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Abstract: Abstract

In Romania, Naturally Occurring Radioactive Materials (NORM) were widely used in many industries. Several radiological investigations of different sites were performed, some of them with important results, from the radiation protection point of view. Although the general regulatory requirements of the NORM related activities are established by the Romanian nuclear legislation, no specific regulations to detail them are in place. Faced with these challenges, a clear necessity to complete the regulatory framework was identified. In this respect, a graded approach was selected, in order to establish the appropriate level of the regulatory regime to be applied to NORM related activities. This work is intended to describe, in general terms, the methodology used in order to assess the radiological risk associated with NORM industries which are relevant for Romania today, as a first stage of a project dedicated to develop the applicable regulatory framework.

RADIOLOGICAL INVESTIGATIONS OF NORM RELATED ACTIVITIES IN ROMANIA

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1. Introduction

Naturally Occurring Radioactive Materials and their radiological impact have been studied intensively in the last years. Managing NORM is interesting from the radiation protection point of view, especially if these materials are produced and used in bulk amount. In Romania, NORM were widely used or processed in many industrial facilities, such as phosphate fertilizer plants, iron and steel factories, oil and gas extraction facilities and other non-uranium mining and milling facilities.

In its Title VII, the Council Directive no. 96/29/Euratom on laying down basic safety standards for the protection of the health of workers and the general public against dangers arising from ionizing radiation requires that workplaces in the non-nuclear industry also need to be subject to regulatory control, if the presence of natural radiation sources can lead to a significant exposure of workers or members of the public, which cannot be disregarded from the radiation protection point of view. Such workplaces are found in industries using or processing types of minerals or rocks containing significant amounts of natural radioactive elements (NORM industry). Other operations such as storage, application or disposal of the residues resulted from the NORM processing have to be included in the control, too.

With the Romania's accession to the European Union, the European regulations regarding radiation protection were transposed into the national legislation. Thus, the Fundamental Norms for Radiological Safety (National Commission for Nuclear Activities Control,

2000) underline that all operators of those facilities which, during the operation, can accumulate NORM or produce technologically enhanced NORM, have to perform a study regarding the concentration of NORM on the production cycle and the possible exposure of workers and public to ionizing radiations and to send the results to the nuclear regulatory body. Based on these results, the regulatory body has to decide the level of the regulatory regime to be applied in order to ensure the radiation protection of workers and/or public.

Faced with the difficulties generated by the application of nuclear legislation to non-nuclear activities, such as those involving NORM, the regulatory body decided to complete the existing regulatory framework with detailed requirements and procedures regarding the licensing and control regime of these activities. In this respect, taking into consideration the international recommendations (International Atomic Energy Agency, 2006), a graded approach was selected. In order to derive the appropriate level of regulation, the regulator contracted a project, dedicated in a first stage to assess the current radiological situation of NORM industries in Romania. Further on, the legislation had to be evaluated too, in order to identify the gaps and possible solutions to complete the regulatory framework. In the end, based on these assessments, new regulations addressing the specific aspects of radiological safety related to these activities involving NORM will be issued, as decided by the regulator and the contractor during the project.

This paper briefly summarises the methodological approach and the final results of the radiological investigations programme carried out in Romania, in terms of dose estimations. It has to be mentioned that, under this project, only workplaces possibly affected by the presence of NORM and work activities generating residues containing NORM were investigated; radiation protection aspects related to aircraft operation and radon in homes and workplaces will be subject of other future investigations.

2. Methodology

2.1. Fact-finding mission and site investigations

The survey of the current situation in Romania in the field of NORM was based on:

- a fact-finding mission to a wider range of industries and sites,
- a dose estimate based on current and future exposure scenarios within each industry.

During the preparation phase, industries were identified which were most likely to be relevant under the aspect of NORM. As a starting point, several publications, such as European Commission, Radiation Protection – 122, 2001, results presented by Wymer in 2007 at the European ALARA Network for NORM workshop and other related publications (Romanian Society for Radiological Protection, 1994, Botezatu and Iacob, 2000, Radulescu and Popescu, 2002, Kunze, 2003, G. Tanase and M. Tanase, 2003, Gellermann et al., 2006) were consulted and matched with the current industrial structure of Romania. The selection of industries to be visited during the fact-finding mission included:

- coal-fired thermo power plants,

- oil/gas production,
- phosphate fertilizer production,
- metallurgical plants and smelters,
- non-uranium mining and ore processing, including coal mining and dewatering of mines,
- thermal water spas,
- drinking water treatment,
- bauxite processing (alumina production),
- use of thoriated materials and thorium alloys.

Apart from this conventional, industry-based approach, a very useful and convenient way to classify NORM is by a comprehensive set of "material types" resulting from 6 distinct elementary processes (Gellermann, 2008):

1. Raw materials,
2. Precipitates,
3. Chemical extraction and processing residues,
4. Slag,
5. Thermic dust,
6. U or Th containing end products.

Each material type is characterized by a typical pattern of the normalized nuclide vector. For example, in dust from high-temperature thermal processes (metallurgy, combustion), there is a peak of Pb-210/Po-210 resulting from the volatile metals lead and polonium which precipitate on dust particles in the flue gas and are removed in scrubbers or electrostatic filters. This generic type approach is useful for several reasons, including the following:

- It avoids to narrow a focus on the "usual suspects" industries when looking for potential NORM industries, but directs the attention to fundamental technological processes which may be applied in many industries where they can lead to the formation of NORM.
- Knowledge of the generic material type helps in the communication with radio-analytical laboratories if samples are analyzed and the results are interpreted.
- The selection of the appropriate on-site measurement equipment can be based on an information of the type of NORM. For example, if filter dusts from thermal processes are to be expected at a plant, beta measurement devices are required to detect hot spots, while the gamma detectors commonly used for a first site characterization are useless in such a situation.

In order to ensure comparability of the site investigation results and the conclusions drawn from it on the relevance of each industry and/or site, a standardised procedure was followed at each site visited. This included on-site measurements and sampling of residues and other materials, which were then sent to an accredited laboratory for an analysis of the nuclide vector.

On-site measurements of the ambient dose rate and the beta count rate were carried out using the following measurement devices:

- Gamma spectrometer "Inspector 1000",
- Gamma-Beta sensitive "MicroCont II" with aluminum shield to selectively measure the beta count rate.

Each site was first scanned using the appropriate measurement device (in accordance with the type of residues and materials to be expected from the technology used). Only if an elevated level of radioactivity was found, samples were taken. Of particular importance was the derivation of activity balances in processes where raw materials were processed (or burnt, e.g., coal) and the radioactivity was accumulated in residues (e.g., bottom ash and filter dust). In these cases, the sampling had to ensure that raw material and residues were taken from the same batch (i.e., same day and hour, same furnace etc.).

Liquid samples were taken either if there were liquid effluents containing NORM (e.g., mine dewatering installations) or if they may interact with solid NORM and lead to radioactive seepage (e.g., seepage from fly ash or red mud ponds). In the latter case, the samples were analysed before and after a leach test.

In total, 21 sites were investigated, 27 solid samples and 5 liquid samples were taken and analysed. Results must be treated confidentially and cannot be disclosed in this paper.

2.2. Dose assessment and identification of priority industries

In order to identify industries which deserve special attention from a regulatory point of view, a radiological risk assessment has been carried out, based on the results of the site investigations and the samples taken during it. However, some of the industries and sites did not exhibit any elevated level of radioactivity at the time of the visit, for a number of reasons, such as:

- temporary cessation of production activity,
- use of raw materials with an untypically low level of radioactivity,
- reluctance of the site operator to grant access to the relevant parts of the operations or to disclose detailed information on NORM within the operations.

If a given industry is commonly known as relevant from a radiation protection point of view, missing information (or untypically low levels of radioactivity) were replaced by typical ranges of comparable sites elsewhere from the literature.

The risk/dose assessment was carried out for workers and members of the public, for all exposure pathways relevant under the industry and site-specific conditions. The pathways considered in the dose calculations can be structured as follows:

- External exposure,
- Inhalation of long-lived alpha / beta emitters,
- Inhalation of radon and its short-lived daughter nuclides,
- Ingestion of radionuclides, directly and via the food chain (drinking water ingestion and secondary exposure pathways).

The dose estimates are merely intended to identify the important exposure pathways and parameters, to provide an order-of-magnitude assessment of the radiological risk and to highlight processes where radiation protection, regulatory and supervision measures are required to keep the exposures reasonably low.

It must also be noted that the dose estimates are beset with uncertainties. Assumptions have been made and model parameters have been used which reflect a likely exposure scenario or, if no information was available, describe a conservative approach.

3. Results

Error! Reference source not found. summarises the current situation of NORM in Romania, based on the site investigations, literature research and dose estimates as described in section 2.

Despite the fact that the dose estimations are based on conservative assumptions, the activity concentrations obtained from the facts finding mission has to be interpreted as spot check. Consequently, the values used here give an indication regarding the radiological relevance and the most important NORM industries in Romania. Therefore, only a systematic survey can identify all sites where radiological relevant materials occur. The legislative regulation should consider this by a relatively broad approach of the work activities and industries which have to examine their specific materials regarding radioactivity ("Positive List").

3. Conclusions

Based on the results of the survey and the radiological risk analysis, and taking into account the assessment of existing regulatory framework in Romania, a new regulation on NORM related activities and residues, is being prepared. The new regulation will be based on a "positive list" of NORM industries which includes those industries which have been identified as relevant today, but will also include industries which are hitherto not relevant in present, but may become so in the future (e.g., existing industries where raw materials or processes are changed, or new industries currently not active in Romania).

Table 1: Summary of the current situation of NORM in Romania

Industries, processes	Radiological relevance for		Disposal of residues	Remarks
	Workers	**Members of the public**		
Coal-fired power plants	Dust can lead to exposure, but < 1 mSv/a	No significant doses except if wastes are used in construction materials	Ash/slag ponds owned by companies	Use of residues must be restricted
Phosphate fertilizer industry	Doses may significantly exceed 1 mSv/a	Water path should be controlled	Ponds owned by companies	
Oil/gas industry	Doses may significantly exceed 1 mSv/a	No doses exceeding 1 mSv/a, but some relevance for uncontrolled use of tubings	Large, but unknown amount, no disposal route available	
Water treatment, mine dewatering	Currently no problems known, but may become important in the future	No significant doses, except if wastes are used in construction materials		If residues occur, their use must be restricted
Geothermal water	Doses < 1 mSv/a	Doses may exceed 1 mSv/a	Smaller amounts of scrap, scales and equipment expected, no disposal route	

Industries, processes	Radiological relevance for		Disposal of residues	Remarks
	Workers	**Members of the public**		
Non-uranium mining	Currently no problems known, but may become important in the future	Doses < 1 mSv/a	Subject to EU Extractive Waste Directive	
Iron-ore smelters	Doses < 1 mSv/a	Uncontrolled spread of filter dust may lead to doses > 1 mSv/a	No disposal route for filter dust available	Uncontrolled spread of filter dust must be precluded
Bauxite processing	Currently, doses < 1 mSv/a, but may be > 1 mSv/a for some ores	Doses < 1 mSv/a	Ponds owned by companies	
Th-Mg alloys	Doses < 1 mSv/a due to optimised work organisation	Not relevant	Disposal of wastes permitted in old uranium mine	No company currently active
Thoriated welding rods	Doses may significantly exceed 1 mSv/a	Not relevant	Not relevant	Companies should be made aware of radiation protection measures (e.g., ventilation)

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