Audit of Radioactive Material in South Australia
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September 2003
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ISBN 1 876562 58 7
September 2003

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FOREWORD

South Australia’s Radiation Protection and Control Act 1982 (the Act) aims to protect people and the environment from the harmful effects of radiation. The Act is committed to the Minister for Environment and Conservation, who has delegated to the Chief Executive of the Environment Protection Authority (EPA) and officers of the EPA’s Radiation Protection Division powers, roles and functions under the Act and its regulations.

Concern about the safety and security of radioactive material and the management of radioactive waste in South Australia has increased in recent years. To review the current management of radioactive material, the Government of South Australia announced in August 2002 that the EPA would conduct an audit of radioactive material stored in the State. A project brief, ‘Audit of Radioactive Material Storage in South Australia’, was prepared by the EPA and approved by the Hon. John Hill, Minister for Environment and Conservation.

The audit was conducted by officers of the EPA’s Radiation Protection Division, who have expertise in the safe management of radioactive material. A draft report on the audit was provided to the South Australian expert body on radiation protection issues, the statutory Radiation Protection Committee. Additional information was later included in the report to enable a clearer understanding of its technical aspects by a broad audience. This report has been endorsed by the Radiation Protection Committee and noted by the EPA Board.

I endorse the report with its recommendations as a key document for the future management of radioactive material in South Australia.

Dr Paul Vogel

CHIEF EXECUTIVE AND CHAIR
ENVIRONMENT PROTECTION AUTHORITY
CHAIR, RADIATION PROTECTION COMMITTEE

September 2003
Errata

The following corrections (shown in bold) should be made to the text of this report:

7.2.1—page 28, fourth paragraph:
The operation of the stockpiles is in accordance with approvals granted under the Radiation Protection (Mining) and Radioactive Waste Management codes.

Table 8—page 48, footnote (a):
Bq = bequerel = unit of radioactivity; terabequerel (TBq) = \(10^{12}\) Bq.

Chapter 12 page 57, definitions:
ISD-RW Indicator of sustainable development for radioactive waste management.

Page 58, definitions:
Isotope—one of a set of atoms which have the same atomic number (number of protons in the nucleus) but different mass numbers (number of protons plus neutrons in the nucleus); see nuclide.
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EXECUTIVE SUMMARY

In August 2002 the Government of South Australia announced that the Environment Protection Authority (EPA) would conduct an audit of radioactive material in South Australia. The Hon. John Hill, Minister for Environment and Conservation, requested the EPA to undertake the audit, with particular emphasis on material designated as waste, and to determine the nature and volume of the material and whether it was safely and securely stored.

The audit revealed 134 sites where radioactive material was stored or used, of which 80 contained radioactive waste.

A summary of South Australia’s radioactive waste is provided in Table 1. In general, it was found that the material was stored safely and securely. In cases where the safety or security was found to be in need of improvement, the EPA did not consider it to be an immediate public health issue. Nevertheless, in these cases the EPA is working with the owners to improve the safety and security of their stored radioactive material.

By far the greatest volume of stored radioactive material is tailings located at current and former uranium mining and milling sites. This material continues to be managed on site.

Very low level radioactive waste generated by laboratories in hospitals and research institutions is either stored until its activity reduces by radioactive decay to levels that are not regulated, or disposed of by owners in accordance with the National Health and Medical Research Council Code of practice for the disposal of radioactive wastes by the user (1985). The need for ongoing disposal of this type of waste is emphasised.

The remaining stored radioactive waste, consisting of low and intermediate level waste, has a volume of approximately 22 cubic metres (m$^3$). The report recommends that in the near future the government investigate the feasibility of establishing facilities for safe interim storage, handling and packaging of this waste pending the establishment of appropriate facilities for long-term management.

The report also provides a number of options for the future management of radioactive waste in South Australia for consideration by government.

Table 1  Summary of South Australia’s radioactive waste

<table>
<thead>
<tr>
<th>Type of waste radioactive material</th>
<th>Volume (m$^3$)</th>
<th>Activity (TBq$^{(1)}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sealed sources</td>
<td>8</td>
<td>6.8</td>
</tr>
<tr>
<td>Very low level</td>
<td>&lt;16</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>14</td>
<td>Not known$^{(2)}$</td>
</tr>
<tr>
<td>Mining</td>
<td>35,400,000</td>
<td>~5,000</td>
</tr>
</tbody>
</table>

$^{(1)}$ Bq = becquerel = unit of radioactivity; terabecquerel (TBq) = $10^{12}$ Bq.

$^{(2)}$ The activity of most legacy waste was not known by owners, nor quantified during the audit.

The background to the audit, its scope, and a brief introduction to radiation and radioactive material are discussed in Section 1. The audit applied only to radioactive material containing radionuclides with an activity and activity concentration at levels regulated by the South Australian Radiation Protection and Control Act 1982. It included the inspection and evaluation of the safety and security of the following radioactive materials:
• registered sealed sources in hospitals, universities and industry
• unsealed radioactive material in hospitals, universities and other organisations
• uranium product and other radioactive material at the Olympic Dam, Beverley and Honeymoon mine sites
• radioactive tailings and residues at Radium Hill and Port Pirie, where uranium ore was mined or processed in the past
• miscellaneous radioactive material, including smoke detectors that contain radioactive material, geological samples held in core libraries and museums, and radioactive material used in secondary schools.

This project involved approximately two person-years of EPA resources, with inspections extending over a 7-month period. The quantity of radioactive material and whether or not it was waste was determined at the time of each inspection. Some radioactive material has since left South Australia, new radioactive material has arrived, and new radioactive waste has been generated. The quantities of radioactive material, its classification as waste and its location were therefore constantly changing.

At June 2003 there were:

• 684 sealed sources that were either registered or subject to applications for registration. In addition, there were 18 sealed sources registered in South Australia that were not inspected as they were based interstate.

• 172 premises that were either registered, or subject to applications for registration, most of which were laboratories where unsealed radioactive material in solid, liquid and gaseous forms was used. There were many instances where a number of registered premises were located at a single site.

• 3 current uranium mine sites and 2 sites containing tailings and residues from past uranium mining and milling practices.

• A wide range of radioactive material that did not fall into the types mentioned above, such as smoke detectors.

Sections 2 and 3 of the report give a brief overview of the types of radioactive material and radioactive waste existing in South Australia.

Section 4 provides a summary of the legislative controls on radioactive materials and radiation protection standards and limits in South Australia.

Findings and recommendations from the inspection of registered sealed sources are discussed in Section 5.

Unsealed radioactive material routinely used in hospitals and laboratories in research institutions is covered in Section 6.

Results of examination of uranium product and other radioactive material and waste stored at the Olympic Dam, Beverley and Honeymoon mine sites, and also radioactive tailings and residues at Radium Hill and Port Pirie where uranium ores were mined or processed in the past, are discussed in Section 7.
Section 8 includes findings and recommendations on a number of miscellaneous types of radioactive material not covered in other sections of the report. These include smoke detectors, which collectively contain significant quantities of radioactive material. The management of waste smoke detectors should be reviewed.

The data obtained from the audit is presented in Section 9. The locations of radioactive material are presented on two maps, metropolitan Adelaide (Figure 17) and South Australia (Figure 18). Table 4, Table 5, Table 6 and Table 7 give further details regarding postcode locations of sealed sources, unsealed radioactive material, mining and milling waste, and miscellaneous material respectively.

The international principles and practices for management of radioactive waste are reviewed in Section 10. Australia’s and South Australia’s management of radioactive waste should accord with the agreed principles of radioactive waste management published by the International Atomic Energy Agency. This is the official body of the United Nations, with statutory responsibilities and obligations relating to protection of human health and the environment from harmful effects of ionising radiation.

Options for future management of South Australia’s radioactive waste are discussed in Section 11.
RECOMMENDATIONS FROM THE FINDINGS OF THE AUDIT

Registered sealed sources (Section 5)

Recommendation 1
That owners of sealed sources regularly review the safety and security of sealed sources and the information contained in their source register, and report periodically to the EPA.

Recommendation 2
That owners of legacy sources that are poorly described ensure that essential shielding and containment is provided, but not attempt complex conditioning until the long-term management options for waste sealed sources are determined.

Recommendation 3
That the EPA contribute to the development and implementation of a national policy on the use of sealed sources beyond their nominal working life.

Recommendation 4
That, where possible and appropriate, the EPA assist in identifying suitable owners for reuse of sealed sources considered to be waste by their present owners.

Recommendation 5
That the capability of the EPA's Radiation Licensing Database be extended to record and maintain details of waste sealed sources and the reasons for cancelling registrations.

Recommendation 6
That the provision for three years' registration and renewal of registration be removed so that registrations and renewals are for one year only.

Unsealed radioactive material (Section 6)

Recommendation 7
That the EPA and other government agencies work together to ensure continued availability of suitable disposal pathways for very low level radioactive waste in accordance with the User Disposal Code.

Radioactive material from uranium mining (Section 7)

Recommendation 8
That management of radioactive waste at uranium mine sites be kept continually under review to take account of any changes in internationally accepted practices.

Recommendation 9
That long-term management plans be developed as required by conditions of registration of the Radium Hill site under the Radiation Protection and Control Act 1982.

Recommendation 10
That the government develop options for management of the types of waste previously disposed of at the Radium Hill repository.

Recommendation 11
That long-term management plans be developed as required by conditions of registration of the Port Pirie site under the Radiation Protection and Control Act 1982.
Miscellaneous radioactive material (Section 8)

**Recommendation 12**
That the EPA review the legislative requirements for storage of smoke detectors.

**Recommendation 13**
That the EPA investigate the possibility of approving disposal of small numbers of smoke detectors with domestic waste, giving due consideration to the current waste management principles and policies used in South Australia.

**Recommendation 14**
That suppliers of smoke detectors fully investigate the feasibility of returning waste smoke detectors to their overseas manufacturers.

**Recommendation 15**
That owners of legacy radioactive waste ensure that essential shielding and containment is provided, but not attempt complex conditioning until long-term management options are determined.

**Recommendation 16**
That the radiation level in any store containing large quantities of radioluminous items be assessed and appropriately managed.

**Recommendation 17**
That the EPA provide guidance for museums and other owners regarding the hazards of articles containing radium paint.

**Recommendation 18**
That owners be encouraged to return waste containers made of depleted uranium to the supplier or transfer them to another suitable owner.

**Recommendation 19**
That the EPA assist owners of unwanted anti-static devices in investigating management options, including export to their overseas suppliers.

**Recommendation 20**
That options for the long-term management of miscellaneous radioactive material be developed.

**Key recommendations for future management of radioactive material (Section 11)**

**Key recommendation 1**
That owners be required to regularly review the safety and security, and their inventory, of radioactive material, and report periodically to the EPA.

**Key recommendation 2**
That the current revision of the IAEA’s *Code of conduct on the safety and security of radioactive sources* (IAEA 2001) and other national and international guidance on safety and security be applied as appropriate to the storage of radioactive material in South Australia.

**Key recommendation 3**
That future management of South Australia’s radioactive waste be in accordance with internationally agreed principles.
Key recommendation 4
That options for management of very low level radioactive waste be developed urgently, and acceptable alternatives be identified as soon as possible but no later than December 2004.

Key recommendation 5
That regulatory control of sites containing mining radioactive waste be kept under review to provide an appropriate system for radioactive waste management for protection of human health and the environment.

Key recommendation 6
That, wherever possible, owners be encouraged to arrange return of radioactive waste to the supplier or to another suitable owner for recycling or reuse.

Key recommendation 7
That South Australia progress toward sustainability in management of its radioactive waste, guided by the UN’s Indicator of Sustainable Development for Radioactive Waste Management as a measure of progress.

Key recommendation 8
That the government undertake a rigorous feasibility study of options for future management of South Australia’s radioactive waste and that this study be commenced as soon as practicable.

Key recommendation 9
That the government investigate the feasibility of establishing a facility for the safe handling, packaging and interim storage of waste pending the establishment of appropriate facilities for long-term management.
1 INTRODUCTION

1.1 Background

In October 2000, at the request of the then Minister for Human Services, the Radiation Protection Branch of the Department of Human Services, which is now the EPA’s Radiation Protection Division, carried out a desktop survey of registered sealed sources that were considered by their owners to be waste. The purpose of the survey was to determine the level of demand for a central store for this type of radioactive waste. The survey provided useful information, but it did not involve site inspections and did not include unsealed radioactive material or miscellaneous material such as non-registrable sealed sources held in South Australia.

Since September 2001 there has been increased consciousness about the security of radioactive material both nationally and internationally, particularly in regard to radioactive material that may potentially be used for malevolent purposes such as terrorism. In recent years public interest and concern about the management of radioactive waste in South Australia has also increased, and there has been considerable parliamentary debate on radioactive waste management issues.

In August 2002 the Government of South Australia announced that the EPA would conduct an audit of radioactive material in South Australia. The Hon. John Hill, Minister for Environment and Conservation, requested the EPA to undertake the audit, with particular emphasis on material designated as waste, and to determine the nature and volume of the material and whether it was safely and securely stored. The Minister approved the project on 21 September 2002.

1.2 Radiation and radioactive material

While it is widely known that radioactive material is hazardous to humans and the environment if not properly managed, it should be noted that it is not unique in this regard; there are many hazardous materials (e.g. asbestos) that are used, stored, transported and disposed of in South Australia every day. In addition, while some radioactive material takes many thousands of years or longer to decay to harmless levels, some hazardous materials never lose their hazardous properties.

Almost everything contains some radioactive material. Naturally occurring radioactive materials, remaining from the formation of the planet, are present in varying amounts in the earth’s crust, and in the oceans and waterways. All soils and rocks contain some naturally occurring radioactive material, from high enough concentrations to mine as uranium ore (or thorium ore in some parts of the world), to lower concentrations in granite and other types of rock, and even lower but still measurable concentrations in garden soils. Plants and animals also contain small concentrations of radioactive material, such as potassium-40, which makes up 0.012% of all potassium. The presence of naturally occurring radioactive material in our bodies, homes, soil, the air we breathe and the food we eat, results in exposure to ionising radiation. We are also exposed to natural radiation from space, known as cosmic radiation.

Radioactive materials are used extensively in medicine for diagnosis of many diseases and for treating some types of cancer; in industry (including agriculture); in research; and in education. Many of these uses produce some radioactive waste.
Radioactivity is the term used to describe the disintegration of the nucleus of an atom, which contains particles known as protons and neutrons. Some elements (naturally occurring or artificially produced—for example, in a nuclear reactor) are unstable because they have too many or too few neutrons in their nucleus. The unstable nucleus of these elements will disintegrate or decay and in the process eject nuclear material in the form of alpha particles (helium nuclei), beta particles (electrons), gamma rays (electromagnetic radiation) or neutrons.

Radioactive elements, or radionuclides, decay at a characteristic rate that remains constant, regardless of external influences such as temperature or pressure. The time that it takes for half the radionuclides to disintegrate or decay is called ‘half-life’. This differs for each radionuclide, ranging from fractions of a second to billions of years.

The term ‘radiation’ is very broad, and includes such things as light and radio waves. The focus of this audit is on ‘ionising’ radiation. When ionising radiation passes through matter, it can cause the matter to become electrically charged or ionised. In living tissues the electrical ions produced by radiation can affect normal biological processes, and can impair the normal functioning of living cells or even kill them.

The amount of energy necessary to cause significant biological effects through ionisation is so small that our bodies cannot feel this energy (unlike non-ionising infra-red rays that produce heat). Although we cannot see or feel the presence of ionising radiation, it can be detected and measured in minute quantities with quite simple radiation measuring instruments.

It has long been recognised that large doses of ionising radiation can damage human tissues. The need to regulate exposure to radiation prompted the formation of a number of expert bodies to provide a suitable framework for radiation protection.

The International Commission on Radiological Protection (ICRP) is an independent non-governmental body formed to establish basic principles for, and issue recommendations on, radiation protection. These principles and recommendations form the basis for national standards and regulations governing the exposure of radiation workers and members of the public (ICRP 1991).

The International Atomic Energy Agency (IAEA) has also incorporated these principles and standards into its Basic Safety Standards for Radiation Protection published jointly with the World Health Organization (WHO), International Labour Organization (ILO), and the OECD Nuclear Energy Agency (NEA) (IAEA 1996). These standards are used worldwide to ensure safety and radiation protection of radiation workers and the general public.

The biological effects of ionising radiation vary with the type and intensity of radiation, and with its energy. A measure of the risk of biological harm is the dose of radiation that tissues receive. The unit of effective dose is the sievert (Sv). Since one sievert is a large quantity, radiation doses normally encountered are expressed in millisieverts (mSv) or microsieverts (µSv), which are one-thousandth and one-millionth of a sievert respectively.

Basic approaches to radiation protection are consistent all over the world. The ICRP recommends that any exposure above the natural background radiation should be kept as low as reasonably achievable, but below individual dose limits. The individual annual dose limit for radiation workers is 20 mSv averaged over 5 years, and for members of the general public is 1 mSv per year; both these limits exclude doses received from background radiation and doses from medical procedures. These dose limits have been established based on a prudent
approach by assuming that there is no threshold dose below which there would be no effect, and therefore any additional dose is presumed to cause a proportional increase in the chance of a health effect. This relationship has not yet been established in the range where the dose limits have been set.

For comparison, it has been estimated that, on average, the Australian population receives 2.3 mSv per year from all sources of radiation. Of this total, approximately 1.5 mSv is from natural background radiation (65%) and 0.8 mSv is from medical exposure (35%) (Webb et al 1999). While doses from all other sources, including industrial activity and nuclear weapons fallout, have not been estimated recently for the Australian population, they are expected to be lower than those in the UK (Hughes 1999), where they make up less than 1% of the total, even though the UK has a substantial nuclear industry.

As with many other materials in use today, radioactive materials can be hazardous if not handled properly. The benefits associated with the use of radioactive materials must be balanced against the potential hazards. Our use of radiation and associated technologies has generated radioactive materials requiring storage, and wastes that need to be managed safely. This audit provides a review of the safety and security of radioactive material and management of radioactive waste in South Australia, with recommendations to ensure the risks to human and environmental health posed by those materials are minimised.

1.3 Scope of the audit

The audit applied only to radioactive material containing radionuclides with an activity and activity concentration at levels regulated by the South Australian Radiation Protection and Control Act 1982 (the Act). It included the inspection and evaluation of the safety and security of the following radioactive materials:

- registered sealed sources in hospitals, universities and industry
- unsealed radioactive material in hospitals, universities and other organisations
- uranium product and other radioactive material at the Olympic Dam, Beverley and Honeymoon mine sites
- radioactive tailings and residues at Radium Hill and Port Pirie, where uranium ore was mined or processed in the past
- miscellaneous radioactive material, including smoke detectors that contain radioactive material, geological samples held in core libraries and museums, and radioactive material used in secondary schools.

The audit did not include radioactive material that was in the process of being transported (including storage in transit), already disposed of, or under federal jurisdiction.

Radioactive material under federal jurisdiction includes material used or stored at premises of CSIRO, the Australian Customs Service, the Australian Army, Navy and Air Force, and the Defence Science and Technology Organisation; on Maralinga lands; and waste stored at two Australian Government sites near Woomera. Provisions of the Australian Government’s Australian Radiation Protection and Nuclear Safety Act 1998 (ARPANS Act) and associated regulations specifically preclude federal entities from control by the South Australian Act. The ARPANS Act is administered by the Australian Government’s Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).
1.4 Essential terminology

A complete list of terms used in this report appears in the glossary, with key terms repeated below.

- **disposal pathway**: the method by which waste is disposed of (e.g., household waste which cannot be reused or recycled is usually disposed of via a landfill disposal pathway)
- **half-life**: the time taken for the activity of a radionuclide to lose half of its value through radioactive decay
- **near-surface repository**: a purpose-built structure either above ground or up to 30 m below ground where radioactive waste appropriate for disposal in such a facility is placed with no intention of retrieval
- **safety**: measures intended to minimise the likelihood of accidents with radioactive material and, should such an accident occur, to mitigate its consequences
- **sealed source**: radioactive material that is permanently sealed in a capsule, or closely bonded and in a solid form
- **security**: measures to prevent unauthorised access or damage to, and loss, theft or unauthorised transfer of, radioactive material
- **site**: a location where radioactive material is stored or used that is physically separate from other such locations (e.g., where a university has a number of campuses, each containing a number of premises or stores, each campus is considered to be a separate site)
- **store**: a room, pit or enclosed area used for storage of radioactive material
- **unsealed radioactive material**: radioactive material that is not a sealed source
- **waste**: material in gaseous, liquid or solid form for which no further use is foreseen

1.5 Statistics

This project involved approximately two person-years of EPA resources, with inspections extending over a 7-month period. The quantity of radioactive material and whether or not it was waste was determined at the time of each inspection. Some radioactive material has since left South Australia, new radioactive material has arrived, and new radioactive waste has been generated. The quantities of radioactive material, its classification as waste and its location were therefore constantly changing.

At June 2003 there were:

- 684 sealed sources that were either registered or subject to applications for registration. In addition, there were 18 sealed sources registered in South Australia that were not inspected as they were based interstate.
• 172 premises that were either registered, or subject to applications for registration, most of which were laboratories where unsealed radioactive material in solid, liquid and gaseous forms was used. There were many instances where a number of registered premises were located at a single site.

• 3 current uranium mine sites and 2 sites containing tailings and residues from past uranium mining and milling practices.

• A wide range of radioactive material that did not fall into the types mentioned above, such as smoke detectors.

While the EPA went to significant lengths to include all radioactive material that fell within the scope of the audit, it is acknowledged that some may not have been included.
2  RADIOACTIVE MATERIAL IN SOUTH AUSTRALIA

Sealed sources and unsealed radioactive material are used widely in medicine, research, education and industry, and in some consumer products. South Australia also has two operating uranium mines, Olympic Dam and Beverley, which produce uranium for export.

2.1 Registered sealed sources

These are sources of ionising radiation, typically in the form of a welded stainless steel capsule containing radioactive material, or radioactive material closely bound in a solid. Sealed sources allow the emission of radiation but prevent any dispersal of radioactive material and contamination of the surroundings.

The main uses of registered sealed sources in South Australia are:

• radiation gauges for the monitoring or control of industrial processes, such as sensing material in bins or on conveyor belts, and determining whether containers are correctly filled

• borehole logging, for geophysical surveys of rock strata

• moisture/density meters, commonly used in civil engineering

• moisture probes, commonly used in agriculture

• industrial radiography, for non-destructive testing of metal welds and castings

• radiation therapy and other medical uses.

2.2 Unsealed radioactive material

Unsealed radioactive material in solid, liquid or gaseous forms is used in registered premises such as laboratories in universities, hospitals, and research, scientific and industrial organisations. Uses include:

• radioimmunoassays, used for a range of biochemical tests such as determining the constituents of blood (e.g. hormones and drugs)

• medical diagnostic studies using radiopharmaceuticals to provide information about a specific organ or its function, and the localisation of tumours or abscesses

• medical treatment of certain tumours or diseased organs

• tracing of small leaks in complex systems such as large heat exchangers

• tracking of flow in gas and oil wells.

The radionuclides that are most commonly used for research and scientific purposes include tritium (hydrogen-3), carbon-14, phosphorus-32, sulphur-35, iodine-125 and iodine-131. Radionuclides with short half-lives are commonly used for diagnostic nuclear medicine. These include technetium-99m (half-life 6 hours) which is used for brain, bone and other organ imaging; thallium-201 (half-life 73 hours) for heart scans; and fluorine-18 (half-life 110 minutes) as a metabolic tracer in positron emission tomography (PET) imaging of organs.
In radionuclide therapy, unsealed radioactive materials with longer half-lives are used and include iodine-131 (half-life 8 days) for thyroid disorders, and strontium-89 (half-life 50 days) for pain relief from bone metastases.

2.3 Uranium

South Australia has a long history of uranium mining, with uranium bearing ore being first mined at Radium Hill and Mount Painter during the early 1900s for its radium content. Radium is a decay product of uranium, which decays through a chain of 14 radionuclides until eventually reaching a stable form of lead. Radium was used in medical therapy in the early to mid 1900s, and had some use in the manufacture of radioluminous paint (see section 8.2.4). Some uranium compounds were also used in the manufacture of ceramics and glass. Immediately following World War II, exploration in South Australia intensified and uranium ore was mined at Radium Hill and processed at Port Pirie to supply uranium for use in British and US nuclear weapons programs.

Since the 1980s two commercial uranium mines have been established and one other uranium project has completed field trials. The two commercial mines, Olympic Dam (WMC Resources Ltd) and Beverley (Heathgate Resources Pty Ltd), export uranium for use as fuel for nuclear power plants in accordance with the requirements of the Australian Safeguards and Non-Proliferation Office (ASNO). Australia only exports uranium to countries with which it has a bilateral safeguards agreement, which provides for accounting of material through the nuclear fuel cycle and ensures that Australian uranium is only used for peaceful purposes and does not enhance or contribute to any military process. This agreement is additional to the safeguards specified by the IAEA, which ensure restrictions on retransfers, high enrichment and reprocessing.

Olympic Dam is an underground mine in which the ore is extracted and crushed, then brought to the surface where it is milled to a fine particle size. The ore is then subjected to various physical and chemical processes to extract the copper, uranium, gold and silver, leaving tailings.

The method used at the Beverley and Honeymoon mine sites is acid in-situ leach (ISL), which is used to bring uranium, located approximately 100 m below ground in porous sandy deposits (aquifers), to the surface for production of uranium oxide.

2.4 Miscellaneous radioactive material

There is a range of radioactive material not mentioned in the above sections, which is collectively referred to in this report as ‘miscellaneous radioactive material’. This includes:

- sealed sources of lower activity than that requiring registration (e.g. sources used in domestic and industrial smoke detectors, static eliminators used in the printing and spray painting industries, and sources used for calibration and educational purposes)

- radioactive waste resulting from uses of radioactive material for medical, industrial and scientific purposes in the past

- luminous devices containing radioactive material (e.g. radium paint on dials of wrist and pocket watches, alarm clocks, compasses and aircraft instrument panels; and gaseous tritium light sources used for emergency exit signs and in self-illuminating watches and compasses)

- industrial radiography source containers that use depleted uranium for shielding

- geological samples containing radioactive minerals.
3 RADIOACTIVE WASTE IN SOUTH AUSTRALIA

Radioactive waste has been generated and continues to be generated by the uses of radioactive material, the mining of radioactive ore, and some other mining and industrial processes. Waste that has accumulated in South Australia, mainly over the last 40–50 years, primarily consists of:

- tailings and residues generated in the processing of radioactive ore
- smoke detectors
- sealed sources formerly used in industry, science, medicine and education
- unsealed radioactive material that has been left after diagnosis, treatment, research and analytical uses.

3.1 Classifications of radioactive waste

The IAEA has described a range of radioactive waste classifications (IAEA 1994, IAEA 2003a), from waste with activity concentrations so low that it may be considered non-radioactive, through to the most highly radioactive waste (see Table 2). These are fairly general descriptions, leaving individual countries to determine the boundaries between classes of waste in terms of their relevant legislation.

To aid in management of radioactive waste in Australia, three codes have been published by the Australian Government, two of which were promulgated by the National Health and Medical Research Council (NHMRC):


When referring to radioactive waste in this report, the waste classifications of the IAEA and those detailed in the federal codes above are used. The relationships between the IAEA classifications and the additional classifications used in Australia are set out in Table 2.

Exempt waste is not regulated under the Act by virtue of the trivial activity or activity concentration of radionuclides in the waste material.

Very low level waste is defined by the IAEA (IAEA 2003a) as ‘waste considered suitable by the regulatory body for authorised disposal, subject to specified conditions, with ordinary waste in facilities not specifically designed for radioactive waste disposal’. To manage this class of waste, the EPA applies the User Disposal Code (see section 3.3).

For low and intermediate level waste in Australia, Categories A, B, C and S wastes are defined in the Near-surface Disposal Code. Categories A, B and C wastes meet the criteria for disposal in a near-surface repository, while Category S waste does not meet the criteria. Category S waste requires storage until some means of disposal, such as deep burial in a geologically stable site, becomes available.
Mining waste, which includes tailings, contaminated plant and equipment, and liquid waste from chemical processes, is managed in accordance with the Radioactive Waste Management Code.

High level waste is described by the IAEA as spent nuclear fuel and waste resulting from reprocessing. There is no high level waste in South Australia.

Table 2 Radioactive waste classifications

<table>
<thead>
<tr>
<th>IAEA waste classifications</th>
<th>Classifications used in Australia</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exempt</td>
<td>Unregulated</td>
<td>Waste generated in laboratories using unsealed radioactive material where the activity and activity concentrations are below the limits that require control under legislation</td>
</tr>
<tr>
<td>Very low level</td>
<td>Very low level</td>
<td>Gloves, paper, syringes and vials contaminated with radionuclides in concentrations that do not exceed the limits for disposal under the User Disposal Code</td>
</tr>
<tr>
<td>Category A</td>
<td>Equipment, rags, glassware, gloves, paper, etc. contaminated with radionuclides in concentrations that exceed the limits for disposal under the User Disposal Code</td>
<td></td>
</tr>
<tr>
<td>Category B</td>
<td>Sealed sources used in industrial, scientific and medical applications, smoke detectors, and small items of contaminated equipment where the quantities of radionuclides involved do not exceed the limits specified in the Near-surface Disposal Code</td>
<td></td>
</tr>
<tr>
<td>Category C</td>
<td>Bulk waste such as contaminated soil</td>
<td></td>
</tr>
<tr>
<td>Mining</td>
<td>Tailings generated in the mining and milling of radioactive ore</td>
<td></td>
</tr>
<tr>
<td>Category S</td>
<td>Sealed sources used in industrial, scientific and medical applications, that contain quantities of radionuclides that exceed the limits specified in the Near-surface Disposal Code</td>
<td></td>
</tr>
<tr>
<td>High level</td>
<td>Not applicable</td>
<td>Spent nuclear fuel rods</td>
</tr>
</tbody>
</table>

### 3.2 Waste sealed sources

Sealed sources become waste when the device of which they are a part becomes obsolete or is no longer functional, or the owner ceases to conduct the work in which the source was used.

Waste sealed sources generally fall into either Category B or Category S waste described in the Near-surface Disposal Code.
There is no disposal pathway in South Australia for waste sealed sources. If the owner is unable to sell or otherwise transfer ownership of the sealed source, the only options are to store it, or engage someone else to store it, indefinitely.

There are several companies offering a service for the removal of sealed sources to other countries for recycling or disposal. Provided the source is not leaking, the source may be removed from the device and repackaged for transport overseas. However, this service is generally only available for commonly used radionuclides such as caesium-137 and cobalt-60. There is no state control over the destination of waste sealed sources to other states or territories or other countries. The Australian Government controls export of radioactive material from Australia.

### 3.3 Unsealed radioactive waste

The many uses of unsealed radioactive material in hospitals and research and scientific organisations result in the production of unsealed radioactive waste daily. For example, hospitals administering radioactive material to patients for treatment generate radioactive biological waste, contaminated clothing, bed linen and food utensils. All radioactive waste that falls into the very low level category may be disposed of in accordance with the User Disposal Code, subject to approval by the EPA. Disposal pathways under the User Disposal Code include:

- landfill burial
- incineration
- discharge to sewers
- exhaust of gases to the outside atmosphere.

Approximately half of the organisations that dispose of waste in accordance with the User Disposal Code dispose of some of their waste via landfill burial at the Adelaide City Council Waste Disposal Depot at Wingfield, while the remaining organisations use one or more of the other means of disposal. Waste for landfill disposal is collected from organisations every two months and disposed of into a prepared pit, which is covered with non-active waste or soil as soon as possible. The resultant coverage depth is at least 3 metres. An EPA officer is present when the waste arrives at the facility, and any packages that are assessed to be unsuitable for burial are rejected and returned to the originating organisation.

Some very low level radioactive waste that contains radionuclides with a short half-life is kept in storage for a period of time to allow the radioactive material to decay. Once the activity and activity concentration of the radionuclide have reduced to levels below those at which the regulations apply, the waste can be disposed of with normal waste.

Disposal of unsealed radioactive waste that satisfies the requirements of the User Disposal Code may be approved for periods of up to 12 months. The owner of the radioactive material must submit an application detailing a waste management plan (refer to requirements in section 4.2.7) for approval by the EPA. Currently, 25 organisations have approved waste management plans.

### 3.4 Mining waste

As noted in section 2.3, there are two different mining methods used to recover uranium in South Australia. These are underground hard rock mining conducted at Olympic Dam, and in-situ leach (ISL) mining conducted at Beverley and proposed for the Honeymoon mine. Both methods produce uranium product but they result in different waste streams requiring different management approaches.
3.4.1 Olympic Dam mine

The Olympic Dam mine is located approximately 520 km north-north-west of Adelaide. The mining and processing recover copper, uranium, gold and silver from the ore. The material that remains is called tailings and is the main form of waste generated at Olympic Dam. It has the appearance and consistency of watery mud and consists of the remaining solids and liquids from the physical and chemical processing of the ore. The tailings from the process plant are pumped to a large rock and clay walled containment known as the tailings storage facility (TSF), where the solids and liquids separate. The liquids drain to collection sumps near the centre of the TSF and are pumped away to evaporation ponds. Olympic Dam currently adds approximately 8 million tonnes per annum of tailings to the TSF (WMC (Olympic Dam Corporation) Pty Ltd 2002).

The mining and processing of uranium also result in the generation of small quantities of waste equipment, soil and consumables that are contaminated with radionuclides from contact with the ore or process streams. Where the contamination cannot be removed, the material is disposed of on site by burial. Further information can be found in the Olympic Dam Expansion Project EIS (WMC (Olympic Dam Corporation) Pty Ltd 1997).

3.4.2 Beverley mine

The Beverley mine is located approximately 600 km north of Adelaide between the North Flinders Ranges and Lake Frome. The in-situ leach (ISL) method used at the Beverley mine involves injecting groundwater containing a weak acid solution mixed with an oxidising agent into the uranium bearing aquifer. The uranium dissolves in the solution which is then pumped back to the surface, and the uranium is extracted by a method known as ion exchange. No ore is brought to the surface and no tailings are produced.

A small fraction of the circulating extraction solution, known as the bleed stream, is removed and pumped to holding ponds. The pond liquid, consisting of the bleed stream, plant washdown water, spent process solution and filter backwash, is disposed of by pumping back down to a barren area of the ore zone aquifer.

The processing of uranium at the Beverley mine results in the generation of small quantities of waste plant equipment, soil and consumables that are contaminated from contact with the process streams. This waste is collected and stored in a dedicated area within the plant before disposal on site in a purpose built pit. Further information can be found in the Beverley project EIS (Heathgate Resources Pty Ltd 1998).

3.4.3 Honeymoon mine site

The proposed uranium extraction method to be used at the Honeymoon mine site, located 75 km north-west of Broken Hill, is very similar to that in use at Beverley; the only difference is the use of solvent extraction techniques rather than ion exchange to remove uranium from the extracted solution. The Honeymoon proposal is outlined in detail in the EIS (Southern Cross Resources Australia Pty Ltd 2000).

Since the end of the Field Leach Trial in August 2000, the well-field and plant have been decommissioned and the plant decontaminated. Contaminated solid waste such as piping and plant components are held, along with drummed items such as discarded clothing, on the contaminated equipment storage pad adjacent to the holding pond. Final disposal of these items may not be decided until the future of the Honeymoon Project is determined.

3.4.4 Radium Hill mine site

The site of the former Radium Hill mine is approximately 460 km north-east of Adelaide and 100 km south-west of Broken Hill. The underground mine was operated from 1954 to 1961
by the Government of South Australia. The mine produced ore which was physically
concentrated on site. Approximately 200,000 tonnes of concentrate was sent for chemical
processing at the Port Pirie Treatment Plant to produce uranium oxide for sale overseas.
There are approximately 400,000 tonnes of tailings that remain at Radium Hill, held in a
rectangular pile consisting of two sections, each approximately 125 m square and 8 m high.
The northern end of the tailings dam has been used intermittently as a repository for low
level radioactive waste since April 1981, when the site was gazetted under the Crown Lands
Act 1929 and placed under the care, control and management of the (then) Minister of Mines
and Energy.

The material placed in the repository between 1981 and 1998 includes contaminated soil and
ore residues from the Australian Mineral Development Laboratories (AMDEL) (Thebarton), ore
residues from AMDEL (Frewville), contaminated soils from a former radium plant at Dry
Creek, and some contaminated equipment from test work conducted at the Honeymoon site
in the early 1980s.

The repository now contains approximately 200 m$^3$ of material in 200 L and 50 L drums
buried in the dam.

Management of the Radium Hill site remains the responsibility of the Minister for Mineral
Resources Development.

3.4.5 Port Pirie
The site of the former uranium treatment plant is located north of the township of Port Pirie,
approximately 1 km west of the Port Pirie River. Between 1955 and 1962 uranium ore
concentrate from Radium Hill was processed at this site and approximately 850 tonnes of
uranium was produced.

Six clay-lined dams were constructed for the storage of tailings and waste water generated in
the uranium extraction process. Approximately 200,000 tonnes of solid tailings were
deposited in several of these dams.

It was later determined to be feasible to reprocess the tailings in order to extract rare earth
elements (e.g. scandium and yttrium). During the early 1960s the Rare Earth Corporation
(REC) operated on the site, extracting scandium, yttrium oxide and other rare earths from
the uranium tailings and some imported material. As part of the operations, four smaller
dams were built immediately to the east of the uranium tailings dams. A monazite cracking
plant was later set up on the site and operated from 1969 to 1972. The by-products from this
industry, which include monazite residues containing elevated levels of radionuclides (mainly
thorium), were deposited in the REC dams. The total area of the site, including the dams and
the processing plant, is approximately 26 hectares.

Management of the Port Pirie site remains the responsibility of the Minister for Mineral
Resources Development.

3.5 Other radioactive waste
Waste in this category includes smoke detectors$^1$, a variety of legacy waste resulting from
past practices such as research or education, and old instruments and devices that contain
radioactive material. Miscellaneous radioactive waste does not meet the requirements for
disposal in accordance with the User Disposal Code, and is currently stored by its owners.

$^1$ It is estimated that in South Australia approximately 50,000 smoke detectors per year will become waste, based on a 10-year life for
a smoke detector and every dwelling in South Australia having at least one smoke detector installed.
4 LEGISLATIVE CONTROLS ON RADIOACTIVE MATERIAL

As noted in section 1.2, almost everything contains some radioactive material. Only radioactive material containing quantities above certain exemption limits is subject to legislative controls.

While South Australia has had the benefit of legislative controls on activities involving radioactive material since the 1950s, more detailed controls on radioactive material did not come into force until the 1980s with the proclamation of the current Act. The objective of the Act is to provide for controls on radioactive material and radiation apparatus in order to protect people from the harmful effects of radiation.

The Act is committed to the Minister for Environment and Conservation and administered by the EPA through delegations to its Chief Executive and officers of the Radiation Protection Division. The Act is currently under review, with the aim of enhancing the provisions for protection of people and the environment.

Regulations under the Act, the Ionizing Radiation Regulations 1985 and the Radiation Protection and Control (Transport of Radioactive Substances) Regulations 1991 (the Transport Regulations), were subsequently introduced. The Ionizing Radiation Regulations, which contained detailed provisions for controls on sources of ionising radiation (primarily X-ray machines and radioactive material) and doses received by radiation workers and the public, were revised in 2000, and are now the Radiation Protection and Control (Ionising Radiation) Regulations 2000 (the Regulations). The Transport Regulations contain detailed provisions for controls and safety in the transport of radioactive material. They are being revised to introduce the current national and international requirements for transport of radioactive material contained in the Code of practice for the safe transport of radioactive material (2001) (ARPANSA 2001a).

4.1 Provisions of the Act

Provisions of the Act pertaining to radioactive material include the following:

- Sealed sources, as well as premises in which unsealed radioactive material is used, handled or stored, must be registered.

- Uranium mining and milling operations must be licensed.

- People using or handling radioactive material must be licensed.

- There shall be a public register of licences and registrations issued under the Act.

4.2 Provisions of the Regulations

4.2.1 Material that is subject to regulation

The Regulations prescribe the concentrations of uranium or thorium in ore that, when exceeded, classify the ore as ‘radioactive ore’ that is controlled under the Act and Regulations. The Regulations also prescribe the activity concentration and activity of radionuclides in material below which the material is not subject to control under the Act and Regulations. In particular, ores that contain less than 0.02% by weight of uranium or less than 0.05% by weight of thorium, and other material that has a specific activity of no greater than 35 kBq/kg and contains lower activities than those prescribed in the Regulations, are not subject to the Act or Regulations.
4.2.2 Radiation protection standards and limits
The Regulations specify the annual dose limits that must not be exceeded for a radiation worker or a member of the public. The responsibility for ensuring the dose limits are not exceeded is carried by the ‘specified employer’, who is defined as the person:

- who employs a radiation worker, or
- who is the registered occupier of premises in which unsealed radioactive material is used, handled or stored, or
- in whose name a sealed source is registered, or
- who holds a licence to mine and mill radioactive ore.

For a radiation worker the annual dose must not exceed 20 mSv averaged over five consecutive years; or 50 mSv in any single year. For a member of the public the annual dose must not exceed 1 mSv. In the case of a pregnant radiation worker, the exposure to the unborn child must not exceed the annual limit prescribed for a member of the public. In all cases the annual dose limits do not include exposures received as a result of background radiation or as a patient undergoing medical diagnostic or therapeutic procedures.

4.2.3 Appointment of a radiation safety officer
The Regulations require a specified employer to appoint a radiation safety officer (RSO) to assist the employer in complying with the Act and Regulations, to advise on radiation safety applicable to the activities carried out by the specified employer, and to perform other duties required by the Regulations. The RSO must have detailed knowledge of the principles and practices of radiation protection applicable to the activities carried out by the specified employer.

4.2.4 Sale of radioactive material
The Regulations contain requirements for a business that sells radioactive material or registrable devices, and for owners of registered sources who wish to sell or dispose of sources, to notify the EPA of the transfer of ownership. The EPA must be notified if the seller becomes aware of any fault or defect in a registrable device that has been sold. A licence is not required to sell radioactive material in South Australia, but the EPA must be notified of all sales or transfers of ownership.

4.2.5 Accounting for radioactive material
The occupier of premises in which unsealed radioactive material is used, handled or stored, and the owner of a sealed source, registered or not, must keep a register of radioactive material and be able to account for all material received.

4.2.6 Requirements for storage of radioactive material
Owners of sealed sources, and occupiers of premises in which unsealed radioactive material is used or handled, must store radioactive material when not being used so that:

- the dose rate at any area accessible to members of the public and outside the place of storage is as low as reasonably achievable, and in no case exceeds 25 μSv per hour
- no radiation worker or member of the public receives a dose exceeding the annual dose limit
• the place of storage is ventilated in such a way that the concentration of airborne radioactive material within the place of storage will, for any period of time that the place of storage is occupied, be as low as reasonably achievable

• reasonable precautions are taken to prevent unauthorised access or removal of radioactive material from the place of storage

• a radiation warning sign showing the radiation symbol and words such as ‘STORE FOR RADIOACTIVE MATERIAL’, and bearing the name and telephone number of the person to contact in the event of an emergency arising from the area, must be displayed at every door and entrance to an area where radioactive material is kept

• each radioactive source or vessel containing radioactive material must be labelled with the radiation symbol, the word ‘RADIOACTIVE’ and the identity and activity of the radionuclide.

4.2.7 Disposal of radioactive material
The Regulations prohibit disposal of any radioactive material without prior approval. The requirements for an application to dispose of radioactive material are specified in the Regulations. The application must include:

• details of the radioactive material to be disposed of, including its chemical/physical form and the activity

• details of the proposed method of disposal, including description of the type of packaging, storage, segregation, labelling, monitoring and transport

• details of the proposed place of disposal

• the proposed date of disposal

• the name of persons who will handle the radioactive material during disposal.

The EPA may direct applicants to provide additional information. In granting approval to dispose of radioactive material, the EPA may place conditions on the disposal that may relate to more than one radioactive material on more than one occasion extending over a period of up to 12 months from the date of the approval.

4.2.8 Registration of sealed sources
The Regulations specify certain classes of sealed sources containing small quantities of radioactive material that do not require registration.

Requirements for sealed sources that need to be registered under the Act are specified in the Regulations. These include requirements that:

• the sealed source capsule must be designed and constructed so that any radioactive material remains effectively enclosed within the capsule during all conditions of normal use, and all conditions that are likely to arise if the source is involved in an accident during normal use

• the activity of the sealed source must be no larger than necessary
• the energy and type of radiation must be appropriate to its use
• the half-life must be as short as practicable.

4.2.9 Unsealed radioactive material in premises
Premises in which unsealed radioactive material is kept or handled may be registered provided that they comply with the requirements specified in the Regulations. These include:
• the display of appropriate signs on the entrances to the premises
• smooth surfaces on walls, ceilings, floors and laboratory fittings
• warning signs at access points in pipes and drains that carry radioactive effluent
• the provision of a properly designed and constructed fume cupboard or total enclosure where an operation or process is conducted that is likely to produce airborne radioactivity in excess of the concentration that could result in a radiation worker receiving the dose limit from inhalation
• the display in prominent positions of the working rules, containing a prohibition against eating, drinking or smoking on the premises, and a contingency plan in the event of a foreseeable spill of radioactive material.

4.3 Uranium mining

4.3.1 Current mining activities

Mining and milling operations are also subject to requirements of the Regulations, and transport of uranium product is subject to the Transport Regulations.

The production, storage and transport of uranium product is also subject to Australian Government’s authorisations granted by ASNO.

4.3.2 Former mining activities
The Radium Hill site, including the repository, and the Port Pirie site are registered premises and are subject to conditions aimed at establishing specific long-term management plans for each site.

4.4 Miscellaneous radioactive material
Miscellaneous radioactive material is subject to the general requirements as outlined in section 4.2.

Radioactive material used in schools for educational purposes must be used in accordance with the NHMRC Code of practice for the safe use of ionizing radiation in secondary schools (1986) (Cwlth 1988). The code sets out how radioactive material may be used in education while at the same time keeping human exposure to a trivial level. This is achieved by a range of measures, including using very...
small sealed sources (e.g. the maximum recommended activity for an americium-241 source for use in a secondary school is approximately half the activity contained in a smoke detector), and allowing students to use radioactive material only under the direct supervision of a teacher.

4.5 Transport of radioactive material

Many consignments of radioactive material are transported within South Australia every week. These include radiopharmaceuticals, portable devices such as nuclear moisture/density meters and industrial radiography sources, and uranium product. All transport of radioactive material must comply with the Transport Regulations. These regulations do not distinguish between waste radioactive material and radioactive material that is in use.

The Transport Regulations have requirements for packaging and labelling of radioactive material, documentation that identifies the consignor and destination of the material, the radionuclide(s) present and the activity of the radionuclide(s), and the display of radiation warning signs on transport vehicles.

These requirements are in addition to the requirements imposed by the Regulations. However, under the Regulations, premises in which a consignment of radioactive material is stored during transit do not require registration, and persons handling consignments of radioactive material are not required to hold a licence.
5 AUDIT OF REGISTERED SEALED SOURCES

This section reports only on registered sealed radioactive sources, such as those used in industrial gauging applications (Figure 1), nuclear moisture meters (Figure 2) and industrial radiography. Sealed sources that do not require registration (such as sealed sources in smoke detectors and other small sealed sources that are below registrable activity) are discussed in Section 8.

5.1 Inspection process

Registered sealed sources were inspected at all sites where they were used or held in storage\(^2\). The safety and security of sealed sources and of the facilities for storage were evaluated. Details of any waste sealed sources were recorded. Other aspects of radiation protection and regulatory compliance such as the keeping of records were also reviewed.

5.2 Findings and recommendations

Registered sealed sources were located at 87 sites, of which 31 held waste sealed sources. There were 488 sources in use and 196 sources that were designated as waste.

5.2.1 Safety and security

Sealed sources that were in use were either fixed in place on a larger piece of equipment, located in an operating position within a plant or, in the case of sources in portable devices such as nuclear moisture/density meters and industrial radiography projectors, temporarily held in storage between jobs. It was noted that some nuclear moisture/density meters were kept in the operator’s vehicle between jobs.

The display of radiation warning signs in the vicinity of devices containing the sources and labelling on these devices was found to be good and in accordance with the Regulations. However, some labels on devices on plant and equipment were found to be obscured with dirt.

Security of stored sealed sources was found to comply with the regulatory requirements. Most stores were secured with locked or padlocked doors and located within a supervised area. Warning signs required on entrances to stores were also found to comply with the Regulations, as were radiation dose rates adjacent to stores.

There have been two occasions in recent years where nuclear moisture/density meters have been stolen from locked vehicles, one of which occurred after the inspections of radioactive materials for the audit had been completed. The security of portable devices in unoccupied vehicles is being reviewed by the EPA.

5.2.2 Record keeping

Under the Regulations, owners are required to keep a register of their sealed sources. The register must contain details of each source, including those not required to be formally registered under the Act. The details include the identity and activity of the radionuclide, the identity of the device containing the source, and the place where it is normally located. The register must include all sealed sources whether they are installed on plant or equipment, or held in storage, and whether or not they are considered waste.

\(^2\) With the exception of two sites, both of which were at remote locations. One site stored two portable devices containing registrable sealed sources, while the other site was the location of a gauge containing a sealed source that was in continual use.
While most owners of sealed sources maintained appropriate records of their sources, it was noted that generally procedures were not in place to regularly review the contents of the register, including the location of sealed sources. Although it is expected that records be kept up to date, at present there is no specific regulatory requirement for owners to periodically review their register. Such a review is necessary to ensure records are kept up to date, and should include proper verification that each source is still at the indicated location. The review should also include a check that the required labelling and warning signs are legible, and that the storage of the sealed sources, or any equipment that incorporates sealed sources, continues to provide appropriate safety and security. The review process would be particularly beneficial to the safety and security of waste sealed sources.

Concern was expressed by some radiation safety officers that equipment in which sealed sources were contained may eventually be forgotten about within a company. This is of particular concern for radiation equipment that is unwanted and where staff previously responsible for the equipment may have left the company or ceased to be involved with the equipment. In such cases, there is increased risk that the sealed sources might be inadvertently disposed of with general rubbish or scrap metal.

**Recommendation 1**
That owners of sealed sources regularly review the safety and security of sealed sources and the information contained in the source register, and report periodically to the EPA.

**Waste sealed sources**
In most cases those sealed sources designated as waste were part of a device that was no longer in use. The device had generally been taken out of service and placed in storage because it was obsolete or no longer operable.

**Legacy waste**
Most owners of old waste sources maintained satisfactory registers. However, there were a small number of owners who had accumulated sealed sources prior to the Act coming into force in the 1980s. These owners, mainly universities, hospitals and some government departments, have difficulty in providing details required for the source register for some sealed sources taken into custody prior to the 1980s as such information was not provided, not documented or has been lost.

The audit identified a need to assess such poorly described sources to determine the physical and chemical properties of the material and the integrity of containment. When poorly described sealed sources are properly assessed, it is probable that some may need to be conditioned for safer interim storage. In some cases, conditioning to prolong safe interim storage may be a relatively simple and safe process. However, complex conditioning that may be necessary for final disposal or long-term storage may be a more hazardous task, and should not be undertaken until the future management options for waste sealed sources are determined.

**Recommendation 2**
That owners of legacy sources that are poorly described ensure that essential shielding and containment is provided, but not attempt complex conditioning until the long-term management options for waste sealed sources are determined.
Old sources
At some point in the life of a sealed source the encapsulation may fail and permit leakage of radioactive material. The timing of this will depend on whether the source is exposed to corrosive or abrasive agents and whether it is subject to vibration or any form of mechanical shock. In order to ensure that the encapsulation does not fail while the source is in use, manufacturers often nominate a conservative ‘working life’ for the source. Typically this is 15 years. While exceeding the working life does not necessarily mean that a source is at risk of leaking, manufacturers suggest that consideration should be given to replacing the source when it reaches this age.

As part of the audit, the age of sealed sources was reviewed and it was found that a large proportion of sealed sources were older than the typical nominal working life of 15 years. In particular, of the 684 sealed sources that were considered during the audit:

- 196 were designated waste, 167 being more than 15 years old
- 488 were currently in use, 205 of which were more than 15 years old.

If sealed sources beyond their nominal working life were taken out of service, an additional 205 may become waste. This would more than double the number of waste sealed sources. While the EPA considers the continued use of sealed sources a few years beyond their nominal working life unlikely to constitute an unsafe practice in most cases, there is currently no uniform national approach to the ‘retirement’ of sources (although this is under consideration). A review of standards and practices regarding this issue should be conducted with a view to developing a national policy on the matter. The policy should address whether sealed sources may be used beyond the nominal working life and, if so, what testing of encapsulation integrity would be required. It is important that a nationally uniform policy be adopted on this matter, to prevent the possibility of old sources accumulating in whichever jurisdiction has the least stringent requirements.

Recommendation 3
That the EPA contribute to the development and implementation of a national policy on the use of sealed sources beyond their nominal working life.

Reuse of sources
In some cases relatively new and serviceable devices containing sealed sources may be unwanted and therefore considered waste by their owner, while another person may have a definite use for the device. By facilitating communication between the two, it is possible that fewer new devices containing sealed sources will be brought into South Australia and the number of waste sources requiring management will be reduced.

Recommendation 4
That, where possible and appropriate, the EPA assist in identifying suitable owners for sealed sources considered to be waste by their present owners.

3 These numbers relate to sealed sources as at June 2003. They do not include 18 sealed sources normally stored interstate, but do include sealed sources not registered but contained in a device together with a registered sealed source. A number of waste sealed sources left South Australia during the period of the audit.
5.2.4 Changes to inventory of waste sealed sources since 2000

In October 2000 a survey was conducted to ascertain the number of sealed sources that were considered to be waste, or could become waste by 2005 (see Table 3). The purpose of the survey was to determine the level of demand for a central store for such waste. The survey questionnaire was mailed to the 92 owners of sealed sources resident in South Australia at the time, with 97% of the owners responding.

Table 3  Waste sealed sources in 2000 and 2003

<table>
<thead>
<tr>
<th></th>
<th>Category A &amp; B</th>
<th>Category S</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of sources</td>
<td>Volume (m³)</td>
<td>Activity (TBq)</td>
</tr>
<tr>
<td>2000 survey</td>
<td>185</td>
<td>4</td>
<td>0.34</td>
</tr>
<tr>
<td>2003 audit(a)</td>
<td>149</td>
<td>3</td>
<td>0.24</td>
</tr>
</tbody>
</table>

(a) The numbers in this row relate to sealed sources as at June 2003. They include sealed sources not registered but contained in a device together with a registered sealed source. A number of waste sealed sources left SA during the period of the audit.

The survey found that there were 28 owners of sealed sources who, among them, had 217 sealed sources that they would dispose of if they could. Of these, 197 were in storage and 20 remained installed on plant. A further 56 sealed sources were listed as likely to become waste within 5 years. Of the 28 owners, only one considered that storage was inadequate in the short term, the reason given being poor access and congestion. Ten owners said their stores were inadequate in the longer term, with reasons given including proposed redevelopment of the area in which the store was located, concerns about long-term security and concerns about leakage of sealed sources.

Since 2000 the total activity and volume of waste sealed sources has been reduced significantly as a result of the transfer of ownership of three medical (radiotherapy) sources to an overseas organisation.

5.2.5 EPA’s Radiation Licensing Database

The Radiation Licensing Database presently has no means of distinguishing registrations of waste sealed sources from other sealed source registrations. This created some difficulties when comparing data from the audit with that of the survey in 2000. The recording and reporting on waste sealed sources would be greatly enhanced by identifying waste sealed sources in the database, and recording reasons for cancelling registrations, such as transfer of a source to another state, territory or overseas.

Recommendation 5
That the capability of the Radiation Licensing Database be extended to record and maintain details of waste sealed sources and reasons for cancelling registrations.

As a result of the information collected during the inspections, a large number of corrections were made to the data kept on the Radiation Licensing Database. These ranged from minor changes to recorded locations of sealed sources to the cancellation of registration of sources that had left South Australia. A significant factor contributing to the database being out of date is that many registrations are renewed for three years at a time, and changes are only notified at the time of renewal.
Recommendation 6
That the provision for three years’ registration and renewal of registration be removed so that registrations and renewals are for one year only.

Figure 1  Radiation gauges used in industry for process control

Figure 2  Portable moisture/density meter used for civil engineering
6    AUDIT OF UNSEALED RADIOACTIVE MATERIAL

This section reports on unsealed radioactive material routinely used in laboratories and hospitals. The mining and milling of radioactive ore and the related waste, which is also unsealed radioactive material, is discussed in Section 7, while unsealed radioactive material not routinely used in laboratories or hospitals is discussed in Section 8.

6.1 Inspection process
All sites where unsealed radioactive material was stored or used were inspected\(^4\). Radiation safety practices were also assessed, including the handling and storage of radioactive material, and segregation and disposal of radioactive waste.

6.2 Findings and recommendations
Unsealed radioactive material was located at 42 sites, all of which held unsealed radioactive material in storage, and 35 of which held waste.

6.2.1 Research laboratories in hospitals, universities and industry
Good radiation safety practices and procedures were found in the handling of radioactive material in most premises inspected during the audit. A number of relatively minor housekeeping issues were identified and brought to the attention of occupiers in some premises.

Organisations had generally maintained good records of the purchase, use and disposal of their radioactive material. Stock solutions in shielded containers were labelled and appropriately stored.

Generally, solid or non-aqueous radioactive waste was stored for a period of time, pending disposal in accordance with the User Disposal Code. Aqueous radioactive waste resulting from washing of laboratory and other equipment was discharged via designated sinks to sewers, also in accordance with the User Disposal Code. In some cases aqueous radioactive waste has been retained to allow for decay if its activity was too high for immediate discharge into sewers.

The management, storage and disposal of waste were satisfactorily carried out in accordance with each organisation’s waste management plan. All waste stores were found to comply with the requirements for storage under the Regulations and were also found to be safe and secure.

It was concluded that no changes were required to the current practices within premises of research laboratories in hospitals, universities and industry.

6.2.2 Mineral laboratories
There are a number of laboratories that store or analyse radioactive ore, tailings and uranium product, several of which are located on mine sites. The storage of radioactive material at mineral laboratories was found to be satisfactory. Any waste generated from laboratories not on mine sites was returned periodically to the mine site from which it came. Waste from laboratories located on mine sites was managed on site. Consequently, mineral laboratories were not categorised as storing waste.

\(^4\) One site was not inspected during the audit period, but was inspected during July 2003. The site is included in the audit data.
6.2.3 **Diagnostic nuclear medicine**  
The most commonly used radionuclide in nuclear medicine departments is technetium 99m, which has a short half-life of 6 hours. Because the half-life is so short, molybdenum-99/technetium-99m generators are generally used in nuclear medicine departments for the daily production of technetium-99m. When the generators are no longer in use, they are either stored in designated lead-lined cabinets in the ‘hot’ laboratory or taken to a central store in the institution. The residual radionuclides are left to decay to background levels for up to 2–3 months before the generators are returned to their interstate supplier at Lucas Heights, New South Wales.

Other pharmaceuticals containing radionuclides, such as thallium-201, gallium-67 and iodine-131 used or handled in the ‘hot’ laboratory, are normally stored in lead pots and placed behind a lead glass screen, or surrounded by lead bricks on the bench adjacent to the dose preparation area.

Current management of unsealed radioactive waste from nuclear medicine departments does not present a disposal problem. Most of this waste contains short-lived radionuclides that are allowed to decay to a level that it is not regulated before the waste is disposed of in general hospital waste.

It is concluded that the practices for management of radioactive wastes from current diagnostic nuclear medicine procedures in South Australia are satisfactory.

6.2.4 **Radionuclide therapy**

Radioactive waste arising from hospitals administering radioactive material to patients for treatment of malignant disorders may include patients’ biological waste, contaminated clothing, bed linen and food utensils. In-patients receiving therapeutic doses of iodine-131 for thyroid cancer are normally hospitalised for two to three days. These patients are discharged from hospital only after the radionuclides not taken up by cancerous tissues have been excreted via designated toilets into sewers. All contaminated material from these patients is sealed in plastic bags and labelled.

Disposable waste (e.g. gloves, tissues) is stored prior to disposal to allow the radionuclides to decay to a very low level. Non-disposable items (e.g. soiled bed linen) are retained until radioactive decay permits them to be safely returned to the hospital laundry. These practices are all carried out in accordance with each organisation’s approved waste management plan and radiation safety manual.

Occasionally a terminally ill patient who had been injected with radioactive strontium-89 for pain relief dies before the strontium has completely decayed. If the deceased is cremated, the ashes may be slightly radioactive and may need to be stored for a period of time, to allow the strontium to decay, before they are returned to relatives.

It is concluded that the practices for management of radioactive wastes from current radionuclide therapy procedures are satisfactory.

6.2.5 **Veterinary radiotherapy**

In one veterinary centre iodine-131 capsules are used for treating cats with hyperthyroidism. The management of radioactive waste (such as cat litter) was assessed and found to be satisfactory and in accordance with the centre’s approved waste management plan and radiation safety manual. In this case the radioactive waste was stored until radioactive decay allowed for its disposal with general waste. Current practices for management of radioactive material in veterinary radiotherapy are satisfactory.
6.2.6 Existing disposal pathways
Disposal pathways were available for all very low level waste (see section 3.3) generated in hospitals, universities and research organisations. However, one of the currently approved disposal pathways—landfill burial at the Adelaide City Council Waste Disposal Depot at Wingfield—will not be available when the waste depot closes in 2004. So that hospitals, universities and industries using unsealed radioactive materials may continue to work safely and efficiently, disposal pathways for very low level waste need to remain available.

Recommendation 7
That the EPA and other government agencies work together to ensure continued availability of suitable disposal pathways for very low level radioactive waste in accordance with the User Disposal Code.

Figure 3 Inspection of a university research laboratory
Figure 4  A molybdenum-99/technetium-99m generator for nuclear medicine

Figure 5  Very low level waste from medical and scientific research stored pending disposal
7 AUDIT OF RADIOACTIVE MATERIAL FROM URANIUM MINING

The audit process examined:

- uranium product and other radioactive material and waste stored at the Olympic Dam, Beverley and Honeymoon mine sites
- radioactive tailings and residues at Radium Hill and Port Pirie where uranium ores were mined or processed in the past.

The storage of sealed sources and of unsealed radioactive material used in laboratories on these sites is included in the discussion in Sections 5 and 6 respectively.

7.1 Inspection process

Olympic Dam, Beverley, Honeymoon, Radium Hill and Port Pirie, which all store waste, were inspected as part of the audit.

The Olympic Dam, Beverley and Honeymoon operations are subject to quarterly and annual reporting requirements to the EPA in relation to radiation monitoring, including radioactive waste management activities. In addition, each operation presents the results of monitoring for discussion at quarterly Radiation Review Meetings held between the operators and officers of various government agencies.

7.2 Findings and recommendations

7.2.1 Olympic Dam Mine

Product

Uranium product at Olympic Dam is stored in sealed and labelled drums, which are then packed in shipping containers in a secure compound within the plant area prior to transport for export. During the inspection, storage at Olympic Dam was found to be in accordance with all the requirements of the Regulations and the Radiation Protection [Mining] Code. Storage and transport of uranium product are also subject to requirements of ASNO for security and safeguards.

Tailings storage

Approximately 60,000,000 tonnes (35,000,000 m$^3$)$^5$ of tailings$^6$ are held in four purpose built dams or ‘cells’ covering a total area of approximately 380 ha. This is called the tailings storage facility (TSF). As noted in section 3.4.1, tailings are added to the cells at a rate of approximately 8,000,000 tonnes per annum, or 22,000 tonnes per day. Waste liquids collected from the cells are sent to four nearby evaporation ponds, all within the tailings retention system (TRS).

The operation of the TRS is complex and the operator conducts extensive and constant monitoring to assess both performance of the system and impacts on the surrounding environment, particularly groundwater. Results of monitoring conducted under the Environment Management Program (EMP) are published each year in the annual Environmental Management and Monitoring Report (WMC (Olympic Dam Corporation) Pty Ltd 2002).

$^5$ Based on the density of tailings being approximately 1.7 tonnes/m$^3$.

$^6$ The volume of tailings is such that if it were spread evenly over a circular area one kilometre in diameter, it would extend to a height of approximately 45 metres.
These reports note there is seepage from the general area of the tailings cells, causing a rise in the groundwater levels immediately below the cells. A key target for the operation of the TRS is therefore control of the liquid that collects on the surface of the deposited tailings. It is important to ensure the maximum amount of liquid is collected at the central sumps for pumping to the evaporation ponds, and also that the smallest possible area of the tailings is covered with liquid, to minimise the potential for seepage through the tailings.

The reported position and movement in recent years of the groundwater ‘mound’ below the TRS reflects the commencement of operations of Cell 4 and the closure of the old mine water disposal pond. The groundwater mound is kept under surveillance via a system of monitoring bores throughout the TRS. This water is of suitable quality for use in the mining operation, and is extracted for that purpose.

An audit of monitoring reports provided by the operator indicates the tailings remain securely stored within the TRS, and the operation of the overall water balance monitoring system is satisfactory and in accordance with current approvals issued under the Radioactive Waste Management Code. Monitoring confirms the groundwater levels remain some 20 m below the action level for the TRS (the level at which native vegetation could be affected).

**Process stockpiles**

There are a number of ore, mullock and smelter slag stockpiles on the mine site. The quantity of material in each is constantly changing as ore is deposited and processed, slag is recycled to the plant, and mullock is returned underground as backfill for mined-out stopes. The operation of the stockpiles is in accordance with approvals granted under the Radiation Protection and Radioactive Waste Management Codes.

**Contaminated solids disposal site**

Contaminated solids are buried on site in an area located to the east of the TRS. This disposal site receives predominantly inert uncontaminated material mixed with material that may have some contamination (e.g. drums, clothing, workshop waste, unsalvageable equipment). An inspection of the site found that it was operating in accordance with an approval granted under the Radioactive Waste Management Code.

**Pilot plant**

The pilot plant at Olympic Dam was established to provide design data for the main Olympic Dam Processing Plant and operated during 1984–85. The waste produced from the pilot plant copper and uranium circuits was pumped to four small tailings dams and the associated liquids to five smaller evaporation ponds. These small tailings dams are still in place at the pilot plant and contain approximately 14,000 tonnes of tailings.

The EMP proposes that these tailings from the pilot plant TSF will be reprocessed or relocated to the main TSF. The site will then be rehabilitated.

**Conclusion**

While current practices at the Olympic Dam mine were found to be in accordance with approved methods, those methods were considered best practice at the time the approval was granted in the 1980s. The management of radioactive waste at Olympic Dam is being reviewed by the operator, in consultation with the EPA and other relevant agencies, to take into consideration changes in internationally accepted practices (see recommendation 8).

**7.2.2 Beverley mine**

**Product**

Uranium product at Beverley is stored in sealed and labelled drums in shipping containers in a secure compound within the plant area prior to transport for export. Storage was found to
be in accordance with all the requirements of the Regulations and the Radiation Protection [Mining] Code. Storage and transport of uranium product are also subject to requirements of ASNO for security and safeguards.

**Solid waste**
Solid waste (consisting of contaminated soil, consumables and items of plant equipment) is stored (Figure 8) within the plant area before periodic disposal in a purpose built pit on site. The volume of the material stored varies, but may be up to 100 m$^3$ prior to disposal.

**Liquid waste**
Liquid waste is held in ponds prior to disposal. The pond liquid consisting of the bleed stream, plant washdown water, spent process solution and filter backwash is disposed of by pumping back down to a barren area of the ore zone aquifer. Approximately 40 ML is pumped to the ore zone each year.

**Conclusion**
The audit confirmed that the operation of the solid waste holding area and liquid waste disposal system at the Beverley mine is in accordance with current approvals granted under the Radioactive Waste Management Code. The management of radioactive waste is kept under review (see recommendation 8).

7.2.3 **Honeymoon mine site**
The Honeymoon mine site is currently in care and maintenance following the completion of the field leach trial in 2000 and the approval of the EIS for the commercial project.

**Product**
At the time of inspection, drummed uranium product arising from the field leach trial was stored on site in a secure fenced compound and was found to be in accordance with all the requirements of the Regulations and the Radiation Protection [Mining] Code. Storage and transport of uranium product are also subject to requirements of ASNO for security and safeguards.

**Solid waste**
Solid waste (consisting of contaminated soil, consumables and items of plant equipment) generated during the field leach trial is being stored in a dedicated area of the plant awaiting final disposal in an approved facility. The inspection found that the material was held in accordance with current approvals granted under the Radioactive Waste Management Code.

**Liquid waste**
Liquid waste is held in a pond within the plant area. Since the completion of the field leach trial the only liquid sent to the pond consists of plant washdown water and wastewater from the reverse osmosis plant.

**Conclusion**
The audit confirmed that the operation of the solid waste holding area and liquid waste disposal system at the Honeymoon mine site is in accordance with current approvals granted under the Radioactive Waste Management Code. The management of radioactive waste should be reviewed from time to time to take into consideration any changes in internationally accepted practices.
Recommendation 8
That management of radioactive waste at uranium mine sites be kept continually under review to take account of any changes in internationally accepted practices.

7.2.4 Radium Hill

Tailings storage
The main feature of the former uranium mine at Radium Hill is the tailings dam (Figure 10), which consists of approximately 400,000 tonnes of tailings in a rectangular clay capped pile approximately 250 m long, 125 m wide and 8 m high. These tailings are the result of the physical separation of uranium-bearing minerals from the ore conducted at Radium Hill and are different in nature from the tailings arising from the final chemical processing at the Port Pirie treatment plant. Several piles of material, possibly crushed waste rock or rejects from the former heavy media separation plant, also remain on site.

The inspection confirmed the tailings dam was in fair condition with little degradation of the clay capping. As noted in section 4.3.2, the Radium Hill site is registered under the Act. The current conditions attached to the registration of the site are designed to begin the process of establishing specific long-term management plans for the whole Radium Hill site.

Recommendation 9
That long-term management plans be developed as required by conditions of registration of the Radium Hill site under the Radiation Protection and Control Act 1982.

Repository
As noted in section 3.4.4, a repository for contaminated material is located in the northern end of the tailings dam. Approximately 200 m$^3$ of solid material has been placed in the repository consisting of contaminated soil, plant and equipment arising from uranium mining and treatment activities conducted in South Australia during the 1900s.

The EPA's inspection found no degradation of the cover on materials buried in the repository area on top of the tailings dam.

The repository has not been used since 1998. It is regularly inspected by officers of PIRSA for any damage to the clay cover, and remedial action is taken as appropriate. As noted in section 4.3.2, the Radium Hill site, including the repository, are registered premises and are subject to conditions aimed at establishing specific long-term management plans for the site. The long-term management of the repository will be addressed as part of the overall waste management plan for the Radium Hill site.

The future intermittent disposal of radioactive waste at the Radium Hill repository is not recommended as the site is not engineered to a standard consistent with current internationally accepted practice. Assuming there will be more such waste arising in the future (for example, the radium contaminated flue mentioned in section 8.2.12), a disposal pathway must therefore be identified which conforms to internationally accepted best practice.
Recommendation 10
That the government develop options for management of the types of waste previously disposed of at the Radium Hill repository.

7.2.5 Port Pirie
As noted in section 3.4.5, there are six tailings dams from uranium operations and four smaller dams from rare earth operations on this site. In the mid 1980s, slag from the adjacent Pasminco smelter was used to cover dams 2, 3 and 4 and parts of dams 1 and 5 to minimise radon emissions and any potential for dust emission. From 1989 to 1990 the plant area was surveyed and partially decontaminated, and contaminated soil and other material was deposited in the eastern end of dams 5 and 6. The slag coverage was recently extended to cover the northern end of the former processing plant area following the demolition of the original processing tanks.

The inspection found that the three uranium tailings dams (dams 2, 3 and 4) and the smaller REC thorium waste dams remain covered with approximately 2 m of slag from the adjacent Pasminco smelter. The clay capping layer over the tailings dam areas remains in fair condition and has provided a base for some vegetation growth. The inspection also indicated no visible reduction in integrity of the fenced tailings dams.

As noted in section 4.3.2, the Port Pirie site is registered under the Act. Conditions attached to the registration are designed to begin the process of establishing specific long-term management plans.

Recommendation 11
That long-term management plans be developed as required by conditions of registration of the Port Pirie site under the Radiation Protection and Control Act 1982.
Figure 7  Aerial photograph of Olympic Dam Tailings Storage Facility

Figure 8  Solid waste stored at Beverley pending periodic disposal on site
Figure 9  Uranium product in drums being loaded into a shipping container

Figure 10  Tailings dam at Radium Hill
Figure 11  Aerial photograph of Port Pirie Treatment Plant and tailings dams, circa 1960.
8 AUDIT OF MISCELLANEOUS RADIOACTIVE MATERIAL

Radioactive material that has not been reported in previous sections is included in this section.

8.1 Inspection process
During the audit the EPA inspected a large number of sites where miscellaneous radioactive material was being used or stored. While it was not possible to inspect all miscellaneous radioactive material, all potentially significant locations identified by the EPA were inspected.

8.2 Findings and recommendations
Miscellaneous radioactive material was located at 54 sites; 39 sites held waste in storage, 35 of which held waste with no disposal pathway. The 4 sites holding waste with a disposal pathway were storing smoke detectors to be sent out of South Australia for return to suppliers.

8.2.1 Smoke detectors
Most smoke detectors contain a very small quantity of the radionuclide americium-241 (figure 12). A few small stores of smoke detectors, such as those held at supermarkets and hardware outlets, were inspected during the audit but have not been included in this report. Similarly, South Australian dwellings, which are now required to have a smoke detector installed, were not included in this report.

While the Regulations impose requirements for storage of radioactive material that could include dwellings where smoke detectors are installed, it was not intended to control the storage of individual smoke detectors, as the risk is considered to be trivial. However, the storage of large quantities of smoke detectors must comply with the requirements of the Regulations.

Nine significant stores of smoke detectors were inspected. Each of these stores held more than 100 smoke detectors. The largest quantity was found at a warehouse in Wingfield, where up to 100,000 new smoke detectors were stored pending national distribution.

Recommendation 12
That the EPA review the legislative requirements for storage of smoke detectors.

Disposal of waste smoke detectors has not been approved in South Australia and each smoke detector carries a label stating ‘Return to supplier or Department of Health for disposal’ (Standards Australia International Ltd. 2001). Despite this, most of the waste smoke detectors discarded by South Australian householders every year are presumably being disposed of with normal waste.

The Radiation Health Committee (RHC)\(^7\) has recommended that disposal via landfill burial of small numbers of waste smoke detectors be permitted (ARPANSA 2001b). However, this recommendation may require review in the light of waste management principles and policies now used in South Australia.

\(^7\) The Radiation Health Committee is an advisory body to the CEO of ARPANSA, established under the ARPANS Act 1998.
Recommendation 13
That the EPA investigate the possibility of approving disposal of small numbers of smoke detectors with domestic waste, giving due consideration to the current waste management principles and policies used in South Australia.

Suppliers and the EPA store waste smoke detectors that are returned by members of the public. The volume of waste smoke detectors in storage by the EPA and a major supplier at the time of the audit was estimated to be 11 m$^3$. Of this, approximately 2 m$^3$ will probably be returned to interstate suppliers. The volume is constantly growing and becoming an issue for the major supplier. The recent mandatory requirement for smoke detectors in dwellings may result in an estimated 15 m$^3$ of smoke detectors being returned to suppliers or the EPA for storage each year.

The Radiation Health Committee (ARPANSA 2001b) recommended that large numbers of smoke detectors be disposed of in accordance with the Near-surface Disposal Code. However, the possibility of returning waste smoke detectors to their overseas manufacturers for recycling warrants further investigation, as this would significantly reduce the volume of waste destined for a store or repository, if such a facility were to be established.

In conclusion, waste smoke detectors are becoming a significant storage issue for South Australia, and their long-term management needs to be determined as a matter of urgency.

Recommendation 14
That suppliers of smoke detectors fully investigate the feasibility of returning waste smoke detectors to their overseas manufacturers.

8.2.2 Legacy radioactive waste
In addition to legacy sealed sources noted in section 5.2.3, a total of approximately 2 m$^3$ of miscellaneous radioactive waste resulting from uses of radioactive material for medical, industrial and scientific purposes in the past is stored at hospitals, universities and other institutions. Typically the waste is in solid or liquid form and contains radionuclides such as uranium, thorium and radium. Some of the unwanted material was adequately identified and quantified, but the extended period over which this material has accumulated has generally made identifying and quantifying the radionuclides involved very difficult.

This waste needs to be properly characterised before final management options can be considered. It is probable that some of the material will need to be repackaged and shielded for safer interim storage. While conditioning for interim storage may, in some cases, be a relatively simple process, the assessment of the material and complex conditioning that may be necessary for final disposal or long-term storage may in some cases be hazardous and require specialised knowledge and expertise. The complex conditioning should not be undertaken until long-term management options for this type of waste are determined.

Recommendation 15
That owners of legacy radioactive waste ensure that essential shielding and containment is provided, but not attempt complex conditioning until long-term management options are determined.
8.2.3 Radioactive ore and tailings in small quantities
A number of organisations have samples of radioactive ore and tailings from mines stored at their premises. Some of this material is considered waste. Waste ore and tailings samples are normally returned to the mine from which they originated for disposal by the mine operator. However, there is approximately 0.5 m³ of this type of waste with no disposal pathway, mainly because the origin of the material is not known.

8.3.4 Radioluminous paints
Radium paint which produces visible light (radioluminous paint) contains the radionuclide radium-226. The widespread use of radium paint ended approximately 40 years ago. Museums and other collectors of historic artefacts may keep significant quantities of articles that contain radium paint (Figure 13). A large collection (hundreds) of such articles is stored within the premises of a museum inspected as part of the audit. It is assumed there are a number of other museums holding this type of radioactive material.

The articles are not considered waste by the museum. While the store appeared to be well ventilated, it would be prudent to properly measure the radiation levels, as the radiation produced through the storage of this quantity of radium painted articles may pose a risk to persons spending extended periods in the store.

**Recommendation 16**
That the radiation level in any store containing large quantities of radioluminous items be assessed and appropriately managed.

These articles generally do not have a warning label regarding the radioactive material that they contain. Persons unaware of the hazards of radioactive material may be at risk if they were to, for instance, remove the radium paint from instrument faces.

**Recommendation 17**
That the EPA provide guidance for museums and other owners regarding the hazards of articles containing radium paint.

Over the years members of the public have surrendered numerous articles containing radium paint to the EPA. As there is no disposal pathway for such articles, they are stored by the EPA. It is assumed that many more articles are disposed of with domestic waste.

8.3.5 Gaseous tritium light sources
A gaseous tritium light source provides visible light without the need for an external power source. While some emergency exit signs used in the past contained a gaseous tritium light source, current exit signs do not contain such a source (with the exception of exit signs on some aircraft). The EPA currently stores three waste gaseous tritium light source exit signs.

The Regulations prohibit the sale of articles containing a gaseous tritium light source for domestic, personal or occupational use (e.g. watches and compasses). However, some jurisdictions in Australia have approved the sale of such devices to the public, where it can be demonstrated that there is trivial risk to people and the environment. The devices are sold outside South Australia, including on the Internet, and it can be assumed that some South Australians own these devices.

The EPA will investigate any reports of commercial sales of these devices in South Australia.
8.2.6 Thorium alloy
Between 100 and 200 kg of waste thorium alloy is stored at the premises of a metal recycling company. While the storage was regarded as moderately secure, the material was kept with corrosive chemicals. The owner has been directed to relocate the material to a safer and more secure location. The owner cannot recycle the material, and there is currently no disposal pathway available.

8.2.7 Thorium gas mantles
A number of hardware stores and outdoor centres were inspected to assess the storage of thorium gas mantles (figure 14). It was found that these stores had no more than about 100 such mantles in stock at any one time. The EPA does not know of any significantly larger stores of thorium gas mantles in South Australia.

8.2.8 Borehole logging calibration pits
An inspection of a number of borehole calibration pits was conducted as part of the audit. Some of the calibration pits, which extend underground to a depth of 10 m, contain concrete mixed with a known concentration of radioactive material. The concentration of the radionuclides in the concrete varies up to 0.92% for uranium oxide, 4.52% for potassium-40 and 0.22% for thorium oxide. The calibration pits are not considered waste.

8.2.9 Depleted uranium
A number of industrial radiography sealed source containers made of depleted uranium either are waste or will become waste in the next 5 years. A disposal pathway may exist through the vendor of replacement containers arranging for the return of the old containers to the original manufacturer.

Each container has a mass of approximately 20 kg. At the time of the inspection, these containers were stored securely and safely.

Recommendation 18
That owners be encouraged to return waste containers made of depleted uranium to the supplier or transfer them to another suitable owner.

8.2.10 Geological drill cores
In addition to drill core samples held at uranium mines, three drill core libraries within South Australia were inspected—one in metropolitan Adelaide, one in Moonta and one in Whyalla. The Adelaide and Moonta core libraries contained radioactive samples. The inspections found that drill cores containing radioactive material were stored appropriately. They are not considered waste.

8.2.11 Sources used in schools
There are 233 schools, including government and independent schools, where radioactive material may be used for secondary level science classes (figure 15). Due to the large number and wide distribution of these schools, a questionnaire was used to survey radioactive material held in schools, and a small number of schools was subsequently inspected. The locations of schools that hold radioactive material have not been included in the maps and tables of this report, nor have they been included in the total number of sites where radioactive material is located in South Australia.

In all cases where inspections were carried out, the storage arrangements were satisfactory. The EPA usually receives one or two requests each year from schools wishing to surrender
small sealed sources (see section 8.2.13) or mineral samples, and currently stores the surrendered material in voluntary arrangements with those schools.

In response to the questionnaire, 134 replies were received, of which 87 indicated they stored radioactive material. There were 47 replies indicating no radioactive material was held. Informal indications suggest that about 40 schools may have some radioactive material that they may wish to surrender due to its age, condition or lack of use.

The total activity of all small sealed sources held by schools is estimated to be approximately 30 MBq. In addition there is an estimated 15 kg of mineral samples and some radioactive (chemical) compounds. The amount and type of radioactive material held by schools is reasonable for normal teaching purposes.

8.2.12 Radium contaminated flue
Within one of the buildings at The University of Adelaide there is a flue contaminated with radium-226. The flue is no longer used and has been bricked over. Its existence is documented and under the supervision of the university’s radiation safety officer. While the radioactively contaminated material is fixed at present, should this section of the building be removed, it would need to be managed as radioactive waste. This would generate a large volume of radioactive waste, for which at present there is no appropriate storage or disposal facility available.

8.2.13 Small sealed sources used for calibration and education
Sealed sources (below the activity requiring registration) are used for calibration purposes in nuclear medicine and analytical laboratories, and for educational purposes in secondary schools. When the activities of these sources decay below levels that are useful, the sources are stored indefinitely. They are physically small in size and do not add greatly to the volume of waste. There is currently no approved disposal pathway for these items.

8.2.14 Sources used in devices
A number of devices that incorporate radioactive material were inspected. The volume of this type of material represented a small fraction of the total volume of waste miscellaneous material.

Anti-static devices
A number of South Australian companies use anti-static spray guns and wands containing polonium-210. These have a short useful life and in some cases have been surrendered by their owners for storage at the EPA. The radionuclide decays to an activity that is below regulatory control after approximately seven years. While the preferred option is for owners of such devices to return them to their overseas suppliers, there have been problems gaining the appropriate export permits.

Recommendation 19
That the EPA assist owners of unwanted anti-static devices in investigating management options, including export to their overseas suppliers.

Liquid scintillation counters
Liquid scintillation counters contain a small sealed source of the radionuclide caesium-137 below the activity requiring registration. The EPA understands there are approximately 50 liquid scintillation counters in South Australia. During the audit, three stores were found containing waste sources from liquid scintillation counters.
Liquid level detectors
Radioactive material is used in portable liquid level detectors. One company was inspected that owns three detectors. Two of the detectors contain cobalt-60 in the form of a wire and the other incorporates a caesium-137 sealed source that is below the activity requiring registration. The company considers all these detectors to be waste.

8.2.15 Other radioactive material
In addition to the miscellaneous radioactive material reported above, the EPA found a number of old dew point meters (figure 16) containing radium-226 in Adelaide. All are considered to be waste. There may be many more of these devices in South Australia, and there are other miscellaneous radioactive devices of historic nature held by the public, such as clocks and compasses with radioluminous dials. In many cases the owners may not be aware that the devices contain radioactive material as they are not usually labelled radioactive.

The EPA has occasionally taken possession of unwanted items of this type, but has limited capacity for storage.

Recommendation 20
That options for the long-term management of miscellaneous radioactive material be developed.

Figure 12 Waste smoke detectors
Figure 13  Clocks with radioluminous dials

Figure 14  Gas lantern mantles containing radioactive thorium
Figure 15  Small sealed sources used for science education

Figure 16  Old dew point meter containing radium
MAPS AND TABLES OF SOUTH AUSTRALIA’S RADIOACTIVE MATERIAL

Figure 17 Locations of radioactive material in metropolitan Adelaide.
Figure 18 Locations of South Australia's radioactive material
## Table 4  Postcodes of sites in South Australia where registered sealed sources are located

<table>
<thead>
<tr>
<th>Postcode</th>
<th>Is waste stored?</th>
<th>Estimated waste volume (m³)</th>
<th>Postcode</th>
<th>Is waste stored?</th>
<th>Estimated waste volume (m³)</th>
<th>Postcode</th>
<th>Is waste stored?</th>
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<td>5290</td>
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<td>Moomba</td>
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</table>

Audit of Radioactive Material in South Australia
### Table 5  Postcodes of sites in South Australia where unsealed radioactive material is located

<table>
<thead>
<tr>
<th>Postcode</th>
<th>Waste stored?</th>
<th>Estimated max. waste volume stored (m³)</th>
<th>Postcode</th>
<th>Waste stored?</th>
<th>Estimated max. waste volume stored (m³)</th>
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</thead>
<tbody>
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<td>0.1</td>
<td>Honeymoon</td>
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</tr>
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</table>

* These are mineral laboratories that return any waste generated to the originating mine site for management (see section 6.2.2). The volume of waste from these laboratories is included in the figures contained in Table 6.

### Table 6  Radioactive waste stored at mining and milling sites in South Australia

<table>
<thead>
<tr>
<th>Site</th>
<th>Estimated waste volume (m³)</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>Beverley</td>
<td>100</td>
<td>Contaminated items stored pending disposal on site</td>
</tr>
<tr>
<td>Honeymoon</td>
<td>40</td>
<td>Contaminated items</td>
</tr>
<tr>
<td>Olympic Dam</td>
<td>35,000,000</td>
<td>Tailings</td>
</tr>
<tr>
<td>Port Pirie</td>
<td>120,000</td>
<td>Tailings</td>
</tr>
<tr>
<td>Radium Hill</td>
<td>250,000</td>
<td>Tailings</td>
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</table>
Table 7  Postcodes of sites in South Australia where miscellaneous radioactive material is located

<table>
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<tr>
<th>Postcode</th>
<th>Waste stored?</th>
<th>Estimated waste volume stored (m$^3$)</th>
<th>Postcode</th>
<th>Waste stored?</th>
<th>Estimated waste volume stored (m$^3$)</th>
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<td>0.0001</td>
<td>Honeymoon</td>
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<td></td>
</tr>
</tbody>
</table>

* These sites store waste smoke detectors that will be sent out of South Australia. The volume of this waste has not been specified, as it does not affect the volume of waste requiring management.
## Table 8 Volume and activity of South Australia’s waste in storage

<table>
<thead>
<tr>
<th>Waste type</th>
<th>Estimated volume (m³)</th>
<th>Estimated activity (TBq(^{(a)}))</th>
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<tbody>
<tr>
<td><strong>Registered sealed sources</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Category S</td>
<td>5</td>
<td>6.5</td>
</tr>
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<td>Category A &amp; B</td>
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<td>0.3</td>
</tr>
<tr>
<td>Total sealed sources</td>
<td>8</td>
<td>6.8</td>
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<tr>
<td><strong>Unsealed waste in laboratories</strong></td>
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<td></td>
</tr>
<tr>
<td>Very low level(^{(b)})</td>
<td>&lt;16</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>Total very low level</td>
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<td>&lt;0.002</td>
</tr>
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<td><strong>Miscellaneous waste</strong></td>
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<td></td>
</tr>
<tr>
<td>Waste from past practices (Category A, B &amp; S)</td>
<td>5</td>
<td>(c)</td>
</tr>
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<td>Discarded smoke detectors (Category A &amp; B)</td>
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<td>0.0003</td>
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<tr>
<td>Total miscellaneous</td>
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<td>(c)</td>
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<tr>
<td><strong>Mining waste</strong></td>
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<td></td>
</tr>
<tr>
<td>Olympic Dam</td>
<td>35,000,000(^{(d)})</td>
<td>4800(^{(e)})</td>
</tr>
<tr>
<td>Beverley</td>
<td>100</td>
<td>&lt;0.001(^{(f)})</td>
</tr>
<tr>
<td>Honeymoon</td>
<td>40</td>
<td>&lt;0.001(^{(f)})</td>
</tr>
<tr>
<td>Port Pirie</td>
<td>120,000(^{(d)})</td>
<td>160(^{(g)})</td>
</tr>
<tr>
<td>Radium Hill – tailings</td>
<td>250,000(^{(d)})</td>
<td>5(^{(h)})</td>
</tr>
<tr>
<td>– repository material</td>
<td>200</td>
<td>&lt;0.001(^{(f)})</td>
</tr>
<tr>
<td>Total mining waste</td>
<td>35,400,000</td>
<td>~ 5000</td>
</tr>
</tbody>
</table>

\(^{(a)}\) Bq = becquerel = unit of radioactivity; terabecquerel (TBq) = 10 Bq.

\(^{(b)}\) Maximum quantity stored pending disposal in accordance with the User Disposal Code.

\(^{(c)}\) The activity of most legacy waste was not known by owners, nor quantified during the audit.

\(^{(d)}\) Based on the density of tailings being approx 1.7 tonnes/m³.

\(^{(e)}\) Based on an activity concentration of 80 Bq per gram.

\(^{(f)}\) This is an estimate; waste includes surface contaminated items, the activity of which was not quantified during the audit.

\(^{(g)}\) Based on an activity concentration of 800 Bq per gram.

\(^{(h)}\) This is an estimate, based on surface gamma dose rate measurements.
10 INTERNATIONAL AND NATIONAL PRINCIPLES AND PRACTICES

10.1 Management of radioactive waste

The International Atomic Energy Agency (IAEA) is the official body of the United Nations that has statutory responsibilities and obligations relating to protection of health and the environment from harmful effects of ionising radiation. The IAEA, in cooperation with its member states (of which Australia is one), has developed, established through international agreement and published a large number of nuclear and radiation standards, including standards for safe management of radioactive waste. These are all complementary to the International Basic Safety Standards, published by the IAEA and sponsored jointly by the international organisations FAO, IAEA, ILO, OECD/NEA, PAHO and WHO (IAEA 1996).


The internationally agreed principles of safe radioactive waste management are as follows:

**Principle 1:** Protection of human health
Radioactive waste shall be managed in such a way as to secure an acceptable level of protection for human health.

**Principle 2:** Protection of the environment
Radioactive waste shall be managed in such a way as to provide an acceptable level of protection of the environment.

**Principle 3:** Protection beyond national borders
Radioactive waste shall be managed in such a way as to assure that possible effects on human health and the environment beyond national borders will be taken into account.

**Principle 4:** Protection of future generations
Radioactive waste shall be managed in such a way that predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today.

**Principle 5:** Burdens on future generations
Radioactive waste shall be managed in such a way that will not impose undue burdens on future generations.

**Principle 6:** National legal framework
Radioactive waste shall be managed within an appropriate national legal framework including clear allocation of responsibilities and provision for independent regulatory functions.

**Principle 7:** Control of radioactive waste generation
Generation of radioactive waste shall be kept to the minimum practicable.
Principle 8: Radioactive waste generation and management interdependencies
Interdependencies among all steps in radioactive waste generation and management shall be appropriately taken into account.

Principle 9: Safety of facilities
The safety of facilities for radioactive waste management shall be appropriately assured during their lifetime.

In addition to the document on fundamental principles, the IAEA’s Radioactive Waste Safety Standards documents include safety standards, guides and practices. These publications are used to assist in deriving national criteria, standards and practices for radioactive waste management.

Near-surface disposal is an option regarded as suitable by international agreement for low and intermediate level waste (LILW) that contains mainly radionuclides that decay to insignificant levels within a few decades or centuries (i.e. the operating life of the facility plus a subsequent period of institutional control). When a near-surface repository is closed, it is covered with soil or other material and the area is controlled for 100 years or more, until the radioactivity has decayed to insignificant levels. Limited concentrations of long-lived LILW may also be suitable for near-surface disposal. LILW that is not suitable for near-surface disposal is generally held in long-term storage facilities until deeper geological repositories are developed. Planning for such repositories is under way in several countries.

Near-surface disposal of LILW has been practised for more than 50 years, with establishment of more than 100 near-surface repositories around the world, and more than 30 in various stages of development. The IAEA and others have published many technical reports detailing the experience of countries in constructing and operating near-surface disposal repositories, ranging from simple to more engineered facilities. Examples include Vaalputs (South Africa), Drigg (UK), Centre de l’Aube (France), El Cabril (Spain), Trombay (India), Rokkasho-mura (Japan) and Barnwell (USA). The National radioactive waste repository draft EIS (DEST 2002) lists near-surface repositories around the world, and the status of LILW disposal facilities in various countries in 1996 was reviewed in an IAEA Bulletin (Kyong Won Han et al 1997).

In Australia, a code of practice was developed under the auspices of the NHMRC, and published as the Code of practice for the near-surface disposal of radioactive waste in Australia (1992) (Cwlth 1992). This code categorises waste suitable for near-surface disposal into categories A, B and C, and gives qualitative descriptions of these categories according to their general characteristics. Quantitative criteria for these categories will be derived for a specific disposal facility at a particular site. The code designates waste not suitable for disposal at such a near-surface facility as Category S. Such waste will require storage until a suitable disposal facility (e.g. one that is hundreds of metres below the surface) is available.

The IAEA has held a number of international conferences on radioactive waste management and has also established a Net Enabled Waste Management Database (NEWMDB) to collect information about radioactive waste management activities in its member states, for the exchange of scientific and technical information amongst waste safety specialists. The reporting requirements of the Joint Convention will also provide an opportunity for formal peer review of radioactive waste management in countries that are Contracting Parties to the Convention, including Australia. Australia is an active participant in the various radioactive waste safety initiatives of the IAEA.

The IAEA was assigned the responsibility to develop indicators of sustainable development for radioactive waste management (ISD-RW) in accordance with Chapter 22 of Agenda 21, issued
from the UN Conference on Environment and Development held in Rio de Janeiro in June 1992. A single ISD-RW was developed by the IAEA in 2001–02, and submitted to the UN’s Department of Economic and Social Affairs (DESA) in November 2002. DESA has agreed to include this ISD-RW in its list of core indicators.

The purpose of the indicator is to provide a measure of both the current status of radioactive waste management at any point in time and the progress made over time towards the overall sustainability of radioactive waste management. The indicator is meant to be calculated for each class of radioactive waste that exists in a country (other than very low level waste disposed into the environment in accordance with regulatory approvals), regardless of the varying definitions of classes of waste that are used in different countries.

Progress in managing radioactive waste is measured against key milestones related to both the processing of waste into forms suitable for either safe storage or placement into a designated endpoint (the ‘form factor’); and the placement of waste into an endpoint facility (the ‘endpoint factor’). The ‘endpoint’ may be disposal or long-term storage in a purpose-designed facility which meets relevant international criteria.

The most sustainable condition is reached when the amount of radioactive waste awaiting disposal or long-term storage is not increasing, and the waste is in the final form required for disposal or long-term storage and is being stored safely in the interim.

However, while DESA has accepted an indicator that recognises that some countries are currently opting for indefinite storage rather than final disposal, a conclusion of the IAEA’s International Conference on Issues and Trends in Radioactive Waste Management held in December 2002 was that, in the long term, surface storage is unsustainable because of the need to maintain institutional control to guarantee the safety of the storage facility. Such control cannot be guaranteed indefinitely. A recent position paper on the safety and sustainability of long-term storage by a group of international experts (IAEA 2003c) confirms this view.

10.1.1 Conclusion
The UN’s indicator of sustainable development for radioactive waste management provides a measure of both the current status of waste management and progress towards sustainable management. Although designed for application on a national scale, the concept may also be usefully applied as a measure of the sustainable management of South Australia’s low and intermediate level radioactive waste. The present management of this waste in South Australia must be judged unsustainable as no endpoint (repository or indefinite storage facility) has been identified, and no waste has been processed or prepared for its final disposition to the endpoint.

10.2 Radioactive waste facilities in other states and territories
In Australia, only Queensland and Western Australia have purpose-built facilities for the disposal or long-term storage of radioactive waste. In particular:

- Queensland has a purpose-built store owned by the Queensland State Government and operated by Queensland Health.
- Western Australia has the Mount Walton East Waste Disposal Facility for the permanent disposal of intractable (chemical and radiological) waste generated within Western Australia.
The other states and territories have the following facilities:

- Australian Capital Territory has a small store for waste generated in the ACT.
- New South Wales has a non-operational store for waste generated in NSW.
- Tasmania has a small store for waste generated in Tasmania.
- Victoria has the Victorian Interim Storage facility for seized and abandoned radioactive materials.
- The Northern Territory has a small store for waste generated in the NT.

10.3 Security of radioactive material

Prior to events of terrorism in recent years the requirements for safety and security of radioactive sources have primarily been aimed at measures to prevent inadvertent loss of radioactive sources, unintentional access by people who are unaware of the hazards, or theft. The International Basic Safety Standards (IAEA 1996) specify the basic requirements for protection of people against exposure to ionising radiation and for safety of radiation sources, including basic requirements for ‘security of sources’.

The threat of terrorism and malevolent use of radioactive sources has prompted a review of safety and security of sources at both international and national levels. In this regard, the IAEA has commenced development of a safety guide on safety and security of radiation sources. It will contain detailed recommendations for security measures that should be applied to different categories of radioactive source. The IAEA has also made efforts to address security issues in more depth in the current revision of the *Code of conduct on the safety and security of radioactive sources* (IAEA 2001). The objective of the revised code is to achieve and maintain a high level of safety and security of radioactive sources; prevent unauthorised access or damage to, and loss, theft and unauthorised transfer of, radioactive sources; and prevent malicious use of radioactive sources to cause harm to individuals, society or the environment.

At its meeting in June 2003 the G-8 summit released an action plan aimed at preventing terrorists from gaining access to highly radioactive material. The G-8 leaders agreed to work closely with the IAEA on steps to strengthen the safety and security of radioactive sources.

In Australia a National Directory for Radiation Protection (National Directory), which will provide an overall agreed framework for radiation safety, is being developed by a working group of the Radiation Health Committee (RHC), established under the Australian Government’s *Australian Radiation Protection and Nuclear Safety Act 1998*. A national radioactive source security strategy is currently being developed with the aim of incorporating agreed controls on radioactive sources in the National Directory. The strategy will take into account international guidance for safety and security of sources.
11 FUTURE MANAGEMENT OF RADIOACTIVE MATERIAL

11.1 Storage of radioactive material

The audit found that most owners of radioactive material maintained appropriate records of their inventory of radioactive material in storage. However, inventories of radioactive material that had accumulated prior to the Act coming into force were generally unsatisfactory as the nature of the material was not accurately known. While this was not a requirement prior to the Act coming into force in the 1980s, it is now a requirement for all radioactive material entering stores.

Owners need to remain aware of the regulatory obligations with regard to accounting for and storing radioactive material. The safety and security of the storage of radioactive material would be enhanced by requiring owners to conduct regular reviews of the radioactive material in storage.

Key recommendation 1
That owners be required to regularly review the safety and security, and their inventory, of radioactive material, and report periodically to the EPA.

In recent years there has been increasing awareness of the potential use of radioactive material for terrorism, and this has been reflected in the international approach to the management of radioactive materials. When the current revision of the IAEA Code of conduct on the safety and security of radioactive sources (IAEA 2001) is officially adopted internationally, consideration should be given to the introduction of additional measures for safety and security of radioactive material in South Australia, as appropriate.

Key recommendation 2
That the current revision of the IAEA’s Code of conduct on the safety and security of radioactive sources (IAEA 2001) and other national and international guidance on safety and security be applied as appropriate to the storage of radioactive material in South Australia.

11.2 Principles of radioactive waste management

Internationally agreed principles of radioactive waste management require protection of people and the environment for future generations. Each generation should manage its radioactive waste in a manner that does not place an undue burden on later generations. However, some costs for ongoing maintenance of waste facilities by future generations may be justified.

Key recommendation 3
That future management of South Australia’s radioactive waste be in accordance with internationally agreed principles.

11.3 Management of very low level radioactive waste

Very low level radioactive waste is currently disposed of in accordance with the Code of practice for the disposal of radioactive waste by the user (1985) (Cwlth 1986), which includes
landfill disposal. With the closure of the Adelaide City Council Waste Disposal Depot at Wingfield in December 2004, it is essential for disposal options for very low level waste to be re-assessed urgently.

### Key recommendation 4
That options for management of very low level radioactive waste be developed urgently, and acceptable alternatives be identified as soon as possible but no later than December 2004.

### 11.4 Management of mining radioactive waste

Mining waste is produced in large volumes, and options for its management are considered in the environmental assessment of the entire mining project. Management of the waste is usually carried out on the mine site. This is the case for South Australia’s current uranium mine sites at Olympic Dam, Beverley and Honeymoon. Radioactive waste at the former mining and milling sites at Radium Hill and Port Pirie will also continue to be managed on site, with long-term surveillance due to the long half-life of the naturally occurring radionuclides in the waste.

### Key recommendation 5
That regulatory control of sites containing mining radioactive waste be kept under review to provide an appropriate system for radioactive waste management for protection of human health and the environment.

### 11.5 Management of other radioactive waste

This section discusses the management of radioactive waste not already covered in section 11.3 (very low level radioactive waste) and section 11.4 (mining radioactive waste). As identified in various sections of this report, some unwanted radioactive material stored in South Australia may be suitable for recycling or reuse.

### Key recommendation 6
That, wherever possible, owners be encouraged to arrange return of radioactive waste to the supplier or to another suitable owner for recycling or reuse.

Not all radioactive waste can be dealt with in this way. For example, some sealed sources may not be accepted by the supplier, the supplier may have gone out of business or the cost to return the radioactive material may be prohibitive. Unsealed radioactive waste cannot usually be returned or recycled. Owners must continue to store this low and intermediate level waste in such a manner that ensures the risk to people and the environment is acceptably low. Three technically feasible options for the management of this waste are:

- **Option 1** — that individual owners maintain safe storage of their waste indefinitely.
- **Option 2** — that a long-term waste storage facility be established.
- **Option 3** — that both a near-surface repository and a long-term storage facility be established.
11.5.1 Discussion of option 1
Option 1 is the preferred option of those who consider that requiring owners to be responsible for their waste in perpetuity will result in minimisation of waste generation. While this argument may have some merit in the case of corporate owners that are likely to maintain their operations on the same site for extended periods (generations), it essentially postpones the development of final management options, leaving the burden to a future generation, thus failing to comply with Principle 5 of the internationally agreed principles described in section 10.1. It is also inconsistent with the requirements for management of other types of hazardous waste, and will lead to a proliferation of storage sites.

Furthermore, this option is not possible in cases where the owner goes out of business or leaves South Australia, which is not uncommon. In the past, ‘orphan’ radioactive material or waste left in such circumstances has been accepted by the EPA, or occasionally by a university or major hospital, to ensure its safe custody. These ad hoc arrangements are not sustainable.

In addition, there are occasions where substantial volumes of radioactive material may arise from the clean-up of site contamination. In the past, some waste radioactive material from mineral processing has been deposited at Radium Hill.

The amount of waste in indefinite storage without a final option or endpoint identified is increasing. It was concluded in section 10.1 that, on the criterion accepted by the UN as an indicator of sustainable development for radioactive waste management, this is an unsustainable situation. Options therefore need to be developed to progress towards sustainability in the management of South Australia’s radioactive waste.

In conclusion, option 1 (indefinite storage by individual owners) does not lead to sustainability in radioactive waste management.

11.5.2 Discussion of options 2 and 3
Option 2 involves long-term storage of radioactive waste in a suitably sited and secure facility. While this option is not sustainable indefinitely because the volume of waste in storage would continue to increase, it may be employed as an interim measure for a number of years until appropriate disposal options for radioactive waste become available. It is not possible to guarantee the security of storage of radioactive material in the long term.

Option 3 involves final disposal in a near-surface repository of that portion of the waste that is considered suitable on internationally agreed criteria for this type of management, and long-term storage of the remainder until a suitable disposal option such as a deeper geological disposal facility is established. As explained above, many countries have chosen option 3, which has the advantage of reducing the burden on future generations.

In either case, the long-term storage or disposal facility may be owned and operated publicly or privately, or by a public–private partnership.

Other important considerations will influence which option is preferred, including financial and socio-political factors in South Australia that have not been considered in this report.

**Key recommendation 7**
That South Australia progress toward sustainability in management of its radioactive waste, guided by the UN’s Indicator of Sustainable Development for Radioactive Waste Management as a measure of progress.
It has been the experience in many countries, including Australia, that development of any facility for long-term management of radioactive waste, whether a near-surface repository or an above ground store, may take a number of years. Development of these facilities will probably involve detailed site selection and environmental impact assessment processes to demonstrate compliance with the Australian Government’s *Environment Protection and Biodiversity Conservation Act 1999* and relevant South Australian legislation.

**Key recommendation 8**
That the government undertake a rigorous feasibility study of options for future management of South Australia’s radioactive waste and that this study be commenced as soon as practicable.

In the interim, to continue to ensure safe and secure storage for existing and newly arising waste, it is desirable for the government to investigate the feasibility of establishing a facility for interim storage in cases where the owner cannot continue to maintain safe interim storage. Such a facility will probably be required even after the establishment of long-term facilities (repository or store), which may only accept waste in short campaigns, for example on an annual or biennial basis. Facilities for safely handling and packaging waste are also needed.

**Key recommendation 9**
That the government investigate the feasibility of establishing a facility for the safe handling, packaging and interim storage of waste pending the establishment of appropriate facilities for long-term management.
12 GLOSSARY OF TERMS, ABBREVIATIONS, ACRONYMS

ARPANSA  Australian Radiation Protection and Nuclear Safety Agency
ASNO  Australian Safeguards and Non-Proliferation Office
CSIRO  Commonwealth Scientific & Industrial Research Organisation
Cwlth  Commonwealth of Australia
DESA  Department of Economic and Social Affairs (UN)
DEST  Department of Education, Science &Training (Cwlth)
EMP  Environmental Management Program
EIS  environmental impact statement
EPA  Environment Protection Authority (South Australia)
FAO  Food and Agriculture Organization of the United Nations
IAEA  International Atomic Energy Agency
ICRP  International Commission on Radiological Protection
ILO  International Labour Office
ISD-RW  indicators for sustainable development for radioactive waste management
ISL  in-situ leach
LILW  low and intermediate level waste
NHMRC  National Health and Medical Research Council
OECD/NEA  Nuclear Energy Agency of the Organisation for Economic Co-operation and Development
PAHO  Pan American Health Organization
PIRSA  Primary Industries & Resources South Australia
RHC  Radiation Health Committee
TRS  tailings retention system
TSF  tailings storage facility
WHO  World Health Organisation

activity—the number of atomic transformations that occur per second in a radioactive material, and is a measure of the quantity of radionuclides present in a material at a given time. The unit for activity is the becquerel.

alpha particle—a relatively large particle, consisting of two protons plus two neutrons, emitted by a radionuclide. Alpha particles have a very short range (a few centimetres) in air and can be stopped by a thin layer of material (e.g. paper or outer layers of skin), but are a significant hazard within the body.

becquerel—the unit of activity. One becquerel (Bq) equals one atomic transformation per second.

beta particle—an electron or positron emitted by a radionuclide. Beta particles can travel up to a few metres in air and penetrate several millimetres of human tissue, but are stopped by a thin sheet of metal.
borehole logging tool—a device comprising a sealed source and a radiation detector that is used to acquire information about geological strata by lowering it into a borehole.

conditioning—those operations that produce a waste package suitable for handling, transport, storage and/or disposal. Conditioning may include the conversion of waste to a solid waste form and/or enclosure of the waste in containers.

depleted uranium—uranium containing a lesser percentage of uranium-235 than in natural uranium. It is a by-product of uranium enrichment and has about 60% of the radioactivity of natural uranium.

disposal pathway—the method by which waste is disposed of (e.g. household waste which cannot be reused or recycled is usually disposed of via a landfill disposal pathway).

electron—a particle with low mass ($\frac{1}{1836}$ that of a proton) carrying a negative charge.

gamma ray—a discrete quantity of electromagnetic energy emitted by a radionuclide.

half-life—the time taken for the activity of a radionuclide to lose half of its value through decay.

high level radioactive waste—radioactive waste that contains high levels of beta and gamma emitting radionuclides and significant levels of alpha emitters. It typically arises from reprocessing of spent nuclear fuel. It requires careful handling and substantial shielding, and generates significant heat requiring measures for heat dissipation.

industrial radiography source—a sealed source, usually iridium-192 or cobalt-60, that produces an intense beam of gamma radiation for radiographing metal welds and castings.

interim store—a store designed to hold radioactive material on a temporary basis, typically for periods of 2 to 5 years, until the radioactive material is moved to a repository or long-term store.

intermediate level radioactive waste—radioactive waste which contains significant quantities of beta and/or gamma emitting radionuclides, and may contain significant quantities of alpha emitting radionuclides. It includes longer-lived sealed sources used in medicine and industry, chemical process residues from production of radioactive material, and reactor components. Because of its radionuclide content, it requires shielding but little, if any, provision for heat dissipation during handling and transportation. Intermediate level waste may be subdivided into short-lived and long-lived, according to the length of time it will remain significantly radioactive.

ionising radiation—electromagnetic or particulate radiation capable of producing ions directly or indirectly. Examples include alpha particles, beta particles, gamma rays, X-rays and neutrons.

isotope—one of a set of species atom which have the same atomic number (number of protons in the nucleus) but different mass numbers (number of protons plus neutrons in the nucleus). See nuclide.

long-term store—a store designed to hold radioactive waste for an extended period of time (e.g. while a deep geological burial site is established).
low level radioactive waste—radioactive waste which contains low levels of beta and gamma emitting radionuclides, and very low levels of alpha emitting radionuclides. It includes contaminated items of plastic, glassware and clothing used in laboratories, contaminated plant and soil, and some sealed sources formerly used in medicine, industry and research. It does not normally require shielding during handling and transportation.

moisture/density meter—a portable device typically containing a sealed source that emits neutrons fixed within the body of the device, and a gamma source on a small probe that can be inserted approximately 30 cm into a hole in the ground.

moisture probe—a portable device, containing a sealed source that emits neutrons, on a cable up to 3 m long. The device body, which contains the data recording and display electronics, also doubles as a radiation shield when the sealed source is retracted.

near-surface repository—a purpose built structure either above ground or up to 30 m below ground where radioactive waste appropriate for disposal in such a facility is placed with no intention to retrieve it.

neutron—an elemental particle with an approximate unit atomic mass ($\frac{1}{12}$ the mass of a carbon-12 atom) and no electric charge. Neutron radiation is most effectively shielded by water, plastic and other hydrogenous material.

nucleus—the central core of an atom that has a positive charge and occupies little of the atom’s volume but contains most of its mass and, with the exception of hydrogen that contains only one proton, contains protons and neutrons.

nuclide—an atom of a particular element characterised by the number of protons and neutrons in the nucleus and the energy state of its nucleus.

positron—a particle with low mass ($\frac{1}{1836}$ that of a proton) carrying a unit positive charge.

premises—any land, building or structure whether fixed or moveable, or any part of any land, building or structure.

proton—an elemental particle with unit mass and unit positive charge.

radiation—see ionising radiation.

radiation gauge—a device fixed in place and containing a sealed source that uses the detection of a beam of radiation transmitted through or scattered by an item or material of interest to measure a parameter associated with that item or material of interest.

radioactive material—any material with an activity and activity concentration that is regulated by the Act.

radioactive—possessing the property of radioactivity.

radioactive decay—the process of spontaneous transformation of a radionuclide resulting in a decrease in activity of a radioactive material.

radionuclide—an unstable (radioactive) nuclide that emits ionising radiation.

registered—registered under the appropriate section of the Act.
risk—the probability of injury, harm or damage.

safety—measures intended to minimise the likelihood of accidents with radioactive material and, should such an accident occur, to mitigate its consequences.

sealed source—radioactive material that is permanently sealed in a capsule, or closely bonded and in a solid form.

security—measures to prevent unauthorised access or damage to, and loss, theft or unauthorised transfer of, radioactive material.

site—a location where radioactive material is stored or used that is physically separated from other such locations, even if they are owned by the same person or organisation (e.g. where a university has a number of campuses, each containing a number of premises or stores, each campus is considered to be a separate site).

store—a room, pit or enclosed area that contains radioactive material.

the Act—the South Australian Radiation Protection and Control Act 1982.


unsealed radioactive material—radioactive material that is not a sealed source.

very low level radioactive waste—waste in which the activity concentrations do not exceed the limits permitted for disposal in accordance with the User Disposal Code.

waste—material in gaseous, liquid or solid form for which no further use is foreseen.
REFERENCES


http://wwwiaeao rg/worldatom/Periodicals/Bulletin/Bull391/bonne.html


