Mineral Sands

Naturally-Occurring Radioactive Material Appendix 1

(Updated September 2010)

- **Australia and Africa are major producers of mineral sands containing titanium minerals and zircon.**
- **A minor constituent of many mineral sands deposits is monazite, which is the main source of thorium.**
- **As thorium is radioactive, occupational health provisions are required for handling materials containing thorium.**

Australia and Africa have extensive deposits of mineral sands which comprise:

- Titanium minerals: rutile – TiO_2 with up to 10% iron; ilmenite – $FeTiO_3$ with some manganese and magnesium; and leucoxene – hydrothermally altered ilmenite.
- Zircon (zirconium silicate, $ZrSiO_4$), which may have traces of uranium & thorium (up to 500 ppm) in the crystal structure, along with hafnium.
- Monazite – a rare earth phosphate containing a variety of rare earth minerals (particularly cerium and lanthanum) and 5-12% (typically about 7%) thorium.
- Xenotime – yttrium phosphate with traces of uranium and thorium.

These mineral sands are in placer deposits which have been naturally concentrated by gravity. They have been mined since 1934 and Australia has a major share of the world market for both titanium minerals and zircon. In the mining plant they are concentrated by gravity (in spiral sluices) and magnetically (for ilmenite).

While the main products of mineral sands mining are titanium oxide and zircon, monazite is also a significant component. In some deposits xenotime also occurs. Monazite and xenotime may be processed to recover rare earth oxides[a], which are used in electronics and other specialist fields, but the presence of thorium[b] makes them commercially unattractive. Monazite is thus normally returned to the mine with the tailings.

Western Australian mineral sands deposits contain up to 10% heavy minerals, of which 1-3% is monazite. This in turn typically contains 5-7% of radioactive thorium and 0.1-0.3% of uranium, which is barely radioactive. However, if decay products of either are present in the minerals, the radioactivity levels may be significant when the monazite is concentrated.

Radioactivity

The occupational health issue of specific relevance to the mineral sands industry is radiation. In ore, or general heavy mineral concentrate, the radiation levels are too low for radioactive classifications. However, when the radioactive material is concentrated in the process of separation and production of monazite, the radiation levels are increased, creating the need for special controls to protect some designated employees in dry separation plants.

The most significant potential radiation problem is alpha radiation arising from thorium in airborne

dust dust, which may be inhaled. Dust control is therefore the most important objective in radiation safety for the titanium minerals industry. This contrasts with other industries where the focus for radiation protection has been direct gamma radiation from materials in rock. Exposure to gamma radiation still needs to be controlled in the mineral sands industry, due principally to uranium and thorium in zircon.

Australian radiation protection standards

In Australia, the more precise identification of airborne radiation in mineral sands dry separation plants led to the introduction of voluntary codes of practice in 1980. These codes were incorporated into protective legislation in 1982. The method of calculating permissible exposure levels was changed in 1984 and again in 1986. The result was an effective six-fold reduction in radiation exposure limits.

The industry responded with two major initiatives:

- Engineering programs to reduce airborne dust in the dry separation plant.
- Research programs to improve industry and community knowledge about airborne radiation.

Collectively, the titanium minerals mining companies in Western Australia[c] have spent more than $30 million on engineering programs to improve dust control measures. As a result, average radiation levels have been reduced by more than 70%. Protective masks are no longer required for most plant operators. All new plant is designed to incorporate efficient dust control equipment.

Titanium minerals production is managed under the *Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing*[1]. The current occupational exposure radiation levels are well below the Code limit of 20 millisieverts per year (mSv/yr)[d].

Further Information

Notes

a. 'Rare earths' (scandium, yttrium, and the fifteen lanthanides), while valuable, are not particularly rare and preferred sources do not have thorium present. For example, lanthanum and cerium now come from ionic clays in China, which do not have thorium present. [Back]

b. Thorium oxide is used in refractories, lamp mantles, specialised glass and welding electrodes. However, the potential supply as a by-product of mineral sands mining vastly exceeds demand. [Back]

c. Most of Australia's mineral sands occur on the east coast of Australia between Sydney and Fraser Island or on the southern section of the west coast. New South Wales and Queensland producers are required to meet the same standards as Western Australian miners. However, the limited monazite content of most east coast deposits means that radiation levels in New South Wales and Queensland dry plants have always been well below occupational health limits. [Back]

d. Australian occupational exposure limits correspond to those set by the ICRP (International

Commission for Radiological Protection). These are given in paragraph 166 of the ICRP 1990 Recommendations, *ICRP Publication 60*: "A limit on effective dose of 20 mSv per year, averaged over five years (100 mSv in five years), with the further provision that the effective dose should not exceed 50 mSv in any single year." [Back]

References

1. Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005), Radiation Protection Series No. 9, Australian Radiation Protection and Nuclear Safety Agency (August 2005) [Back]

General sources

Titanium Fact Sheet on the Australian Atlas of Mineral Resources, Mines, and Processing Centres website (www.australianminesatlas.gov.au)

Greg Baker, Thorium in Australia, Research Paper no. 11 2007-08, Parliament of Australia (September 2007)