An Overview of the Regulation of Low Dose Radiation in the Nuclear and Non-nuclear Industries

Shankar Menon
Programme Co-ordinator, OECD/NEA Co-operative Programme on Decommissioning

Luis Valencia
Forschungszentrum Karlsruhe, Germany

Lucien Teunckens
Belgoprocess, Belgium

ABSTRACT

Now that increasing numbers of nuclear power stations are reaching the end of their commercially useful lives, the management of the large quantities of very low level radioactive material that arises during their decommissioning has become a major subject of discussion, with very significant economic implications. Much of this material can, in an environmentally advantageous manner, be recycled for reuse without radiological restrictions. Much larger quantities – 2-3 orders of magnitude larger – of material, radiologically similar to the candidate material for recycling from the nuclear industry, arise in non-nuclear industries like coal, fertiliser, oil and gas, mining, etc. In such industries, naturally occurring radioactivity is artificially concentrated in products, by-products or waste to form TENORM (Technologically Enhanced Naturally Occurring Radioactive Material).

It is only in the last decade that the international community has become aware of the prevalence of TENORM, specially the activity levels and quantities arising in so many non-nuclear industries. The first reaction of international organisations seems to have been to propose different standards for the nuclear and non-nuclear industries, with very stringent release criteria for radioactive material from the regulated nuclear industry and up to thirty to a hundred times more liberal criteria for the release/exemption of TENORM from the as yet unregulated non-nuclear industries.

There are significant strategic issues that need to be discussed and resolved. Some examples of these are:

- Disposal aspects of long-lived nuclides,
- The use of radioactive residues in building materials,
- Commercial aspects of differing and discriminating criteria in competing power industries in a world of deregulated electric power production.

Of even greater importance is the need for the discussion of certain basic issues, such as

- The quantitative risk levels of exposure to ionising radiation,
- The need for in-depth studies on populations of the naturally high background dose level areas of the world,
- The validity of the various calculation codes currently used to arrive at mass specific clearance levels for redundant material.

The paper discusses these and other strategic issues regarding the management of redundant low radiation material from both the nuclear and non-nuclear industries, underlining the need for consistency in regulatory treatment.

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 over 40 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 minimisation of the large volumes of contaminated materials that have to be disposed of as radioactive waste is a high priority goal for decommissioners. The recycling of such material (or its reuse or disposal) without radiological restrictions could be a significant means of achieving this goal.

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. A report of the work of the Task Group was published in 1996[1]. The report noted that the criteria proposed by international and national organisations considered only the hypothetical radiological risks associated with recycling. They totally ignored the statistically based, considerably larger industrial risks connected with the replacement (i.e. mining and refining) of material condemned to be buried as radioactive waste, instead of being recycled.

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 µSv/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 report establishing unconditional release levels for solid materials [3], IAEA TECDOC 855, was issued in January 1996 on an interim basis and is being revised reacting 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 [4] - 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 [5] 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 [6], 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 [7]. The individual dose criterion to be used according to this NRC regulation is a maximum of 250 μSv/year to be compared to the 10 μSv/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 [8]. These were, however, based on 10 μSv/year maximum allowable individual dose.

The Health Physics Society has endorsed the ANSI Document N13.12, ‘Surface and Volume Radioactivity Standards for Unconditional Releases [9]. This has been suggested as an alternative to the draft NRC criteria NUREG-1640. N13.12 is also based on a 10 μSv/a individual dose criterion, while until a year or so ago, the ANSI N13.12 draft was still based on 100 μSv/a.

During 1999, the USNRC held a number of public meetings to discuss the issue of clearance, but was unable to convince consumer and environmental groups (and even some industrial groups) that clearance was desirable. The National Research Council (of the US National Academies) was then asked by the USNRC to set up a committee to provide advice. The committee’s report “The Disposition Dilemma” [10] was issued in 2002. It suggested a number of policy approaches covering case-by-case, general, conditional clearance or “no-release”, without recommending any specific one of these. It pointed out that if the NRC chooses to develop new regulations for clearance, it should take into account the implications for the management of TENORM

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 1 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[4]. 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 1: Some NORM Quantities [11]

Waste Stream	Production rate (t/year)	U+Th+Ra (Bq/g)
Phosphates	5 x 10^7	up to 3,700
Coal ash	6.1 x 10^7	up to 2
Petroleum production	2.6 x 10^5	up to 3,700
Water treatment	3 x 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 different levels for clearance and exemption on the basis of "quantities" can no longer be justified.

The EC Approach

The European Commission, in their BSS [6], 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 µSv/year/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.

During 2001, the EC has published document Radiation Protection 122, regarding the application of the concepts of Exemption and Clearance to Practices (Part I) and Work Activities (Part II). The individual dose criterion for clearance of material from practices is 10 µSv/year, while that for work activities is 300 µSv/year. This glaring inconsistency in the regulatory treatment of radioactivity (and the consequent doses to the public) in the nuclear industry and the non-nuclear industries is illustrated clearly in the proposed clearance levels for Ra 226 in Radiation Protection 122. In Part I, which covers "practices" (i.e. the nuclear industry), the prescribed clearance level in 0.01 Bq/g. In Part II, which deals with "work activities" (i.e. TENORM industries), the proposed clearance level is 0.5 Bq/g, a value that is 50 times higher.

The IAEA Approach

It seems that the IAEA is considering to propose the 10 µSv/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 different standards for the judgement of risks to the public from ionising radiation, depending on the industry it arises in.

The process of optimisation seems vague and undefined. 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.

In the summer of 2001, the IAEA presented a basically new approach by suggesting

– It is sensible to use one unique set of radionuclide specific levels for the purpose of indicating a boundary between radioactive material that may not warrant imposition of the regulatory system and material that may warrant regulation.

– Preliminary proposals:
  - Single set of values for defining scope of BSS in terms of Bq/g (would, in principle, replace previous generic exemption levels, clearance levels and commodity levels),
  - Applies to all materials except food and water,
  - The BSS would be modified by introducing a definition of its scope and removing existing exemption levels and references to clearance.

These proposals are laid out in a report entitled *The Scope of Radiation Protection Safety Standards: Strategy for Rationalisation of Policy*.

At a Technical Committee Meeting in July 2001, a proposal was discussed of 300 µSv/year for "de facto" situations (meaning TENORM) and 10 µSv/year for practices (the nuclear industry). All the above suggests that the situation is fluid and that there is no international consensus in this area.

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 μSv/year ('less than 10 mrem in practice'). It does seem rather peculiar that, in spite of the 100 μSv/year, instead of 10 μSv/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 BASIC ISSUES

Basis for judgement of risks

The risk assessment on the health effects of incremental doses (incremental to background) is generally expressed in terms of the lifetime risks of cancer. The cancer risk factor is based on epidemiological studies of 75000 atomic bomb survivors (from Hiroshima/Nagasaki) who received more than 200 mSv at a dose rate of 6 Sv/s. ICRP 60 states: "Although the study group is large (about 80000), excess numbers of malignancies, statistically significant at the 95 % level, can be found only at doses exceeding 0.2 Sv". ICRP 60 also says that, based on UNSCEAR (1988b) and BIER V Committee estimations, the "average" of the various values for risks used by these committees is broadly about 10 x $10^{-2}Sv^{-1}$ and this value will be used as the nominal risk for acute high dose exposure. Then they use a dose and dose-rate effectiveness factor (DDREF) of 2 to give a nominal value of 5 x $10^{-2}Sv^{-1}$ for the probability of an induced fatal cancer in a population of all ages exposed to low dose radiation.

Regarding DDREF, a number of UNSCEAR, BEIR and NUREG committees have used values between 2 and 10. ICRP 60 writes "In view of these considerations and especially that limited human information suggests a DDREF in the low region of the range, the Commission has decided to recommend that for radiation protection purposes, the value of 2 be used for the DDREF, recognising that the choice is somewhat arbitrary and may be conservative".

To summarise, the results of the high dose, high dose-rate exposures at Hiroshima/Nagasaki are being extrapolated by a factor of over 12 orders of magnitude when evaluating the risks for an annual exposure of 1 mSv (e.g. 1000 h at 1 μSv/h). In the case of an annual exposure of 10 μSv, the extrapolation will be over 14 orders of magnitude.

High Background Dose Radiation Areas

Ramsar is a city on the Caspian Sea in northern Iran. The 2000 inhabitants of this city receive an annual absorbed dose from external beta-gamma radiation alone of up to 260 mSv/year, which is many times higher than the 20 mSv/year, that is the permitted dose for workers at many nuclear power stations. The high radiation levels are due to the presence of Ra 226 in the local rocks, which are used in the building of most of the houses in the city.

A presentation was made at the recent VALDOR (VALues in Decisions On Risks) international conference on the results of some preliminary biological studies on the citizens of Ramsar [21].

In addition to the external beta-gamma radiation, the inhabitants are exposed to ground water radium concentrations of several hundred Bq/*l* plus the radium in the food, as well as indoor radon concentrations of up to several thousand Bq/m^3. The inhabitants of Ramsar have thus been subjected to a wide range of exposure levels and types of exposure (external beta-gamma, inhaled radon, ingested radium) over several generations. Thus they appear to constitute an appropriate group for being the basis for the formulation of radiation protection measures for the public.

The results of the preliminary biological studies show that:

- Cancer mortality and life expectancy do not appear to be different in the High Background Radiation Areas (HBRA) and in near-by Normal Background Radiation Areas (NBRA). These results are at present based on anecdotal information and an epidemiological study has been started to confirm them.
- Citogenic tests have shown that there are no statistically significant differences between HBRA and NBRA residents. Other testing has shown that there is no reduction in immune system functions or adverse hematological effects among Ramsar citizens compared with NBRA residents.
- The most interesting results were those of an *in vitro* exposure of blood samples (lympocytes) from people from both HBRA and NBRA to a "challenge" dose of 1.5 Gy of gamma radiation. Here, the HBRA residents showed only 56 % of the average number of induced chromosomal abnormalities of NBRA inhabitants, indicating the development of certain adaptive response to radiation dose in the HBRA residents.

The authors note that similar studies at other HBRAs such as Yangjiang, China and Kerala, India, had also given similar results regarding cancer mortality, life expectancy, chromosome aberrations and immune function.

Validation of Calculation Codes

All proposals for clearance levels are based on predicted scenarios for subsequent utilisation of the released materials. The calculation models used in these scenarios tend to utilise conservative data regarding exposure times and dose uptake as well as other assumptions as a safeguard against uncertainties.

Another aspects is common to all these calculation models and codes: none of them has ever been validated by comparison with the actual real life practice of recycling. An international project has recently been concluded where two calculation codes used for this purpose (the RESRAD-RECYCLE and CERISE codes) were used to calculate the dose uptake by workers, during the segmentation and melting of a contaminated fuel rack at Studsvik RadWaste, Sweden. These calculated doses were compared with electronic dosimeter measurements on workers participating in the various operations. The measurements showed that segmenting was the work operation that gave the highest dose, almost 65 % of the total dose incurred, while melting itself accounted for only about 13 %.

The project was a co-operation between the Swedish Radiation Protection Institute, Studsvik (Sweden), the US Department of Energy, Argonne National Laboratory (USA), the Institute de Radioprotection et Securité Nucléaire (France) and Belgoprocess (Belgium).

The comparison of the calculation results indicated that, even with a carefully controlled reflection of reality with respect to geometry and exposure time and with a "best judgement" choice of densities for each operation, the calculation programmes have tended to overestimate the dose uptake by a factor 4 to 7, i.e. about an order of magnitude. An obvious explanation is the fact that the workers are not static, they move about constantly, changing the geometry, thus not taking the assumed doses. There are also some other practical aspects difficult to reflect exactly in the calculations. It should be noted that the Swedish Radiation Protection Institute were not completely of the same opinion as the project team, pointing out that the codes also underestimated doses for certain operations. We feel, however, that this is irrelevant, as only the maximum estimated doses for any operation in the process are used for the determination of clearance levels.

It seems reasonable to state that the use of 'enveloping' scenarios, which necessarily cover a wide range of scenarios in connection with the calculation of clearance levels, would tend to accentuate this tendency of overestimation of dose uptake in most individual cases of recycling by melting. Taking into account the sensitivity of the modelling and the practical aspects listed above, the estimated doses can be, say, one or even more orders of magnitude higher than those actually taken.

A side aspect of the execution of the Validation Project – specifically the background measurements – was the revelation of radioactivity in unexpected places: the paint used for the painting of moulds at Åkers (3-5 Bq/g), the slag binding product (twice background radiation), the stamp mass, insulation and new asphalt at the Studsvik furnace (all at three to four times background). This serves to illustrate the undetected omnipresence of radioactivity in the human habitat at dose rate levels considerably higher (up to 400 % over background) than the levels (ca 1 % over background) at which the currently proposed clearance criteria are based on.

Finally, it is important to note that the degree of overestimation (a factor of 4 -7), as recorded in the validation project, is generally regarded as 'acceptable' by dose modellers. The results will most probably not lead to any revision or refinement of these codes. For the nuclear decommissioner and the other producers of large volumes of only slightly radioactively contaminated material, the clearance levels resulting from such a degree of conservatism can lead to huge amounts of material unnecessarily being condemned to burial as radioactive waste. Considering that most such producers transfer their costs to the public, it is society at large that will foot the bill for this exercise in conservatism.

SOME INCONSISTENCIES/COMPLICATIONS IN PROPOSED REGULATORY APPROACHES

Recycling with two differect standards

As mentioned earlier, both the IAEA and the EC are proposing different 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 µSv/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 different standards for different industries, 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 each 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 µSv/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 differing 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".

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. It is noted that the risks for cancer from the low dose/low dose-rate exposures in connection with such clearance of material are being judged on the "somewhat arbitrary" extrapolation of the results of studies at Hiroshima/Nagasaki, where the doses/dose-rates were more than 10 orders of magnitude higher. The first ever actual validation of two calculation codes used for determining clearance levels has indicated that the doses in connection with recycling by melting may be overestimated by one or even more orders of magnitude.

The ICRP criterion of 'some tens of microsieverts' became 'ten microsievert or less' in Safety Series 89, which was created at a time when TENORM 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 this approach can no longer be used.

Both the EC and the IAEA seem to be proposing different standards of 10 µSv/year individual dose criterion for release of material from the nuclear industry and 300 µSv/year (or even 1 mSv/a) for the orders of magnitude larger quantities of material from the non-nuclear industries. 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 30-100 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.

Even the 300 µSv/year criterion is 2 to 3 orders of magnitude lower than the doses taken for generations by tens of thousands of people living in the high background dose areas of the world, without showing noticeable effects on cancer mortality, life expectancy, chromosome aberrations or immune function.

In Radiation Protection 122, the EC has justified the selection of the 300 μSv/year criterion by the following:

- It is comparable to regional variations in dose from natural background radiation,
- It is coherent with exemption levels for building materials (in Radiation Protection 112),
- It is coherent with dose constraints for effluents to air and water (300 μSv recommended by ICRP for the nuclear industry),
- It is below the lower marker point for worker exposure in "work activities" (EC term for non-nuclear industries).

It is to be noted that all the above justifications are equally relevant for the clearance of material from the nuclear industry.

Additionally, against the background that:

- The BSS says in its title "for the protection of workers and the general public against the dangers of ionising radiation",
- The US Academy of Sciences has stated that there is no plausible rationale for any difference in risks from naturally occurring or any other radionuclides,
- The candidate quantities of TENORM for release are more than 3 orders of magnitude larger than those from the nuclear industry,

it is suggested that the proposed EC dose criterion for "work activities" should apply also for material from the nuclear industry. It is time to do away with inconsistencies and have one unique dose criterion for all types of exposure to ionising radiation, regardless of its source.

REFERENCES

1. OECD NUCLEAR ENERGY AGENCY, Nuclear Decommissioning. Recycling and Reuse of Scrap Metals, OECD, 1996.
2. INTERNATIONAL ATOMIC ENERGY AGENCY, Principles for the Exemption of Radiation Sources and Practices from Regulatory Control. IAEA Safety Series No. 89, Vienna 1988.
3. INTERNATIONAL ATOMIC ENERGY AGENCY, Clearance Levels for Radionuclides in Solid Material. Interim Report for Comment, IAEA TECDOC 855, January 1996.
4. EUROPEAN COMMISSION, Radiation Protection 89. Recommended radiological protection criteria for the recycling of metals from the dismantling of nuclear installations. Luxembourg 1998.
5. 1990 Recommendations of the International Commission on Radiological Protection. ICRP 60 Pergamon Press, 1991.
6. EUROPEAN COMMISSION, Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of workers and the general public against the dangers arising from ionising radiation.
7. Subpart E, "Radiological Criteria for License Termination" of 10 CFR Part 20, published as 62 FR 39058, July 21, 1997.
8. US NUCLEAR REGULATORY COMMISSION, Radiological Assessments for Clearance of Equipment and Material from Nuclear Facilities (Draft Report for Comment), NUREG 1640, 1999.
9. AMERICAN NATIONAL STANDARDS INSTITUTE, Surface and Volume Radioactivity Standards for Unconditional Releases. ANSI 1997 N13.12.
10. US NATIONAL RESEARCH COUNCIL
The Disposition Dilemma
Controlling the Release of Solid Materials from Nuclear Regulatory Commission – Licensed Facilities, 2002
11. US ENVIRONMENT PROTECTION AGENCY, Diffused NORM Waste - Waste Characterisation and Preliminary Risk Assessment. April 1993, Draft RAE - 9232/1, 1993.

12 MARTIN A., et al, Materials containing natural radionuclides in enhanced concentrations. Nuclear Science and Technology. European Commission EUR 17625 EN, 1997.

13 SAPPOCK M., QUADE U., WIENERT R., Experiences with the Release of Radioactive Wastes and Problems related to their Storage in Final Depository. Waste Management '99, Tucson, Arizona, 1999.

14 SHELL SAFETY AND HEALTH COMMITTEE, Ionisation Radiation Safety Guide. Shell Internationale Petroleum Maatchappij BV, The Hague, The Netherlands, 1993.

15 EUROPEAN COMMISSION/KEMA/SIEMPELKAMP, Proceedings of the NORM II Second International Symposium.

16 AMERICAN NATIONAL STANDARDS INSTITUTE, Guide for Control and Release of Technologically-Enhanced Naturally Occurring Radioactive Material, ANSI Draft (Ver.2), March 1999 update.

17 INTERNATIONAL ATOMIC ENERGY AGENCY, Draft Document on a Common Framework for the Application of the Principles of Radioactive Waste Management to All Types of Radioactive Waste, Vienna, June 2000.

18 US NUCLEAR REGULATORY COMMISSION, Release of Solid Materials at Licensed Facilities: Issues Paper. Federal Register: June 30, 1999 (Vol.64, Number 125).

19 LEFAURE C (CEPN), Van der STEEN J (ERG)
Advancing Optimisation of Radiological Protection
Nuclear Europe Worldscan 9-10 ---, 2000

20 US NATIONAL ACADEMY OF SCIENCES, Evaluation of Guidelines for Exposure to Technologically Enhanced Naturally Occurring Radioactive Materials. National Academy Press, Washington.

21 KARAM A, JAVAD MORTAZAVI S M

The Very High Background Radiation Area in Ramsar, Iran: Public Health Risk or Signal for Regulatory Paradigm Shift?
VALDOR conference, Stockholm, June 2001-08-10