New approach to the assessment and reduction of health risks and environmental impacts originating from TENORM according to EC regulation

A. Poffijn, W.D. Kraus*

Laboratory for Nuclear Physics, Proeftuinstraat 86 B-9000 Gent, Belgium
**Bundesamt für Strahlenschutz, Waldowallee 117, Berlin, Germany*

Abstract: The New Basic Safety Standards as laid down in the Directive 96/29/Euratom differ from the earlier versions in that specific provisions have been formulated in Title VII for exposure to natural radiation sources. The scope of its application involves work activities, within which the presence of natural radiation sources may lead to exposures of workers and/or members of the public that cannot be ignored form the point of view of radiation protection.
Two groups of work activities are of particular concern : the processing and/or storage of materials with enhanced concentrations of naturally occurring radionuclides and the production of residues causing a significant increase in the exposure of workers and members of the public.
The Member States have to identity the activities of concern and they are given a high degree of flexibility in implementing the articles on natural radiation sources into national legislation. There is, however, a great need to harmonize the national approaches. Therefore guidance on the likely level of regulation of various materials and recommendations on the identification of such workplaces and on the nature of appropriate control have been prepared.
The proposed set of screening and reference levels is intended as a first order approach, needing in some cases more detailed investigations. As a particular case, the detailed investigations done in relation to the phosphate industry and its environmental impact will be described and discussed.

1. INTRODUCTION

The international recommendations and national regulations of radiological protection issues have evolved to ensure safety in the use of artificial sources of radiation exposure. Little attention has been given to exposures that can occur as a result of the use of naturally occurring radioactive materials (NORM). The levels of naturally occurring radioactivity in different minerals of the earth's crust vary widely. In some cases, raw materials which are exploited for industrial use contain natural radionuclides at concentration that may not be disregarded from the point of view of radiation protection. Additionally, some industrial processes can lead to further enhancement of the radioactivity level either in the products and by-products or in waste materials.

The EU Council in 1996 published the Council Directive 96/29/Euroatom (The EC Basic Safety Standards). Title VII of this Directive [1] requires the members of the EU to identify work activities which can cause significant increase of radiation exposure of workers or members of the public due to the presence of enhanced concentration of natural radioactivity and to imply appropriate control.

2. RECOMMENDATIONS FOR IMPLEMENTATION

General guidance on the implementation of Title VII has been produced by the group of experts established under Article 31 of the Euratom Treaty and published as Radiation Protection 88 [2].
For industrial processes (use, storage, waste) involving materials with enhanced levels of natural radionuclides no special control of the exposure of the workers is required if the yearly doses are less than 1 mSv. In the other case the normal scheme for controlling exposures has to be applied. For annual doses in the range 1 to 6 mSv it is recommended to consider whether it is possible to reduce effectively the doses and whether it is possible that they increase either over time or as the result of an accident. For doses over 6 mSv/y it is considered appropriate to define a controlled area.
A generic list of the most relevant industries/activities/materials whereby enhanced exposure to natural sources of radiation may occur has been set-up:

- The phosphate processing and use as fertilizer
- The processing of metal ores
- Rare earth and titanium oxide industry
- Zirkonium and ceramics industry
- Oil and gas extraction
- The application of radium and thorium
- The coal mining and the power production from coal

More details about the type of activity and the typical activity concentration have also been collected (Table 1).

3. SCREENING AND REFERENCE LEVELS

In order to use the general guidance in practice, it is necessary to link the annual dose reference system to the specific activity of the materials used or handled at the different stages of the industrial processes. Therefore different pathways by which workers could receive a significant radiation dose were investigated:

- External irradiation
- Inhalation of dust
- Inhalation of radon
- Ingestion of dirt and dust
- Skin contamination.

A set of typical exposure situations (exposure from stockpiles, from scales & residues and from process vessels & pipes) was developed, generating a relationship between the activity concentration of the materials processed and the involved doses. For the classification of the processes a system with four control bands is used (Table 2).

For a first order approach, appropriate when only a rough estimate of the radionuclide composition of the input material is available, screening levels for each marker point, are derived. If the process falls into band 1 no further investigation has to be made. In the other cases more detailed analyses of the radionuclide composition of the material have to be made to allow more accurate dose calculations and to demonstrate the necessary level of regulation more precisely. Thereby sets of reference levels, typical for the different industrial processes have to be used.
Based upon this research performed by NPRB and CEPN [3] a guide has been published for assisting Member States as well as the relevant industries in identifying and categorising the industrial processes with potential increased exposure of workers [4].

4. PUBLIC EXPOSURE AND ENVIRONMENTAL IMPACT

The model calculations are only applicable to exposure of workers in industry and not to the more complex situation of exposure of members of the public neither to the study of the environmental impact. For this purpose case by case investigations have to be performed.
As part of the these type of investigations in relation to the phosphate industry, particular interest was given to the impact of phosphate ore acidulation with hydrochloric acid. By this process large amounts of liquid waste with enhanced levels of radium and heavy metals are released in rivers. Ongoing investigations in Flanders [5,6] for this type of activity reveal large areas with significantly increased gamma exposures (up to 2 μSv/h) and with radium contents in soil up to 15 kBq/kg, due to dredging and regular flooding of the two rivers in which the release takes place.
Taking into account the currently most frequent use of most of the contaminated land, the radiation burden to the population is not expected to exceed 1 mSv/y (max. 400 μSv/y for very conservative assumptions). Only for people living in houses built on the heavily contaminated ground, the yearly doses can - due to radon inhalation - largely exceed the 1 mSv-level. Therefore all houses in the neighbourhood of the rivers are been investigated on radon and the future use of the concerned parcels of land will be restricted. A systematic study about the impact on the eco-system due to the combined radioactive and chemical contamination of these phosphate releases is currently in progress.

5. REFERENCES

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4. Commission of the European Communities, in *Radiation Protection 95*, Luxemburg (1999)
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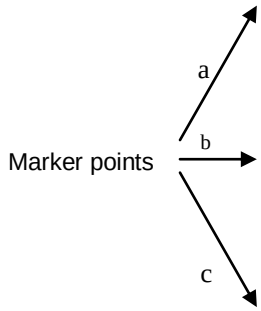
Table 1 Examples of industries where enhanced exposure to natural sources of radiation might occur

Work activity/industry/product	Radionuclides and typical activity concentrations	Occupational exposure above 1 mSv/main pathways/particularities	Public exposure above 1 mSv/ main exposure routes/special features
Phosphate industry (fertilizer production) Phosphoric acid (detergents and food)	Feed material: 1.5 kBq kg^{-1} U By-product gypsum: 1 kBq kg^{-1} Ra-226 But high concentrations of Ra (100 kBq kg^{-1}) may precipitate in the plant	POSSIBLE/Gamma radiation and inhaled dust at production plants/Accumulated radium-rich scales (~ 100 kBq kg^{-1})	POSSIBLE/Liquid discharges, re-use of by product gypsum, atmospheric discharges if thermal processing involved (Pb-210 and Po-210)
Sulphuric acid production	Pyrites: slag containing > 1 kBq kg^{-1}	? Inhalation and external doses	?
Coal mine de-watering plants	Sludges may contain 50-100 kBq kg^{-1}	POSSIBLE/External gamma and internal hazard during maintenance	Disposal will need attention
Coal and fly-ash	Fly-ash: typically 0.2 kBq kg^{-1} U, Th Levels up to 10 kBq kg^{-1} have been reported in special circumstances	NOT LIKELY	POSSIBLE/Re-use of fly-ash as construction material
Metal production: smelters	Tin ore: U, Th ≤ 1 kBq kg^{-1} Lead/Bismuth smelting (bismuth may contain 100 kBq kg^{-1} of $^{210}Bi/^{210}Po$) Ilmenite, rutile (titanium) Bauxite, red mud (aluminium): U, Th; < 1 kBq kg^{-1} Pyrochlore or columbite (for ferro-niobium): 50 kBq kg^{-1} Th Activity may concentrate in slags and furnace dusts	POSSIBLE/Gamma radiation and inhalation of dust at production plant/Dust scales: (~ 100 kBq kg^{-1})	POSSIBLE/Atmospheric discharges (particularly of volatile materials such as Pb-210 and Po-210), Re-use of waste

Table 2 : Control band system for regulation



	Upper limit effective dose (mSv/y) Normal situation	Upper limit effective dose (mSv/y) Unlikely situation
Band 1 No regulation necessary	1	6
Band 2 Lower level of regulation	6	20
Band 3 Higher level of regulation	20	50
Band 4 Process not permitted		