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Holistic Approach to Management of Naturally Occurring Radioactive Material (NORM)

A Case Study in Brazil

HOLISTIC APPROACH TO MANAGEMENT OF NATURALLY OCCURRING RADIOACTIVE MATERIAL (NORM)

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A CASE STUDY IN BRAZIL

INTERNATIONAL ATOMIC ENERGY AGENCY
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For further information on this publication, please contact:

Section on Decommissioning and Environmental Remediation
International Atomic Energy Agency
Vienna International Centre
PO Box 100
1400 Vienna, Austria
Email: Official.Mail@iaea.org

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FOREWORD

Many industrial operations use or process materials containing small or very small quantities of naturally occurring radionuclides. In most instances, the presence of these radionuclides is purely incidental to the processes of recovery, production and use of the target resource. Oil, gas, coal and phosphorus resources, for example, have very low levels of radioactivity. In the case of uranium, the radioactive properties of the primary material are themselves of direct economic interest as an energy resource.

When properly handled and managed, these resources and related residues pose negligible or low risk of harmful effects of ionizing radiation to workers and the public and to the environment. There are, however, situations where the concentration of naturally occurring radionuclides will be higher than typical values. In such cases due consideration to possible exposures needs to be paid and proper measures of protection need to be adopted.

The IAEA has been supporting Member States in managing naturally occurring radioactive material (NORM) in a safe way for more than three decades. This support is provided by means of various mechanisms of capacity building that include workshops, training courses, fellowships, scientific visits and the issuance of IAEA publications.

Under the scope of the activities of the Network on Environmental Management and Remediation, known as ENVIRONET, a project — The ENVIRONET NORM Project — was initiated with the objective of providing enhanced, more structured and comprehensive support to Member States so that more tangible developments could be achieved. The ENVIRONET NORM Project comprises six working groups intended to elaborate guidance publications in each one of the topical areas covered by the working groups. Combined these six topics form the holistic approach to NORM management which is a framework that, once implemented in a Member State, will facilitate timely, safe and cost effective NORM management.

In 2021, Brazil, through the IAEA, requested support to address the issues associated with the management of NORM waste generated by the oil and gas industry in the country. A workshop was organized to analyse the situation of the country in relation to the reported national situation using elements of the holistic approach to NORM management.

The virtual workshop included more than 250 attendees, including international experts who shared their experience in each of the topics addressed by the six working groups of the ENVIRONET NORM Project.

The outcome of the workshop was the development of a road map which describes steps that Brazil could consider taking when putting in place a structure to deal with NORM. This road map, the description of the framework and the results of the workshop are described in this publication.

The IAEA wishes to express its thanks to all who contributed to the organization of the workshop and to the experts who shared their experiences and contributed to the drafting and review of this publication. The IAEA would like to express its appreciation to the Brazilian authorities which agreed to share the results of the workshop with the international community.

The IAEA officer responsible for this publication was H. Monken-Fernandes of the Division of Nuclear Fuel Cycle and Waste Technology.

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Guidance and recommendations provided here in relation to identified good practices represent expert opinion but are not made on the basis of a consensus of all Member States.

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CONTENTS

1. INTRODUCTION

1.1 BACKGROUND

Naturally occurring radioactive material (NORM) is defined in the IAEA Safety and Security Glossary [1] as radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides. When NORM is associated with the processing of a given raw material it takes the form of a residue i.e. a material that remains from a process and comprises or is contaminated by NORM. It is very important to note that a NORM residue may or may not be waste i.e. a material for which no further use is foreseen.

Since the first technical scientific events and publications reporting the presence of enhanced levels of natural radionuclides in some residues generated by processing of metal ores, the oil and gas industry, fertilizer production, coal burning and water treatment among others proper solutions for the management of such residues have been pursued with different results being obtained in different countries. These solutions need, at the same time, to be technically feasible, safe, economically viable and acceptable to society.

Nowadays, there is the understanding that the so-called 'linear model of the economy' embodied in the nexus of extract–process– dispose (the waste) could be replaced by a circular approach in which emphasis is given to recycling of residues instead of their disposal as waste.

The issue here is that the circularity concept, at the present time, is misaligned with regulations developed in the context of linear thinking. It could be proposed however that a more encompassing analysis of the pressure modern society puts on natural resources could result in the opposite approach whereby the regulations are realigned to meet the needs of the circular economy.

It would be naïve to believe though that the proper management of NORM is just a matter of regulations. There are many other factors that need to be considered, from education/awareness to public and occupational safety and economic (market) considerations.

Experience has shown that efficient, safe, and cost-effective management of NORM can only be achieved within a holistic approach. While nuclear energy related activities are regulated in all countries that operate nuclear reactors by means of stringent requirements – noting that only 30 countries operate nuclear power plants – NORM related activities can be found in many more countries worldwide, countries which have differing capabilities and infrastructure to deal with NORM-related industries. This situation ends up imposing additional challenges especially in a world that has become more and more globalized and interconnected.

It is also to be recognised that the Radiation Protection framework was originally developed to protect workers and the public from harmful effects of ionizing radiation from activities that were originally related to situations arising from planned exposures, for example nuclear related

activities (energy generation and research), medical exposures and practices involving sealed sources. Applying this framework to situations involving exposure to natural sources has proven to be quite challenging.

IAEA issued a dedicated publication on the concepts of Exclusion, Exemption and Clearance that was supersede by two new publications that deal with exemption and clearance separately, [2] and [3] respectively. In both it is stated that "The primary radiological basis for establishing values of activity concentration for the exemption of bulk amounts of material and for clearance is that the effective doses to individuals should be of the order of 10 μSv or less in a year".

By contrast, both Safety Guides above [2, 3] do not take into consideration an effective dose value of 10 μSv/y for exemption and clearance criteria for radionuclides of natural origin, but it states that "The values of activity concentration for radionuclides of natural origin, derived using the exclusion concept. The values have been determined on the basis of consideration of the worldwide distribution of activity concentrations for these radionuclides".

These differences in approach clearly need to be better understood and due consideration to these differences need to be paid, understood and possibly pragmatic approaches need to be pursued, while maintaining safety considerations as the paramount point of reference.

In the context of NORM, for more than three decades, the IAEA has put in place a series of efforts to support its Member States. These efforts include the publication of IAEA safety standards, Safety Reports and TECDOCs; direct assistance to Member States by means of Technical Cooperation Projects at the national, regional and interregional levels (that include training courses, workshops, fellowships, scientific visits, expert missions and procurement of equipment) and organizing and sponsoring Conferences and Symposia (with the publication of the related proceedings). All these efforts have contributed to some extent to meaningful progress that has been observed in some of the IAEA Member States. However, much progress is still needed.

At the 2015 Annual Meeting of the Network of Environmental Remediation and NORM Management (ENVIRONET), a project dedicated to NORM was proposed by meeting participants. The following year a Consultants Meeting established draft Terms of Reference for this project which were then formally adopted at a Technical Meeting hosted in Sweden. Two further Technical Meetings dedicated to the project were held in Vienna, 2017 and in Katowice, 2018. In 2020, the IAEA organised its first full NORM Conference NORM2020, with the programme content mirroring the organizational structure of the four Environet NORM working groups, details of which are described later in this report. NORM2020 had a strong thematic focus on the circular economy, and the level of interest in how to achieve this led to the decision to form two further working groups. Each of these working groups was tasked with producing a guidance document. When taken together, the documents as a whole will comprise a set of robust building blocks on which a "Holistic Approach to NORM Management" can be based at national level. Even if one can consider that some countries made reasonable progress in dealing with NORM

without such building blocks the likelihood of successfully delivering a functional, complete, effective and well-accepted framework to manage NORM will be low.

The first time this approach was pilot tested in consultation with a Member State was in May 2021 with Brazil. A week-long, virtual workshop was held which brought together representatives from different Brazilian governmental institutions and organizations, private and public sector operating companies, research institutions and IAEA nominated experts to explore and test the model. The discussion addressed the needs, challenges, responsibilities and views on the management of NORM as understood and experienced in Brazil at a national level, while being complemented by generic presentations from the international experts , such that after the national and international presentations, a more global perspective on the Holistic Approach was achieved. Day four was given over to six thematic breakout groups, each dedicated to in-depth discussions one of the core topics covered by the six respective Environet NORM Project working groups. At the end, the findings of the group discussions were presented in summary at a Plenary session, which in turn led to the compilation of this report. This now constitutes as Roadmap to help Brazil at national level form its own set of building blocks of the Holistic Approach with a view to helping the country implement sound and effective means to manage NORM.

1.2 OBJECTIVE

The objective of this publication is first, to introduce the Holistic Approach to NORM Management as being developed in the scope of the Environet NORM Project. This publication also presents an analysis of how this framework can be systematically applied to scope the way in which a given country can deal with management of NORM residues within a circular economy transition. Such a process will identify and characterise existing gaps both in knowledge and experience at the national level that currently impair the proper management of NORM residues and pinpoint concrete and feasible actions to be taken. It is also expected that with this publication ,other IAEA Member States may gain inspiration to establish a more coherent approach to deal with NORM at the national level, achieving a timely, safe and cost-effective system infrastructure to support the necessary actions for a smooth and effective transition to a circular, holistic approach.

1.3 SCOPE

This publication complements existing IAEA safety standards and other publications that relate to NORM. In particular, this publication proposes how relevant requirements can be met in a contemporary context and how to overcome barriers to implementation of a management approach that is functional, rational and feasible. A particular point of focus is on the management of residues generated by different NORM-related industrial operations, but it does not address NORM-specific radiation protection aspects as they relate to either workers at these operations or wider issues of public or environmental health and safety. Nevertheless, all points addressed in this publication are fully aligned with radiation protection principles and requirements and

recognize that both management and operational teams are obliged to comply with all applicable regulatory and safety requirements.

1.4 STRUCTURE

This publication provides a brief introduction to relevant aspects related to the management of NORM. In the second section, the different efforts put in place by the IAEA to assist its Member States in this field (covering the relevant publications already issued by the IAEA on NORM) are described. In the third section, a general description of the Holistic Approach to NORM is provided while the subsequent section is dedicated to describing in detail the workshop implemented in Brazil. Conclusions are presented in the last section and form the structure of the Road Map for the implementation of the Holistic Approach to NORM in Brazil.

2. UNDERSTANDING THE FRAMEWORK OF NORM

After many years dealing with NORM some of the IAEA Member States still find difficulties in properly categorizing NORM. The remaining issues relate to when NORM is waste, when NORM is a residue and which framework applies to deal with situations in which NORM is involved.

In an attempt to provide more clarity to these issues some definitions are provided below. As a starting point one has natural source that is defined as:

"A naturally occurring source of radiation, such as the sun and stars (sources of cosmic radiation) and rocks and soil (terrestrial sources of radiation), or any other material whose radioactivity is for all intents and purposes due only to radionuclides of natural origin, such as products or residues from the processing of minerals; but excluding radioactive material for use in a nuclear installation and radioactive waste generated in a nuclear installation" [1].

In addition to the above "Examples of natural sources include naturally occurring radioactive material (NORM) associated with the processing of raw materials (e.g. feedstocks, intermediate products, final products, co-products, waste)" [1].

Another important definition provided is related to radioactive material that is "Material designated in national law or by a regulatory body as being subject to regulatory control because of its radioactivity" [1].

It is to be noted that the above definition entails the 'regulatory' meaning of radioactive, is not to be mistakenly seen as the 'scientific' meaning of radioactive that is essentially a material that exhibits radioactivity i.e. emitting or relating to the emission of ionizing radiation or particles. In addition the scientific meaning of radioactive deals only with the presence of radioactivity giving no indication at all about the magnitude of the hazard involved.

With the above in mind the provided definition of NORM is then:

"Radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides. Material in which the activity concentrations of the naturally occurring radionuclides have been changed by a process is included in naturally occurring radioactive material (NORM)" [1].

Materials that contain natural radionuclides and result from an industrial process can be classified as residue or waste. In the first case, a residue can be defined as "Material that remains from a process and comprises or is contaminated by naturally occurring radioactive material (NORM). A NORM residue may or may not be waste" [1].

And NORM waste is then defined as "Naturally occurring radioactive material (NORM) for which no further use is foreseen" [1].

An issue that is also raised is whether NORM waste is radioactive waste or not. In that regard, radioactive waste is "For legal and regulatory purposes, is waste that contains, or is contaminated with, radionuclides at activity concentrations greater than clearance levels as established by the regulatory body" [1].

The definition above indicates that radioactive waste is indeed a legal definition and is related to the concept of clearance that is defined as "Removal of regulatory control by the regulatory body from radioactive material or radioactive objectives within notified or authorized facilities[1] and activities[2]" [1].

In principle, exposure to natural sources is generally considered existing exposure situation but the requirements for planned exposure situations apply wherever "Exposure due to material in any practice … where the activity concentration in the material of any radionuclide in the uranium decay chain or the thorium decay chain is greater than 1 Bq/g of the activity concentration of ^{40}K is greater than 10 Bq/g" [4].

[1] Facilities and activities - A general term encompassing nuclear facilities, uses of all sources of ionizing radiation, all radioactive waste management activities, transport of radioactive material and any other practice or circumstances in which people may be subject to exposure to radiation from naturally occurring or artificial sources. 'Facilities' include: nuclear facilities; irradiation installations; some mining and raw material processing facilities such as uranium mines; radioactive waste management facilities; and any other places where radioactive material is produced, processed, used, handled, stored or disposed of — or where radiation generators are installed — on such a scale that consideration of protection and safety is required.

[2] Activities includes: the production, use, import and export of radiation sources for industrial, research and medical purposes; the transport of radioactive material; the decommissioning of facilities; radioactive waste management activities such as the discharge of effluents; and some aspects of the remediation of sites.

3. REVIEW OF THE RELEVANT IAEA INITIATIVES ON NORM

The International Atomic Energy Agency has been supporting Member States in managing NORM in a safe way, through a wide range of mechanisms. The next sub sections present a description of some of these.

3.1 PUBLICATIONS

The IAEA has produced many publications — including Safety Standards, Technical Report Series, Safety Series Reports and TECDOCS — associated with NORM. One of the first of these publications was the Proceedings of an International Symposium taking place in Rio de Janeiro [5]. At that time the acronym NORM was not fully consolidated and instead the acronym TENR (Technologically Enhanced Natural Radiation) was used. The objective of the symposium was:

> "To provide a forum for the international exchange of information on the scientific and technical aspects of those components of exposure to natural radiation that warrant consideration. These components were examined under the headings: the technological enhancement of natural radiation in mining and non-nuclear industries; radon indoors and outdoors; mobility and transfer of natural radionuclides; natural radiation and health effects; analytical techniques and methodologies; the remediation of contaminated sites as well as and regulatory and legal aspects" [5].

The technical report on the Extent of Environmental Contamination by Naturally Occurring Radioactive Material (NORM) and Technological Options for Mitigation [6] aimed at raising awareness of the residues arising from the processing of various naturally occurring radioactive materials and the possible environmental contamination arising from them.

Also, relevant was the proceedings of a technical meeting held in Vienna in 2004 that collected a series of papers on Regulatory and Management Approaches for the Control of Environmental Residues containing Naturally Occurring Radioactive Materials (NORM). The papers presented an overview of the NORM residue regulation and management situation in several Member States at that time [7].

Different publication from the Safety Report Series were issued investigating and reporting on different aspects associated with radiation protection and radioactive waste management in different types of NORM related industry such as oil and gas [8], rare earths from thorium containing minerals [9]; the phosphate industry [10]; zircon and zirconia industries [11], titanium dioxide and related industries [12].

Another important publication of the IAEA on NORM covered the exposure of the public from large deposits of mineral residues [13]. The objective of this report included determination of the doses expected to be received by members of the public exposed to large NORM residue deposits, considering all potentially significant exposure pathways while providing evidence on the

consequences of applying the recommended activity concentration criterion of 1 Bq/g in situations where individuals are exposed to large mine residue deposits. A major conclusion of this report was that dose incurred in a year by an individual living next to a bulk mine residue deposit will, in all reasonable situations, be significantly less than 1 mSv/a per unit activity concentration (in Becquerels per gram) in the residue. That was an important finding as 1 Bq/g has been established as a clearance value for NORM residues as already mentioned above.

An attempt to provide a more generic but at the same time structured and comprehensive framework was made with the publication of a report on the management of NORM residues [14], including their disposal as waste, across a broad range of industrial activities. It also covered NORM residues at so-called legacy sites. The publication aimed at providing guidance to Member States on good practices in the management of NORM residues, having in mind that no single approach is applicable to all situations.

The IAEA has also published the proceedings of a series of NORM Symposiums which were sponsored by the Agency [15 - 19].

More recently the IAEA has issued a Safety Guide covering the management of residues containing NORM from uranium production and other Activities [20]. This Safety Guide provides recommendations on the establishment of an appropriate regulatory framework for the management of naturally occurring radioactive material residues in an integrated manner and using a graded approach. It also deals with individual roles and responsibilities at an operational level, options for management of NORM residues, long term safety of NORM residues, and exemption and clearance.

Additional publications of the IAEA relevant to NORM are listed in Table 1.

TABLE 1. IAEA NORM RELATED PUBLICATIONS

Year	Publication Type	Title
2002	Safety Reports Series No. 27 [21]	Monitoring and Surveillance of Residues from the Mining and Milling of Uranium and Thorium
2004	IAEA TECDOC No. 1403 [22]	The Long Term Stabilization of Uranium Mill Tailings
2006	Safety Reports Series No. 49 [23]	Assessing the Need for Radiation Protection Measures in Work Involving Minerals and Raw Materials
2006	Safety Fundamentals SF-1[24]	Fundamental Safety Principles
2009	IAEA Nuclear Energy Series NF-T-1.1 [25]	Establishment of Uranium Mining and Processing Operations in the Context of Sustainable Development
2009	IAEA Safety Standards Series No. GSG-1 [26]	Classification of Radioactive Waste
2010	Training Course Series No. 40 [27]	Radiation Protection and the Management of Radioactive Waste in the Oil and Gas Industry
2010	IAEA Nuclear Energy Series NF-T-1.2 [28]	Best Practice in Environmental Management of Uranium Mining
2013	Technical Reports Series No. 474 [29]	Measurement and Calculation of Radon Releases from NORM Residues
2013	IAEA TECDOC No. 1728 [30]	Regulatory Control for the Safe Transport of Naturally Occurring Radioactive Material (NORM) - Report of a Coordinated Research Project 2007–2010
2014	General Safety Requirements IAEA Safety Standards Series No. GSR Part 3 GSR part 3 [4]	Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards
2015	IAEA Safety Standards Series No. SSG-32 [31]	Protection of the Public against Exposure Indoors due to Radon and Other Natural Sources of Radiation
2017	IAEA TECDOC No. 1816 [32]	Model Regulations for Decommissioning of Facilities (also applicable to Facilities involving Naturally Occurring Radioactive Material (NORM) including the mining and processing of radioactive ore)
2018	IAEA Safety Standards Series No. GSG-7 [33]	Occupational Radiation Protection (coverage on NORM)
2019	Safety Reports Series No. 98 [34]	Design and Conduct of Indoor Radon Surveys
2020	Safety Reports Series No. 100 [35]	Occupational Radiation Protection in the Uranium Mining and Processing Industry
2021	IAEA TECDOC No. 1951 [36]	Protection against Exposure Due to Radon Indoors and Gamma Radiation from Construction Materials — Methods of Prevention and Mitigation
2022	IAEA Safety Standards Series No. GSG-16 [37]	Leadership, Management and Culture for Safety in Radioactive Waste Management (also applicable to NORM management)

3.2 OTHER EFFORTS OF THE INTERNATIONAL ATOMIC ENERGY AGENCY

IAEA has in place other mechanisms to supports its Member States in this area. One of these mechanisms is the support provide by means of the establishment of technical cooperation projects that can be structured at the national, regional and even inter-regional levels.

An analysis of the national projects sustained by Member States with the IAEA revealed that support was requested in the following areas:

— Analytical Aspects:
  i) Improvement and upgrade of analytical and technical capabilities;
— Safety and Regulatory Aspects:
  i) Design and implementation of monitoring programmes;
  ii) Establishment of administrative and standard operating procedures for assessing possible NORM contamination and its impact on workers and the environment;
  iii) Establishment of good operational practices in production in relation to the radiological safety of the workforce and the environment;
  iv) Establishment of an appropriate regulatory framework associated with NORM industry operations;
– Technical Issues and Waste Management
  i) Establishment of a Policy and Strategy (P&S) for NORM Waste;
  ii) Identification of concepts in NORM waste management;
  iii) Training on the identification of NORM generating industries, NORM generation estimates, decontamination techniques, radon measurements and NORM waste treatment and storage;
  iv) Advice on plans for NORM disposal, techniques for conditioning and storage, long term storage design and cost (design + facilities + operations);
  v) Training on technical works required for waste treatment, storage, radiological measurements and disposal options;
  vi) Providing and discussing examples of procedures for decontamination, conditioning and pre-storage and calculation of the cost of disposal facilities;
  vii) Building regional capacities of specialists to carry out comprehensive NORM waste management options;
  viii) Actions in relation to remediation programmes to minimize the impact of radioactive residues on populations and to create a favourable condition for the sustainable development of the affected territories.

The IAEA has also established the Regulatory Forum for Safety of Uranium Production and Management of NORM (REGSUN) which is intended to build capacity in Member States undertaking or considering uranium production or the management of NORM residues and to promote good regulation and safe and environmentally responsible practices, through the application of IAEA Safety Standards.

In the scope of Network of Environmental Remediation and NORM Management (Environet) the NORM Project has been created. The underlying assumption underpinning the project implementation is that Member States will find it difficult to have in place a proper, workable and functional system to deal with NORM related issues, notably the safe and cost-effective management of NORM residues unless a Holistic Approach is in place. This fully embodies the application of a graded approach as set out in other publications of the IAEA.

The Environet NORM Project itself has been structured accordingly into six free-standing but fully complementary working groups as represented in Fig. 1.

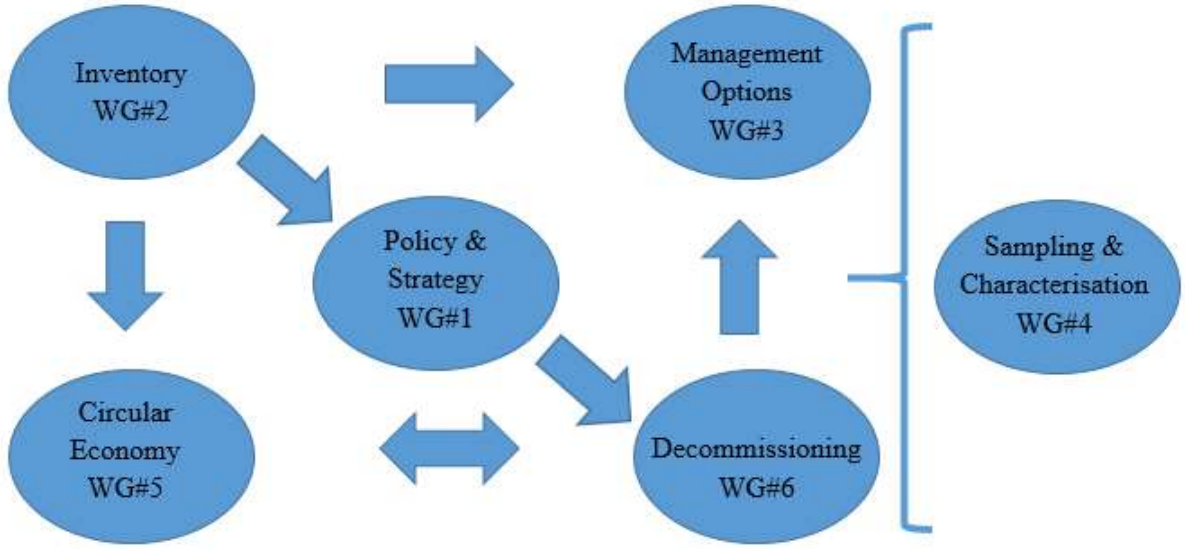

FIG.1. The six working groups of the Environet Project

The Holistic Approach will be described in greater depth later in this publication and the results of a workshop implemented in Brazil in 2021 in which the methodology was used to assess the situation of the country in terms of its infrastructure to manage NORM residues. As Figure 1 clearly shows, the six complementary building blocks of the Holistic Approach are all interconnected with established policy and strategies as its centrepiece.

In 2020, the IAEA organised its first conference on NORM – the International Conference on the Management of Naturally Occurring Radioactive Materials (NORM) in Industry (IAEA-NORM2020). The purpose of the conference was to foster the sharing of experiences in the management of NORM in industrial operations with the aim of contributing to the harmonization of approaches and adoption of good practices that are simultaneously cost effective and safe, taking into consideration needs and expectations of both the workforce, stakeholders and the wider public. Conference sessions were arranged in such a way that each of the building blocks of the Holistic Approach could be addressed. As a result, evidence of the adequacy of the proposed methodology to deal with NORM related issues was acquired with a strong emphasis on the need to examine in

more detail the different aspects involved on valorisation of residues and wastes in the context of the circular economy. The Conference also called attention to the need for improved communication and engagement with different NORM stakeholders while establishing more fluid and effective channels of communication with the industry.

4. THE HOLISTIC APPROACH TO THE MANAGEMENT OF NORM

The term holistic can be characterized by the belief that the parts of something are intimately interconnected and explicable only by reference to the whole. The basic assumption to call for a holistic approach to manage NORM residues is that no country will be able to conveniently address the challenges imposed by the implementation of a sound, safe and cost-effective NORM management strategy unless different pieces (building blocks) depicted in Fig. 1 are in place. So the six elements in Fig.1 form what is called in this publication the Holistic Approach to the Management of NORM. The absence of one or more of these elements will create difficulties for a country to adequately manage these materials.

4.1 INTRODUCTION

For example, the absence of disposal options for NORM wastes will most likely mean that these materials end up being accumulated on-site i.e. within the facilities they were generated. This situation implies significant costs in terms of maintenance and oversight, in addition to legacy issues if the facility is to be closed and decommissioned. Safety related issues may also become a problem.

The lack of policy stimulating the valorization of residues, for example in line with the principles of the circular economy, will hinder the putting of these materials to beneficial use and the development of innovative technologies that can make such valorization possible. As a result, these residues will need to be dealt with as waste implying again elevated costs for disposal. Also in terms of policy, a lack of definition of which organization is in charge of specific regulatory aspects together with lack of coordination among these organizations may lead to conflicting positions and requirements.

In terms of the characterization of residues, the absence of agreed sampling and radioanalytical protocols and accredited laboratories has the potential to impair the acceptability of the results by regulatory authorities. Lack of capabilities for the characterization of NORM residues will in turn prevent the establishment of NORM inventories which provide crucial information to support the consideration of valorization options for NORM residues and the establishment of appropriate and needed strategies to manage NORM, especially when the residues are declared waste. The Environet NORM Project – as already mentioned – operates six working groups, each of which are intended to produce guidance material on how to implement the different aspects of the Holistic Approach

4.2 POLICY AND STRATEGY.

Policy and strategies are to be seen as a core element of the Holistic Approach. IAEA Safety Standards Series No. SSG-60 [20] endorses the need to have Policy and Strategy (P&S) for NORM as follows:

> "For the safe management of NORM residues, the government should establish a policy and strategy that is appropriate to the national situation. The policy and strategy should acknowledge existing governmental, legal and regulatory frameworks; promote a graded approach to regulation; identify further industries that might need oversight; and coordinate the overall approach to the management of NORM residues" [20]

The wording is centred on the safety aspects of the management of NORM and seen through the lens of applicable legal and regulatory frameworks. If the Strategy for NORM proposed by the United Kingdom [38] is considered, it can be seen that while preserving the objectives of safety and security it also speaks about sustainability and resilience of the system. Reference is also made to the removal of policy barriers to the development of suitable waste treatment and disposal facilities. In other words, it contemplates a necessary level of pragmatism to establish a workable strategy that will enable the safe and cost-effective management of NORM.

SSG-60 [20] is mute about the role of P&S in relation to circular economy as applied to NORM. However, any waste policy has to be seen as a part of a broader environmental policy dealing with issues such as natural resources depletion. The traditional approach has been, what can be called the 'linear pattern of consumption' that can be translated into the logic of 'produce-use-discard'. This model leads to the generation of large amounts of waste that need to be disposed of. EU Directive 2018/851 states that "Waste management in the Union should be improved and transformed into sustainable material management … ensuring prudent, efficient and rational utilisation of natural resources, promoting the principles of the circular economy" [39]. Policies are important tools to promote new modes of production such as those that are aligned to circular economy. Note is to be made that the waste management hierarchy, i.e., waste prevention, minimisation, reuse, recycling and disposal, may need to be realigned to better fit a non-linear model.

It is to be noted that whilst the initial goal of the waste management hierarchy is to prevent the generation of waste, and encourage reuse and recycling, it still anticipates disposal as an End-of-Life (EOL) option. This is different from the circular economy vison where all resources remain preserved within the system boundaries for use. Detailed discussions on elements of P&S for NORM are out of the scope of this publication. These aspects will be dealt with in an IAEA publication fully dedicated to P&S for NORM. However, the main message from this sub-section is that P&S for NORM do not have to be fully focused on safety/regulatory aspects but rather constitute a tool, an enabler, for the proper and efficient management of NORM, promoting the necessary conditions to accommodate the new roles to be played by the many different stakeholders in the context of the circular economy to the overall benefit of the environment and consequently society.

4.3 NORM INVENTORY

When dealing with a problem, it is important to be aware of the nature and size of the problem. It is not uncommon to see some countries attempting to formulate regulations for NORM without a proper understanding of the existence of NORM related industries in the country, where they are located and the nature and amounts of residues that they may generate. SSG-60 states that "A detailed understanding of NORM activities is essential for the proper implementation of the graded approach" [20] and adds that "The regulatory body should compile an inventory of the NORM facilities and activities that generate or manage NORM residues, including a description of the processes and materials" [18]

Understanding a country's inventory (at the national level) will also be crucial to strategize solutions that can be applied in the management of these materials. It is inadvisable to propose NORM waste management options if the amounts to be disposed of are not known. Disposal options may in consequence be significantly either under- or overestimated, jeopardizing the national capacity to make the appropriate types and levels of investment in the NORM waste management supply chain which critically depends on the accuracy of such information. Accurate data and information about current and future NORM waste arisings are essential for the development of any management and disposal policy and practices. This is endorsed by SSG-60 which states that "The government should coordinate the establishment of an appropriate national inventory of significant NORM residues arising from new and existing NORM activities" [20].

4.4 MANAGEMENT OPTIONS INCLUDING COST ESTIMATES.

With the potential use of NORM residues aligned with the concepts of the circular economy, there will still be circumstances in which NORM will be declared as waste and will call for treatment and disposal. The characteristics of such NORM waste are, however, sufficiently different from those of other waste that may require specific regulatory considerations. Of relevance are the long half-lives of radionuclides present and the usually relatively large volumes of materials arising [26]. Indeed, some countries classify this type of waste as a particular sub-category named HV-VLLW-LL (High volume, very low-level waste, long lived) that needs specific waste management approaches.

In IAEA TECDOC 1712 [14], practical guidance is provided in terms of how having in place a NORM waste management strategy. The process is divided into three main phases; the first one deals with the evaluation of the current situation (in which the inventory plays a key role); the second involves the selection of the optimum NORM waste management option; and the third refers to the implementation of the optimum NORM waste management option. Within the overall waste management strategy, the chosen management option needs to provide as much as possible, a complete solution that can be considered at the same time practicable, sustainable, acceptable, and designed in such way that long term safety can be assured.

In order to address all these issues, it is important to understand the costs involved in each of the chosen management options that can be considered. Working group 3 of the Environet NORM Project is dedicating efforts to provide guidance on how to build up cost estimates for NORM waste disposal. Understanding the unit costs involved in each management option while considering the particular aspects that prevail in a given country is crucial to assess if a particular management option is feasible (from a safety and economic point of view).

Many IAEA Member States do not have available disposal routes for NORM wastes, for instance for those wastes coming from example from the oil and gas industry. This is a significant constraint to the implementation of effective management options for NORM waste.

In the case of mining processing, the initial disposal sites (such as tailings dams) will also be the final destination of the process waste if recycling or reuse of the materials cannot be achieved. For new operations appropriate preparation of the disposal structure needs to be considered. Careful studies such as, but not restricted to, the potential migration of radionuclides and other elements to ground water and analysis of geo-mechanical stability will need to be in place. A long-term risk management timeframe within which all the activities are to be managed will also need to be considered. SSG-60 [20] provides recommendations on such considerations for the long-term management of NORM residues. IAEA TECDOC 1403 [22] – a report of a more technical nature – covers the relevant aspects related to the long-term stabilization of uranium mill tailings. Many aspects dealt with in this publication, can be also applied to other types of metal and non-metal mining processing wastes [22].

4.5 SAMPLING AND RADIOLOGICAL CHARACTERIZATION

Sampling of NORM residues and determination of the activity concentration of relevant radionuclides in these materials is very important. Without appropriate, accurate and up-to-date data, operations such as the clearance of materials, will not be possible. Therefore, it is imperative that agreed Standard Operating Procedures (SOPs) (i.e. between the residue generator and the regulatory body) are in place. The residue generator may be able to collect samples and analyse them for their content of natural radionuclides. However, that will not be enough if the regulatory body will not accept the provided results, for example is they consider them to be non-representative. On the other hand, there will be no use in requiring the residue generator to provide evidence of the activity concentrations of different radionuclides if the country does not have the necessary infrastructure to produce these results. Laboratory capabilities might exist in research institutions and universities, or within the regulatory body. However, these institutions might not be able to cope with the demand. In case of the regulatory body it may not even be appropriate for such organizations to undertake the analyses if there is a potential risk of conflict of interest.

In addition to having standardized procedures for sampling and analytical work it is equally important that a country has suitably equipped analytical laboratories staffed with qualified and experienced personnel to provide accurate and consistent analyses. In this context, accreditation is

a well-accepted procedure for ensuring that the laboratory has the necessary capabilities to generate results that can be trusted. On the other hand, accreditation can be a time-consuming and expensive process, demanding execution of a complex set of managerial and technical procedures. Details of administrative, operational and technical requirements for meeting accreditation standards for laboratories for measurement of radionuclide content in commodities are provided in Ref. [40].

In conclusion while it is necessary to achieve a correct understanding of the existing and future situation regarding NORM materials at a national level, a correct planning and execution of the characterization and sampling campaigns with the associated laboratory analyses are necessary for the adequate definition of the national inventory size and characteristics to support the overall NORM management in a country.

4.6 VALORIZATION OF WASTE IN THE SCOPE OF THE CIRCULAR ECONOMY

NORM related industries can generate large amounts of residues that can find beneficial uses in agriculture (soil amendment), civil construction (building materials) and other applications. The existence of clear policies encouraging the use of such residues can be an important driver in that direction backed up by regulatory requirements that are aligned with the principles of a circular economy. Other points to observe is the proper understanding of market conditions vis-à-vis the absorption of these residues and public acceptance as well.

A large number of policy papers, scientific articles and technical reports have been published on the circular economy. The European Union (EU), for example, has issued 54 actions that integrate an action plan guiding the EU's transition to a circular economy. The actions under the action plan contributes to accelerate Europe's transition by helping to "close the loop" of product lifecycles through greater recycling and reuse. [41]. In this context, the transition to a more circular economy, in which the value of materials, resources and products is sustained in the economy for as long as possible, while the generation of waste is minimised, is a fundamental contribution to the EU's efforts to establish a sustainable, resource efficient and competitive economy. In that perspective, waste management plays a central role in the circular economy [42]. Although NORM is not clearly expressed in these publications, some issues that are raised can be relevant. One of them is the uncertainty regarding the quality of secondary raw materials. In this case, the composition of these materials in respect to natural radionuclides content is of particular importance. The development of material quality standards in this regard can contribute to increase trust in secondary raw materials and help support the market. The revision of current proposition of a 'hard' activity concentration level (1 Bq/g) in the direction of the adoption of a criterion that is linked with the dose resulting from the specific application of a given residue could make room for a larger and more intensive use of NORM residues as secondary raw materials without compromising safety. Another area that has been identified as deserving close attention is the cross-border circulation of secondary raw materials so that their trading can easily take place.

The existence of a dynamic market for secondary raw materials with sufficient demand for them driven by the use of recycled materials in products and infrastructure is indispensable. For certain raw materials such as metal, demand is already high; for others, it is still developing. Therefore, the role of the private sector in creating demand and helping to shape supply chains will be essential. It is recognized that that market-driven initiatives can be a fast way to deliver tangible results. Public authorities can also contribute to the demand for recycled materials through dedicated policies. Also, it is important to observe that the extraction of critical raw materials can give rise to significant environmental impacts, and this provides another reason to encourage the use of equivalent secondary raw materials.

The transition to a circular economy will demand a systemic change that in addition to targeted actions affecting each phase of the value chain and key sectors will demand the creation of the necessary conditions under which a circular economy can flourish. Dedicated policies as well as creativity and process innovation will play a key part in this systemic change.

4.7 DECOMMISSIONING OF NORM RELATED FACILITIES

Decommissioning of NORM related facilities, particularly, oil and gas platforms will be a major development in the scope of industrial activities related to NORM. For instance, approximately, 1,885 active production platforms exist in the USA outer continental shelf with more than 60% of these facilities being more than 25 years old [43]. It has been estimated that between 2016 and 2021 around 600 offshore assets would have been decommissioned globally [43]. Maturing oil and gas fields and aging offshore infrastructure are key drivers of the offshore decommissioning market. In 2015, spending on decommissioning projects was approximately US$2.4 billion. The offshore decommissioning market is projected to reach USD 8.9 billion by 2027. By 2040, it is predicted to reach $13 billion per year and Europe is expected to be the largest offshore decommissioning market in this period [43]. Applying an estimation methodology, based on Norwegian decommissioning data with regional activity factors, allows a NORM waste forecast to be established for the decommissioning of Australian oil and gas offshore infrastructure. The total NORM disposal burden is estimated to be in the range of 223–1,674 tonnes for decommissioning activity to 2060, with over 68% of this material generated between 2018 and 2025 [44]. Up to 2011 about four tonnes of radioactive waste (scale, sludge and sediments) with an average activity concentration of 10 Bq/g[1] or more has been found in each offshore installation decommissioned in Norway [45]. Management of NORM waste in the context of decommissioning of such structures is of crucial importance. In this regard it is important to implement environmental, financial, and economic cost–benefit analysis of minimizing the amount of NORM waste to be managed. Consideration can be given to recovery of wastes through use in industrial processes. Waste recycling is the preferred way forward. Volume reduction ensures best use of disposal capacity. Finally, it needs to be considered that waste disposal capacity is a precious resource, and it has to be used sparingly and as a last resort.

The major trend that is observed is the increased adoption of the concept of circular economy in the context of decommissioning (the same being true regarding nuclear decommissioning). In this context the default becomes the focus on the secondary, reusable resource, with the lead purpose of conserving primary resources. This thinking correlates with the United Nations Sustainable Development Goal (SDG) #12 “Responsible Consumption and Production” [46] entailing the sustainable management and efficient use of natural resources while substantially reducing waste generation through prevention, reduction, recycling, valorization and reuse. The expansion of similar approaches will involve formation of constructive partnerships that can lead to innovative solutions. These solutions are not only restricted to new technologies but may also address societal and regulatory dimensions. New technologies will be necessary to allow for the wide (re)use of residues, eventually promote their revalorization by extracting remaining and valuable substances or energy that remain in these residues e.g. uranium from mill tailings and phosphates or sludge from the oil and gas industry. Regulatory innovations may be necessary in reviewing requirements that were conceived in the context of a linear economy to a reality aligned to the principles of a circular economy, allowing for integration of sustainability concepts. Within this framework, management of NORM residues is fully consistent with similar principles of a circular economy to be applied in nuclear decommissioning and to the concept of integrated environmental management.

5. THE WORKSHOP IN BRAZIL

The Brazil national workshop Holistic Approach to NORM Management took place on 3–7 May 2021 and was supported by the IAEA through the Agency's Technical Cooperation (TC) Program (TC Latin America and the Caribbean - LAC) under the project IAEA-TC-Project BRA0024 "Developing Human Resources in Nuclear Technology" and in conjunction with the Brazilian Nuclear Energy Commission (CNEN).

5.1 INTRODUCTION

The workshop consisted of five sessions building on each topic. In session one, views from various Brazilian stakeholders were presented including regulatory authorities, research institutes and representatives from the industry. The presentations outlined current national policies, adopted practices, and associated challenges. In all sessions the presentations from Brazilian participants were complemented by presentations provided by international experts from Argentina, UK, Spain, USA, EU, Germany, and Norway.

To facilitate in-depth discussions, smaller break-out groups (Working Groups – WG) were then formed, focussing on six different aspects: Radiation Protection and Regulatory Approaches to NORM (WG#1), Policy, Strategy and Inventories for NORM (WG#2), Revalorization of Residues (WG#3), Disposal Options (WG#4); Sampling and Radiological Characterization of NORM Residues (WG#5) and Decommissioning of Off-Site Oil &Gas (O&G) Platforms (WG#6).The results of the discussions within the working groups were captured by pre-appointed rapporteurs and presented in the final plenary session The workshop had over 170 online participants. All presentations and videos of the sessions are available on the IAEA Environet website [47].

The workshop revealed that Brazil, in addition to having appropriate awareness and understanding about potential radiological issues associated with NORM-related industries, has in place mechanisms to be applied to guarantee the safety of such industries. Well qualified human resources are available in terms of regulatory controls (mainly in the scope of the nuclear regulatory authority) the same being true for analytical capabilities (mainly available in governmental institutions).

There are challenges to be addressed in regulating NORM-related industries such as in the oil and gas sector, fertilizer and other metal mining operations. The country can benefit from a coordinated effort to integrate all these capabilities in order to fill existing gaps. That can be achieved by producing the necessary policies, strategies, and inventories to support NORM management in an effective and sustainable manner. The next sessions were aimed at describing in more detail the existing situation regarding NORM-related industries in the country with regard to management of generated residues and wastes. Finally, suggestions provided to the Brazilian authorities as a result of the discussions during the workshop were presented.

5.2 THE PREVAILING SITUATION IN BRAZIL

Brazil has a well-established nuclear power sector and a diverse range of industries related to NORM. The later can be sub-divided into two broad sectors, the mining and processing related industries and oil and gas industries. This section describes first the current status of the nuclear sector in the country and subsequently it addresses NORM related industries.

5.2.1 The nuclear sector in Brazil

At the federal level, nuclear installations are subjected to two types of licensing, one dealing with nuclear related aspects, which is under the responsibility of the Brazilian Nuclear Energy Commission (CNEN) and another covering potential environmental impacts under the authority of the Brazilian Institute of the Environment (IBAMA) which is in the structure of the Ministry of the Environment.

From the point of view of the nuclear regulatory related process, federal Law No. 6.189 (1974) [48], which was amended by Law 7781/1989 [49], empowers CNEN to issue standards, licences, and authorizations related to:

- Nuclear installations;
- Possession, use, storage, and transportation of nuclear material;
- Commercialization of nuclear material, nuclear ores and concentrates containing nuclear elements.

CNEN is also empowered to issue safety and protection regulations and standards related to:

- The use of nuclear facilities and materials;
- The transport of nuclear materials;
- The handling of nuclear materials;
- The treatment and disposal of radioactive waste;
- The construction and operation of facilities designed to produce nuclear materials and to use nuclear energy.

It is also the responsibility of CNEN to specify the ores that should be considered nuclear materials. Moreover, in article 17 [48] it is established that the export of products that contain nuclear elements in coexistence with other elements or substances of greater economic value will depend on authorizations to be issued by CNEN.

5.2.2 Naturally occurring radioactive materials

Activities related to NORM potentially involving safety and radiation protection concerns are deemed to be:

- The mining and processing of raw materials and minerals (due to the presence of radionuclides of the U and Th decay series and ^{40}K);

- The oil exploration and production industry (mainly due to the presence of ^{226}Ra in scales deposited in materials related to the operations);
- Underground mining operations (due to the potential elevated concentrations of ^{222}Rn and its progeny in the air);
- Management and disposal of NORM residues and waste, including controls over tailings dams and stacks.

In relation to NORM the federal environmental licencing specifically comprises the following facilities and/or activities:

- NORM deposit from Petrobras in the state of Espirito Santo;
- Transport and export of NORM by Shell;
- Transport and export of NORM by Equinor;
- Transport and export of NORM by Petrobras;
- Petrobras NORM deposit in Cabiunas in the state of Rio de Janeiro;
- Improvement of other NORM deposits of Petrobras;
- Activities related to NORM in mining and processing operations under the oversight of CNEN's division responsible for the environmental licensing of mining activities not covered by DENEF[3].

The total revenue of the mining sector in Brazil was estimated to be R$ 209 billion in 2020 (approximately US$ 40 billion). Sixty six percent of that income comes from iron ore, followed by gold (11%) and copper (7%) [50].

It has been reported that the nuclear regulatory authority controls a total of 54 mining and processing facilities. The majority being located at the south-eastern and northern region of the country with 23 and 16 of these facilities, respectively.

The standard CNEN NN 4.01 [50] classifies the mining and processing facilities in three categories according to the activity concentrations of materials dealt with in the processing operations as shown in Table 2. The level of regulatory oversight for the industries classified in these categories will vary from a simple notification to a full licensing process. This framework is very much in line with the application of a graded approach.

[3] DENEF stands for Environmental Licensing Division related to Nuclear Energy, Thermal, Wind and Other Alternative Sources

TABLE 2. CLASSIFICATION OF MINING PROCESSING INDUSTRIES.

Category	Specification
Category I	Total activity concentration of ores, by-products, or waste > 500 Bq/g
Category II:	Activity concentration of ores, by-products or waste ≥ 100 Bq/g and ≤ 500 Bq/g
Category III	Activity concentration of ores, by-products or waste < 100Bq/g and > 10 Bq/g

The standard also states that safety and radiation protection requirements do not apply to facilities whenever:

- The total activity concentration of any material is < 10 Bq/g averaged over 3 years;
- There are no changes in the processes;
- The effective annual dose to workers is below 1 mSv/y; and
- The annual dose to the representative person of the public is below 0.3 mSv/y.

Out of the 54 controlled facilities 10 belong to Category I; 5 to Category II; and 15 to Category III. Eight are exempted from regulatory control while a further sixteen were subjected to ongoing classification procedures on the occasion of the workshop. Also depending on the classification of the facilities, different levels of information (documentation) will be required to be provided by the owner of the facility.

CNEN carries out inspections to the industries to assign them to their correct categories if the operator does not provide the necessary information upon request. The inspection process starts with taking and characterizing samples according to a standardized protocol. Samples can include the ore and materials from different waste streams. Radiological analyses are carried out in CNEN's own laboratory.

It has been reported that some operators simply declare that their operations are "radiation free" meaning that they do not feel the need to present any results from sampling and characterisation procedures to CNEN.

Presentations on these matters in the workshop did not make it clear if and/or how environmental impacts and occupational exposure are assessed and considered. It was reported that while disposal of process residues onsite is allowed, that solution may not be appropriate from a long-term perspective, particularly when the characteristics of the site do not meet the necessary requirements established for final disposal facilities. The need to have in place mechanisms and procedures to conduct a safety analysis of the disposal facilities have been stressed with emphasis on the importance of having qualified personnel and computational tools to be used in such analysis.

Concern has also been expressed in relation to the need of evaluating the structural integrity of waste/tailings dams and addressing the lack of suitable institutional control mechanisms to be applied to many of the so-called disposal facilities, including but not restricted to the prevention

of unauthorised access to these sites and acceptance of the disposal facilities by local communities and relevant authorities.

No clear mechanisms of enforcement were presented, nor were the consequences of non-compliance with CNEN's regulatory requirements. It was suggested that if effective enforcement mechanisms were in place, for example requiring the operators to present a radiological characterization of the generated residues to the regulatory authorities, then the number of accredited laboratories would likely increase to meet the demand for radiological analyses.

At the time of the workshop there were only two accredited laboratories in Brazil to run this kind of analysis. One of them – the LAPOC –belongs to the regulatory authority and the other one is a private laboratory. By law the LAPOC/CNEN cannot provide services to private companies and is only able to serve the nuclear regulatory body in support of the inspections conducted by the organization. It was also raised in the discussions that there are no established procedures for the sampling of NORM residues and the subsequent radiological analysis. In such circumstances, the acceptance of the results related to the radiological characterization of NORM residues by the operator of a facility is indeed uncertain and that is an issue to be addressed.

The use of mining residues for different purposes may be constrained by what has been considered a very restrictive criterion. It has been argued that if aspects such as the occupancy factor associated to some applications were considered the use of residues above the level of 1Bq/g could possibly be allowed without any significant increase of radiation risks to members of the public. It has also been suggested that residues arising from NORM related industries, with activity concentrations above 1Bq/g could be eventually disposed in industrial waste disposal facilities and not in radioactive waste disposal facilities as is dictated by current regulations.

It was reported that mining companies are reluctant to have stronger engagement and compliance with the existing regulatory framework due to the fear that by declaring the amounts of uranium (and eventually thorium) in the different residue streams the company may incur some issues with governmental authorities because a Brazilian law states that uranium is under government monopoly. With that said, the state-owned company Industrias Nucleares do Brasil declared its interest in establishing collaborative partnerships with private companies to explore means of recovering uranium from the residues of their operations. But the existence of the monopoly law was reported as an impediment to this intent[4].

CNEN has also conducted a survey to measure ^{222}Rn concentrations in several underground mines in the country. The total number of mines (as reported in 2012) is 87, and the survey encompassed 44 of these. Among the surveyed operations, 12 presented average ^{222}Rn concentrations above 1,000 Bq/m^3; 6 between 500 and 1.000 Bq/m^3 and 26 below 500 Bq/m^3.

[4] That was the situation on the occasion of the workshop. New government decree has changed this situation.

In terms of the oil and gas sector, the state-owned company Petrobras which is the most important oil producer in the country has consolidated the amounts of waste containing natural radionuclides. Currently Petrobras has circa 18,500 drums containing NORM (70% of this amount accumulated in the provisional deposit in Macae – Rio de Janeiro state) and about 80,000 9.5-metre-long pipes accumulated in its storage area. The amounts of NORM generated during decommissioning (e.g. scale in tubulars and other operating equipment) is unknown but it is expected, based on international experience, that the quantity will be significant.

A key challenge for the oil and gas sector regarding NORM is that there is no disposal route available in Brazil. It was also mentioned that it is not possible for the oil producers to subcontract service providers for NORM initial disposal. Therefore, a considerable number of drums containing NORM waste is being stored offshore in oil platforms or in Floating Production Storage and Offload. Under the current conditions, exporting NORM waste is the only viable solution to deal with the generated wastes pending authorization by the regulatory bodies (CNEN and IBAMA) to do so. A case study concerning export of NORM waste to the USA was presented at the workshop.

The existing disposal problem will be aggravated once decommissioning of offshore installations begins. Solutions to address the problem of disposal of NORM waste need to be addressed before the beginning of decommissioning activities, to avoid bottlenecks during the course of the process.

Decontamination of tubing and equipment by means of high pressure water jetting appears to be the preferred option for cleaning of material incrusted with scales. But this will generate significant amounts of NORM waste, with precise quantities yet to be determined.

5.3 BREAKOUT GROUP DISCUSSIONS

In order to explore the inputs provided by Brazilian participants and international experts, six working groups were formed on:

- Regulatory issues;
- Inventory, policy, and strategy;
- Revalorization of NORM residues;
- Disposal of NORM waste;
- Sampling and characterization;
- Decommissioning of offshore platforms.

The following subsections provides a summary of the discussions in each of the working groups.

5.3.1 Regulatory issues

The ultimate objective of a comprehensive strategy for NORM residues is to ensure that secure, sustainable, and resilient NORM waste management options are available, preferably in the

country of origin. Ambitious strategies have a long term horizon and are conceived as an iterative process rather than a linear one, consisting of the following phases:

— Development;
— Implementation;
— Review and update.

The working group recognized that NORM-related facilities can give rise to multiple hazards and that exposure to ionizing radiation is not necessarily the dominant one. It has been agreed that NORM-related operations need to be under some sort of radiation protection control since they do have the potential to cause exposures of workers and the public to ionizing radiation. However, it was noted that the radiation protection system – originally developed to deal with nuclear facilities - may not be fully adequate to be applied to natural radiation sources such as NORM without causing unnecessary burden to NORM-related industries and to regulatory bodies. That can happen when unnecessary controls are imposed to certain operations and those will demand efforts of the regulatory authority such as licensing process and inspections without aggregating significant benefits to safety. The group highlighted the importance of using a graded approach to control NORM related operations. In this aspect, the optimization principle of radiation protection is the driving force behind the graded approach. CNEN has already regulations that resemble a graded approach, CNEN Standard 4.01 [51], that could eventually benefit from a fresh look.

Discussions were also dedicated to the use of the values of 1 Bq/g and 1mSv/a used to exempt NORM operation from regulatory controls. The group debated which one of these criteria would be the most appropriate to be used in the management of NORM residues and whether they need to be applied to all industries or on a case-by-case basis.

The working group found that NORM residues, when classified as wastes, might not be considered radioactive waste since many unnecessary constraints for these materials' management and burdens to the government arise from that classification without any meaningful contribution to safety.

Instead of being categorised as radioactive wastes, NORM residues might be classed as industrial wastes and be treated/managed as hazardous materials. This is especially significant when the residues can be put to further use in the market. Such reclassification could be encouraged by the competent authority with appropriate conditions for the prospective use being defined in line with the principles of sustainability and safety requirements.

In terms of the NORM waste generated by the oil and gas industries, it has been found that it is managed under a very bureaucratic process originally designed for managing wastes arising from nuclear installations. The group indicated that clear rules for this situation including the availability of disposal solutions for the generated wastes would facilitate the safe and cost-effective management of such materials. In that respect one example was given of the disposal of NORM waste from one oil and gas operation in an industrial landfill after a detailed radiological assessment was conducted. That disposal was implemented – as explained at the workshop – under a special "conditional disposal" authorization.

Additional point raised within the working group pointed to the need for closer cooperation between CNEN and the Department of Labour towards identification of radiation protection improvements that might be needed regarding occupational exposure to radiation in oil and gas facilities. Continued capacity building in radiation protection in different organizations was encouraged.

In conclusion, the working group position was that the revision of CNEN regulatory framework, in line with the issues raised during the workshop, could be promoted in a timely manner.

5.3.2 Policy, strategy, and inventory

The main objective underpinning the activities of this working group was the discussion around aspects related to policies and strategies on NORM residues management and on the development of the inventory of NORM residues and wastes generated in the country. The implications of the current regulatory framework for achieving a sound management and control of NORM residues were also reviewed with additional attention being paid to due consideration of advantages of transitioning to production models based on prevention of waste generation, recycling and recovery of residues as opposed to the current linear system.

The working group started by recognizing the existence in Brazil of conditions that can support the achievement of a sound institutional framework that can support the adoption of an optimized management approach for NORM in the country. These conditions include but are not restricted to:

- Having in place a regulatory framework that is in line with the IAEA Basic Safety Standards established in GSR Part 3 [29].
- Good cooperation amongst different regulatory authorities that have a say in NORM related issues.
- A nuclear regulatory authority (CNEN), that plays a key role in the controls applied to NORM related industries, and which has a highly skilled workforce well versed on NORM related issues.
- The existence of a fluid dialogue between operators of NORM related industries and relevant regulatory organizations. In this regard it has been recognised that most of the NORM related industries in the country are committed to manage NORM in a responsible way with due consideration to human health and the environment.
- The size of the oil and gas sector in Brazil favours the establishment of private agents that can supply the necessary services to support appropriate management of materials that are considered NORM wastes.
- A great deal of information on NORM residues and wastes generated in the country is already available.

Despite the above considerations, Brazil faces different challenges towards the implementation of a sound, timely and cost-effective management framework to deal with NORM. To start, the establishment of National Policies to deal with NORM was seen as an important step to be taken by the country. Policy instruments would provide, among other things, attributions of clearer

responsibilities to the different regulatory authorities in relation to NORM. It would also be important to promote the application of sustainability principles in line with the concepts of the circular economy and consequently creating the necessary conditions for the use of residues. A crucial policy decision would be to establish whether NORM waste is to be classified or not as radioactive waste.

The working group considered that one of the most pressing challenges of the country is to have in place management solutions for NORM when these materials are declared waste. The lack of disposal options implies that exportation ends up being the only disposal solution. It may be argued however, that this is an unsustainable option. The situation will be aggravated when the decommissioning of offshore platforms starts to take place.

The need to simplify the control of NORM related industries — especially in the mineral sector — was recognized by the working group. The current regulations do not include provisions for exemption or clearance of particular activities and materials (residues and waste) based on dose criteria[5]. If that were the case, the group indicated that more options would be available to use and recycle NORM residues.

The lack of funds for implementing the remediation of NORM contaminated sites was pointed out as an important constraint. The proper identification and register of these sites were recognized as relevant actions to be put in place by the Brazilian authorities.

In order to tackle the above challenges, the working group considered it appropriate that the competent authorities might consider working together to have in place a national policy that would allow the implementation and consolidation of a holistic (integrated) framework for NORM management in the country. Such a policy would be the result of a comprehensive dialogue that would encompass different stakeholders representing different sectors of the society.

In order to achieve policy goals, the working group concluded that a national strategy would also need to be developed and implemented. Two critical elements that will inform the establishment of such strategy would be:

- Definition of an inventory of the NORM waste arising in the country. As part of this action, the organization responsible for developing and maintaining the national NORM waste inventory would need to be identified.
- Costs related to different management options of the generated waste would need to be assessed.

5.3.3 Revalorization of residues

The discussions of the working group on residue valorization led to a consensus of the current state of NORM residue management in Brazil. Objective factors such as environmental impact, damage and pollution, are balanced against subjective factors, such as public attitudes and effects such as

[5] That situation has changed – need to make reference about that.

fear, anger, resistance, which are now recognized as an essential part of sustainability reporting and investment risk analysis.

5.3.3.1 Inappropriate grouping and classification of NORM industries

While the term 'NORM industries' encompass a large number of extractive industries there is a very wide range in relation to the amounts of residues produced by them. In the phosphate sector, residue production is measured in the hundreds of thousands or millions of tonnes. The largest amount is phosphogypsum (PG) most of it showing activity concentrations below 1Bq/g. In contrast, the quantities of scales generated annually by the oil and gas industries are measurable in tens or hundreds of tonnes.

The working group noted that, given the very low activity concentration levels found in phosphogypsum, the term 'radioactive', for so long loosely applied, prevented large quantities of usable materials from entering commerce. But if strict scientific considerations are considered (i.e. from a risk management perspective) there would be no impediment for the use of PG. [10]. The working group considered that by calling PG a radioactive material valorization of the material will be unnecessarily deterred. In addition to the use of PG as soil conditioner, which is successfully done in Brazil, other possible applications can be considered given the large volumes of stacked PG. One of these possibilities is to use PG as a component of building materials.

5.3.3.2 Inventory of NORM in residues

One important step for the establishment of an approach for the valorisation of PG (and other NORM residues) is to start building an inventory of NORM related industries in Brazil and the amounts of residues they generate. The working group considered it quite likely that these pieces of information are already available, they just need to be put together in a single database that can be used by different stakeholders.

5.3.3.3 Sampling and measurement

The working group concluded that common standards and procedures for sampling, characterisation and measurement would enhance operator transparency and accountability, while fostering public understanding and acceptance. Laboratories and personnel have to be subject to accreditation and certification procedures with appropriate training of staff and independent quality assurance (e.g. inspections and audits), plus peer-to-peer networking and sharing of good practices.

5.3.3.4 Economic viability of reuse and reprocessing

The working group concluded that procedures for well-structured cost-benefit analysis of reuse versus disposal of NORM residues have to be put in place in line with an international financial risk assessment and sustainability reporting standards.

5.3.3.5 Mixing of residues with different activity concentrations

While the grouping of NORM industries in a "positive list" is currently a well-accepted approach, the working group noted that this practice can produce unintended consequences such as treating NORM materials in a 'one size fits all' categorization that may be clouded by a regulatory classification system essentially derived from the nuclear industry.

The group noted that the result of the above situation is that residues containing higher levels of radioactivity (such as scales) might be mistakenly mixed with PG. Therefore, if a different grouping is adopted, and materials are segregated according to their activity concentrations, materials with very low activity concentrations can be kept strictly separated. The common practice in the phosphate sector of burying spent filter cloths, used PPE etc in PG stacks could be strictly avoided if not prohibited.

5.3.3.6 Suggestions

The discussions above led to the following suggestions from the working group:

- Suggestion 1: Authorities have to consider separating very low level NORM residues (less than or equal to 1 Bq/g) from production 'wastes' (e.g. scale on filter cloths or the walls of tubulars) in which activity concentration levels are likely to be at least three orders of magnitude higher.
- Suggestion 2: Revise the definitions of 'waste' to exclude materials that are evidently reusable either 'as produced' or with only very minor pre-treatment (e.g. neutralisation to modify pH), even if there is no immediate market demand.
- Suggestion 3: An independent review could be conducted regarding the current barriers to market access for the treatment and valorization of NORM residues, or recycling of production facility equipment (contaminated tubulars, equipment, rigs, vessels, etc.) with evidence-based options, where justifiable, to lower or eliminate any barriers that are unnecessary. Minimum use targets for high volume, low activity residues might be considered as regulatory options for encouraging/fostering the use of such materials.
- Suggestion 4: Blending down can result in the safe and beneficial uses of some NORM residues marginally above exemption activity concentration levels; consequently, this practice could be encouraged, subject to strict quality control and independent monitoring.
- Suggestion 5: When implementing stakeholder outreach and engagement, communications strategies and awareness-raising activities, care has to be taken not to cause fear and anxiety among the public about the reuse and recycling of very low risk materials. Use of the proportionality principle could apply in equal measure to that of the precautionary principle as in many cases the long-term risks of disposal and continued accumulation of high volumes of residues, with commensurate pressure on land use, will far outweigh the benefits of use[6];
- Suggestion 6: In the context of transitioning to a circular economy, previous efforts in Brazil by IPEN to pioneer uses of PG in construction materials (e.g. for affordable

[6] See Ref. [10]

housing), could be restarted with a view to making legacy materials available for use in the construction sector.

— Suggestion 7: 'Comprehensive extraction' approaches could be taken to include all potentially usable resources in ore bodies, not just a single primary target mineral or energy resource.

The working group noted that there was an excellent reference case available in the Santa Quiteria project with its integrated resource recovery flowsheet covering both phosphate and uranium resources. In such an approach, both environmental and economic benefits are delivered. From a project finance perspective there are multiple revenue sources from a single deposit (see Table 3) and 'waste' volumes (i.e. materials discarded because of no interest to the project owner) are much reduced.

TABLE 3: SANTA QUITERIA/ITATAIA PROJECT – COMPREHENSIVE EXTRACTION BY A SINGLE INTEGRATED FLOWSHEET [52]

	Recoverable	Geological
Total Ore Reserves	80 x 10^6 t	520 x 10^6 t
Main Content	11% in P_2O_5	1.92 % in P_2O_5
	0.1 % U_3O_8	0.02% in U_3O_8
Phosphate Reserve	9 x 10^6 t P_2O_5	10 x 10^6 t P_2O_5
Uranium Reserve	83 x 10^3 t U_3O_8	90 x 10^3 t U_3O_8
Marble Reserve	> 300 x 10^6 m^3	

Two desired outcomes were articulated by the working group, as follows:

— With regard to a circular economy, all waste is to be seen as a resource for which a marketable use has not yet been found.

— In the scope of NORM related industries, if the use for a specific residue is not yet anticipated it could be considered to be desirable in future. Instead of calling the residue radioactive waste, the concept of hazardous waste or a reusable resource could be adopted instead.

5.3.4 Disposal options

The discussions of the working group were centred on the identification of the main technical issues to be addressed in relation to the implementation of strategies for different disposal options for NORM wastes.

In the working group discussions, a starting point was the recognition that the responsibility for the final disposal of radioactive waste belongs to the Brazilian Government, through the Brazilian Nuclear Energy Commission (CNEN). Notwithstanding this, the law makes it possible for CNEN to delegate the design, construction, and operation of a disposal facility to third parties. The group

considered that this is a well-established mechanism to serve the management of radioactive waste from nuclear and radioactive facilities, however, it was questioned if that approach works well for the disposal of NORM waste.

As already noted, NORM waste is classified as radioactive waste within the Brazilian regulatory framework established in 2014. Because of that the current legal provisions also have implications to NORM waste disposal. The working group also considered that it would be appropriate to reassess the adequacy of classifying NORM waste as radioactive waste. That reassessment would imply rethinking the attribution of responsibilities for NORM disposal. It would also include revisiting the roles of the government, operating organizations and waste management companies. The working group recommended that discussions on the responsibility for the final disposal, the institutional control after closure, the cost liability and funding be clearly addressed in specific legislation. The group also noted that authorities need to be open to consider (assess) different disposal options and it would be appropriate to establish safety goals to be met by the different systems in such way that long term protection of members of the public and the environment can be ascertained, ideally by means of passive controls instead of those that would require (costly) operational and maintenance interventions.

The working group recognized the importance of having in place well defined NORM waste inventories with a view to support the decision-making process regarding the determination of the optimal disposal option(s). According to the group, a comprehensive and consistent inventory has to include considerations on the volume of waste stream, the range of the activity concentration of each radionuclide of interest and the frequency distribution of volume against activity concentration. For the oil and gas industry, the inventory of some waste streams is already known, but the working group noted that efforts will have to be made to estimate other important streams, such as those arising from the decommissioning of subsea assets.

The working group concluded that the clearance of NORM residues containing activity concentrations above 1 Bq/g may be appropriate in certain situations, provided that the regulatory authority believes that future exposures associated with such wastes will not require the reinstatement of controls. In this sense, clearance of NORM waste under some specific conditions (conditional clearance) would be possible if agreed by the regulatory authority. Conditional clearance could be applied to a particular material, sometimes for a specified amount of that same material and/or to a particular destination of the material. Example of the application of conditional clearance could include situations involving scrap metal for recycling (melting) and NORM waste to be disposed in landfills. The working group concluded that NORM waste exceeding a clearance level of 1 Bq/g could be released with no further radiological consideration, provided that specific dose criteria set by the regulatory authority are fulfilled. It is possible to derive conditional clearance levels in terms of activity concentration per unit mass, or activity concentration per unit surface area, using an appropriate set of scenarios.

Conditional clearance levels derived in such ways will depend on how credibly it can be ensured that the scenarios considered in the derivation of the (dose) criteria associated with the clearance level are met for the specific material. Therefore, it was suggested by the working group that the

conditional clearance, in the application of a graded approach, could be implemented (or set) in national regulations by means of a derived activity concentration range (as well as an annual total activity and volume), from a particular set of scenarios.

For NORM waste with higher activity concentrations an authorized disposal option will need to be made available e.g. near surface repository, deep disposal, injection). It was considered by the working group that it could be appropriate if the regulatory authority provided a document containing guidance and pre-validated forms for disposal that would be accepted in Brazil.

From the working group discussions and previous presentations, it is important to highlight that Brazil has available technological capabilities and expertise that are already in motion to address solutions for NORM waste disposal. Initiatives such as this workshop could help to join the efforts of these assets to optimize the results.

5.3.5 Sampling and characterization

The main objective of this working group was to assess the role of sampling and characterization within the general context of NORM; the available infrastructure in the country and the challenges for the laboratories that might be involved in this activity. Although the group focused the discussions on radiological characterization, it was a common understanding that the characterization of NORM may involve several other aspects such as physical and chemical characterization.

It was clear to the working group that sampling, and characterization are crucial steps in the management of NORM, whether to establish an inventory, verification of compliance with regulatory requirements, process control, decommissioning planning and predisposal management or disposal (e.g. verification of Waste Acceptance Criteria). All the above add to the more traditional aspects of characterization within the scope of occupational radiation protection of workers.

The working group noted that NORM residue involves a wide range of materials. Therefore, sampling as well as characterization methods need to be designed to meet each specific type of NORM related industry and NORM matrix. In some cases, sampling and subsequent characterization in laboratory is recommended, in others, in situ measurements may be a suitable approach. It was recognised however that in general, a mixed approach will be needed in most cases.

As far as sampling of NORM waste is concerned, the working group recognized that there is a Brazilian regulation that deals with the theme [53]. Nevertheless, it was a common understanding that this standard is incomplete (too general) for this activity, and that guidance from a specialist, even for the simplest types of sampling, was needed.

It was also pointed out that the USEPA Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) could be an appropriate tool for a final status survey to demonstrate that a NORM site, having been decontaminated, is in compliance with the applicable regulatory requirements for remediation [54] and hence declared hazard free.

The working group also identified a lack of professionals who could be evaluators in the area of sampling of radioactive materials, making it difficult to accredit national laboratories under ISO 17025 [55].

Finally, the group highlighted that there is an opportunity to create a working group on sampling with the objective of harmonizing national and international standards and, if applicable, proposing specific NORM sampling procedures, containing at least the minimum sampling requirements to ensure representative samples are taken.

With regard to radiological characterization, the focal point of the working group discussions was the accreditation of laboratories under ISO 17025[55]. The group acknowledged an improvement in the country's analytical capacity with the entry of new companies from the private sector that can provide this type of service. The group noted that these new laboratories, in the Brazilian market, created a new paradigm on the recognition of laboratories with the implementation of ISO 17025 [55]. The working group also strongly suggested that other national laboratories make efforts to obtain ISO 17025 accreditation.

The working group noted that in-situ characterization using a high-resolution spectrometer, when properly performed, produces results that are compatible with laboratory results, saving significant amounts of time and money. However, it was recognized that samples will need to be sent to the laboratory for analysis for isotopic definition and scale factors determination, and for quality control backup.

5.3.6 Decommissioning of offshore platforms

The objective of the discussions of this working group was to establish a common understanding of how to deal with the issue of decommissioning of oil and gas installations with regard to the presence of NORM and how to establish an integrated approach to NORM waste management in oil and gas operations considering:

- Route for disposal of waste in Brazil;
- Lifecycle approach;
- Existing requirements and recommendations;
- The regulatory framework for decommissioning.

The issue of decommissioning was addressed within the context of the expectation of an increase in this activity in Brazil in the coming years and the need to identify the amounts of NORM waste (e.g. equipment containing scale and oily sludge from the bottom of oil storage tanks) generated with those operations.

5.3.6.1 Route for disposal in Brazil

The finding of a regulatory gap for the final disposal of NORM was the starting point of the working group discussions, which concluded:

— The lack of regulations by the (CNEN) that allows for the final disposal of waste contaminated with NORM above the clearance level imposes restrictions to the adoption of waste disposal technologies in Brazil.
— In order to ensure protection of workers and members of the public the decontamination techniques of equipment and tanks need to provide the best performance possible with regard to the removal of sludge and scales.
— It was indicated that the disposal of radionuclide free waste is cheaper than the disposal of waste contaminated with NORM. That leads to the concept of 'cleaning everything', 'removing contamination to the extent possible and executing the final disposal with appropriate technology.
— In general terms, the disposal options depend on economic viability of a given alternative and what is offered by the waste treatment market. In the current Brazilian context the export of waste contaminated with NORM has been adopted by the oil and gas operators in the country as the only available option. This alternative has a high cost and needs a sustainability analysis in the context of the increased volumes to be generated in the future with the increase of decommissioning activities.

5.3.6.2 Lifecycle approach

In the working group discussions, the need for operators (waste generators) and regulators to work together, having in mind a planning and evaluation approach that consider the whole life cycle of oil production units, was noted. Knowledge management and monitoring during the operational phase would inform the decommissioning activities so that the work to be developed will be supported by complete and consistent information.

The working group noted that precautions to be adopted during cleaning activities during the operational phase need also to be followed in the decommissioning phase. In this regard two aspects are to be considered:

— Radiation protection of persons;
— Management of waste contaminated with NORM, after removing the materials and equipment to be decommissioned to protect the environment.

The experience presented by the working suggested the following methodology:

— The first step is to confirm whether there is contamination in a given material, making use of 'trigger values', to technically justify the need for dedicated sampling and characterization. Some approaches were discussed, such as the use of 'double background' [56] or triggers equal to dose rate readings of 0.3 μSv/h (a value used in Norway), or 0.5 μSv/h (a value used by some companies in Brazil);
— The second step is the characterization, with sampling performed by collecting material and forwarding it to the laboratory for analysis by gamma spectrometry. Systematic monitoring of dose rates needs to be performed to classify areas with the objective of protecting workers, identifying, and mapping materials that can contribute to the NORM inventory.

Another topic addressed in the working group discussions was the development of a concept/limit that classifies the cleaning of equipment for exporting platforms. The questions raised such as how 'NORM-free' would equipment be considered; what cleaning procedures are needed and how to effectively consider what is 'NORM-free' within the expectations of international platform commercialization. The designation of equipment as clean means more favourable and safer sales conditions.

5.3.6.3 Existing requirements and recommendations

Some examples of NORM good practice guides developed in Brazil were mentioned in the working group discussions:

- Notebook of Good E&P Practices - Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM). From the Brazilian Petroleum Institute [57];
- Offshore decommissioning in Brazil - Opportunities, Challenges & Solutions. The publication presents the results of research carried out by FGV Energia, in conjunction with the National Oil, Gas and Biofuels Agency (ANP), and other entities related to decommissioning in the country [58].

The existing technical regulation for the decommissioning of facilities for the exploration and production of oil and natural gas in Brazil was established in 2020. [59]. This regulatory instrument had the participation of the environmental regulatory authority (IBAMA) and representatives from the Brazilian Navy.

Article 2.4.1 of Ref. [59] states that "the contractor (to carry out the decommissioning) must have an adequate management plan for the treatment and disposal of naturally occurring radioactive material (NORM), in the event of its occurrence in the encrustation of pipelines and other equipment".

In the scope of the nuclear regulatory authority there are no regulations that specifically deal with the decommissioning of oil and gas production units.

The working group discussions showed the need to provide clarity on the scope of the regulatory framework in relation to decommissioning of oil and gas facilities. considering that oil and gas production is not classified as nuclear activity. This can induce and streamline communication between regulatory authorities with the possibility of creating an environment for exchanging successful experiences.

5.3.6.4 The regulatory framework for decommissioning

In terms of decommissioning related activities the working group concluded that the main task to be accomplished is the creation of disposal routes in Brazil to meet the expected demand to be generated by the future decommissioning of oil and gas platforms. In addition to this, the definition of an agenda to support the discussions among stakeholders could include:

- Development of a NORM lifecycle approach to regulations and management practices to provide complete and consistent, evidence-based information for decommissioning.

- Definition of the roles to be played by each involved organization involved with decommissioning activities.
- Adoption of international best practices related to sampling and characterization and cleaning (decontamination) procedures with well-defined activity concentration levels that allow the reuse/recycling of equipment and other materials considering the potential exportation of scrap metals.
- Creation of a forum to discuss, monitor and adopt best practices and procedures for radiation protection and management of NORM in the context of the high volumes of materials to be generated by decommissioning activities.

6. ROAD MAP FOR THE IMPLEMENTATION OF THE HOLISTIC APPROACH TO NORM IN BRAZIL

The workshop was an opportunity to gather different Brazilian stakeholders with an interest in NORM management in Brazil so that they could share their own experience and be aware of each other perspectives on the different topics dealt with during the event.

It became clear that while the country has organizations (at different levels) and professionals with a good understanding of the different aspects related to NORM, opportunities exist to put in place a framework that can provide more consistency and organization to the way NORM related issues are dealt with in the country.

The workshop also identified different opportunities for services to be provided by the supply chain in different areas. The main outcome was the identification of items that can be part of what can be called a 'Road Map' that the relevant official institutions may wish to consider in order to create the proper conditions for the implementation of the proposed Holistic Approach to NORM. The Road Map would then consider:

(a) At the policy level:
- Establishment of a policy and strategies that can, among other things, attribute clear responsibilities concerning regulatory aspects relevant to NORM related industries and NORM residues.
- The need to carefully reconsider the classification of NORM residue as radioactive waste, as is the case now. This approach was seen as imposing heavy constraints and disproportionate burdens related to the management of such materials especially if disposal is considered.
- As part of an overall strategy to deal with NORM waste, Brazil could give due consideration to having private organizations in charge of disposing such materials. However, the workshop did emphasise that NORM residues – to a great extent – can serve beneficial purposes such as application in agriculture or as building materials and due consideration of these possibilities and the creation of necessary conditions for that use would need to be carefully considered, always paying attention to safety related considerations.

(b) At the inventory level:
- The workshop recognized the efforts put in place by Brazil in organising an inventory of NORM industries in operation in the country. However, opportunities still exist to enhance and complement this inventory. Additional data is needed, particularly on estimating future arisings from oil and gas operations, particularly from the decommissioning of offshore platforms. This inventory will be critically important in the establishment of the strategy to be adopted at the national level to support the management of NORM residues and wastes.
- In connection with the above, there is a need to have accredited laboratories in the country to support the analytical work (sampling and radiometric analysis) related to the

characterization of NORM residues. Two points are particularly relevant: (i) the enforcement of requirements so that industries produce the necessary data; and (ii) if industries are enforced to produce the necessary data that will lead to the creation of a demand for such analytical services that will then stimulate the implementation of a wider range of accredited laboratories. Certified services for decontamination of tubing and other equipment contaminated with NORM are also important.

(c) At the regulatory level:

— It was recognised that the current regulatory requirements impose significant challenges regarding the management of NORM. It was concluded that the strict application of the 1 Bq/g value does not always provide the optimal approach for regulation of NORM. It was suggested that there will be circumstances in which the use of residues with an activity concentration above 1 Bq/g for different purposes will not be associated with an increase of radiation risks. Therefore, a pragmatic approach regarding the application/use of this criterion was suggested in such a way that the use of NORM residues in specific applications that would be associated to doses below 1 mSv/a could be accepted. Blending down residues with activity concentrations slightly above 1 Bq/g value could also be given due consideration. Other than that, the concept of conditional clearance[7] is an additional option for the management of residues/wastes with activity concentration above 1 Bq/g. Conditional clearance provides for more flexibility in management of residues/waste from authorized facilities and activities.

(d) Disposal options:

— It has been considered imperative to make available disposal routes for materials that are eventually classified as NORM waste, i.e. those materials for which further use is not possible due to their activity concentrations. As has been demonstrated, the only currently (viable) solution in Brazil for the disposal of such materials in the current context is the exportation. It was noted that in addition to this solution being expensive, it cannot be considered a sustainable option.

(e) At the decommissioning level:

— Attention has to be paid to decommissioning scenarios and the impact these operations will cause in terms of the management of NORM wastes. It is necessary that due consideration is given to mechanism to allow for the clearance of materials eventually contaminated with NORM. In this regard the workshop identified the urgent need for establishment of agreed sampling and radiological characterization protocols that can be used by the NORM residues/wastes generators and accepted by the relevant regulatory bodies.

[7] Ref [3] deals with that by introducing the concept of specific clearance.

Finally, emphasis would have to be directed towards building additional capacity in the various areas that are needed to support NORM management related activities. In this regard, effective approaches such as ‘train the trainers’ could be considered.

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ABBREVIATIONS

CNEN	Comissão Nacional de Energia Nuclear (Brazilian Nuclear Energy Commission)
ENVIRONET	Network of Environmental Remediation and NORM Management
EU	European Union
IBAMA	Instituto Brasileiro do Meio Ambiente (Brazilian Environmental Institute)
LAPOC	Laboratorio de Poços de Caldas (Pocos de Caldas Laboratory)
NORM	Naturally Occurring Radioactive Material
P&S	Policy and Strategy
TC	Technical Cooperation

CONSTRIBUTORS TO DRAFTING AND REVIEW

Amaral, E.	Comissão Nacional de Energia Nuclear (CNEN), Brazil
Borges, F.	University of Surrey, United Kingdom
Dias, A.	Comissão Nacional de Energia Nuclear (CNEN), Brazil
Franklin, M.	Instituto de Radioprotecão e Dosimetria, Brazil
Gonzales, A.	Nuclear Regulatory Authority (ARN), Argentina
Hebert, M.	A-Bear Consult LLC, United States of America
Hilton, J.	Alef Group, United Kingdom
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Monken-Fernandes, H.	International Atomic Energy Agency
Recio Miranda, T	Tecnatom, Spain
Schenato, F.	Comissão Nacional de Energia Nuclear (CNEN), Brazil
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