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The Regulation of NORM from a Nuclear Decommissioner's Viewpoint

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

ABSTRACT

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) and the enhancement of its concentration in various non-nuclear industrial processes. This technologically enhanced NORM is 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.

Nuclear decommissioning projects are characterised by the large volumes of very low activity level materials arising. So the regulatory treatment of much larger volumes of material with similar radiological characteristics in the non-nuclear industries is being viewed with the greatest interest by the nuclear industry.

This paper gives an overview of the quantities of NORM arising both in Europe and the United States. An evaluation of the radiological impact of NORM in the Nordic countries is presented. Finally a comparison is made between some of the regulatory approaches being considered for NORM and the current regulatory treatment of very low level material in the nuclear industry.

INTRODUCTION

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. Much of the redundant material is at very low levels of activity and is valuable for recycling, thus conserving natural resources and protecting the environment. The recycling of such material (or its reuse or disposal), without radiological restrictions, is seen as a significant means of achieving the aim of waste minimisation.

In the last few years, there has been an increasing awareness of naturally occurring radioactive material (NORM and the enhancement of its concentration in various non-nuclear industrial processes. This technologically enhanced NORM is of the same activity levels as the low level redundant material arising from the decommissioning of nuclear facilities, but occurs in quantities that are huge in comparison.

Many national and international organisations have put forward (or are working on) proposals, recommendations or directives regarding the activity levels at which material could be exempted or released from radiological regulation. Lately such discussions have also covered NORM. As the radiological characteristics of technologically enhanced NORM are very similar to those of candidate material for recycling from the nuclear industry, nuclear decommissioners are very interested in the regulatory treatment of such material.

This paper will focus on the quantities of NORM arising in the USA and in Europe, the collective dose impact of NORM on the population and on a comparison between the proposed regulatory treatment of NORM and radiologically similar material from the nuclear industry.

QUANTITIES OF NORM ARISING

The quantities of candidate material assumed in various studies on recycling from the nuclear industry have been

- 10000 t of steel per year arising from decommissioning projects in European studies [1],
- 50000 t of steel per year in the OECD Nuclear Energy Agency's Task Group on Recycling and Reuse study [2].

In comparison, the quantities of technologically enhanced NORM arising in the USA are huge, as illustrated in Table I, which shows the volumes and radioactivity of such material arising annually in the United States [3, 4]. More or less comparable quantities of NORM arise in Europe, with similar concentrations of radioactivity, as shown in Table II [5].

TABLE 1 Sources, Volumes and Concentrations of Naturally Occurring Radioactive Materials [3]*

Waste Stream	Production Rate per Yr.	Total U Bq/kg	Total Th Bq/kg	Total Ra Bq/kg
Phosphate	5.0×10^{10} kg	bkgd - 3000	bkgd - 1800	400 - 3700000
Phosphogypsum	4.8×10^{10} kg	bkgd - 500	bkgd - 500	900 - 1700
Slag	1.5×10^{9} kg	800 - 3000	700 - 1800	400 - 2100
Scale	4.5×10^{6} kg	**	**	1100 - 3700000
Coal Ash	6.1×10^{10} kg	100 - 600	30 - 300	100 - 1200
Fly Ash	4.4×10^{10} kg	**	**	**
Bottom Ash	1.7×10^{10} kg	**	**	**
Petroleum Production	2.6×10^{8} kg	**	**	bkgd - 3700000
Scale	2.5×10^{7} kg	**	**	bkgd - 3700000
Sludge	2.3×10^{8} kg	**	**	bkgd - 3700
Petroleum Processing	**	**	**	***
Refineries	**	**	**	> 4000
Petrochem Plants	**	**	**	> 4000
Gas Plants	**	**	**	***
Water Treatment	3.0×10^{8} kg	**	**	100 - 1500000
Sludges	2.6×10^{8} kg	**	**	100 - 1200
Resins	4.0×10^{7} kg	**	**	300 - 1500000
Mineral Processing	1.0×10^{12} kg	6 - 129000	8 - 900000	< 200 - 129000
Rare Earths	2.1×10^{7} kg	26000 - 129000	9000 - 900000	13000 - 129000
Zr, Hf, Ti, Sn	4.7×10^{8} kg	6 - 3200	8 - 660000	300 - 18000
Alumina	2.8×10^{9} kg	400 - 600	500 - 1200	300 - 500
Cu and Fe	1.0×10^{12} kg	< 400	< 400	< 200
Geothermal Waste	5.4×10^{7} kg	**	**	400 - 16000
Paper Mills	**	**	**	> 3700

* Derived partially from US EPA, 1993 [4]
** Data not available
*** Lead-210 and Polonium-210

Table II:1 NORM and Technologically Enhanced NORM [5]

PROCESS **i) Feed materials** **ii) Product** **iii) By-product/Waste**	**SCALE OF OPERATION**	**PROMINENT RADIONUCLIDES**	**TYPICAL ACTIVITY CONCENTRATIONS (Bq/kg) AND ENHANCEMENT**	**RADIOLOGICAL IMPACT** **(O)ccupational** **(P)ublic**
Power production from coal: i) Coal. ii) Energy production. iii) Coal ash (bulk and aerosol), sludges.	World-wide usage. iii) 30 Mt/a coal ash in the EU.	i) U 238 and Th 232 + d's. iii) As feed material but more volatile components (Pb 210 and Po 210) follow airborne pathways.	i) 20 Bq/kg for each of U 238 and Th 232, both with d's in equilibrium. iii) Factor 10 enhancement for U 238 and Th 232, perhaps a factor 100 for volatiles: Pb 210, Po 210.	(O) Active dust exposure: Pb 210 and Po 210, ~μSv/a. (P) Negligible dose from power plant, but poorly disposed ash can contaminate foodchain, 10's μSv/a.
Phosphate ore processing and use: i) Phosphate rock. ii) Phosphoric acid, fertiliser. iii) Slag, slurry, off-gas.	i) 126 Mt/a (world). ii) 4 Mt/a phosphate fertiliser in EU.	i) U 238 and Th 232 +d's. ii) Up to 50 % enhancement, especially Ra 226 in fertilisers. iii) Ra 226, Pb 210, Po 210.	i) 100's - 1000's Bq/kg in ore. ii) 100's - 1000's Bq/kg in fertiliser. iii) 5000 Bq/kg Ra 226 in phosphogypsum.	(O) 5 μSv/a for plant workers and 100's μSv/a for transport and storage workers. (P) 2 μSv/a from fertilisers, up to several mSv/a doses from certain marine pathways otherwise only μSv/a doses from alternate pathways.
Recycling waste in building materials: i) By-products/wastes. ii) Bricks, concrete, cement... iii) Slag, scales, gases, used products.	i) Process wastes recycled whenever possible: coal ash, phosphogypsum, slag... ii) Only lower activity materials used in inhabited structures. iii) Further recycling possible.	U 238 and Th 232 + d's as from process wastes. ii) Rn 222 + d's accumulation in buildings, otherwise external exposures from gamma emitting nuclides.	ii) 50 - 100 Bq/kg U 238 / Th 232 / Ra 226.	(O) 100's μSv/a from dusty operations. (P) Up to 500 mSv/a from close association with active buildings and roads. Rn + d's build-up in unventilated buildings
Rare earths and zirconium: i) Rare earth and zirconium ores. ii) Refined ores, glazes, polish, refractories. iii) Solid waste, aerosols, used products.	i) 0.7 Mt/a of zirconium ore (world), 30 kt/a rare earths in EU. ii) Milling and processing of Zr operations on 1 y in EU.	U 238 and Th 232 + d's.	100's - 1000's Bq/kg for both ores, products and wastes.	(O) Minimal μSv/a doses due to protective measures. (P) Little impact noted.

Table II:2 NORM and Technologically Enhanced NORM [5]

PROCESS **i) Feed materials** **ii) Product** **iii) By-product/Waste**	**SCALE OF OPERATION**	**PROMINENT RADIONUCLIDES**	**TYPICAL ACTIVITY CONCENTRATIONS (Bq/kg) AND ENHANCEMENT**	**RADIOLOGICAL IMPACT** **(O)ccupational** **(P)ublic**
Metal smelting: i) Metal ores (Sn, Nb, Pb, Bi, Fe...). ii) Metals / alloys (steels). iii) Slags, scales, aerosols and gases.	130 Mt/a crude steel in EU. Niobium steel production much smaller.	ii) Pb 210 and Po 210 in tin smelting. iii) U 238 and Th 232 in slag, Pb 210 and Po 210 in dusts.	i) 500 - 100 Bq/kg in ores. iii) Various waste products 10^2 10^5 Bq/kg. 10 000's Bq/kg U 238 and Th 232 in niobium steel ore, product and waste.	(O) Fractions of mSv/a from tin smelting and low doses from steel production. Niobium steel production: 4 mSv/a with protective measures. (P) 10's µSv/a from various exposure pathways.
Storage and use of copper mining tailings: i) Copper ore. ii) Copper. iii) Rock, slags, sludge, roast product.	Exploitation of high activity tailings previously occurred in Eastern Germany.	i) U 238 and Th 232 + d's in ores. iii) Ra 226, Pb 210 and Po 210 progeny in solid and sludge wastes. Pb 210 and Po 210 in airborne waste streams	iii) Slags: 1000 Bq/kg Ra 226. some sludges and furnace wastes have up to 20 000 Bq/kg Pb 210 and Po 210.	(O) Nil - industry closed. (P) Local waste piles: dose rates of 100's - 1000's µSv/h.
Oil and gas production: i) Natural oil and gas reservoirs. ii) Purified oil and gas. iii) Sludge, scale.	i) Largely North Sea regions. ii) 140 Mt/a oil in EU, 2×10^{11} m^3/a gas in EU. iii) 10 000/m^3 of active waste before treatment from EU oil and gas industries.	i) U 238 and Th 232 0 d's. ii) Natural gas has radon content. iii) Ra 226, Pb 210 and Po 210 in scales and sludges.	ii) 300 Bq/m^3 Rn 222 on average in natural gas. iii) 10^5 Bq/kg each in sludges and up to several times this in scales.	(O) 1-2 mSv/a from working with or in the vicinity of scales and sludges. (P) Little contact between the public and the industries.
Other minor processes: i) Various. ii) Chemicals, water usages, glass... iii) Various.	Generally small scale operations with limited public contact. Water use in treatment plants and spas. Chemical industry scale in not recorded.	Various: U 238 and Th 232 + progeny. Water: radon plus progeny can be significant.	Little known about the radionuclide involvement in the chemical industry. Perhaps as much as 10^5 Bq/kg Ra 226 in mineral waters.	(O) Tend to be localised doses to parts of the body. Perhaps several mSv/a from Rn 0 d's to those workers in spas. (P) 10's µSv/a from radon in water supplies.

RADIOLOGICAL IMPACT OF NORM

A characteristic of NORM is that, because of their wide distribution from many sources, they give rise to relatively large collective radiological doses to the public in comparison to those caused by the nuclear industry. This is vividly illustrated in a study, made in 1990 [6] by the radiation protection authorities from the five Nordic countries, on the annual collective dose to their populations from natural radioactive sources, including some NORM-related ones. The respective contributions of the various sources were compared with the collective dose taken by the Nordic populations during the first year after the Chernobyl accident as well as with the annual collective dose from the operation of the 16 nuclear reactors in Sweden and Finland, with the following results:

Table III **Annual collective dose to population in Nordic Countries from natural radioactive sources, Chernobyl and operation of 16 nuclear power plants**

Source	Collective Dose Person-Sv/a
Radon in dwellings	65 000
Artificial fertiliser	50
Energy production (Thermal, non-nuclear)	80
Radioactivity in own body	8 100
Ground, building materials, etc	11 600
Cosmic radiation	7 100
Chernobyl accident (First year)	6 000
Normal operation of nuclear reactors in Sweden and Finland	20

On closer examination of the study report, the comparative impact of some of the NORM-related industries are, in fact, even more significant than shown.

The 20 person-Sv/year from the operation of the nuclear reactors is mostly occupational doses to the operating personnel. The total collective dose to the general public from plant emissions is less than 1 person-Sv/year.

The annual 50 person-Sv dose shown in the figure coming from artificial fertiliser covers only the internal doses taken by the Nordic public, through ingestion of food produced on the fertilised soil. The external doses have not been included. The figure does not either cover the use of the by-product, gypsum, as a building material. Even a modest use of gypsum in homes could lead to an annual collective dose of about 100 person-Sv.

The figure of 80 personSv/year due to energy production from coal (mainly in Denmark) and from peat (mainly in Finland) refers only to radioactive emissions from the power plants. Not shown are the effects of the use of some of the fly ash in concrete, which increases the external gamma radiation in buildings and is likely to dominate the total dose from the use of coal and peat. The report mentions that most of the bottom ash ends up on municipal tips but does not attempt to estimate the radiological impact.

The Nordic study thus shows that the collective dose from the operation of the 16 nuclear plants is 1 person-Sv, while the use of artificial fertiliser and the operation of coal and peat for energy production causes two to three orders of magnitude higher collective population doses.

CURRENT REGULATORY APPROACHES

In connection with regulation of radioactivity, the following words are conventionally in use to denote specific conditions:

- **Exclusion** covers activity sources not amenable to control, such as K-40 in the human body, cosmic radiation, etc.,
- **Exemption** denotes radioactive materials which never enter the regulatory regime because it is considered that they give rise to low risks, and control would be a waste of societal resources,
- **Clearance** refers to material that has earlier been regulated but is released from regulatory control.

It is to be noted that, in principle, both "exempted" and "cleared" materials have, at the same activity levels, the same radiological impact on human beings.

In the nuclear industry, exemption and clearance are based on the IAEA Safety Series 89 [7], which prescribes

- a maximum individual dose/practice of about 10 μSv/year,
- a maximum collective dose/practice of 1 person-Sv/year,

to determine whether the material can be cleared from regulatory control or other options should be examined. The IAEA TECDOC 855 [8] was issued on these bases in January 1996 on an interim basis and will be revised after about three years to react to comments received and to experience gained in its application. This document presents recommended nuclide specific clearance levels for solid materials.

The EC recommendations for clearance levels for recycling of metals [1] were also based on the Safety Series 89 criteria.

To a large extent, the radiation protection regulators have been focusing on the nuclear fuel cycle with little attention given to the technological concentration of radioactivity in the

NORM industries. Consequently, the current regulatory management of NORM is very inconsistent with that of similar material arising in the nuclear industry.

Examples:

- Current level for clearance of material from the nuclear industry in Sweden is 0.5 Bq/g, while current exemption level for non-nuclear industries (by European Commission Directive 84/467/Euratom of 1984) is 100 Bq/g (or 500 Bq/g for "solid natural material").
- Exemption level for oil and gas industry NORM wastes [9]:
  - In the Netherlands, 100 Bq/g,
  - In Germany, 500 Bq/g.
- For subsurface road stabilisation in Germany:
  - Clearance level for concrete from a nuclear plant was 0.5 Bq/g,
  - Exemption level for slag from melting of scrap from the oil and gas industry was 65 Bq/g (to be diluted by a factor 4)

The EC came out with a new Directive in May 1996, with revised basic safety standards (BSS) for the radiation protection of both workers and the general public [10]. The Directive covers radioactivity in both nuclear and non-nuclear industries and will have to be ratified by member states within 4 years, i.e. by May 2000. In the BSS, industries are divided into "practices" (where radionuclides are, or have been processed in view of their fissile or fertile properties) and "work activities" (where the presence of radioactivity is incidental). Broadly speaking, "practices" refer to the nuclear industries, while "work activities" to the non-nuclear ones, i.e. industries like oil and gas or phosphate industries. The table of exemption values in the new EC-BSS covers only practices. The exemption values for work activities are not explicitly given. It seems clear, from the presentations at the NORM II meeting in November 1998, that the exemption values for material from non-nuclear industries can be based on a criterium of 1 mSv/year individual dose to the public, which is a factor of 100 greater than that for similar material from the nuclear industry [12].

In the United States, a draft set of regulations for technologically enhanced NORM (TENORM) was given out in February 1997 by the Conference of Radiation Control Program Directors (CRCPD). The CRCPD is an organisation primarily consisting of directors and technical staff from state and local radiation control programs and functions as the common forum for state, local and federal regulatory agencies to address NORM-related health and safety issues. Several states have already regulations in place to meet their specific individual needs. There is, however, no uniformity in these regulations. One of the main aims of CRCPD is working towards uniformity in regulations governing radiation [11].

SUMMING UP

The recycling and reuse of material arising from the decommissioning of nuclear facilities can very significantly affect the volume that would have to be disposed of as radioactive waste. Internationally accepted radioactivity clearance levels for such material are a necessary requirement for utilising this alternative advantageously.

Various national and international bodies have issued interim or draft recommendation on exemption and clearance levels. Recent discussions have also covered the management of radioactivity in "non-nuclear" industries, where naturally occurring radioactivity is technologically enhanced to levels similar to those in low level redundant material arising from the decommissioning of nuclear facilities. The quantities of such technologically enhanced NORM are much larger than the candidate material for recycling from the nuclear industry.

The current approach as to the radiological regulation of technologically enhanced NORM seems to differ greatly from the stringent regulation of similar material in the nuclear industry. There is a great need for imposing consistency on the regulatory treatment of radioactive material, irrespective of the industry it arises in.

REFERENCES

1. EUROPEAN COMMISSION
Radiation Protection 89.
Recommended radiological protection criteria for the recycling of metals from the dismantling of nuclear installations. Luxembourg 1998

2. OECD NUCLEAR ENERGY AGENCY
Nuclear Decommissioning.
Recycling and Reuse of Scrap Metals.
OECD 1996

3. SCOTT L.M.
Regulation of Naturally Occurring Radioactive Materials in Non-nuclear Industries.
IAEA Specialists' Meeting on Exclusion, Exemption and Clearance, Vienna, May 1997.

4. US ENVIRONMENT PROTECTION AGENCY
Diffused NORM Waste - Waste Characterisation and Preliminary Risk Assessment,
April 1993, Draft RAE - 9232/1, 1993.

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

6. CHRISTENSEN T., EHDWALL H., STRANDEN E.
Natural Radiation, Nuclear Wastes and Chemical Pollutants,
Nordic Nuclear Safety Research,
Report NKA-RAS-430 (1990).

7. INTERNATIONAL ATOMIC ENERGY AGENCY
Principles for the Exemption of Radiation Sources and Practices from Regulatory Control.
IAEA Safety Series No. 89, Vienna 1988

8. INTERNATIONAL ATOMIC ENERGY AGENCY
Clearance Levels for Radionuclides in Solid Material.
Interim Report for Comment.
IAEA - TECDOC-855 January 1996

9. Van Weers A. W. et al
Current practices of dealing with natural radioactivity from oil and gas production in EU member states.
Nuclear Science and Technology,
European Commission EUR 17621 EN 1997

10. 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.

11. CRCPD
Part N: Regulation and Licensing of Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM). Draft,
Frankfort, Kentucky, February 1997

12. EUROPEAN COMMISSION/KEMA/SIEMPELKAMP
Proceedings of the NORM II Second International Symposium.
November 10-13, 1998 Krefeld, Germany