Radiation Protection Challenges for Exposures to Naturally Occurring Radioactive Material (NORM)

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Abstract: Technological and regulatory developments concerning exposure to naturally occurring radioactive material (NORM) during the last two decades have resulted in progress towards achieving broad international consensus on managing exposure to NORM. However, the standards and regulatory approaches being adopted at the national level still needs to be harmonized especially in developing countries with limited regulatory resources. The new International Basic Safety Standards (the BSS) published by the IAEA in 2011 provides requirements reflecting the concept of planned, existing and emergency exposure situations and are in line with the 2007 Recommendations of the ICRP. Exposure to natural sources continues to be generally subject to the requirements for *existing exposure situations.* Major radiation protection challenges for NORM are — Differences in standards and regulatory approaches between countries, and even within individual countries; the need for an industry-specific approach - no single approach to the control of exposure to NORM was appropriate for all industrial processes involved; resurgence of uranium mining industries and fast expanding worldwide exploration activities for uranium; the identification of situations that could be classified as either existing exposure situations or planned exposure situations and how such exposures should be optimized using, as appropriate, reference levels or dose constraints; adoption of a very conservative and cautious approach, resulting in undue attention being given to industrial processes and residues for which there was no real evidence of the need for control; the need for an evidence-based approach to the making of policy and regulatory decisions; problems of interpretation of the 2007 recommendations of the ICRP, particularly concerning the distinction between existing exposure situations and planned exposure situations; differences in interpretation of the standards, especially with respect to the concepts of exclusion, exemption and clearance; exposure of workers; radon in workplaces; transport issues; NORM residue recycling and use; management of NORM residues designated as wastes; legacy situations and shortage of trained radiation protection professionals in the industry. The paper also summarizes the International Standards and guidance on NORM with a focus on the new BSS and other industry specific safety reports of the IAEA.

Keywords: Mining, NORM, Industry

1. INTRODUCTION

Exposure to natural sources of radiation occurs in a number of situations which includes exposure to uranium and thorium series nuclides present in earth, radon, thoron and their progenies in the environment, other natural radionuclides, exposure to cosmic rays and cosmogenic nuclides. The minerals and raw materials usually encountered in the day to day life contain the primordial radionuclides , ^{238}U, ^{232}Th and their decay progeny, and ^{40}K in low or significant concentrations. In most cases, the concentrations are in the normal background ranges, however, in some situations the radionuclide concentrations are either enhanced by technological processes or significantly higher than the background levels and there may be a potential for exposures that are of concern from a radiation protection point of view. Such items of natural raw materials, ores, minerals, process residues and wastes containing elevated concentrations of natural radionuclides falls within the definition of Naturally Occurring Radioactive Material with the acronym NORM. There are several radiation protection challenges for exposures to NORM for regulators, operators, workers and public. This paper outlines those radiation protection challenges and the available current international guidances.

2. RADIATION PROTECTION CHALLENGES

2.1 Standards and regulatory approaches

One of the most significant developments in the recent past is the revision of the International Basic Safety Standards (the BSS) which greatly influences the radiation protection regime including natural

sources. The new BSS now published as interim edition [1] is consistent with the radiation protection recommendations by the International Commission on Radiological Protection (ICRP), in particular, the ICRP's categorization of exposure situations into three types — planned exposure situations, emergency exposure situations and existing exposure situations. The stringency of protection in existing exposure situations (referred to earlier as chronic exposure situations) has been significantly increased by strengthening, and widening the scope of application of, the requirements for optimization of protection. In the case of radon, the stringency of control is further increased as a result of the radon statement by the ICRP in which it considers the health risk due to inhalation of radon to be significantly higher than previously assumed. Another important aspect has been the greater use of quantitative criteria for deciding on the mechanism of control to be applied to exposures to natural sources and — in the case of exposures to be controlled as practices — for deciding on exemption and clearance.

Most countries either adopt the BSS in their national regulation directly or incorporate relevant parts with modification suitable to national situations. Also, in the case of European Union, the draft European Council Directive contains new requirements for the control of exposure to natural sources, including specific requirements for building materials. Industrial activities involving NORM that are known to require regulatory consideration are listed in the draft and are essentially the same as those identified in IAEA Safety Reports Series No. 49 [2]. A list of building materials of concern is also included. There has been progress made towards the harmonization of standards and regulatory approaches for the control of exposure to NORM, but there is still a long way to go. The new BSS, with greater clarity and detail regarding NORM, provides a more substantial platform on which to base national standards and regulations on NORM, but there are concerns that the standards will still suffer from being too complicated and open to misinterpretation. A listing of industrial processes involving NORM that are most likely to need regulation as practices, first put forward by the IAEA in 2006, has now received widespread acceptance, thus providing national authorities with the means to focus their regulatory attention on those areas where it is most needed. In particular, there is a growing acceptance of the 1 Bq/g criterion for uranium and thorium series radionuclides as a tool for determining which industrial process materials need to be considered for regulation. However, there are still differences in standards and regulatory approaches between countries, and even within individual countries and growing concerns over the need for an evidence-based approach to the making of policy and regulatory decisions.

2.2 Graded approach to regulation

A graded approach to regulation is one of the key principles embodied in the BSS, which state that the application of the requirements for planned exposure situations "shall be commensurate with characteristics of the practice or source and with the magnitude and likelihood of exposures." This applies to all sources of radiation subject to regulation, however, it is particularly relevant to operations involving exposure to natural sources in NORM industries because the exposures are generally (but not always) moderate with little or no likelihood of extreme radiological consequences from accidents. Exemption, notification and authorisation (which include registration, licensing and control measurers) are the regulatory options under the graded approach. The basic level in the graded approach is where the regulatory body decides that the optimum regulatory option is, in fact, not to impose regulatory requirements. The mechanism for giving effect to such a decision could take the form of an exemption. Experience with industrial activities involving exposure to NORM indicates that the dose received by a member of the public living near the industrial facility concerned is generally no more than a few microsieverts per year [2] and exceptionally of the order of 100 μSv/a [3], and is consequently only a small fraction of the dose that could be received by a worker. Therefore, a decision not to impose regulatory requirements (i.e. a decision to exempt the practice or source) can generally be made on the basis of the worker dose not exceeding 1–2 mSv in a year, secure in the knowledge that under such circumstances the dose received by a member of the public living nearby is likely to be lower by at least an order of magnitude. This approach greatly facilitates the decision making process because it avoids the practical problems involved in making reliable assessments of doses to members of the public at small increments above background levels. The

soundness of any decision as to whether or not to impose regulatory requirements, made on the basis of the doses received by workers, depends on how realistically such doses are estimated. This implies, for instance, that due account is taken of the effectiveness of existing occupational health and safety controls, e.g. ventilation systems, personal protective equipment. Where the regulatory body decides that there is a need to apply regulatory requirements to a particular type of process, a formal notification to the regulatory body is the next step in the graded approach. Practically, this is similar to exemption, but with the important difference that the regulatory body is kept informed of all such operations or processes. If the nature of hazard is such that further obligations beyond notification need to be placed on the legal person, the Standards require that the person apply to the regulatory body for an authorisation which takes the form of either a registration or a licence. The nature and extent of control measures in such cases will be commensurate with the type of practice and the levels of exposure. However, there are still concerns resulted by an over-cautious approach based on questionable risk assessments derived from conservative modelling and implausible exposure scenarios.

2.3 Industry-specific approach

No single approach to the control of exposure to NORM was appropriate for all industrial processes involved is again a challenge in deriving a uniform approach. This is true in the regulatory context, since the nature and level of the radiological risk varies considerably from one industrial process to another. Similarly, it was noted on several occasions that actions taken to comply with regulation, under the general banner of 'good practice' , were situation-specific and could not be defined on a more general 'NORM industry' basis. For instance, the oil and gas industry operates under difficult and diverse environmental conditions in many parts of the world where appropriate regulatory systems are not always sufficiently developed. However, good progress had been made in developing good practices tailored to the industry's own particular set of circumstances. Mining operations, particularly those with associated legacy issues, have particular challenges, as is evident in the case of legacy uranium mining sites in Central Asia or some of the former metal mining sites in Africa [4]. There has been therefore a strong call in NORM conferences for an industry-specific approach to the control of exposure to NORM and the ongoing efforts of the IAEA to develop industry-specific Safety Reports is getting increasing attention of industry, workers and public. Various countries have either adopted or considered for a similar approach in their regulatory guides on NORM management for which industry specific guidances becomes part of the document. This highlights the particular need for an industry-specific approach when applying radiation protection measures in challenging operating environments.

2.4 Resurgence of uranium exploration and mining

Currently, the world's uranium industry is experiencing a resurgence of activity both in the mining and exploration after many years of economic pressures with increase in price for yellow cake since a decade ago. Many abandoned mines from a previous era are being re-examined for their potential to be re-opened or have their residues re-treated; planning for exploitation of previously known but undeveloped uranium deposits is proceeding in many countries new to uranium mining; and, worldwide exploration activity for uranium is expanding with more than 500 companies now claiming to be involved in the uranium mining market [4]. All of these activities have significant challenges for the radiation protection profession particularly in meeting with the operating and regulatory requirements at every stage of the uranium production cycle, from exploration through mining and processing to remediation. In this context, the IAEA has been working with radiation protection authorities and uranium mining industry representatives from around the world to address the issue.

2.5 Planned exposure situations or existing exposure situations

It is recognized that there exists some difficulty in the practical application of the ICRP recommendations on radiation protection for exposures to NORM from either planned activities or in existing situations. The identification of situations that could be classified as either existing exposure situations or planned exposure situations and how such exposures should be optimized using, as appropriate the reference levels or dose contraints is one of the main challenges. Recognizing this aspect, and also several others, ICRP Committee 4 constituted a Task Group to develop a decision aiding framework for the practical implementation of the Commission's recommendations set out in

ICRP Publication 103 on radiation protection for NORM. The framework would cover the entire range of NORM activities, including shipment and waste management of bulk quantities, as well as the presence of NORM in consumer products, particularly construction materials. The Task Group would also seek to illustrate how the framework would be applied to certain activities that are currently of concern, such as oil and gas production, burning of coal and the production of rare earths and phosphate fertilizers while taking into account the recent publications and documents of other international organizations such as the IAEA. Task group would consider a variety of exposure situations, ranging from those that should be excluded from any control, to existing exposure situations where exposures were not significantly different from background exposures, up to planned exposure situations where occupational exposures may be of concern. Some of the important topics under consideration by the task group are; the identification of problem areas where exposures to natural sources are present, particularly in industrial situations where radionuclide concentrations become enhanced in products or waste streams; the identification of any changes that might be needed in the ICRP system of protection relevant to NORM and how such changes would impact on NORM industries in terms of the management of exposures; the application of the concepts of existing and planned exposure situations, categories of exposed persons (public and occupational) and principles of exclusion and exemption and the identification of the ranges of activity concentrations and pathways that arise from NORM activities.

2.6 Reference levels and dose constraints

Reference levels and dose constraints are concepts that are used in conjunction with the optimization of protection to restrict individual doses. Reference levels are levels above which it is inappropriate to plant to allow exposures to occur, below which optimization of protection should be implemented. In the new BSS, there are requirements for the optimization of protection and safety by establishing dose constraints or reference levels as appropriate. The maximum reference level for exposure to radon is set at radon concentrations of 1000 Bq/m^3 for workplaces and 300 Bq/m^3 for homes corresponding to 10 mSv per year. Establishing appropriate or single national reference level is an issue in several countries and the issue is complex when considering countries with federal and state level administrative systems. The ‘reference levels’ and ‘dose constraints’ sometimes have been either used or considered, as limits defeating the purpose of optimization. Also, at least in few cases, there exists some confusion between the ‘reference level’ and the previously used ‘action level’ (at or below which remedial action and thus the need of optimization is not normally necessary) in terms of practical application in workplaces.

2.7 Exclusion, emeption and clearance

Differences in interpretation of the standards, especially with respect to the concepts of exclusion, exemption and clearance were reported from various conferences on NORM. For instance: The 1 Bq/g criterion for subjecting material to regulatory consideration as a source within a practice was variously referred to as an exclusion level, an exemption level, a clearance level or even a limit; There was a tendency to apply the concept of exemption not only to planned exposure situations but to existing exposure situations as well.

There appeared to be a particular problem with the use of the terms exclusion and exemption. These terms tended to be used interchangeably without appropriate qualification. For instance, reference to the 1 Bq/g criterion as an exclusion level could mean either that the material satisfying this criterion was excluded from regulation as a planned exposure situation (but not necessarily from control as an existing exposure situation), or that the material was excluded from the standards entirely. Similarly, NORM in transport that fell outside the scope of the IAEA Regulations for the Safe Transport of Radioactive Material (the Transport Regulations) was sometimes referred to as being excluded, but such material was not necessarily excluded from the requirements of the BSS. Interpretation of the concept of clearance was also with its own difficulties. Sometimes material being cleared from regulatory control, but with conditions applied raises the question of whether this is truly clearance, since the imposition of conditions could imply the need for some form of on-going regulatory control. Numerical criteria for exemption and clearance of NORM have been included in the new BSS. Exemption is determined on the basis of dose commensurate with natural background levels (about 1 mSv per year). Clearance criteria for NORM are 1 Bq/g for U and Th series

radionuclides and 10 Bq/g for K-40. These criteria are now gaining increased acceptance among the industry, regulators and public at large.

2.8 Exposure of workers

The adoption of a graded approach to the regulation of worker exposures, in line with international standards, has been implemented in practice. Also, it would appear that the role of general occupational health and safety regulations in controlling radiological hazards at work, particularly in the case of airborne dust control, is becoming increasingly recognized as an important part of the graded approach to regulation. However, the acquisition of exposure data for workers and the assessment of dose still suffer from a non-standardized approach and incomplete information in several countries, making a reliable assessment of the need for, and extent of, regulatory control difficult. It is becoming increasingly clear that, in the majority of industrial workplaces involving NORM, the annual effective dose received by a worker is likely to be less than 1 mSv. For instance: an investigation carried out in France [4], covering more than 400 workplaces in seven types of industrial activity it was found that a third of the annual doses were below 0.1 mSv and half were below 0.25 mSv, while only 15% of the doses were above 1 mSv. In some cases, doses of a few millisieverts per year may be received, in relatively rare situations, such as might occur in the uranium, thorium and monazite-based rare earths industries, would the dose be likely to exceed 5 or 6 mSv in a year probably a similar dose distribution as that observed for work with artificial sources suggesting that the familiar protection philosophy of engineering controls, working procedures and personal protective equipment is equally appropriate for exposure to NORM. The radon concentrations in most of the workplaces concerned except uranium and thorium ore processing were generally less than about 100 Bq/m^3. Some of the uranium mines are reported to have higher radon concentrations which pose additional challenge for protection of workers in the industry.

2.9 Radon in workplaces

In the new BSS, the maximum reference level for exposure to radon is set at radon concentrations of 1000 Bq/m^3 for workplaces corresponding to an annual effective dose of the order of 10 mSv. Also, if, despite all reasonable efforts to reduce radon levels the activity concentration remains above the established reference level, the requirements for occupational exposure in *planned exposure situations* shall apply. In the case of exisiting exposure situations, if the radon concentration in the workplaces is not able to bring below the national reference level with all reasonable efforts, the current guidances are inadequate and calls for more practical guidances for the protection of workers.

Recently, ICRP has observed an increased risk for exposures to radon [5]. Combining this with the new dosimetric approach to derive dose conversion coefficient for intake of radon pose a great challenge to control exposures to radon in workplaces especially in uranium mines. For example, analysis of the dose data for uranium mines in the Czech Republic suggests that those mines generally have radon concentrations of up to about 800 Bq/m^3 and very occasionally up to about 2000 Bq/m^3[4] and the mean radon concentration would appear to be around 500 Bq/m^3. Considering the expected doubling of the dose for the same concentration previously, the radiation protection against radon in uranium mines may require increased attention and measures to control exposures. However, the radon concentrations in most of the other workplaces concerned (covering the production of zircon, zirconia and refractory ceramics and the processing of ores of metals other than uranium) were generally less than about 100 Bq/m^3.

2.10 Exposure of public

The results of various estimates of doses received by members of the public (excluding doses from radon) from mining and minerals processing facilities, as well as from the use of residues from such facilities, are summarized in the proceedings of NORM VI conference. As is inevitably the case when assessing doses to members of the public, the estimates are likely to be subject to considerable

uncertainty and tend to be conservative, owing to the necessity for modelling of the relevant exposure scenarios. The estimated doses are in general significantly below 1 mSv per year.

There is a lack of uniformity in the approach to the use of NORM as a component of building material, although it is generally agreed that any situation giving rise to a dose of more than 1 mSv per year would need special consideration and in certain cases some form of restriction. Information suggest that the approach to the use of NORM in building materials, while in all cases taking radiological considerations into account, tends to be more conservative in countries with highly developed economies and more realistic and pragmatic in countries with emerging economies. For example, in the case of use of phosphogypsum in building materials, although the activity concentration of the phosphogypsum is an important factor, the way in which it is used has a strong influence on the incremental exposure level in the building concerned, with doses ranging from "insignificant" to more than 1 mSv per year. Limited studies are available on the exposure to indoor radon for houses constructed using phosphogypsum panel and plasterboards. It is worth mentioning that one country has recently established specific criteria for permitting the use of phosphogypsum in building materials, so as to maintain radiological safety without losing the considerable social and economic benefits to be gained from such use. There is a strong need for an evidence based approach in assessing radiation protection of the public from NORM. Social licencing and public communication are also important challenges when considering such issues.

2.11 Transport issues

The present criterion for application of the IAEA Transport Regulations to NORM (namely, 10 times the activity concentration for exempt material) is generally valid. Some of the results from previous NORM conferences showed that this criterion was unnecessarily strict for at least some of the transport situations involving NORM, implying the need for consideration on a case by case basis [4]. Such a provision does not currently exist in the Transport Regulations.

Transport of NORM is falling increasingly under the spotlight because of the triggering of alarms designed to detect radioactive sources in scrap metal or to combat the trafficking of illicit nuclear material. Container shipments were now being monitored for radioactive material at major ports around the world. For instance, such a monitoring system at the port of Antwerp is an example revealing that this had led to a large number of alarms being triggered due to the presence of moderately radioactive NORM (such as zircon) in the container. A methodology had been developed for determining the activity and activity concentration of each radionuclide of natural origin. This is an area of growing concern worldwide and that continued improvements will be needed in the design and operation of such monitoring systems and in the training of operators. Similar portal monitoring systems are installed for the screening of commercial vehicles at the entrances to metal scrap recycling facilities. The presence of NORM contamination accounted for more than half of all the alarms triggered. The main objective was to be able to determine the activity concentrations of the NORM-contaminated items to enable them to be segregated into items that could be recycled by melting and those that had to be removed and transported to a radioactive waste facility. The criterion for segregation was an activity concentration of 1 Bq/g for ^{226}Ra and ^{232}Th. The risk of inadvertent melting of radioactive sources is a worldwide problem and the Spanish Protocol approach may be a way forward in dealing with it on an international scale.

2.12 Management of NORM Residues

The use of NORM residues as recoverable resources, either directly or following some form of treatment or recycling process, are increasingly attracted and the concept of using NORM residues rather than disposing of them as waste is gaining increasing acceptance around the world. Some countries are now specifically providing for NORM residue recycling and use in their regulatory systems. Only if the options of use or recycling are not feasible can the material be disposed of and only then is it considered as waste. Many instances of NORM residue recycling and use are now

available. Instances of dilution are also reported and in some countries dilution is not only a treatment option but also a legal obligation for some specific case. To ensure that the doses received from the use of the NORM residues remains within acceptable levels, various conditions are being applied or are being considered by the regulatory authorities concerned. Some of the examples are [4]: In Sweden, historical NORM residues may be used in landfilling and construction applications if the activity concentrations of radionuclides in the ^{238}U decay series do not exceed 3 Bq/g, this being 3 times the 'exemption' level; In terms of new regulations in India, the use of phosphogypsum in building materials is permitted if the ^{226}Ra concentration does not exceed 1 Bq/g (after dilution with lower activity material if necessary). Phosphogypsum panels are permitted for house construction if the surface activity concentration does not exceed 40 000 Bq/m^2.; In the draft European Council Directive, building materials can be used without restriction if the dose from indoor external exposure does not exceed the background outdoor external exposure by more than 1 mSv per year. If this value is exceeded, control measures should be considered, ranging from registration and general application of relevant building codes to specific restrictions on the use of the material.

There is a lack of uniformity in the approach to the use of NORM as a component of building material, although it is generally agreed that any situation giving rise to a dose of more than 1 mSv per year would need special consideration and in certain cases some form of restriction. The placing of restrictions on the use of NORM residues in building materials as an issue is attracting ever more attention. While there seemed to be a degree of agreement on the value of 1 mSv as a general reference level for building materials, there was less of a common view on how this should be translated into measurable quantities such as activity concentration. A more conservative approach was discernible in European countries compared with some countries elsewhere and even within Europe there were differences. For instance, some countries in Europe are applying, or are considering applying, an additional criterion for building materials to specifically control radon exposure. As a result of new recommendations by the ICRP and the World Health Organization, reference levels for indoor radon are undergoing a downward trend. This has heightened concerns within some European countries that a restriction based only on external exposure might not be sufficient to adequately control radon exposure. There also appeared to be different views on whether the 1 mSv dose criterion should refer to the total external dose from the building material or just the contribution from NORM contained within it.

2.13 NORM Wastes

With regard to the establishment of good practices for the management of NORM waste, a risk-based and situation specific approach is essential. Some of the NORM wastes usually considered for disposal are, Tailings and other waste from the processing of uranium ore; Tailings, slag and chemical processing wastes associated with the production of thorium and rare earths; Radium-rich scale from the oil and gas industry; Sludge from water treatment facilities. Most commonly used options for disposal of these wastes are,

(a) For large volumes of relatively low activity waste, such as mine tailings, the only two practicable options available were for it to be isolated in above-ground, custom built containments such as tailings dams or to be diluted with non-radioactive soil or sand and returned into the remediated land form. The latter option is accepted practice for mineral sand tailings.

(b) Low and intermediate volumes of relatively high activity NORM waste such as pipe scale from the oil and gas industry and process residue from the extraction of rare earths and thorium were usually disposed of in one of three ways:
   (i) By emplacement in underground radioactive waste repositories
   (ii) By emplacement in shallow ground, engineered (usually concrete) structures
   (iii) In the case of pipe scale from the oil and gas industry, by reinjection into the formation using a process known as 'slurry fracture injection'.

(c) Moderate volumes of NORM waste with low activity concentrations (but above the applicable exemption or clearance level) were increasingly being authorized for disposal in conventional disposal facilities for industrial or hazardous waste, such as landfill sites, sometimes with some additional, relatively simple protection measures being applied to cater for the radionuclide

content. In certain cases, the upper bound on the radionuclide activity concentration was being set at 10 times the exemption or clearance level.

2.14 Legacy situations

There exists a number of legacy situations worldwide from former industrial activities where the industrial production stopped and sites were simply abandoned with little or no attention paid to remediation. Most of these sites are connected to uranium or other heavy metals mining and processing and few cases of monazite/thorium processing. The situation in Central Asia regarding former uranium production sites (nearly 48 sites in Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan) was often highlighted as a major challenge in this regard, requiring coordinated international effort to assist the countries concerned in planning and carrying out the necessary remediation work. The sites were generally uncontrolled and the NORM residues from the mining and processing were a source of environmental contamination. Much of the efforts has been undertaken by the IAEA in developing remediation strategies and support to Member States.

2.15 Lack of trained radiation protection professionals in industries

The long period of reduced activity in uranium mining has meant that few young people have been joining the industry over the past several years. There is now a shortage of trained and experienced radiation protection professionals associated with the mining industry that cannot be overcome overnight. Also, there is a global shortage of suitably qualified and experienced radiation protection and safety workers. The rapidly expanding international uranium mining industry is likely to need many more of these staff than are available at present, especially over the next five to ten years. There is also a need for a longer term assured supply of personnel as replacements for the inevitable retirements associated with the present aging workforce. All these people will be needed to staff not only the existing mines but also those new uranium mining projects that seem likely to develop over the next 10 to 20 years. Training, development and involvement of these radiation safety professionals only can assure safety in uranium mining and other NORM industries.

3. IAEA INDUSTRY SPECIFIC SAFETY REPORTS

The need for radiation protection measures in work activities involving minerals and raw materials has been addressed by the IAEA in Safety Reports Series No. 49: “Assessing the Need for Radiation Protection Measures in Work Involving Minerals and Raw Materials” [2]. The report identifies the industry sectors and process materials most likely to need regulatory consideration and provides information to assist regulatory bodies in establishing the necessary radiation protection measures. Recognizing the need for an industry specific approach for radiation protection for exposure to NORM, Agency has been producing several Safety Reports specific to the identified industry types. These include oil and gas industry [6], zircon and zirconia industries [7], production of rare earths from thorium containing minerals [8] and titanium industry [9]. Specific reports on phosphate industry and other industries such as coal and metal production are under development stages.

4. CONCLUSION

Considerable progress has been made towards the harmonization of standards and regulatory approaches for the control of exposure to NORM. The new international basic safety standards provide greater clarity on the control of exposure to natural sources and is seen as an opportunity for establishing a more substantial platform on which to base national standards and regulations on NORM. A listing of industrial processes involving NORM that are most likely to need regulation as practices, first put forward by the IAEA in 2006, has now received widespread acceptance, thus providing national authorities with the means to focus their regulatory attention on those areas where it is most needed. In particular, there is a growing acceptance of the 1 Bq/g criterion for uranium and thorium series radionuclides as a tool for determining which industrial process materials need to be considered for regulation. There is growing recognition that an industry or process specific approach is needed for ensuring that exposures to NORM are controlled optimal and effectively. Industrial

activities involving NORM, and legacy situations from such activities, are very diverse and each has to be addressed by developing 'good practice' according to the particular set of circumstances. IAEA promotes the graded approach to regulation to control exposures to NORM. Differences in standards and regulatory approaches between countries, the need for an industry-specific approach, resurgence of uranium mining industries and fast expanding worldwide exploration activities for uranium, the identification of situations that could be classified as either existing exposure situations or planned exposure situations and how such exposures should be optimized using, as appropriate, reference levels or dose constraints, implications of conservative and cautious approach in modelling for estimating doses, the need for an evidence-based approach to the making of policy and regulatory decisions, differences in interpretation of the concepts of exclusion, exemption and clearance, exposure of workers, radon in workplaces, transport issues, NORM residue recycling and use, management of NORM residues designated as wastes and legacy situations are the major radiation protection challenges.

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