NORM IN AUSTRALIA: A REGULATORY AND SCIENTIFIC PERSPECTIVE.

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1. ABSTRACT

Naturally occurring radioactive materials (NORM) are found in many aspects of our daily lives. These materials are often used in large volumes and in situations where they are not thought of as being "radioactive". This paper commences with a description of the wide range of NORM found in Australia and the uses to which they are put, including the processes which give rise to NORM and the products, by-products, wastes, etc., that result from those processes. The paper then presents the current radiation protection approach taken by the various federal and state authorities. The regulatory regimes are described as well as descriptions of the manner in which various authorities are dealing with the associated issues of realistic risk assessment and enhancement of community awareness in respect of NORM. There is also a discussion on the various codes of practice in place to dealwith issues of waste handling and disposal. Finally, the paper provides a scientific perspective of the risk assessment processes currently in use.

2. INTRODUCTION

In many aspects of our daily lives society uses, or is exposed to, materials which are naturally radioactive but not regarded with concern in the same way as other radioactive materials such as nuclear reactor waste or X-Ray producing isotopes. The natural items are described by scientists as NORM (Naturally Occurring Radioactive Materials). There are also materials whose natural radioactivity may become concentrated as a consequence of physical or chemical processing. These are often referred to as TENORM – Technologically Enhanced NORM. In the context of this paper NORM is considered to comprise materials which c o n t a only those radionuclides that occur in the natural environment. This contain fallout and reactor fission products, radio-pharmaceuticalsand associated wastes, etc. NORM tends to be materials that are present and used in daily life, frequently in large quantities. Many NORM materials are products, by-products and waste materials from mining and mineral processing, including some manufacturing, operations. The pathways by which these materials move through the environment are varied and complex[1.

Australia has a wide range of NORM which arise primarily from activities in the minerals industry and agriculture as well as various industrial applications. None of these materials are unique to Australia, although in terms of their specific composition some may present greater challenges than elsewhere. What is uniquely Australian is the wide range of climatic environments found in the one

nation, sometimes even in one state. This provides great variation in the conditions under which NORM are produced and have to be managed. Australia has every climate type from tropical rainy through desert and temperate zones to cool snowy using the Koppen classifications A to D [2]. Only class E (polar) is missing from the "mainland' (but it is present in Antarctica). The technical and management challenges and implications of such a climatic range are discussed later in this paper. A further complication is that many of the wastes may be dispersed into the environment as they are produced or used.

3. SOURCES OF NORM IN AUSTRALIA

The mining and mineral processing industries produce the majority of NORM. Many of the minerals and ores mined for commercial exploitation are either themselves radioactive or contain radioactive contaminants, all of which require appropriate management. The following paragraphs describe the most common sources of NORM found in Australia and their uses and associated management hazards.

Processing of phosphate rock - fertiliser production - phosphogypsum

Rock phosphate is mainly used as a source of phosphorus for fertilisers[3]. Australia uses large quantities of manufactured phosphate fertilisers, about 1.4 Mt in 1997-98. Whilst some rock phosphate is mined in Australia on Christmas Island and in Queensland a substantial fraction of the fertiliser used in Australia is produced from imported phosphate rock. After processing the uranium and thorium tend to stay with the phosphorus in the fertiliser (product), while the radium precipitates out with the phosphogypsum (by-product or waste). Studies[3],[4] have shown that the use of this phosphogypsum as a substitute for natural gypsum in plasterboard in Australian dwellings should not lead to significant increases in indoor gamma radiation exposures or indoor radon.

Aluminium processing

Bauxite is mined in Australia, mostly using strip mining or open cut methods producing 40% of the world's bauxite and **35%** of the alumina. The capacities of alumina refineries and aluminium smelters are 11.3 Mt and 1.25 Mt respectively[5]. The radionuclide content of the ore can vary from nilto amounts that would be considered radioactive. Disposal of the red mud waste requires careful management as itis also caustic and presents a significant environmental hazard. NORM waste from bauxite mining ('red mud')is produced in large volumes. In recent years some red mud has been used to increase phosphorus retention in sandy soils and reduce the leaching of nutrients[6].

Coal burning power stations

Australia produced more than 213 Mt of coal in 1999. Annual domestic consumption of brown and black coals exceeds 100 Mt (mainly for electricity generation). The NORM wastes from coal burning (fiy ash and bottom ash) have traditionally been used as landfilland in road construction. No systematic

studies of the radiological risks associated with the use of these materials or these releases have been conducted in Australia.

Oil and gas production

Much of Australia's crude oil and gas is produced by off-shore drilling and extraction platforms in Bass Strait, the Northwest Shelf and the Timor Sea. In these operations, elevated concentrations of the radium isotopes ^{226}Ra and ^{228}Ra, together with their radioactive progeny, are found in the formation water associated with the oil and gas. When the oil and/or gas and water are pumped or forced to the surface, the reduction in pressure and temperature causes the radium isotopes to come out of solution and plate out onto the interior surfaces of pipes, valves, etc., as well as the surfaces of mineral particles suspended in the water, resulting in the formation of scales and sludges containing elevated concentrations of radium isotopes.

Although the quantities of NORM waste resulting from oil and gas production are small, these wastes are often contaminated with oil, and their safe management and disposal pose special problems for the environment. [pers com. O'Brien & Cooper].

Uranium mining

Australia has three operational uranium mines, using conventional underground and open cut extraction methods, and in-situ leaching. Radiation parameters and radon dispersion in an open cut uranium mine have been reported[7],[8]

Disposal of the tailings can pose significant environmental problems due to radon emissions and the presence of residual radionuclides including radium. Tailings represent the largest volume of NORM waste in uranium mining and disposal strategies include in–pit burial in the Alligator Rivers Region and above ground tailings storage facilities at Olympic Dam[9]. The sub-economic grades of mineralised rock that remain unprocessed after mining are also a form of NORM and are frequently present in large volumes. In the Northern Territory the regulatory level for ore is material above 0.02% U_3O_8

There are also concerns with exposed materials at abandoned mines from the 50s and 60s, exploration sites (drill cuttings and core, old costeans etc). Many of these sites are currently being assesed for radiological hazards and remediation plans prepared [10].

Mineral sand mining

Mineral sand mining is a significant industry in Australia with the mines, mainly located in Western Australia and Queensland, producing over 3.2Mt of product annually. The major products are rutile, synthetic rutile, ilmenite and zircon, with smaller quantities of leucoxene being produced. The following table depicts typical radionuclide concentrations found in Western Australian mineral sand products.

Rutile and ilmenite are a major source of titanium. Synthetic rutile, converted to. titanium dioxide, is widely used in the production of pigment for paint, paper and plastics because of its whiteness, brightness and opacity. These titanium

materials are not considered a significant radiological problem because the majority of the radionuclides are removed in the production process.

Material	Range of Radionuclide Concentration	
	Uranium (ppm)	Thorium (ppm)
Ilmenite	**7** to 20	**180** to 450
Leucoxene	**10** to 40	**210** to **260**
Rutile	20 to **50**	30 to **65**
Synthetic Rutile	**10** to **20**	**190** to 430
Zircon	200 to 240	**175** to **200**

Zircon is used in ceramics, refractories, foundry cores and moulds. In the ceramics industry zircon is widely used as a constituent of glazes and frits, to adjust the thermal expansion coefficient of glaze (to ensure an even colour) and because of its opacity and whiteness. A study [ll]. on the use of zircon glaze on ceramic bathroom tiles showed that, although the thorium concentrations in the tile glaze were of the order of 3-4 Bq g-', the use of very thin layers of glaze and the relatively small exposure time resulted in doses (to the occupants of houses where these materials are used) that are low compared to natural background radiation doses and should not be of concern

Ilmenite has been used in Queensland as sand blasting grit. However, there are concerns that use of this material would expose operators to doses above the public limit and so the practice has been discontinued. There were also concerns about the poor hygiene practices of the operators concerned.

Mineral sands tailings

The radionuclides encountered in mineral sands tend to be attached to the heavy minerals and therefore stay with the products. There is some off grade material that will contain some radionuclides, but these are in concentrations that are readily diluted with barren material. As there is no chemical separation involved in the separation process the natural decay chain is not interfered with and the solubility or mobility of individual radionuclides does not have to be considered in waste management. Tailings from the dry separation process are therefore in the same physical form as the original ore and are returned to the original mining void. In the past tailings with elevated radiation levels from the mineral sands separation process have been used as landfill. Current regulatory processes control the disposal of these wastes and the previous situation is no longer tolerated.

Monazite

Changes in market forces have resulted in West Australian monazite no longer being saleable. This has been brought about mainly due to the cost of processing and disposal of the radioactive materials involved. Consequently the monazite concentrate produced has to be managed. The proposal is that it be returned to the previously mineralised zone within the mining void. There is a process being developed that will allow this monazite concentrate to be diluted

with barren mining waste to such a concentration that it will not be considered radioactive. This is in accord with the ICRP philosophy of dilute and disperse.

Zinc smelter slag
There was an attempt in the past to introduce zinc smelter slag as an abrasive medium for sandblasting in Queensland The level of activity found in the raw material was such that the State regulating authorities were obliged to ban the use of the material in this way. The producers were obliged to manage this material in an alternative manner, as a radioactive waste.

4. REGULATORY APPROACH TO RADIATION PROTECTION

The Commonwealth Government has no specific regulations for the disposal of NORM waste. Each State or Territory has it's own legislation relating to the management and disposal of radioactive materials and NORM. Whilst the laws are generally very similar, there are differences in detail, including the regulations, between the jurisdictions. For example, there is no single uniform definition, used by all the states, of what constitutes a radioactive material. State laws call up the various Codes of Practice.

Since NORM contains only radionuclides that are present in the natural environment it would seem reasonable to consider exposures to NORM in the context of the natural radiation background. Natural background radiation levels range from 1.5 mSv per year to 30 mSv per year in some parts of the world; in Australia the average is approximately 1.5-2 mSv per year. There is no evidence that there are significant health problems associated with these variations in average background levels. Local variations (over a scale of kilometres) tend to be approximately 10% of the local average. In general, Australia follows the ICRP recommendations of justification, optimisation and limitation of exposures to ionising radiation, together with the IAEA Basic Safety Standards.

Handling of products and by-products containing NORM
The European Community has adopted the IAEA basic safety standard in relation to NORM products and by-products.

Extraction of radionuclides from product has the potential to produce low-volume high-concentration wastes that may require special storage facilities, which may also lead to increased production costs. In those cases in Australia where realistic dose/risk assessments have been carried out, it has generally been shown that, provided reasonable precautions are taken, the doses to members of the public resulting from the use of commercial products containing NORM are very much lower than natural background radiation doses [7] These precautions usually amount to ensuring that only small quantities of these materials are used, and that they are used in places where exposure times are likely to be short. Worker exposures can also be kept to reasonable levels by practices that are already accepted by the radiation protection community.

Mineral sand mining

The initial mining stage in the mineral sands separation process poses few radiological problems because radionuclide concentration in the raw sand is usually very low due to the bulk of material involved. During the separation process the heavy mineral concentration of the product increases. Dry production processes require a free-running material, and can therefore generate significant concentrations of dust. Inhalation of dust has been the major pathway of exposure to radiation in secondary separation plants.

Handling and disposal of wastes containing NORM

The radiation protection approach to this problem is essentially the same as that for products containing NORM. Procedures adopted in Australia include some or all of the following, depending on the site specific situation: realistic dose/risk assessment, open public discussion of issues, and enhancement of industry and community awareness of the health effects of exposure to ionising radiation, etc.

The Commonwealth Government and the States produce Codes of Practice which include most of the practices used for the disposal of NORM wastes. Commonwealth Codes are currently under review and the)include the Near-surface Disposal Code[l7], the User Disposal Code[l8], the Occupational Exposure Limitation Standard[l9], the Transport Code (20), and the Mining and Milling Code[21].

The User Disposal Code [16] is applicable to materials that can be mixed with other wastes and disposed to municipal tips. This usually implies small volumes of material containing low to intermediate radionuclide concentrations, and a chemical and physical form that is suitable for mixing with other wastes (e.g. discarded smoke detectors).

The Waste Management in Mining and Milling and the Radiation Protection Codes are currently under revision and are to be incorporated into one document. The new code will include practices for the production, processing and storage of radioactive minerals and disposal of the resulting radioactive waste. There are some significant changes proposed for the revision. For example, the revised code is being expanded to include any radioactive wastes arising from any mineral processing operations. This will mean the inclusion of the fertiliser industry for the first time due to its use of rock phosphate. Self regulation and local risk assessment are seen as the way to move forward in this area.

The Near-Surface Disposal Code deals with the disposal of large volume materials derived from non-mining industries and containing low to intermediate radionuclide concentrations, and is appropriate for NORM waste. The Code specifies that this type of waste should be disposed of by burial under the following restrictions

- remote site,
- low rainfall area,
- at least two metres of cover (five metres for subsequent non-recreational use of the site),
- the bottom of the waste at least five metres above the water table,
- purpose designed – only used with radioactive wastes
- land unsuitable for any other use
- land has no cultural or economic significance

However, the applicability of such a specification nationwide in Australia does present some challenges. For example, in the Northern Territory the climate is warm all year round but rainfall varies from 1500mm at Darwin in the north to 273mm at Alice Springs in the south. The distribution of the rainfall is highly seasonal with over 90% of Darwin's rain falling between 1 September and 30 April. The storms associated with this distribution can be very intense and are often highly erosive. There are also often major seasonal fluctuations in water table levels. Thus designs and locations for NORM and radioactive waste containments have to be adapted when compared to designs that may be used in the central desert region around Alice Springs, an arid zone. Elsewhere in the country similar ranges of conditions can be found. Thus one simple, prescriptive specification is not applicable for the design of waste containments in Australia. Rather a risk-assessment-based approach has to be employed on a site specific basis.

5. Scientific Perspectives - Radiation Protection

The process of radiological risk assessment for NORM usually undertaken in Australia involves some or all of the following steps:

- identification of possible exposure scenarios;
- identification of the corresponding critical groups;
- identification of the relevant exposure pathways;
- selection of appropriate models and a statement of the assumptions involved;
- risk estimation.

Any radiological assessment involves an estimate of effective doses to humans, animals, flora and fauna, for those exposure pathways considered relevant to the management and disposal practices being applied. The two types of exposure of organisms that result from the presence of radionuclides in the environment or transport of radionuclides through the environment are:

- external exposures, in which the radiation source is outside the organism;
- internat exposures, in which the radionuclides are taken into the organism and subsequently undergo radioactive decay.

The major pathways are

- external exposure;
- inhalation of dust;
- inhalation of radon and its radioactive progeny;
- ingestion of food or water containing elevated concentrations of naturally occurring radionuclides;
- exposure from material which settles on the skin (external gamma radiation or ingestion).

6. Summary and Conclusions

As with many other countries NORM products and wastes are produced and used in Australia in a wide range of situations, frequently in large quantities. In many situations the radiological risk resulting from exposure to radiation from these materials is within acceptable bounds. However, there are some radiological safety issues which require specific management practices to be employed from time to time. The range of climates found across Australia has led to the adoption of a risk-assessment-based site-specific methodology when determining best practice management and disposal options. It is possible that daily life in future may include greater exposure to NORM as the community's awareness of the issue grows.

The major issues for the future are

- developing procedures for using or disposing of NORM that are cost-effective and acceptable to Commonwealth and State Governments, industry and the wider community;
- enhancing Government, industry and community awareness of the health issues related to NORM.

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