Radiation Protection Authority

Zambia

SAFETY GUIDE

RPA SG 13

Naturally Occurring Radioactive Materials (NORM)

2024

NOTICE OF APPROVAL

Under the terms of Part II of the Ionising Radiation Protection Act No. 16 of 2005 and Part V of the Statutory Instrument No.98 of 2011, the Radiation Protection Authority (RPA) is authorized to establish or adopt standards of safety for protection of health and minimization of risk to life and the environment, and to provide for the application of these standards.

The Radiation Protection Authority Board (RPAB), has on the ...../...../2024, approved the safety guide on NORM.

This guide is approved for the purposes of providing practical guidance with respect to the Ionizing Radiation Protection General Regulations No. 98 of 2011.

This guide comes into effect on ...../...../2024

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CHAIRPERSON

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EXECUTIVE DIRECTOR

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1. Background

Naturally occurring radioactive material (NORM) is the term used to describe materials containing radionuclides that exist in the natural environment. The radionuclides of interest include long-lived radionuclides such as uranium-238 (238U), uranium-235 (235U) and thorium-232 (232Th) and their radioactive decay products (such as isotopes of radium, radon, polonium, bismuth and lead), and individual long-lived radionuclides such as potassium-40 (40K), rubidium-87 (87Rb) and indium-115 (115In).

Human activities alter the natural background of radiation either by moving naturally occurring radionuclides from inaccessible locations to locations where humans are present or by concentrating the radionuclide's in the exposure environment. When mineral ores are in the naturally undisturbed environments, the radionuclides in the decay series are more or less in radiological equilibrium. This equilibrium becomes disturbed through mining and mineral processing and other human activity, resulting in either an enrichment or depletion of some of the radionuclides concentrations compared to the original matrix. The generation of products, by-products, residues and wastes containing NORM has the potential to lead to exposure to workers, members of the public and to environmental contamination. Regulation of NORM therefore becomes apparent to ensure protection of the workers, public and the environment from the effects of radiation.

1.1. Types of Radiation

There are three basic types of radiation that may be emitted by NORM:

- *alpha (α) radiation:*

This is made up of heavy, charged particles that cannot penetrate very far, even in air. They can be stopped by a piece of paper. Alpha particles are emitted by many of the heaviest radioisotopes found in NORM. They are small pieces of the atom which are thrown out at high speeds to take away the excess energy of the atom thus they carry a large amount of energy. This means that an alpha can produce a large amount of damage in human tissue. The top layer of skin on a person (the epidermis – which is comprised of dead cells) provides all the necessary shielding to protect from alpha particles. Therefore, they are not considered

to be an external radiation hazard. However, internally deposited alpha particles can cause serious damage to any cells with which they may interact. They are considered to be a high internal radiation risk.

- *beta (β) radiation:*

It consists of lighter charged particles than alpha particles, that travel faster and are thus more penetrating than alpha radiation. Beta particles are electrons which are
shot out with high velocity from a radioactive atom and carry less energy than an alpha particle but are able to penetrate further. They are thus able to penetrate the outer layer of skin and strike the live cells below the epidermis. This makes beta particles an external radiation hazard. However, because they do not carry as much energy as an alpha particle, they do not cause as much damage as an alpha particle. The tissue most affected by exposure to beta radiation is the skin.

- *gamma (γ) radiation:*

It consists of high-energy rays, and is very penetrating, gamma photons are uncharged, bundles of energy with no mass travelling at the speed of light. Gamma rays can carry a wide range of energies, they are exceedingly penetrating and shielding against them usually requires very dense materials such as lead or tungsten. Their ability to penetrate makes gamma rays an external radiation hazard – much greater than either an alpha or a beta particle. A gamma ray has the ability to deliver its energy to any depth of the human body, meaning that sensitive tissues contained within our bodies can reached.

Table 1.1: Radioisotopes and their risk characteristics

Radiation Type and Radioisotopes	**Penetrating Power**	**Energy Content**	**Internal Risk**	**External Risk**
Alpha: Radium-226 Radon-222 Thorium-228 Radium-228	Weakly Penetrating	High	High	Negligible to low
Betta: Lead-210	Low to Medium	Low to Medium	Medium	Medium
Gamma: Lead-212 Lead-214 Bismuth-212 Bismuth-214	High	Low to High	Low	High

The major risk to exposure to NORM is cancer and other long-term health effects.

1.2.Radioactive Decay

Radionuclides are identified by the characteristics of the radiation it emits. These include the decay rate, or half-life of the radionuclide, and the type and energy of radiation emitted. The half-life of the radionuclide is the rate at which particles are emitted, it is the length of time it takes for half of a substance's atoms to 'decay' to a more stable form, or to reduce the radioactivity by half. The half-life can be as short as a fraction of a second or as long as billions of years. As a radionuclide decays, it becomes an isotope of another
element. If this new isotope is also radioactive it decays further. Thus, there can develop a "decay series."

The most common NORM elements are:

- uranium (and its decay products)
- thorium (and decay products)
- radium (and decay products)
- lead-210

The most common being decay series of uranium-238 and thorium-232 series. Table 1.2.2 outlines the radioisotopes associated with the uranium and thorium radioactive decay series and potassium.

Table 1.2: Characteristics of the U-238, Th-232 Radioactive Decay Series and K-40

Uranium 238 Series			
NORM Nuclide	**Symbol**	**Half-life**	**Major Emissions**
Uranium 238	238U	4.5×109 y,	α
Thorium 234	^{234}Th	24.0 d	β, γ
Protactinium 234	234mPa	1.2 m	β, γ
Uranium 234	234U	2.5×105 y	α, γ
Thorium 230	^{230}Th	7.7×104 y	α, γ
Radium 226	226Ra	1.6×103 y	α, γ
Radon 222	222Rn	3.83 d	α
Polonium 218	218Po	3.1 m	α

Lead 214	214Pb	27 m	β, γ
Bismuth 214	214Bi	20 m	β, γ
Polonium 214	214Po	1.6×10-4 s	α, γ
Lead 210	210Pb	22.3 y	β, γ
Bismuth 210	210Bi	5.01 d	β
Polonium 210	210Po	138 d	α
Lead 206	**206Pb**	**stable**	**none**
Thorium 232 Series			
NORM Nuclide	**Symbol**	**Half-life**	**Major Emissions**
Thorium 232	232Th	1.4×1010 y	α
Radium 228	228Ra	5.7 y	β
Actinium 228	228Ac	6.1 h	β, γ

Thorium 228	228^{Th}	1.9 y	α, γ
Radium 224	224Ra	3.7 d	α, γ
Radon 220	220Rn	55.6 s	α
Polonium 216	216Po	0.15 s	α
Lead 212	212Pb	10.6 h	β, γ
Uranium 238 Series			
NORM Nuclide	**Symbol**	**Half-life**	**Major Emissions**
Bismuth 212	212Bi	61 m	α, β, γ
Polonium 212 (65%)	212Po	3×10-7 s	α
Thallium 208 (35%)	208Tl	3.1 m	β, γ
Lead 208	**208Pb**	**stable**	**none**
Potassium 40			
NORM Nuclide	**Symbol**	**Half-life**	**Major Emissions**
Potassium 40	40K	1.3x 109 y	β, γ

1.3.Fundamental Radiation Protection Quantities

There are two fundamental quantities:

i. *Becquerel (= Activity);* The becquerel (Bq) measures the quantity of radioactivity present without consideration for what kind of radiation is emitted. 1 Bq = 1 nuclear transformation (disintegration) per second.

ii. *Sievert: Effective Dose (= Biological Effect);* Different types of radiation have different penetrating power, and different parts of the body have different sensitivities to radiation.

Dose assessment therefore requires knowledge of the type and amount of radiation and the biological sensitivity of the body part exposed. The sievert (Sv) is the unit of Effective Dose of radiation, and accounts for the total effect of different types of radiation on different parts of the body. Regulations express the dose on a yearly basis, as millisieverts per annum or mSv/a.

1.4.NORM Exposure Pathways

The methods of exposure to NORM by workers or members of the public are as follows;

- External gamma exposure,
- Ingestion of NORM-containing materials,
- Inhalation of NORM-containing dust, and
- Inhalation of radon gas and its radioactive decay products.

1.5.Purpose of Guidance

This guidance document details the relevant processes to be applied for the protection of workers, members of the public and the environment from elevated levels of natural radionuclides. Persons exposed to NORM should be subject to the same radiation exposure standards and protection that apply to regulated radioactive materials under the Radiation Protection (General) Regulations of 2011. The principle of optimisation is of essence; if doses can be reduced by reasonable actions and interventions, those actions should be taken as reducing levels to very low doses of radiation may be beneficial. The goal is that doses should be As Low As Reasonably Achievable (ALARA), economic and social factors being taken into consideration.

1.6.Scope

This guide applies to;

- any person who receives, possesses, uses, processes, transports, transfers, distributes, or disposes of NORM,
- the manufacture and distribution of products containing NORM in which the NORM's emitted radiation is considered beneficial to the products and
- the introduction of NORM into products in which the radiation emitted from the NORM is not considered to be beneficial to the products

Sealed radioactive sources and radiation generating equipment are outside the scope of this regulatory guide.

1.7.Industries with NORM

For industries involving NORM as existing exposure situations, radiation is not deliberately introduced in the industrial process for its radioactive properties; it already exists in material used in the process or industry. The regulation applies to processes in which NORM is handled and in which raw materials is concentrated, with changes of chemical-physical form resulting in production of radioactive release, residue and waste. However, when ores are processed for their radioactive or fissile properties, it is treated as a planned exposure situation and is not in the scope of this guide.

Industrial and mining activities that may require regulation as a practice include;

- *Mineral Extraction and Processing:*

NORM may be released or concentrated in a process stream during the processing of ore, such as in the phosphate fertilizer industry and the abrasives and refractory industries. These may include but not limited to;

- Extraction of Rare Earth Elements,
- Production and use of Thorium and its Compounds,
- Production of Niobium and Ferro niobium,
- Mining of Ores other than Uranium Ore,
- Production of Tin, Copper, Aluminium, Zinc, Lead, Iron & Steel,
- The Zircon and Zirconia Industries, and
- Underground mining activities
- *The Phosphate Industry (Fertiliser Production)*
- *Production of Oil and Gas, Coal and Coal Combustion*

NORM found in liquids and gases from hydrocarbon- bearing geological formations.

- *Cement manufacturing, Quarrying and Building Industry,*

- *Metal Recycling and Scrap Processors:*

NORM-contaminated materials can be redistributed to other industries resulting in the formation of new NORM-contaminated products.

- *Water Treatment and Purification:*

fresh or waste water is treated through sorptive media or ion-exchange resins to remove minerals and other impurities from the water being treated and may release radon and other radionuclides.

- *Radon in Mines,*

The identified industries above are based on international experience and recommendations (IAEA Technical Report Series No. 419, and IAEA-TECDOC-1017).

2.INTERNATIONAL & NATIONAL FRAMEWORK

2.1.International Basis

There has been increased international concern over the impacts of elevated levels of NORM with the IAEA, International Commission on Radiological Protection (ICRP) and ILO taking positive steps to ensure development of safety standards and guidance related to the management of NORM.

Radiation Protection and Safety of Radiation Sources: International Basic Safety Standard, General Safety Requirements Part 3, Section 5 (Existing Exposure Situations) Requirement 47, 49 and 52 deal highlights a State's obligation to ensure management of radiation, remediation of areas with residual radioactive material and implementing remediation programmes and post-remediation control measures, and establishment and enforcement of requirements for the protection of workers in existing exposure situations.

The guide is based on the most recent international standards recommended by the ICRP regulations that represent international consensus on radiation protection standards and provide the basis for regulatory control of radioactive materials. As these regulations and standards are subject to periodic amendment, the guide may also be updated to reflect amendments to accepted national and international radiation protection practices. The ICRP and IAEA radiation protection philosophy and recommendations of significance for NORM in Zambia are contained in ICRP reports 60, 65, 68, 72 and 77 and IAEA Safety Series 115. International Labour Organisation further points to the need to ensure protection of workers from the effects of radiation arising from NORM.

3.REGULATORY PROCESS FOR NORM AUTHORISATIONS

For all norm facilities that fall under the NORM regulations the process highlighted in Fig 3. below shall apply.

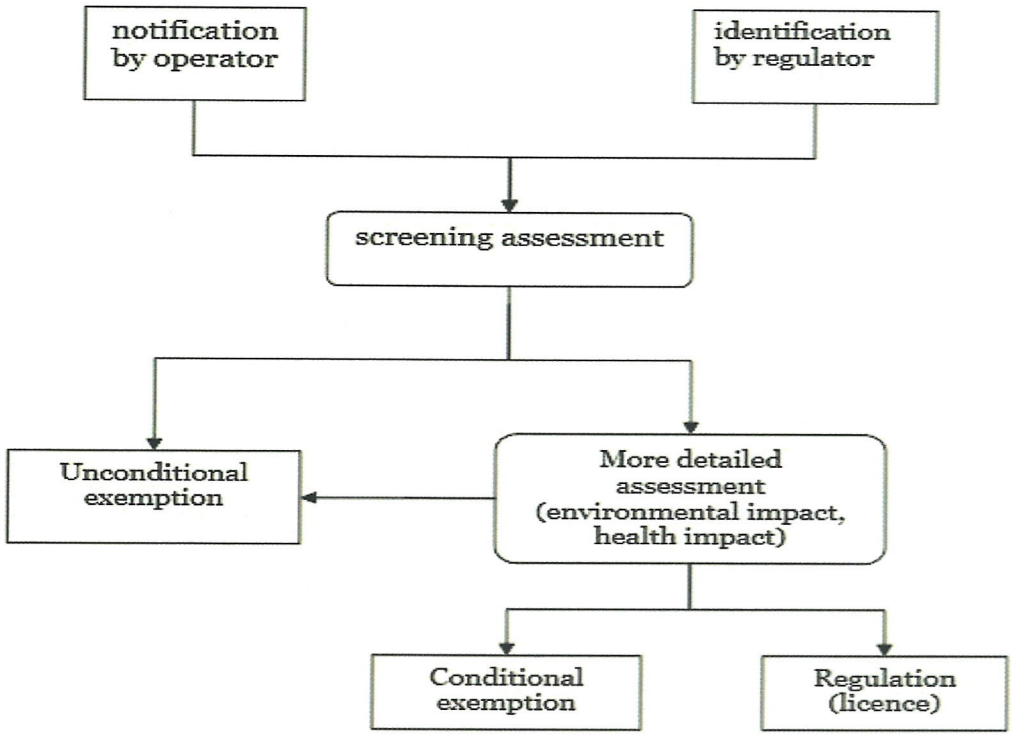


Fig 3: *NORM Regulation: Basic Process*

Table 3. Norm authorisation Classification

Activity Concentration and Effective Dose	**NORM Authorisation Classification**
Below 0.3 Bq/g U, Th, Below 5 Bq/g K-40 Estimated incremental annual effective dose to the public less than 0.3 mSv/a, and to the worker is less than 1.0 mSv/a	Exemption (3-year exemption from regulatory control)
0.3-1 Bq/g U, Th, 5-10 Bq/g K-40 Estimated incremental annual effective dose to the public less than 0.3 mSv/a, and to the worker is less than 1.0 mSv/a	Conditional Exemption (3-year exemption with annual monitoring at specific sites with elevated levels)

Above 1 Bq/g U, Th, Above 10 Bq/g K-40	Licensing (Radiation Protection Measures to be put in place)
Estimated incremental annual effective dose to the public less greater than 1.0 mSv/a, and to the worker greater than 5.0 mSv/a	

3.1 Notification

The guide requires all industries that have potential to lead to radiological exposures be responsible for notifying the Authority through an application that the operation involves naturally occurring radioactive materials. Typically, the nature of the process materials must be reviewed as part of the initial mining and/or processing environmental assessment for a project. The operator must consult the Authority if there is uncertainty as to whether a particular operation may require regulatory attention.

The process of notification provides a record for the Authority of the intended operation and the decision to either exempt the operation where exposures and activity concentrations will not exceed the relevant exemption criteria, or to proceed with a screening assessment. The Authority may, also in turn contact a new or existing industry, and request a screening assessment based on previous or international experience with a particular type of operation.

The notification form is available as ***"Application Form for Authorisation of Naturally Occurring Radioactive Material (NORM)".***

3.2 Screening Assessment: NORM Characterisation

Sampling and Surveying; Upon receiving a notification, the Authority may require an initial screening risk assessment to be made in line with the requirements of SI 99 of 2013. The Authority may, also in turn contact a new or existing industry, and request a screening assessment. The assessment must estimate the following;

- magnitude of worker and member of public doses arising from the operation through dose rate measurements and activity concentrations,
- Sampling at the different stages of mineral mining and processing, waste water, and production process for gamma spectrometry analysis.
- level of optimisation of radiation protection, and
- long term impact of any residues on the environment in the case of recycling or disposal.

The screening assessment should be undertaken for all potential NORM activities and must be negotiated between the operator and the Authority. Procedures for carrying out screening assessments have been published as ***"Procedures for Radiological Screening and Assessment of NORM Industries"***. It is important that a screening assessment be conservative, to ensure that risks are not underestimated. It is strongly required that only a person knowledgeable in radiation protection conduct the work-site radiological evaluation and sampling.

3.3 Regulatory Decision Criteria

The 1Bq/g criteria for uranium and thorium and 10Bq/g for K-40. Possible outcomes of the screening assessment include exemption, annual monitoring and licensing. The Authority may conduct a verification screening as part of the processes of making such regulatory decisions. The verification or more detailed assessment will target the areas that have results that are above 0.3Bq/g.

3.4 Exemption

Exemptions are issued in line with the Radiation Protection Regulations. Exemptions should apply to activity concentrations below 1Bq/g (U and Th series) and less than 10Bq/g (K-40), annual dose less than 1mSv/year to members of the public and workers. It also applies where the estimated incremental annual effective dose to the public is less than 0.3 mSv/a, and to the worker is less than 1.0 mSv/a.

Exemptions shall be in the form of unconditional (exemption) and annual monitoring.

3.4.1 Unconditional Exemption

Where doses are below the exemption criteria, and any other impacts are considered acceptable, the Authority may exempt the operation from further requirements. This would apply to those cases where it is clear that the potential for significant exposures is negligible (even in situations where there are changes to the process or the materials being handled). An exemption certificate is issued for 3 years, after which a new screening/assessment has to be carried out.

This applies to activity concentrations below 0.3Bq/g (U and Th series) and less than 5Bq/g (K-40), annual dose less than 1mSv/year. In the event of significant process change, or where new areas are exploited, a new assessment may be required.

3.4.2 Conditional Exemption (Annual Monitoring)

Where the screening assessment confirms that the criteria for unconditional exemption cannot be met, but the doses to the workforce and members of the public are expected to be well below the relevant dose limits, a conditional exemption must be issued. The Authority will maintain a register of operations with ongoing requirements for monitoring and reporting. Re-assessment must be done annually as a condition of the exemption and verification that the assumptions on which the original assessment was based are still valid.

This applies to activity concentrations between 0.3-1Bq/g (U and Th series) and 5-10 Bq/g (K-40). Annual dose less than 1mSv/year for the workplaces.

In the event of significant process change, or where new areas are exploited a new assessment may be required.

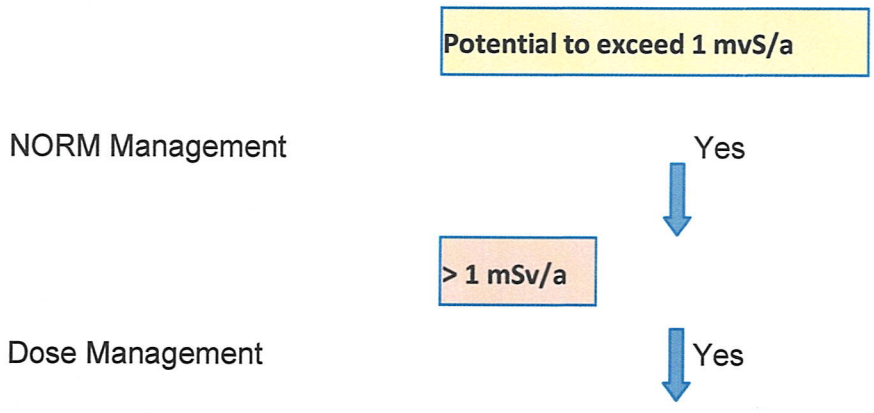
The annual monitoring program should be agreed between the operator and the Authority and will aid in assessing if the facility must either be reviewed to exemption, licensing or remain in the annual monitoring category.

3.5 Licensing

Where an exemption is not granted, regulation require the operator to hold an appropriate licence that is renewed annually. This applies to activity concentrations above 1 Bq/g for U and Th and above 10 Bq/g K-40 from the screening and assessment results and annual
dose above 1mSv/year to members of the public and workers. It also applies where the estimated incremental annual effective dose to the worker is greater than 1.0 mSv/a.
Specific actions and measures must be put in place to control actions of workers, workplace and environmental monitoring, this is addressed be development and implementation of a NORM Management Plan (discussed in Section 4 below) approved by the Authority. An annual monitoring program should also be agreed between the operator and the Authority
Where the results are above the set limit, but there is minimal exposure to workers or the public and no release to the environment (radiation is contained) the facility is issued with a conditional exemption with monitoring.

3.5.1 General License

Issued to operators who generate, possess, own, use, transfer and dispose NORM, with an activity concentration that require licensing as set out in the Radiation Protection Act.
The following measures apply;



Radiation Protection Program

3.5.2 Specific License

Issued to operators who intent to decontaminate, transport or receive NORM

NORM Shipments/Transport

Authorisations for transport of NORM issued under a specific license and IAEA Safe Transport Regulations.

- A transport manifest is completed and contains the descriptor "Naturally Occurring Radioactive Material – NORM",
- The shipment is securely packaged in a manner that effectively prevents release or redistribution of any NORM contamination during transport, and
- The shipment has taken into account any other potential hazardous properties of the materials.

Note: No radioactive placards or labels should be affixed to the transport vehicle or to the exterior surfaces of the packaging.

4. NORM Management Plan

Facilities that fall under the Licensing classification are required to submit for approval a Radiation NORM Management Plan to ensure proper management of NORM, including protection of the public, workers, and environment. Its purpose to demonstrate management responsibility for protection, safety and optimization using management structures, policies, procedures, and organizational arrangements. The employer to establish and manage the plan in close co-operation with company's Health & Safety team.

Protection of the following category of workers are important within the facility.

- Occupationally Exposed Workers are employees who are exposed to NORM sources of radiation because of their regular duties. They are classified as NORM Workers

working in an occupational exposure environment, and their average annual effective dose should not exceed 20 mSv (see Table 2.1 note c, for exception).

- Incidentally Exposed Workers are employees whose regular duties do not include exposure to NORM sources of radiation. They are considered as members of the public who work in an occupational exposure environment and, as such, the annual effective dose limit for these workers is 1 mSv.
- Members of the Public are persons who have no occupational exposure to NORM. The annual effective dose limit for members of the public is 1 mSv. For the control of public exposure an appropriate value for the dose constraint is 0.3 mSv in a year.

It is therefore essential that the facility or operator must develop a NORM Management Plan, it must include;

- *Management system and assignment of responsibilities:*

The plan must be endorsed at the highest management level of the facility, it also has to be integrated into the whole health and safety infrastructure of the facility. A Radiation safety officer within the facility with adequate knowledge on NORM must coordinate NORM management.

- *Description of production/mining/industrial process*
- *Exposure Scenarios and Pathways:*

This has to address all the radiation hazards associated with NORM as well as mitigating against the risks thereof. An action plan to address the identified NORM sites as well as continuous assessment of exposure to workers and the public.

- *Classification of areas:*

Area classification should be considered when there is occupational exposure to radiation. Prior radiological evaluation to identify areas in need of classification.

- *Employee and public radiation safety and protection controls:*

Hierarchy of Control Measures to be instituted

- *Management of NORM Residues and Re-mediation process*
- *Local rules and supervision:*
- *Monitoring, recording and reporting:*
- *Education and training:*
- *Health Surveillance programs:*

5. REFERENCE MATERIALS

Ionising Radiation Protection Act No.16 of 2005 protection against the effects of ionising radiation.

IAEA Technical Report Series No. 419, and IAEA-TECDOC-1017

International Commission on Radiological Protection (ICRP) reports 60, 65, 68, 72 and 77