

A NUCLEAR DECOMMISSIONER'S VIEWS ON THE REGULATION OF TENORM

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ABSTRACT

Large volumes of contaminated materials arise from the decommissioning of nuclear facilities. The management of these redundant materials represents a substantial cost fraction of such projects. The recycling of the material (or its reuse or disposal) without radiological restrictions, was identified by a Task Group of the OECD/NEA Co-operative Programme on Decommissioning, as a significant means of reducing such costs. One major factor seriously limiting the utilisation of recycling as a waste management alternative is the lack of internationally accepted levels of radioactivity at which the material could be utilised without radiological restrictions, i.e., clearance levels.

The emergence of the NORM/TENORM issue has been of great significance for the implementors of clearance regulations in the nuclear industry. TENORM arisings occur in huge quantities; two to three orders of magnitude larger than those used in European studies on recycling in the nuclear industry. The activity levels in such arisings are generally the same as in very low level nuclear waste. Their occurrence in a large number of industries, as well as their activity levels and quantities, have not been generally known, even to regulatory authorities, until fairly recently. Thus the regulation of TENORM is in its early stages.

National and international bodies have or are in the process of suggesting regulations for TENORM. The most important development is the publication of the European Commission Directive of May 1996 (ratified in May 2000) laying down basic safety standards for protection against ionising radiation, arising both in the nuclear and non-nuclear industries. The international Atomic Energy Agency has also started looking into this area in connection with the revision of its Safety Series 89 document. Significant to note is that both these bodies suggest much more relaxed levels of individual dose criteria for the clearance of radioactive material from non-nuclear industries than for similar material from nuclear industries.

The paper discusses various implications of this "double standard" approach to the regulation of radioactive material, depending on which industry it arises in. It also underlines the need for consistency in developing regulations and criteria for exemption and clearance of such material.

INTRODUCTION

The OECD Nuclear Energy Agency's Co-operative Programme on Decommissioning was established in 1985 to exchange scientific and technical information between major decommissioning projects. The Programme is under the direction of the NEA Radioactive Waste Management Committee, and has today 39 participating projects from 14 countries, making it the major forum and spokesman for the implementers of decommissioning.

Quite early during the information exchange, it became obvious that the management of the large volumes of contaminated materials arising from the decommissioning of nuclear facilities represents one of the most substantial cost fractions of such projects. Consequently, the minimisation of the volumes that have to be disposed of as radioactive waste is a high priority goal for decommissioners. It was also recognised that much of the redundant material resulting from decommissioning activities is valuable, e.g., stainless and other high quality steel, but also concrete for road or building construction. The recycling of such material (or its reuse or disposal) without radiological restrictions could be a significant means of achieving the aim of waste minimisation.

So, in 1992, the Co-operative Programme set up a Task Group to study the recycling and reuse of redundant material from the decommissioning of nuclear facilities, in particular to provide information and insights into the practicality and usefulness of the criteria being developed for the release of such material from regulatory control, seen from the perspective of organisations currently engaged in actual decommissioning operations. The Task Group made a survey of available practices and national regulations in this area, studied the technologies associated with recycling, and analysed the proposed international recommendations and proposals for release criteria. A report of the work of the Task Group was published in 1996[1].

In the last few years, an increasing awareness has developed of naturally occurring radioactive material (NORM) and the enhancement of its concentration in various non-nuclear industrial processes. This technologically enhanced radioactive material (TENORM) shows the same activity levels as the material that results, e.g., from the decommissioning of a nuclear facility, and which is sometimes called (very) low level waste. It is very similar to the candidate material for exemption and clearance in the nuclear industry, but occurs in quantities that are huge in comparison.

A great deal is happening today in the area of release of all types of radiologically contaminated material, both internationally and in certain countries. This paper will start with an overview of the regulatory criteria for the release of redundant material from the nuclear industry, compare these with those proposed for the TENORM industries and then highlight a number of inconsistencies and anomalies in regulatory approaches and treatment.

OVERVIEW OF RECOMMENDATIONS/PROPOSALS FOR RELEASE OF MATERIAL FROM NUCLEAR FUEL CYCLE

In 1988, the International Atomic Energy Agency (IAEA) and the OECD Nuclear Energy Agency (NEA), in co-operation, issued Safety Series No. 89 [2] to recommend a policy for exemptions (i.e., clearance) from the basic safety system of notification, registration and licensing that form the basis of regulatory control. Safety Series No. 89 suggests:

- a maximum individual dose per practice of about 10 $\mu\text{Sv}/\text{year}$,
- a maximum collective dose per practice of 1 man.Sv/year,

to determine whether the material can be cleared from regulatory control or other options should be examined. Safety Series No 89 is currently being revised.

A methodology to apply the principles of Safety Series No 89 on the recycling or reuse of material from nuclear facilities was subsequently presented [3]. The results of this document were part of the input in the IAEA process of establishing unconditional release levels for solid materials [4]. This last mentioned report, IAEA TECDOC 855, was issued in January 1996 on an interim basis and is being revised after about three years, to react to comments received and to experience gained in its application. The document recommended nuclide specific clearance levels for solid materials.

EC recommendations - Radiation Protection 89 [5] - were published in 1998 for the recycling of metals from the dismantling of nuclear installations. The proposals cover steel, aluminium, copper and alloys of these metals. While the IAEA TECDOC 855 treated only unconditional clearance, the EC approach provides two options for releasing material

- Direct release based only on surface contamination;
- Melting at a commercial foundry followed by recycle and reuse; mass specific and surface specific levels are provided.

The nuclide specific clearance levels in Radiation Protection 89 are also based on the Safety Series No. 89 criteria.

Earlier, a revised *International Basic Safety Standards for Protection against Ionising Radiation and the Safety of Radiation Sources (BSS)* had been published in 1994. It was based on the recommendations of ICRP 60 [6] and jointly sponsored by the Food and Agricultural Organisation (FAO), the IAEA, the International Labour Organisation (ILO), the OECD/NEA, the World Health Organisation (WHO) and the Pan American Health Organisation (PAHO). The International BSS gives a list of nuclide specific exemption values (both quantities and concentrations).

The EC issued, in May 1996, a Council Directive laying down its BSS for radiation protection [7], with nuclide specific exemption values very similar to those in the International BSS. However, the EC BSS makes a difference between 'practices' covering processes utilising the radioactive, fissile or fertile properties of natural or artificial radionuclides (i.e., the nuclear industry) and 'work activities' where radioactivity is incidental, but can lead to significant exposure of workers or the public (i.e., the TENORM industries).

The USNRC regulation on radiological criteria for the release of a nuclear site for unrestricted use was published in July 1997 [8]. The individual dose criterion to be used according to this NRC regulation is a maximum of 250 $\mu\text{Sv}/\text{year}$ to be compared to the 10 $\mu\text{Sv}/\text{year}$ from Safety Series No 89. The USNRC also published draft criteria NUREG-1640 for the clearance of equipment and material from nuclear facilities in January 1999 [9]. These were, however, based on 10 $\mu\text{Sv}/\text{year}$ maximum allowable individual dose.

The Health Physics Society has endorsed the ANSI Document N13.12, 'Surface and Volume Radioactivity Standards for Unconditional Releases [10]. This has been suggested as an alternative to the draft NRC criteria NUREG-1640. N13.12 is also based on a 10 $\mu\text{Sv}/\text{a}$

individual dose criterion, while until a year or so ago, the ANSI N13.12 draft was still based on 100 $\mu\text{Sv/a}$.

TENORM QUANTITIES

Radiation protection and the management of radioactive material have hitherto been concerned mainly with artificial nuclides arising within the nuclear fuel cycle. In the last few years, there has been an increasing awareness of naturally occurring radioactive material (NORM), however, and the enhancement of its concentration in various non-nuclear industrial processes. This technologically enhanced naturally occurring radioactive material (TENORM) can be of the same activity levels as low level waste and is very similar to the candidate material for exemption and clearance in the nuclear industry, but occurs in quantities that are huge in comparison.

Table I illustrates some of the technologically enhanced NORM arising annually in the United States [11]. Ra 226 with a half-life of 1,600 years is by far the most important radionuclide. These data are only shown to give an idea of quantities and activity levels. Other industries with significant radioactive waste streams are petroleum processing, geothermal plants and paper mills. More or less comparable quantities of TENORM arise in Europe, with similar concentrations of radioactivity[12].

The quantities shown above should be viewed in comparison to candidate material for recycling from the nuclear industry. The European studies for recycling of steel from nuclear facilities have used a basis of 10 000 t/year[5]. The OECD/NEA Task Group on Recycling and Reuse used a quantity of 50 000 t/year in the United States in their study[1].

Table I: Some NORM Quantities [11]

Waste Stream	Production rate (t/year)	U+Th+Ra (Bq/g)
Phosphates	5×10^7	up to 3,700
Coal ash	6.1×10^7	up to 2
Petroleum production	2.6×10^5	up to 3,700
Water treatment	3×10^5	up to 1,500
Mineral processing	10^9	up to 1,100

TENORM REGULATION

Background

The regulatory structure for exempting or releasing material from radiological control is based on the principle of triviality of individual doses to members of the public. The ICRP criterion of 'some tens of microsieverts' became 'ten microsievert or less' in the IAEA Safety Series No 89, which was created at a time when TENORM was unknown or, at any rate, not considered. The **one** and the **same** criterion was later used for two regulatory concepts: **exemption** (from entering regulation), and **clearance** (for release from regulation), with generally a factor ten higher activity concentration values for exemption as for clearance. The difference in activity levels was explained by 'quantities', exemption being applied to **small**

(‘moderate’) quantities and clearance to **large** quantities. In practice, ‘small’ meant say 1-10 t, while in European studies on (clearance for) recycling, the figure of 10 000 t has been used to exemplify ‘large’ quantities.

Later TENORM was discovered. Its **huge** quantities (2 to 3 orders of magnitude larger than those used in the European studies on nuclear recycling), its activity levels and the large number of industries involved are being or have been mapped. It has become obvious that the triviality approach can no longer be used.

The EC Approach

The European Commission, in their BSS [7], propose to solve this problem by dividing occurrences of radioactivity into:

- *Practices*, which utilise the radioactive properties of materials, i.e., the nuclear industry;
- *Work activities*, where radioactivity is incidental (TENORM industries).

The EC-BSS prescribes an individual dose constraint of 10 $\mu\text{Sv}/\text{year}/\text{practice}$ for the nuclear industry. It is not clear in the BSS what is proposed for the TENORM industries. Both in Germany [13] and in Holland [14], however, the level of 1 mSv/year individual dose is being used.

The EC-BSS gives a nuclide specific table of exemption levels for practices. A typical value for nuclides of interest (Co 60, Cs 137, and Ra 226) is 10 Bq/g. The BSS does not give a corresponding table for work activities. However, it was noted at the NORM II meeting in Krefeld, Germany [15], that much higher levels were being used in certain European countries:

- Germany: 500 Bq/g for NORM total activity;
65 Bq/g for Ra 226 (in the above case history);
- Holland: 100 Bq/g for NORM.
- Norway uses the ‘nuclear’ level of 10 Bq/g also for the exemption of Ra 226, and Ra 228 and Pb 210 from the oil and gas industry.

The IAEA Approach

It seems that the IAEA is considering to propose the 10 $\mu\text{Sv}/\text{year}$ individual dose criterion for the nuclear industry and ‘optimisation’ in each individual case of TENORM regulation. In effect, this will mean the release of huge quantities of material from the non-nuclear TENORM industries at much higher levels of individual dose as criterion. Both the IAEA and the EC are thus proposing “double” standards for the judgement of risks from ionising radiation, depending on the industry it arises in.

The process of optimisation seems vague and unde fined. It seems to be ‘intuitive’ rather than being based on any formal risk and cost/benefit analysis. In the IAEA TECDOC 855, there is reference to the optimisation of radiation protection using ‘*cost-benefit analysis, intuitive or formal, or other methods*’. Another IAEA document, TECDOC 987, has an Appendix II on the justification and optimisation of clean-up. The paper refers to ‘*multi-attribute utility analysis*’, and gives an example of an equation, where the net benefit is a function of a number of parameters like avertable collective dose, monetary costs of clean-up,

anxiety regarding the contamination, reassurance by the clean-up, etc. It can be stated about such an 'optimisation' that:

- It is arbitrary; the dollar values of the parameters, specially the last two, can be chosen to give any predetermined result.
- Such 'optimisation' will lead to different results in calculations by different authorities in different states; consistency, harmonisation of regulations as well as trans-boundary transport will be impaired.
- Such calculations will be difficult to explain in communication with the public and difficult to defend in a public debate.

Proposed ANSI Guide

The ANSI guide N13.53 for the control and release of TENORM [16] has administrative release levels based on a maximum of 100 $\mu\text{Sv}/\text{year}$ ('less than 10 mrem in practice'). It does seem rather peculiar that, in spite of the 100 $\mu\text{Sv}/\text{year}$, instead of 10 $\mu\text{Sv}/\text{year}$ as used by IAEA and EC, the release level for Po 210, Pb 210, Ra 226 and other nuclides of the Thorium series is only 0.1 Bq/g, compared to the IAEA's 0.1 to 1 Bq/g (with a representative value of 0.3 Bq/g) and EC's 1 Bq/g. Two questions arise here:

- What are the scenarios used?
- What will this mean to the non-nuclear TENORM industries as regards volumes of radioactive waste?

SOME INCONSISTENCIES/COMPLICATIONS IN PROPOSED REGULATORY APPROACHES

"Double" Standards in Practice

As mentioned earlier, both the IAEA and the EC are proposing "double" standards for releasing radioactive material, with stringent individual dose levels for material from the nuclear industry and a 100 times higher allowable individual dose resulting from the release of similar material from (TENORM) non-nuclear industries. Complications that result from such dual standards in the world of recycling are demonstrated in the following example[13]:

- The German company, Siempelkamp, has melted 350 Mg of scrap from the natural gas industry resulting in:
 - 18 Mg of slag with average specific activity: 93 Bq/g;
 - 1 Mg of filter dust with average specific activity: 535 Bq/g;
 - 3.6 Mg of floor sweepings with average specific activity: 255 Bq/g.

Four of the waste drums exceeded the exemption level of 500 Bq/g. The Federal Collection Depot for radioactive waste offered to store 3 of these for the price of 475 000 DEM. The fourth drum was refused because the activity level of Ra 226 was too high.

'Practicable and economic' waste management alternatives were sought, and the radiological impact of five such alternatives were studied: road construction, shallow land burial, sidewalk, playground, or parking lot. Using the slag for road construction

was finally the chosen method of waste management, and the allowed individual dose criterion was **1 mSv/year**.

- At the same company, radiologically similar slag arises from the melting of material used in ex-vessel core melt experiments (metals with depleted UO_2 powder added to simulate fuel) and scrap from fuel element fabrication. The slag from these melting operations, being from the nuclear industry, is proposed to be regulated under the **10 $\mu\text{Sv/year}$** individual dose criterion.

Disposal Aspects of TENORM

The major TENORM radionuclide is Ra 226, with a half-life of 1600 years, while the dominating nuclides in scrap from the nuclear industry are Co 60 (half-life 5.4 years) and Cs137 (half-life 30 years). Current regulations at many near surface repositories have stringent limits on the quantities and concentrations of longlived nuclides in disposed material, limits that may well make it necessary – according to current regulations for nuclear industry waste – to condemn non-exempted TENORM to deep geological disposal. According to the currently proposed double standards, the same nuclide, at the same concentration, can either be sent to deep geological disposal or release for use in road repair, depending on whether it came from the nuclear industry or a non-nuclear one.

The IAEA has started to study the implications of the need for disposal of huge quantities of such long lived nuclides. A draft paper has been produced on a common framework for the principles of the management of **all** radioactive waste, including waste from mining and processing of radioactive ores and minerals [17]. The document does not, however, consider the candidate material for recycling/reuse or utilisation of very low level radioactive waste. The draft paper mentions mining and milling wastes (MMW) and some other types of slightly radioactive waste streams from non-nuclear industries (TENORM). It does not mention the largest waste stream of this kind: Coal ash.

Coal Ash

According to UNSCEAR, 280 million tons of coal ash arise globally every year. 40 million tons are used in the production of bricks and cement and “a great deal” is utilised as road stabiliser, road fill, asphalt mix and fertiliser. Annual doses to residents can be up to several mSv. These doses are presumably only the gamma component. The main radioactive nuclide in most TENORM is Ra 226 and, as the IAEA draft report [17] points out, SENES has calculated a dose of around 10 mSv/a from 1 Bq of Ra 226 via the indoor radon exposure pathway. So, in addition to the gamma doses, there will also be a considerable dose from the radon.

About 61 million tons of coal ash were generated in the United States by thermal power production in 1990 [11]. Such ash is either disposed or utilised for various industrial applications (more than half for the production of concrete/cement). About 6 million tons of coal ash, with TENORM, is exempted from regulation by the US Environmental Protection Agency (USEPA) for use in building materials. The resulting individual dose to members of the public can be about 100 $\mu\text{Sv/a}$ [18]. The distribution in 1990 between the two alternatives was about 80% disposal to 20% utilisation. The American Coal Ash Association hopes to ultimately reverse this distribution to 20% disposal and 80% utilisation. It is pointed out that

such a high utilisation rate is technically achievable, as rates up to 70% utilisation are not uncommon in Europe.

In Europe, every year about 30 million tons of coal ash are generated. If the American Coal Ash Association is correct, about 21 million tons are utilised. What are the resulting individual doses to the public? It is not known to us whether the EC have made any studies relating to the subject.

Commercial Aspects

The nuclear industry is living in a world where electricity is being deregulated and competition between various sources of power production is fierce. The double standards for clearance/exemption being proposed by the IAEA and the EC for material from the nuclear industries and for TENORM takes on a special significance when it is noted that two of the largest sources of TENORM are the coal and the oil & gas industries.

“Awareness” Aspects

One of the main problems associated with TENORM is that the industries concerned are often not aware of its presence in the product, by-product or the waste. As expressed in an article in Nuclear Europe Worldscan [19]

“Exposure of workers is caused either by external irradiation from stocks of materials or by inhalation of dust. Due to the high radiotoxicity of the natural radionuclides, inhalation of relatively small quantities of NORM gives rise to high internal radiation doses. Dusty working situations are quite common, and in situations where the management is not aware of the presence of NORM, this can easily lead to doses to workers of several mSv per year, up to 20 mSv per year or even higher. A complicating factor is that the detection of inhaled natural radionuclides is generally much more difficult than for artificial radionuclides. The doses to workers in NORM industries is therefore potentially much higher than in the nuclear industry, where internal contamination is usually very well controlled. Also the collective dose to the population due to releases in air (Po 210 and Pb 210 are volatile at higher temperatures) and in water can be significant”.

Codex Alimentarius

The Codex Alimentarius, published by the United Nations bodies, the World Health Organisation (WHO) and the Food and Agricultural Organisation (FAO), suggest guideline levels for radionuclides in foods following a nuclear accident. The Codex guideline levels for various radionuclides are based on a reference level of dose of 5 mSv (= 5000 μ Sv), that being, for most radionuclides, the committed effective dose resulting from the consumption of radioactively contaminated food during the first year following a nuclear accident. Furthermore, the Codex divides radionuclides into three groups based on the dose per unit intake. It suggests that the 5 mSv dose level be applied to each group in order to avoid being unnecessarily restrictive. So theoretically, an individual ingesting food contaminated at the levels specified can be exposed to as much as 15 mSv. Many of the representative nuclides noted in the Codex have long half-lives. Thus, with Cs 137 contamination, the dose levels to the public will not reduce significantly during the following few decades. This results in a direct pathway to the public involving food consumption at doses up to 1.500 times the

hypothetical maximum exposure from the release of cleared materials from the nuclear industry. Even if the Codex corresponds to an accident scenario of low probability, the significant difference in the exposure to the public is disconcerting.

Comparison of Risks between Nuclear and Non-nuclear Radioactivity

Finally, it can be noted that the US National Academy of Sciences has very clearly rejected any possible radiation protection reasons for treating radioactive material from the nuclear industry and that arising from the non-nuclear NORM industries on different risk evaluation standards. In its 'Evaluation of EPA Guidelines for Exposure to NORM [20]', it states:

“The committee is not aware of any evidence that the properties of NORM differ from the properties of any other radionuclides in ways that would necessitate the development of different approaches to risk assessment. In regard to radiological properties, if one accepts the view currently held by all regulatory and advisory organisations involved in radiation protection that estimates of absorbed dose in tissue are the fundamental physical quantities that determine radiation risks for any exposure situation, there is no plausible rationale for any differences in risks due to ionising radiation arising from naturally occurring and any other radionuclides, because absorbed dose in tissue depends only on the radiation type and its energy, not on the source of the radiation”.

CONCLUSIONS

Currently, the regulatory structure for exempting or releasing material from radiological regulation is based on the principle of triviality of individual doses to members of the public. The ICRP criterion of 'some tens of microsieverts' became 'ten microsievert or less' in Safety Series 89, which was created at a time when NORM was unknown. The **one** and the **same** criterion was later used for two regulatory concepts, exemption (from entering regulation), and clearance (for release from regulation), with generally a factor ten higher activity concentration values for exemption as for clearance. The difference in activity levels was explained by 'quantities', exemption being applied to **small** quantities and clearance to **large** quantities.

Since NORM and TENORM were discovered, their **huge** quantities, their activity levels and the large number of industries involved are being or have been mapped. It has become obvious that the triviality approach can no longer be used.

The EC solution to this problem seems to be to relax the **10 μ Sv/year individual dose** to a level of **1 mSv/year for the non-nuclear industries**. The IAEA seems to propose the 10 μ Sv/year individual dose criterion for the nuclear industry and 'optimisation' in each individual case of NORM regulation. This can only complicate the efforts to achieve consistency, harmonisation, ease of trans-boundary movement of material, etc., as it means that radioactivity from the nuclear sphere and the non-nuclear industries are treated on different scales of judgement, having extremely stringent release conditions for the material from the nuclear industries, while allowing up to 100 times higher exposures from the much larger quantities of arisings from non-nuclear industries. In doing this, we are sending a message to the public that nuclear radioactivity is up to a 100 times as dangerous as TENORM radioactivity.

In its 'issues' paper regarding the release of solid materials, the USNRC suggests that the exposure level due to the use of coal ash in building materials (about 100 μ Sv/year individual dose) could be a possible benchmark level for NRC release levels. This seems to reflect the views of the US National Academy of Sciences that there is no plausible difference in the judgement of risks due to exposure to natural or artificial radioactivity.

In the long term, it is absolutely necessary and very important for all the industries concerned, for international transport of material and for public acceptance, to have consistency in the regulatory requirements for radioactivity, irrespective of the industry it arises in.

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