (duration of use, distance between user and product, etc.)
(iv) Name of manufacturer, contact information, etc.

(4) Production of records
(Step 6 in Table 4)

The targeted manufacturers and importers should produce records of measurement of radiation dose rates and evaluation of exposure doses and save them. The records of measurement and evaluation should be saved with written information about the date of measurement, name of the person who made the measurement, results of measurement, and the method and results of evaluation. The records should be saved for the period until the use of targeted consumer goods is assumed to be ceased.

5.3 Regulatory Base or Framework

The materials that contain uranium or thorium are now regulated by the Reactor Regulation Law in Japan concerning the concentration of radioactivity of radionuclide and the quantity thereof. Specifically, as for the regulatory values of uranium and thorium which are subject to utilization notification of nuclear raw materials, as shown in Table 6, the concentration of radioactivity of uranium or thorium is set at 74 Bq/g (370 Bq/g for nuclear raw materials in solid state), and the quantity thereof is provided for that the "total of the three times the amount of uranium plus amount of thorium" is more than 900 g. The quantity of nuclear fuel materials which are subject to utilization permission is set at more than 300 g for natural uranium or depleted uranium and more than 900 g for thorium. It is provided for that the use of enriched uranium requires permission regardless of quantity.

Therefore, raw materials, industrial products and consumer goods, which contain uranium or thorium of radioactivity concentration and quantity less than the values mentioned above, are not subject to the Reactor Regulation Law.

Table 6 Notification and permission of nuclear raw materials and nuclear fuel materials

Nuclear raw materials subject to utilization notification In the case where both the concentration and quantity of uranium or thorium exceed the following values: ・ Radioactivity concentration 74 Bq/g (Solid state: 370 Bq/g) ・ Quantity Amount of uranium × 3 + amount of thorium = 900 g
Nuclear fuel materials subject to utilization permission: ・ Natural and depleted uranium and compounds thereof Quantity in excess of 300 g ・ Enriched uranium Fully subject to regulation ・ Thorium and compounds thereof Quantity in excess of 900 g

5.4 Issues and results of recent researches

5.4.1 Results of recent researches

This report is based on the guidelines published in 2003 and 2009, however updated data from recent surveys were reported at Radiation in the Living Environment (Calculation of National Doses), 3rd Edition, published in Nov. 2020, by Editorial Board of Radiation in the Living Environment on NUCLEAR SAFETY RESEARCH ASSOCIATION [Yonehara et al, 2020].

In this report national dose of Japan were evaluated with surveying doses exposed to Japanese citizens in their living environment during the five-year period from 2014 to 2019.

The doses exposed to the Japanese public were evaluated and aggregated in the following two ways.

(i) Average doses exposed to the general Japanese public in their living environment.

(ii) The collective dose exposed to all Japanese citizens from all sources and the average dose in the exposed population

This report was also surveyed the NORM exposure in the survey results was not likely to exceed 1 mSv/year. Consumer exposure due to NORM and occupational exposure of NORM workers were also measured and were 0.00005 mSv/a and 0.022 mSv/a, respectively.

These values were lower than those of the public or occupational exposures from almost other sources in this national dose survey in Japan. The survey results are presented in Table 5.1-5.5.

Table 5.1 Radioactivity concentration of general consumer goods containing U, Th series nuclides

Samples	**Analysis results (Radioactivity concentration: Bq/g)**	
	238U	232Th
• Radon hot spring bath element	10~34	81~270
• Bracelets, necklaces (ceramic)	1.7~8.8	12~71
• Health appliances (with powder)	5.4	34
• Refractories, refractory bricks	2.9~3.5	0.49~0.57
• Muffler catalyst	3.3	210
• Clothing (kneaded into fibers)	1	8.8
• Supporters, wristbands (kneaded into fibers)	0.011~0.94	0.093~8.5
• Deodorant paint	0.4~0.82	2.9~5.5
• Socks (kneaded into fibers)	0.7	6.2
• Sheets (kneaded into fibers)	0.67	5.4
• Shoe insoles (powder incorporated)	0.085~0.42	0.63~6.2
• Bedding (kneaded into fiber)	0.043~0.26	0.01~2.3
• Yu-no-hana (bath additives made from hot spring mineral deposits)	0.00084~0.0012	0.00081~0.029
• Cosmetics (gel)	15	44
• Cosmetics (powdered white powder)	13	68
• Phosphate fertilizer	0.038~0.073	0.0014~0.0015

Table 5.2 Example of measuring exposure doses from the use of general consumer goods including NORM

General consumer products including NORM	Annual dose in case of use µSv/a	References
• Beddings	110	M. Yoshida et al., Atomic Energy Soc. of Japan, 4(3); 213-218, (2005) (in Japanese)
• Underwear	220	
• Spa equipment	110	
• Wallpaper	10	
• Fuel economy enhancer for cars	< 10	E. Furuta, Japanese Society of Radiation Safety Management, 6(1); 31-36, (2007)
• Cosmetics	< 1000	E. Furuta et al., Health Physics Society, 43(4); 341-348, (2008)
• Accessories	< 1000	E Furuta, Health Physics Society, 45(3); 253-261, (2010).

Average annual dose due to NORM per person in Japan **0.00005 mSv/a**
Dose from various radiation sources due to general consumer goods (products containing NORM, as well as luminous watches, smoke detectors, electric welding machines, glow lamps, etc.)

Table 5.3 Occupational Exposure of Enhanced Natural Radiation

	Number of people	Average dose per person (mSv/a)	Collective dose (person*mSv)
Aircrew (Average of pilots and flight attendants)	18,000	2	36,000
NORM workers (Zircon, monazite, general consumer goods, metal resources, coal and oil handlers)	268.6	0.022	5,910

Table 5.4 Contribution of occupational exposure to population dose and national dose

Categories of Exposure	Type of exposure (source and path)	Number of people	Average dose per person (mSv/a)	Collective dose (person*mSv) (Contribution of national dose %)
Occupational Exposure	• Radiation workers at nuclear facilities (excluding workers at Fukushima Daiichi NPP)	55,091	0.15	8.26 (0.0013%)
	• Radiation workers at Fukushima Daiichi NPP	20,730	5.04	104.5 (0.017%)
	• Decontamination workers related to the accident at Fukushima Daiichi Nuclear Power Station	36,046	0.46	16.58 (0.003%)
	• Radiation workers at medical facilities	352,601	0.37	130.5 (0.021%)
	• Dental care facility radiation workers	23,505	0.03	0.705 (0.0001%)
	• Veterinary medical facility radiation workers	15,217	0.03	0.457 (0.0001%)
	• General industrial radiation workers	68,218	0.06	4.09 (0.0007%)
	• Non-destructive inspection radiation workers	3,662	0.42	1.54 (0.0002%)
	• Research and educational facility radiation workers	66,784	0.02	1.34 (0.0002%)
	• Aircrew (information in 2007)	18,000	2	36 (0.006%)
	• NORM handling workers	268,600	0.022	5.91 (0.001%)
	• **Occupational exposure total**			**309.8 (0.05%)**

Table 5.5 Contribution of public exposure from Natural Radiation Sources to population dose and national dose

Categories of Exposure	**Type of exposure (source and path)**	**Number of people**	**Average dose per person (mSv/a)**	**Collective dose (person*mSv) (Contribution of national dose %)**
Public Exposure	• Exposure to cosmic radiation on the ground	126,706,000	0.3	38,012 (6.12%)
	• Exposure to earth radiation	126,706,000	0.33	41,813 (6.74%)
	• Exposure by inhalation of radon/tron in the air	126,706,000	0.60	76,277 (12.29%)
	• Exposure by oral intake of food, drinking water, etc.	126,706,000	0.99	125,945 (20.3%)
	• Exposure from hot springs, underground environment, etc.	126,706,000	0.005	634 (0.10%)
	• Exposure due to use of airplanes	126,706,000	0.008	1,014 (0.16%)
	• Subtotal of exposure from natural radiation sources			283,695 (45.7%)
	• **Exposure due to general consumer goods (products containing NORM, as well as luminous watches, smoke detectors, electric welding machines, glow lamps, etc.) and use of miscellaneous radiation sources**	**126,706,000**	**0.00005**	**6.34 (0.001%)**

5.4.2 Issues

Based on the above survey results, workers handling NORM and general consumer goods containing NORM are not a major source of exposure in Japan, however, it was pointed out by Yonehara, the chairman of the Editorial Board of Radiation in Living Environments, that a survey based on an up-to-date, good quality, measurement sufficient in number to make a proper inference is the most important issue concerning NORM in Japan.

He commented in the introductive paper of this recent survey report [Yonehara, 2022], as follows;

Information on the public dose is an important material used for risk communication, but this other information, such as radon in dwellings that are not currently regulated and worker exposure from NORMs, is becoming increasingly important from the perspective of radiation protection-related administration. However, in considering this revision, we were keenly aware that there is a great lack of data to assess the current exposure status of the public. As one example, a nationwide survey of radon concentrations in dwellings has not been conducted for more than 20 years. It is possible that radon concentrations have changed during this time due to various factors such as climate change and construction methods, but this information cannot be obtained without conducting a large-scale survey. Thus, general progress in environmental radioactivity research is needed in the future.

The "Comprehensive Survey on Exposure to Naturally Occurring Radioactive Materials (NORM)" (hereinafter referred to as "NORM Survey Project"), a project funded by the Ministry of the Environment for Strategic Promotion of Radiation Safety Regulation Research (Comprehensive Survey on Exposure Due to Naturally Occurring Radioactive Materials (NORM)), was adopted in FY2021 as a feasibility study project for addressing medium- to long-term issues related to radiation protection under the Strategic Promotion of Radiation Safety Regulation Research. The purpose of this NORM survey project is to investigate the effects of radiation exposure by NORM in Japan. The purpose of this NORM research project is to obtain basic data for examining the ideal form of domestic regulations, and to explore new issues that will lead to domestic regulations.

According to Iwaoka, the principal investigator of the FY2021 project result report, the following issues are listed as the next issues to be examined [National Institute of Quantum Science and Technology, 2022]。

- Some of the substances related to rare earths and rare metals and fossil fuels are likely to exceed 1 Bq/g and may be outside the domestic management system (outside the NORM guidelines).

- Regarding rare earths and rare metals, there are many substances whose domestic use has been confirmed but whose radioactivity concentration is unknown. Therefore, as a next step, a survey on radioactivity concentration is expected to be conducted.
- For fossil fuels, a relatively large amount of information on the concentrations of related substances has been gathered. Therefore, as a next step, exposure surveys are expected to be conducted in accordance with the actual conditions of use, referring to these concentration data.

It is expected that these surveys will be conducted by considering feasible surveys (e.g., literature review, scenario calculation, etc.) based on the current status of coronal disasters.

For substances other than those mentioned above, such as those used domestically but unlikely to exceed 1 Bq/g (or whose concentration is unknown), it is also important to show "low concentration" as data from the perspective of risk communication, so surveys should be conducted as necessary while taking into account the needs of society It is expected that the following will be conducted as necessary based on the needs of society.

5.5 Definition of terms

Major terms used in the guidelines are defined as follows:

(1) Naturally occurring radioactive materials (NORM)

Naturally occurring radioactive materials (NORM) mean the generic name of earth-origin radioactive nuclides and cosmic-ray-produced nuclides, which exist in the natural world, in a general sense or in a broad sense. It is known that many nuclides other than uranium and thorium exist as NORM such as potassium-40.

(2) Natural uranium and thorium

As for uranium and thorium, several nuclides of different mass numbers exist. In the guidelines, nuclide composition is not limited unless otherwise particularly mentioned.

Many of them emit radiation and change to other elements (daughter nuclides). In many cases, these daughter nuclides are also radioactive (and create more daughter nuclides).

Therefore, those that contain natural (not refined) uranium and thorium coexist with daughter nuclides.

(3) Refined uranium and thorium

Refined uranium and thorium contain almost no daughter nuclides. When refined uranium or thorium is handled, many manufacturers have permission to use nuclear fuel materials and made notification to use nuclear raw materials. However, those products, of which the concentration and quantity are less than the values prescribed by the Reactor Regulation Law as they are mixed with other materials in the process of utilization, are not subject to statutory regulations. The guidelines are prepared because it is desirable to give consideration to radiation exposure even in such case that above-mentioned products are not subject to laws and regulations.

(4) Those who are protected from radiation exposure

Under the guidelines, workers at production establishments where raw materials and products that contain uranium or thorium are handled, residents in the vicinity, and consumer goods users should be protected from radiation exposure.

(5) Specified raw materials

Under the guidelines, the specified raw materials mean the following materials that contain uranium or thorium:

(i) Ores and mineral sand

Monazite, bastnaesite, zircon, tantalite, phosphate ore, uranium ore, thorium ore, titanium ore (rutile, ilmenite, etc.) and coal ash.

(ii) Metals, glass and others added with refined uranium and thorium.

(6) Standards for radioactivity concentration (unit: Bq/g (Becquerel per gram))

Those materials that contain natural uranium and thorium coexist with daughter nuclides.

If such materials are refined and coexisting daughter nuclides are removed, their radioactivity decreases to about one-tenth in the case where natural uranium and thorium were in the state of radioactive equilibrium. Under the guidelines, therefore, as the indicative values to guarantee that exposure doses due to raw materials, products and others are kept at 1 mSv/year or lower, 1 Bq/g is applied to those materials that contain natural uranium or thorium that can be considered being in the state of radioactive equilibrium with daughter nuclides, and 10 Bq/g to those materials that contain uranium or thorium that are refined and daughter nuclides are removed from them, and those materials that exceeds the indicative values are made subject to the guidelines.

For reference, the mass of targeted material, which is used as the denominator to calculate the concentration, should basically be the mass of raw material. In the case of consumer goods, however, each product used is applied. In the case of products composed of several parts, parts that can be roughly removed should be applied.

(7) Standards for quantity of radioactivity of consumer goods (Unit: Bq (Becquerel))

Under the guidelines, as the indicative values to guarantee that exposure doses due to the use of consumer goods are kept at 1 mSv/year or lower, the quantity of radioactivity of uranium or thorium contained in consumer goods that are used in contact with or close (within one meter) to human bodies is set at 8,000 Bq for those materials that contain natural uranium or thorium, and at 80,000 Bq for those materials that contain refined uranium or thorium, and those materials that exceeds the indicative values are made subject to the guidelines.

(8) Interim products, etc.

Under the guidelines, interim products, etc. mean primary products, semi-finished products, industrial products and by-products other than consumer goods that are processed by using specified raw materials. In the case where defective products produced in the manufacturing process are to be reused and wastes are to be recycled to manufacture other products, such products should be handled in the same manner as interim products, etc. In the case where those products that are not raw materials themselves like welding electrodes but are used in manufacturing processes, such products should also be handled in the same manner as interim products, etc.

In the case where interim products, etc. are used as raw materials in other manufacturing industries, such products may cause radiation exposure of workers at production establishments where they are processed. Therefore, the case where interim products, etc. are processed as raw materials is also made subject to the guidelines.

(i) See Commentary 3 "Regarding the standards for radioactivity concentration."

(ii) Unit that represents the quantity of radioactivity contained per gram

(iii) For example, as for thoriated electrodes that are used for electric-discharge lamps, the weight of electrode is applied in the assembly process. As for finished products, the weight of electric-discharge lamp is applied.

(iv) See Commentary 4 "Regarding the standards for the quantity of radioactivity of consumer goods."

(v) Unit that represents the quantity of radioactivity

(9) Consumer goods

Those products that are processed from specified raw materials or interim products, etc. that are processed by using specified raw materials and that are used by ordinary households and are not further processed or not used for industrial applications should be defined as consumer goods. In addition, those products that are used for business purposes should also be defined as consumer goods. For example, home spa machines, ornaments and stone tiles used in stone spa facilities should also be regarded as consumer goods.

(10) Wastes subject to evaluation

Wastes that are produced in manufacturing process and stored within production establishments or wastes that are scheduled for final disposal as being valueless are made subject to evaluation.

(11) Radiation dose rate

Radiation dose rates should be represented by the quantity of radiation (Sv (sievert)) irradiated for a certain period of time (one hour in general) from materials that discharge radiation.

References

Editorial Board of Radiation in the Living Environment on NUCLEAR SAFETY RESEARCH ASSOCIATION. (2020). Radiation in the Living Environment (Calculation of National Doses), 3rd Edition.

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Appendix

[Appendix 1] Method of measurement of radiation dose rates

(1) As for the equipment that is used for measurement of radiation dose rates, a calibrated energy-compensation-type NaI (TI) scintillation survey meter (detection limit is 0.01 μSv/h or lower) or gamma-ray measurement equipment that has equivalent performance should be selected.

(2) Measuring instruments should be read when their instrument readings become stable. It is desirable to select the largest time constant in the case of measuring instruments whose time constants (seconds) can be changed, and read values after a lapse of time more than three times as long as the time constant.

(3) Measurements should be made twice or more (three times as a reference) at regular intervals for background and in each place of measurement, and measured values and average values thereof should be recorded. Background means a natural radiation dose rate in the place of measurement (radiation from those other than raw materials and products that contain uranium or thorium which is subject to measurement). Therefore, measurements should be made in a sufficiently distant place, where there is no effect of raw materials and products that contain uranium or thorium, from the place to measure radiation dose rates.

(4) Places for measurement should be selected in consideration of the conditions of arrangement of specified raw materials and interim products, etc. (hereinafter referred to as "specified raw materials and others"), the line of flow and access time of workers, distance and other factors.

(5) As for measurements at respective workplaces in production establishments, radiation dose rates should be measured at the positions where workers conduct their operations, if such positions are decided, or at the positions one meter distant from specified raw materials and others, manufacturing equipment, products and wastes and at the height of one meter from the floor face. Measurements should be made when operations are actually conducted in respective processes and specified raw materials and others are stored in the maximum amount of the amount slated to be used per year.

(6) As for measurements on the borders of business establishments, radiation dose rates should be measured roughly along the borders of business establishments (or places inside or outside the fences of the site where radiation dose rates can be easily measured) and at each of the measuring points set at regular intervals in proportion to the length of border at the height of one meter from the ground surface. In this case, those who make measurements should try to find the maximum value of radiation dose rate.

(7) Radiation dose rates of consumer goods should be measured at the positions where they are usually used.

(8) Net radiation dose rates should be calculated by subtracting background dose rates from respective measured values. As for those consumer goods that are used in contact with the skin, net radiation dose rates should be calculated by subtracting background dose rates from the values that are calculated by doubling the measured values (in the case the values of radiation dose rate become negative, they are treated as zero) to take into account β ray.

(9) Those who measure radiation dose rates are not required to have any particular qualification.

[Appendix 2] Evaluation method of exposure doses

1. Evaluation of exposure doses of workers at production establishments

(1) Calculate net radiation dose rates at respective workplaces based on Appendix 1.

(2) Confirm working hours of workers in a year at respective workplaces (including waste storage areas).

(3) Calculate exposure doses of workers in a year by multiplying the radiation dose rates calculated in (1) above by the working hours confirmed in (2) above (if the same worker conducts his or her operations at two or more workplaces, his or her exposure doses should be totaled).

(4) If the exposure doses calculated in (3) above are estimated to exceed 1 mSv/year, the measures prescribed in "2.2.4 (2) Measures for improvement to reduce exposure doses" in the guidelines should be taken.

2. Evaluation of exposure doses of residents living in the vicinities of production establishments

(1) Calculate net radiation dose rates on the borders of production establishments based on Appendix 1.

(2) Calculate one-year exposure doses by multiplying the radiation dose rates calculated in (1) above by a realistic access time10.

(3) If the exposure doses calculated in (2) above are estimated to exceed 1 mSv/year, the measures prescribed in "2.2.4 (2) Measures for improvement to reduce exposure doses" in the guidelines should be taken.

3. Evaluation of exposure doses of consumer goods users

The methods to evaluate exposure doses are shown below. Those who evaluate internal exposure doses should consult with specialized agencies.

(1) Method to evaluate exposure doses based on radiation dose rates

A) Calculate net radiation dose rates at the positions where consumer goods are used based on Appendix 1.
B) Estimate the duration of use of consumer goods in a year. However, the maximum duration of use in normal usage should be adopted to avoid underestimation.
C) Calculate one-year exposure doses by multiplying the radiation dose rates calculated in 1 above by the duration of use estimated in B) above.

(2) Method to evaluate exposure doses based on the values of radioactivity analyses of consumer goods

If the values of radioactivity analyses of consumer goods are available (results of analyses by specialized agencies, etc.), it is allowed to evaluate exposure doses by using the following equations.

In the case of those consumer goods whose radioactivity concentrations can hardly be analyzed, it is allowed to estimate their radioactivity concentrations by calculation. However, the details of estimation should be recorded.

[Exposure dose of consumer goods used not in contact with the skin (effective dose) (Dose I)]

$$\text{Dose I (mSv/a)} = \text{DEX } [\text{mSv/h/(Bq/m}^2)] \times \text{C(Bq/g)} \times \text{M(g)} \times \text{T(h/a)} \div [\text{D(m)}]^2$$

[Exposure dose of consumer goods used in contact with the skin (effective dose) (Dose II)]

$$\text{Dose II (mSv/a)} = \text{DSKIN } [\text{mSv/h/(Bq)}] \times \text{C(Bq/g)} \times \text{M(g)} \times \text{T(h/a)}$$

Where,

DEX: Conversion factor into exposure dose (effective dose) per Bq at a place one meter away [mSv/a/ (Bq/m^2)]

DSKIN: Conversion factor into exposure dose (effective dose) per Bq (mSv/h/Bq)

C: Radioactivity concentration in consumer goods (Bq/g)

M: Weight of consumer goods (g)

T: Assumed duration of use (h/a)

D: Distance between consumer goods and user (m)

Table 6. Conversion factor into exposure dose (effective dose)

Name of radioactive material	DEX	DSKIN
Thorium	1.8E-10	9.6E-09
Uranium	2.7E-10	1.3E-08

(Conversion factors derived from European Commission; Radiation Protection 65(1993))

(3) If the exposure doses calculated in (1) or (2) above are estimated to exceed 1 mSv/year in normal usage, the measures prescribed in “2.2.5 (2) Measures for improvement to reduce exposure doses” in the guidelines should be taken.

Commentary

Commentary 1 Background of guideline preparation

In February 2003, the exemption from regulation for naturally occurring radioactive materials (NORM) was reviewed by the General Administrative Group of the Radiation Review Council, and the Group reviewed the exemption from regulation for NORM in relation to the introduction of "International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources" (hereinafter referred to as "BSS") of the International Atomic Energy Agency (hereinafter referred to as "IAEA") and compiled a report on "Exemption of NORM from regulations" (hereinafter referred to as "General Administrative Group Report") in October 2003.

The General Administrative Group Report concluded, as a result of surveys that were made from various angles such as evaluation of radiation exposure based on the recommendations of the International Commission on Radiological Protection (hereinafter referred to as "ICRP") and the ideas presented in the European Commission's report (RP-122 Part 2) concerning the regulations on NORM and in consideration of the trends in other countries and the realities of use of NORM in Japan, that it was appropriate to clarify the measures for classifications by the state of materials and regulations appropriate to such classifications, and to apply the exemption from regulation pursuant to the characteristics of each classification.

The indicative values and reference values of doses to cope with radiation exposure due to coal ash (fly ash), etc. generated by using those raw materials whose radioactivity concentrations are lower than the BSS exemption levels are clearly stated in the General Administrative Group Report as the matters to be discussed in the future.

In consideration of these points, MEXT's Subcommittee on Safety Regulations for

Research Reactors, etc. made discussions about a desirable safety management in the future in relation to the use of NORM, and put together a report on "Desirable Safety Regulations for Test and Research Reactor Facilities, etc." (hereinafter referred to as "Review Meeting Report") in January 2005 with focus on those materials that contain thorium-232 series nuclides and uranium-238 series nuclides, which exceed exemption levels in BSS.

As the measures to be taken for the present, the Review Meeting Report concluded, taking it into consideration that regulations are applied in other countries pursuant to their situations and that management systems operated by industrial associations are considered effectively working, that it is appropriate to prepare guidelines with reference to the General Administrative Group Report and opinions of knowledgeable persons, rather than immediately introducing regulation under the law, and then to require manufacturers and importers who handle NORM to conduct self management based on the guidelines.

Based on the Review Meeting Report, moreover, the Subcommittee on Safety Regulations for Research Reactors, etc. developed the "guidelines for measurement of and measures for exposure doses at the time of use of matters that contain naturally occurring radioactive materials" (hereinafter referred to as "Proposed NORM Guidelines") in February 2006.

However, in the process of promoting discussions about Proposed NORM Guidelines, various inputs were received from relevant organizations. As effective operation of the guidelines was found to be difficult, the Subcommittee on Safety Regulations for Research Reactors, etc. decided in July 2008 to review the contents of Proposed NORM Guidelines.

Based on the reports mentioned above and review by knowledgeable persons, the guidelines organized the specific matters for manufacturers and importers to voluntarily evaluate doses and take measures for improvements, in order to prevent workers who handle raw materials and products that contain uranium or thorium, among those that contain NORM, and residents living in the vicinities and consumer goods users that contain uranium or thorium from radiation exposure of a certain level or higher.

Commentary 2 Concept of radiation exposure of the general public

(1) Dose limits and others specified by law

In the Reactor Regulation Law, dose limits on workers and the general public are specified, respectively, concerning exposure dose limits on radiation exposure of human beings. In the Reactor Regulation Law, “dose limits on occupationally exposed persons” and “dose limits on places other than supervised areas” are specified. The dose limits on occupationally exposed persons are set at “100 mSv for five years and 50 mSv for one year,” and the dose limits on places other than supervised areas are usually interpreted as “dose limits on the general public” and set at “1 mSv for one year.”

As for these dose limits, other countries have also introduced nearly the same regulations into their domestic laws based on the reports of ICRP and IAEA. Even in the case of lower than dose limits, doses must be reduced to the extent reasonably achievable in principle.

However, even in the case that it is higher than the dose limit (1 mSv/year), clinical findings have not been confirmed with radiation doses of lower than 100-200 mSv. In other words, this dose limit is one-hundredth or lower than the level where clinical findings can be confirmed, meaning the level to conduct risk management by radiation.

(2) Radiation exposure due to natural radiation

The exposure dose due to natural radiation is estimated at 2.4 mSv/year on average in the world (see Daily Life and Radiation as Reference Material).

This is the total of external exposure, which is caused by cosmic radiation that falls down from outer space onto the earth and terrestrial radiation and others from radioactive materials contained in soils and rocks on the ground surface, and internal exposure which is caused by respiration of radon gas in the air and ingestion of potassium-40 contained in foods.

The exposure dose standard of 1 mSv/year, which is adopted by the guidelines, is equivalent to about half of the world average of 2.4 mSv/year as exposure dose from natural radiation.

(3) Position of 1 mSv/year in the guidelines

In recent years, the following direction is presented in Japan and other countries concerning protection from NORM:

A) The General Administrative Group Report insisted that targeted exposure dose standards should be examined between 10μSv/year as the dose standard for exemption for acts and 1 mSv/year as the standard for exemption for intervention.
B) The exemption standard for intervention of products in ICRP Publication 82 is set at about 1 mSv/year.
C) In the chairman’s summary of NORM Symposium V (2007) hosted by IAEA, it is mentioned that “The order of 1 mSv/year, rather than 10μSv/year, is desirable as the level of exemption from regulation for NORM from the viewpoint of effective utilization of regulated resources and is also generally used as the standard value for NORM.”

In consideration of the above-mentioned circumstances in Japan and other countries, the guidelines adopted 1 mSv/year as the standard for exposure dose.

Commentary 3 Regarding the standards for radioactivity concentrations

IAEA's BSS has proposed a regulatory exemption value equivalent to 10μSv/year for materials up to one-ton order. The value for natural uranium or thorium is set at 1 Bq/g.

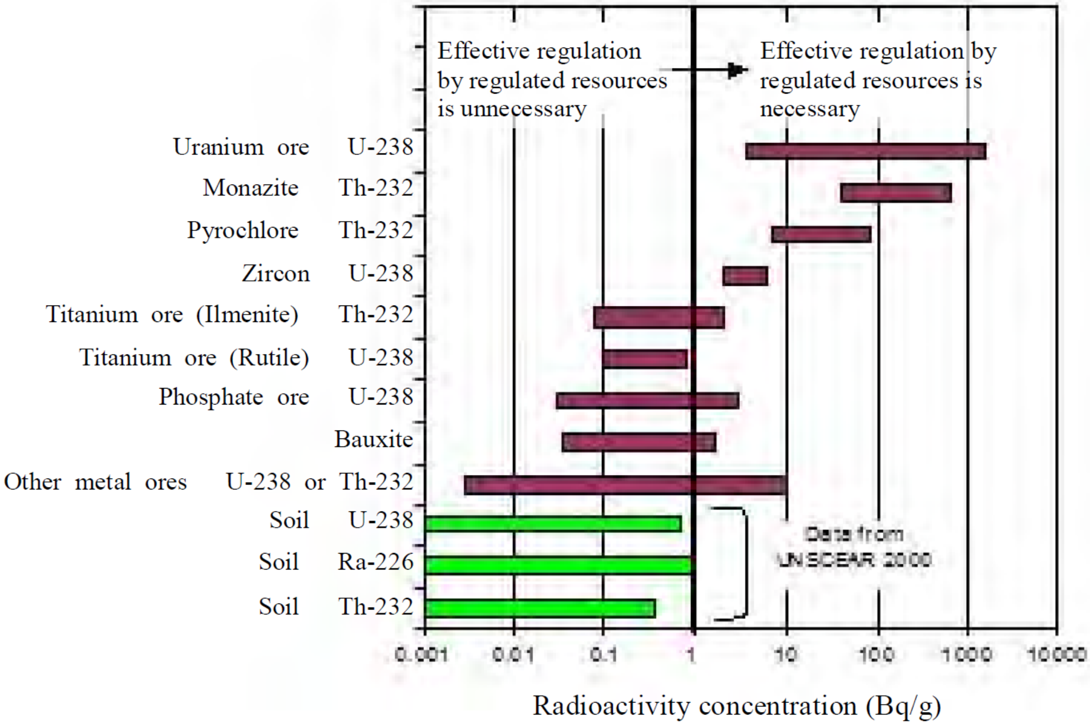
IAEA's Safety Guide No. RS-G-1.7 has proposed 1 Bq/g for natural uranium and thorium as the regulatory exemption value for materials of one-ton order or larger. This value was reported in the report for 2000 of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) as the result of survey on worldwide distribution of radioactivity concentrations of uranium and thorium in soil, and 1 Bq/g as the upper limit thereof was proposed in RS-G-1.7 as the value that needs to be reviewed for regulation of radiation protection. Moreover, it is considered unlikely for this radioactivity concentration of 1 Bq/g to exceed 1 mSv/year, except for exposure to radon.

While taking the above-mentioned international trends into consideration, the guidelines have adopted 1 Bq/g as the standard for the radioactivity concentrations of natural uranium or thorium.

For information, this value is applied to uranium series and thorium series in the state of radiation equilibrium, and represents the radioactivity concentrations (1 Bq/g) of parent nuclides of the series, i.e., uranium-238 in uranium series and thorium-232 in thorium series.

As for exposure dose, the effect of daughter nuclide generated by the disintegration of parent nuclide is also taken into consideration.

As for refined uranium or thorium, on the other hand, exposure is limited to uranium or thorium only because the daughter nuclides that contribute to radiation exposure are removed, and exposure doses drastically decrease. As the standard for radioactivity concentration of refined uranium or thorium, 10 Bq/g was adopted by using the ratio of natural uranium or thorium, which is used by international organizations such as BSS, and the ratio of refined uranium or thorium (1/10).



Source: Proceedings of the 5th international symposium on naturally occurring radioactive material. IAEA. 2007

Fig. 4. Data as the grounds for radioactivity concentration of 1 Bq/g

Commentary 4 Regarding the standards for quantity of radioactivity of consumer goods

The quantities of uranium and thorium contained in consumer goods are much smaller than that of raw materials, which are handled in large quantities on an industrial scale. Therefore, if it is obvious that the quantity of uranium or thorium in consumer goods is less than a certain value, it is considered reasonable to make such consumer goods not subject to the guidelines.

The General Administrative Group Report also states that it is appropriate to make those consumer goods, whose concentrations and quantities of radioactivity exceed certain values, subject to the guidelines.

Therefore, the standard for the quantity of radioactivity contained in consumer goods was calculated based on the following ideas.

By using the equation for evaluation of exposure dose in Appendix 2 of the guidelines, the quantity of radioactivity equivalent to 1 mSv/year as the standard for the exposure dose of the guidelines was calculated. The maximum value of 8,760 hours was adopted as the duration of use on the safety side.

The results of calculation are shown in Figs. 8 and 9.

(1) Results of calculation in the case that the distance between user and product is one meter

The quantity of radioactivity that reaches 1 mSv/year for the duration of use of 8,760 hours in the distance of one meter is about 630,000 Bq for natural thorium and about 420,000 Bq for natural uranium, according to Dose I equation. Divided by the statutory radioactivity concentration of 370 Bq/g (solid), the mass of natural thorium and that of natural uranium are about 1.7 kg and about 1.1 kg, respectively. Such consumer goods that have such a large quantity and heavy mass of radioactivity and are used at a place within one meter for many hours can hardly be assumed.

Table 7. Quantity of radioactivity that reaches 1 mSv/year in the distance of one meter

	Unit	Thorium	Uranium
Exposure dose	mSv/y	1.0	1.0
Conversion factor	mSv/h/(Bq/m2)	1.80E-10	2.70E-10
Quantity of radioactivity	Bq	634,196	422,797
Duration of use	h/y	8,760	8,760
Distance from the product	M	1	1

(2) Results of calculation in the case of use in contact with human bodies

According to the results of calculation by Dose II equation in the case of use in contact with human bodies, the quantity of radioactivity that reaches 1 mSv/year for the duration of use of 8,760 hours is 11,891 Bq for natural thorium and 8,781 Bq for natural uranium.

Table 8. Quantity of radioactivity that reaches 1 mSv/year in the case of use in contact with

	Unit	Thorium	Uranium
Exposure dose	mSv/y	1.0	1.0
Conversion factor	mSv/h/Bq	9.60E-09	1.30E-08
Quantity of radioactivity	Bq	11,891	8,781
Duration of use	H/y	8,760	8,760
Distance from the product	M	In contact with human bodies	In contact with human bodies

(3) Conclusion

Judging from the results of two calculations above, there is no possibility of exposure to consumer goods, which exceeds 1 mSv/year, except for those consumer goods that are used in contact with or close to human bodies.

Therefore, those consumer goods that are used in contact with or close to human bodies and whose quantity of radioactivity of natural uranium or thorium exceeds 8,000 Bq are made subject to the guidelines.

In the case of refined uranium or thorium that contains no daughter nuclide, those consumer goods whose quantity of radioactivity is more than ten times as much or 80,000 Bq for the reasons of Commentary 3.

Commentary 5 Handling of refined uranium or thorium

Metals, glass and others with refined uranium or thorium added to them are included in the definition of "specified raw materials" in the guidelines.

Refined uranium and thorium are nuclear fuel materials, and the handling of more than a certain quantity of them is subject to legal control.

As many of the processes to add refined uranium or thorium to metals and glass use a large quantity and need permission, they are subject to statutory regulations. On the other hand, in the case where the concentrations and quantities of radioactive materials contained in products manufactured under statutory regulations are less than the regulatory values of concentration or quantity, such products may not be subject to statutory regulations. Even in such case, however, if the concentration of refined uranium or thorium is higher than 10 Bq/g, it is decided to make them subject to the guidelines.

Uranium and thorium under statutory regulations are handled in controlled areas, and sufficient consideration is given to radiation exposure control of workers. However, those products whose values of concentration or quantity of radioactive materials are less than statutory regulations (such as thoriated tungsten, uranium glass, etc.) are handled in the same way as ordinary goods, and it is not recognized that radioactive materials are contained in them.

In the case where those that contain uranium or thorium are handled continuously inside and outside a controlled area, it is possible to conduct the management required by the guidelines by sharing available measuring instruments and measurement data of radiation.

On the other hand, in the case where those products whose values are less than statutory regulations are shipped to other companies, necessary information should be provided to help the evaluation of exposure doses and safe handling at the destinations.

Commentary 6 Evaluation of dose exposure from wastes

Rather than disposing of all wastes, recycling them as raw materials or for other applications leads to reduction in consumption of natural resources and environmental loads. Recycling of wastes has become increasingly important.

Under the guidelines, those who produce wastes should be responsible for the evaluation of wastes in storage. When wastes are delivered to other companies for recycling, necessary information for evaluation of exposure doses is required to be provided to the companies to which the wastes are delivered. When wastes are delivered with an aim to landfill disposal as industrial waste (including the case where wastes go through intermediate treatment), as those who produce wastes confirm that exposure doses does not exceed roughly 1 mSv/year, those who dispose of industrial wastes are not subject to the guidelines and, therefore, are not obliged to evaluate exposure doses.

Commentary 7 Conditions of use of specified raw materials

Many of the specified raw materials stipulated in (5) of section 2.4 are used as raw materials of various products as the materials inherently have the characteristics of valuable resources.

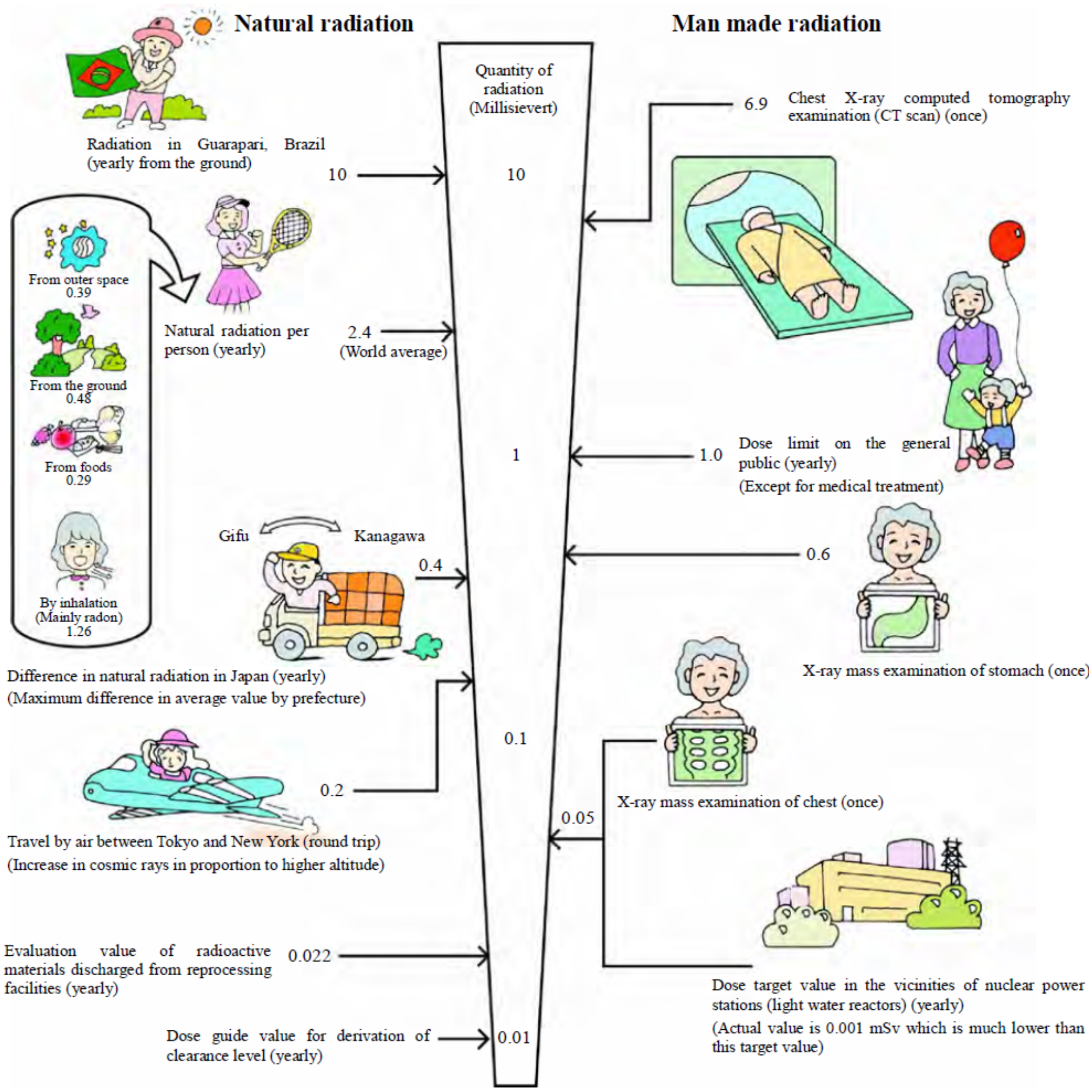
As a result, radioactive materials are contained in some of them. On the other hand, radioactive materials are contained intentionally to use radiation or used as-is in some cases.

The forms of utilization of specified raw materials are as follows:

Table 9. Form of utilization of specified raw materials

Specified raw materials	Industrial products (By-products)	Consumer goods
Monazite	Powder admixture	Negative ion products Textile products: bedding, underclothes, waistcloths, socks, negative ion sheets Accessories: bracelets and wristbands Home spa machines and catalysts for exhaust mufflers of automobiles
Bastnaesite[15]	Classified powders and abrasives	Sandpaper and polishing powder
Zircon	Firebricks, casting sand and glazes for ceramics	Electronic materials and glass
Tantalite	Tantalum alloy and high corrosion-resistant materials	Electronic components
Phosphate ore	Ammonium phosphate and gypsum	Fertilizers and building materials
Titanium ores (rutile and ilmenite)	Pure titanium materials, titanium alloys and titanium oxide	Titanium metal products Paints and pigments, printing ink, resin colorants, rubber colorants, chemical fiber colorant and paper finishing agents
Coal	Clinker and fly ash	Cement
Refined uranium	Glazes and glass coloring agents	Cloisonne ware accessories, ceramic wares and glass products
Refined thorium		Gas lamp mantles, optical lenses, camera lenses, tungsten welding electrode bars and high-intensity discharge lamps

[Fig. 5: Daily Life and Radiation]



Source: "Collection of Nuclear Power Drawings 2007"

6 KAZAKHSTAN

6.1 Sources of NORM&TENORM

Radioactive waste in RK represented by the waste of uranium mining, oil&gas production, and metallurgical industry in a form of dump piles and tail pits, contaminated soils, pipes, equipment, liquid and solid waste of decommissioning BN-350 NPP, operating research reactors in Alatau town and in Kurchatov town, sealed sources, used in different industry, medicine and agriculture, which are not used anymore and should be disposed, and territories and equipment, contaminated in the result of nuclear testing in RK.

At the present time RK has comparatively comprehensive and centralized information for spent sealed sources (logged by CAESC ME RK), operational and decommissioning waste of reactors (logged by the operators, submitted to CAESC ME RK), uranium mining and processing industry (logged by the enterprises, submitted to CAESC ME RK).

Information on the waste, produced in the result of nuclear and “dirty bombs” testing and from mining, coal, and oil industry is not complete and requires implementing additional investigations and developing of RW Inventory Cadastre.

Attempts to gather information from regions and to create national radioactive waste cadastre were made several times. The first and the most comprehensive inventory of radioactive waste storage and disposal sites were carried out in 1993. In the course of this activity, 529 sites of radioactive waste storage and disposal were identified, including:

- 127 related to uranium mining and production industry
- 76 related to non-uranium industry
- 16 related to nuclear testing
- 5 related to reactors
- 301 related to enterprises using sealed sources of different type.

Radioactive waste identification and classification criteria

In accordance with the RK Law “On the atomic energy use” radioactive waste is determined as radioactive substances, nuclear materials or radionuclide sources with radionuclide content above the exemption level the further use of which is not provided for. The exemption levels are established in Hygienic Standards “Sanitary requirements for radiation safety”.

RK Ecology Code (chapter 44, article 307) gives more detailed definition of radioactive waste and its classification:

1. Radioactive waste is the following radioactive substances in any aggregative state, which are not a subject for the further use:

- Materials, items, equipment, objects of biological origin, with radionuclides content, exceeding the levels, established by RK legislation;
- Spent nuclear fuel, which is not a subject for the following reprocessing;
- Spent and failed radionuclide sources;
- Extracted from subsoil and placed into dump piles and tail pits rocks, ores and waste of ore enrichment and extraction, with radionuclides content, exceeding the levels, established by RK legislation.

2. The basis for radioactive waste classification is its aggregative state, origin, activity level, half decay period.

3. By aggregative state radioactive waste is divided on liquid and solid ones. Non-organic solutions, filtering materials sludge, organic liquids are related to liquid radioactive waste. Items, components of machines and mechanisms, materials, biological objects, spent radiation sources are related to solid radioactive waste.

4. The waste is considered as radioactive waste if specific activity of containing radionuclides is more than the values, established by the Hygienic Standards "Sanitary requirements for radiation safety", and if radionuclide composition is not known, if its specific activity is more than:

- One hundred kilo Becquerel per kilogram – for beta-emitting nuclides;
- Ten kilo Becquerel per kilogram– for alpha emitting nuclides (excluding transuranium);
- One kilo Becquerel per kilogram – for transuranium nuclides.

5. By the origin radioactive waste is classified as follows:

- Metal mining industry waste;
- Waste of research and commercial nuclear facilities;
- Waste of nuclear explosions;
- Disused and spent radioactive sources.

6. By the activity level, the solid radioactive waste is classified as follows:

- Low level waste – a waste with specific activity (kilo Becquerel per kilogram): less than one thousand – for beta-emitting nuclides, less than one hundred – for alpha emitting nuclides (excluding transuranium), less than ten – for transuranium nuclides; Intermediate waste– a waste with specific activity (kilo Becquerel per kilogram): from one thousand to ten million – for beta-emitting nuclides, from one hundred to one million – for alpha emitting nuclides (excluding transuranium), for ten to one hundred thousand – for transuranium nuclides;

- High level waste – a waste with specific activity (kilo Becquerel per kilogram): more than ten million – for beta-emitting nuclides, more than one million – for alpha emitting nuclides (excluding transuranium), more than one hundred thousand – for transuranium nuclides.

Spent Nuclear Fuel and Radioactive Waste

At the territory of Republic of Kazakhstan there are 5 reactors, one BN-350 NPP in Aktau, three research reactors at territory of former Semipalatinsk Testing Site in Kurchatov and one research reactor near Almaty (Alatau settl.).

BN-350 Nuclear Power Reactor

Currently in the Republic of Kazakhstan there is only one decommissioning facility – fast breeder reactor of the BN-350 NPP located near Aktau city.

The BN-350spent fuel was packed into dual use metal concrete casks and transported to specially constructed long-term storage site of open type located at “Baikal-1” the branch of IAE NNC RK near Kurchatov City for long-term storage.

There are the following facilities for RW management at the BN-350:

- Storage facility for low level and medium level solid radioactive waste (according to internal enterprise classification). SRW with dose rate from 0.1 to 30 mR/h (0,001-0.3 mSv/h) and from 30 to 1000 mR/h (0.3-10 mSv/h) and for high level waste with dose rate more than 1000 mR/h (10 mSv/h).
- Reactor equipment storage cooling facility.
- BN-350 Hot Cell vault.
- Facility for liquid waste collection and storage.
- Sodium processing facility (SPF).

The Kazakhstan Government adopted Resolution № 456 on BN-350 decommissioning. This Resolution determined the concept of the reactor facility decommissioning. This concept provides the decommissioning in three main stages:

Stage 1. Bringing the BN-350 reactor plant into a state of long-term safe storage.

Stage completion criteria are:

- the fuel is unloaded from the RF and placed for a long-term storage;
- liquid metal coolant is removed from the RF, processed, radioactive processing products are placed for a long-term storage;

- RW are processed and placed for a long-term storage;
- RF, buffer area and control area radiation monitoring is provided;
- The composition of remaining under operation, dismantled and mothballed equipment is determined, and the required work is performed.

Stage 2. Long-term safe storage.

Stage completion criteria are:

- the 50-year long storage period term is being completed;
- the decision to commence work on final dismantling is made.

Stage 3. Partial or complete dismantling of equipment, buildings and structures, and disposal of. Criteria for completion of the third main stage:

- partial or complete dismantling of equipment, buildings and structures is performed;
- complete decontamination and rehabilitation of the territory is performed;
- RW are placed for a long-term storage or disposed of.

In cooperation with organizations of the Russian Federation, a feasibility study for the decommissioning project of the BN-350 RP has been developed and is undergoing approval, which, after approval, will serve as the basis for allocating funding, developing individual projects for construction phases and their implementation.

It is necessary to note that a lot of radioactive waste will be produced during its dismantling. According to estimations, total amount of conditioned and packaged waste produced after the BN-350 decommissioning will be around 62300 m^3.

WWR-K Reactor

Since 2016, WWR-KN fuel assemblies have been used as fuel at the WWR-K reactor. The fuel composition is uranium dioxide dispersed in an aluminum matrix (UO2-Al). Fuel enrichment by uranium-235: 19.7%, uranium density: 2.8 g/cm3. The maximum permissible burnup is 60% for uranium-235.

In the WWR-K reactor core, two types of WWR-KN fuel assemblies are used: eight-pipe (type 1 fuel assemblies) and five-pipe (type 2 fuel assemblies). The rate of spent fuel production of the WWR-KN type averages 9-10 fuel assemblies per year, the total activity at the moment is 134230 TBq.

The spent nuclear fuel (SNF) storage system of the research reactor WWR-K is intended for temporary water storage of spent fuel assemblies (SFAs) removed from the WWR-K core.

The storage system consists of two storage areas: wet storage and storage tank. Both storage facilities are located in the central hall of the reactor.

During the first four years after being removed from the core, spent fuel assemblies are stored in a wet storage facility, and then they are transferred to a storage pool. The minimum total storage time of spent fuel assemblies is determined by the need to reduce the residual energy release to a value that allows safe transportation from the reactor site to the processing facility in a special container of the processing organization.

Radioactive waste generation at the averages: liquid radioactive waste (LRW) from 6 to 24 m^3 per year, with activity up to 3GBq, low active and intermediate active solid radioactive waste (SRW) from 50 to 500 kg per year with the activity up to 14GBq. There is a facility for simultaneous cementation of SRW and LRW. Disposal facility is intended for disposal of low- and intermediate activity liquid waste. The design capacity of the DF makes 2375 m3 and percentage of DF occupation for today makes 80% for low activity and 15-20% for intermediate activity waste. The design capacity in terms of activity makes 40000 Ci, and the actual activity makes 8500 Ci.

IGR Reactor

The rate of accumulation of spent fuel at the IGR is determined by the amount of fuel in the experimental devices tested (irradiated) in the IGR reactor. Defueling is not performed since 1968.

Experimental devices with fuel tested in IGR reactor are placed in the nuclear materials storage facility in premise 0101 of building 1 for aging (3...5 months) and then transported to the radiation-protective chamber (RPC) on "Baikal-1" for the post-reactor examination. After research activities, the fuel is placed for long-term storage. Amount of spent fuel accumulated in 24 experimental devices of IGR reactor makes 94.8 kg of uranium. The total activity is 7450 GBq.

Two storage facilities are used at IGR for storing the spent fuel (located on the IGR reactor site). Radioactive wastes generated at IGR reactor are transported in the prescribed order to the long-term storage facility at "Baikal-1".

IVG.1M Reactor

During the period of operation of IVG.1M reactor (1990 -2023) thirty-three fuel assemblies were unloaded from the reactor core: one fuel assembly in 2004, two – in 2017 and thirty – in 2021. During the period from 2017 to 2019 two LEU fuel assemblies were loaded, tested and unloaded from the reactor. In 2021, two fuel assemblies (which were unloaded in 2017) were returned into IVG.1M reactor.

Thirty-three fuel assemblies are placed for a long term storage into IVG reactor storage facility. Amount of spent fuel accumulated in the assemblies is 5870 grams of uranium. The total activity is 17310 GBq.

The average rate of radioactive waste formation at reactor complexes is as follows:

- Solidwaste-300 ... 400kg/year;
- Liquidwaste-2.0 ...3.0 m^3/year.

The amount of solid radioactive waste at RRC "Baikal-1" assigned to the enterprise’s own accumulations, makes 184 716 kg with a total activity of 4929 GBq.

Total quantity of the wastes placed in "Baikal-1" long-term storage facility with the account of radioactive waste received by NNC RK externally (enterprises, organizations, orphan) is 2 820 194 kg with a total activity of 7658 GBq.

RA reactor

In 1998, in accordance with intergovernmental agreements fuel from the reactor was unloaded and transported to Russia. RA reactor is shut down, but formally reactor is in operation (extended shutdown mode).

Facilities for Management of Waste from Uranium Mining and Production Industry and Oil-extraction Industry

There are the following facilities to handle the waste of uranium mining and production industry in the Republic of Kazakhstan:

- Tail pit of Stepnogorsk ore&chemical enterprise is located in 25 km from Stepnogorsk town and 160 km from Astana city. Hydro-metallurgical plant of the enterprise processes not only uranium ore, but also concentrates of natural uranium for the enterprises of JSC “Kazatomprom”. The enterprise discharge waters are withdrawn into the tail pit, which consists of three ponds with the surface area around 757 hectares (Pond #1 – 162 hectares, evaporation pond – 270 hectares and sludge lines – 22 hectares) and total fine dispersed sludge amount 49.1 million tons. Environmental management system guarantees the safety of the object provided the stable operation of the plant. As a result of upgrading the performance of the plant exceeded the rated capacity and is currently 4000 t of uranium oxide per year. Molybdenum ore processing concentrator is installed and put into operation on available capacity LLP “Stepnogorskore&chemical enterprise” (SOCE) in order to cover uranium tails by low-toxic solid waste of copper and molybdenum production. Currently the tail pits store 41979 cubic meters (49116 thousand tons) of low-level radioactive waste with total activity 7100 TBq.

- Liquid low-level waste are located in 5-evaporative ponds of mine Shantobe belonging to LLP "SMCC" at 450 km from Stepnogorsk town and 420 km apart from Astana city with total area of 6.5 hectares. Currently, the mine has181.4 thousand tons (178 thousand cubic meters) of liquid radioactive waste with a total activity of 1.752 GBq.
- Tail pit Kashkar-Ata of former Caspian mining&smelting enterprise near Aktau city. Kashkar-Ata contains 120000000 m3 of radioactive waste. Since 2006 the tail pit is in rehabilitation process.
- Tail pits (ponds) of Ulba Metallurgical Plant (UMP). Storage of UMP radioactive waste is realized at the “Tailing Site” Storage (TSS). Liquid waste ponds are of open type and store the waste of discharges and sludge from all the production lines. As of the beginning of 2014 total amount of RW is 6411667.7 m^3 with total activity 194.33 GBq.
- Two near surface RW disposal facilities at production sections PV-1 and PV-2with 10000 m^3 and 16 m^3 designed capacity belonging Joint Enterprize Inkay Kazatomprom (RK) and Cameco Corporation (Canada), located in 10 km from Taykonyur settlement in Suzak area of South Kazakhstan oblast.
- Near surface RW disposal facility at Kanzhugan deposit, designed capacity 7200 m^3 belonging to TaukentOre&Chemical Enterprise in Suzak area of South Kazakhstan oblast.
- Near surface RW disposal facility with designed capacity 10000 m^3 belonging to “RU-6” Ltd, located in 90 km from Sheeli settlement of Kyzylorda oblast.
- Near surface RW disposal facility with designed capacity 80000 m^3 belonging to“Stepnoye Rudoupravlenie” Ltd, Kyzemshek settlement, Sozak area, South Kazakhstan oblast. It was commissioned in 2007.

For RW of oil-extraction industry management:

- Facility for deactivation of pipes and metal equipment of oil fields in Mangistau oblast. Sites for cleaning and deactivation of pipes and equipment are constructed at the oil deposits Kalamkas and Zhetybay in Mangistau oblast. Storage facilities for radioactive waste are constructed and commissioned in Zhana-Ozen (100 000 tons) and Zhetybay (70 000 tons) deposits.

6.2 Management of NORM&TENORM

Spent Fuel Management Policy

Decision has not been made yet in the Republic of Kazakhstan if a spent nuclear fuel is the valuable resource or waste.

Spent fuel (SF) management in the Republic of Kazakhstan is represented currently by long-term storage under surveillance at the specialized sites (storages), in compliance with government decisions in this area.

Nevertheless, the long-term storage is not considered as an “end point” in spent fuel management, it is only temporary decision. The real “end point” may be spent fuel utilization (processing) or disposal, that is the actions excluding possibility for further spent fuel management. In order to realize it, it is planned to develop a strategy of future spent fuel management at the example of BN-350 nuclear power plant hereinafter referred to as BN-350 NPP and research reactor spent fuel, which allows achieving the end point. To develop this strategy, RK will consider all the possible management options of further usage aimed to choose the optimal variant meeting different criteria, such as political acceptance, technical and economical feasibility, etc.

Spent Fuel Management Practices

Spent Fuel of BN-350 NPP

The only commercial power reactor in the Republic of Kazakhstan – fast breeder reactor BN-350 NPP, was in operation from 1973 to 1999. During the reactor operation spent fuel was routinely transported to Russian Federation for reprocessing. After the collapse of the Soviet Union in 1991 all the remaining spent fuel was stored in the reactor on-site pool-type storage.

Since 1995 the BN-350 NPP is under IAEA safeguards in accordance with "Agreement of 26 July 1994 Between the Republic of Kazakhstan and the International Atomic Energy Agency for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons”. To comply with the Agreement requirements, computerized system of nuclear materials accounting and control was established at the BN-350 NPP to allow nuclear materials accounting and control. The system allows realizing control and accounting of nuclear materials on the reactor from the IAEA’s point of view and lead accounting of nuclear material quantity in each recorded unit.

In the area of spent fuel management the Republic of Kazakhstan has recently performed a number of several very important and practical steps.

In the field of spent fuel management, the Republic of Kazakhstan has taken a number of important practical steps in recent years. During the operation of the BN-350 reactor plant, the unloaded spent fuel was stored under water in the spent fuel pools, and then was sent to Russia for reprocessing. After the collapse of the USSR, the transportation of spent fuel ceased, and the remaining fuel continued to be stored in the spent fuel pools. Then, with financial and technical support from the United States, the spent fuel was packaged in sealed stainless steel canisters. After that, all the fuel was loaded into specially made two-purpose metal-concrete containers (transportation and long-term storage) and transported to the Baikal-1 site, located on the territory of the former Semipalatinsk test site, where the spent fuel is currently placed for long-term storage under IAEA guarantees. The storage is equipped with all the necessary physical protection systems. The estimated service life of the storage containers is 50 years, taking into account certification every 5 years of storage. Before the expiration of the storage period, it is necessary to make a decision on the final option for management of this fuel.

Spent Fuel of Research Reactors

In the Republic of Kazakhstan there are four research reactors (RR): RA, IVG-1M, and IGR reactors of the Institute of Atomic Energy of National Nuclear Center RK (IAE NNC RK), and WWR-K reactor of the Institute of Nuclear Physics (INP). The first three are located within the territory of former Semipalatinsk Nuclear Test Site near Kurchatov, and WWR-K reactor is located near Alatau settlement, close to Almaty.

Current strategy of RR spent fuel management consists of its unloading from the reactor, transportation into on-site storage and long-term storage under surveillance. The spent fuel of WWR-K reactor has been sent for reprocessing to Russian Federation with further return of high active processing wastes to the Republic of Kazakhstan. Return of high active wastes to RK is planned for 2028-2029, so a decision should be made for selection of disposal site by this time.

Radioactive Waste Management Policy

According to Article 17 of RK Law “On the Use of Atomic Energy”, the policy for radioactive waste management in RK is the following:

- Radioactive waste generated on the territory of the Republic of Kazakhstan should be disposed in such a way as to ensure radiation protection of the population and the environment for the entire period of time during which they may pose a potential hazard.

- The individuals and legal entities realizing the activities in the field of atomic energy use, which resulted in radioactive waste generation, shall take measures to minimize the wastes.
- The safe placement of spent nuclear fuel and radioactive wastes shall be provided for by design and operational documentation as an obligatory stage of any activity leading to the formation of radioactive waste.
- Only legal entities are allowed to handle SNF.
- The activities related to the management of radioactive waste and SNF are carried out on the basis of a license.
- Management of radioactive waste and (or) SNF should ensure compliance with the requirements of nuclear, radiation and nuclear physical security in accordance with the legislation of the Republic of Kazakhstan in the field of nuclear energy use, as well as international treaties ratified by the Republic of Kazakhstan.
- Management of radioactive waste and spent nuclear fuel shall be realized with compliance to the requirements established by the Environmental Code of the Republic of Kazakhstan.
- A complete list of regulatory and legal acts currently in force in the Republic of Kazakhstan applicable to the regulation of the atomic energy use, including the safety of spent fuel and radioactive waste management, is given in Appendix E to this Report.

Radioactive Waste Management Practices

An approach to radioactive waste management of nuclear reactors, commercial and research ones, includes long-term storage in the SRW storage facilities of research reactor complex “Baikal-1” site (for SRW of IGR, IVG.1M and RA research reactors, IAE NNC RK). For the BN-350 NPP reactor, being decommissioned, SRW is also stored in-site and LRW volume is minimized by evaporation followed by on-site storage. Reduction of liquid and solid radioactive waste share and construction of facilities for their conditioning is the main task for the forthcoming years. At the WWR-K research reactor of the Institute of Nuclear Physics, low- and intermediate solid and solidified wastes are cemented and disposed together in the on-site RW storage facility.

Waste of enterprises that use the isotope products such as sealed IRS with the expired lifetime, or if found to be defective shall be placed for the long-term storage in specialized facilities

Waste of former and operating uranium mining and production enterprises in a form of dump piles, sludge of tail pits, contaminated equipment, located in Mangistau (Caspian mining and smelting complex), North Kazakhstan, Akmolinsk (Stepnogorsk mining and smelting complex), Karaganda, Zhambyl, South Kazakhstan, Kyzyl-Orda regions (mine administration of former Kyrgyz mining and smelting complex), and Esat Kazakhstan region (Ulba metallurgical Plant and Irtysh chemical& Metallurgical Plant) are mothballed in accordance with the budget program "Conservation of uranium mining enterprises and elimination of consequences of uranium mining for 2001-2010. Local executive bodies (regions, cities of republican significance, the capital) determine the organization (enterprise) responsible for the implementation of radiation control and maintenance of the mothballed objects in a safe state.

The mothballing of uranium mining waste, contaminated soil and equipment is accomplished. RW was disposed into four available disposal facilities: Joint Enterprise Inkay, Taukent Ore&Chemical Enterprise, "RU-6" Ltd, and "Stepnoe mining administration" Ltd.

The practice of RW management at the territory of former Semipalatinsk nuclear test site (STS) after destruction of nuclear testing infrastructure consists of thorough bordering of areas with radioactive contamination and improvement of barriers created in 1995-2000 on the trilateral basis (RK-RF-USA) to prevent unauthorized access to the nuclear testing waste and contaminated areas. To bring the legal framework in line with the works to be carried out at the STS, a Law of the Republic of Kazakhstan "On the Semipalatinsk nuclear safety zone" has been developed.

Non-uranium mining and processing industry radioactive waste is represented by coal, polymetal, rare earth and phosphorites deposits, some of them contain uranium contamination, which is stored after extraction as dump piles and tail pits. Only small part of them is now rehabilitated as RW. Upper oxidized layers of coal beds are also contaminated with uranium, which is stored as RW up to the moment. Currently the designs of uranium contaminated coal extraction, provide for a storage and following disposal of RW.

At the oil deposits of West Kazakhstan there are storages of radioactive scrap metal, sludge and oil contaminated soils. At present in Zhanaozen area the facilities were constructed for equipment deactivation using the technologies of high pressure water cleaning, sandblasting, vibration one and melting with removal of radioactive slag. At oil deposits of Zhetybay and Zhanaozen in

Mangystau region, the storage facilities were commissioned into operation to store the waste of pipe and equipment cleaning.

Reprocessing of spent fuel

Currently, the Republic of Kazakhstan does not have the capacities to reprocess spent fuel. All the spent fuel from the WWR-K research reactor was moved for reprocessing to the Russian Federation due to a change in the design of the fuel elements; in exchange, fresh fuel was supplied in the new design assemblies. The spent fuel of the BN-350 reactor, which is being decommissioned, was transported to a specialized container storage outside the site. Fuel from other research reactors is stored in on-site storage facilities.

Radioactive waste which contains only naturally occurring radionuclides

Republic of Kazakhstan declares that the waste which contains only naturally occurred radionuclides and does not originate from nuclear fuel cycle is considered as radioactive waste.

Radioactive waste produced within military or defense programs

Republic of Kazakhstan declares that radioactive waste produced within military or defense programs transferred finally to civilian programs and is considered as radioactive waste.

6.3 Regulatory Base or Framework

The entering into force of the Law RK "On Ratification of the Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management" (No. 246-IV, of February 3, 2010) means that the existing legislation of RK does substantially allow implementing the obligations of the Republic of Kazakhstan resulting from the Joint Convention provisions. Adoption of this law on ratification made the provisions of the Convention to be obligatory for all the executive authorities and the organizations involved in management of spent fuel and radioactive wastes.

The Republic of Kazakhstan is developing, and will seek to develop a national strategy for the safe management of spent nuclear fuel and radioactive waste.

Legislative and Regulatory System

Functions specific to the nuclear regulator in terms of the Convention are currently assigned to the Ministry of Energy of the Republic of Kazakhstan (ME RK), which responsibilities in the field of atomic energy use were previously assigned to the Ministry of Industry and New Technologies of the Republic of Kazakhstan (MINT RK). Committee for Atomic and Energy Supervision and Control of ME RK (CAESC ME RK) (former Committee for Atomic Energy MINT RK), is the competent authority carrying out regulatory supervision and realization functions in the field of atomic energy use within the competence of the ME RK. Department of Atomic Energy and Industry, as a part of Ministry of Energy structure, concurrently is responsible for promotion of nuclear energy.

Regulatory functions in the field of the atomic energy use in the Republic of Kazakhstan are also carried out by the Committee for Environmental Regulation and Control of the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan (CERC MEGNR RK), which performs the functions of environmental protection, Committee of Quality Control and Safety of Goods and Services of the Ministry of Health of the Republic of Kazakhstan (CQCSGS MH RK) in the sphere of sanitary and epidemiological welfare of the population, the Ministry of Internal Affairs RK, carrying out permit functions and facilities security, the Committee for Industrial Development and Industrial Safety of the Ministry of Industry and Infrastructure Development of the Republic of Kazakhstan (CIDIS MIID RK), performs control and supervision in the field of industrial safety, and the Committee of Emergency Situations of the Ministry of Internal Affairs (CES MIA RK) performing the functions for liquidation of man-caused accidents.

The State regulation authorities are independent from each other, as well as from organizations whose activities are related to the use of atomic energy.

Legislative and Regulatory framework of safety assurance

The legal basis for regulating nuclear and radiation safety of personnel, population and environment while using the atomic energy in the Republic of Kazakhstan includes the Law RK "On Atomic Energy Use", the Law RK "On Radiation Safety of Population" and "Environmental Code of the Republic of Kazakhstan".

Regulation of safety of spent fuel and radioactive waste management is also realized in accordance with other delegated regulations of the Republic of Kazakhstan in the field of atomic energy use, the departmental technological regulations and safety instructions.

Constituent Parts of Legislative and Regulatory Framework

National Radiation Safety Requirements

Article 4 of the Law "On Atomic Energy Use" specifies that one of the main principles of the state policy in the field of the atomic energy use is the effective protection of people's life and health, their property, environmental protection, maintenance of nuclear, radiation safety and nuclear physical security, and nuclear weapons nonproliferation regime while using atomic energy.

The Law "On Radiation Safety of the Population" establishes the basic principles of ensuring radiation safety, requirements and regulating provisions for radiation safety.

Section 39 "Environmental Requirements for the Use of Radiation Materials, Atomic Energy and Ensuring Radiation Safety" of the Environmental Code of the Republic of Kazakhstan contains requirements for radiation safety from an environmental point of view.

Licensing of the Spent Nuclear Fuel and Radioactive Waste Management Activities

Article 9 of the Law RK "On Atomic Energy Use" establishes that the activities associated with the use of atomic energy shall be subject to compulsory licensing with a procedure established in of the Law of the Republic of Kazakhstan "On Atomic Energy Use" and legislation of Republic of Kazakhstan in the field of permissions and notifications.

In accordance with the Law "On permissions and notifications", the following activities or actions in the field of the atomic energy use are subject to licensing:

- work related to the life cycle stages of the objects using atomic energy;
- management of nuclear materials;
- management of radioactive substances, devices and installations containing radioactive substances;
- management of devices and installations generating ionizing radiation;
- management of radioactive wastes;
- transportation, including transit, of nuclear materials, radioactive substances, radioisotope sources of ionizing radiation, radioactive waste within the territory of the Republic of Kazakhstan.

Prohibition of spent nuclear fuel and radioactive waste management without license

Activities related to the nuclear energy use are subject to mandatory licensing in accordance with the procedure established by the legislation of the Republic of Kazakhstan on permits and notifications.

Any activity related to the use of nuclear energy is carried out under the condition of ensuring the protection of public health and the environment, the protection of property of individuals and legal entities from the harmful effects of ionizing radiation. Nuclear and radiation safety is provided by the operating organization in accordance with established norms and rules.

Article 8 of the Law of the Republic of Kazakhstan "On Atomic Energy Use" establishes that individuals and legal entities that carry out activities in the field of the atomic energy use are required to have a license for the relevant type of activity in the sphere of the atomic energy use.

System of Institutional and Regulatory Control, Documentation and Reporting

Nuclear and radiation safety is provided by the operating organization in accordance with the established rules and regulations.

Terms and conditions of the licenses issued by a state authority for safety regulation stipulate that the operating organization shall take appropriate measures in order for the control, inspection and testing of the equipment and systems important to safety to be carried out in accordance with the established procedures and schedules.

Regulatory control

CAESC ME RK controls the maintenance of a high level of nuclear and radiation safety at the controlled facilities. State control and supervision in the field of atomic energy use is carried out in the form of inspection and preventive control and supervision.

Inspection of the entities carrying out the activities with nuclear facilities and installations of categories I and II of potential radiation hazard (hereinafter referred to as the supervision subjects) is carried out by the competent authority on a periodic basis, but not more often than once a quarter, or may be unscheduled ones.

Periodic inspection is an inspection appointed by the competent authority in relation to the supervision subject in order to prevent and (or) eliminate an immediate threat to human life and health, the environment, the legitimate interests of individuals and legal entities, the state.

An unscheduled inspection is appointed by the competent authority due to specific facts and circumstances that served as the basis for the appointment of an inspection in relation to a specific supervision subject, in order to prevent and (or) eliminate an immediate threat to human life and health, the environment, the legitimate interests of individuals and legal entities, state.

Inspection of the entities carrying out activities with the facilities of III and IV categories of potential radiation hazard, with the exception of nuclear facilities, is carried out in accordance with the Entrepreneurial Code of the Republic of Kazakhstan.

Preventive control and supervision with visits to the entities carrying out activities with objects of I, II, III and IV categories of potential radiation hazard are carried out in accordance with the Entrepreneurial Code of the Republic of Kazakhstan.

Preventive control and supervision without visits to the entities carrying out activities with facilities of I, II, III and IV categories of potential radiation hazard are carried out in accordance with the Entrepreneurial Code of the Republic.

Based on the results of state control and supervision, depending on the established violations of the requirements of the legislation of the Republic of Kazakhstan in the field of atomic energy use, officials issue the following acts:

• Act on the Inspection Results is a document issued by an official exercising state control and supervision in the field of atomic energy use and based on the results of an audit of the entity for its compliance with the requirements of the legislation of the Republic of Kazakhstan in the field of atomic energy use;

• an order to eliminate the violation of the requirements of the legislation of the Republic of Kazakhstan in the field of atomic energy use;

• an order to suspend or prohibit certain types of activities;

• recommendation based on the results of preventive control and supervision without visiting the performer (target) of control and supervision.

Preventive control and supervision without visiting the subject (object) of control and supervision are of a preventive and routine nature.

Preventive control and supervision without visiting the subject (object) of control and supervision in the field of atomic energy use is carried out by analyzing:

• the information and reports submitted by individuals and legal entities in accordance with the requirements of the legislation of the Republic of Kazakhstan in the field of atomic energy use;

• information received at the request of the competent authority on compliance with the legislation of the Republic of Kazakhstan in the field of atomic energy use within its competence – if there is information about legislation's violation;

• information received from third parties regarding compliance with the legislation of the Republic of Kazakhstan in the field of atomic energy use.

If violations are revealed based on the results of preventive control and supervision without visiting the subject (object) of control and supervision in the actions (inaction) of the subject of control and supervision, the competent authority draws up and sends a recommendation no later than five working days from the date of detection of violations.

A recommendation sent in one of the following ways is considered delivered in the following cases:

• courier delivery – with a note of receipt;

• by mail – by sending a registered letter with notification;

• electronically – the competent authority sends a letter to the email address of the subject of control and supervision, which is specified in the documents previously submitted by the subject of control and supervision to the competent authority.

The deadline for the implementation of the recommendation to eliminate violations identified as a result of preventive control and supervision without visiting the subject (object) of control and supervision should be at least ten working days from the day following the day of its delivery.

The subject of control and supervision, in case of disagreement with the violations specified in the recommendation, has the right to send an objection to the competent authority that sent the recommendation within five working days from the day following the day of delivery of the recommendation.

Failure to comply with the recommendation on the elimination of violations identified as a result of preventive control and supervision without visiting the subject (object) of control and supervision in due time, entails the inclusion of the subject (object) of control and supervision in the six-month schedule of special procedure inspections.

The frequency of preventive control and supervisions without visiting the subject (object) of control and supervision is determined as necessary, but not more often than the frequency of providing the information.

Documentation and Reporting

The regulations and rules establish the requirements that the operating organization shall prepare and submit the periodic reports on the safety status of nuclear facilities and storage facilities to the state bodies for safety regulation and state public authorities.

The operating organization shall provide for filing of design documentation, executive documentation for construction, maintenance and repair of the safety systems (components) and the elements important for safety, as well as the materials of the investigations of operation violations throughout the lifetime of a nuclear facility and storage facility.

The operating organization shall ensure the transfer of information on violations at a nuclear facility and storage facility to the state body for safety regulation in accordance with the established requirements.

Measures Taken to Implement Existing Regulations and License Conditions

CAESC realizes the state control over compliance of a licensee with the license conditions in the field of nuclear and radiation safety and applies sanctions within its competence in case of licensee’s failure to do so.

“Code on Administrative Offenses of the Republic of Kazakhstan” on June 5, 2017, stipulates for the imposition of administrative fines and withdrawal of the licenses for violation of the established rules and regulations for management of nuclear materials and radioactive substances.

Division of Responsibilities of the Bodies Involved at Different Stages of Spent Nuclear Fuel and Radioactive Waste Management

Functions specific to the nuclear regulator in terms of the Convention are currently assigned to the Ministry of Energy of the Republic of Kazakhstan (ME RK), which responsibilities in the field of atomic energy use were assigned to the Ministry of Industry and New Technologies of the Republic of Kazakhstan. Committee for Atomic and Energy Supervision and Control of Ministry of Energy RK (CAESC ME RK) (former CAE MINT RK) is the agency carrying out control and realization functions in the field of atomic energy and electric energy use within the competence of the ME RK. Hereinafter referred to as the CAESC ME RK in the performance of its tasks within the competence of the ME RK is referred to as the "competent authority" in accordance with the legal definitions of the legislation of the Republic of Kazakhstan.

According to the Provisions on the CAESC ME RK the main tasks of the Committee under the authority of the Ministry are:

• implementation of the state policy in the field of electric energy and atomic energy use;

• realization of other tasks within the competence of the Committee.

In accordance with its tasks the CAESC ME RK, as prescribed by the legislation performs the following functions in the field of atomic energy use:

• provides for the implementation of state policy in the field of electric energy and atomic energy use;

• carries out the regulatory, realization and control-supervision functions and participates in the implementation of the strategic functions of the central executive body within its competence;

• approves legal acts on the matters within its competence and if it has direct competence for their approval in the ministries acts, with the exception of the normative legal acts concerning human and civil rights and freedoms;

• exercise control and supervision of the activities of individuals and legal entities within its competence;

• carries out control and supervisory functions over the activities of local executive bodies on the matters relating to the responsibilities of Committee;

• implement international cooperation within its competence;

• performs a permissive control;

• conducts inspections related to the execution of its responsibilities in the field of atomic energy;

• realizes state control in the field of atomic energy use;

• monitors compliance with the norms and rules of radiation safety and license conditions;

• carries out the state control in the field of radiation safety of the population;

• exercise control over the export, import, movement, transit and placement of nuclear materials and other ionizing radiation sources;

• exercise control over exports in the field of atomic energy use;

• performs state accounting and control of nuclear materials;

• performs state accounting and control of ionizing radiation sources;

• coordinates the issuance of a license from the authorized state body exercising state regulation in the field of export control for the export and import of nuclear and special non-nuclear materials, equipment, installations, technologies, ionizing radiation sources, equipment and related dual-use (purpose) goods and technologies, works, services related to their production;

• carries out licensing in the field of atomic energy use and permit control in accordance with the legislation of the Republic of Kazakhstan about the permissions and notifications;

• makes a decision on state registration or removal from state registration of nuclear materials, ionizing radiation sources;

• agree on calculation methods related to ensuring nuclear, radiation and nuclear physical safety and security presented by an expert organization;

• approves the designs of transport packaging sets, and also extends the validity of their certificates-permits, approved by the authorized bodies of other countries, on the territory of the Republic of Kazakhstan;

• organizes research on nuclear, radiation and nuclear physical safety and security, ensuring the nuclear non-proliferation regime and monitoring of nuclear tests;

• develops and approves methodological recommendations for individuals and legal entities carrying out activities in the field of atomic energy use, regarding methods and options of confirming the compliance of a facility involved in atomic energy use with the requirements of nuclear, radiation, nuclear physical safety and security established by the legislation of the Republic of Kazakhstan in the field of atomic energy use;

• sets the values of the threshold activity for various radioisotopes;

• analyzes and verifies the information received on the presence, location and movement of ionizing radiation sources and enters it into the register of ionizing radiation sources;

• carries out certification of personnel employed at nuclear facilities;

• conducts accreditation of organizations carrying out expertise of nuclear, radiation and nuclear physical safety and security;

• maintains a register of accredited organizations carrying out expertise of nuclear, radiation and nuclear physical safety and security;

• develops, coordinates and approves, within its competence, normative technical acts of the Republic of Kazakhstan, instructions, guidelines in the field of electric power industry and the atomic energy use;

• within the competence, participates in the development, implementation of strategic and program documents, proposals for the Strategic and Operational Plans of the Ministry of Energy of the Republic of Kazakhstan;

• exercises other rights provided by the laws of the Republic of Kazakhstan, acts of the President of the Republic of Kazakhstan and the Government of the Republic of Kazakhstan.

CAESC ME RK realizes the state control of licensee's compliance with license conditions and in case of failure, it imposes sanctions within its competence.

"Code on Administrative Offences of the Republic of Kazakhstan" provides administrative fines imposition and license denial for violation of established rules and regulations while handling the nuclear materials and radioactive substances.

Ministry of Ecology, Geology and Natural Resources, which replaced Committee of Ecological Regulation and Control of Ministry of Energy Republic of Kazakhstan, provides for environmental protection functions, including the field of atomic energy use. Main goals of the Ministry:

• provides for the implementation of state policy within its competence;

• carries out the regulatory, realization and control-supervision functions and participates in the implementation of the strategic functions of the central executive body within its competence;

• approves legal acts on the matters within its competence and if it has direct competence for their approval in the ministries acts, with the exception of the normative legal acts concerning human and civil rights and freedoms;

• exercise control and supervision of the activities of individuals and legal entities within its competence;

• carries out control and supervisory functions over the activities of local executive bodies on the matters relating to the responsibilities of Ministry;

• implement international cooperation within its competence;

• performs licensing and permissive procedures within its competence;

• performs a permissive control;

• carries out state environmental examination within its competence, and coordinates the implementation of environmental impact assessment in the Republic of Kazakhstan and carries out its methodological guidance;

• maintain the State Register of natural resources users and sources of environmental pollution;

• provides access to environmental information within their competence in accordance with the legislation of the Republic of Kazakhstan;

• carries out state ecological control over the observance of environmental legislation of the Republic of Kazakhstan, environmental quality standards and environmental requirements, including:

- compliance with the environmental legislation of the Republic of Kazakhstan;
- mitigation of consequences of environmental pollution;
- conservation and liquidation of subsoil use facilities;
- disposal of harmful substances, radioactive waste and discharge of waste water into the subsoil;
- compliance with the rules of use, storage, transportation, disposal, recycling or other treatment of radioactive and other environmentally hazardous substances in terms of environmental requirements for the prevention of environmental pollution;
- compliance with environmental requirements for sanitary-protection areas of facilities with stationary sources of emissions, discharges of pollutants and storing the production and consumption wastes;
- radiation situation on the territory of the Republic of Kazakhstan, the implementation of design solutions for the prevention of pollution of environment by radioactive substances;
- compliance with the requirements on the mandatory state environmental review and the implementation of its conditions;
- performs other functions in accordance with the laws of the Republic of Kazakhstan, Acts of the President and Government of Republic of Kazakhstan.

Committee of Quality Control and Safety of Goods and Services of the Ministry of Health of the Republic of Kazakhstan (functions of state authority in the sphere of sanitary and epidemiological welfare of the population) replaced the Committee for Public Health Protection of the Ministry of Health of the Republic of Kazakhstan. It performs the following functions:

• issuance of the sanitary-epidemiological conclusions on the basis of test results, and other forms of control and sanitary-epidemiological examination, in accordance with the legislation of the Republic of Kazakhstan;

• inspections of vehicles within its competence on compliance with legal and regulatory documentation in the field of sanitary and epidemiological welfare of the population, which are used for the transportation of passengers, food products, food raw materials, technical and drinking water, radioactive, hazardous, chemical and toxic substances, conditions of carriage passengers and cargo;

• development of hygienic standards and sanitary regulations regulating the radiation safety of the population, the organization of sanitation and educational activities aimed at the protection of public health;

• implementation of the unified state accounting and control of individual and collective doses of the citizens of the Republic of Kazakhstan;

• implementation of state supervision and control within their competence on the territory of the State in accordance with the legislation of the Republic of Kazakhstan;

• approval of the import of X-ray equipment, devices and equipment using radioactive substances and isotopes;

• control within its competence in the form of inspections and other forms of control in accordance with the current legislation of the Republic of Kazakhstan;

• implementation of radiation monitoring in the field of sanitary and epidemiological welfare of the population on the territory of the Republic of Kazakhstan;

• the suspension of certain types of work, operation of existing, new or renovated facilities to eliminate violations of normative legal acts in the field of sanitary and epidemiological welfare of the population and hygienic standards in accordance with the legislation of the Republic of Kazakhstan on administrative violations;

• establishing and changing of the size of the sanitary protection zones.

Committee for Industrial Development and Industrial Safety of the Ministry of Industry and Infrastructure Development of the Republic of Kazakhstan performs control and supervision in the field of industrial safety and is responsible for compliance with the statements of the Law # 188-V “On Civil Protection” dated on April 11, 2014. In accordance with Article 70 of the Law the dangerous industrial objects are the facilities, which produce, use, process, generate, store, transport, or eliminate the radioactive and (or) ionizing radiation sources.

Industrial safety is ensured by:

• establishment and implementation of the requirements of industrial safety, which are mandatory with exceptions established by the legislation of Republic of Kazakhstan;

• approval to use technology, technical devices and materials at hazardous production facilities that comply with appropriate requirements of industrial safety;

• approval for use at the territory of Republic of Kazakhstan of dangerous technical devices, which meet the industrial safety requirements;

• declaration of industrial safety of hazardous production facilities;

• state supervision, as well as industrial control in the field of industrial safety;

• examination of industrial safety;

• certification of legal entities to have a right for performing the works in the field of industrial safety;

• monitoring of industrial safety;

• service of dangerous industrial facilities by professional emergency services and formations.

In the period until 1996, the procedure for issuing permits for the disposal of radioactive waste in the Republic of Kazakhstan was regulated by the rules in effect in the USSR. Beginning 1996, the distribution of responsibilities of state bodies for disposal of radioactive waste was determined by the Decree of the Government of the Republic of Kazakhstan "Regulations on the disposal of radioactive wastes in the Republic of Kazakhstan" of October 18, 1996, No. 1283, according to which permits for disposal were issued by the Ministry of Environmental Protection and Water resources in coordination with other authorized bodies.

In 2011, by Decree of the Government of the Republic of Kazakhstan dated April 2, 2011 No. 347 "On Approval of the Rules for the Disposal of Harmful Substances, Radioactive Wastes and Wastewater Discharges into the Subsoil", these powers were transferred to the authorized body for study and use of mineral resources (the Committee of Geology of the Ministry of Energy of the Republic of Kazakhstan). During the validity period of these Rules, only a few permits were issued and in 2012 they were no longer valid. In the period until 2016, the disposal of radioactive waste in the Republic of Kazakhstan was carried out within the framework of approved draft emission standards in coordination with local authorities and environmental departments of Ministry of Ecology and Water Resources.

At the moment, when handling radioactive waste, the Rules for the organization, collection and disposal of radioactive waste are in force, which were enacted by the Order of the Ministry of Energy of the Republic of Kazakhstan No. 39 of February 8, 2016.

Regulatory Body

The Chairman of the Committee directs and is personally responsible for the implementation of the tasks assigned to the Committee and for the performance of its functions; and within the limits of the authority presents the Committee in state bodies and other organizations.

Interaction of CAESC ME RK with other state executive bodies, as well as with the organizations responsible for the atomic energy use is conducted in accordance with applicable laws and other normative legal acts of the Republic of Kazakhstan.

The competent authority of the Republic of Kazakhstan in the field of atomic energy use is provided with human, financial and technical resources to allow performing its functions.

6.4 Issues related to NORM&TENORM

Minimization of radioactive waste generation

A general approach to spent fuel and radioactive waste management includes efforts to reduce the amount of generated waste by all available means and methods. A great attention is paid to this at all the stages of nuclear fuel cycle, from the time of the initial design till a full decommissioning completion and site closure.

Minimization of radioactive waste generation and its reliable isolation from population and the biosphere for the duration of waste's potential hazards is one of the basic safety measures at all stages of spent fuel management.

In accordance with Technical Regulations "Nuclear and Radiation Safety", when choosing a process technology one should prefer continuous processes and safe handling of radioactive materials, as well as minimal, practically achievable: number of technological operations, emissions and discharges, formation of explosive and flammable concentrations of substances, quantities of generated radioactive waste.

Interdependencies among the different steps in spent fuel management

At the present the storage of the spent fuel is realized in two options:

• The spent fuel of BN-350 reactor is stored in double-purpose steel concrete containers on the specially designed site for a long-term storage, on the earth surface.

• The spent fuel of the research reactors is on the supervised storage in special near-reactor depositories.

The system existing in RK that regulates design, construction, operation, maintenance and repair, inspection and testing of the facilities for spent fuel management, as well as accounting and review of irregularities in their work, ensures the continuity of safety of spent fuel management at all stages, taking into account the interdependence of these stages. Regulatory bodies are responsible for safety implementation of these activities at all stages of the life cycle of nuclear installations.

IRS in RK

CAESC ME RK created and maintains the Register of radionuclide sources on the basis of processing of reports of organizations, data on export-import operations, as well as the results of the inventory of radiation sources.

Using the information from licensed organizations, which they submit in their annual reports CAESC RK verifies its database on the used radiation sources

CAESC RK maintains a database on radionuclide sources that have served their service life and are placed for long-term storage in specialized storage facilities. There are 5 storage facilities for long-term storage of sources of ionizing radiation (IRS) in the Republic of Kazakhstan:

1. The IRS storage facility located at "Baikal-1" RRC site near Kurchatov city, in the branch of the IAE RSE NNC RK (IAE NNC RK).

2. IRS storage facility located in Ala-Tau settlement near Almaty of the Institute of Nuclear Physics (RSE INP).

3. IRS storage facilities located in several buildings and premises of BN-350 RP, MAEC-Kazatomprom (NAC-Kazatomprom).

4. IRS storage facility belonging to Ulba Metallurgical Plant (UMP), (NAK-Kazatomprom).

5. Storage facility of “Kazphosphate” LLP, located in Taraz city. Currently, the issue of moving a part of the sources to other storages at territory of the Republic of Kazakhstan is being considered.

Radioactive waste of the non-uranium industry

A number of deposit occurrences of complex ores, rare-earth metals and phosphorites in Kazakhstan contain uranium mineralization, which is extracted together with the main ore during ore production. Part of radioactive mineralization goes to damps and tailings; part stays in the main product (especially in phosphate fertilizers). As a result of aero-gamma-spectrometry there were registered radioactive waste of metallurgical, chemical and metal mining enterprises within the limits of established sanitary-protective zones in Semey, Taraz, Shymkent and Akmola region.

Top oxidized parts of coal beds at some coal deposits are accompanied with uranium mineralization as well. This coal is not realized as a fuel and subject to stockpiling as RW.

The storage sites for bulk radioactive waste in non-uranium mining and processing plants, have generally not been designed so far. Currently, coal mining projects with oxidized parts provide for the storage and subsequent disposal of radioactive waste.

Contaminated (mainly Ra-226 and Th-232) soils, oil-slimes, equipment, pipes were revealed when surveying oil-gas fields. It relates to long-term exposure of oil water enriched with natural radionuclide. Overwhelming part of the waste (98%) is generated at oil fields. Currently, RW of this group is gaining more and more importance due to intensive development of Mangyshlak-Caspian oil fields and mass inclusion into development of small deposits of brown coals characterized by increased content of natural radionuclide. 57 from 76 registered storing places relate to contaminated equipment and soils at oil-gas fields.

The strata water of oil fields contains the maximum number of radionuclide in comparison with all known strata water, except water of uranium deposits. For example, permissible content of radium was determined the hundreds of times and thorium in 20-30 times exceeding as a result of sample analysis from the wells of Uzen, Zhetybai fields. There were revealed 1.3 mln.m3 of radioactive waste and 650 ha of contaminated territory with surface radiation over 1mcSv/h only as a result of conducted surveys on the territory of Mangistau and Atyrau regions.

The plans for the development of new fields provide for measures to ensure radiation safety, but the normalization of the situation at old and already used facilities is proceeding slowly. To date, at the Kalamkas and Zhetybai oil fields in the Mangistau region, sections have been created for the decontamination of equipment and pipes. At the Zhetybai and Zhana-Ozen oil fields, radioactive waste storage facilities were commissioned for 100 thousand tons (Zhana-Ozen) and 70 thousand tons (Zhetybai).

According to some estimations, the volume of radioactive waste of non-uranium industry is 2.3 mln tons with the activity of 4921 GBq.

Territories contaminated with radionuclides as a result of nuclear tests

Nuclear explosions on the territory of the Republic of Kazakhstan were during the period from 1949 to 1989, on Semipalatinsk test-site, Azgyr and Lira test-sites. Since 1965 to 1987 on the territory of the Republic of Kazakhstan there were 39 underground nuclear explosions for national economy needs, 17 of them with explosion yield of 584 TNT equivalent on the territory of the Azgyr test-site, where in salt domes there were created 9 cavities with initial volume around 1,2 mln. m3, at this in the generated cavities there were deposited radionuclide with total activity of $0{,}7\times10^{16}$ Bq. Two cavities were used for disposal of radioactive soil and contaminated metal construction and mechanism units. Totally, in the Azgyr underground cavities there are disposed solid RW with volume of 200 m3 and activity of 18.5 GBq. Daylight surfaces of all the sites were subject to decontamination and remediation in 1989-1994 by VNIIEF.

The Semipalatinsk test site (SIP) covers an area of 18,500 km^2. 456 explosions were tested at territory of the Semipalatinsk test site. Of these, 86 are air, 30 are ground and 340 are underground.

Among all the ground-based nuclear tests carried out at the Semipalatinsk test site, some tests can be distinguished, which, in general, determined the scale of radioactive contamination of the environment in the test site and adjacent regions. These are ground nuclear tests conducted on the site “Opytnoe pole” on 29.08.49 (yield ~ 22 kt), 24.09.51 (yield ~ 38 kt), 12.08.53 (yield ~ 400 kt), 24.08.56 (yield ~ 26,5 kt), 07.08.62 (yield ~ 9,9 kt), and underground tests with soil burst conducted on the test-site “Balapan” (15.01.65) and “Sary-Uzen” (14.10.65). The radioactive tracks, as a rule, were generated on the territory of the test-site after other ground explosions characterized by low and, basically, ultra-low yield.

Until now, radioactive fallout traces from ground tests carried out on 24.09.51 and 12.08.53 and underground tests carried out on 15.01.65 and 14.10.65 are well detected on the ground by radiometric methods, and laboratory analyzes of selected samples of natural environments confirm the presence of technogenic radionuclides 137Cs, 90Sr and 239,240Pu in quantities of hundreds and thousands of Bq/kg.

Thus, radioactive fallout after ground nuclear tests formed radionuclide contamination of the area in the form of extended traces and separate spots, both on the territory of the test site territory and outside its limits.

The exposure dose rate in air on the site "Experimental field" due to the presence of gamma-emitting radionuclides Cs-137, Eu-152, Co-60, is very high and in extreme points reaches 80-100 mSv/h or more (natural background 0 10-0,25 mSv/h) and on the site Balapan - up to 10.5 mSv/h. In areas of above-ground nuclear explosions the plutonium isotope concentrations reach 28000 Bq/kg, in the areas of excavation explosions –up to 3222000 Bq/kg; there is excessive concentration in communities outside of the Test site. In 1953-57, on STS there were implemented programs on testing of the radiological warfare agents (RWA). RWA tests were conducted on the sites "4" and "4a" located to the north and to the west from “Opytnoe pole”. RWA spreading was carried out by blasting of individual shells, bombing of areas by mortar shells, release of bombs by bombers or dispersion of RWA by aircraft. The basic contaminant is radionuclide 90Sr, at the same time there are present other radionuclide (137Cs, 241Am,60Co, Pu and Eu isotopes). The specific activity of radionuclide 90Sr reaches 5x108Bq/kg in soil covering on separate areas. The areas of contamination vary from hundreds up to hundred thousand square meters and the extent of some of them reaches several kilometers. The radionuclide content in soil-vegetable covering can be classified as RW.

During the period from 1995 to 2000, work was carried out on elimination of infrastructure for conducting nuclear tests. The facilities intended for underground testing, 181 tunnels of the Degelen mountain massif and 13 unused wells at the Balapan site were brought to a state that did not allow their use for testing nuclear weapons (closing of tunnel portals, liquidation of wells).

Less known are the tests carried out for peaceful purpose in other places in Kazakhstan. These are the objects "Lira" (6 explosions), "Sai-Utes" (3 explosions), as well as explosions within the framework of the programs "Meridian" (3 explosions), "Region" (2 explosions), “Batolit” (1 explosion) for the study of the geological structure of the earth's crust.

At the Lira test site, at a depth of 700-900 m, 6 cavities with a volume of about 50 thousand m3 were created, designed to store gas condensate from the Karachaganak field.

According to survey data for 2006, the total amount of radioactive waste from nuclear tests is 237,200 thousand tons with an activity of 570 million GBq. Including high-activity 0.5 thousand tons with activity 70 million GBq, intermediate-activity 6,500 thousand tons with activity 488 million GBq, low-activity 230,700 thousand tons with activity 11.1 million GBq.

7 MALAYSIA

7.1 Sources of NORM&TENORM

Currently in Malaysia, the main activities contributing to generating radioactive waste are industry, medicine, research, and education. The most common activities related to the technological enhancement of natural radioactive materials (TENORM) are industrial activities related to mining and subsequent processing, such as tin mining and smelting, processing of minerals, and the oil and gas industry. The major volume of radioactive waste comes from industrial activities related to mineral processing and oil and gas production.

NORM waste has low specific activity but contains long-lived alpha emitters and is present in huge volumes compared to other types of radioactive waste. Normally, NORM waste in Malaysia containing concentrations of U-238 and Th-232 radioactivity is slightly higher than 1.0 Bq/g, the clearance limit for naturally occurring radionuclides from series of uranium and thorium, as stipulated in the Atomic Energy Licensing (Low Activity Radioactive Material) (Exemption) Order 2020.

7.1.1 Tin Mining and Smelting Industry

At the end of the 19th Century, Malaya was the world's largest tin producer. Due to NORM co-existing with the tin ore or cassiterite in the ground, certain minerals of tin-mining by-product or tin tailing, such as amang (heavy mineral sand), monazite, ilmenite, zircon, or xenotime also contain NORM. Tin tailing (monazite) containing 328Bq/g of Th-232.

After the total collapse of the world tin industry in October 1985 when the price of tin fell by more than 50%, most of the companies stopped their operation but at the same time, most of them decided to store their tin tailing at the site as a stockpile for reprocessing in the future when it's economic to be reprocessed. At the same time, tin smelting companies also ceased their operation and left tin slag as their legacy waste. Tin slag is a TENORM and is classified as radioactive waste according to Malaysian regulations. Lately, the intention to reprocess tin tailing reprocessing is increasing due to the increasing demand for rare earth elements (REE). There are a few studies on reused of tin slag reported but neither one successfully come to commercialize until now. Figure 1 and 2 shows tin tailing (monazite) and tin slag respectively.

Figure 1. Tin tailing (Monazite) containing 328 Bq/g Th-232

Figure 2. Tin slag containing 1.1 Bq/g U-238 and 0.8 Bq/g Th-232

7.1.2 Mineral Processing

Since the 1980s, the mineral processing industry caused arising of public and political issues because the activity generates a huge amount of TENORM waste. Mineral processing in Malaysia initially starts with down-stream processing of tin tailing, such as ilmenite, zircon and monazite, to produce end products such as titanium oxide, zirconium and rare earth elements, and at the same time generate waste or by-product containing NORM. In the mineral extraction process, these radioactive elements become more concentrated and need proper management.

The first monazite cracking plant for rare earth elements which started operation in the 1980s was closed operation due to public issues. A near-surface repository was specifically built to solve the problem arising from its NORM. Malaysia has closed repository in 2014 which was previously built specifically for disposal of legacy thorium oxide waste from the rare earth extraction plant. Figure 3 shows the near surface repository for thorium hydroxide waste disposal.

Figure 3. Near surface repository for thorium oxide waste completely closed in 2014.

In 2010s, another monazite cracking plant started operation to produce concentrated rare earth elements and gypsum containing thorium as the main byproduct. The gypsum byproduct contains 6 Bq/g of thorium and is classified as very low-level radioactive waste. Public and political issues arose related to the management of a huge amount of gypsum byproduct since the construction phase of the plant. The gypsum byproduct is stored onsite in an engineered landfill or temporary storage facility that is designed and constructed to meet standards for a permanent disposal facility. Figure 4 shows the onsite landfill for storage gypsum residue.

Figure 4. Onsite landfill for gypsum temporary storage.

The company's proposal to reuse the gypsum byproduct as a soil conditioner and backfill material was rejected by the government. A site was proposed for near-surface disposal but was not approved by the regulator due to the site is considered a water catchment area. Until now, the plant is still in operation and the management of gypsum byproduct is still unresolved.

In titanium production industries, cracking of ilmenite to produce titanium dioxide pigment also produces very low-level TENORM waste in the form of red gypsum. However, the replacement of local ilmenite with export ilmenite reduced the NORM contained in the by-product red gypsum to below the exemption limit. The red gypsum was reported containing 52 ± 30 Bg/kg of Ra-226, 100 ± 41 Bq/kg of Ra-228, 0.006 – 0.019 Bq/kg of U-238 and 0.064 – 0.125 Bq/kg. In 2003, the red gypsum residue was exempted in accordance to Act 304 after monitoring results continuously showing that the activity concentrations of natural radionuclides were less than exemption limit 1.0 Bq/g. Figure 5 shows red gypsum residue is transferred into the landfill using a conveyor.

Figure 5. The red gypsum residue is transferred into the landfill using a conveyor.

Currently the residue is classified as schedule waste in accordance with Environmental Quality (Schedule Waste) Regulations 2005. With a generation rate of 30,000 to 50,000 metric tons per month, a huge volume of red gypsum is stored onsite in a landfill licensed by the Department of Environmental (DOE). Figure 6 shows the red gypsum residue dumping in a landfill.

Figure 6. Red gypsum residue dumping in a landfill.

For closure, the landfill will be covered with 60 cm compacted clay and a layer of soil for vegetation to prevent erosion and the red gypsum can be retrieved easily in the future. Research on red gypsum started a few decades ago, but until now a very small amount of red gypsum is reused in cement production.

7.1.3. Oil and gas industries

Another important source of TENORM is from the oil and gas industry - in this case mostly from the oil sludge and scales from oil well production and oil refinery. The most dominant radionuclide in oil sludge is Ra-226 and Ra-228, whereas U and Th contribution is very small compared to other minerals such as ilmenite zircon etc. The total activity in oil sludge/scale ranged from 0.2 -13.0 Bq/g. Oil sludge/scales contained 0.3 Bg/kg Ra-226 and 0.3 Bq/kg Ra-228.

At the oil and gas production facilities, sludge accumulates in the processing vessels whereas scales are deposited on the interior surface of the production components when there is a temperature or pressure drop. The highest mean Ra-226 and Ra-226 concentrations of 114 and 130 Bq/g, respectively, were measured in scales. However, the volume of the scales generated is much smaller as compared to the sludge. And with the introduction of scale inhibitors, less scale is accumulated. Figure 7 and 8 show scale and sludge from oil and gas industry.

Figure 7. Scale contained 1.1 U-238 and 0.8 Th-232

Figure 8. Oil sludge contained 0.3 Bq/g Ra-228 and 0.3 Bq/g Ra-226.

The volume of sludge generated is substantial. The treatment of sludge generates secondary residues such as matured sludge from sludge farming, chemical extraction residues and incineration ash. Overall, about 75 % of the waste, mostly untreated sludge and residues from chemical extraction of sludge has radioactivity levels similar to the normal soils of Malaysia. Oil sludge was exempted and classified as scheduled waste.

7.2 Management of NORM&TENORM

The Atomic Energy Licensing Act 1984 (or Act 304) empowers the Atomic Energy Licensing Board (AELB) to ensure that the user obtains an appropriate license for activities dealing with NORM waste management and to take appropriate actions to rectify the situation which deemed unsafe. The board will consider the issuance of the license after scrutinizing the applicant's capability. In the case of NORM, a person intending to conduct the following activities should apply for a license under Class G, which is:

(a) To dispose of NORM or their wastes,
(b) To store NORM or their wastes prior to their disposal, or
(c) To decommission a milling installation and waste treatment facility involving NORM.

7.2.1 Disposal

The scales and sludge collected shall not be accumulated or disposed of without prior approval by the AELB. For disposal purpose, a Radiological Impact Assessment (RIA) shall be carried out to demonstrate that no member of the public will be exposed to more than 1 mSv/year from all activities.

The waste classification scheme reflects the general principle that the higher the activity concentration, the greater the need to contain the waste and isolate it from the biosphere. In terms of the proposed classification scheme, NORM waste, which generally contains radionuclides with very long half-lives, would generally be classified as low-level waste (LLW), very low-level waste (VLLW) or exempt waste. On this basis, non-exempt NORM waste could therefore be expected to be disposed of in surface or near-surface disposal facilities.

7.2.1.1 Very Low-Level Waste (VLLW)

NORM waste with an activity concentration of each radionuclide in the uranium decay chain or the thorium decay chain, which is above the clearance levels, but less than 100 Bq/g is classified as VLLW. VLLW does not need a high level of containment and isolation and, therefore, is suitable for disposal in engineered surface landfill-type facilities with limited regulatory control.

This is the usual practice for waste from some mining operations, minerals processing and other activities. The designs of such disposal facilities range from simple covers to more complex disposal systems and, in general, such disposal systems require active and passive institutional controls. The period for which institutional controls are exercised will be sufficient to provide confidence that there will be compliance with the safety criteria for the disposal of the waste.

The engineered near surface landfill type facilities for the disposal of NORM waste classified as VLLW shall consist of at least two (2) layers of impermeable liner and be equipped with an under-liner leak detection system (ULLD). The dual liner can be made from high-density polyethylene (HDPE) material and clay layer.

The engineered near-surface landfill-type facilities shall be equipped with a leachate collection system at the bottom layer to prevent the accumulation of leachate and the leachate shall be channeled into a wastewater treatment plant. For closure, the landfill shall be capped with impermeable liners to reduce the water infiltration into the landfill. Figure 9 shows an example illustration of a landfill disposal type facility with engineered features.

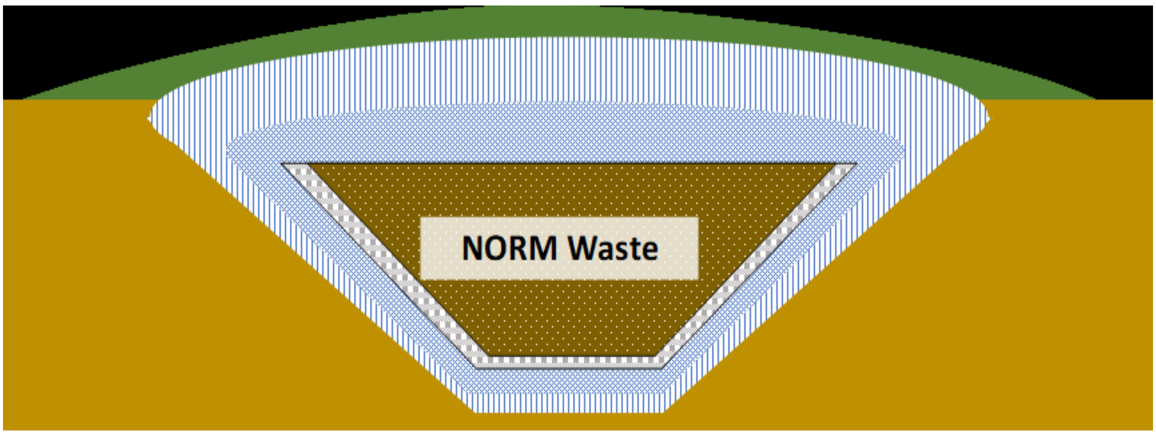


Figure 9. Example illustration of landfill disposal type facility with engineered features.

7.2.1.2 Low Level Waste (LLW)

NORM waste with the activity concentration of each radionuclide in the uranium or the thorium decays chain which is greater than 100 Bq/g up to 400 Bq/g is classified as LLW. Such waste requires robust isolation and containment for periods of up to a few hundred years and is suitable for disposal in engineered near-surface facilities. This class covers a very broad range of waste. LLW may include short-lived radionuclides at higher levels of activity concentration, and also long-lived radionuclides, but only at relatively low levels of activity concentration. LLW is suitable for near-surface disposal.

There are various design options for near-surface disposal facilities. These design options may range from simple to more complex engineered facilities and may involve disposal at varying depths, typically from the surface down to 30 meters. They will depend on safety assessments and national practices and are subject to approval by the appropriate authorities.

The near surface disposal facility shall consist at least two (2) layers of impermeable liner, for example, the HDPE polymer layer and geosynthetic layer as shown in Figure 10.

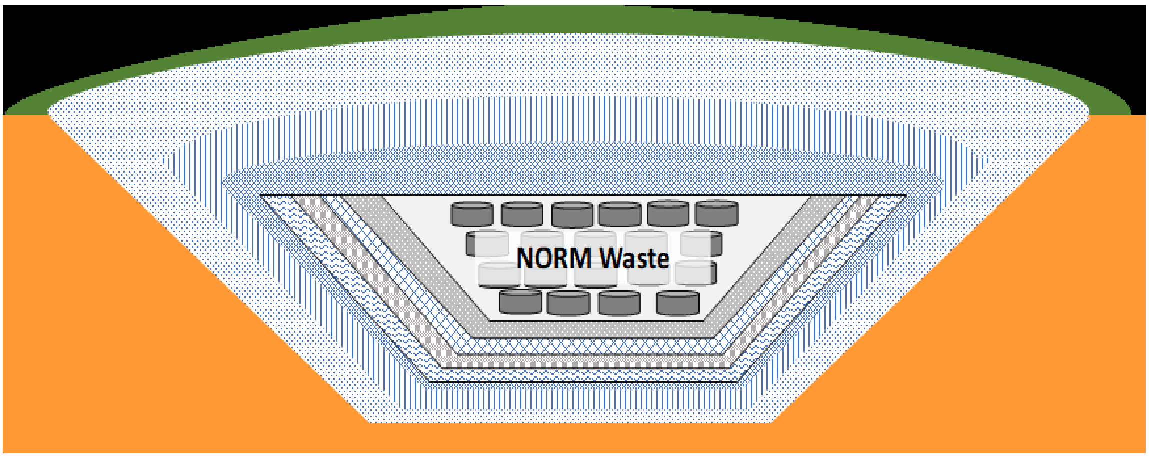


Figure 10. Example illustration of near-surface disposal facility

For closure, the near-surface disposal facility shall be capped with layers of HDPE liner or equivalent material, sand, bio-barrier layer consisting of rocks, soil layer and top with fertile soil layer to promote grass growth as vegetation can play an important role in the performance of a capping system, specifically in reducing erosion.

The environmental and radiological monitoring shall be conducted as determined by the Board (based on risk) according to a graded approach or for at least six (6) months prior to construction to get the baseline data. The monitoring also shall be conducted after the completion of closure of the disposal facility, to ensure that dose to the public is below 1 mSv/ year.

An applicant who would like to develop and operate a disposal facility for NORM waste should apply for license Class A and Class G, which they need to submit these documents:

a) Radiological Impact Assessment (RIA)
b) Safety Case for the Radioactive Waste Management Facility
c) Radioactive Waste Management Plan
d) Decommissioning Plan
e) Emergency Response Plan
f) Criteria For Siting of Disposal Facility for Wastes Containing NORM
g) Site approval for the repository from State Government/Local Government

Radiological Impact Assessment (RIA) should demonstrate that the dose limits to the workers, members of the public and the environment do not exceed those stipulated in the Atomic Energy Licensing Act 304 and the Regulations.

7.2.1.3 Siting for NORM Disposal Facility

Siting is a fundamentally important activity in the disposal of radioactive waste. The safety case and supporting safety assessment must demonstrate that there is adequate geological, geomorphological or topographical stability (as appropriate to the type of facility) and features as well as processes that contribute to safety. It also must demonstrate that other features, events and processes do not undermine the safety case.

Siting process for a radioactive waste disposal facility can be recognized as conceptual and planning stage, area survey stage, site investigation stage and site confirmation stage. At the start of a siting process, a selection is made of one or more preferred sites on the basis of geological setting and with account taken of other factors. Sociopolitical factors are an important consideration in any site selection process (e.g., demographic conditions, transport infrastructure and existing land use). The siting process shall also refer to other relevant acts and regulations for the site selection methodology. All criteria that must avoid during siting are listed as Exclusion Criteria.

7.2.2 Storage of NORM&TENORM

Storage of NORM should have a valid license. Licensees are required to submit a detailed location plan, design of the store, engineered design, dimension, and calculation of the dose outside of the store (including safety features facilities to prevent the resulting exposure from radioactive materials). Info of the NORM to be stored and certificate radioactivity analysis of the NORM (U-238 and Th-232) should be submitted together during application.

The NORM waste generated by the milling activities under a Class A (Milling) license is stored temporarily at the licensee's premises. However, if the licensee intends to dispose of the NORM waste at a proposed disposal facility, the Class G license for disposal is required.

7.3 Regulatory Base or Framework

7.3.1. Act

The Atomic Energy Licensing Act 1984 (Act 304) was gazette on the 24th of June 1984 and enforced on the 1st of February 1985. The Atomic Energy Licensing Act 1984 (Act. 304) provides the regulation and control of atomic energy and all activities related to it. The main objective of the Act is to ensure the safety of radiation workers, members of the public and the environment from radiation hazards because of activities related to atomic energy.

Sections 26-31 of Act 304 empower the Atomic Energy Licensing Board (AELB) to ensure users (licensees) obtain appropriate licenses prior to dealing (accumulating, transport or disposing) with radioactive waste and to take appropriate actions to rectify situations which deemed unsafe.

Act 304 provides the provision for the exclusion of the activity of prospecting or mining for any radioactive materials, nuclear materials or prescribed sub-stance. These activities shall be governed by the relevant laws relating to mining. Nevertheless, any person who, in carrying out either of the activities of prospecting or mining or both, encounters, discovers or comes into possession of any radioactive materials, nuclear materials or prescribed substance shall immediately report such fact to AELB in writing and shall comply with all directions that the AELB may give in the matter, being directions not inconsistent with the relevant laws related to mining.

7.3.2. Regulations

Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011 came into operation on 16 August 2011 which apply to all aspects of radioactive waste. Disposing of or cause to be disposed of radioactive waste requires a valid license. This regulation stated the responsibilities of the licensee, appointment and responsibilities of a radioactive waste management officer, discharge limit, etc.

Radioactive waste to be discharged shall not be more than 1 cubic meter and in accordance with the clearance level. Radioactive waste to be released, discharged, or disposed of to the environment shall comply with all other laws concerning non-radiological properties. For NORM containing a mixture of radionuclides, the following calculation method shall be used:

$$\sum_{i=1}^{n} \frac{C_i}{(activity\ concentration)_i} \leq 1$$

Where,

C_i is the activity concentration (Bq/g) of the ith radionuclide in the radioactive waste.

$(activity\ concentration)_i$ is the value of activity concentration (Bq/g) for the radionuclide i as in the Second Schedule in the regulations.

n is the number of radionuclides present in the radioactive waste.

According to Atomic Energy Licensing (Radioactive Waste Management) Regulations 2011, for discharging, releasing or disposing of more than 1 cubic meter, the proposed release, discharge or disposal requires approval from the regulator. Since there are many questions about the control limit especially for NORM in consumer products, in October 2020, Atomic Energy Licensing (Low Activity Radioactive Material) (Exemption) Order 2020 was implemented. The exempted Low Activity Radioactive Material under provisions of this Order will be exempted from all provisions of Act 304. Residues containing NORM less than clearance or exemption limits are regulated under the Environmental Quality Act 1974 (Act 127).

The licensee shall ensure all radioactive waste discharges are as low as reasonably achievable below the authorized limits; and monitor and record with sufficient detail and accuracy to demonstrate compliance with the authorized limits and to provide estimation of the public exposure. If radioactive waste is not suitable for release, discharge, or disposal to the environment within one year of its creation or any greater time as the regulator approves, the licensee shall submit a proposal, obtain approval from the regulator, and then comply with any requirement made by the regulator.

For any disposal activity of NORM&TENORM, the license is required to submit a Radiological Impact Assessment (RIA) to the Regulator, demonstrating that the dose limits to the workers and members of the public do not exceed those stipulated in the Atomic Energy Licensing Act 304 and the Regulations. The transportation of NORM&TENORM shall be in accordance with the requirements of Radiation Protection (Transport) Regulations 1989.

7.3.3 Order

Currently, there are two orders that have been gazette and still in effect for NORM&TENORM that is:

(a) Atomic Energy Licensing (Radioactive Materials Low Activity) (Exemption) Order 2020; and

(b) Atomic Energy Licensing (Small Amang Factory) (Exemption) (Revocation) Order 2021).

Atomic Energy Licensing (Radioactive Materials Low Activity) (Exemption) Order 2020 came into effect on October 1, 2020. The Order provides an exemption from all the provisions of Act 304 to any person in his possession or dealing with any low-activity radioactive material. Exemption levels in relation to substance low activity radioactivity from natural sources whose amount is more than one tone are 10 Bg/g for K-40 and 1 Bq/g for any radionuclides in the uranium or thorium decay chain. The applicant must submit a copy of the Certificate of Analysis (CoA) of raw materials and residue/waste [including activity concentration analysis for radionuclide U-238, Th-232 and K-40 (ppm units or Bq/g)] issued by laboratories recognized by the Regulator.

The Atomic Energy Licensing (Small Amang Factory) (Exemption) (Revocation) Order 2021 comes into operation on 1 June 2022 to increase the control on small amang factory activity after increasing intention to reprocess amang and related minerals for rare earth element recoveries.

7.3.4 Guides

Guides are important documents for licensees to refer to. All requirements to be fulfilled by the licensee including requirements stated in regulations and orders are clarified in the guide. Guides, codes, and standards are provided by the regulator to ensure all licenses comply with requirements and the goals imposed in regulations are achieved.

LEM/TEK/30 Sem. 3 is a document issued by AELB at the end of 2016, regarding guidelines on radiological monitoring for oil and gas facilities operations associated with TENORM. The external radiation shall not exceed 1.0 mSv a year. [Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010]. The surface will be considered to be contaminated if for alpha emitters it exceeds 0.04 Bq cm-2 and others 0.4 Bq cm-2. [Radiation Protection (Transport) Regulations 1989]. When and where the limits are exceeded, the operators shall inform the Regulator for negotiation of the necessary regulatory requirements.

Equipment contaminated with TENORM must be sent for decontamination prior to its 'disposal'. These guidelines govern the transportation of equipment for decontamination. They apply to all equipment contaminated with radioactive scale or sludge which has a surface contamination greater than 0.04 Bq cm-2. In this context 'disposal' means equipment, which may later be resold, reused or scrapped.

Any solid lumps of TENORM released during the decontamination job should be collected and placed in a container. The lumps should then be broken up and disposed of in accordance with the conditions of the disposal license [Radiation Protection (Licensing) Regulations 1986 Part 11 Classification of License Section 3(G) and also Part IV Application for Amendment and Renewal of License, Section 13 (l)]. The representative samples of the radiological contamination encountered in the vessel are taken and sent for content and specific activity (Bq g-1) analysis.

Once the existence of scales is established, it is essential that regular monitoring of the overall production system is performed to establish the extent of deposition. Scales and sludge collected from any work shall be sampled and analyzed for its radioactivity content. Routine monitoring is recommended to be conducted at a suitable frequency for at least once a year for normal operation and should include parameters stated in this Guide. Similar monitoring shall also be conducted prior to and after shutdown, workover, and descaling and related equipment maintenance.

The transportation of any scales, sludges, contaminated tubing or any equipment shall be in accordance with the requirements of Radiation Protection (Transport) Regulations 1989. TENORM. Under the transport regulations, NORM&TENORM is addressed under low specific activity materials (LSA) or surface contaminated objects (SCO).

LEM/TEK/30 SEM I is a document issued by the AELB in early 1996, regarding guidelines on handling and radiological monitoring of TENORM from oil and gas industry. This document was superseded by a revised edition, LEM/TEK/30 SEM 2, in September 1996. Among others, it addresses the requirement and format for radiological impact assessment for the management of oil sludge containing TENORM.

Under the transport regulations, NORM&TENORM is addressed under low specific activity materials (LSA) or surface contaminated objects (SCO).

LEM/TEK/74 Sem. 1 Pin. 2 is a guideline for licensing decision activity related to NORM under Act 304. This document guides whether the activity related to NORM, raw material processing and generation of residue containing NORM is subject to the regulations under the provision of Act 304. Activity concentration for U-238, Th-232 and K-40 in raw materials and residue/waste must be analysed by the Regulator's recognized laboratory. The result must be compared with exemption limits stipulated in Atomic Energy Licensing (Low Activity Radioactive Material) (Exemption) Order 2020. A copy of the analysis certificate should be submitted together with the application for Regulator consideration.

LEM/TEK/76 Sem. 1 Pind. 1 is criteria for siting of disposal facility for waste containing naturally occurring radioactive material (NORM). This document is prepared to provide guidance for the applicant of Class G license who intends to dispose of waste containing Naturally Occurring Radioactive Materials (NORM) at a disposal facility. This document addresses the safety requirements and procedures that should be followed and complied with for the siting of a disposal facility with regard to landfill disposal which is known as an engineered surface landfill type facility or near surface disposal facility (NSDF) for waste-containing NORM. This guidance material is intended to address both radiological and non-radiological hazards associated with the disposal facility. However, this document emphasizes the radiological hazard as its control falls under the purview of the Department of Atomic Energy Malaysia. The licensees shall comply with other standards, guidelines and regulatory requirements for more detailed requirements and procedures of non-radiological hazard controls for the siting of the disposal facility.

7.4 Issues related to NORM&TENORM

The waste associated with TENORM account for a significant number of the radioactive waste management problem in Malaysia. TENORM waste characteristics are the presence of long-lived alpha radionuclides and present in very large volumes compared to other types of radioactive waste. A large area disposal site is required for the disposal of TENORM waste. Most of the flat areas have been developed for residences and plantations. The hilly area is covered by forest which some gazette as a permanently reserved forest. The hilly terrain also received heavy rainfall making the valley as a water catchment area for the river which is used as water resources for the public. Permanently reserved forest and water catchment areas are classified as exclusion criteria for disposal sites. All these factors make site selection for

TENORM waste disposal very challenging. Figure 11 shows a proposed site for disposal of gypsum residue.

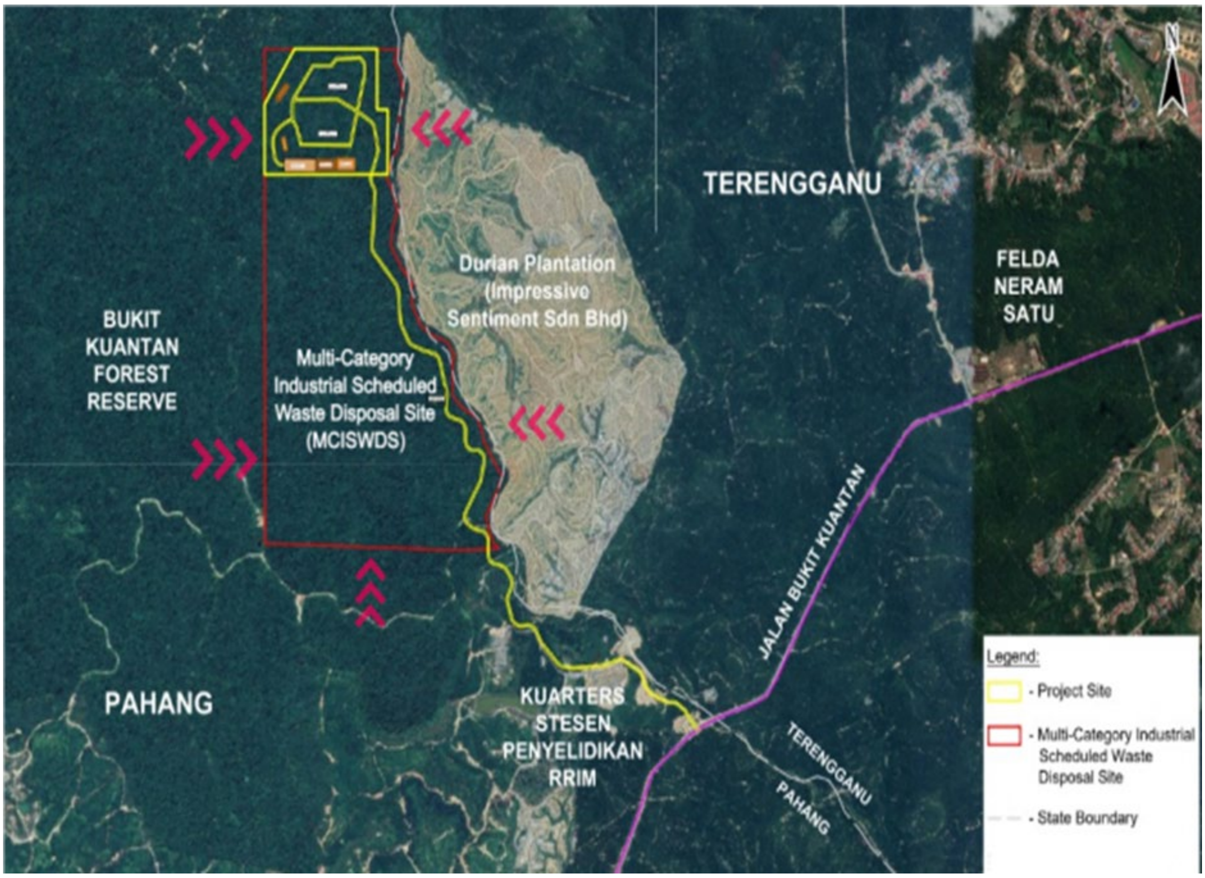


Figure 11. A proposed site for disposal of gypsum residue.

The proposed site of about 202 hectares has received the 'green light' from the State Government. The Regulatory body approves the proposal to establish the site, however subject to the results of Radioactive Impact Assessment (RIA), Environmental Impact Assessment (EIA), and other requirements deemed necessary by the relevant local authorities. In Jan 2021, EIA report for proposed development of a dedicated permanent disposal facility was rejected by DOE due to the area being classified as a water catchment area based on the existing of river and streams. Figure 12 shows the river and streams at the proposed site.

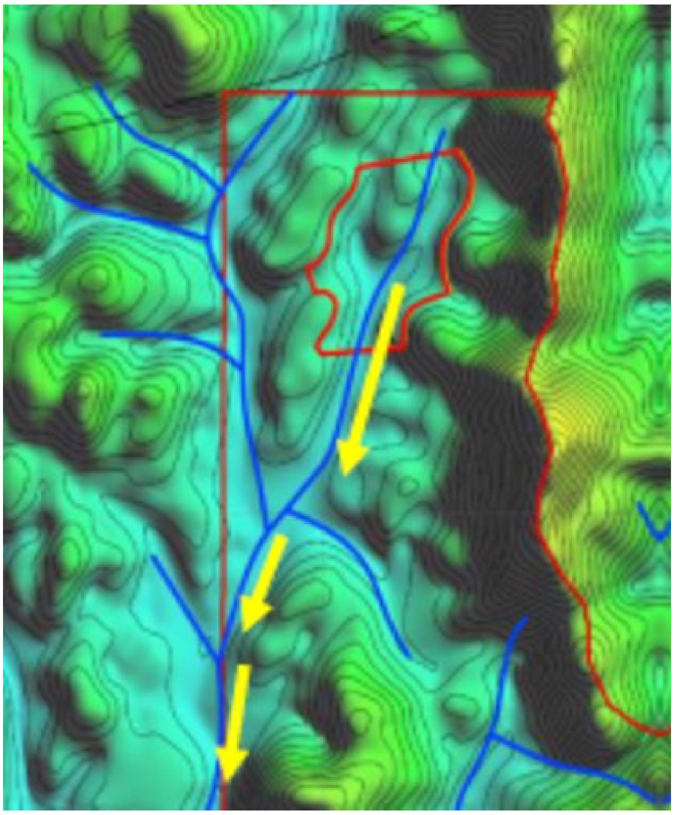


Figure 12. River and streams flow through the proposed site.

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8 MONGOLIA

Mongolia is a non-nuclear country since there are no nuclear power plants and research reactors. Mongolia is known for its significant mineral wealth, and the country has abundant deposits of various minerals. Some of the key minerals found in Mongolia include: gold, copper, coal, uranium and iron.

Mongolia has substantial copper and gold deposits, and the oyu tolgoi mine is one of the largest copper-gold mines globally. Mongolia possesses vast coal reserves, with the tavan tolgoi coal deposit being one of the largest untapped coal reserves in the world. The country has significant iron ore deposits, with the tumurtei iron ore mine being one of the notable examples. Mongolia has uranium deposits, and the country has explored the possibility of developing its uranium resources.

It's important to note that while Mongolia is rich in mineral resources, the development and utilization of these resources come with both opportunities and challenges. The mining industry has been a significant contributor to Mongolia's economic growth, but it has also raised environmental and social concerns. Sustainable and responsible mining practices are crucial to balancing economic development with environmental and social considerations.

8.1 Sources of NORM&TENORM

Mongolia, like many countries, has natural deposits of radioactive materials in its soil and rocks. The presence of naturally occurring radioactive materials (norm) can have implications for various activities, particularly in industries that involve the extraction and processing of minerals. Here are some aspects related to norm activities in Mongolia:

NORM Actives:

- Coal-fired power plants and maintenance of boilers
- Cement production, maintenance of clinker ovens
- Production of oil and gas
- Primary iron production
- Mining of ores other than uranium ore
- Ground water filtration facilities

NORM Planning:

- Processing of rare earth minerals
- Production of phosphate fertilizers
- Processing of niobium/tantalum ore
- Phosphoric acid production

- Tin/lead/copper smelting

8.2 Management of NORM&TENORM

Many coals of North-central Mongolia are exceptionally radioactive and listed uriniferous coals in Soviet achieves in the Mongolian state geological fund.

Thermal power plants are used for generating electricity by burning raw coal. Currently, 304 organizations have special licenses for coal mining, and 13 thermal power plants burn raw coal from these mines. These power plants play a crucial role in meeting the country's energy needs.

The issue of mining coal in Mongolia and using the resulting waste ash to produce building materials, which may contain elevated levels of radiation, is of greater concern when compared to other activities associated with the norm.

Researching the activity of radioactive heavy elements in Mongolian coal, as well as the levels of radioactive substances in coal waste ash, and construction materials derived from it, is crucial for ensuring public and environmental safety. Additionally, studying neutralization technologies for managing these radioactive elements is essential to mitigate potential risks associated with their presence.

This table provides information on the uranium-238 activity and uranium concentration in various lignite deposits of Mongolia.

The table showing the specific activity of some lignite deposits, including the U-238 activity (in Becquerels per kilogram, Bq/kg) and uranium concentration (in grams per ton, g/t). This information is obtained from the 2013 NEC project report on coal and TPP ashes. Here's a summary of the data:

Table 1. Specific activity of some lignite deposits (coal)

Deposit name /sample/	U-238 activity Bq/kg	U concentration g/t
Shivee Ovoo /30/	10.2- 62.6	0.5 - 4.5
Bayanteeg /10/	18.4 - 91.4	1.5 - 7.4
Aduunchuluun /16/	69.0 -1008.0	21.6 – 81.6
Khushuut /13/	19.2 – 30.3	1.9 -2.5

Maanit /13/	32.4 – 91.1	2.2 – 7.4
Bayantsagaan /6/	16.5 – 86.4	1.9 -7.5
Shariin gol /16/	21.6 – 45.9	1.8 – 3.6
Baganuur /35/	4.8 - 47.9	2.0- 3.7
Mogoin gol /9/	25.4-215.7	14.9 - 17.5
Alal Tolgoi /9/	66.0 – 202.5	5.0 – 16.4

SOURCE: 2013 NEC project report on coal and TPP ashes

Following table provided the composition to ash ponds at thermal power plants in Ulaanbaatar and Choibalsan city. This table outlines the average concentration of uranium (U) and thorium (Th) in ash, measured in grams per ton (g/tn).

Table 2. Ash pond of TPP no 3 and 4 of UB city

Thermal power plant	Deposit	Average concentration in ash g/tn	
		U	Th
TPP UB city	Baganuur	53,4	12,4
TPP Choibalsan city	Aduun chuluun	207	n/a

This type of information is essential for understanding the composition of ash ponds, which can be crucial for environmental impact assessments and management strategies associated with thermal power plant activities.

Researching the activity of radioactive heavy elements in Mongolian coal, as well as the levels of radioactive substances in coal waste ash, and construction materials derived from it, is crucial for ensuring public and environmental safety. Additionally, studying neutralization technologies for managing these radioactive elements is essential to mitigate potential risks associated with their presence.

Mongolia has not established a formal indoor radon program. The NRA (Nuclear Regulatory Authority) is establishing a radon survey of exposure to radon at workplaces and public buildings. A special guidance for measuring radon in air since 1991 as National Standard. There was an urgent need for continuing indoor radon measurements due to the extensive use of coal ash as a building material.

Uranium Resources in Mongolia:

Mongolia has a total uranium resource estimated at 143,500 tons, ranking 11th globally. As of October 2023, there are 13 entities holding a total of 14 exploration licenses and 8 mining licenses for uranium-related activities in Mongolia. Planning for uranium production is underway, involving two entities and targeting seven deposits.

In 2021, Badrakh Energy initiated the In-Situ Recovery (ISR) Pilot Test at the Zuuvch Ovoo site. The estimated low radioactive waste from Badrakh Energy projects is reported to be 260 tons per year.

According to the nuclear energy law of Mongolia, the state-owned company "Mon-Atom" LLC is responsible for ensuring Mongolia's equity and controlling the activities of joint venture companies involved in uranium projects.

Regulatory body

The Nuclear Energy Commission (NEC) of the Government of Mongolia was established in 1962. NEC is responsible for the development of national policy for the activities relating to development of nuclear research and technology, use of radiation sources, and to ensure radiation protection. The Member of the government in charge of science issues is a chairman of the Nuclear Energy Commission.

The Nuclear and Radiation Safety Inspection Department under the Ministry of Education and Science is tasked with the responsibility of ensuring the adherence to nuclear and radiation safety regulations concerning the exploration and exploitation of radioactive minerals and the use of radiation sources, as stipulated in the Nuclear Energy Law.

Key responsibilities include:

- Legislative Compliance: Ensuring compliance with Mongolian legislation, international conventions, contracts, agreements, and standards.
- Inspections: Implementing inspections to verify compliance with safety regulations.
- Licensing: Issuing licenses for the use of radioactive sources.
- Environmental and Public Exposure Monitoring: Overseeing environmental and public exposure to radiation from norm activities.
- Occupational Exposure Monitoring: Monitoring and regulating the occupational exposure of radiation workers.

In accordance with The Nuclear Energy Law, the department collaborates with relevant professional bodies to conduct inspections and analyze radiation levels in the environment, consumer goods, materials, food, and drinking water. The objective is to assess potential negative impacts on human health and ensure measures for quality assurance.

Additionally, the department is involved in:

- Monitoring personal occupational doses of radiation workers.
- Conducting workplace radiation level assessments.
- Controlling clinical jaundice.
- Developing a database of professional experience for radiation workers.
- Establishing methods, standards, and norms for evaluating professional qualifications.

Regarding the general population, the department is responsible for:

- Regular monitoring of radiation levels in the external environment.
- Monitoring radiation levels in food products and drinking water.
- Radon monitoring in residential areas.
- Assessing radiation levels in construction materials, mining, and minerals.
- Establishing a database for population demographics.
- Evaluating jaundice prevalence in the population.

The Nuclear and Radiation Safety Inspection Department plays a vital role in ensuring the safe use of nuclear and radiation technologies in Mongolia.

Here is a table of the norm monitoring program conducted by the nuclear and radiation inspection departments in Mongolia for the period 2015–2023:

Table.3. Radiation monitoring program

Type	**Explanation**	**Results of analysis (scope 2015–2023)**	**Reference level**
Food product	86 samples of domestic food products 698 samples of imported food products	**13 samples** /0.7-5.7 Бк/кг/	Radiation safety norm 100 Bq/kg
Radon	Sources of drinking water (total of 360 samples)	**61 samples** /102 – 691 Bq/l/	MNS: 900 – 2018 100 Bq/l
	Air of schools, kindergartens, libraries, archive buildings, and structures (total of 183 buildings)	**11 building** 206-483 Bq/m^3	Radiation safety norm 200 Bq/m^3

Building materials factory	Raw materials: 135 samples of ash pond from 34 Thermal power plants.	210-1002 Bq/kg	
	Final product/total of 286 product samples	The requirements were met.	Radiation safety norm 370 Bq/kg
Environmental monitor	35 measurement points in the Department of Meteorological and Environmental Analysis	<0.2 μSv/h	
	Mining sector: 178 samples from 123 mines	**6 mines** /1003-4730 Бк/кг/	Radiation safety norm /U-1000 Bq/kg/
	Soil of Mongolia (total of 173 samples)	**139 samples Cs-137 isotope** /0.3-29.7 Bq/kg/	

These monitoring activities aim to ensure radiation safety standards in various aspects of the environment and food supply chain in Mongolia. Regular assessments are conducted, and the results are compared against established reference levels to safeguard public health and the environment.

- **Environmental dose rate measurement**
  - The continuous radiation monitoring is conducted with (Berthold) devices at 2 stations (Ulaanbaatar) and Bayanulgii province (near the Kazakhstan border) and the data are collected with on-line network system.
  - In addition at more than 23 places of meteorological station (see Fig.1), the dose rates are measured 3 times a day with portable dose rate meter and transmitted to the meteorological center in Ulaanbaatar twice a week.

- **Soil monitoring**

  Soil-grass-animal pathway is considered as a most important radionuclides transport pathway to population of Mongolia because meat and milk etc. produced by the pastured animals is the staple food in Mongolia. Soil monitoring activity can be improved using in-situ gamma spectrometry system. To obtain the background level of radionuclide activity in soil the samples are taken at 173 sampling points (covering all the country every 2-3 years. A gamma spectrometer with HPGe detector is used to analyze radionuclides in soil samples.

- **Mining and milling**

Radiation source practices in Mongolia are not of the type that would ordinarily require environmental monitoring, but capability is needed in case of accidents resulting in contamination. Environmental radiation measurements are made by Radiation Laboratory of NRA of the SSIA around uranium and other open pit mines and electrical power stations. There is no additional environmental security provided for the tailings pile at the standby uranium mine.

In Gurvanbulag uranium deposit, the activity concentrations of Ra-226, Th-232 and K-40 varied in the range of 10.1-180.2 (ave.37.1), 14.1-64.0 (ave.29) and 523.1-1225.1 (ave.939) Bq/kg, respectively. The Cs-137 activities in the soil samples vary from 0-55.6 Bq/kg and averaged value is 17.7 Bq/kg.

Radon in dwellings

Main populations in Mongolia live in Ger (traditional house). The construction of the Ger impermissible accumulates radon. But the indoor radon measurements need in houses and flats, which are made of bricks and concrete. Although such housing is normally well ventilated sometimes there may be possibilities of accumulation of radon indoors, emanating from building materials, particularly during the winter season. On a personal level some measurements of Radon (Rn-222) and Thoron (Rn-220) in some flats of Ulaanbaatar city were carried out in 1995 and 1996 using a passive SSNTD with assistance from Dr. S. Kobayashi, Dr. K. Fujimoto and Dr. M. Doi from National Institute of Radiation Science of Japan. Measurements were carried out for radon and thoron and the concentrations for radon varied from 6 Bq/m^3 to 63 Bq/m^3 and thoron from 3 Bq/m^3 to 110 Bq/m^3. The maximum indoor ^{222}Rn and ^{220}Rn concentration were 62.8±6.8 Bq/m^3 and 110±49 Bq/m^3, respectively.

NATURAL RADIATION MEASUREMENT

The Applied Nuclear Physics Studies are established and carried out at the Nuclear Research Laboratory of National University of Mongolian since 1970 and at the Department of Applied Physics of the Institute Physics and Technology, Academy of Sciences from 1990 until now at the new Nuclear Research Center. The studies have been initiated for developing the applications of Nuclear and Related Analytical Techniques (NAT), Utilization of Radioisotopes and Radiation in Industry, increasing the natural resources exploration and Environmental Research and Monitoring. The natural radioactivity and radionuclides determined using gamma spectrometry systems. Our center has been participated in Regional Intercomparison Program for Radioactivity analysis and measurement for Environmental samples.

Radiation Laboratory of Nuclear Regulatory Authority is routinely carried out environmental radiation measurements including air, soil, water, food and vegetation for natural and artificial radionuclides using environmental monitoring network of the Ministry of Environment (Fig.1). Basic facilities are available for alpha, beta and gamma monitoring using a variety of equipment, including high-resolution gamma spectrometry.

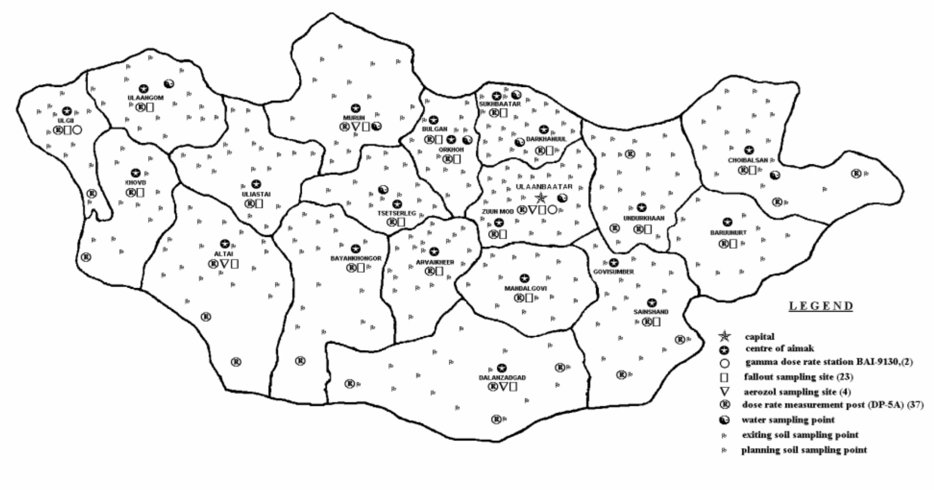

Fig.1. Environmental Radiation Monitoring Network of Mongolia

RADIOACTIVE WASTE MANAGEMENT

Mongolia has no disposal facilities. A detailed inventory exists of all sources stored or buried at the facility. Mongolia does not produce the radioactive material. Amount of the radioactive waste respectively low and mostly it is generated from the spent sources of medical and industrial practices

At present, the generation of unsealed radioactive waste material is not considered to be a problem, but the situation could change with the development of new phosphate, oil, gas and uranium industries.

The NEC has a dedicated secured and fenced-off long-term storage facility about 20 km from Ulaanbaatar. The facility consists of a large building with several storage pits. Scattered around the compound are other concrete pits with concrete lids for storing disused or orphaned sources. The compound also has a small burial area where contaminated material from a ^{90}Sr incident has been buried.

8.3 Regulatory Base or Framework

The Nuclear Energy Law of Mongolia is enacted on 16 July 2009,

The purpose of Nuclear Energy law shall be to regulate relations pertaining to exploitation of radioactive minerals and nuclear energy on the territory of Mongolia for peaceful purposes, ensuring nuclear and radiation safety, and protecting population, society and environment from negative impact of ionizing radiation. Functions and powers of Regulatory Authority have been described in the Nuclear Energy law.

The legislative basis for NORM in Mongolia is the relevant articles 11^1.1.8 of Nuclear Energy Law. Mongolia hasn`t got specific laws and regulation for NORM. Law of Mongolia on Disaster Protection was enacted on 20 June 2003 and amended on 13 January 2005.
Law of Mongolia on the Nuclear-Weapon-Free Status was enacted on 3 February 2000

Purpose: to establish safety standards and limits for permissible annual radiation doses for the population and radiation workers should be determined in accordance with relevant international recommendations, permissible levels of radiation in food, permissible levels of radon in workplaces, apartments, and dormitories, and possible levels of surface radiation contamination. First approved in 1983 and updated in 2015.
It is a basic document that sets out the basic dose limits, the permissible levels of ionizing radiation, and other requirements for limiting ionizing radiation exposure to radiation workers and the general public.

Table.3. Regulations for nuclear and radiation safety

Regulation	Year
Basic safety standards	2015
Radiation safety department of an organization engaged in radiation-related activities	2015
Security of radiation sources	2015
Radiation safety regulation for exploration and research of radioactive mineral	2015
Radiation safety regulation on mining and processing of radioactive mineral	2015
Management of radioactive waste from mining and milling of ores	2015
Radiation protection and safety	2016
Safe transport of radioactive material	2019

Procedures for licensing activities related to nuclear material	2019
Rules on Nuclear material accountancy and control	2020
Technical regulations for underground acid leaching	2015
Safety regulation for Radioactive waste generate from Nuclear installation and radiation	2022

Regulations and Standards:

National Standards	Year
Radiation protection. Permissible concentration of Rn indoors.	MNS 5627:2006
Ceramic bricks and stones. Technical requirements	MNS 0138:2010
Concrete bricks. Technical requirements	MNS 5610:2014
Determination of Radioactive elements content in building materials, soil and earth crust by Gamma spectrometer method	MNS 5072:2001
Radiation protection. Charcoal canister method for determination of radon concentration in indoors	MNS 5625:2006
Radiation protection. Nuclear track solid state detector method for determination of radon concentration in water.	MNS 5629-2006
Gamma spectrometry method for determination of radon concentration in water	MNS 5632-2006
Water quality. Maximum limit of substance contaminating the groundwater	MNS 6148:2010
Thermal power plant fly ashes for concrete. Technical requirements	MNS 6469:2014
Thermal power plant fly ashes for building materials. Technical requirements	MNS 3927:2015
Drinking water. Method for determination of uranium	MNS 3893: 86
Drinking water. Method for determination of Ra-226	MNS 3895:86
Drinking water. Hygienically requirements, assessment of the quality and safety	MNS 0900 : 2005

Water quality. Determination of the activity concentration of radionuclides by high-resolution gamma ray spectrometry	MNS ISO 10703:2002

These standards and regulations play a crucial role in ensuring the safety of various elements, including building materials, water, and the environment, by setting permissible limits, technical requirements, and methods for determination of specific substances. Adherence to these standards is essential for safeguarding public health and maintaining environmental quality in Mongolia.

8.4 Issues related to NORM&TENORM

1. Project Development:
   - Reduced Investment: Due to an unstable political situation, economic crises, and the impact of events like the COVID-19 pandemic, there is reduced investment in projects related to NORM&TENORM.
   - Detailed Information for Investors: Providing detailed information data to investors becomes challenging in such uncertain economic and political conditions.
2. Legislation and Regulatory Framework:
   - Lack of Long-term Implementation: The absence of a long-term implementation plan, including specific actions like a RADON action plan, national radon survey, calibration laboratories, and facility standards. Additionally, the lack of legislation such as a Landfill law adds to regulatory challenges.
3. Human Resource:
   - Insufficiency of Professionally Qualified Personnel: There is a shortage of qualified professionals to manage NORM&TENORM-related activities, including waste management.
   - Self-Management by Operators: Operators independently managing their NORM wastes may result in inadequate or inconsistent practices without proper expertise.
4. Safety, Health, and Environment:
   - Monitoring Issues: Challenges related to monitoring, including heavy metal and chemical components transport, can lead to environmental contamination.
   - Water Resource and Underground Water Recovery: Concerns related to the impact of NORM on water resources, including underground water recovery, need attention.
   - Baseline Study: Conducting a baseline study is crucial to understanding the initial environmental conditions before NORM-related activities begin.
5. Public License:

- Lack of Public Perception and Acceptance: There is a lack of public understanding and acceptance of NORM&TENORM activities.
- No General Program and Policy: The absence of a comprehensive program and policy for enhancing public understanding contributes to the challenges in obtaining public approval.

Addressing these issues requires a multidisciplinary approach, involving government bodies, regulatory agencies, industry stakeholders, and the public. Developing and implementing clear regulations, investing in education and training, and fostering transparent communication are crucial steps to mitigate the challenges associated with NORM&TENORM activities.

9 THE PHILIPPINES

9.1 Sources of NORM&TENORM

Naturally occurring radioactive materials (NORM) have been investigated in the Philippines. For instance, geochemical surveys have been performed since the 1950s to characterize the uranium distribution in various provinces and delineate areas with elevated uranium concentrations. Stream sediments and heavy mineral concentrates were collected from bodies of water. Nuclear analytical techniques, such as delayed neutron activation analysis, fluorimetry, radiometric, gamma metric, and other techniques, were performed to determine the uranium concentration in the samples. The results of some of these research undertakings are summarized in Table 1.

Table 1. Results of selected uranium geochemical surveys (minimum – maximum)

Location	Sample	Uranium concentration	Reference
Oriental Mindoro	Stream sediments	0.2 – 1.6 ppm	Santos et al., 1981
	Heavy metal concentrates	0.1 – 14.6 ppm	
Leyte Island	Stream sediments	0.3 – 0.8 ppm	Santos et al., 1982
Zamboanga Del Norte – Misamis Occidental	Stream sediments	0.5 – 2.4 ppm	Santos et al., 1983
	Heavy metal concentrates	0.1 – 1.4 ppm	
Pangasinan	Stream sediments	0.1 – 1.4 ppm	Santos et al., 1984
	Heavy metal concentrates	0.1 – 23.2 ppm	
Bohol Island	Stream sediments	0.33 – 0.96 ppm	Hernandez et al., 1988
	Heavy metal concentrates	0.69 – 3.44 ppm	

No significant uranium deposits were found after studying and exploring almost 70% of the country. According to Reyes (2014), there is a generalization that the Philippines's geological features lack the similarity from uranium-producing countries.

Research for unconventional sources of uranium was also undertaken based on the preliminary studies on uranium exploration. Radiometric surveys performed on the beaches of northern Palawan have determined major rare earth elements (REE) and thorium (Th), including minor uranium (U) areas. The Larap-Paracale mineralized districts are another identified unconventional source of uranium investigated in the Camarines Norte province

(Reyes, 2014). Several radiometric or car-borne surveys have also been conducted in Batanes and Marinduque island provinces to determine the area's baseline data on natural background radiation (Reyes et al., 2005). The results of these surveys, summarized in Table 2, indicate potential areas of uranium sources and exposure to NORM.

Table 2. Results of uranium surveys

Location	REE concentration	K concentration	Th concentration	U concentration
Ombo site[a]	5.64 %	ND	0.14 %	0.015 %
Erawan site[b]	4.63 %	ND	0.09 %	0.006 %
Larap-Paracale[c]	ND	ND	ND	93.8 – 225 ppm
Batanes Island[d]	ND	0.025 – 1.84 %	3.28 – 22.45 ppm	0.18 – 5.62 ppm
Marinduque Island[d]	ND	1.25 ± 0.62%	1.17 ± 1.00 ppm	3.16 ± 4.54 ppm

[a] estimated reserve of 30,450 t of REE, 750 t of Th, and 80 t of U contained in about 540,000 t of beach sand.

[b] estimated reserve of 2,200 t of Th, 113,430 t of REE, and 150 t U contained in 2,450,00 t of beach sand.

[c] drill core samples from a copper-molybdenum-uranium assemblage.

[d] car-borne surveys.

Aside from uranium, radon was also investigated in water samples, ambient air, and building materials since it is a major NORM that must be addressed. Radon monitoring was conducted from 1992 – 1995, with data collected from 2,626 houses nationwide. It was found that the average radon concentration in the Philippines is 21.4 Bq/m^3, with a maximum of 25.1 Bq/m^3 and a minimum of 1.4 Bq/m^3 from the Western Visayas and Western Mindanao regions, respectively. The findings were below the standard that was adopted during the conduct of the study (Dela Cruz et al., 2012). Since then, no subsequent monitoring has been performed for indoor environments. In the same period, nine non-uranium underground mines (coal, chromite, silver, gold, and copper) had an average radon concentration ranging from 30 – 347 Bq/m^3. The results show that the radon concentration does not exceed the action limit prescribed during that time, which does not pose any health risks to workers and may be affected by improved ventilation of the mines and low uranium concentration in the area (Garcia et al., 2011).

On the other hand, radon was also investigated inside a fertilizer production facility. The highest radon concentration in the facility was found at the storage of phosphate rocks at 77 Bq/m^3. In contrast, radon in phosphogypsum storage, a by-product of fertilizer production, was found to be 23.6 Bq/m^3. These values were also below the recommended safety limit for radon exposure (Duran et al., 1993). A recent study about radon exposure inside tourist caves in Bohol Island was investigated, and it was found that the elevated radon levels, ranging from 127 to 1,829 Bq/m^3, may pose significant risks to cave workers and tour guides (Panlaqui et al., 2023).

Data on various industries in the Philippines for 2021 is presented in Table 3. The table provides an insightful overview of key production and import figures, including coal, oil, natural gas, geothermal power, phosphate rocks, diammonium phosphate (DAP) fertilizer, and the mining sector. These industries are significant contributors to the Philippine economy and are recognized as potential sources of NORM and TENORM (IAEA, 2006; 2013).

Table 3. Results of uranium surveys from non-conventional sources

Industry	Relevant information	Reference
Coal	14.4 million metric tons produced	Department of Energy, 2021
Oil	632.29 million barrels produced	
Natural gas	121.089 million MMSCF	
Geothermal power	10,681 GWh of electricity generated	
Fertilizer a. *Phosphate rocks* b. *Diammonium phosphate (DAP) fertilizer*	a. 1.97 million metric tons imported / year b. 1.17 million metric tons produced / year	Haneklaus et al., 2015
Mining	PHP 282.20 billion contributed (2022)	Mines and Geosciences Bureau, 2023

Naturally occurring radioactive elements within some of these resources and their associated waste materials necessitate rigorous monitoring and management to ensure radiation safety and environmental protection. Several studies have delved into this subject matter, shedding light on the source characterization, risk assessment, and environmental implications of NORM and TENORM. The study by Socrates et al. (2007) found that the activity concentrations of ^{226}Ra in the phosphogypsum ponds near Isabel, Leyte, ranged from 91.5

Bq/kg to 935 Bq/kg. Leaching experiments revealed low ^{226}Ra leaching percentages, indicating a strong binding of the radionuclide to the phosphogypsum matrix. Laboratory simulations demonstrated that the local soil could effectively sequester and hinder the mobility of ^{226}Ra, preventing its migration into the groundwater. This study concluded that, regarding ^{226}Ra, phosphogypsum ponds did not lead to groundwater contamination. Sahoo et al. (2011) measured the specific activity of ^{238}U in coal and fly ash from coal-fired thermal power plants in the Philippines. The study revealed a good correlation between uranium measurements using high-resolution gamma-ray spectroscopy and inductively coupled plasma mass spectrometry (ICP-MS). The highest uranium concentration was found in fly ash (268.0 ± 10.7 Bq/kg), which was expected due to its proximity to phosphogypsum. Uranium isotopic composition was analyzed, providing insights into its behavior and sources in the environment. Garcia et al. (2013) conducted a radiological assessment near the PHILPHOS Fertilizer Plant in Isabel, Leyte. The results of gamma dose rate measurements were within the background radiation levels and range of values observed in the Philippines. The concentrations of radioactivity in samples of ^{40}K (120.85 ± 1.56 Bq/kg), ^{238}U (135.85 ± 2.18 Bq/kg), and ^{232}Th (6.70 ± 0.22 Bq/kg) were generally consistent with nationwide levels, except for ^{238}U activity in the soil, which was relatively higher near the phosphogypsum pond. Notably, the ^{226}Ra activity concentration (0.017 Bq/L) in groundwater samples was below the maximum contaminant level (MCL) set by the US EPA, indicating no significant health implications. Another study by Palad et al. (2019) focused on ambient gamma dose rates in and around industrial facilities in Leyte. The study found that the ambient gamma dose rates were within the range of the background ambient gamma dose rates in the Philippines, ranging from 21 to 124 nSv/h. Workers in the phosphate rock storage and phosphogypsum pond areas received the highest annual effective external dose of 0.76 mSv. The study indicated that industrial activities related to geothermal energy generation did not significantly affect gamma radioactivity levels in the region.

These studies provide valuable insights into the radiological safety of workers and the public and offer guidance for the responsible handling of radioactive materials and waste generated by these industries. The summary and details of the data gathered in these studies are summarized in Table 4.

Table 4. Average concentrations of NORM&TENORM in multiple samples from various industries

Industry (sample type)	Radionuclide	Activity Concentration (minimum – maximum)	Reference
Fertilizer Industry (groundwater)	226 Ra	0.001 – 0.093 Bq/L	Garcia et al., 2013
Fertilizer Industry (Phosphogypsum)	40 K	0.0 – 328.7 Bq/kg	Diwa et al., 2022
	238 U	87.8 – 1684.8 Bq/kg	
	232 Th	1.6 – 36.0 Bq/kg	
	226 Ra	665 – 1020 Bq/kg	Palad et al., 2019
	228 Ra	< 1 – 6 Bq/kg	
Coal-fired thermal (Fly ash)	226 Ra	51 – 181 Bq/kg	Palad et al., 2019
	228 Ra	65 – 140 Bq/kg	
	40 K	252 – 414 Bq/kg	
Coal-fired thermal (Bottom ash)	226 Ra	30 – 158 Bq/kg	
	228 Ra	36 – 67 Bq/kg	
	40 K	180 – 638 Bq/kg	
Minerals (soil and sediments)	40 K	3 – 2,723 Bq/kg	Samaniego et al., 2021
	238 U	18.5 – 2,910 Bq/kg	
	232 Th	4.1 – 2,216 Bq/kg	

9.2 Management of NORM&TENORM

The Philippines currently lacks a formalized system for managing NORM and TENORM. This absence of a structured management framework is primarily attributed to the absence of specific and comprehensive regulations that delineate the responsibilities, procedures, and protocols required for effectively overseeing these radioactive materials within various industries. This regulatory void has, in turn, impeded the development and implementation of coherent management strategies to address NORM and TENORM.

This absence of management can be attributed to several factors. Firstly, the inherently complex and dynamic nature of NORM and TENORM, coupled with the unique characteristics of each industry where these materials are present, presents a challenge in crafting uniform regulations adaptable to diverse contexts. Furthermore, there may be limited public awareness and political prioritization surrounding the issue, contributing to the absence of regulatory attention.

Despite the absence of a formal management system, various industries that handle potential sources of NORM and TENORM may, to varying degrees, adopt individualized and ad hoc approaches to address radiological safety concerns. However, these ad-hoc measures often lack the comprehensive nature and regulatory oversight to ensure a consistent and effective approach to NORM and TENORM management.

Considering these challenges, there is a growing recognition of the need to establish a robust regulatory framework that addresses the management of NORM and TENORM. Such regulations would serve as the cornerstone for developing comprehensive and standardized management strategies that safeguard public health and the environment while ensuring the responsible handling of these naturally occurring radioactive materials.

9.3 Regulatory Base or Framework

Generally, the Philippines does not have specific rules and regulations for managing NORM and TENORM. However, existing laws may support the craftmanship of such regulations in the future. For instance, the Science Act of 1958 (Republic Act No. 2067) provides a framework for promoting and developing scientific research and technological advancement. Moreover, the Act created the National Science and Development Board (NSDB) and other agencies, including the Philippine Atomic Energy Commission (PAEC). In connection to PAEC's establishment, the Atomic Energy Regulatory and Liability Act of 1968 (Republic Act No. 5207) mandated it to license and regulate atomic energy facilities. This law primarily regulates and controls the country's development, use, and handling of atomic energy and radioactive materials. It addresses issues related to nuclear safety, radiation protection, and liability in cases of nuclear accidents. While R.A. No. 2067 and R.A. No. 5207 do not specifically mention NORM and TENORM, their overarching principles of regulation, safety, radiation protection, and scientific research can be applied to these naturally occurring radioactive materials (CPR Part 0, 2020).

Government reorganization has led to PEAC being reassigned under the Department of Science and Technology (DOST) and renamed the Philippine Nuclear Research Institute (PNRI). Its Nuclear Regulatory Division (NRD) performs the regulatory function of PNRI as mandated and develops standards related to the use of nuclear science and technology in the country. These standards are known as the Code of PNRI Regulations (CPR). CPR Part 3 describes the basic standards for protecting people, radiation workers, and the environment against the harmful effects of ionizing radiation resulting from activities licensed in the country. In addition, the exempt concentration of bulk materials is also presented in this regulation. However, it does not specify that these limits exclude NORM and TENORM sources (CPR Part 3, 2021).

On the other hand, the requirements for licensing a land disposal facility for radioactive waste are described in CPR Part 23. However, it only highlights the inclusion of contaminated plant materials and equipment that may contain NORM and does not directly address the waste management aspect of NORM and TENORM. Lastly, the predisposal management of radioactive waste and the requirements needed for its licensing are outlined in CPR Part 28 but do not have direct instructions for NORM and TENORM management (CPR Part 23, 2005 and CPR Part 28, 2021). The existing regulations do not directly address the regulatory requirements or limits for exposure due to NORM and TENORM in various industries and their corresponding waste management strategies.

9.4 Issues related to NORM&TENORM

Issues related to NORM and TENORM become particularly complex and challenging when specific regulations are absent. It can result in inconsistent radiological safety standards, potentially exposing workers and the public to varying radiation levels. Without clear guidelines, ensuring that safety measures are uniformly implemented across different industries and activities involving NORM and TENORM becomes challenging. Furthermore, the management and disposal of waste materials containing NORM and TENORM can be insufficiently controlled. It may lead to environmental contamination, affecting ecosystems, groundwater, and soil quality. The absence of regulatory guidance can hinder the responsible handling of radioactive waste materials.

Additionally, effective monitoring of radiation levels and reporting incidents related to NORM and TENORM might not be standardized, making it difficult to identify and address potential issues promptly. Regulations often serve as tools for raising public awareness of potential radiological risks. In its absence, there may be limited awareness among the general public and even industry stakeholders about the presence of NORM and TENORM and their associated risks. On the other hand, industries that handle NORM and TENORM materials might adopt varying practices without specific guidelines. Some may prioritize safety and environmental responsibility, while others may not. It can lead to inconsistencies in industry practices and raise concerns about potential health and environmental impacts.

Addressing these issues without specific regulations necessitates a proactive and responsible approach by industries, government bodies, and relevant stakeholders. Establishing industry-specific standards, promoting research, and fostering international cooperation can help mitigate the challenges related to NORM and TENORM management when specific regulations are not in place. Nevertheless, developing comprehensive regulations remains essential to ensure consistent and effective management, safeguarding public health and the environment.

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10 THAILAND

10.1 Sources of NORM&TENORM

The study on NORM/TENORM in Thailand remains incomprehensive to acquire data on radiation baseline levels to be utilized in the development of national NORM regulatory programs. In 2002, the NORM: “Radionuclides Analysis Research Project”, also known as the NORM project, was initiated in order to assist such development [1, 2]. The project is under the collaboration between Thailand (i.e., academic institutions, regulator, and public health organizations, relevant industries), Japan (i.e., National Institute of Radiological Sciences, Hirosaki University, and Ministry of Education, Culture, Sports, Science and Technology), and the United States of America (i.e., Florida State University). The project intends to obtain new data regarding the characteristics of NORM from the industries that joined voluntarily.

Table 1. Industrial sectors that potentially produce NORM/TENORM [3].

11 Industrial sector	12 Estimated waste volume 13 (ton/y)	14 Activity concentration 15 (Bq/g)
16 Oil and gas exploration and production	17 3.4×10^{3}	▪ 13.3, for Ra-226 in scales. ▪ 2.07, for Ra-226 in sludge.
18 Tantalum and niobium extraction	19 9,612	20 Not known
21 Tin production	22 Not known	▪ 1.59, for U-238. ▪ 0.7, for Th-232.
23 Rare earth production	24 16	25 Not known
26 Cement production	27 Not known	28 Not known
29 Steel refinery	30 Not known	31 Not known
32 Water treatment	33 Not known	34 Not known
35 Coal and coal power production	36 1.49×10^{6}	37 0.14, for Ra-226
38 Chemical fertilizer	39 Not known	▪ 0.41-1.3, for Ra-226 in Phosphogypsum. ▪ 0.74-1.85, for U and Th in phosphate slag. ▪ 0.15-1.5, for Ra-226 in phosphate slag.
40 Residues from past activities	41 Not known	42 Not known

Currently, information on NORM types, quantities, and sources remains scarce. In 2005, there was an investigation on TENORM generated from industries in Thailand [3]. The estimates of the TENORM waste volumes were performed and the activity concentrations of certain waste were reported as shown in Table 1.

The activities performed for the NORM project led to the acquisition of the valuable NORM information and NORM measurement methods. There was the development of the systematic approach for measuring natural radiation exposure and characterizing NORM [1]. These two studies [1, 2] also examined natural radionuclide (i.e., Ra-226, and Ra-228) contents in various materials in the mineral industries and the results are shown in Table 2. The sampling locations of the samples were given in [2]. It is clearly shown that the radionuclide concentrations in these investigated materials were found to be enhanced (i.e., TENORM), especially in the precipitate/waste from the tantalum processing.

Table 2. The Ra-226 and Ra-228 contents in product, by-product, waste, soil and plants/vegetable from the industries and nearby locations [1].

43 NORM materials	44 Number of samples	45 Concentration (Bq/g)			
		46 Ra-226		47 Ra-228	
		48 Mean	49 Range	50 Mean	51 Range
52 Metal ore dressing	53	54	55	56	57
58 Concentration ore (raw material)	59 2	60 0.1	61 0.5–1.7	62 0.9	63 0.6–0.8
64 First by-product	65 3	66 2.6	67 1.1–3.3	68 6.3	69 2.8–8.4
70 Second by-product	71 2	72 1.6	73 1–2.2	74 4.7	75 1.3–8
76 Discard by-product	77 1	78 3.1	79 3.1	80 8.5	81 8.5
82 Local soil	83 13	84 0.094	85 0.013–0.38	86 0.2	87 0.003–0.5
88 Mineral sands dressing	89	90	91	92	93
94 Ore (raw material)	95 1	96 2.5	97 2.5	98 10.3	99 10.3
100 Rutile	101 1	102 0.9	103 0.9	104 0.4	105 0.4
106 Eucoxene	107 1	108 1	109 1	110 2.2	111 2.2
112 Monazite	113 1	114 28.6	115 28.6	116 260	117 260
118 Zircon	119 1	120 3.8	121 3.8	122 1.9	123 1.9
124 Tailing	125 1	126 0.1	127 0.1	128 0.2	129 0.2

43 NORM materials	44 Number of samples	45 Concentration (Bq/g)			
		46 Ra-226		47 Ra-228	
		48 Mean	49 Range	50 Mean	51 Range
130 Local soil	131 3	132 0.046	133 0.02–0.067	134 0.073	135 0.034–0.1
136 Tantalum	137	138	139	140	141
142 Scale	143 2	144 370	145 195–544	146 $<2\times10^{-5}$	147 $<2\times10^{-5}$
148 Precipitate/waste	149 2	150 4405	151 1820–6990	152 213	153 89–337
154 Local soil	155 1	156 0.08	157 0.08	158 0.06	159 0.06
160 Phosphate	161	162	163	164	165
166 Phosphate ore	167 1	168 0.004	169 0.004	170 $<7\times10^{-4}$	171 $<7\times10^{-4}$
172 Phosphogypsum	173 1	174 0.75	175 0.75	176 $<7\times10^{-4}$	177 $<7\times10^{-4}$
178 Local soil	179 1	180 0.08	181 0.08	182 0.06	183 0.06
184 Petroleum (oil and gas)	**185**	**186**	**187**	**188**	**189**
190 Produced water (onshore) (kBq/m^3)	191 32	192 0.97	193 0.08–4.02	194 1.05	195 0.03–2.4
196 Scale (onshore)	197 16	198 10.13	199 0.009–18.3	200 3.1	201 0.01–12.8
202 Cutting (onshore)	203 21	204 0.03	205 0.009–0.063	206 50	207 0.016–0.102
208 Sludge (onshore)	209 5	210 0.18	211 0.004–0.4	212 0.187	213 0.002–0.463
214 Produced water (offshore) (kBq/m^3)	215 33	216 0.89	217 0.09–2.12	218 0.72	219 0.15–2.11
220 Sludge (offshore)	221 15	222 0.09	223 0.015–1	224 0.029	225 0.013–0.044
226 Local soil	227 83	228 0.09	229 0.014–0.107	230 0.075	231 0.009–0.169
232 Old ore-dressing plant	**233**	**234**	**235**	**236**	**237**
238 Ore tailing	239 1	240 10.5	241 10.5	242 62.6	243 62.6
244 Soil nearby areas	245 6	246 0.4	247 0.040–1.4	248 0.8	249 0.076–2.41
250 Soil Inside dressing plant	251 7	252 7.6	253 10.1–17.7	254 40.1	255 2.1–154

43 NORM materials	44 Number of samples	45 Concentration (Bq/g)			
		46 Ra-226		47 Ra-228	
		48 Mean	49 Range	50 Mean	51 Range
256 Soil and plant @ the southern	257	258	259	260	261
262 Local plants	263 101	264 0.007	265 4×10^{-5}–0.05	266 0.014	267 4×10^{-5}– 0.5
268 Cultivated area	269 44	270 0.082	271 0.01–0.33	272 0.16	273 0.007–1.6

As listed in Table 1, Rare earth production can produce NORM/TENORM. Figure 1(a) shows the disused rare earth processing facility owned by Thailand Institute of Nuclear Technology (TINT) [4-6]. Figure 1(b) illustrates the radioactive residues found in the facility. The liquid and solid residues were sampled from 175 drums and 30 drums, respectively. These liquid and solid residues are now being measured their element contents using the inductively coupled plasma optical emission spectroscopy (ICP-OES) and the X-ray fluorescence (XRF), respectively. The obtained results were used to estimate the activity concentration levels.

The updated results of the Th-232 and U-238 concentration levels are shown in Table 3. It can confirm that the activity concentration levels of these residues are exceedingly higher than the safety criteria [7] (see Table 4).

Table 3. The estimates of the Th-232 and U-238 contents in the NORM residues found in the disused rare earth processing facility.

274 NORM materials	275 Concentration			
	276 Th-232		277 U-238	
	278 Mean	279 Range	280 Mean	281 Range
282 Liquid residues (Bq/L)	283 12400.22 284 (≈12.40 Bq/g)	285 0.00–58266.47 286 (≈0.00–58.27 Bq/g)	287 19651.27 288 (≈19.65 Bq/g)	289 0.00–269854.95 290 (≈0.00–269.85 Bq/g)
291 Solid residues (Bq/g)	292 344.20	293 0.00–2140.98	294 51.65	295 0.00–421.94

Figure 1 (a) Pathum-Thani Rare Earth Processing Facility; and (b) some of the NORM residues in the drums stored in the facility [5].

10.2 Management of NORM&TENORM

In Thailand, the interpretation of radioactive waste is based on considering the activity content (i.e., activity concentration, and total activity) of radionuclide contaminated materials. In 2019, the Nuclear Energy for Peace Commission (NEPC) defined the activity content, also known as "Safety criteria", for the contaminated materials, according to the NEPC Requirement on Safety Criteria B.E. 2562 (2019) [7]. Material that has the activity content greater than the specified levels of activity content [7-9] must be considered as radioactive waste. Regarding NORM, the NEPC also specified the levels for NORM contaminated materials, as shown in Table 4. Hence, materials contain or are contaminated with NORM in the levels of higher than these values might be considered as radioactive waste.

Table 4. The exemption threshold for NORM contaminated materials [7].

296 Radionuclide	297 Activity concentration (Bq/g)
298 K-40	299 10
300 Radionuclides in the Uranium Series	301 1
302 Radionuclides in the Thorium Series	303 1

Table 5. Classification of radioactive waste [10].

304 Waste class	305 Half-life, $T_{1/2}$	306 Activity concentration or total activity, A	307 NORM disposal method
308 Very short-lived waste (VSLW)	309 $T_{1/2} \leq 100$ days	310 $A > B$	311 -
312 Very low-level waste (VLLW)	313 $T_{1/2} > 100$ days	314 $A \leq 100 \times B$	315 Disposed of in near-surface landfill type facilities. No waste containment and isolation are required.
316 Low level waste (LLW)	317 100 days < $T_{1/2} \leq 30$ years	318 $A > 100 \times B$	319 Disposed at the depths of at least 30 meters below ground level. Waste containment and isolation are required for periods of ≤300 years.
	320 $T_{1/2} > 30$ years, for alpha emitting radionuclides	321 $A \leq 4000$ Bq/g (for each package), and average value ≤ 400 Bq/g (for multiple packages)	
322 Intermediate level waste (ILW)	323 $T_{1/2} > 30$ years	324 Restricted A, (A does not generate heat > 2 kW/m^3	325 Disposed at the depths between 30 and 300 meters below ground level. Waste containment and isolation are required for periods of >300 years.
	326 $T_{1/2} > 30$ years, for alpha emitting radionuclides	327 $A > 4000$ Bq/g (for each package), and average value > 400 Bq/g (for multiple packages)	
328 High level waste (HLW)	329 -	330 High A, (A can generate heat > 2 kW/m^3	331 -

B is the activity content levels specified in the NEPC Requirement [7].

Thai radioactive waste is divided into 5 classes listed in Table 5, as specified in the Ministerial Regulation on Radioactive Waste Management B.E. 2561 (2018) [10]. Radioactive waste resulted from the utilization of NORM-containing materials and the NORM-containing waste arising from industrial activities are permitted to be treated, conditioned, and disposed of using different methods depending on their waste class (see Table 5).

Thailand allows the waste producers or holders to manage their waste themselves (if capable) [10]. According to the Ministerial Regulation on Permission to Import Radioactive Waste into and Export out of the Kingdom B.E. 2561 (2018) [11], Thailand also permits the holders to transfer their waste to the countries capable of managing radioactive waste, for the waste management purposes. However, Thailand does not permit the importation of radioactive waste into the kingdom unless such waste is the waste that is exported to be processed outside the kingdom.

Any person who wishes to export the waste out of the Kingdom, or to import it into the kingdom, must obtain a license from the Secretary General of the Office of Atom for Peace (OAP). The person must also import the waste into or export it out of the Kingdom through the customs checkpoints designated by the OAP Secretary General [8, 9]. The customs checkpoints to support this requirement have not been designated yet. However, the following 21 customs checkpoints have been proposed in the Draft OAP Guideline on Designation of the Customs Checkpoints that Licensee Imports, Exports, or Transits Radioactive Material, Nuclear Material, or Radioactive Waste [12]. The rules, procedures, and conditions for the waste exportation and importation can be found in the Ministerial Regulation [11].

(1) Bangkok Customs Office, Bangkok
(2) Ladkrabang Cargo Clearance Customs Office, Bangkok
(3) Suvarnabhumi Airport Cargo Clearance Customs Bureau, Samut Prakan
(4) Bangkok Port Customs Office, Bangkok
(5) Laem Chabang Port Customs Office, Chonburi
(6) Maesai Customs House, Chiang Rai
(7) Chiangsaen Customs House, Chiang Rai
(8) Chiangkhong Customs House, Chiang Rai
(9) Maesot Customs House, Tak
(10) Thali Customs House, Loei
(11) Chiang Khan Customs House, Loei
(12) Nongkhai Customs House, Nongkhai
(13) Buengkan Customs House, Buengkan
(14) Nakhonphanom Customs House, Nakhonphanom
(15) Mukdahan Customs House, Mukdahan
(16) Arayaprathet Customs House, Sa Kaeo
(17) Prachuap Kirikhan Customs House, Prachuap Kirikhan
(18) Songkhla Customs House, Songkhla

(19) Padangbesar Customs House, Songkhla
(20) Sadao Customs House, Songkhla
(21) Phuket Customs House, Phuket

Certainly, the importation and exportation mentioned above are involved in the waste transportation. As specified in the Act [8, 9], a person possessing radioactive waste, who wishes to arrange for the waste transport, shall submit a notice to the OAP Secretary General. The person and a carrier who agrees to transport such waste have a duty to comply with the rules, procedures, and conditions regarding nuclear and radiation safety and security prescribed by the ministerial regulation. The supporting ministerial regulation has not been established. However, OAP has drafted this regulation as the Draft Ministerial Regulation on Nuclear and Radiation Safety and Security in Transportation [13]. The exemption criteria for NORM transportation were also provided in this draft.

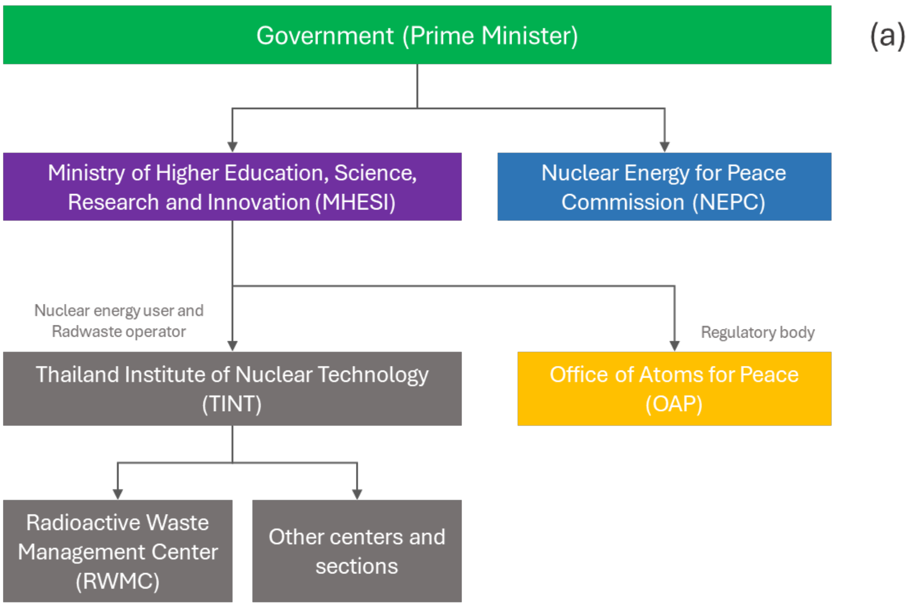
Although Thailand permits the waste producers to export their waste so that the waste can be managed safely by the overseas waste operators capable of managing the waste, most waste producers decided to send their waste to the authorized waste operator or store the waste at their areas [5, 14]. Formal agreements between the two countries involved (i.e., intergovernmental agreement) and between the waste senders and receivers (i.e., commercial contract) shall be made. Additionally, the transboundary moments of the waste might be involved with not only the sending and receiving countries but also the third country if the waste transit is needed. This causes the complicated logistics. Basically, countries in which the waste operators offer the waste management services to foreign clients ban the disposal of foreign waste in their country areas. Therefore, the processed waste must be returned to the country of origin. These activities (i.e., exportation, and importation) are then costly and difficult to perform.

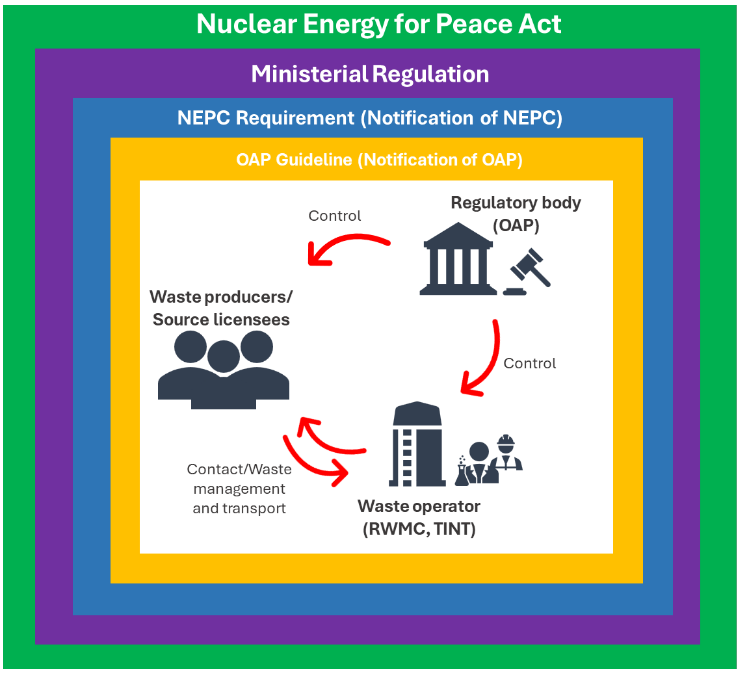
In practical terms, NORM/TENORM waste generated from industries is stored and disposed of at the origin sites, as shown in Figure 2(a) [14]. The NORM/TENORM contaminated materials illustrated in figure 2(b) are often transferred to the waste operator, Radioactive Waste Management Center (RWMC), Thailand Institute of Nuclear Technology (TINT). Here, the waste holders are required to pay for the cost of the waste management and the cost of the waste transportation (if requested). The current service charge for NORM waste management are set to be 42,800 THB/ton (VAT-inclusive price) [5].

Figure 2. (a) the by-product phosphor-gypsum stored at the National Fertilizer Public Company [14], (b) NORM contaminated metal from companies buying scrap metal.

10.3 Regulatory Base or Framework

Figure 3 shows the current Thai organizations associated with radioactive waste management and the hierarchy of Thai nuclear and radiation legislations. Under the Nuclear Energy for Peace Act [8, 9], the Ministry of Higher Education, Science, Research and Innovation (MHESI) has the power to enact the ministerial regulations regarding the nuclear energy utilization and radioactive waste management, under advice from the NEPC. The NEPC was instituted in order to propose nuclear and radiation policies to the council of ministers. Also, the NEPC can establish specific requirements on nuclear energy, namely, the NEPC Requirements issued as the Notification of NEPC.





(b)

Figure 3. (a) a schematic diagram showing the current Thai organizations associated with radioactive waste management, (b) a diagram showing the hierarchy of Thai nuclear and radiation legislations, and activities of each unit.

The OAP is assigned to be the regulatory body controlling and inspecting nuclear energy utilization and radioactive waste management. The OAP is furthermore allowed to develop fundamental guidelines supporting the ministerial regulations and the NEPC requirements, namely, the OAP Guideline issued as the Notification of OAP. Any person who intends to conduct the activities regarding nuclear and radioactive materials, including radioactive waste management shall obtain a license from the OAP.

The TINT is a nuclear energy user and radioactive waste operator. The radioactive waste met the waste acceptance criteria developed by the RWMC can be transferred from the waste producers to the unit subordinate to the TINT (i.e., RWMC), for further management.

10.4 Issues related to NORM&TENORM

Although there have been some studies on NORM/TENORM waste, the existing information on the waste does not cover all sectors that could generate such waste. Further NORM/TENORM waste studies are therefore needed. This is not only to improve the protection of the public and the environment from the potential risks due to the natural radiation from the waste but also to assist the development of national NORM regulatory programs.

The NORM/TENORM contaminated materials illustrated in figure 2(b) are often received from companies buying scrap metal. Large amounts of the scrap metal were processed and the output products were then sold. As a matter of fact, the metal is mostly from abroad. The question is how they were brought into the country while the importation gates probably have radiation surveillance systems. Is it possible that not all gates have such systems? To solve this problem, the OAP should check whether the intended 21 customs checkpoints have the systems before promulgating the OAP Guideline [12].

As being a centralized waste operator, the RWMC realizes that there will be a problem with the inadequacy of the storage space for unsealed radioactive waste including NORM/TENORM contaminated materials. As currently happen, the NORM/TENORM residues from the disused rare earth processing facility shown in Figure 1 were kept in the temporarily designated area because the remaining space cannot support them. As reported in [5], there is approximately 30% of the storage space that can support the unsealed radioactive waste.

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11 VIETNAM

11.1 Sources of NORM&NORM waste

Radioactive waste in Vietnam originates from a variety of sources, including research activities, industrial production, medical practices, the operation of research reactors, and the manufacturing of radiopharmaceuticals. It's important to note that Vietnam does not have any nuclear power plants.

NORM - naturally occurring radioactive material (currently, Vietnam only uses the term NORM and does not use TENORM) waste is also generated within the country through activities such as:

- Uranium and thorium ores mining and processing
- Rare earth ores mining and processing.
- Titanium ore mining and processing and related industries.
- Aluminum production.
- Metal production: tin, copper, lead, iron, steel, etc.
- Phosphorus industry.
- Oil and gas production.
- Coal mining and usage.
- Water treatment and geothermal energy utilization.

The types of waste corresponding to the activities generating NORM waste listed in table 1.

Table 1. The types of NORM waste generated from activities related to the mining and processing of uranium ore, thorium ore, rare earths, titanium ore

Activities generating NORM waste	NORM tailing	NORM waste in liquid form	NORM waste in solid form		
			Scale deposites	Sludge / filter	Dust
Uranium ore mining and processing using traditional methods	x	x	x	x	x
Uranium ore mining and processing using heap leaching	x	x	x	x	x
Uranium Processing through in-situ leaching	x	x	x	x	x

Mining of thorium ore, rare earths, and titanium ore	x	x	x	x	x
Rare earth processing	x	x	x	x	
titanium dioxide powder manufacturing	x	x	x	x	x
Zircon and Zirconia industry		x		x	x

We provide in detail some of the main activities that generate NORM waste in Vietnam as below:

11.1.1 Generation of NORM waste from uranium and thorium ores mining and processing

Vietnam possesses approximately 240,000 tons of uranium reserves, but commercial-scale uranium mining has not been initiated in the country. Nevertheless, there have been various research projects at the ministerial and state levels relating to uranium ore extraction, refining, and the production of UO_2 ceramic pellets. These activities encompass several stages that give rise to different types of radioactive waste, which can be categorized as follows:

-Solid waste stemming from the uranium leaching process: This waste typically contains a modest concentration of uranium (approximately 0.01% in technological samples at Thanh My mine, Quang Nam province). It presents itself in the form of fine and coarse particles resembling sand grains and yields a surface equivalent dose of approximately 10 µSv/hr.

-Waste water generated during uranium ore leaching: This waste water can have acidic or alkaline characteristics and contains small amounts of uranium and thorium. Additional waste water is produced during the uranium refining process, including ion exchange, solvent extraction, ADU precipitation, and UO_2 ceramic pellet production.

-Emissions of radioactive dust in exhaust gases: These emissions occur during the management of uranium ore, such as in dam construction, crushing of uranium products (ADU, UO_2 powders), and drying processes. They are particularly hazardous as they can be inhaled, leading to internal irradiation and adverse health effects for workers.

-Other waste types include ion exchange resins, solvents, and adsorbents, which also contribute to the overall radioactive waste generated in the uranium mining and processing industry.

Table 2. Composition and activity concentration of uranium ore leaching residue

No.	Elements	Content (wt.%)	Activity (Bq/g)
1	U	0.01	1.482

2	Th	4.10^{-3}	0.162
3	^{226}Ra & isotopes	-	96

11.1.2 Generation of NORM waste from rare earth ores mining and processing

Vietnam boasts a substantial reserve of rare earth elements, totaling over 20 million tons. Rare earth mines are primarily concentrated in the northern regions of Vietnam, including provinces like Lai Chau, Lao Cai, Yen Bai, and Nghe An…. Rare earth minerals, such as monazite and xenotime, are also discovered in coastal placer deposits, often associated with ilmenite mining. Notably, monazite ore - (La, Th)PO_4, predominantly found in coastal placer deposits, and xenotime - YPO_4, as extracted from the Yen Phu mine, are rich in radioactive materials. The generation of radioactive waste is primarily linked to the mining, beneficiation, leaching, and purification processes of these rare earth ores.

Table 3. Chemical components in rare earth concentrate samples

Components	Unit	Monazite		Xenotime
		Quang Nam mine	Binh Thuan mine	Yen Phu mine
TREO	%	47.33	58.85	19.5
ThO_2	%	4.40	5.43	0.19
U_3O_8	%	0.18	0.31	0.05

Table 4. Activity concentration of residue obtained from the hydrometallurgy process of xenotime concentrate (at pilot scale)

Activity (Bq/kg)			
K-40	Ra-226	U-238	Th-232
632	8682	6309	8989

Vietnam currently lacks a comprehensive rare earth processing facility. However, a minimal quantity of NORM waste with a dose equivalent ranging from 80-120 µSv/hr results from laboratory-scale and pilot-scale research activities.

In Yen Bai province, a rare earth concentrate beneficiation plant is in operation, generating thousands of tons of xenotime concentrate annually, and consequently, NORM waste is produced during this process. Additionally, a hydrometallurgy plant is under construction at this location, aiming to produce total rare earth oxides from the concentrate.

In central Vietnam, a company is in the testing phase for the separation of total rare earth elements from monazite. This process may lead to the generation of several tons of NORM waste, with a portion of this waste currently being stored in the company's warehouse, necessitating treatment and proper disposal in the near future.

11.1.3 Generation of NORM waste from titanium ore mining and processing and related industries

Vietnam boasts a wealth of coastal resources, including placer deposits (titanium placer) exceeding 650 million tons. These deposits contain various valuable minerals that can be extracted from beach sands. Some of the primary minerals separable from beach sands are shown below:

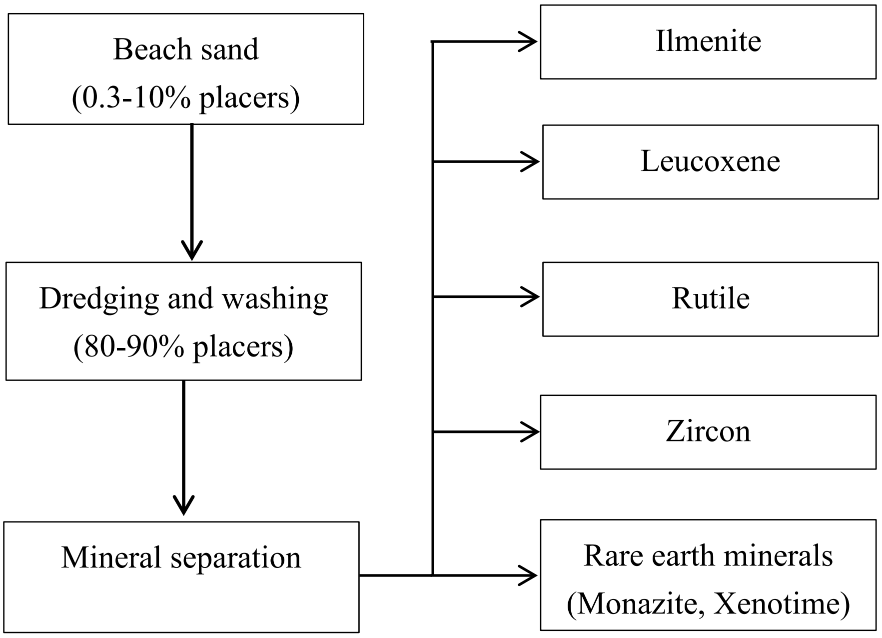


Fig. 1. Schematic placer process.

NORM waste is produced during the processes of dredging and washing, which are part of the mineral beneficiation operations in Vietnam. Among the minerals found in these processes, monazite and zircon are notable for their high levels of radioactivity.

Table 5. Activity and Equivalent dose of placers

Minerals	Activity (Bq/g)		Equivalent dose
	226 Ra	228 Ra	(μSv/hr)

			(at surface)
Ilmenite	<0.1 – 0.4	0.6 – 6	0.7
Leucoxene	0.25 – 0.6	0.04 – 0.35	-
Rutile	<0.1 – 0.25	< 0.6 – 4	-
Zircon	0.2 – 0.4	2 – 3	3-8
Monazite	10 – 40	600 – 900	90
Xenotime	50	180	-

NORM waste in Vietnam predominantly arises from the production of zircon and rare earth minerals, specifically monazite. Notably, in Ba Ria – Vung Tau province, there exists a ZOC (zirconyl oxychloride octahydrate) factory with an initial capacity of 13,500 tons per year (state 1) and an expanded capacity of 21,800 tons per year (state 2, be operated in 2023).

11.2 Management of NORM waste

11.2.1 Management of NORM waste from uranium and ores mining and processing

Due to the cessation of the first nuclear plant project located in central Ninh Thuan province, uranium mining and processing activities in Vietnam have also come to a halt. Presently, research pertaining to uranium is conducted on a smaller scale within research facilities, resulting in a relatively minor production of NORM waste.

Under a state project initiated in 2012, which focused on the search and evaluation of 8000 tons of U_3O_8 reserves, around 100 tons of uranium tailings were generated. The technological process for the management of this radioactive waste is outlined below:

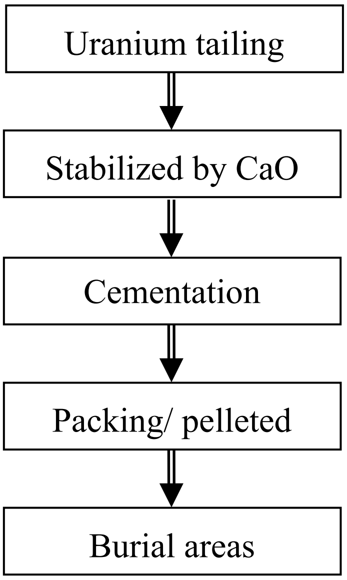


Fig. 4. Technological process for solid rad-waste.

Concrete tank preparation

Load the cemented RW into the tank

Cover the tank with cement grout

Cover the tank by 1 metre of soil

Fig. 5. NORM waste burial.

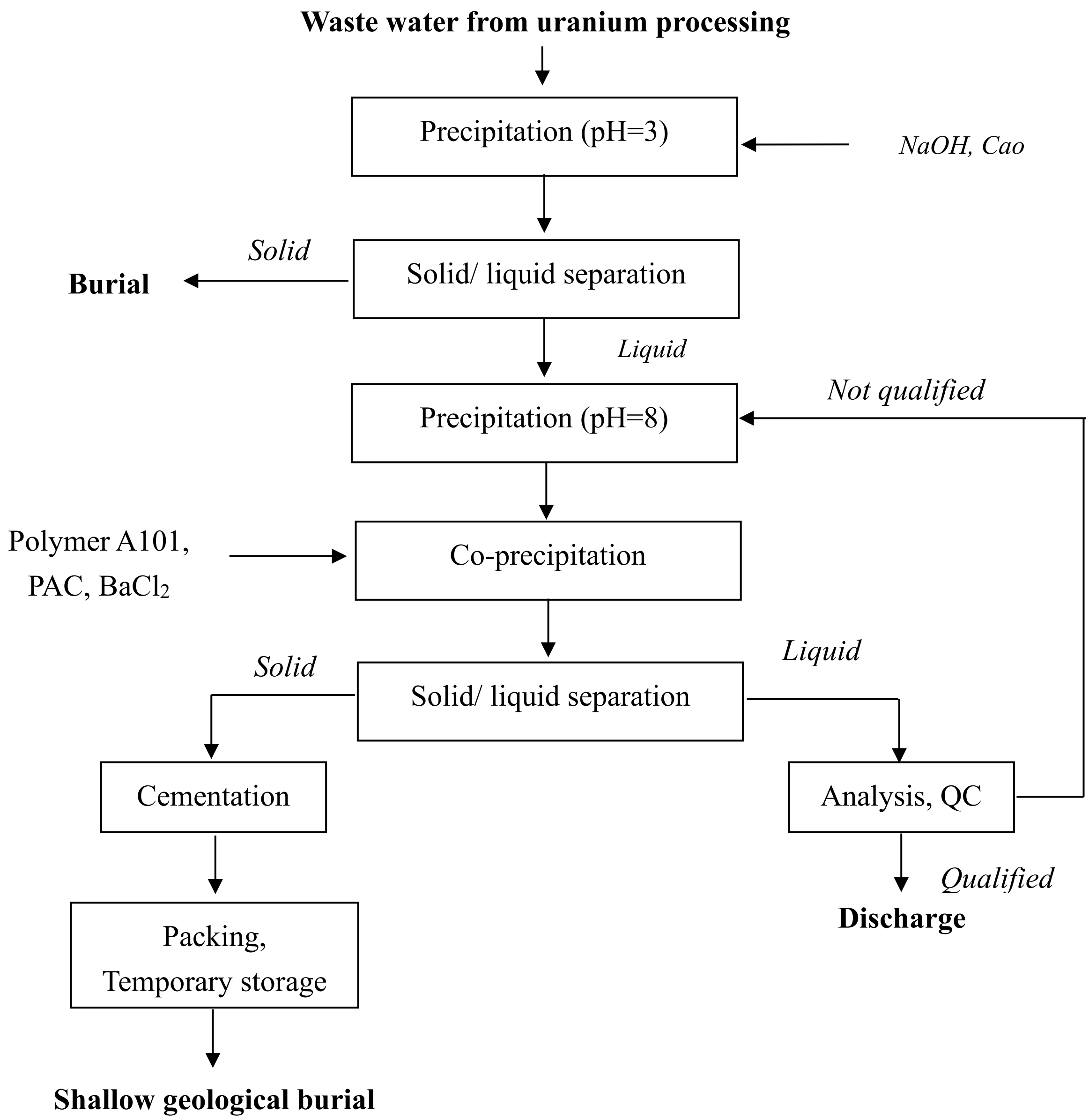


Fig. 6. Technological process for waste water.

11.2.2 Management of NORM waste from rare earth ores mining and processing and research facilities

NORM waste generated from ore mining and rare earth extraction activities by companies such as the Lai Chau Rare Earth Joint Stock Company (owner of the Dong Pao rare earth mine, the largest rare earth mine in Vietnam) and the Yen Phu Rare Earth Joint Stock Company (owner of the Yen Phu rare earth mine) are being managed with a focus on environmental and radiation safety.

These companies have successfully defended their environmental impact assessment reports and radiation safety assessment reports for their investment projects related to the construction and operation of rare earth ore facilities. The NORM waste generated during the mining and rare earth extraction processes (as well as NORM waste from other activities) can be stored in reservoirs, dumps or storage tanks. The tanks are designed in one of three forms: submerged underground, partially submerged or entirely above ground. The tank must meet the following requirements:

- The walls and the impermeable concrete base, with a reinforced steel structure are placed on a reinforced ground to ensure resistance to settling, cracking, leakage, and seepage in accordance with the technical standards and construction criteria.
- Around the submerged part of the walls (below ground level) and underneath the tank, there is an additional impermeable lining layer, consisting of at least one of the following materials: Compacted clay with a permeability coefficient of K ≤ 10-7 cm/s, with a minimum thickness of ≥ 60 (sixty) cm; HDPE membrane or synthetic PVC, butyl rubber, neoprene synthetic rubber, or equivalent materials with a thickness of ≥ 2 mm.
- Complete sun and rain protection must be provided for the entire tank surface, and measures should be taken to limit direct wind exposure into the tank during use until the tank is closed.
- In the case of tanks designed as submerged or partially submerged: after filling, the tank must be sealed with an impermeable concrete cover, a durable reinforced steel structure, in compliance with the regulations in the technical standards and construction criteria. The cover must completely seal the entire tank surface to ensure no water leakage or seepage. The tank cover should have an additional impermeable lining consisting of at least one of the following materials: Compacted clay with a permeability coefficient of K ≤ 10-7 cm/s, with a minimum thickness of ≥ 60 cm; HDPE membrane or synthetic PVC, butyl rubber, neoprene synthetic rubber, or equivalent materials with a thickness of ≥ 2 mm.

Currently, there isn't any deep rare earth mining plant in operation in Vietnam (except for a rare earth ore concentrate beneficiation plant in Yen Bai province and a rare earth solvent extraction plant using imported pure raw materials in Ha Nam province). NORM related to rare earth was born primarily from research activities at the laboratory and pilot scales. The figure below shows the waste disposal scheme for monazite processing.

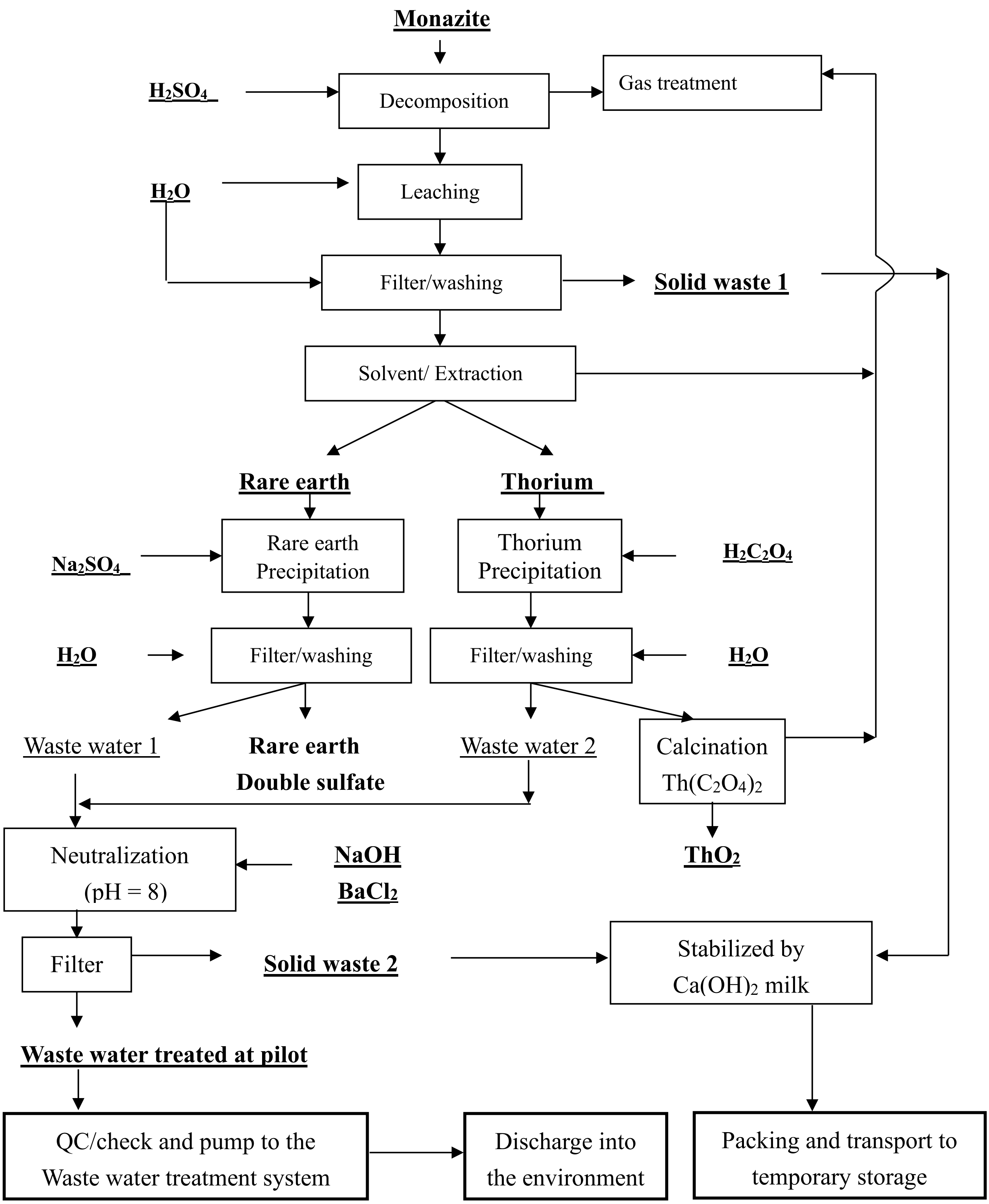


Fig. 7. Schematic monazite process.

Tons of radioactive waste resulting from monazite processing are subject to treatment and are currently stored in the warehouse of the Institute for Technology of Radioactive and Rare Elements (ITRRE). Within this facility, all radioactive wastes generated by ITRRE and other institutes in the northern region of Vietnam, stored in 807 drums, each with a capacity of 200 liters, are gathered, categorized, treated, and subsequently stored in a temporary storage area designated for radioactive waste..

Fig. 8. The radioactive waste facility at Phung Tower, Hanoi.

Experiments to develop suitable technologies for the treatment of various types of radioactive waste have been conducted in a dedicated laboratory for this purpose. The procedures applied for the treatment of radioactive wastes in general are as follows:

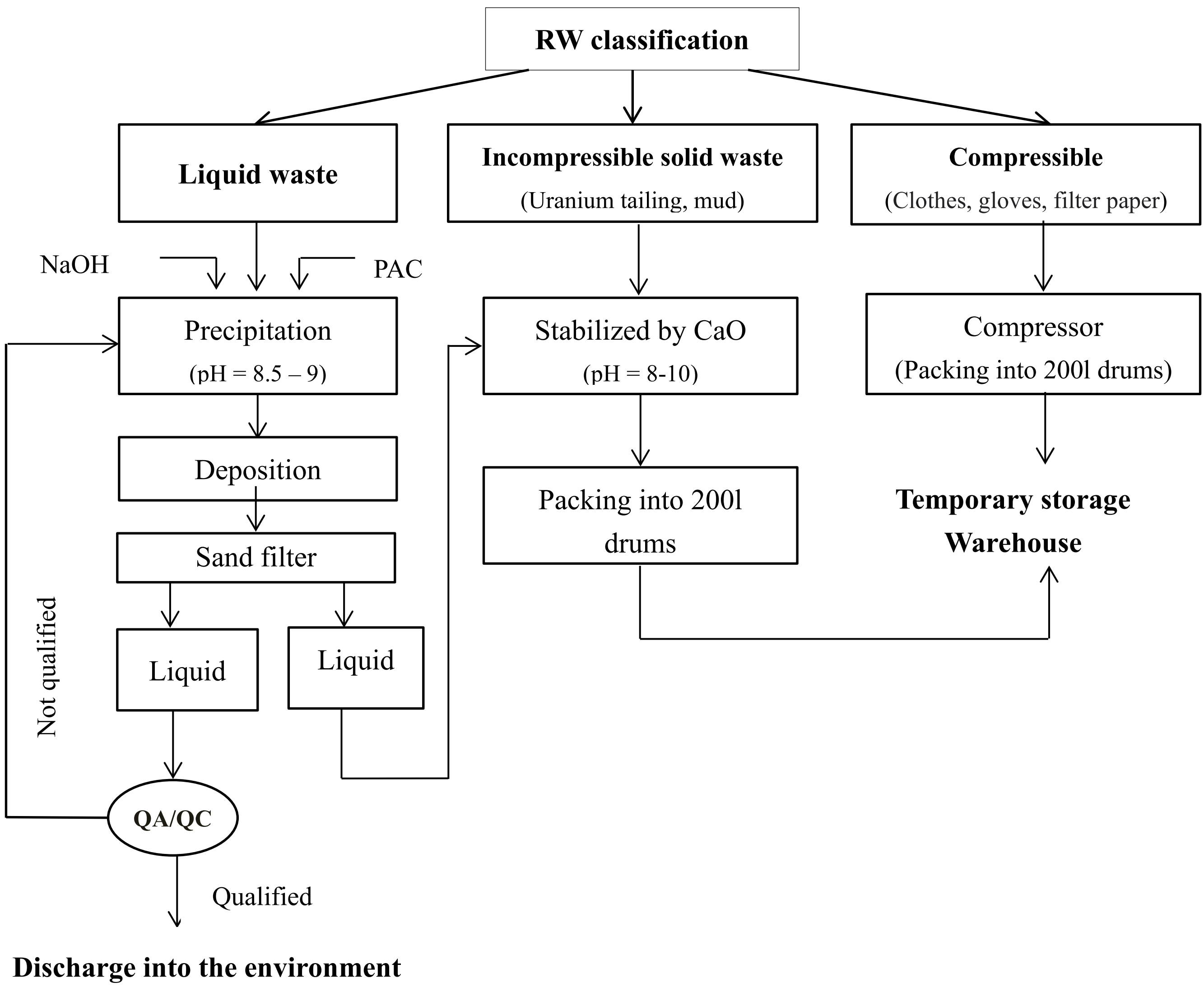


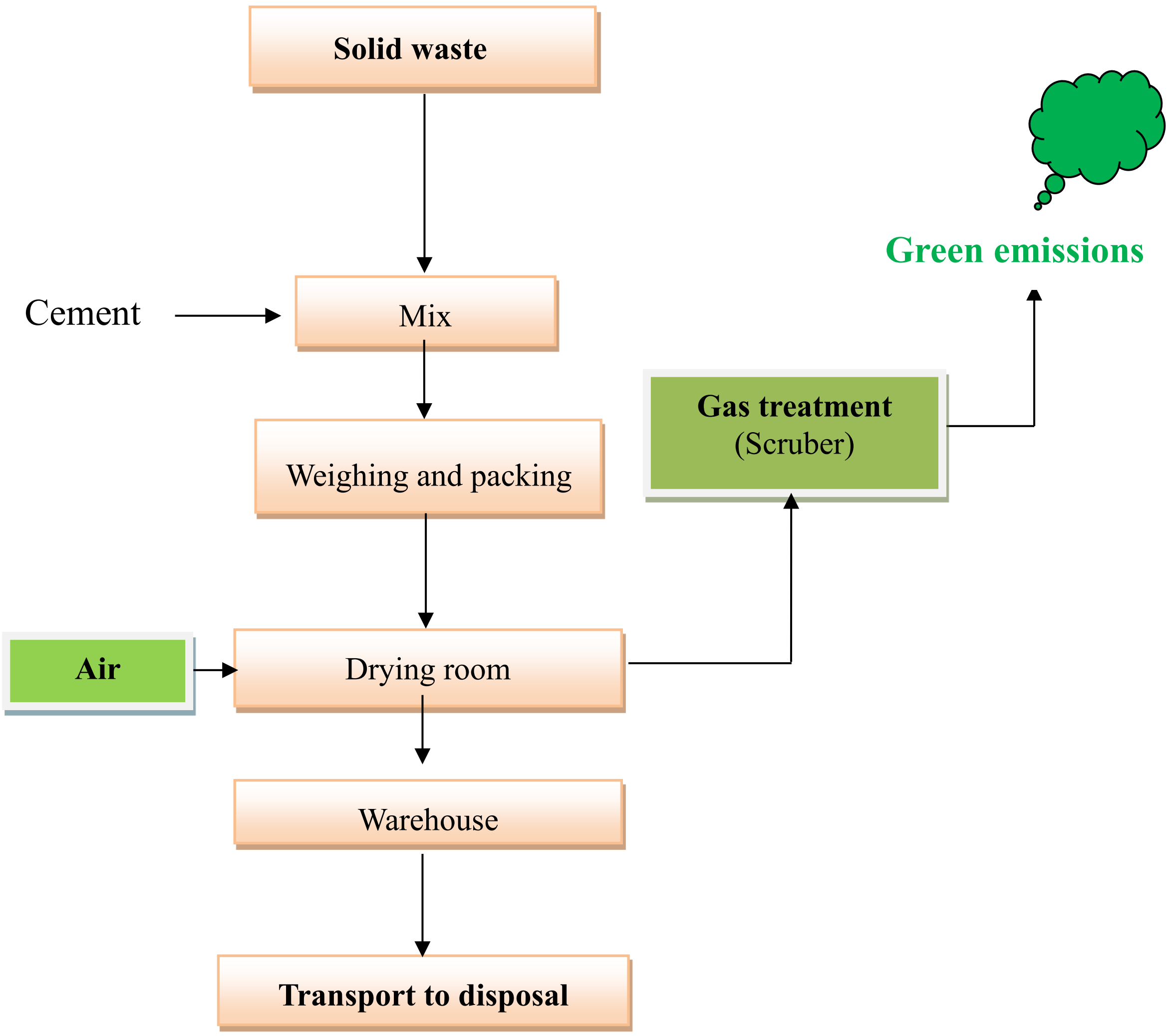
Fig. 9. General schematic radioactive waste process.

11.2.3 Management of NORM waste from titanium ore mining and processing and related industries

Typically, the mining sites are situated near the coastline and at a distance from the processing facilities. The extraction process involves pumping beach sand with water from the valley floor. Subsequently, the separation of black sand from white sand occurs using a weight-based method. White sand typically exhibits dose rates of 0.15-0.20 μSv/hr, while black sand, or other minerals, can have higher dose rates of 3-3.5 μSv/hr. Clean or low-activity tailings from this separation process are returned to fill the mined valley (pit).

Historically, Vietnam primarily exported refined ore. However, due to export restrictions on raw minerals, several companies have ventured into the deep processing of placer resources. The Vietnam Rare Elements Chemical Joint Stock Company (VREC) has been industrially producing ZOC from zircon concentrate, which has a dose rate of 3-3.5 μSv/hr. This production results in thousands of tons of NORM waste with dose rates ranging from 0.7-1.8 μSv/hr. The radioactive waste is managed according to the following procedure.

Fig. 10. Pre-treatment of solid waste from ZOC process.



The radioactivity waste is then transported to the disposal areas owed by Blue River Co., Ltd.

Radioactive measurement of waste bags

Transfer waste bags to a truck

Transfer waste to cocrete tank

Environment survey the closed tank

Fig. 11. Management of residue from ZOC process.

In general, the management of radioactive waste generated from zircon processing is executed effectively by the companies involved. All waste bags undergo radiation measurements, and the transportation process is meticulously designed to ensure radiation safety. Furthermore, specialized agencies prepare quarterly radiation safety reports for both the processing plants and burial sites. This radioactive waste management model can serve as a valuable example and be applied to other facilities in Vietnam, should they exist.

11.3 Regulatory Framework

11.3.1 Atomic Law

Under the Atomic Law 18/2008/QH12, the Government of Vietnam has established a policy framework for the management of radioactive waste, with key principles as follows:

-Radioactive waste must adhere to internationally agreed principles for control and safety management.
-Classification of radioactive waste is required, followed by appropriate treatment, conditioning, and disposal.
-Emphasis on minimizing the generation of radioactive waste.

11.3.2 Circulars

-To support the Atomic Law, several circulars have been issued, including:
-Circular 22/2014/TT-BKHCN, which deals with the management of radioactive waste and used radioactive sources.
-Circular 04/2016/TT-BKHCN, which outlines regulations for the appraisal of radiation safety assessment reports in the exploration and extraction of radioactive ores.

11.3.3 Standards on Radioactive Waste Management

-Various standards have been established to guide the management of radioactive waste, including:
-TCVN 6868:2001, which focuses on the safe management and treatment of radioactive waste, including the classification of radioactive materials.
-TCVN 7078-1:2002, which addresses the evaluation of surface contamination, specifically for beta-emitters with a maximum beta energy greater than 0.15 MeV and alpha-emitters.
-TCVN 7078-2:2007, related to the assessment of surface contamination, with a focus on tritium surface contamination.
-TCVN 6854:2011, which provides methods for testing and assessing the ease of decontamination for radioactively contaminated surfaces.
-TCVN 1469:2015, which deals with the measurement of radioactivity in solid materials designated for reprocessing or disposal.
-QCVN 23:2023/BKHCN: National technical regulation on naturally occurring radioactive material waste.

11.4 Issues Related to NORM

Vietnam currently has a number of radioactive waste management facilities, but most of them are of small scale. The country lacks a national facility for the storage of radioactive waste and used radioactive sources. To ensure the safe and effective management of NORM, there is a need to establish a regulatory framework in the near future.

Immediate actions related to NORM management should include:

-Upgrading or expanding existing small-scale radioactive waste management facilities.
-Developing management documents related to radon gas in residential high-rise buildings, underground public works, and mines.
-Enhancing the capacity of state management agencies to oversee all NORM-related industries to prevent environmental incidents and accidents related to NORM.
-Strengthening the capacity of technical assistance agencies in the appraisal and assessment of exemption, licensing, decommissioning, and environmental monitoring for NORM waste landfill sites.

RECENT ACTIVITIES

2023 Workshop

- **Date**: 7th – 9th November 2023
- **Host**: Malaysian Nuclear Agency

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- **Host**: Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan. (Hybrid format)

2021 Workshop

- **Date**: 9th – 10th November 2021
- **Host**: Online meeting

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