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The European Waste Catalogue – is it a good tool to raise awareness about Technologically Enhanced Naturally Occurring Radioactive Materials?

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Abstract. Since radiation risk is usually considered to be related to nuclear energy or atomic bomb, majority of researches on radiation protection has focused on artificial radionuclides and radioactive waste. Far less attention has been paid to radiation risk caused by exposure to ionizing radiation originating from naturally occurring radioactive materials despite the fact that their presence touches many aspects of our life, especially when a huge amount of bulk waste had been dumped in our vicinity. Existing regulations have pointed out the strong needs to take into account non-nuclear industry where materials containing enhanced natural radioactivity occur and enclose them in frame of formal control of radiation risk but in reality often such cases of radiation risk are still out of, not only control, but even simple monitoring. This is caused by the shortage of information about radiation occurring outside nuclear industry or radioactive source and irradiating apparatus use. Such lacking information can be included in European Waste Catalogue to make the first awareness for the all stakeholders of concern.

1. INTRODUCTION

Many processes in non-nuclear industry create a situation when the concentration of naturally occurring radioactive material is additionally enhanced. Such situation usually exists in industrial processes leading to a significant mass reduction of raw materials and/or with changes of their chemical composition or state of aggregation which might influence their further properties. As a matter of course, these industries of concern are not aimed at the production of natural radionuclides or the deliberate use of radiation. Therefore radioactive isotopes are usually accumulated in waste. Such alterations to the natural state results in an increment of radiation risk to people as well as to environment in case of disposal of such waste. Each particular way of occurring of enhanced natural radioactivity determines some unique scenario of exposure, usually differing from those ones caused by artificial radionuclides.

Usually the quantity of such type of waste materials can amount to hundreds of thousands of cubic meters or tonnes; they had been created or dumped directly into environment and associated with other pollutants as heavy metals or hydrocarbons. Therefore the application of routine rules used for assessment of risk caused by artificial radioactivity (i.e. radioactive waste) and practices[1] can lead to the completely misunderstandings. Finally, it results in that the problems of waste containing enhanced concentration of natural radioactivity are mostly out of any regulation and even it has been controlled it is carried out on case-by-case basis. Non-nuclear industry of concern is till now not aware of the problems connected with natural radioactivity or would expect negative consequences in case of implementing radiation protection measures.

2. SYSTEM OF ENHANCED NATURAL RADIOACTIVITY OCCURRENCE CLASSIFICATION

Natural radioactivity in aspects of derived radiation risk to people was discussed widely. Some authors have followed terminology applied by Gesell and Pritchard [1] i.e. Kathren [2], Righi et al. [3]

[1] Activity focused on an use of radioactive materials, ionizing radiation or fissile materials according to the definition given by IAEA.

but a lot of different abbreviations have emerged to describe these phenomena. For example Baxter [4] applied TERM (technologically enhanced radioactive material), Vandenhove [5] used "materials containing natural radionuclides in enhanced NORs". In Canada two names: NORM- contaminated and Naturally Occurring Nuclear Substances have been applied to distinguish non-nuclear industry from uranium ore extraction and processing [6]. Martin in the first report completely dealing with European industry coping with natural radioactivity used simple descriptive name "materials containing natural radionuclides in enhanced concentrations" [7]. IAEA report [8] has distinguished two situations when natural radioactivity in non-nuclear industry can cause significant increment of radiation risk: NORM (naturally occurring radioactive materials) and technologically enhanced NORM. Such approach was followed in many articles presented during periodic conference NORM IV held in Poland [9]. All mentioned above abbreviations are used by authors interchangeably to describe situation when presence of the natural radioactivity causes not negligible radiation risk. But after even rough analysis of branches of industry processing minerals it is clear that such enhanced risk can be created in two different way and acronyms NORM and technologically enhanced NORM (TENORM) reflected them the best.

The term NORM (Naturally Occurring Radioactive Materials) should be used, accordingly to the definition, only for cases, when radiation hazard is due to the presence of materials with elevated concentration of natural radionuclides, significantly above average level of radioactivity, albeit not related to or caused by any type of human's activity. It have to be pointed out, that NORMs are taken into account in the radiation hazard assessment scenarios only in cases, when appear in the natural or work environment due to industrial activity, otherwise are treated as sources of the natural background and not taken into considerations as enhanced radiation risk.

The acronym TENORM(s) means Technologically Enhanced Naturally Occurring Radioactive Materials. This term is used for the description of any raw material, product or waste, in which concentrations of the natural radionuclides have been altered (enhanced) as a result of technological processes to the levels, causing significant increase of the radiation hazard above natural background. It doesn't matter, if the enhancement is intentional or not. It can be seen, that in some cases NORMs are used as a substrate(s) for the process(es) where TENORMs are created as products or by-products. On the other hand, it's possible to create TENORMs in processes, where no NORMs have been used as raw materials. An example of such processes is coal combustion for power generation. Hard coal is well known as a material with relatively low concentration of natural radionuclides, and cannot be treated as NORM at all. The combustion leads to the very big reduction of the initial fuel mass. Owing mainly to the elimination of organic component of hard coal, during combustion process there is approximately one order of magnitude enhancement of the radioactivity concentration from fuel to ash.

One should remember, that usual exemption from TENORM classification concerns raw materials and substances, used in the nuclear industry either for civil or for military purposes. But radiation protection in both types of mentioned above activities is their immanent part (due to current terminology applied in radiation protection such activities are classified as "practices" on contrary to these dealing with NORM or TENORM that are named "work activities").

IAEA in its Safety Report Series recently recommends using the term NORM for all cases when occurrence of natural radioactivity can cause significant increase of radiation risk to people, but only if it is designated in national law or by a regulatory body as being subject to regulatory control because of its radioactivity.

3. TENORM/NORM WASTE PROPERTIES

Processes leading to the increase of the radiation hazard due to natural radioactivity can be distinguished and enclosed into two groups. The first one encloses exploitation, transfer or disposal to the natural environment raw materials or waste without any changes of their properties. Such processes are mainly performed in the industrial branches, relating to exploitation of mineral resources with elevated

concentrations of natural radionuclides (NORM) – phosphates, thin, titanium, niobium and rare earth metal ores. The tailings produced in the exploitation processes are in form of natural materials, with the similar chemical composition and physical properties as excavated raw materials. The enhancement of radiation hazard caused by them is usually a result of the direct exposure to radiation emitted by them due to increase of the amount of waste in the installation or its release to the work or natural environment. Also different excavation technologies, applied in underground mining or drilling, may lead to unintentional release of waters or gases with elevated levels of natural radioactivity. In general, for waste included in this group the presence of NORM is crucial to create significant radiation risk. Following waste materials can be stated as mentioned below substances:

- Waste rocks from mining exploitation and raw materials cleaning or enrichment, together with possible contamination resulting from leaching of radionuclides;
- Brines, released from oil and gas rigs or hard coal mines;
- Radon and its progeny in caves, underground mines, in tunnelling and in natural gas;
- Dust from air cleaning systems.

The second group of industrial processes generating radiation risk consists of technologies leading to significant mass reduction of initial raw materials. These processes can also change of chemical composition or state of aggregation processed materials which might influence its further behaviour in the environment. Such processes are characteristic for industrial branches, where raw materials are exposed to high temperature. Mass reduction in these processes may cause concentration of all impurities in produced waste materials, together with natural radioactivity. Tailings with concentration of natural radionuclides several tens higher than in the raw materials are often created as the results of such processes. Besides fossil fuels combustion, also all parts of the processes of metal ores treatment (metallurgy) as well as particular stages of certain inorganic chemical technologies can be included to this category. In this case to create radiation risk it is not necessary to process NORMs and these raw materials in practice are often contain less natural radioactivity than usually taken as average for Earth's crust.

Properties of the waste materials resulting from the second group of technologies are related to the level of accumulation of the natural radionuclides due to the mass reduction within the process. For such kind of waste the abbreviation TENORM (Technologically Enhanced Naturally Occurring Radioactive Materials) can be applied in order to distinguish them from NORMs. Following waste materials can be taken into account in this category:

- Waste from fossil fuel combustion (i.e. CCP – coal combustion products);
- Waste materials from chemical technologies (mainly production of phosphoric acid and titanium dioxide pigment);
- Slag from metallurgical industry (iron ore processing and steel production);
- Waste products from non-ferrous ore processing – mainly tin, copper, zirconium and niobium;
- Tailings from rare earth metals industry.
- Deposits in underground galleries and settling ponds, scales in the dewatering systems in well and underground mining industry;

Besides the occupational risk and possible risk to the members of the public inhabiting neighbouring areas, NORM/TENORM type waste impacts upon the environment where they have been dumped. After had been placed into environment they might set some additional processes in motion, leading to the selective transfer and accumulation of particular radionuclides and disequilibrium in chains of natural radioisotopes.

4. EXISTING REGULATION

The importance of radiation risk caused by natural radioactivity first have been underlined in the Council Directive 96/29EURATON laying down basic safety standards for the protection of the

health of workers and the general public against the danger arising from ionizing radiation. Namely, in the paragraph 40 of this directive, was clearly stated that:

1. This Title shall apply to work activities not covered by Article 2 (1) within which the presence of natural radiation sources leads to a significant increase in the exposure of workers or of members of the public which cannot be disregarded from the radiation protection point of view.
2. Each Member State shall ensure the identification, by means of surveys or by any other appropriate means, of work activities which may be of concern. These include, in particular:

   (a) work activities where workers and, where appropriate, members of the public and exposed to thoron or radon daughters or gamma radiation or any other exposure in workplaces such as spas, caves, mines, underground workplaces and aboveground workplaces in identified areas
   (b) work activities involving operations with, and storage of, materials, not usually regarded as radioactive but which contain naturally occurring radionuclides, causing a significant increase in the exposure of workers, and, where appropriate, members of the public
   (c) work activities which lead to the production of residues not usually regarded as radioactive but which contain naturally occurring radionuclides, causing a significant increase in the exposure of members of the public, and, where appropriate workers
   (d) (aircraft operation)

(As one can see the point “b” and “c” are comply with the definition NORM add TENORM mentioned in previous paragraph) .

In case of significant radiation risk would be identified, the directive, in article 41 requires the application exactly the same countermeasures as it was defined for risk caused by artificial radioactivity and fissile materials.

In this form the directive the crucial decision where risk caused by natural radioactivity is significant has been left under each member state competences. In the light of lack good enough information about NORM/TENORM occurrence majority of the member states introduced to their own regulation only cases, directly mentioned in the directive, namely, underground mining, caves and spas. It results in that the problems of waste containing enhanced concentration of natural radioactivity are mostly out of any regulation. On the other hand, without direct appointment nobody in non-nuclear industry is interested in “discovering” a radiation risk in his yard.

After the directive had been published a lot of efforts were devoted to establish the exemption or clearance levels of natural radionuclides activity concentration that let one to release materials of concern from any control but still there are not appropriate and complete information what kind of materials is subject to the rules [10].

5. REGULATION INCONCLUSIVENESS

In each EC member state the national Atomic Acts and subsequent enactments establish a uniform legal framework for regulatory control of activities subjected to radiation risk. Such activities are traditionally considered to be directly related to the deliberate use of ionizing radiation, radioactive sources or fissile materials. These activities are carried out under determined circumstances and such parameters necessary to carry in them, as a source activity, kind of radiation, dose rate, etc. are exactly the same as used within the radiological protection. So there the monitoring of radiation risk is obvious. Regulatory control steps in just when the radiation risk exceeds the allowed limits. Hence, in such situations one can distinguish two levels of radiation risk monitoring. The first can be called “physical control”, is carried every in each of above situation and its main objective is to reveal when the level of the risk is close to the limits. The second one, regulatory control, is carried out above the specific levels of radiation doses and usually legitimizes the use of radiation but it forces a user to keep the radiation risk at the level allowed by relevant law.

Such approach is well-founded and effective only in case when the physical control of radiation risk is assured or at least alleged. Otherwise a vicious circle can appear: there are not information about radiation risk in default of physical control, so that, there is no reason to take regulatory control on. No regulatory control, no driving force to start any activity focused on radiation risk monitoring. Finally, even severe radiation risk can be denied.

In case of radiation risk caused by enhanced natural radioactivity the necessity of physical control is not obvious. Natural radioactivity is a primordial property of the surrounding matter. Natural radionuclides are present in almost all substances that we deal with. Therefore, the generic question is: when is their presence significant from a radiation protection point of view? The answer seems to be very simple: when the derived radiation risk exceeds acceptable level, it means, when the necessity of regulatory control appears. But to get such answer is not so simple. In case of exposure to the risk caused by natural radioactivity there are usually no physical control in default of precise regulation. This results in the gap of knowledge about the real radiation risk. So, no one knows whether allowed limits of risk have been exceeded or not, hence the problem of regulatory control does not exist. This implies that there are no risk evaluation and no needs for physical control. In this way quite often even serious radiation risk can be out of control of radiation protection.

On the other hand, the problem of natural radioactivity is completely excluded from regulations dealing with the environmental protection in general. Moreover, the problem of NORM/TENORM is completely pushed away from acts ruling the treatment of industrial waste and health protection. Actually ionising radiation due to its carcinogenic and mutagenic properties is mentioned in these acts but in details, they finally address to recommendation dealing with radiation protection and the circle is closing again. Finally hazard caused by radiation originating from naturally radioactive materials is rarely taken into consideration when the treatment of industrial waste is planed.

6. PROPOSED SOLUTION

To solve the mentioned problem one would enforce the physical control of the radiation risk in each industry dealing with exploration or processing of natural resources in general. But such approach would be a substantial overuse and due to actual level of knowledge in this matter is not justified enough.

Solution applied in many countries, also recommended by IAEA, consists in a pointing out the industries where presence of natural radioactivity can cause significant radiation risk. In comparison with mentioned EC directive, where only examples as underground mining and caves were listed, so called “positive list” contains currently the twelve branches of industry [11].

- Mining and processing of uranium ore
- Rare earths extraction
- Thorium extraction & use
- Niobium extraction
- Non-uranium mines
- Oil and gas
- Phosphate industry
- Zircon & zirconia
- TiO2pigment production
- Metals production (Sn, Cu, Al, Fe, Zn, Pb)
- Burning of coal etc.
- Water treatment (Rn, solid residue).

Existence of this list results in the obligatory monitoring of radiation risk in the companies concerned. Such approach makes one actually apply the requirements and regulation that have been developed in order to control risk caused by artificial radioactivity, including exemption or clearance levels expressed as mass or volume activity concentration. But the direct application of these rules and recommendation to TENORM/NORM management lead to many discrepancies or even paradoxes. For an example,

usually amount of NORM type waste is so big, that taking into account total activity concentration criterion it almost always should be treated as radioactive waste. But for the same reason, there is not possibility to fulfil all requirements related to radioactive waste with the reasonable costs.

The solution based on introduction of the "positive list" to national regulation is still a substantial generalization and does not provide the end user with help how to cope with the problem. But if one considers thoroughly TERNORM occurring as waste, the possibility to define in detail the circumstances of radiation risk creation on case-by-case basis will emerge. Namely, European Waste Catalogue (EWC) seems to be a good basis to gather together all information about waste, including properties important form radiation protection point of view. Such idea is additionally supported by the fact that TENORM/NORM type waste looks like "common" industrial waste rather than nuclear or radioactive ones. Also the consequences of TENORM occurrence can be amplified by the simultaneous presence of other pollutants.

The European Waste Catalogue was produced following the Commission's decision[2] and it is a fundamental part of a duly waste disposal. It classifies both hazardous and non-hazardous waste produced pursuant to European Council *Directive 75/442/EEC of 15 July 1975 on waste* and categorizes them according to what they are and how they were produced. The catalogue defines standardized nomenclatures and monitoring levels of the various waste types. The EWC codes are valid throughout Europe and contain just about any waste conceivable. Although, the EWC defines the basic necessity of monitoring certain wastes but the monitoring level can be adapted to one's special needs because of requirements imposed by authorities, customers or internal regulations.

The preliminary analysis of EWC in relation to literature available TENORM data showed that waste accounted as *wastes from thermal processes* (group 10) are the most numerous category well known as containing enhanced concentration of natural radionuclides. It is caused mainly by concentration of radioactive isotopes during such processes as combustion, melting, evaporation etc. As one should have expected, also the groups 01 and 06, *Waste resulting from exploration, mining, quarrying, physical and chemical treatment of minerals* and *waste from petroleum refining, natural gas purification and pyrolytic treatment of coal* respectively contain a host of different waste materials where high concentrations of natural radioactivity is a primordial property of these waste or have been obtained exactly due the technological process or resulted from unwanted side effects. In the light of the common radiation protection requirements, waste enclosed in these groups are the most important from point of view of the expected radionuclide activity concentrations as well as their total amount usually produced.

Among individual waste already classified in EWC the above 240 are at least suspected as being TENORM or NORM. In spite of the EWC contains so big number of different type of waste sometimes it seems worth distinguishing a new category of individual waste, taking into consideration just concentrations of natural radionuclide. For example, sludge settled at the bottom of ponds in coal mining industry have so high activity concentration of radium that they deserve to be isolated from other waste classified as subgroup *01 01 wastes from mineral excavation.*

7. CONCLUSION

In the light of other European regulations that very often contain a lot of details concerning subjects that in comparison with radiation risks appear not to be so serious and plenty with negative consequences, the EC Directive 96/29/EURATOM seems as if enclosing not so many details as necessary. In spite of the number of reports issued recently and describing effects of TENORM and NORM occurrence in industry and environment this kind of risk is not appreciated enough. There is a great need to provide

[2] The EWC was originally established by Commission Decision 94/3/EC. It was replaced by 2000/532/EC and amended by Decisions 2001/118/EC, 2001/119/EC and 2001/216/EC. The full EWC is available from the European Commission's web-site at: http/europa.eu.int/eur-lex/en/lif/reg/en_register_15103030.html.

mineral industry operators with well-founded information about real risk caused by enhanced natural radioactivity. The EWC is a good tool to make the first awareness about significant radiation risk beyond the nuclear industry and use of radioactive sources. Completion the EWC with qualitative information about possibility of radiation risk should be followed by data bases containing specific properties of each kind of TENORM waste, as it was done in case of hazardous and dangerous materials.

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