NORM WASTE IN THE SYSTEM OF RADIOLOGICAL PROTECTION CONTROL

E. Ettenhuber
Federal Office for Radiation Protection
Germany

1 ABSTRACT

Some industries process materials, ores or minerals containing natural radionuclides from the uranium and thorium decay series in concentrations above the normal level of radioactivity. These materials are termed Naturally Occurring Radioactive Material – acronym NORM. For industries dealing with NORM the term NORM industries and for waste of these industries the term NORM waste are usually used. There are no generally applicable criteria to declare NORM. Dealing with NORM can lead to a significant increase in the exposure of workers and, if the residues of NORM industries are re-used or disposed of in the environment, for members of the public, too. In many cases, protective measures have to be considered and such materials should be subject to institutional control of radiological protection. Criteria - reference levels - are necessary to identify relevant materials.

In the field of 'planned practices' the concept of exemption and clearance is applied to decisions on radiation sources that are subject to regulatory control. This concept is, however, not useful for NORM and waste from NORM industries since nearly all industrial residues have to be controlled and costs may result which would be excessive in relation to the benefit.

Therefore, the Directive 96/29 EURATOM gives a guiding principle: only materials containing naturally occurring radionuclides are of concern which cause a significant increase in the exposure of workers or members of the public. Generally applicable criteria, e.g. numerical values for radionuclides are, however, not provided. The national authorities have, therefore, to specify appropriate criteria. Average and normal range of natural radiation exposure can be applied as a yardstick for reasonable reference levels. In specifying these levels not only the geological situation, the content of radionuclides in soils and rocks or the variation of the background radiation exposure should be taken into account. Other relevant issues e.g., habits, social and economic conditions and not least the acceptance by the public can be of significance. The reference levels can be specified in terms of effective dose values or radionuclide concentrations. The advantages and disadvantages of both approaches are discussed.

2 INTRODUCTION

In the last decade the attention of radiological protection was directed increasingly towards the radionuclides naturally occurring and the radiation exposure due to these radiation sources. Taking into account the intensive discussions in the past on the detrimental risk attributable to a radiation exposure due to the use of radioactivity or ionizing radiation and the fact that the risk resulting from a radiation exposure is independent of its origin, the attention is understandable since the major contribution to the total radiation exposure of man is caused by these sources. Logically, for precautionary reasons, measures to control the radiation exposure due to natural radiation sources have to be considered as well and they should be subject to the regulatory system of radiological protection. It holds nearly for all components of radiation exposure due to natural radiation sources. Only few components of this exposure are unamenable to control, e.g. the internal exposure due to K-40, the exposure due to cosmic rays at ground level and above ground exposure to radionuclides in the undisturbed earth's crust (1). Although most components of the radiation exposures are amenable to control, we refrain in many cases from protective measures for several reasons, e.g. the measures required to decrease radiation exposure in a case of concern may be very expensive or they are not accepted by the public because of radical changes of the habits connected with that.

Human activities can affect the level of radioactivity in the working and living environment and can change the exposure of man to natural radiation sources. These human activities are labelled 'work activities' and, of course, the components of the radiation exposure resulting from them are considered amenable to any control. Mining and other types of earth material extraction and processing, including oil and gas production, are typical examples of work activities since the materials brought to the surface from deeper geological strata, their industrial products, the by-products and, in particular, the processing waste frequently contain concentrations of natural radionuclides above the 'normal' levels of natural radionuclides in the environment, e.g. above the concentrations in soils and surface near rocks.

Materials containing increased concentrations of naturally occurring radionuclides are usually designated as NORM. There are, however, no generally applicable criteria to declare NORM. For industries dealing with NORM the term NORM industries has been adopted into colloquial language and so has the term NORM waste for waste of these industries.

In dealing with NORM one must consider significant radiation exposures of both workers and members of the public. Typical exposure pathways for workers are the external exposure to gamma radiation and the inhalation of dust. In a few cases the inhalation of radon released from waste can also be a pathway of concern. Appropriate control measures can include the attention to the arrangements for waste disposal, dust control and limitation of exposure time. Exposure to the public may arise from the emission of radioactivity into the environment during work activities. Examples are the discharges of the

phosphate industry into waters and airborne effluents from smelters. However, radiation exposures may arise, in particular, from the re-use or disposal of residues since the radionuclides are concentrated mostly in the by-products and residues. In order to limit the radiation exposure of members of the public the residues of NORM industries have to be subject to institutional control of radiological protection.

The hazard to people or to the environment from these materials, however, does not only arise from radioactivity but also from toxic chemicals and other harmful substances contained in the residues of NORM industries. Therefore, in order to achieve proper conditions in dealing with NORM waste, not only must the radioactivity be subject to control but also the other harmful substances. Regulations are necessary for both problems.

3 CHARACTERISTICS OF RESIDUES OF NORM INDUSTRIES SIGNIFICANT FOR RADIOLOGICAL PROTECTION

Just as the term NORM industry is applied to totally different branches of industry the terms residues of NORM and NORM waste summarize different types of materials which may be of concern, e.g. mining debris from magmatic or sedimentary rocks, slag, ash, fly-dust, phosphogypsum, sludge and scales. The amounts of residues and waste can also be very different, in many cases, e.g. in mining and ore processing, huge amounts of residues and waste result. Although industrial processes are currently optimised, residues are mostly inevitable and the amount of them can be influenced in narrow limits only.

Chemical and physical properties permitting, the residues are more and more used for different purposes, e.g. for road construction, landfilling and for the production of building materials. In many countries the use of industrial residues has priority over the disposal and is required by law. If the residues cannot be used they are dispersed in the environment, placed in conventional refuse disposal sites or, because of the chemicals or other harmful substances, in hazardous waste depots. A sharp dividing line, however, cannot be drawn between re-use and disposal of the materials. As an example: the use of mining debris or slag for landfilling can also be regarded as final disposal of mining or processing waste. In the past, millions of tons of these residues were used for several purposes, they were dispersed or disposed of in the environment without taking aspects of radiological protection into account.

Not only are types and amounts of residues but also the concentrations of natural radionuclides in the residues of NORM industries totally different. In particular, they depend on the radionuclide concentrations in the raw materials and the technologies applied for processing. The concentrations of radionuclides in a material of concern can, therefore, differ from the concentrations of these radionuclides in other residues of the same type. Moreover, in assessing the radiological relevance of the industry or work activity, consideration should be given to the extent to which the radioactive

equilibrium is affected by the processes. As an example: processing of raw materials at high temperatures may enrich airborne dust in some radionuclides of the uranium and thorium series, e.g. Pb-210 and Po-210. Chemical processes can also affect the radioactive equilibrium in the residues or waste.

At last we should not forget that in a few cases there is no connection between the concentrations of radionuclides in the residues and the concentrations of the materials exploited or extracted and predictions on the radionuclide concentrations in waste are impossible, e.g. scales incurring in oil or gas production contain very high concentrations of Ra-226 whereas the radioactivity in oil and gas can be neglected from the radiological protection viewpoint.

Until now there is no comprehensive survey of the materials of concern, the activity concentrations and other characteristics required for assessing the radiation exposure resulting from their use or disposal. Table 1 gives a few examples for industrial processes/work activities which may result in significant exposures and levels of radioactivity in raw materials, by-products, residues and waste. They were more or less arbitrarily selected and should not be taken to be comprehensive but rather illustrating the kind of process where increased exposures may occur. Conversely, the fact that an industry or a work activity is listed does not imply that it will always lead to significant exposures.

In summary one can say that the variability in concentrations of natural radionuclides in NORM waste is limited and the concentration factors are not extremely high. Concentrations in NORM waste are always small relative to the concentration range which is possible for radioactive waste from practices. Nevertheless, increased radiation exposures can result for workers when dealing with such materials, and, if the residues are re-used or disposed of in the environment, for members of the public, too. Criteria - reference levels - are necessary to decide on the residues which should be subject to institutional control of radiological protection.

4 CRITERIA FOR THE INCLUDING OF RESIDUES FROM NORM INDUSTRIES IN THE REGULATORY SYSTEM OF RADIOLOGICAL PROTECTION

The regulatory system for radiation protection is intended to ensure the protection of people against risk arising from exposure to ionizing radiation. The International and European Basic Safety Standards - BSS and Directive 96/29 EURATOM - provide basic requirements for it (2,3).

In the past, a consensus emerged that annual effective doses in the order of 10μSv or less can be ignored for regulatory purposes and the BSS and the Directive 96/29 EURATOM express this by means of the concepts of exemption and clearance. The concept of exemption defines the criteria, under which human activities applying radioactivity or ionizing radiation - practices - may be exempted from requirements of the radiation protection standards. Exemption levels in terms of activity or activity concentrations were derived by modelling

exposures in particular for workers. They are provided in the BSS and the Directive and accepted in the national regulations. The concept of clearance is related to removing radioactively contaminated materials from regulatory control for the unrestricted use of radioactivity or ionizing radiation. Although the dose criterion for clearance is the same as that for exemption, the clearance values in terms of activity concentrations are mostly lower than the exemption values because the exposure scenarios are different from those taken into account in calculating the exemption levels. In the case of naturally occurring radionuclides the clearance levels are mostly smaller than the concentrations usually occurring in soils and surface near rocks.

If the concept of clearance, in particular the clearance levels derived in this way for naturally occurring radionuclides were applied for deciding on the inclusion of NORM waste in the regulatory system of radiological protection, most of the waste would have to be subject to institutional control, since the concentrations in industrial waste are mostly higher than these criteria. Radiation protection measures would be required in most cases. If they can feasibly be done, they may be very expensive. In particular the costs incurring for disposing of waste - it has to be dealt with as 'radioactive waste' from practices – would be extremely high considering the huge amounts of waste to be disposed of. In summary, one can say: the resources that would need to be expended in regulating industrial waste with radionuclide concentrations above the clearance levels, like radioactive waste from 'practices', would be excessive in relation to any benefit that might ensue in terms of reduced risk.

Following the Directive 96/29 EURATOM a reasonable approach is possible. Article 2 of the Directive defines those human activities as work activities, 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. In addition Article 40 of the aforementioned Directive provides that only those materials causing a significant increase in the exposure of workers and, if appropriate, members of the public should be subject to the institutional control of radiological protection. These provisions can be used as guide line. However, the Directive does not provide generally accepted approach to put the formulation 'significant increase....., that cannot be disregarded from the radiation protection point of view' in a numerical value of annual effective dose or radionuclide concentrations. From the regulatory point of view such criteria are necessary for identifying the residues that should be subject to institutional control. In the case of NORM and NORM waste natural radiation exposure and its variability can only be taken as a yardstick for specifying common-sense reference levels that can be applied to identify NORM waste for which protective measures should be considered.

Taking natural radiation exposure into account Article 31 Experts (4) proposes the annual effective dose increment of 300μSv as a criterion for exemption/clearance for work activities. This criterion is coherent with the exemption level proposed by the experts for building material (5), too, and it is

comparable to or smaller than the regional variations in the effective dose from external background radiation. It may, therefore, also be applied to NORM waste. Taking into account the high variability of the normal exposure range due to natural radiation sources excluding the exposure to radon, the annual effective dose increment of 1mSv can also be considered. Also for reasons of acceptance an annual effective dose level in this order of magnitude seems to be reasonable. After all, the dose limit of 1mSv per year in force for members of the public was derived by ICRP not only due to more or less hypothetical risk assumptions but also due to the natural background exposure to achieve acceptance by the public. A dose level in this range permits common-sense precautions, it avoids unnecessary expenditures and does not contradict theoretical risk assumptions, and, not least is it coherent with the concept of controllable dose recommended by R.Clarke

Since the natural variability of the natural radiation exposure differs in the individual countries, national authorities should specify the criteria for the identification of residues of concern on the basis of comprehensive investigations of the national situation. The following issues should be taken into account: the average and normal range of natural radiation exposure due to the geological conditions, e.g. superficial and bedrock geology, content of the radionuclides of the uranium and thorium series in soil and rocks, habits, social and economic conditions, legal aspects in the field of environmental protection and in radiological protection as well. Furthermore the public acceptance of both radiation exposure and measures possibly requiring decreasing it are important points. Not least, in specifying the reference levels have we to recall that huge amounts of industrial waste have been disposed of in the environment and the necessity of remediation measures should be considered. The dividing line between waste due to past work activities and waste due to ongoing work activities is often imperceptible since, in many cases, the materials are dealt with in the same management areas. For reasons of acceptance a coherent approach between the control of ongoing work activities and the remediation of disposal sites from past work activities is desirable. For all these reasons the criteria have to be specified by the national authorities taking the national conditions into account. In this process, however, the national authorities should not forget that the distribution of NORM, the re-use of residues from NORM industries and also the disposal of NORM waste know no borders. It would, therefore, be advantageous if the national authorities adopt the same criteria in identifying the relevant waste that should be subject to control.

5 SPECIFICATION OF REFERENCE LEVELS FOR NORM WASTE IN REGULATIONS

The reference level can be specified in terms of the annual effective dose or in terms of numerical values for radionuclide concentrations. These reference levels are applied as follows: if the radiation exposure arising from the disposal of a NORM waste is below the reference level of effective dose or if the radionuclide concentration in a residue is below the reference level specified in terms of radionuclide concentration the residue is not subject to the control of radiation protection and further considerations are not necessary. Otherwise

aspects of radiation protection have to be observed and protective measure are provided for, e.g. additional requirements for disposal, restrictions of the amount to be disposed of.
If the reference level is specified as annual effective dose its application requires an exposure analysis specific for each case of concern taking into account the type and amount of waste, its chemical and physical properties, the characteristic of the disposal site and the conditions for the planned disposal. Scenarios and pathways relevant for workers and members of the public have to be taken into account. Provided that the exposure scenarios, models and parameters are adequately selected, this approach offers flexible possibilities for disposing of waste and optimized solutions can be found.

We should, however, consider that this approach can be very expensive because of the site-specific investigations. Therefore the alternative - specification of reference levels in terms of radionuclide concentrations - should be discussed. From the regulatory point of view this alternative is preferable if numerous work activities have to be assessed. These levels can be derived from an accepted effective dose level for several options:

- It can be specified as a numerical value generally applicable to all types of NORM waste and management
- It can be specified as a set of numerical values for types of material that are similar with regard to their physical and chemical properties, e.g. for mining debris, slags or sludges
- It can be specified as a set of numerical values for types of similar materials taking into account additionally standarized methods of disposal.

In specifying a reference level generally applicable to NORM waste the type of material, its chemical and physical properties, its destination and the characteristics of the disposal site are not defined. All possible exposure scenarios and pathways following the disposal must, therefore, be taken into account and it is understandable that the parameters used for calculation are very conservative. Logically the resulting levels are restrictive.

In specifying a generally applicable reference level the natural background can also be used as a yardstick and two approaches can be discussed: establishing the criterion at the average or the upper end, e.g. the 95% percentile of the frequency distribution of the naturally occurring concentrations in soils or surface near rocks. The advantages and disadvantages of the possibilities have to be weighed up. When the average exposure level is established as a reference level we must accept that exposure situations often occurring naturally are subject to institutional control and protective measures are required. As another option the upper end of the normal exposure range can be discussed. Because of the provisions in the Directive 96/29 EURATOM - work activities should be subject to control which lead to a significant increase of radiation exposure – only the upper end of the normal concentration range should be applied.

Unnecessary restrictions can be avoided if reference levels are established for types of waste and the physical and chemical properties of the materials can be taken into account in calculating the numerical values. As an example: in the case of slags leaching of radionuclides can be ignored, and, in calculating the reference levels for these materials the aquatic exposure pathways can be left out of consideration. This approach results in considerably higher reference levels for numerous materials.

A further modification of the reference levels for certain types of waste is possible, if in addition standardized disposal methods are considered. Applying these criteria the vast majority of problems can be decided and site-specific assessments are necessary only for exception cases.

Although the last mentioned options take more effort than the calculation of a reference level generally applicable to all cases of concern, it seems to be the best solution from the regulatory viewpoint.

6 REGULATORY APPROACH

In most cases work activities resulting in NORM waste are already ongoing and known by the authority, and so are the general characteristics. On the basis of information on the geology of the ore deposits and the uranium and thorium concentrations of the raw materials, on the basis of the origin of the processed ores and the technologies applied, the national authority can identify the industries of concern. These industries should be asked for an investigation of the waste management concept applying the specified reference levels as follows: if the activity concentration of the materials does not exceed the reference levels, further investigations and measures of control are not necessary. Otherwise the material is subject to further control. A site specific analysis has to be made in order to assess the dose resulting from the materials disposed of. If the calculated does is below the reference level of the effective dose the practice of waste management does not have to be changed. If the resulting effective dose exceeds the reference level specified for it the waste management concept and the suitability of the site for disposal of waste have to be revised taking into account aspects of radiological protection. In addition measures of radiological protection - remediation measures - should be considered in the waste management area for the materials already disposed of.
If the industries are unknown the authoritiy should carry out an appropriate survey or a reporting procedure to get the information required for identifying work activities of concern.

7 SUMMARY

In many cases waste of NORM industries contain increased concentrations of radionuclides and, if the materials are disposed of without considering aspects of radiological protection, significantly increased radiation exposures for workers and for members of the public may result. That is why these material should be subject to institutional control of radiation protection. Criteria are

required to identify materials which should be subject to any of the regulatory controls. The criteria for the unconditional clearance of materials from ‘planned practice’ should not be applied when deciding, since costs would result that would be excessive in relation to any benefit attributable to risk reduction. In addition we should not forget that the risk is of hypothetical nature in the exposure range of interest. The Directive 96/29 EURATOM gives a guiding principle for specifying reasonable reference levels. They should be orientated towards the normal range of natural exposure and can be specified as numerical values of the effective dose or concentration of radionuclides. If they are specified in terms of concentrations for the radionuclides of interest the reference levels should be specified for types of waste that are similar with respect to their chemical and physical properties. In this way unnecessary restrictions can be avoided. Taking into account both the range of doses which can result from naturally occurring radionuclides in terrestrial materials and the explanation of ICRP for the dose limit for members of the public a dose level of about 1mSv per year seems to be appropriate for NORM waste. The numerical values should be derived from this exposure level. If numerical values for the concentrations are specified a step-wise approach is possible for identifying the material for which additional measures of radiological protection are necessary in disposing of it. If the reference levels in terms of radionuclide concentrations are not exceeded further considerations of radiological protection are not necessary and the materials can be moved from the institutional control of radiation protection. Otherwise the material should be subject to further control. A site-specific analysis should be made to assess the effective dose for people living in the surrounding of the disposal site and, if the radiation exposure exceeds the reference level specified in terms of an effective dose, the waste management concept and the suitability of the site for the disposal of waste have to be revised. Additionally remedial measures are required in the waste management area used until now.

8 REFERENCES

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Table 1: Examples of NORM industries / work activities

Industry / work activity	Residues			Scenarios for public exposure
	Typ	Radionuclide	Activity Concentration in kBq/kg	
Phosphate industry	By-product gypsum	Ra-226	1	Liquid effluents Re-use
Dewatering of coal mines	Sludges	Ra-226	> 10	Disposal
Energy production (coal)	Fly-ash	U Th Ra-226	< 10	Re-use Building material
Metal production	Processing waste (dust) Slags	U Th Ra-226 Pb-210 Po-210	Depending on the raw material, < 100	Airborne effluents Disposal Re-use
Processing of monazite sand	Processing waste	U Th	< 10 < 1000	Disposal
Oil / gas industry	Scales	Ra-226	< 4000 kg	Disposal