The management of radiation hazards from the mining of mineral sands in Western Australia

"Life on earth has developed with an ever present background of radiation. It is not something new, invented by the wit of man: radiation has always been there".[1]

1. Introduction

This paper is concerned with the approach followed in Western Australian for dealing with the environmental hazards of ionising radiation associated with the mining and processing of titaniferous minerals contained in mineral sands deposits. There is a growing public awareness of the risks posed by one of these minerals, monazite, which emits low levels of radiation as it contains thorium and uranium. This concern has precipitated increased public scrutiny of practices adopted by the mineral sands industry to address the occupational and public health risks that arise from mining and processing.

Questioning of the industry's standards has come from a broad cross section of the public, including environmental organisations, farmers and local community groups. The spotlight of public attention may have somewhat tarnished the industry's well-established "clean" image derived from it's major end product, titanium dioxide (TiO_2), which is widely used in paints for its whiteness and in sunscreen products. This opposition is surprising as mineral sands mining has occurred continuously in Western Australia (WA) since the mid 1950s with little apparent opposition about environmental impacts.

The recent example of environmental concerns being associated with the industry is illustrated by the proposal to construct a rare earths oxide (REO) processing plant, which involves the processing of monazite at Pinjarra[2] and the transport of radioactive wastes for burial at a designated site.[3] While opposition to the Pinjarra REO plant involves issues related to the transport, processing and disposal of low level radioactive waste, it has also triggered a wider debate about the benefits and costs of minerals sands mining. Examples of wider concern about environmental concerns include:

- pollution of local groundwater supplies and river systems through leakage from settling and evaporation ponds;[4]
- the transport of minerals by heavy haulage vehicles along local roads;[5]
- dredging operations in fragile costal dunes;[6]
- the clearing of forest to construct high voltage distribution systems to mine sites;[7] and
- the loss of remnant stands of native forest.[8]

The State's environmental impact assessment regime appears to discount this growing chorus of concerns about the adequacy of the environmental safeguards applied to the mineral sands industry due to an overemphasis on projected economic and social benefits by proponents in their environmental review and management plans

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[1] Hall EJ. Radiation and life. Nuclear Energy Agency Library (http://is.eunet.ch/geneva-intl/gi/egimain/etyos.htm), June 1995.
[2] Guild F. "Rare earths plant gets green light". Sunday Times 7 April 1996; Tan-Van Baren C, MacDonald J. "Radiation fears rejected". The West Australian 8 April 1995; Amalfi C. "Guarantee call on rare earths firm". The West Australian 7 August 1996.
[3] Capp G. "Firm to push on with plant". The West Australian 16 July 1996; Amalfi C. "Query over radiation tip decision". The West Australian 23 July 1996.
[4] Lewis Environmental Consultants. Environmental review and management program, heavy minerals mine Beenup. Perth, BHP-Utah Minerals International, 1990; BHP Titanium Minerals. Beenup titanium minerals project. Proposal to extend approved mining area, submitted in accordance with section 46 of the EP Act. Perth, BHP Titanium Minerals, 1995.
[5] BSD Consultants Pty Ltd, Mitchell McCotter & Associates, MA Ashbolt & Associates, Pregelj J. Mineral sands road study: Sue's Road to Capel, Public Environmental Review. Perth, Main Roads Department, 1991.
[6] Dames and Moore. Westralian Sands Ltd. Environmental review and management program, Minninup sand mining proposal. Perth, Dames and Moore, 1988.
[7] Western Australia, Environmental Protection Authority. Proposed 132 kV transmission line, Manjimup to Beenup mineral sands mine, State Energy Commission of Western Australia, report and recommendations. EPA Bulletin 707. Perth, Environmental Protection Authority, 1993.
[8] Harris J. "Forest monarchs - sandmining threatens a Tuart dynasty". 1989 17(6) Habitat Australia 4.

(ERMPs) and draft environmental impact statements (EIS). The dominance of economic imperatives in the State's environmental decision making process is underscored by a statement in a recent publication referring to the minerals and energy sector as the "bedrock" of the State's economy as it "accounts for around 25% of Gross State Product, some 73% of State exports and 65% of private investment".[9]

It was recently observed this State's Environmental Protection Act:

> "is starkly different than other EIA legislation, in that it runs in tandem with resource development controls and 'is intended to aid the Minister for Environment in coming to a decision whether or not to allow a proposal to be implemented', rather than advise the public or a particular agency of the impacts of a proposed project".[10]

Public participation in the environmental review process in relation to the processing monazite to extract concentrated REOs is more problematic than other titaniferous minerals because:

1. radiation hazard levels are determined by reference to Codes of Practice and standards set by national and international scientific and medical bodies;
2. implementation of standards depends on complementary State and Commonwealth legislative arrangements;
3. the enforcement of environmental and radiation standards is a State responsibility;
4. the administrative arrangements established by the States are fragmented as they consist of provisions contained in mining, radiation health and other legislative enactments; and
5. monazite constitutes a minor proportion of total mineral sands production.

The structure of the paper is as follows. There is an overview of the environmental issues associated with the exploitation of mineral sands deposits, with particular reference to need for a framework to manage the risks posed by the release of low level ionising radiation once monazite has been separated at the dry processing stage from ilmenite, the major economic titaniferous mineral. This is followed by a short history of mineral sands mining in WA. This history is concerned with the shift that has occurred from the 1970s to 1990s in mining and processing, from an export oriented operations in the Southern Swan Coastal Plain based on high grade deposits, to mining of lower grade deposits in the Northern Swan Coastal Plain. There will be consideration of the implications of this shift, with particular reference to the establishment of "value added" secondary processing industries in close proximity to regional centres. Finally, the matrix of Commonwealth and State statutory provisions and guidelines concerned with the radiation hazards is examined to pinpoint some of the problems posed through the mining, processing, storage and transport of monazite.

2. Environmental issues and the minerals sands industry

There are a number of reasons why it is important to examine the regulatory regime developed in this State to deal with the mining of titaniferous minerals. While all mineral sands deposits contain a small proportion of monazite, when this mineral is concentrated and separated through processing it emits a significant amount of low level radiation.

The first reason is to ensure that former mineral sands mines are properly rehabilitated as they are progressively decommissioned after the depletion of ore bodies, or abandoned following low world commodity prices. While minerals sands mining results in short-term alteration of ecosystems, there is a particular concern that thorium, the principal radioactive component of monazite, may over time leach from tailings dumps into local water supply systems. Also, as elevated radiation levels are likely to occur at areas of spillage adjacent to monazite loading and storage facilities on former mining sites, it may be necessary to have a system of controls to restrict the public and nearby landowners from having contact with some parts of former mine sites. Such concerns are pertinent in the South West region of the State as former mines are rehabilitated and repastured for cattle grazing as deposits often occur in dairy farming areas along Southern Swan Coastal Plain.

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[9] MacLeod J, Gerhardy S. Minerals in Western Australia - bedrock of the economy. Perth, Chamber of Mines and Energy, 1996.
[10] Myers GD. "Meeting public expectations - judicial review of environmental impact statements in the United States: lessons for reform in Western Australia?" (1996) 3 E Law, Murdoch University Electronic Journal of Law [http://www.murdoch.edu.au/elaw/]

The second reason is because over the past 40 years there has been a change in scale and mode of mining in this State, with concomitant greater environmental impacts. Since the mid 1970s the industry has expanded from its original focal area of operations in the Southern Swan Coastal Plain, where small-scale mining operations commenced in the mid 1950s, to large scale operations in ecologically fragile areas at Eneabba and elsewhere on the Northern Swan Coastal Plain. A history of unsatisfactory rehabilitation of former mine sites has been noted.[11]

Since the early 1990s new mineral deposits have been identified in the South Coast region, between Augusta and Point D'Entrecasteaux and if mined are likely to involve large scale dredging operations on agricultural land and in State forests. The development of the Beenup mine, for instance, highlights environmental and social impacts of mining on local communities in areas previously not exposed to capital intensive mining operations. Impacts include the construction a dedicated heavy haulage road system for the transport of mineral products to the export facility located at the Bunbury port,[12] land clearing for high voltage transmission power lines[13] and the contamination of local water systems from release of mining waste water.[14]

The third reason is because of the State government's encouragement of "value added" secondary processing of titaniferous minerals in WA. This has involved TiO_2 processing plants based on the chloride process at Kwinana and at Kemerton near Bunbury and the expansion of synthetic rutile plants at Capel in the South West of the State, at Narngulu near Geraldton and at Muchea north of Perth.

A particular example of "value added" secondary processing has been a number of proposals over the past 10 years to establish a REO processing facility. The first proposal, released in 1985, was for a REO processing plant to be based at Narngulu to process locally sourced monazite.[15] Serious environmental concerns about the contamination of local ground water systems from released radionuclides after disposal of radioactive wastes from the plant was a factor in the abandonment of this project.[16] The second proposal for a REO processing plant was released in 1988 by Rhone-Poulenc Chimie, proposed to establish a plant that would utilise locally sourced monazite and be co-located at Pinjarra adjacent to their gallium plant.[17] The third proposal was submitted for environmental approval in 1995.[18] This proposal, like the 1988 proposal, is of particular interest as it will pose significant environmental and occupational risks because it:

1. involves movement of about 12,000 tonnes per annum (tpa) of bulk monazite product to the REO plant from the established local mineral sands processing plants at Capel, Bunbury and Eneabba;
2. uses an evaporative process with the possibility of leachate seeping from settling ponds and entering local acquifers; and
3. requires the transport of 6,000 tpa of gangue[19] from the Pinjarra site to a designated low level radioactive waste repository site at the Mount Walton Integrated Waste Disposal Facility (IWDF) in the Eastern Goldfields.[20]

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[11] Western Australia, Working Party on Conservation and Rehabilitation in the Mining Industry. Report on conservation and rehabilitation in the mineral sands mining industry. Perth, Department of Minerals and Energy, 1987; Western Australia, Environmental Protection Authority, Mineral Sands Working Group. Mineral sands - doing it better, a report. Perth, Environmental Protection Authority, 1990.

[12] BSD Consultants Pty Ltd, Mitchell McCotter & Associates, MA Ashbolt & Associates, Pregelj J. Mineral sands road study: Sue's Road to Capel, Public Environmental Review. Perth, Main Roads Department, 1991.

[13] Western Australia, Environmental Protection Authority. Proposed 132 kV transmission line, Manjimup to Beenup mineral sands mine, State Energy Commission of Western Australia, report and recommendations. EPA Bulletin 707. Perth, Environmental Protection Authority, 1993.

[14] Capp G. "BHP abandons SW river discharge plan". The West Australian 3 August 1995.

[15] Western Australia, Environmental Protection Authority. Allied Eneabba Ltd proposed rare earth processing plant, report and recommendations. EPA Bulletin 236. Perth, Environmental Protection Authority, 1985.

[16] Western Australia, Environmental Protection Authority. Allied Eneabba - disposal of thorium rich waste from proposed monazite treatment plant. Specialist group report to the EPA. Environmental Note 174. Perth, Environmental Protection Authority, 1985.

[17] Dames and Moore. Proposed rare earths processing plant, Pinjarra, Western Australia. Environmental review and management program, draft environmental impact statement. (2 vols.) Perth, Dames and Moore, 1988.

[18] Dames and Moore. Rare earth project, Pinjarra, Western Australia. Environmental review and management program, rare earth plant for Rhone-Poulenc Chimie Australia Pty Ltd. Perth, Dames and Moore, 1995.

[19] Waste containing thorium and uranium and associated decay products.

3. The WA mineral sands industry

Over the past 40 years the State's mineral sands mining industry has come to occupy a dominant role in Australian and international terms as a producer of titaniferous minerals. The State produces approximately 43% of the world's ilmenite, 21% of the world's rutile, 40% of the world's zircon and 54% of the world's monazite. For the year 1988 the aggregate of mineral sands production was estimated to be $350 million.[21]

As mineral sands mining involves the removal of the soil to a depth of up to 30 metres or more, except for about 250 mm of topsoil which is removed prior to mining and replaced following recontouring of tailings dumps, mining leads to the loss of trees and other vegetation. Some of the soils with the richest heavy mineral deposits are favourable to orchids and other unique flora and fauna. The combined impact of forestry, large scale clearing for dairy farming and grazing will mean some of these unique communities of flora and fauna now occur as remnants as small reserves which may be mined. An example of the difficulty in sustaining environmental values is the instance of where a mining company proposed to mine a mineral sands deposit in the Ludlow tuart forest, which contained the last remnant of former extensive Tuart forests on the Southern Swan Coastal Plain.[22]

A driving force in the expansion of mineral sand mining in this State has been due to environmental restrictions that were imposed in the early 1980s on opening new mineral sands mines in the Eastern States.[23] These restrictions resulted in the virtual cessation of mineral sands mining operations in New South Wales and Queensland, where deposits are often located in fragile dune systems and in national parks.

Arguably, the expansion of mining and downstream processing industries in this State over the past 15 years, with the attendant environmental risks, may have involved lower environmental standards than would have been acceptable elsewhere in Australia.

3.1 Value added processing of titaniferous minerals

Governments in WA have for a number of years encouraged the establishment of "value added" processing of ilmenite. This has been an important factor in the viability of the State's titaniferous mineral industry, as Western Australian ilmenite has a relatively low TiO_2 content of 45-60%. This means it has a significantly lower export value compared to rutile-rich deposits.[24]

To overcome the problem of producing a lower value product, in the early 1970s producers in this State pioneered the production of synthetic rutile through a complex process of removal of the iron oxide content of ilmenite through metallurgical conversion. Synthetic rutile plants now operate at Capel and at Narngulu and Muchea.[25] An advantage of synthetic rutile is that it is a preferred feedstock for the more environmentally friendly chloride process of TiO_2 production.

For about 30 years a sulphate processing plant to produce TiO_2 from ilmenite, was operated by SCM Chemicals at Australind.[26] This particular arrangement permitted the release of untreated effluent of iron oxides and associated acidic wastes over many years into large settling ponds in a pristine dune system.[27]

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[20] Western Australia, Department of Environmental Protection. The management of low level radioactive gangue residue at the Mt Walton East intractable waste disposal facility Western Australia. Environmental Management Program. Perth, Waste Management Division, Department of Environmental Protection, 1995.

[21] Western Australia, Working Party on Conservation and Rehabilitation in the Mining Industry. Report on conservation and rehabilitation in the mineral sands mining industry. Perth, Department of Minerals and Energy, 1987; Western Australia, Environmental Protection Authority, Mineral Sands Working Group. Mineral sands - doing it better, a report. Perth, Environmental Protection Authority, 1990; South West Development Authority. South west mineral sands industry report: an information handbook. Bunbury, South West Development Authority, 1990.

[22] Surprisingly proposals were recently made to mine portion of these vestiges of tuart forest: Harris J. "Forest monarchs - sandmining threatens a Tuart dynasty". 1989 17(6) Habitat Australia 4.

[23] Bonyhady T. Places worth keeping. Conservationists, politics and law. Sydney, Allen & Unwin, 1993.

[24] The Eastern States mineral sands deposits contain higher proportions of zircon and rutile, which is more valuable as it has a titanium dioxide content of about 92-98%.

[25] Woodward-Clyde. Synthetic rutile plant at Chandala. Production debottlenecking to 200,000 tonne per annum for TiWest Joint Venture. Section 46 public review document. Perth, Woodward-Clyde, 1995.

[26] Chandler B. "The great escape. Steps taken to restore an area affected by iron sulphate waste from the mineral sands processing plant at Australind". (1989) 4(4) Landscope 8.

A TiO_2 chloride process was established at the Kemerton industrial estate and recently SCM Chemicals announced a $470 million expansion of this operation.[28] Another chloride process TiO_2 plant has been established at Kwinana.[29] There will need to be substantial supplies of feedstock to sustain these plants, a number of which have recently announced plans to expand their operations. This expanded capacity will in turn exert a strong demand for expanded mineral sands mining in this State.

3.2 Titaniferous minerals and their uses

The economic heavy minerals present in WA mineral sands deposits can be grouped into three groups:

1. titanium-bearing minerals (such as ilmenite, rutile and leucoxene);
2. zirconium-bearing minerals (such as zircon); and
3. rare earth bearing minerals (such as monazite and xenotime).[30]

The Southern Swan Costal Plain heavy mineral deposits are mined primarily for ilmenite, which contains oxides of titanium and iron. The mineral suite is typically ilmenite (75-80%), zircon (5-10%), leucoxene (5%), rutile (0.5%) and monazite (0.4%). The heavy mineral deposits on the Northern Swan Costal Plain deposits, which are older, contain up to 20% of zircon and lower proportions of ilmenite.

3.2.1 Titanium

The principal use of TiO_2 is as a base for pigments in paint, paper and plastics, with applications in the rubber industry, in the manufacture of inks, synthetic fibres and ceramics. Some rutile is also exported for the production titanium metal, which because of its strength, lightness, non-toxicity, corrosion resistance, opaqueness and reflectivity, is used by the aerospace industry and in medicine.

3.2.2 Zircon

As zircon is very heat resistant it is widely used in refractory applications, such as in the manufacture of glass and steel, and as a special foundry sand for precision casting of turbine blades and intricate engineering designs. This mineral is also widely used in the ceramics industry, because of its properties as a hard-wearing surface, and in the production of chemicals used in optical glass applications. A less important use of zircon, but which gives it a strategic value, is in the manufacture of cladding for nuclear reactor fuel rods.

3.2.3 Rare earth oxides

There are a number of REOs present in monazite and xenotime, including lanthanum, cerium, europium, and yttrium. These elements have a wide range of applications in:[31]

- computers and televisions, for colour, monitor luminescence, in electronic components and bubble memory systems;
- high-performance magnets (cerium);
- electric stepping motors, which are used in robots;
- energy efficient lanthanum lamps;
- X-ray screens, fibre optics, pain-killing elements;
- catalysts; and
- pigments used in ceramics.

REO products from monazite are also used in metallurgy, flints, ferro-alloys, glass polishing, jewellery, fuel cells, refractories, lamp mantles (thorium) and welding electrodes.

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[27] This operation was underpinned by an agreement whereby a government instrumentality was made fully responsible for the disposal of all wastes emanating from the plant throughout its economic life: Laporte Industrial Factory Agreement Act 1961 (repealed by Act No. 92/1986)
[28] Armstrong P. “Giant plans $470m SW plant upgrade”. The West Australian 18 May 1996.
[29] Dames and Moore. Titanium dioxide pigment plant at Kwinana - production debottlenecking to 80,000 tonne per annum for TiWest Joint Venture. Consultative environmental review. Perth, Dames and Moore, 1994.
[30] Referred to in this paper as rare earth oxides.
[31] Australian Titanium Minerals Industry. Mineral sands, nuclear issues briefing paper 25. November 1995.

4. Monazite as a radiation hazard

It is possible that the term “low level radioactive waste” which is used to distinguish the high risks posed to the environment through all stages of the nuclear fuel cycle from high level waste, may have in part conveyed the impression, at least until the early 1980s that meant monazite posed little risk.[32]

Monazite constitutes between 1 and 3 per cent of the mineral suite in mineral sands deposits in this State.[33] But when separated from ilmenite and the other mineral products contains between 5 and 7 per cent radioactive thorium (Th-232) and between 0.1 and 0.3 per cent uranium (U-238), occurring as ThO_2 and U_3O_8. For a number of years ilmenite was the major economic mineral that was produced by the South West miners. This meant other heavy minerals, including monazite, were regarded as uneconomic and discharged as waste to tailings dumps, or utilised of as cheap land fill by local authorities and in new housing developments.[34] Thus, it is likely that some of these old tailings dumps at abandoned mines will constitute low level radiation hazards.[35]

Radioactivity is measured by the SI unit of the becquerel (Bq), defined as one nuclear transaction per second.[36] A radioactive disintegration (a “transaction” in the language of the Regulations) may occur as a consequence of the emission of either an alpha particle or gamma particle. The consequences of radioactivity on human tissue is determined by the notion of an “absorbed dose”, being the number of joules of energy deposited by ionising radiation per kilogram of absorber. The unit of an absorbed dose is the Gray (Gy), referred to in dose equivalents.

A dose equivalent, measured as the Sievert (Sv)[37], is a modified measurement of absorbed dose that measures radiation damage induced in an absorber by ionising radiation.[38] The advantage of measurement of radiation by dose equivalents is that one sievert of radiation produces a constant biological effect, irrespective of the type of radiation.

The radioactivity of monazite derives from thorium and uranium and their decay products.[39] The level of radioactivity for Radium-228 (emitted by Th-232) and Radium-226 (emitted by U-238),[40] is 2.5×10^5 Bq/kg and

[32] Poulsen R & Troy J (eds). Mineral sands scandal: radiation and health. Fremantle, SV Publications, 1983; Hartley BM, Toussaint LF. “Radiation doses in the sand mining industry, what we know and what we don’t know”. In Proceedings of Conference, Australia: a world source of ilmenite, rutile, monazite and zircon. Perth, September-October 1986. Parkville, Victoria, Australasian Institute of Mining and Metallurgy, 1986.

[33] It should be noted there is detectable levels of ionising radiation through the release of thoron and radon gas which emanate the parent materials Th-232 and U-238 which are contained in monazite when present in unmined ore bodies. While these levels of radiation are usually considered to be so low as to be close to normal background levels, they permit the detection of mineral sands deposits by radiological methods of exploration.

[34] In the early 1980s high levels of radioactivity were found in Geraldton and Capel in tailings that had used as sand filling in the construction of school playing fields and at a number of housing developments. A level of 170 microrems per hour was measured near a classroom in Capel. After a public campaign the solid from contaminated areas was removed. Cf Poulsen R & Troy J (eds). Mineral sands scandal: radiation and health. Fremantle, SV Publications, 1983.

[35] Hartley BM, Toussaint LF. “Radiation doses in the sand mining industry, what we know and what we don’t know”. In Proceedings of Conference, Australia: a world source of ilmenite, rutile, monazite and zircon. Perth, September-October 1986. Parkville, Victoria, Australasian Institute of Mining and Metallurgy, 1986.

[36] Radiation Safety (General) Regulations 1983, Reg. 3.

[37] Radiation Safety (General) Regulations 1983 defines a sievert as the “SI unit of dose equivalent corresponding to the absorption of one joule in one kilogram of biological matter, taking into account the quality factor and other modifying factors” Reg. 3.

[38] In the case of ionising radiation emitted by radioactive substances contained in mineral sands, the Gy and Sv measures are numerically equal. Cf Dames and Moore. Proposed rare earths processing plant, Pinjarra, Western Australia. Environmental review and management program, draft environmental impact statement. (Volume 2). Supporting document II: radiological issues of the Rhone-Poulenc rare earths processing plant proposal. Attachment 2. Perth, Dames and Moore, 1988, p. A2-iii.

[39] Dames and Moore. Proposed rare earths processing plant, Pinjarra, Western Australia. Environmental review and management program, draft environmental impact statement. (Volume 2). Supporting document II: radiological issues of the Rhone-Poulenc rare earths processing plant proposal. Perth, Dames and Moore, 1988, Attachment 1.

[40] Contained in Figure 5.5(a), Dames and Moore. Proposed rare earths processing plant, Pinjarra, Western Australia. Environmental review and management program, draft environmental impact statement. (Volume 2). Supporting document II: radiological issues of the Rhone-Poulenc rare earths processing plant proposal. Perth, Dames and Moore, 1988, Attachment 5.

2.1 x 10^4 Bq/kg, respectively.[41] In Rhone-Poulenc's 1995 ERMP these values were 2.16 x 10^5 Bq/kg and 3.1 x 10^4 Bq/kg, respectively.[42]

A "radioactive substance" is defined in section 4 of the Radiation Safety Act 1975, as being a substance which contains more than the maximum prescribed concentration of any radioactive element, whether natural or artificial. The prescribed level of radioactivity was previously set as 7.4 x 10^4 Bq/kg in 1991.[43] This level was reduced to 7.0 x 10^4 Bq/kg in 1994.[44]

5. Mining and environmental issues

Following the exhaustion of some of the large and rich deposits in the Capel in the South West of the State, mining and processing operations have been developed in the Northern Swan Coastal Plain, at places such as Eneabba and Muchea.[45] Unlike the South West mines, which often mined farming land, the mines on the Northern Swan Coastal Plain are located on economically marginal wheat and sheep farms and Crown land. Unlike the South West mines these areas are characterised by lower rainfall and sandy soils and are thus more difficult to rehabilitate.

The development of secondary processing facilities brings with it a pressure for expansion of mineral sands mining, which in turn is likely to result in higher levels of environmental damage as larger scale mining is required to produce sufficient tonnages of product. An example of environmental impact is the Beenup mine which involves large scale dredging of a low grade deposit.[46] To ensure long term economic viability the company successfully obtained approval to expand its mining area in early 1996.[47] There is also the possibility of mining of State forests in the longer term adjacent to the mining area. As this is a part of the State with relatively high rainfall there has been concern about the impact of the release of waste water from this mine on the local river systems and that mining will disturb acid sulphate soils.[48]

Concerns have been raised about the contamination of local water supplies at TiWest's Muchea dry processing plant due to leakage from tailings dams. "Both TiWest and the DEP had admitted that the leaks could have started up to five years before they were detected".[49] The TiWest plant is close to a local river system that is part of the Gnangara Mound, a key source of the Perth metropolitan area's underground water supplies.[50] Professor Phil Jennings, as a spokesman for the Conservation Council of WA, identified the type of contamination that could occur from this leakage. "There's all sorts of heavy metals in those tailings dams including vanadium, manganese and chromium and also the possibility of uranium and thorium present in mineral sands".[51]

Another impact of the expansion of new mines is that the established companies will continue to operate their Capel-based separation plants, as these involve large capital investments. Mineral concentrates from newer mines will need to be transported in the first instance by road heavy haulage vehicles to Capel for separation. The impact of the movement of such tonnages of minerals is illustrated by the Beenup mine, where about

[41] Ie 250,000 and 21,000 becquerels per kilogram, respectively.
[42] Dames and Moore. Rare earth project, Pinjarra, Western Australia. Environmental review and management program, rare earth plant for Rhone-Poulenc Chimie Australia Pty Ltd. Perth, Dames and Moore, 1995, Figure 3.5, p. 3-13.
[43] Radiation Safety (Transport of Radioactive Substances) Regulations 1991, Reg. 4 Government Gazette 22 March 1991, 1222.
[44] Radiation Safety (Transport of Radioactive Substances) Amendment Regulations 1994. Government Gazette 5 August 1994, 3903.
[45] Involves Kerr McGee and Minproc Cooljarloo joint venture containing both dry separation and synthetic rutile plants, operated by the consortium TiWest.
[46] Lewis Environmental Consultants. Environmental review and management program, heavy minerals mine Beenup. Perth, BHP-Utah Minerals International, 1990.
[47] BHP Titanium Minerals. Beenup titanium minerals project - proposals to extend approved mining area. Perth, BHP Titanium Minerals, 1996.
[48] Tan-Van Baren C. "Mine anti-acid damage plan flawed: expert". West Australian 3 June 1995.
[49] Jacobson I. "Mine's fouled water fight flows onto DEP". Sunday Times 5 May 1996.
[50] Buthcer T. "Perth's hidden water supply". (1988) 3(4) Landscope 36.
[51] Ibid.

600,000 tpa of titaniferous minerals will be transported by road to Bunbury,[52] necessitating the construction of major transport road.[53]

6. Proposed REO processing plant at Pinjarra

There would be significant economies of scale in the development of this REO plant, as it shares infrastructure of the company's co-located gallium plant. A key consideration that supports the 1995 proposal, is that by an amendment in November 1994[54] to the Radiation Safety (General) Regulations 1983, the *Code of practice for the near-surface disposal of radioactive waste in Australia (1992)* [55] has been adopted in this State.

The proposed REO processing plant at Pinjarra involves a range of radiation risks, such as to the local environment arising through seepage from evaporation ponds, atmospheric escape of radioactive gas, spillage while being transported to and from the site and high risks for workers employed at the plant itself. The breadth of exposure risk is substantial, as it encompasses employees at the REO plant itself, transport workers and the public, who may be exposed by means including:

- radiation from *internal* doses through inhalation or through contamination of potable water;
- airborne particulate matter containing inhalable particles of monazite and/or thorium residue containing alpha emitting parent radionuclides, and associated daughter products;
- the alpha emitting gases thoron and radon;
- alpha and beta emitting radionuclides dissolved or suspended in process water; and
- from *external* doses as gamma radiation from solids and liquids containing gamma active nuclides, such as waste water lines and the gangue residue from the evaporation ponds.[56]

The revised 1995 ERMP is for the design of a plant that will utilise up to 12,000 tpa of monazite feedstock and will produce 15,000 tpa of solid REO nitrate concentrate that will be transported by road to Fremantle for export. Up to 6,000 tpa of gangue is required be disposed of as 2 tonne bulk bags of residue. The radiation from one of these bags is estimated to be about 200 mSv per hour, at zero distance.[57] The radioactivity levels of this residue is estimated to be 4.2×10^5 Bq/kg and 6.0×10^4 Bq/kg, for Radium-228 and Radium-226, respectively.[58]

The possibility for serious health and environmental risks has been recognised by local residents, following a recommendation for construction in early April this year to the Minister for the Environment by the EPA.[59] The Conservation Council of WA, the Shire of Murray, a local group of ratepayers and members of the public oppose the development of the REO plant, on land adjacent to the Pinjarra alumina refinery.[60]

As there is a high level of commitment by government to the expansion of downstream processing of monazite the community opposition is unlikely to prevent the project proceeding. The Pinjarra site is highly favoured as it would appear to overcome the serious environmental problems that were identified in relation to a proposal by Allied Eneabba in 1985 to construct a REO processing plant at Narngulu.[61] This earlier proposal was to build

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52 The port at Bunbury has a major storage and loading facility for mineral sands products.
53 BSD Consultants Pty Ltd, Mitchell McCotter & Associates, MA Ashbolt & Associates, Pregelj J. Mineral sands road study: Sue's Road to Capel, Public Environmental Review. Perth, Main Roads Department, 1991.
54 Reg. 31A, Government Gazette 11 November 1994, 5695-96.
55 National Health and Medical Research Council. Code of practice for the near-surface disposal of radioactive waste in Australia (1992). Approved at the 114th session of the Council, November 1992. Canberra, Australian Government Publishing Service, 1993.
56 Dames and Moore. Proposed rare earths processing plant, Pinjarra, Western Australia. Environmental review and management program, draft environmental impact statement. (Volume 2). Supporting document II: radiological issues of the Rhone-Poulenc rare earths processing plant proposal. Perth, Dames and Moore, 1988, 18.
57 Dames and Moore. Rare earth project, Pinjarra, Western Australia. Environmental review and management program, rare earth plant for Rhone-Poulenc Chimie Australia Pty Ltd. Perth, Dames and Moore, 1995, p. 3-12.
58 Ie 250,000 and 21,000 becquerels per kilogram, respectively.
59 Guild F. "Rare earths plant gets green light". Sunday Times 7 April 1996.
60 Tan-Van Baren C, MacDonald J. "Radiation fears rejected". The West Australian 8 April 1995.
61 Western Australia, Environmental Protection Authority. Allied Eneabba Ltd proposed rare earth processing plant, report and recommendations. EPA Bulletin 236. Perth, Environmental Protection Authority, 1985; Kinhill Stearns. Proposed rare earth processing plant for Allied Eneabba. Supplement to the draft environmental impact statement. Perth, AMC Mineral Sands, 1985.

relatively close to the coast on sedimentary soils, typical of most of the Swan Coastal Plain and accordingly thorium residue would ultimately reach the sea through seepage from evaporation ponds.

7. Regulation of radiation hazards

While monazite is only present as a minor mineral in unmined ore bodies, with each stage of processing more sophisticated measures must be introduced to control increasing radiation risks to workers, especially from ionising radiation from thorium. The greatest risk to workers occurs through the inhalation of dust particles which emit alpha particles rather than from whole of body irradiation from gamma rays.[62] While the gamma rays emitted from stockpiled monazite are also a serious risk to health, this source of radiation can usually be adequately controlled by shielding. However, as expensive ventilation systems are required to control airborne particulate sources of ionising radiation, the imposition of appropriate standards involves substantial outlays by producers.

7.1 International regulatory framework

A number of prestigious international scientific bodies are responsible for setting radiation levels, such as the management of high level radioactive waste from nuclear reactors and the transnational movement of nuclear materials.[63] The key body is the International Atomic Energy Agency (IAEA), which was established by the United Nations (UN) in October 1956, and came into force in July 1957.

Article 2 of IAEA Statute provides that *"the Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world", [and to ensure as much as is possible,] "that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose"*.

The IAEA is in turn reliant on the advice of technical and scientific organisations in setting standards for exposure to ionising radiation. These include the:

- International Commission on Radiological Protection (ICRP);
- United Nations Committee on the Effects of Atomic Radiation (UNSCEAR);
- World Health Organisation (WHO);
- International Labour Office (ILO); and
- Nuclear Energy Agency (NEA) of the Organisation for Economic Cooperation and Development.

The setting of Australian standards for radiological protection in relation to low level radiation hazards (which encompasses monazite), is effected through the adoption of recommendations published by the International Commission on Radiological Protection (ICRP). The force for ICRP recommendations derives from the scientific credibility of its members. The principles by which the ICRP frames its recommendations are that:[64]

1. no practice shall be adopted unless its introduction produces a positive net benefit;
2. all exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account;[65] and
3. the dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances.

The ICRP was setup in 1928 and in conjunction with UNSCEAR, established in 1955, evaluates dosage levels and the effects and risks from ionising radiation on a worldwide scale. The scientific criteria for radiation protection standards is contained in a series of published reports, referred to as recommendations, which take

[62] Poulsen R & Troy J (eds). Mineral sands scandal: radiation and health. Fremantle, SV Publications, 1983; Hartley BM, Toussaint LF. "Radiation doses in the sand mining industry, what we know and what we don't know". In Proceedings of Conference, Australia: a world source of ilmenite, rutile, monazite and zircon. Perth, September-October 1986. Parkville, Victoria, Australasian Institute of Mining and Metallurgy, 1986.

[63] For instance, in 1990 the IAEA General Conference adopted a Code of Practice on International Transboundary Movement of Radioactive Waste, containing measures to limit the uncontrolled international movement and disposal of radioactive waste.

[64] Hall EJ. Radiation and life. Nuclear Energy Agency Library (http://is.eunet.ch/geneva-intl/gi/egimain/etyos.htm), June 1995.

[65] The ALARA principle. The Mines Safety and Inpsection Regulations 1994, Reg. replicates this phrase by stating that the "effective dose of radiation to employees generally is reduced to levels that are as low as practicable".

account of UNSCEAR research and reports. A key ICRP report, *Limits for intakes of radionuclides by workers*, commonly referred to as ICRP 30, proposes a regulatory framework for occupational exposure in mines and other environments where radionuclide materials are handled or stored.[66]

7.2 Federal regulatory framework

In Australia radiation protection is achieved through a combination of Commonwealth, State and Territory legislative measures and voluntary codes of practice. The key national body is the Joint Commonwealth-State Consultative Committee (JCSCC) which has operated for a number of years as a cooperative arrangement.

The JCSCC has resulted in agreement on three Codes of Practice. The impetus for which arose from the inquiry and approval process undertaken by the Commonwealth in the mid to late 1970s in relation to the mining of uranium in the Northern Territory at the Ranger mine. These codes are of sufficiently wide application to encompass low level radioactive materials such as monazite. These codes are the:

1. *Radiation protection in the mining and milling of radioactive ores*, agreed to in 1980;[67]
2. *Safe transport of radioactive substances*, agreed to in 1982; and[68]
3. *Management of radioactive waste from the mining and milling of radioactive ores*, agreed to in 1982.[69]

However, to be effective each code must be adopted by each State and Territory. The Commonwealth statute,[70] the Environment Protection (Nuclear Codes) Act 1978 (EP(NC)A), only extends to Australian territories, such as the Australian Capital Territory and the Northern Territory.[71] Under the EP(NC)A the Commonwealth may issue Codes of Practice through regulation in relation to "nuclear activities". A very broad definition of a nuclear activity under the EP(NC)A means the Act may encompass all stages of processing, as it includes the mining, milling, storage and transport of radioactive substances.[72] However, the Commonwealth may not however promulgate regulations without the consent of a State.[73] Codes of practice promulgated under the EP(NC)A have a potentially wide ambit as "nuclear activities" includes the "production of any prescribed substance".[74] A "prescribed substance" is defined as "uranium, thorium, an element having an atomic number greater than 92 or any other substance declared by the regulations ... to be a radioactive substance".[75]

It is submitted that the approach embodied in the EP(NC)A leaves the Commonwealth is a weak position to regulate the mining, treatment and transport of monazite, which as indicated is a significant source of ionising radiation. This can be contrasted with the approach taken by the former Keating government in relation to woodchips, where export licenses were granted subject to compliance by the States with environmental conditions intended to limit the exploitation of old growth forests.[76]

There are other powers available to Commonwealth which could be exercised in a limited manner, if so desired, to impose standards on the mineral sands mining industry. Firstly, it has scheduled a range of metals and minerals, including monazite concentrates and other mineral sands products, under the Customs (Prohibited Exports) Regulations, Schedule 7. Thus, an exporter must first obtain an permit from the Minister for Primary Industries and Energy before scheduled products can be exported. Arguably the Commonwealth could attach

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[66] International Commission on Radiological Protection. Limits for intakes of radionuclides by workers. ICRP Publication No. 30. Oxford, Pergamon Press, 1978.
[67] Commonly known as the Mining and Milling Code.
[68] Commonly known as the Transport Code.
[69] Commonly known as the Radioactive Waste Code.
[70] This statute implemented an agreement under the IAEA signed in July 1974, known as the Agreement for the Application of Safeguards in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons.
[71] Environment Protection (Nuclear Codes) Act 1978 s 5.
[72] Id s. 4.
[73] Id s. 14(8).
[74] Id s 4.
[75] Ibid.
[76] Environment Protection Authority. Report and recommendations of the EPA on the Department of Conservation and Land Management proposals to amend the 1987 forest management plans and timber strategy and proposals to meet environmental conditions on the regional plans and the WACAP ERMP (Bulletin 652). Perth, Environmental Protection Authority, 1992; Australia, Department of Environment Sports and Territories. National forest conservation reserves, Commonwealth proposed criteria, a position paper. Canberra, Department of Environment Sports and Territories, 1995.

conditions to export licenses to set minimum occupational and environmental radiation standards, if any of the States failed to do so.

There is a requirement under the Income Tax Assessment Act (ITAA), Regulation 4, for the exporter of mineral sand products (as well as a range of other metals and minerals), referred to as "prescribed minerals", to obtain an export permit. However, as the object of this provision is to determine liability for income tax from the sale of minerals under section 23 (pa) of the ITAA this legislation has little application to radiation safety standards.

In June 1987 the Commonwealth issued a draft code, the Radiation Protection (Mining and Milling) Code, to replace the 1980 Mining and Milling Code. As this code did not receive the necessary Commonwealth legislative approval it lapsed. If this code had been adopted it would have resulted in the implementation of the standards contained in ICRP 30. A comparison between dose limits for members of the public based on ICRP 30 and the standards contained in Australian codes of practice is contained in the 1985 EIS for the REO processing plant at Narngulu. It was concluded:

> "that adoption of ICRP 30 results in much lower PDLs for thorium isotopes and generally higher PDLs[77] for the radium isotopes. The ERMP/draft EIS indicated that, on the basis of the current codes of practice, only the radium isotope 226 Ra presented any significant environmental hazard. An increase in the allowable concentrations by a factor of 2.6 does not significantly alter the assessments made in the ERMP/draft EIS".[78]

7.3 State regulatory framework

7.3.1 Mines Safety and Inspection Act 1994

An article published in 1995[79] provides a useful analysis of key Western Australian legislative provisions applicable to the management of monazite-containing tailings after cessation of mining. It should be noted references to the Mines Regulations Act 1946 are no longer applicable as this Act and associated Regulations were repealed in early December 1995.[80] Harman points out that under Section 114(7) of the Mining Act 1978 that when a:

> "mine is decommissioned, the ownership of the tailings reverts to the Crown. Thus once the conditions and requirements of rehabilitation have been met and the tenement surrendered by the mining company, the radioactive tailings buried on the land become the property of the Crown, that is, the Crown secures the title to the intractable radioactive mine waste".[81]

The provisions that existed before the passage of the Mines Safety and Inspection Act 1994,[82] which repealed the Mines Regulation Act 1946,[83] and the Mines Safety and Inspection Regulations 1995,[84] which repealed the Mines Regulation Act Regulations,[85] contained provisions for determining exposure levels permitted at mines in this State. The expansive definition of a mine site encompasses secondary processing plants, including the proposed REO plant at Pinjarra.

The Mines Regulation Act Regulations adopted two of the Commonwealth Codes of Practice, the *Mining and Milling Code 1987*, and the *Radioactive Wastes Code 1982*. The levels in these Codes of Practice were set by

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77 A public designated limit (PDL) is an alternative form reference to limits of exposure to ionising radiation.
78 Kinhill Stearns. Proposed rare earth processing plant for Allied Eneabba. Supplement to the draft environmental impact statement. Perth, AMC Mineral Sands, 1985, 12.
79 Harman AW. "Legislative control of radioactive waste disposal by the mineral sands industry in Western Australia". (1995) 14 AMPLA Bulletin 193.
80 Amendments made to the Environmental Protection Act 1986, which included formation of the Department of Environmental Protection may also effect some of the law in this area Cf Gardner A. "Reforming the Environment Protection Authority of WA". (1993) 3 Australian Environmental Law News 40.
81 Harman AW. "Legislative control of radioactive waste disposal by the mineral sands industry in Western Australia". (1995) 14 AMPLA Bulletin 193, 208.
82 Proclaimed in Government Gazette, 8 December 1995, 5935.
83 Mines Safety and Inspection Act 1994, s 107.
84 Proclaimed in Government Gazette, 8 December 1995, 5629.
85 Mines Safety and Inspection Regulations 1995, Reg. 17.2.

the National Health and Medical Research Council (NHMRC) as the safe upper limit for the general public.[86] These levels also conform to Australian radiation protection standards, based on ICRP recommendations, which divide exposure into two categories:

1. occupational (maximum permissible dose should be 20 mSv per year, averaged over 5 years, ie a total of 100 mSv); and
2. public (maximum dose of 1 mSv per year averaged over 5 years, ie a total of 5 mSv.

The Mines Safety and Inspection Regulations 1995, which do not replicate the two Commonwealth Codes of Practice, provide that certain persons employed at mines, “designated employees”, may be exposed to an effective annual dose of radiation exceeding 5 mSv. The Regulations provide for different levels of exposure according to whether a person is:

1. a “designated employee”, defined as someone who works or may work under conditions where the annual effective dose equivalent might exceed 5 mSv;
2. a “non-designated employee”, someone who is not a designated employee; and
3. a “member of the public”, as any else other than an employee.

The structure of three levels of exposure follows the approach contained in the draft Commonwealth Radiation Protection (Mining and Milling) Code of 1987, which also provided for designated employees, non-designated employees and members of the public. Under the 1995 Western Australian legislation effective annual dose limits were 50 mSv, 5 mSv and 1 mSv per year, respectively.[87] The dose limits for designated employees and members of the public, as provided by Regulations 16.18 and 16.19, are set out in Table 1 (below).

Table 1: Dose limits employees and members of the public

	Employees	Public
Effective dose limit (single year)	50 mSv	1 mSv (per year)
Equivalent dose limit (per year)		
· in lens of the eye	150 mSv	15 mSv
· in any single organ or tissue, excluding the lens of the e ye	500 mSv	50 mSv

It should be noted that Part 16 of the 1995 Regulations, which deals with radiation and safety, applies only to and in relation to a mine if:

1. thorium or uranium ores are mined at the mine;
2. employees at the mine are likely to receive doses of radiation in excess of an effective dose of 1 mSv per year arising from mining; or
3. members of the public at, or in the vicinity of, the mine are likely to receive doses of radiation, as a consequence of that mining operation, in excess of one half of the dose limits set forth in Regulation 16.19.[88]

[86] National Health and medical Research Council. Recommended radiation protection standards for individuals exposed to ionising radiation. Approved at 89th session of the Council, June 1980. Canberra, Department of Community Services and Health, 1980; National Health and medical Research Council. Amendment of the recommended radiation protection standards for individuals exposed to ionising radiation Approved at 100th session of the Council, November 1985. Canberra, Department of Community Services and Health, 1980; National Health and medical Research Council. Guidelines for remedial action in areas where residues from mineral sand mining and processing have been deposited. Canberra, Department of Community Services and Health, 1987.
[87] Dames and Moore. Proposed rare earths processing plant, Pinjarra, Western Australia. Environmental review and management program, draft environmental impact statement. (Volume 2). Supporting document II: radiological issues of the Rhone-Poulenc rare earths processing plant proposal. Perth, Dames and Moore, 1988, Attachment 2, A2-v.
[88] Regulation 16.19 refers to the right column headed public in the following table.

The Mining Operations Division of the Department of Minerals and Energy (DME), which enforces compliance with safety and occupational matters at mines, provides additional guidelines which the industry is encouraged to follow. These are not mandatory.

The DME has endorsed a document entitled *Guidelines for remedial action in areas of enhanced background gamma radiation levels*. This document permits variations above the maximum safe limits, by setting safe limits of emissions as ratios above the natural background radiation level. In these guidelines the recommended public radiation limit is 0.11 uGy/hr,[89] derived from 1 mSv, the public annual radiation dose limit, divided by the number of hours in a year (8,760). The public exposure limit of 1 mSv, is usually referred to as the *annual effective dose equivalent*.

The guidelines suggest as there is a degree of variability in natural background radiation, a "maximum acceptable background" of 0.35 uGy per hour is appropriate. Interpretation of these levels of safe exposure (Table 2 below) justifies higher radiation levels on roads, for instance, as they have lower frequencies of occupancy.[90]

Table 2: Guideline values (microGrays)

Type of occupancy	Assumed occupancy	Maximum uGy h^{-1}
Dwellings	100%	0.46
Schools	50%	0.57
Other areas	25%	0.79
Roads	10%	1.5

7.3.2 Radiation Safety Act

The new legislation introduced in late 1995 for the mining industry means there is may be more scope to refer to other regulatory provisions, than was formerly possible. The basis for advancing this proposition stems from another piece of Western Australian legislation, the Radiation Safety Act 1975.

If there is inconsistency between subsidiary legislation, the Radiation Safety (General) Regulations 1983 and the Radiation Safety (Transport of Radioactive Substances) Regulations 1991, or any regulations relating to the mining or milling of radioactive ores made under the Mines Regulation Act 1946 or the Nuclear Activities Regulation Act 1978, then such regulations shall prevail over the Radiation Safety (General) Regulations 1983.[91]

Arguably with the repeal of the Mines Regulation Act 1946, the Radiation Safety (General) Regulations 1983 may now be applicable to minesites. This may be a preferable approach in determining radiation safety levels at mines as these regulations appear to be more rigorous in setting lower levels of risk. The argument that additional regulatory material may be referred to determine the adequacy of radiation standards in the mining industry is bolstered by a provision in the Mines Safety and Inspection Act 1994, which provide that: [92]

> Regulations under subsection (1) (zk) in relation to the prescription of maximum levels of radiation to which persons may be exposed are only to be made on the recommendation of the Radiological Council established under the Radiation Safety Act 1975.

Another advantage as to why the Radiation Safety Act may be preferable is that it was primarily developed with reference to the risks associated with exposure to radioisotopes and medical applications of ionising radiation.

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[89] uGy = microgray.
[90] National Health and Medical Research Council. Guidelines for remedial action in areas of enhanced background gamma radiation levels. Canberra, Department of Community Services and Health, 1988.
[91] Radiation Safety (General) Regulations 1983 reg. 4.
[92] Mines Safety and Inspection Act 1994 s 104.

The Act also establishes a Radiological Council, which is composed of up to eight members, with stipulated qualifications and expertise, as follows:[93]

- a medical practitioner, who is to be chairman;
- two additional medical practitioners, one of whom is to be specialist in radiology or radiotherapy and the other to be a physician specialising in nuclear medicine;
- a physicist;
- a radiation or electronics engineer;
- a representative of the interests of tertiary educational institutions; and
- two other members with special knowledge of the problems of radiation hazards nominated by the Minister for Health.

Conceivably the Radiological Council, which has wide discretionary powers, [94] may offer more independent determinations in relation to radiation safety as it may be less susceptible to influence by the mining industry. For instance with respect to thorium, (one of the many radioactive substances covered in the Regulations), the Radiation Safety (General) Regulations 1983 are triggered when the emission level of thorium exceeds 4.0 megabecquerel. This is a lower threshold value than provided under the Mines Safety and Inspection Act 1994. The Radiation Safety (General) Regulations 1983 also deals with radiation safety issues concerned with the storage of radioactive substances (Reg. 30), the release or disposal of radioactive substances (Reg. 31) and the control of exposure to radiation (Reg. 33).

7.3.3 Radiation Safety (Transport of Radioactive Substances) Regulations 1991

As indicated earlier, the Commonwealth Codes of Practice do not have force in the States unless they are adopted through a State enactment. The Radiation Safety (Transport of Radioactive Substances) Regulations 1991 incorporate specified numbered paragraphs Commonwealth Code of Practice for the Safe Transport of Radioactive Substances (1990). This particular Code of Practice in turn is based on IAEA regulations.[95]

The Regulations have application to "radioactive substances"[96] and adopt numbered paragraphs of the International Regulations contained in an appendix to the 1990 Code of Transport, with respect to carriers (Schedule 1) and consignors (Schedule 2) of radioactive substances.

It is necessary, therefore, to refer to the Commonwealth Code of Practice for the Safe Transport of Radioactive Substances (1990), for provisions which are applied as State law under the 1991 Regulations. While many of the adopted paragraphs set out detailed technical provisions concerned with labelling and packaging, for instance, some of the provisions have wider ramifications. One such example is provided by Clause 6. This stipulates the NHMRC should hold a key role in standards setting, as follows:

> In addition to the requirements of the Basic Safety Standards for Radiation Protection (1982), referenced in paragraphs 201 and 203, the radiation exposure of transport workers and members of the public shall be subject to the recommendations of the NHMRC, given in its *Recommended Radiation Protection Standards for Individuals Exposed to Ionising Radiation*, as adopted at its 89th Session, June 1980, as amended from time to time. Where differences occur between Basic Safety Standards for Radiation Protection (1982) and the NHMRC recommendations, the latter shall prevail.

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[93] Radiation Safety Act 1975 s 13.

[94] The Radiological Council also has the power to place a radioactive ore under the Regulations. If the Council is of the opinion that a radioactive ore which is a natural radioactive substance may give rise to a radiation hazard or result in an individual receiving a dose equivalent exceeding the dose equivalent limit, when that radioactive substance is mined or milled, that radioactive substance consists of more than the maximum prescribed concentration referred to in subregulation (1) while it is being mined or milled: Radiation Safety (General) Regulations 1983 reg. 5(5). It has not been determined that this residual power has been exercised.

[95] As provided for by the 1990 Code, these refer to the International Atomic Energy Agency Regulations for the Safe Transport of Radioactive Materials 1985 incorporating the 1988 supplement, as amended to and published in December 1988, as set out in Annexe 1 to the Code.

[96] A "radioactive substance" is defined by Reg. 4 of the Radiation Safety (Transport of Radioactive Substances) Regulations 1991 as a natural or artificial radioactive element, the radioactivity of which exceeds 70,000 becquerels per kilogram.

There are advantages in setting Australian radiation standards through the adoption of international exposure limits, rather than according to locally determined parameters. For instance, it was found an error had been incorporated into the Commonwealth Codes of Practice, which were established in the 1980 to 1982 period. Following re-examination of the ICRP 30 levels, it was found that an error had been made in these codes in the thorium limit. The effect of this error was that "a seven-fold decrease in the limit for thorium dust should have applied and this, when converted to gross alpha activity, should have required about four-fold decrease in the gross alpha activity limit for airborne dust".[97] The same commentator, the State's former chief radiation scientist, observed that as a consequence of this error, "that reduction of dose from inhalation of dust should be an occupational health priority of sand mining companies and this may involve considerable expense".[98]

8. Conclusion

It should be acknowledged while it has been argued that there are advantages gained by relying on international standards for determination of radiation standards, setting of these standards is subject to industry pressure, through the ALARA principle. This concept is incorporated into the various regulations referred to earlier, by inclusion of the phrase "as low as reasonably achievable", or similar phraseology. The principle behind ALARA is that there is a risk associated from exposure to any level of radiation, and that the magnitude of this risk is proportional to the size of a dose ionising radiation that someone may receive.

The implications of the ALARA principle is appreciated by acknowledging that the definition includes the terms "economic and social factors considered". This caveat may support objections raised by the mineral sands companies, that to achieve background radiation levels in relation to the production of monazite would force them to bear prohibitive costs. However, as the setting of radiation standards involves economic issues, it would appear that dose limits could be frequently revised by a vigilant regulatory agency to take advantage of technological improvements and to reward individual producers who implement improvements in their processing facilities. As Hartley notes, "(t)he fact that economic and social factors are part of the ALARA implies the need for an appropriate cost-benefit analysis of alternative lower operational doses and perhaps the application of operations research techniques in obtaining an optimal solution".[99]

The present structure of the Western Australian mineral sands industry is one of growing integration between mining, processing and "value added" secondary industries. The State has very large reserves of heavy minerals, with just over 21 million tonnes of proven reserves and with the inclusion of probable and possible reserves it is estimated there may be up to a total of 80 million tonnes of heavy mineral reserves. The environmental impact of mining, if all these reserves were exploited, is difficult to anticipate.

A 1989 report on the State's mineral sands mining and processing by the WA Chamber of Mines and Energy noted, "[b]y the mid 1990s mineral sands production and processing will employ 3,000 people earning more than $1.2 billion a year, North West Shelf Gas will employ 1,300 workers, generating $1.5 billion in export earnings."[100] The magnitude of the investments and the scale of mining now been undertaken means the industry can claim it is a major contributor to the State's economy as an employer and earner of export dollars. This may make it more difficult to impose rigorous radiation standards, without the credibility and influence of credible international scientific and medical opinion.

[97] Hartley BM, Toussaint LF. "Radiation doses in the sand mining industry, what we know and what we don't know". In Proceedings of Conference, Australia: a world source of ilmenite, rutile, monazite and zircon. Perth, September-October 1986. Parkville, Victoria, Australasian Institute of Mining and Metallurgy, 1986, 168.
[98] [98] Hartley BM, Toussaint LF. "Radiation doses in the sand mining industry, what we know and what we don't know". In Proceedings of Conference, Australia: a world source of ilmenite, rutile, monazite and zircon. Perth, September-October 1986. Parkville, Victoria, Australasian Institute of Mining and Metallurgy, 1986, 168.
[99] Hartley BM, Toussaint LF. "Radiation doses in the sand mining industry, what we know and what we don't know". In Proceedings of Conference, Australia: a world source of ilmenite, rutile, monazite and zircon. Perth, September-October 1986. Parkville, Victoria, Australasian Institute of Mining and Metallurgy, 1986, 166.
[100] Chamber of Mines and Energy of Western Australia. Western Australia's mineral sands industry - potential for the 1990's. Perth, Chamber of Mines and Energy of Western Australia, 1989, 1.

The industry's rehabilitation and environmental record was criticised in the 1987 report by a working party to consider conservation and rehabilitation in the mineral sands industry.[101] One company, RGC Mineral Sands Ltd, has sought to meet this criticism by converting former mining areas left as water-filled pits into a 52 hectare wetland system with funding of $200,000 per year over a five year period with the Royal Australasian Ornithologists' Union.[102] The companies have linked their activities in this area to participation by "moderate" conservation groups. As the Chambers of Mines observes:

> "WA producers have developed an information program to show that mineral sands mining can make a positive contribution to the environment. An emphasis on rehabilitation to develop wetlands wildlife sanctuaries, reafforestation technology, the expansion of national parks and environmental research projects will recognise the greening of Australian attitudes. The companies are working to establish a productive relationship with moderate conservation groups."[103]

The possibility of irreparable environmental harm following the gradual release of radionuclides which become sources of ionising radiation over extremely long periods of time cannot be underestimated. As observed by the Specialist Group who provided a report to the 1985 Allied Eneabba environmental inquiry, "(a)s thorium in the residue has a very long lifetime (in excess of many millions of years) the waste will eventually be released to the environment and dispersed."[104] As a community do we want to contaminate our environment for such a price?

The issue of radiation hazard cannot be separated from broader environmental concerns about mineral sands mining. This means government and industry must develop very good partnerships with local communities to earn their trust and confidence in the regulatory regimes that are implemented and maintained. Such partnerships will become increasingly important in this State because of the projected expansion in large scale mining operations of low grade mineral sands deposits in zones outside of the established mining zones on the Southern and Northern Swan Coastal Plain[105] and because of encouragement by government for State-based secondary processing facilities.[106]

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[101] Western Australia, Working Party on Conservation and Rehabilitation in the Mining Industry. Report on conservation and rehabilitation in the mineral sands mining industry. Perth, Department of Minerals and Energy, 1987.

[102] Bethwaite M. "Education through rehabilitation: RGC Mineral Sands Ltd". (1994 October) Business Council Bulletin (Supplement) 54.

[103] Chamber of Mines and Energy of Western Australia. Western Australia's mineral sands industry - potential for the 1990's. Perth, Chamber of Mines and Energy of Western Australia, 1989, 2.

[104] Western Australia, Environmental Protection Authority. Allied Eneabba - disposal of thorium rich waste from proposed monazite treatment plant. Specialist group report to the EPA. Environmental Note 174. Perth, Environmental Protection Authority, 1985.

[105] South West Development Authority. South west mineral sands industry report: an information handbook. Bunbury, South West Development Authority, 1990; Western Australia, Department of Resources Development. South coast mineral sands: government strategy. Perth, Department of Resources Development, 1990; Western Australia, Environmental Protection Authority. Heavy minerals mine at Jangardup, Cable Sands (WA) Pty Ltd, report and recommendations. EPA Bulletin 422. Perth, Environmental Protection Authority, 1990; Western Australia, Environmental Protection Authority. Heavy mineral sands exploration, Bremer Bay, Placer Pacific Ltd and Eucla Mining, report and recommendations. EPA Bulletin 494. Perth, Environmental Protection Authority, 1991.

[106] Armstrong P. "Giant plans $470m SW plant upgrade". The West Australian 18 May 1996; Dames and Moore. Titanium dioxide pigment plant at Kwinana - production debottlenecking to 80,000 tonne per annum for TiWest Joint Venture. Consultative environmental review. Perth, Dames and Moore, 1994; Woodward-Clyde. Synthetic rutile plant at Chandala. Production debottlenecking to 200,000 tonne per annum for TiWest Joint Venture. Section 46 public review document. Perth, Woodward-Clyde, 1995.