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NUCLEAR MEDICINE MANUFACTURING PROGRAM

NMMF Waste Management Plan

For Siting Licence

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1. Purpose

The purpose of this Waste Management Plan is to describe the organisational arrangements for radioactive waste management under the siting and development phase for a new Nuclear Medicine Manufacturing Facility (NMMF) at the ANSTO Lucas Heights campus.

The plan outlines the processes used in selection of the proposed site and to ensure compliance with the relevant legislation, including the Australian Radiation Protection and Nuclear Safety (ARPANS) Act [Ref: (1)] and Regulations [Ref: (2)]. This plan is an integral element of the ARPANSA Siting Licence Application.

ANSTO is committed to maintaining and enhancing the high standards of radioactive waste management recommended by the International Atomic Energy Agency (IAEA) and required by ARPANSA. The plan is consistent with AB-0103 ANSTO Radioactive Waste Management Policy [Ref: (3)] and G-7363 Radioactive Waste Philosophy and Business Plans Ref: (4) and with IAEA standards and guidelines, specifically IAEA Safety Standard Series No. GSG Part 5 [Ref: (5)].

This plan should be read in conjunction with the NMMF Safety Analysis Report (SAR) [Ref: (6)] and Plans and Arrangements supporting the Siting Licence Application.

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Please note for clarity, NMMF refers to the Nuclear Medicine Manufacturing Facility, i.e., the physical structure. NMMP is the Nuclear Medicine Manufacturing Program which includes the NMMF, and the Program of works required to deliver the NMMF.

2. Scope

The scope of this NMMF Waste Management Plan is to ensure safety aspects of the ANSTO radioactive waste management policy, philosophy and processes are addressed and incorporated during the development phase for the NMMF and subsequently integrated in the overall facility lifecycle.

Key aspects of the scope are:

- Responsibilities
- Waste avoidance, reduction and minimisation.
- Classification of radioactive waste (solid, liquid and gaseous states).
- Waste hold and storage arrangements.
- Waste movement and transfer processes and systems.
- Record keeping and disposition.

3. Responsibilities

There will be no radioactive waste generated during the siting and construction stages of the program.

Radioactive waste generated by the NMMF during operations will be under the effective control of the NMMF Facility Officer until Waste Management Services (WMS) workers receive the waste. The location and process of transfer may vary depending on the waste stream. The Facility Officer will ensure that wastes are safely stored and shielded to minimise dose to ANSTO workers, in accordance with the As Low As Reasonably Practicable (ALARP) principles. Areas where wastes are stored will be regularly monitored for radiation levels.

4. Management of Radioactive Waste

The AB-0103 ANSTO Radioactive Waste Management Policy [Ref: (3)] and AG-2517 Safe Management of Radioactive Waste Guide [Ref: (7)] provide a framework for managing radioactive waste at ANSTO. This policy states that all radioactive waste at ANSTO will be managed in a manner that protects human health and the environment both now and into the future.

4.1. General

This Waste Management Plan has been developed to interface and complement NMMF Radiation Protection Plan NMMP-0410-PM-0003 [Ref: (8)], and the NMMF Effective Control Plan NMMP-0410-PM-0001 [Ref: (9)]. The Plans and Arrangements also interface with the existing F0262 Waste Operations [Ref: (10)] facilities and processes.

During the siting and construction phases of the program, no radioactive wastes will be generated. Construction tasks will be conventional, other than the requirement to use a calibration or check source for commissioning of radiation monitors and hot cells. Non-active waste will be generated, for example, general building wastes, packaging waste (from the new equipment), and some minor chemical wastes. These wastes will be managed by the established conventional waste systems at ANSTO.

A1 4.2. Classification of Radioactive Waste

The NMMP Waste Management Strategy NMMP-0750-PM-0001 [Ref: (11)] complies with the ANSTO waste classification requirements and in accordance with ARPANSA Guide: Classification of Radioactive Waste [Ref: (12)] and NSW Classification of Waste Guidelines [Ref: (13)].

ANSTO WMS define radioactive waste as contact handled or remote handled waste. Radioactive waste at ANSTO is divided into five main categories based on their physical form and emitted dose rate as below:

- **Free Release Waste** – waste that meets the criteria for exemption (activity concentration and activities of radionuclides).
- **Contact Handled Solid Waste** – radioactive solid waste that is above the exemption levels and has a radiation contact dose rate below 2 mSv/hr.
- **Contact Handled Liquid Waste** - radioactive liquid waste that is above the exemption levels and has a radiation contact dose rate below 2 mSv/hr.
- **Remote Handled Solid Waste** - radioactive solid waste that is above the exemption levels and has a radiation contact dose rate above 2 mSv/hr.
- **Remote Handled Liquid Waste** - radioactive liquid waste that is above the exemption levels and has a radiation contact dose rate above 2 mSv/hr.

4.3. Waste Minimisation

The waste management hierarchy is a framework that outlines the preferred approaches to managing waste, emphasising the most effective strategies for environmental conservation. It categorises waste management options in a descending order of environmental desirability, starting with the most favourable. Avoiding or minimising the generation of waste at its source is the preferred approach, in alignment with the Waste Hierarchy (Refer to Figure 1).

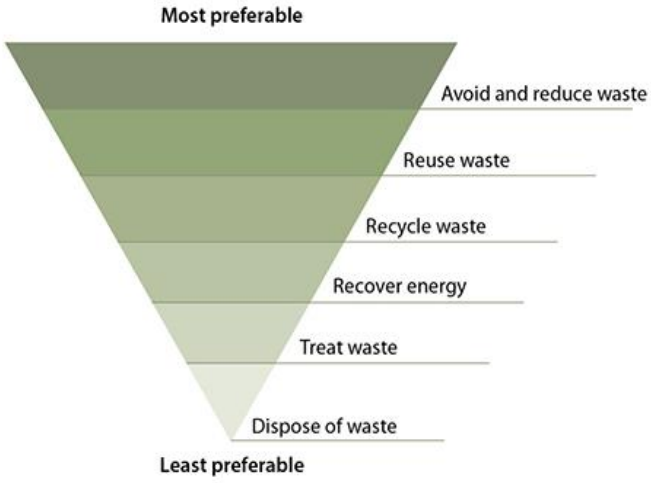

Figure 1: Waste Hierarchy

Where possible, the generation of additional waste will be eliminated or reduced as much as possible by the implementation of engineering and/or administrative controls for all waste handling procedures. The hierarchy is applied through the following initiatives:

- If possible, eliminate the hazardous substance or substitute it with a less hazardous material.
- Purchase only the volume of substances required.
- Classify waste appropriately so that waste can be safely handled, treated, stored, or disposed of.
- Segregate waste into different streams such as: radioactive and non-radioactive, liquid, and solid, Contact Handled and Remote Handled radioactive waste, short-lived isotopes, and long-lived isotopes for better management of each waste stream and reduction in volume of waste which will be eventually classed as radioactive.
- Delay and decay short-lived radioactive waste and maximise free release disposal of the exempt waste which is exempted from regulatory control and can be sent to conventional landfills or recycling centres.
- Recycle or reuse items (following appropriate decontamination) where possible to minimise the cost of operation, treatment, or storage of legacy waste.
- Appropriately package and properly label waste to prevent spillage thus preventing contamination and minimising radiation exposure.
- Ongoing education and training of ANSTO staff on waste minimisation and radiation safety.

4.3.1. Design Systems and Processes

The facility will be designed around the flows of material, personnel, and waste as well as the concept of nested cleanliness zones. The building is separated into “active” and “non-active” areas. Active areas include all spaces where radioactive materials or waste will be handled. The facility is designed so waste is removed from GMP production zones and managed in dedicated waste storage and processing areas.

The design of the NMMF follows a ‘whole-of-life’ cycle approach that will facilitate decommissioning of the structures, systems and components to manage radioactive waste. At the time of decommissioning, the facility will be characterised to understand the level of contamination. Each system, component, and material will likely have a tailored decontamination and dismantling strategy.

4.3.2. Estimated Waste Quantities

The radioactive waste generated within the NMMF will be segregated and decayed aligned with ANSTO’s waste management philosophy [Ref: (4)] with the waste streams being detailed in Table 1.

There are no fissile materials managed in the future operations of the NMMF.

ANSTO Waste Category	Waste Classification	Waste Stream Description	Example	Volume of Generated Waste	Radiation Levels	Package	Treatment / Storage Process
Solid Waste Type A Hot Cell Solid Waste (Target and Cans)	Remote Handled Solid Waste (RHSW)	Irradiation cans and manufacturing equipment contaminated with target materials. Typically, long-lived isotopes.	OPAL irradiation cans and components (activated aluminium and titanium cans), Iodine furnace crucibles.	240 L per year (nominally 4 ARB movements per year)	>2 mSv/hr at contact	Aluminium Retrievable Bin (ARB) transported using a shielded flask	ARB flask transporting waste to remote handled waste storage facility
Solid Waste Type B Hot Cell Solid Waste (All other)	Contact Handled Solid Waste (CHSW) or Potential Free Release (PFR)	Manufacturing equipment and consumables heavily contaminated. Typically, short-lived isotopes.	The majority (90%) of this waste volume is decayed and disposed as FR. Single use consumables from technetium, lutetium and iodine manufacture or equipment consumables (e.g., used Lu-177 separation columns) that are contaminated by short lived isotopes. This waste stream is typically generated from within hot cells.	40 L per week (nominally 1 mega bin movement per month)	~10 µSv/hr at contact after decay	Mega bin or 200 L steel drum if not characterised as free release waste	Mega bin transported to contact handled waste management facility and storage facility

ANSTO Waste Category	Waste Classification	Waste Stream Description	Example	Volume of Generated Waste	Radiation Levels	Package	Treatment / Storage Process
Solid Waste Type C Clean Room Waste	Contact Handled Solid Waste (CHSW) or Potential Free Release (PFR)	Manufacturing equipment (contaminated with short lived isotopes) – but unable to reach FR levels within the NMMF bunker.	The majority (95%) of this waste volume is decayed and disposed as FR. This waste stream is typically generated from within hot cells or fume hoods, or cleanrooms.	<10 L per week (waste that does not meet PFR specifications within the NMMF decay window)	~10 µSv/hr at contact after decay	Mega bin or 200 L steel drum if not characterised as free release waste	Managed through ANSTO's existing contact handled waste processes and procedures
Liquid Waste - B-Line	Contact Handled Liquid Waste (CHLW)	(Laboratory) waste	QC laboratory sink drains and manufacturing room floor drains from active areas.	200 L per week	< B-Line limit (as per AG-2071 Discharge Limits of Substances into the B-line and C-line [Ref: (14)]) for 20 off labs.	Underground pipework and tanks	Managed through ANSTO's existing B-line network and effluent management procedures

ANSTO Waste Category	Waste Classification	Waste Stream Description	Example	Volume of Generated Waste	Radiation Levels	Package	Treatment / Storage Process
Liquid Waste – D-line	Contact Handled Liquid Waste (CHLW)	(Decayed manufacturing liquid waste)	Decayed Tc, Lu and I manufacturing liquid waste streams. These waste streams are decayed and with acid and alkaline liquid waste streams managed separately within the NMMF, prior to transport.	10,000 L per month (max: at full production capacity)	< 200 MBq/day beta-emitters	Underground pipework and tanks	Managed through underground pipework and tanks with proposed treatment using a drum drying process
Gaseous Waste	N/A	HVAC stack release from hot cell environments	Primarily iodine and Tc-99m as volatile or loose particulate.	TBA	< ARPANSA B23 limit	N/A	Capture and decay two filter types, a. iodine on carbon bed absorption beds and b. particulates on HEPA filters. Both are treated as contact handled waste.
Non-radioactive solid waste from 'white' classified rooms	Free Release	Solid waste from offices and ancillary rooms.	Paper, kitchen and ancillary waste	500 L per week	Below free release activity limit	Sulo bin	Stored, cleared, and disposed through ANSTO's free release.

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ANSTO Waste Category	Waste Classification	Waste Stream Description	Example	Volume of Generated Waste	Radiation Levels	Package	Treatment / Storage Process
A1 Decayed Solid Waste Type B Hot Cell Solid Waste (All other)	Free Release	Decayed and 'cleared' solid waste from hot cells and other production spaces. It requires clearance to be defined as FR.	Single use pharmaceutical tubing and components	500 L per week	Below free release activity limit	Sulo bin	Stored, cleared, and disposed through ANSTO's free release.
A1 Decayed Type C Clean Room Waste	Free Release	Decayed and 'cleared' solid waste from clean rooms. It requires clearance to be defined as FR.	Operator PPE and ancillary laboratory waste	600 L per week	Below free release activity limit	Sulo bin	Stored, cleared, and disposed through ANSTO's free release.
A1 Liquid Waste C-Line	Non-radioactive	Building trade waste	Kitchen and amenity liquid waste	N/A	N/A	Underground pipework and tanks.	Managed through ANSTO's existing C-line network and effluent management procedures.
Decommissioning / Production Equipment	Contact Handled Solid Waste (CHSW) or Potential Free Release (PFR)	Larger items which will not fit into standard containers.	Reactor vessels/pumps large items	TBA	~10 µSv/hr at contact after decay		Managed through ANSTO's WMS on a case by case basis.

Table 1: Waste streams leaving the NMMF building

4.3.3. Environmental Management System

ANSTO has an established Environmental Management System (EMS), as detailed in AG-2067 Environmental Management System Manual [Ref: (15)], which is currently certified to ISO AS/NZS 14001:2016 – Environmental Management Systems. The ANSTO Corporate Plan provides the strategic direction for ANSTO over the short-term. The EMS falls beneath the ANSTO Corporate Plan, underpinned by the ANSTO Core Value – Safe, Sustainable, Secure to responsibly protect the environment and minimise pollution.

The scope of ANSTO's EMS also extends to its compliance obligations governed through binding regulations and licence conditions, contractual arrangements with service providers and procurement sourcing activities.

To address, manage, monitor, and report upon the interactions that ANSTO has with the environment, the AE-5362 Environmental Sustainability Strategy [Ref: (16)] has been developed. This high-level document has been developed to communicate ANSTO's strategic direction towards minimising emissions, water consumption, waste, and improve biodiversity outcomes for our sites and managed bushland.

4.4. Codes of Practice

There are several Codes of Practice relevant to waste management that have been utilised by ANSTO as part of its current arrangements.

These include:

- ARPANSA RPS C-2 (Rev.1) Code of Practice for the Safe Transport of Radioactive Material (2019) [Ref (17)].
- ARPANSA RPS C-3 Code for Disposal Facilities for Solid Radioactive Waste (2018) [Ref: (18)].
- ARPANSA RPS G-4 Guide for Classification of Radioactive Waste (2020) [Ref: (12)].
- ARPANSA RPS C-6 Code for Disposal of Radioactive Waste by the User (2018) [Ref: (19)].
- ARPANSA RPS No.16 Safety Guide for the Predisposal Management of Radioactive Waste (2008) [Ref: (20)].
- Sydney Water: Consent to Discharge Industrial Trade Wastewater [Ref: (21)].

4.5. Limiting Exposure to Radioactive Waste

The standards and guides on radiation protection and control measures within the ANSTO WHS Management system focus on minimising the risks of radiological hazards associated with radioactive waste sources.

The preliminary design features include:

- Shielding
- Health Physics Related Design Features
- Dose Rate Design Objectives for all radioactive operational and waste areas
- Airborne Emissions monitoring
- Area Classification and Access Control
- Component Layouts
- Material Characteristics from a Radiological Viewpoint.

The ALARP principle is applied, where applicable, to minimise the routine radiation exposure from the waste sources to ANSTO staff, members of the public and the environment.

Further analysis into identifying credible exposure pathways for radioactive waste will be undertaken in future stages of the program. In the future operational stages, processes for monitoring and assessing results to show that discharges are within specified limits, as informed by the risk assessment and demonstrated by a documented system for compliance, will be analysed in future program stages.

ANSTO has documented procedures for performing and recording dose rate measurements at the surface of each package and at one metre from the surface of each package to ensure compliance with the maximum allowable dose rates.

4.6. Packaging and Containment of Radioactive Waste

The general requirements for packaging and containment for transport of radioactive waste are based on the IAEA Regulations for the Safe Transport of Radioactive Material [Ref: (22)] and ARPANSA Guide and Code of Practice for Safe Transport of Radioactive Material [Ref: (17)].

Packages managing waste from the NMMF are designed in relation to its mass, volume, and shape so that it can be safely and easily lifted and properly secured in/on the conveyance during transport. The package is designed, manufactured, and tested against the defined specifications by qualified ANSTO or external engineers.

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The guidance in AG-1266 Packaging Waste from Classified Areas [Ref: (23)] specifies the local requirements of waste packaging prior to collection by WMS. Waste is segregated and placed in the appropriate container according to its waste type. The identification and characteristics of waste are recorded on the AF-2358 Waste Service Request Form [Ref: (24)] together with the dose rate and contamination level measured by a qualified Health Physics Surveyor on contact and dose rate at one metre as well as the details of the point of contact. This information is then recorded in an electronic database for tracking of all radioactive waste packages.

Details on waste packaging for waste types is found in Table 1.

4.7. Holding Storage of Radioactive Waste in Facility

Waste streams are decayed as close to the point of generation as practicable in order to reduce transport risks within the facility.

The concept design for the NMMF has accounted for:

- Local hot cell hold-up and decay of liquid or solid waste (where possible due to Good Manufacturing Practice constraints) at each manufacturing line.
- Centralised hold-up and decay of liquid and solid waste in the basement Centralised Waste Decay area.
- Further hold-up of D-line liquid waste in external tanks prior transfer to WMS.

Radiation monitors and ventilation systems are installed in the stores where appropriate. Radiation warning signs are displayed at the front of the store. The hazard identification board clearly indicates the hazards in the area and specific personal protective equipment (PPE) required for entering the zone.

Further details on the safety and security provisions for storage including location and capacity, package types, engineering controls, administrative controls, and documented procedures will be addressed in future licensing stages for the facility.

4.8. Movement and Transfer of Waste

Movement of radioactive waste materials from the NMMF will be carried out in accordance with ANSTO procedure AG-2515 Safe Movement and Transport of Radioactive Material guide [Ref: (25)]; transport of radioactive waste off site will only be under the direction and control of ANSTO Waste Management Services.

Non-radioactive items leaving contamination control areas and radioactive materials or waste moving between buildings require Radiation Protection Services (RPS) Clearance or radioactive consignment documents. The radiological conditions of these materials are recorded on Radioactive Contamination Clearance Certificates, Waste Operations Service Request Forms or Radioactive Consignment Documents.

Each waste item is labelled and identified before being transported and has been checked by a Health Physics Surveyor (HPS) for the dose rate and contamination of the package. If a package is contaminated, or broken, it will not be transported.

[redacted]

4.9. Record Keeping and Documentation

The Waste Management Services (WMS) Business and Compliance Management System provides the framework to effectively maintain and control waste documentation and records. Standard operating procedures and work instructions are prepared, reviewed, and approved for the handling, transport, characterisation, treatment, and storage of radioactive waste.

WMS has strict inventory control for all sealed and unsealed radioactive sources. All materials exiting the NMMF will need to be authorised by the appropriate person and the movements tracked and recorded. Waste in the NMMF will be recorded in the ANSTO Enterprise Business System, SAP, or recorded in an electronic database on local networks.

The identification, tracking, and monitoring system shall capture the following data (but not limited to):

- Waste classification and physical form
- Specific Radionuclides
- Description
- Location (facility and/or process) of generation
- Special requirements
- Treatment and Conditioning Method
- Potential hazards
- Radioactivity dose rate
- Radioactivity contamination
- Chain of custody (including details of acceptance, movement, storage, discharge, and disposal)
- Unique package identifier.

Waste procedures and records are legible, readily identifiable, and retrievable at any time for operational and auditing purposes. The waste details, including waste characteristics, chain of custody, identification, and storage location are captured. WMS is also accredited to ISO:9001 and this is subject to routine surveillance by both internal and external auditing functions and routine re-certification by an external party.

In the future when a disposition pathway has been identified for contact handled waste and remote handled waste, information such as the waste matrix used for immobilisation and the treatment or conditioning method used will be tracked through the waste management system.

4.10. Training of Personnel

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ANSTO has comprehensive processes which collectively ensure that potentially hazardous work involving radioactive waste management is performed by and supervised by properly trained, authorised, and qualified workers. This process is initiated by the recruitment process for employees and non-employees where the selection is based on the approved selection criteria for the role. The criteria include the qualifications, knowledge, and experience appropriate for the work to be performed.

Personnel are trained to the competency level required for the proficient performance of tasks and are supplied with the necessary equipment to safely carry out their work. Additional Work Health and Safety and Health Physics support is provided when required to ensure that all hazards are properly addressed and minimised.

Basic training in radiation safety is carried out in accordance with ANSTO WHS Standards. Training in radiation safety is commensurate with the responsibilities of the role an individual is performing and the hazard to which the person is potentially exposed. The minimum requirement for training of a Radiation Classified worker at ANSTO is the Basic Radiation Safety course and the Radiation Protection Workshop.

5. Solid Waste Management

Solid wastes generated from the NMMF will be managed using existing WMS infrastructure, processes, and expertise. The contact handled and remote handled waste generated at the facility will be managed by trained personnel using risk assessed instructions/procedures. All arrangements in place align with the waste management philosophy of minimisation and the principle of ALARP.

5.1. Contact Handled Solid Waste

Short lived solid waste streams shall be decayed and scanned as Free Release waste.

Lower activity solid waste streams from the process hot cells are envisaged to be transported in approved bins (flasks/devices/containers) to the Centralised Waste Decay area in the building's basement.

Once decayed, solid waste will have capability to be moved within mega-bins or steel drums by hoist or forklift; or moved within wheeled 'Sulo' bins.

5.2. Remote Handled Solid Waste

Remote handled solid waste (such as OPAL irradiation cans or tellurium crucibles) will be stored in a waste hot cell and periodically loaded into an ARB for transport to Waste Management. Other high activity waste that will not decay within a 'reasonable time' for safe handling by alternate means (steel drums or mega bins) will also be transferred to the NMMF waste hot cell for periodic ARB transport to Waste Management.

Longer lived and/or highly active solid waste streams from the process hot cells are envisaged to be transported to a dedicated waste hot cell, in the Active Receipt area, either by direct inter-cell transfers or via approved shielded bins (flasks/devices/containers).

5.3. Limiting Exposure to Solid Waste

Reduction of personnel exposure to ionising radiation associated with the generation of waste is described in the ANSTO Radioactive Waste Philosophy and Business Plans G-7363 [Ref: (4)]. The primary goal is to eliminate by avoidance, followed by reduction at source according to the waste hierarchy described in the Waste Management Strategy [Ref: (11)] and AG-2985 ANSTO Non-radioactive Waste Guidelines [Ref: (26)].

For the NMMF, the ALARP principle and ANSTO Radioactive Waste Philosophy is applied when considering the handling, treatment, movement, and storage of radioactive waste for each radioisotope production process. The minimisation of radiation exposure to ANSTO staff and members of the public is achieved through an optioneering process (ALARP Study) and a combination of the following:

- Engineering design of interlocks, ventilation, radiation, and contamination monitors.
- Isolation of the radioactive source by distance or limiting time exposure to the source.
- Shielding radioactive waste using hot cells, shielding containers, lead bricks, shielding flasks during transport.
- Delay and decay of short-lived isotopes.
- Administrative controls such as training and procedures.
- Suitable equipment and personal protective equipment.
- Effective work planning to minimise the dose received by staff members.
- Appropriate characterisation and monitoring to ensure the disposal of exempt waste and routine discharge of gaseous or effluent waste are within regulatory limits.
- Emergency plans to mitigate the consequence of significant spillage of radioactive waste to the environment.

5.4. Monitoring and Characterisation of Solid Waste

All waste from areas designated as having a potential contamination hazard (Blue or Red contamination areas) are to be monitored for dose rate and external surface contamination by a HPS or Radiation Protection Adviser (RPA) or Waste Management, before being transported to WMS, prior to being disposed offsite.

Waste is scanned to understand the activity and nuclide composition of waste packages. This analysis provides data to determine the appropriate storage and processing, and potential disposition pathway for the waste. This data can be compared to the regulatory limits for each nuclide to determine if the waste is exempt or cleared from regulatory control.

6. Liquid Waste Management

The NMMF will have active process liquid waste streams from the manufacturing lines. These shall include dedicated B, C & D pipelines which, where practicable, are connected to the dedicated Centralised Waste Decay area within the facility's basement. A means for transport of liquid waste in approved vessels shall also be considered for a back-up or future products. After an appropriate level of decay, this waste shall be piped to external tanks for further hold-up and decay before being piped (D-line) to WMS.

Active liquid waste streams (B-line) shall be piped to an external in-ground B-line pit tank, in the campus site network. Non-active liquid waste streams (C-line) shall be piped to an external in-ground C-line pit tank in the campus site network.

The facility will be connected to ANSTO's B-line network to transport liquid to the site effluent treatment plant for processing and discharge. Effluent discharges to the sewer must comply with the current trade wastewater agreement between ANSTO and the Sydney Water Corporation (Consent to Discharge Industrial Trade Wastewater #4423 [Ref: (21)]) for treated discharges from the site. Sydney Water conducts independent testing of liquid effluent discharges to the sewer.

The Trade Wastewater Agreement is periodically reviewed to provide assurance that ANSTO's discharges remain within authorised radiological and non-radiological limits and pose no threat to the environment.

6.1. Remote Handled Liquid Waste

No remote handled liquid waste will be discharged from the NMMF.

6.2. Contact Handled Liquid Waste

General Laboratory and Plant Room liquid waste from non-active areas will be classified as C-line waste.

Laboratory liquid waste generated from active areas will be classified as B-line waste.

Manufacturing process liquid waste, potentially containing trace levels of long-lived isotopes is unlikely to meet B-line entry limits. Hence, this waste is treated as D-line waste.

D-line liquid waste will be collected at the hot cell, and where possible, decayed locally for a short period of time (considering GMP constraints). The liquid waste will then be transferred to larger tanks within the building's Centralised Waste Decay area for further decay. The liquid waste can then be transferred to the external D-line decay tanks for further hold-up prior transfer to Waste Management.

There are separate D-line decay tank(s) for acidic and alkaline (iodine-131) waste streams. Segregation of acidic and alkaline waste prevents precipitation of solids due to mixing or neutralisation of these two waste streams. The segregation of these two waste streams will enable Waste Management flexibility in how to sequence the management/treatment of this waste. The D-line liquid waste streams from the NMMF should be capable of truck vessel transport as the back-up strategy.

Sewer, C-line and B-line entry exemption limits are based on ANSTO discharge limits in accordance with AG-2071 [Ref: (14)].

Release limits for these waste liquid streams (with the exception of stormwater) is summarised below in Table 2 [Ref: (11)].

Pollutant	Substance Limits			
	Sewer	C-Line	B-Line *	D-Line *
Alpha emitting isotope	Nil	Nil	1000 KBq/day	1000 KBq/day
Beta emitting isotope	Nil	Nil	20 MBq/day	200 MBq/day
Tritium	Nil	Nil	6000 MBq/day	6000 MBq/day
Inorganic and Organic Pollutant	As per AG-2071	As per AG-2071	As per AG-2071	N/A
Exclusions	As per AG-2071	As per AG-2071	As per AG- 2071	N/A

Table 2: Liquid Waste Entry Exemption Limits for NMMF

* Concentrations are averaged for the 20 off NMMF Labs (11 Production, 2 QC, 1 Maintenance, 6 Ancillary).

6.3. Non-Active Liquid Chemical Waste

Non-active liquid chemical waste will be collected by Waste Management Services and stored in a centralised store awaiting collection for recycling or disposal at a licensed hazardous waste facility.

6.4. Limiting Exposure to Liquid Waste

Application of the ALARP principle for limiting exposure of personnel to ionising radiation from liquid waste generated from the NMMF is described in the ANSTO Radioactive Waste Philosophy [Ref: (4)].

This philosophy is applied to the handling, treatment, movement, and storage of radioactive waste for each NMMF radioisotope production process. The methodology to minimise exposure of personnel and members of the public is achieved through a robust optioneering process (ALARP Study) and a combination of the following:

- Engineering design of interlocks, ventilation, radiation, and contamination monitors.
- Isolation of the radioactive source by distance or limiting time exposure to the source.
- Shielding radioactive waste using hot cells, shielding containers, lead bricks, shielding flasks during transport.
- Delay and decay of short-lived isotopes.
- Administrative controls such as training and procedures.
- Suitable equipment and personal protective equipment.
- Effective work planning to minimise the dose received by staff members.
- Provision of non-flammable spillage trays for containers of liquid waste.
- Appropriate characterisation and monitoring to ensure the disposal of exempt waste and routine discharge of gaseous or effluent waste are within regulatory limits.
- Emergency plans to mitigate the consequence of significant spillage of radioactive waste to the environment.

6.5. Monitoring and Sampling of Liquid Waste

Provision has been made for drawing waste samples from the NMMF liquid waste holding tanks. As per the AG-2517 Safe Management of Radioactive Waste Guide [Ref: (7)], WMS must collect samples of wastewater discharged to the sewer as required by the Consent to Discharge Industrial Wastewater agreement with Sydney Water. Composite samples should be prepared and analysed for gross alpha, gross beta, and tritium activity.

The results of these analyses and other effluent discharge data are collated by WMS and a written report must be provided to Sydney Water Corporation, ARPANSA and ANSTO's Environmental Monitoring Team. Authorised workers of the Sydney Water Corporation and ARPANSA will have access to ANSTO's wastewater system to take samples for auditing purposes. Composite samples may also be requested for independent analysis.

7. Gaseous Waste

During the siting and construction phases of the facility there will be no radioactive airborne releases to the atmosphere.

Once operational, the NMMF will produce volatile radioactive wastes, gases, dust, or other airborne emissions which will be controlled through an active ventilation system with a HEPA and carbon filtration (Standard Iodine Adsorption Module – SIAM filter) unit, supported by routine stack discharge monitoring.

7.1. Monitoring and Characterisation of Airborne Discharges

The discharge from controlled area stacks is measured and monitored by the Environmental Monitoring Group to ensure the discharges to the atmosphere are below the established discharge levels.

The Environmental Monitoring group gives advice on airborne discharges and provides (within ANSTO) airborne discharge results in the weekly stack monitoring reports and in the quarterly and annual reports to ARPANSA. The procedure for the control, monitoring and reporting of airborne discharges is described in P-3976 Stack Monitoring Program [Ref: (27)].

8. Long Term Disposition

ANSTO will manage radioactive waste in a manner that protects human health and the environment, both now and in the future. The organisation is committed to safely treat and store ANSTO's radioactive wastes in preparation for final disposal, minimising exposures while considering economic factors, and minimise radioactive waste generation and provide custodianship of waste from source to storage and final disposal.

8.1. Miscellaneous Waste

Waste exempted or cleared from regulatory control is considered non-radioactive waste. For operational convenience, such waste could be mixed with other non-radioactive wastes streams, for example site garbage or demolition waste, for disposal if necessary.

Recycling and re-use of waste shall be given high priority where possible. All free release waste suitable for recycling shall be channelled to appropriate recycling facilities. Some free release waste (empty drums, lead, and concrete shielding blocks etc.) may have a high re-use potential. Such items shall be considered for internal or external re-use.

Some waste may contain chemical contaminants and hence need chemical characterisation and classification based on waste classification guidelines issued by the NSW Environmental Protection Agency. In such cases, representative samples of waste shall be taken for chemical characterisation. The results of such characterisation may be required by waste disposal facility operators prior to acceptance of waste.

Waste items containing trefoil signs such as on decayed radiopharmaceutical bottles, unused containers, or unused trefoil labels shall not be disposed of in landfills. Incineration is one of the disposal options available for such wastes. Table 3 gives some standard disposal options for free release waste.

Waste Type	Disposal Route
Scrap metal	Metal recycling facilities
General garbage	Municipal waste disposal facilities
Industrial waste	Licensed industrial waste disposal facilities
Unused chemical and chemical waste	Recycling or licensed hazardous waste disposal facilities.
Excavation spoil	Municipal waste disposal facility
Non-radioactive waste with trefoil signs, chemically contaminated glass, and clinical wastes.	Incineration and disposal

Table 3: Disposition pathways for miscellaneous waste

8.2. Remote Handled Liquid Waste

No remote handled liquid waste will be generated at the NMMF.

8.3. Contact Handled Solid Waste

Contact handled solid waste which is designated for free release will be disposed at a municipal or hazardous waste landfill in alignment with ANSTO's current process.

If contact handled solid waste is categorised as low-level solid waste in alignment with the future National Radioactive Waste Management Facility's (NRWMF) Waste Acceptance Criteria (WAC), waste will be disposed at this repository.

8.4. Contact Handled Liquid Waste

Contact handled liquid waste will be converted to a solid by Waste Management Services using approved processes and depending on the final waste form will be classified as non-radioactive, low level or intermediate level solid waste. Liquid waste streams with the potential to be disposed of through licenced waste disposal contractors will be assessed in detail on a case-by-case basis in line with AG-2985 [Ref: (26)].

Future conditioning of liquid solutions will be explored through a Best Available Technique (BAT) analysis to immobilise active components of the waste form for future disposition.

8.5. Liquid Disposal via B-Line

B-line effluent can be pumped to one of the site effluent plant's mixing tanks where the primary treatment process for the potentially radioactive effluent is to let it decay. By allowing the liquid waste to decay over a week, the radioactivity can then be mixed with the holding tank effluent and discharged in alignment with the Consent to Discharge Industrial Wastewater agreement with Sydney Water.

B-line wastewater that has elevated radioactivity can be mixed with alum and the precipitated solids allowed to settle. The mixing tank contents are then decanted, and the settled sludge pumped to a centrifuge to remove the precipitated solids. The solids removed by the centrifuge are transferred to sludge storage tanks and finally directed to a drum dryer. The drum dryer takes in the sludge and boils off the liquid under vacuum, with the drum entering the contact handled waste management procedure for determining a future disposition pathway.

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8.6. Liquid Disposal via D-Line

D-line effluent can be pumped to Waste Management for analysis and final treatment, prior any further decay and mixing with the holding tank effluent and discharge in alignment with the Consent to Discharge Industrial Wastewater agreement with Sydney Water.

8.7. Non-Radioactive Wastes

Non-radioactive wastes from the NMMF will be managed according to the AG-2985 Non-Radioactive Waste Guidelines [Ref: (26)].

As defined in the guideline, the waste generator is required to classify their wastes to prevent health risks to the community and minimise any harm to the environment.

The waste classes include:

- Special Waste (Clinical, Asbestos)
- Liquid Waste (Not able to be discharged to sewer)
- Hazardous Waste (including laboratory chemicals)
- Restricted Solid Waste (Assessed chemically and radiologically and restricted land fill disposal)
- General Solid Waste (Putrescible)
- General Solid Waste (Non-Putrescible).

9. Definitions

The following abbreviations / definitions have been used in this document:

Term	Definition
ALARP	As Low As Reasonably Practicable
ANSTO	Australian Nuclear Science and Technology Organisation
ARB	Aluminium Retrievable Bin
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
ASOC	ANSTO Site Operations Centre
BAT	Best Available Technique
CHLW	Contact Handled Liquid Waste
CHSW	Contact Handled Solid Waste
EMS	Environmental Management System
GMP	Good Manufacturing Practice
HPS	Health Physics Surveyor
IAEA	International Atomic Energy Agency
NMMF	Nuclear Medicine Manufacturing Facility
NMMP	Nuclear Medicine Manufacturing Program
NRWMF	National Radioactive Waste Management Facility
OPAL	Open Pool Light-water Reactor
PFR	Potential Free Release
PPE	Personal Protective Equipment
RHSW	Remote Handled Solid Waste
RPA	Radiation Protection Advisor
RPS	Radiation Protection Services
SIAM	Standard Iodine Adsorption Module
WAC	Waste Acceptance Criteria
WMS	Waste Management Services

10. References

The following items are referred to in this document or were used in its creation.

1. Australian Radiation Protection and Nuclear Safety (ARPANS) Act. s.l. : Cth, 1998.
2. Australian Radiation Protection and Nuclear Safety (ARPANS) Regulations. 2018.
3. AB-0103 Radioactive Waste Management Policy. 2020.
4. G-7363 ANSTO Radioactive Waste Philosophy and Business Plans.
5. IAEA Safety Standards, GSR Part 5, Predisposal Management of Radioactive Waste.
6. NMMF Safety Analysis Report. NMMP-0410-RT-0004.
7. AG-2517 ANSTO Safe Management of Radioactive Waste.
8. NMMP-0410-PM-0003 NMMF Radiation Protection Plan.
9. NMMP-0410-PM-0001 NMMF Effective Control Plan.
10. F0262 ANSTO Facility Licence.
11. NMMP-0750-PM-0001 Waste Management Strategy.
12. ARPANSA Radiation Protection Series G-4 Guide for Classification of Radioactive Waste. 2020.
13. Waste Classification Guidelines, Part 1: Classifying Waste. [Online] November 2014. [Cited: 23 April 2019.] https://www.epa.nsw.gov.au/~/media/EPA/Corporate%20Site/resources/wasteregulation/140796-classify-waste.ashx. ISBN 978 1 74359 798 9.
14. AG-2071 Discharge Limits of Substances into the B-line and C-line.
15. AG-2067 ANSTO Environmental Management System Manual.
16. AE-5362 ANSTO Environmental Sustainability Strategy.
17. ARPANSA Radiation Protection Series RPS C-2 (Rev.1) Code for the Safe Transport of Radioactive Material. 2019.
18. ARPANSA Radiation Protection Series C-3 Code for Disposal Facilities for Solid Radioactive Waste. 2018.
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22. IAEA Safety Standards, SSR-6, Regulations for the Safe Transport of Radioactive Material. Vienna : International Atomic Energy Agency, 2018. SSR-6.
23. AG-1266 ANSTO Packaging Waste from Classified Areas.
24. AF-2358 Waste Service Request.
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26. AG-2985 ANSTO Non-Radioactive Waste Guidelines.
27. P-3976 Stack Monitoring Program.
28. P-6449 Effluent Procedure.
29. P-6547 Low Level Liquid Waste Procedure.
30. P-6567 Contact Handled Solid Waste Procedure.
31. ARPANSA-GDE-1735 ARPANSA Regulatory Guide - Plans and Arrangements for Managing Safety. 2023.
32. G-5416 WMS Plans and Arrangements for Managing Safety.

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