Management of Radioactive Waste at Lucas Heights

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SUMMARY Radioactive waste is an inevitable product of the activities of ANSTO performed in the national interest. Most of the wastes arise from the production of radiopharmaceuticals for nuclear medicine. The regulatory framework, waste management practices and historic wastes stored at ANSTO are described. ANSTO has complied with all relevant State and Commonwealth requirements in managing radioactive wastes. Extensive monitoring of discharges demonstrates that its practices have protected human health and the environment. The policy on radioactive waste management within ANSTO has been reviewed to ensure it continues to manage wastes in accord with evolving best practice internationally.

1. INTRODUCTION

Radioactive waste is an inevitable product of ANSTO's activities in nuclear science and the production of radiopharmaceuticals, isotopes and radiochemicals for medical, industrial and research purposes. These are beneficial activities, directed at

- improving health in the community
- protecting the environment
- supporting Australian industry
- and training the next generation of scientists in a range of disciplines.

Currently, ANSTO supplies about 85% of the demand for radioisotopes and radiopharmaceuticals in Australia. ANSTO's share of the Australian market for technetium generators, the work-horse of nuclear medicine, is about 93%. ANSTO's unique nuclear science facilities are used by researchers in the 33 universities which are members of the Australian Institute of Nuclear Science and Engineering (AINSE).

Radioactive waste, for legal and regulatory purposes, is defined by the IAEA as material that contains or is contaminated with radionuclides at concentrations or activities greater than clearance levels as established by the regulatory body, and for which no use is foreseen. These wastes can occur as gases, liquids or solids. In recognition of the potential hazards associated with radioactive waste a rigorous system of control and surveillance during the transfer, treatment, storage and discharge of radioactive waste was set up from the beginning of activities at the Lucas Heights Research Establishment.

The objective of radioactive waste management at ANSTO has always been to protect human health and the environment. The waste management system at the AAEC and ANSTO has evolved taking into account international guidelines, regulations and national and state requirements. These requirements largely stem from the work of the International Commission on Radiological Protection (ICRP), which is an independent body of experts and the International Atomic Energy Agency (IAEA), which is an organisation within the United Nations system.

The methods available for the management and treatment of radioactive waste depend on the characteristics of the waste, but generally are governed by three basic principles:

- **Dilute and disperse:** This technique is only used where the radioactivity in the effluent is at a very low level and its release to the environment will not affect the natural radioactivity levels in the area to any significant extent.
- **Concentrate and contain:** This is used for wastes, usually liquids, with a higher level of radioactivity or toxicity. The radioactive or toxic materials are concentrated by volume reduction and commonly converted to a solid for storage in specially managed facilities.
- **Delay and decay:** This method is used for wastes having short half-lives. These materials are held in a suitable container until the radioactivity decays to a level acceptable for further treatment or discharge.

This paper describes the current system for waste management at ANSTO, regulatory aspects, independent assessments of safety and future directions to ensure that ANSTO practices are in accord with evolving international best practice.

2. REGULATORY FRAMEWORK

Regulation of radiation and activities involving radioactive materials in Australia is primarily the responsibility of the individual State Governments, usually implemented through a radiation health act and regulations. The national (Commonwealth) Government plays a coordinating role in promoting uniform standards through the development, jointly with the state authorities, of a set of codes of practice and guidelines which are subsequently adopted into state regulations. The codes have been developed to date through the auspices of the National Health and Medical Research Council (NHMRC) and under the Commonwealth Environment Protection (Nuclear Codes) Act (1978). The Code of Practice for the Safe Transport of Radioactive Substances (1990), which has been adopted by all state authorities, is based closely on the corresponding IAEA Regulations.

While there is extensive safety oversight of ANSTO by independent bodies there are no formal regulations or licensing processes of radioactive waste management including radioactive effluent discharges by the Commonwealth. To fill this gap and to provide for comprehensive regulatory control of all Commonwealth radiation and nuclear activities, the Government has initiated the formation of a national nuclear regulatory body to be called the Australian Institute for Radiation Protection (AIRP). The AIRP will be an amalgamation of two existing bodies; the Australian Radiation Laboratory (ARL) and the Nuclear Safety Bureau.

Since the 1960's, the AAEC and then ANSTO have discharged radioactive effluents from LHRL in compliance with authorisations approved at various times by the NSW Radiological Advisory Council (NSW RAC) in accordance with the NSW Radioactive Substances Regulations (1959)as amended. The discharge limits for both liquid and gaseous effluents approved by the RAC were based on a consideration of conservative exposure scenarios and associated pathways, relevant at the time, whereby members of the public could potentially be exposed to radiation doses. In September 1993, the NSW Radioactive Substances Regulations (1959) were repealed and replaced with Radiation Control Regulation (1993) under the Radiation Control Act (1990). The regulation is administered by the Director General of the NSW Environment Protection Authority (NSW EPA) through a new NSW Radiation Advisory Council. In 1994, the NSW EPA withdrew from any regulatory function in relation to the operation of ANSTO.

Following the withdrawal of the NSW EPA from any role in monitoring of emissions from LHRL, ANSTO:

- has to undertaken to meet the requirements of the previous NSW RAC authorisations for airborne emissions until such time as AIRP regulatory requirements are in place. The limits are based on the ICRP and NHMRC recommendations for dose to the general public. ANSTO compliance with this undertaking is verified by independent monitoring by ARL.
- continues to be subject to licensing of its liquid effluents by the Sydney Water Corporation in accordance with emissions specified in a formal Trade Waste Agreement. Compliance with these arrangements is monitored by the Water Board and the ARL.

The Trade Waste Agreement with Sydney Water for the next three years from 1 September 1995 requires ANSTO radionuclide content in liquid effluent discharges to comply:

- with the former NSW Radioactive Substances Regulations (1959), activity concentration limits at the point of discharge to the sewer, based on a monthly average concentration.
- with reference activity concentration limits in the WHO Guidelines for Drinking Water Standards at the Cronulla Sewage Treatment Plant (CSTP), based on a measured dilution factor of 25 for ANSTO effluent at the CSTP.

The effective operation of this system of monitoring and control is verified through oversight by the independent Safety Review Committee (SRC) which reports annually to Parliament.

3. WASTE MANAGEMENT POLICY

A review of waste management practices and policies was initiated within ANSTO during 1994. This action was driven by the following international and domestic developments:

- ANSTO's ongoing commitment to ensuring that radiation exposures are kept as low as reasonably achievable (ALARA);
- progress within the IAEA on the development of a comprehensive series of waste management standards (RADWASS) and guidelines reflecting international consensus on best practice;
- Commonwealth participation within the IAEA on the development of a proposed Convention on the Safety of Radioactive Waste Management;
- the impending establishment of AIRP with powers to regulate and license waste management at ANSTO;
- reflections on the outcome of the Mission Review which identified waste management as a key research area.

The Radioactive Waste Management Policy adopted by ANSTO in 1995 states:

ANSTO will manage its radioactive waste in a manner that protects human health and the environment now and in the future. In doing so, ANSTO is committed to:

- complying with all relevant legislative and regulatory requirements, and in particular,
  - to ensure that all discharges are within authorised limits,
  - to monitor and report regularly radioactive releases to the environment;
- ensuring that radiation exposures will be kept as low as reasonably achievable (ALARA), economic and social factors taken into account;
- disposing of wastes when appropriate disposal routes are available,
- being in accord with international best practice.

The objectives of ANSTO's radioactive waste management are:

- safe treatment and storage of radioactive wastes, taking into account the need to minimise dose uptake to operators and economic factors;
- minimisation of radioactive waste generated and stored;
- maintenance of inventories of all wastes from source to disposal;
- consistency by the year 2000 with best practice as identified in the RADWASS Standards and Safety Guides currently under development within the IAEA;
- broad public understanding and acceptance of ANSTO policy and practices.

The implementation of the policy and the achievement of the objectives requires an ongoing review of practices, future waste arisings and the preparation of an integrated predisposal plan that addresses waste reduction at source, improved waste segregation waste volume reduction and consideration of inter-dependencies between waste generation, treatment, storage, transport and disposal.

The achievement of the objectives will also require effective interaction with relevant Government Departments, regulatory authorities and enhanced liaison with the community and local interest groups.

4. WASTE CLASSIFICATION

Radioactive wastes can be gaseous, liquid or solid. They are classified as low, intermediate or high level, depending upon the amount and characteristics of the radionuclides present and on the dose rate of the container and intended disposal route. Most of the waste generated at ANSTO is low-level waste containing levels of beta and gamma emitting radionuclides not requiring special shielding for handling and transport purposes. These wastes can be disposed in near-surface facilities because they contain only very low levels of long-lived alpha emitting radionuclides. Intermediate level waste (ILW) contains significant levels of beta and gamma emitters and could also contain significant levels of alpha emitters. These wastes do not generate significant heat from decay processes but require shielding during handling and transport. Depending on the level of contained alpha emitters, the ILW can be disposed with LLW in near-surface facilities. Deep geological disposal is necessary for ILW containing significant levels of long-lived radionuclides.

High-level waste (HLW) is not generated in Australia. According to the IAEA (1) HLW is characterised by heat generation in excess of 2000W/m^3.

The NHMRC Code of Practice for the Near-Surface Disposal of Radioactive Waste in Australia (1992) (2) provides three categories (A,B and C) of radioactive waste (LLW) suitable for near-surface disposal. Category S wastes in the Code are unacceptable for near-surface disposal and are to be retained in storage until alternative disposal methods are available. The NHMRC (2) has also provided generic concentration limits for each category for a conservative LLW disposal facility in an arid remote site for institutional control periods of 100 and 200 years after which inadvertent human intrusion is assumed. The Code specifies principles to be followed in the derivation of activity concentration limits for a specific disposal facility. These limits would form part of the repository waste acceptance criteria.

The NHMRC Code is not intended to cover disposal of waste containing very low levels of activity to sewer, air and municipal landfill, addressed by the NHMRC Code of Practice for the Disposal of Radioactive Waste by the User (1985) (3). Although much of ANSTO's LLW could be disposed to municipal disposal sites, the NSW EPA has failed to nominate a designated disposal site in accordance with the requirements of the Code.

Since all materials contain some level of natural radioactivity, in the context of radioactive waste management it is necessary to define "exempt waste" that is released from nuclear regulatory control in accordance with clearance levels, because the associated radiological hazards are negligible. The definitions of "radioactive substance" in the Regulation (1993) of the Radiation Control Act (1990) of New South Wales provides a useful approach to exemption levels.

5. WASTE TREATMENT AND STORAGE

The principal source of radioactive waste at ANSTO arises from the production of radiochemicals and radiopharmaceuticals which account for more than 90% of all liquid wastes and more than 70% of all solid radioactive wastes. The remaining radioactive wastes arise from the operations of HIFAR and research programs. A detailed overview of waste management at LHRL was published by the SRC (4) and the following sections summarise the salient features.

5.1 Gaseous wastes

Airborne wastes arise from the operation of HIFAR and from the processing of irradiated targets for the production of radiopharmaceuticals. Ventilation systems for all areas handling significant quantities of radioactive material include high efficiency filters for particulate materials (HEPA filters). The HEPA filters are supplemented with banks of activated charcoal, where required, to absorb iodine and, to a lesser extent the noble gases (argon, neon, krypton, xenon and radon). Gases passing through these filters are monitored continuously before release under controlled conditions from ventilation stacks. The filters and charcoal constitute solid waste.

5.2 Liquid wastes

To facilitate treatment, waste waters are segregated into three categories:

- liquid low level effluent from laboratories in which radioactive material is handled.
- Trade effluent from laboratories and workshops in which radioactive and toxic materials are not handled.
- non-radioactive sewage.

Average yearly arising of aqueous low level waste is about 16,000m^3. The liquid waste from trade effluent and sewage is about 42,000m^3 in each case. The liquid wastes drain into three different sets of auto pumping pits. The trade effluent is pumped to holding tanks via a settling pit. Sewage effluent is pumped into an activated sludge plant (biological treatment) before discharge to the holding tanks.

Strict control and surveillance of the radioactive liquid low level effluent are achieved by a series of storage tanks. The radioactivity from the aqueous effluent is removed by a two-step process involving chemical and physical processes in the mixing tanks. The addition of aluminium salt into the effluent in a mixing tank produces a highly adsorbent floc which retains colloidal materials, radioactive and chemical pollutants. The aluminium hydroxide floc is removed as a sludge. It is dewatered using a centrifuge and dried in solar evaporation ponds. The dried sludge is then transferred into epoxy-coated 200 L drums for storage as low level solid waste. The treated effluent is also pumped to the holding tanks where total alpha and beta activity (including tritium) are measured. The effluent must meet the standards specified under the Trade Waste Agreement with the Sydney Water Corporation as noted in section 2. The tested effluent is then discharged to sewer which after a primary treatment plant discharges to an ocean outfall at Potter Point.

Small volumes of other liquid low level wastes that require individual treatment (for example neutralisation) are treated on a batch basis. The resulting solids are transferred to solid waste and the effluent is dispatched to the holding tanks.

Manufacture of molybdenum-99 for use in radiopharmaceuticals gives rise to about 300 litres/year of intermediate level liquid wastes. These wastes are stored in shielded stainless steel tanks suspended above stainless steel catch trays capable of holding liquid equivalent to the volume of the tanks. The catch trays are designed to provide secondary containments in the event the tanks are ruptured. The total volume accumulated is currently about 6m^3. The tanks are located within a secure, shielded facility. The liquid ILW contains slightly enriched uranium, some fission products, magnesium and other process contaminants. The activity of the waste is about 1M Bq and 1 G Bq per litre respectively of alpha and beta activity.

Two routes for the treatment of these wastes have been investigated. The separation of uranium from the fission products was investigated but there would still have been a need for immobilisation of the fission product solution. Further progress has been made with plans to solidify the wastes by evaporation within stainless steel canisters. The dry product would not be suitable for disposal but could be stored until waste acceptance criteria for category 'S' waste are developed.. In the meantime a volume reduction of about 20-30 is achievable and the safety of storage with respect to low probability seismic events could be enhanced. Recent research on the use of inorganic ion-exchangers is showing promise for the solidification of the ILW liquid waste.

5.3 Solid waste

ANSTO's low and very low level solid wastes are comprised generally of paper, plastics, protective clothing, laboratory glassware, and dried sludge from the effluent treatment plan. Around 130m^3 of uncompacted low level waste are generated each year. Depending on the surface dose-rate from the waste package, the waste is either subjected to a period of storage to allow the radioactivity to decay or compacted into 200 litre epoxy-coated steel drums. (A volumetric reduction of six- to eight-fold is achieved with the existing low-pressure compactor).

The drums are stacked within a storage building on-site pending the establishment of the national low-level waste repository. At June 1995, some 4,400 drums (about 880 m^3) were in the storage. The storage building protects the drums from the environment and provides an additional barrier against intrusion.

Most of the intermediate level solid wastes generated at the LHRL are associated with the production of radiochemicals and radiopharmaceuticals and the operation of the HIFAR reactor. The wastes include the aluminium ends cropped from spent HIFAR fuel elements, used air filters, spent ion-exchange resins, used irradiation cans and contaminated equipment from radioisotope production. The current annual average arising is less than 5 m^3. The accumulated quantity stored at the LHRL is about 200 m^3.

Solid intermediate level wastes are stored in concrete-lined vaults in a special storage facility. Groundwater drainage bore-holes have been drilled around the vaults as a control measure against the possible ingress of groundwater. A newer retrievable storage facility has been constructed with fewer but larger vaults containing storage racks. The solid ILW is placed in bins which are then stored at designated rack locations. ILW will continue to be stored at LHRL until a national facility for this class of waste has been established. It is likely that the shorter-lived ILW could eventually be disposed of at the planned national near-surface repository. Prior to disposal, most of the ILW will require some form of treatment and conditioning to facilitate handling and transport, and to minimise any release of radioactivity from the repository.

The total activity of accumulated ILW amounts to about 2200 TBq based on estimated activities of individual waste packages / items at the time of receipt into the waste storage facilities. No allowance has been made for subsequent radioactive decay and hence the inventory contains significantly lower activity than given above. The older aluminium components, including cropped ends of spent fuel elements, may now meet criteria for LLW. To minimise worker exposure, unnecessary double-handling of wastes is avoided and the activity of old wastes will be measured prior to conditioning. Recent experiments on melting of aluminium irradiation cans have demonstrated significant volume reduction and low residual activity.

6 WASTE DISPOSAL

During the period 1960 to 1968, the AAEC practiced shallow ground disposal at the Little Forest Burial Ground (LFBG) which is located on ANSTO land about 1.6km north west of the main site. About 1700m^3 of low level solid waste and about 1.1 tonnes of beryllium metal and beryllium oxide were disposed in accordance with international practices at that time and in consultation with NSW authorities. The details of the site and wastes buried there are fully described in an AAEC report (5). In October 1990, the NSW Government commissioned Coffey Partners International Pty Ltd to carry out Stage 1 of a study of potentially contaminated lands at Little Forest. This study concluded that:

> Since there has been little evidence of radioactive waste in groundwater and initially no evidence of radioactive movement from the site, the health impact for humans living off the site is so small as to be unquantifiable

In 1990-91, the independent Safety Review Committee undertook a major review of radioactive waste management activities at the LHRL at the request of the then Minister for Industry, Technology and Commerce. The Committee endorsed (4) the Coffey Partners' conclusions.

7 HIFAR SPENT FUEL

Most of the spent fuel from the 37 years operation of the HIFAR reactor is still at Lucas Heights where it is stored in monitored, retrievable facilities in accordance with international standards and guidelines. The spent fuel is subject to IAEA international safeguards inspections. At 1 May 1995, ANSTO had 1661 spent fuel elements from the operation of HIFAR in interim storage at the Lucas Heights site and a further 36 elements are discharged from the reactor each year. While storage of spent fuel at Lucas Heights is conducted to high standards of safety, it is an interim measure and not permanent disposal. The original strategy, at the time the reactors were built and commenced operation, was based on the understanding that spent fuel would be sent to the UK or the US for reprocessing, recovery and recycle of the residual high enriched uranium (HEU). One shipment of 150 elements was sent to Dounreay in the UK in 1963. A shipment was being prepared for return to the US when in January 1989 the US suspended acceptance of spent fuel from foreign research reactors pending an environmental review. The Draft Environmental Impact Statement was published in March 1995 by the US DOE but implementation of the policy to renew acceptance of return of spent research reactor fuel containing HEU exported from the US is not expected until 1996.

HIFAR spent fuel is stored at Lucas Heights as follows:

- Irradiation Pond, the principal wet storage facility is being re-racked to accommodate a total of 400 elements;
- HIFAR Spent Fuel Storage Facility (1086 elements) with dry storage for 1100 elements in 50 stainless steel tubes in holes drilled into rock;
- LHRL 120 cask (114 elements) awaiting shipment to the United States:
- Dounreay flasks (175 elements) once intended for shipping spent fuel to Britain, now used for storage.

HIFAR fuel elements are 1.7m long and the fuelled section is 600mm. The amount of U-235 increased from 115 g in early elements to 170 g in recent elements and the enrichment reduced from 93% to 60% U-235. The fuel consists of uranium aluminium alloy clad in aluminium. The aluminium cladding protects the uranium from corrosion and prevents release of the highly radioactive fission products. After discharge, the top and bottom aluminium sections of the fuel element are cropped to a length of 638mm which contains the spent fuel. The total mass of all stored, cropped spent fuel elements is about 5.1 tonne including the contained 0.23 tonne uranium and other heavy metal. The average burnup is around 42% of the original U-235. Most of the spent fuel has been stored for more than 10 years and the decay heat from each element is less than 2 Watts.

Although the spent fuel from the HIFAR reactor is not regarded as a waste-form in itself, certain spent fuel management options (such as reprocessing at Dounreay in the UK) would result in radioactive residues being returned to Australia in the form of long-lived, intermediate-level waste (Category S) requiring eventual disposal in geological formations. Wastes from Dounreay reprocessing plant are immobilised in cement in 500 litre stainless steel drums with a heat output of about 6 Watts per drum (12 Watts/m^3). This compares with over 2000 Watts/m^3 for HLW.

The majority of the spent fuel is stored in the engineered dry storage facility built in 1968 to store 1100 spent fuel elements. The facility consists of 50 lined holes, 16 metres in depth, drilled into sandstone and lined with 14 cm internal diameter sealed stainless steel tubes. HIFAR spent fuel elements are placed in this facility in individual aluminium cans, two cans in stainless steel canisters, and eleven canisters in each lined hole. The tubes in the storage facility are filled with dry nitrogen to inhibit corrosion of the fuel cladding. Periodic monitoring of the nitrogen gas when the nitrogen is replaced shows no traces of krypton-85, a long-lived fission-product gas, except in one hole which contains fuel elements that were sectioned in 1967 for detailed metallurgical examination. Spent fuel from the dry storage facility has been inspected in 1984, and in 1989/90, and again in 1995. No evidence of deterioration of the fuel elements was noticed.

The fuel and the stainless steel tubes are being inspected again in the current maintenance program of the facility. High resolution video examination and extensive thickness determination have shown no corrosion of the stainless steel tubes. Cl-36 has been detected in the stainless steel tubes housing a batch of fuel that was manufactured by brazing with a chloride flux. Preliminary examination of the fuel clad has not revealed any significant corrosion during extended dry storage.

8. ENVIRONMENTAL MONITORING

A comprehensive program of environmental monitoring and surveillance around the LHRL site has been carried out by the AAEC/ANSTO since 1959 to ensure that all effluents meet regulatory requirements and to verify that these authorised discharges do not cause detriment to the wider environment. The results of this environmental monitoring program are published in a series of annual AAEC/ANSTO 'E' reports which are publicly available, including at the Sutherland Council Library.

The results of the environmental monitoring programs have shown:

- that gaseous and liquid discharges of radioactivity from LHRL have always been below regulatory limits. Independent checks and analyses have confirmed compliance;
- dose rates to residents living in the immediate neighbourhood of the site are not measurable and calculated hypothetical maximum doses at the site boundary are less than 1% of the dose from natural background radiation.
- The regular monitoring program includes the Little Forest Burial Ground which ceased accepting wastes in 1968 and the Woronora River estuary. Previous to the extension of the sewer service to LHRL in 1980, the AAEC discharged treated liquid effluents to the Woronora River under an authorisation granted by the NSW RAC pursuant to the NSW Radioactive Substances Regulations (1959).

The safety of radioactive waste management operations at ANSTO is kept under continual review by the Safety Review Committee which presents an Annual Report to Parliament on their findings. There have also been several recent overall examinations of ANSTO's radioactive waste management; the comprehensive audit of these operations by the Safety Review Committee in 1991, the NSW Land and Environment Court in 1993 and the Research Reactor Review in 1993. The Research Reactor Review noted that:

> "The liquid and gaseous emissions from Lucas Heights are within the most recent limits set by the International Committee on Radiological Protection (ICRP 60), and the equivalent limits set by the National Health and Medical Research Council, by a wide margin"

9. CONCLUSIONS

1. ANSTO has complied with all relevant State and Commonwealth requirements in managing its radioactive waste.

2. Independent recent inspections and reviews of documentation have shown that waste storage procedures and practices at LHRL do not represent threats to public health either on site or off site.(SRC, Annual Report 1993-1994).

3. ANSTO has reviewed and adopted a new policy on radioactive waste management and is implementing strategies to ensure it continues to manage radioactive waste according to evolving best practice internationally. The strategies address inter alia, waste minimisation, pre-treatment of historic wastes currently stored at ANSTO, research and development programs to strengthen operational needs.

4. ANSTO is committed to being a good neighbour and is conscious of the need to gain public acceptance of its policies and practices.

5. ANSTO strongly supports recent Commonwealth initiatives to set up AIRP and to establish a national repository for low- and short-lived intermediate waste.

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