Australian Government
Department of Industry, Science and Resources

Australian Radioactive Waste Agency

Australia's National Inventory of Radioactive Waste 2021

Acknowledgement of Country

Our department recognises the First Peoples of this nation and their ongoing connection to culture and country. We acknowledge First Nations Peoples as the Traditional Owners, Custodians and Lore Keepers of the world's oldest living culture and pay respects to their Elders past, present and emerging.

CEO's foreword

The Australian Radioactive Waste Agency is committed to providing safe and sustainable radioactive waste management over generations.

The vast majority of the waste produced today is associated with the production of nuclear medicine that every Australian, on average, will need during their lifetime for diagnoses and treatments.

Australia's radioactive waste is currently spread over more than 100 locations around the country including in science facilities, universities and hospital basements.

The National Radioactive Waste Management Facility, proposed to be built near Kimba in South Australia, will provide for the disposal of Australia's low level radioactive waste, and temporary storage for Australia's intermediate level radioactive waste, while a permanent disposal pathway for that waste is developed.

To ensure the facility has capacity to house Australia's current and future waste holdings, the Australian Radioactive Waste Agency has undertaken extensive work to provide an updated national inventory of radioactive waste. This is the first update of the national inventory since the 2018 Radioactive Waste Management Framework.

Australia's National Inventory of Radioactive Waste 2021 is an important milestone in improving the transparency of national radioactive waste holdings in Australia, and this and future developments will under-pin our growing national capability.

Sam Usher

CEO of Australian Radioactive Waste Agency

August 2022

About this update

This report represents the first formal update of Australia's National Inventory of Radioactive Waste since it was published in the Australian Radioactive Waste Management Framework in 2018.

It summarises the information provided to the Australian Radioactive Waste Agency (ARWA) by organisations across Australia on their respective inventories of radioactive waste. ARWA has collated the data provided and produced a series of tables and charts for each waste category to show the volumes, activity levels, and key radionuclides of the reported waste streams.

This data provides an estimate of Australia's radioactive waste inventory that exists currently, or is likely to be produced for the foreseeable future.

It is important to note that information collected for this formal update contains voluntarily provided information from waste-holders. The reported volumes included should be read in this context. As ARWA works with stakeholders to develop a nationally coordinated approach for the management of radioactive waste, the completeness of the data will increase.

For the first time, organisations with relatively small waste inventories have been contacted through the relevant regulators. This has been an important exercise to capture more information about the types of wastes that are being stored by schools, universities, hospitals, research institutions, and industry. While not all of this waste will be managed at the National Radioactive Waste Management Facility (NRWMF) in the future, particularly if there are existing disposal pathways, the national inventory will be used to inform the development of the safety case and the facility design.

ARWA intends to update the national inventory on a regular basis and will continue to implement improvements to the information gathering process, working together with waste holders and federal and state and territory regulators.

Alongside the inventory update, this report also includes:

- Details of the update process;
- Key issues encountered; and
- A discussion of recommendations for future updates.

Collecting the data

Waste holder engagement with and provision of inventory data to ARWA was on a wholly voluntary basis. In March 2021, ARWA requested information from the major Commonwealth radioactive waste holders in Australia, namely the Australian Nuclear Science and Technology Organisation (ANSTO), the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Department of Defence, and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), directly. This requested information included waste types, volumes and activity levels.

In order to expand the scope to cover all radioactive waste holders in Australia, and in the absence of a national register of waste holders, ARWA worked with ARPANSA, the Australian Safeguards and Non-proliferation Office (ASNO), and the relevant state and territory regulators for radiation safety. This saw these bodies forwarding letters requesting inventory information to their licence or permit holders on ARWA's behalf.

ARPANSA provided contact details for its smaller licence holders with whom ARWA did not already have a relationship, such as the Australian National University, the Australian Bureau of Meteorology, Australian Antarctic Survey, and Australian Institute of Marine Science, among others, so that detailed inventory information could be directly sought. ASNO also forwarded ARWA's request to its permit holders, and many of these have responded.

State and territory regulators were not able to provide ARWA with details of their licence holders for a variety of legislative reasons, so the majority of these regulators supported ARWA by contacting their licence holders on ARWA's behalf. Not all licence holders subsequently provided information on their respective waste holdings. The resulting information from the wider Australian waste holder group is therefore incomplete.

It should also be noted that, while respective regulators publish lists of their licence holders, they do not differentiate between radioactive wastes and other holdings, so these lists were unable to be used for this inventory update.

The last submission included in this update was provided on 25 August 2021. ARWA will include any further submissions in the next inventory update, which is anticipated again within 3 years.

To note when reading this report

Radioactivity is the energy or particles (ionizing radiation) released when an unstable, radioactive, atom transforms into a stable form. This can happen in one or more steps. Radioactive decay is measured in a unit called the becquerel (Bq), which is one disintegration per second. Radioactivity comes in a number of different forms: alpha particles, beta particles, gamma rays, and neutrons.

A waste stream is a collection of radioactive waste that has similar radiological, chemical, and physical properties. All wastes in a waste stream are likely to have the same or similar origin.

The summary data in this report only includes waste stream information that has been provided by waste holders (unless otherwise noted). For example, the summary activity values only include waste streams for which activity has been reported, and so although incomplete, they are the best information available at this time.

During the data collation process, data received in the correct template format were generally copied directly into a master spreadsheet. In some instances, some reported waste streams were re-categorised where there was a clear error in the initial categorisation, for example sealed sources reported as low level waste (LLW) instead of short-lived sources (SLS). This will also be a focus area for future inventory improvement.

In addition, several submissions were not in ARWA's required template and sometimes presented as a single list without segregation based on the waste category. For such cases, ARWA categorised each waste stream based on its key radionuclides, total activity (if available), and/or physical properties. ARWA will continue to work with individual organisations to ensure that data is provided in the standard template format in future updates.When reading this report, it should also be noted:

- Where a waste stream has not been specified to be already existing or still currently in use to become waste in future, it is specified as 'TBD'.
- Units for activity levels have generally been chosen as MBq (mega-becquerel, or millions of becquerels) so that relatively small numbers are not lost. Larger units are used for the activity breakdown by radionuclide, and are explained in the relevant section.
- Except for the major waste holders ANSTO, CSIRO, Defence, and ARPANSA, organisations have been grouped into the following categories:
  - Research and education – universities, schools and research institutes
  - Hospitals
  - Industry – mining, chemical and other unknown industries (all of Tasmania's licence holders are included in this category)
  - State or territory government – includes state and territory regulators and other government agencies
  - Other Commonwealth government – all Commonwealth government agencies excluding ANSTO, CSIRO, Defence and ARPANSA
- The volumes presented are the estimated volumes provided and do not include volume uncertainties, which can be up to 150% for some reported waste streams. The exception is ANSTO's ILW, where the reported packaged volumes include uncertainties. Volumes presented are in cubic metre units (1 cubic metre = 1,000 litres).

Purpose of this inventory

Current inventories of radioactive waste are reported by ARPANSA under our obligations for the Joint Convention. While this is complete and well-maintained for regulatory purposes, the information required by ARWA to facilitate a nationally coordinated approach to waste management varies in its specificity.

Separate from these regulatory requirements and international obligations, the purpose of this task is to ensure well-informed decision making for policy and planning, as well as a range of educational opportunities as Australia builds capacity in this highly technical space.

2021 inventory summary

Summaries of LLW and ILW volumes are presented in Table 1 (2021 inventory) and Table 2 (2018 inventory data from the Waste Framework Directive, WMF).

The data are not always directly comparable across the 2018 and 2021 inventory versions, because the 2021 data has been reported for more waste categories and for more individual waste holders. To this end, Table 1 provides ILW and nuclear materials volumes combined in order to allow comparison with 2018 volumes in Table 2.

For 2021, future LLW waste streams volumes are now estimated for the next 100 years, which is different from the 50 years used in 2018. The 2021 and 2018 ILW waste volumes are both estimated over the next 50 years.

Table 1: Total LLW and ILW volumes in 2021 inventory (nuclear materials included with ILW for comparison with 2018 inventory)

TOTAL 2021 INVENTORY	LEGACY WASTE (m^3)	FUTURE WASTE (m^3)	TOTAL (m^3)
ILW including nuclear materials	2,061	2,316	4,377
LLW	2,490	10,797	13,287

Table 2: Total LLW and ILW volumes in 2018 inventory

TOTAL 2018 INVENTORY	LEGACY WASTE (m^3)	FUTURE WASTE (m^3)	TOTAL (m^3)
ILW	1,771	1,963	3,734
LLW	4,975	4,843	9,818

Additional summaries of the 2021 inventory data are presented for each waste category in subsequent sections. Key comparisons are made for the major waste holders for each waste category. This year, total activity and activity by radionuclide are also reported to provide more insight into the reported waste streams.

It should be noted that although the waste volumes are reported to the nearest cubic metre, there is significant uncertainty in the figures (especially for future waste volumes that are based on certain assumptions, for example related to decommissioning, that may need to be modified). For this reason, they should be thought of as estimates rather than absolute values.

Key inventory changes in 2021

The following provides a description of key changes to the summary volumes from the 2018 Waste Management Framework Inventory, by waste holder. Disused sealed sources are no longer included in the LLW or ILW categories, but are now separate categories. This has only a small implication for waste volumes.

ANSTO

The estimated volumes of ANSTO's future LLW and ILW are substantially greater than previously reported.

For LLW, the changes are mainly due to revised estimates of future waste generation rates (about 10% increase annually) and increased timeframes (100 years instead of 50 years waste volumes).

For ILW, the main reason is that volume uncertainty is now included in the packaged volume estimate, where it had not been included previously.

This illustrates that waste characterisation (including volume estimation) requires continued efforts, and that assumptions made about waste characteristics and the waste package may change over time.

CSIRO

The estimated volumes of CSIRO LLW and ILW have reduced sharply.

CSIRO has undertaken initial waste characterisation work on approximately 10,000 drums of legacy waste held at Woomera. The results indicate that none of the drums would be ILW and the actual amount of LLW is around 200 drums. The equivalent volume of LLW legacy waste is 44m^3.

This is still a very preliminary estimate of the amount of LLW at Woomera, and will continue to be updated as more information becomes available from CSIRO's waste characterisation efforts.

Other CSIRO LLW and ILW streams remain unchanged.

States and territories

The state and territory waste volumes were previously compiled from earlier information on sealed sources, ARPANSA's 6th National Report to the Joint Convention on the Safety of Spent Fuel Management, and on the Safety of Radioactive Waste Management in 2017.

For the 2021 update, ARWA requested information from the relevant regulators of each state and territory and individual licence holder organisation where possible. ARWA received information from only some of the regulators and licence holder organisations, which are included in the data.

In addition, sealed sources – which make up the majority of the state and territory licenced materials – are now reported as separate categories.

Others

The LLW and ILW volumes reported by Defence and ARPANSA are similar to the previous 2018 inventory version. Any changes are likely due to further waste characterisation efforts, and materials that were previously in use becoming waste.

For example, for Defence, some volume of waste streams previously reported as ILW have now been characterised as LLW.

LLW inventory 2021

LLW description and classification

Low level waste emits radiation at levels which generally require minimal shielding during handling, transport, and storage. It comes from ongoing activities, such as the production of nuclear medicine, including the gloves, gowns, and other tools used in the production, distribution, and use of nuclear medicines.

These types of waste are generally packed in steel drums for storage, and the waste packages will need to undergo a conditioning process, such as compaction and / or mixing with cement, before disposal. Large and bulky items, such as decommissioning rubble, may require larger containers such as shipping containers. Examples of what LLW drums may look like before conditioning and after super-compaction are shown in the images below.

Example LLW drums, showing the types of waste that may be contained inside.

Example of compacted drum after super-compaction

Cut through example of conditioned waste

Significant volumes of LLW are also expected to be generated from the decommissioning of buildings formerly used for radiological purposes such as reactors, nuclear medicine facilities, and waste storage facilities.

For the purposes of the National Radioactive Waste Inventory, ARWA has defined limits on the radioactivity concentration of waste that can be categorised as LLW. Currently these are based on the legal definitions used in the UK, however they may change in future to better reflect the safety requirements for the NRWMF. A low level waste stream must meet both of the following conditions:

- Less than 4,000 Bq per gram of waste for radionuclides that decay by emitting alpha particles; and
- Less than 12,000 Bq per gram of waste for radionuclides that decay by emitting beta particles or gamma rays.

If either of these conditions are not met, the waste stream is categorised as ILW. The conditions do not apply to waste streams that are otherwise categorised as disused sealed sources, nuclear materials, or naturally occurring radioactive materials.

LLW inventory details

The total volumes of low level waste (LLW) are reported in 2021 by major waste holders and waste holder groupings as summarised in Table 3, while the total activity levels are summarised in Table 5. The 2018 LLW volume information is provided in Table 4.

Waste volume estimates were not provided for some reported waste streams, and many waste streams with estimated volume do not have estimated activity. Both estimates are therefore limited in this regard. ARWA will work with waste holders in future to improve the completeness of the information.

Table 3: LLW volumes in 2021 inventory (m^3)

ORGANISATION / GROUP	FUTURE	LEGACY	TBD	TOTAL
ANSTO	10,665	2,307	-	**12,972**
Defence	88	70		**158**
CSIRO	40	44		**84**
ARPANSA	-	66		**66**
Hospital	2	-	1	**3**
Other Commonwealth govt	-	2		**2**
Research and education	1	1		**2**
Total	**10,796**	**2,490**	**1**	**13,287**

Table 4: LLW volumes in 2018 inventory (m^3)

ORGANISATION / GROUP	FUTURE	LEGACY	TOTAL
ANSTO	4,685	2,771	**7,456**
Defence	84	224	**307**
CSIRO	40	1,967	**2,007**
ARPANSA	36	6	**42**
Total	**4,844**	**4,968**	**9,812**

Table 5: LLW activity in 2021 inventory (MBq)

ORGANISATION / GROUP	FUTURE	LEGACY	TBD	TOTAL
ANSTO	4,400,000	3,700,000	-	**8,100,000**
Defence	-	42,000	-	**42,000**
Other Commonwealth govt	-	600	-	**600**
Hospital	-	-	80	**80**
Total	**4,400,000**	**3,742,600**	**80**	**8,142,680**

Figure 1 and Figure 2 show the proportion of total LLW activity contributed by each radionuclide, where Figure 2 shows the radionuclides included in the 'Other' group in Figure 1. The figures only include the waste streams where radionuclide activity values were provided. The activity values are expressed as multiples of ten to the power n. This means that $2x10^3$ is 2x10x10x10 = 2000 etc.

There are approximately 45 other radionuclides (with total activity less than 2×10^9 Bq) that are not shown in Figure 2, due to chart size limitations.

The Figures show that cobalt-60 is the biggest contributor of radioactivity in the LLW waste streams as a whole. Cobalt-60 is commonly produced in components of nuclear reactors, where the stable isotope cobalt-59 contained in metal structures is exposed to neutrons and converted to cobalt-60. It has a half-life of about 5 years and decays by emitting beta particles and gamma radiation.

Figure 1: LLW activity (10^{12} Bq) by main radionuclides in 2021 inventory

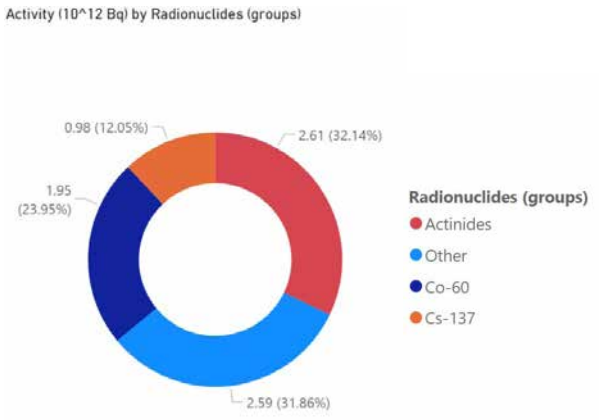
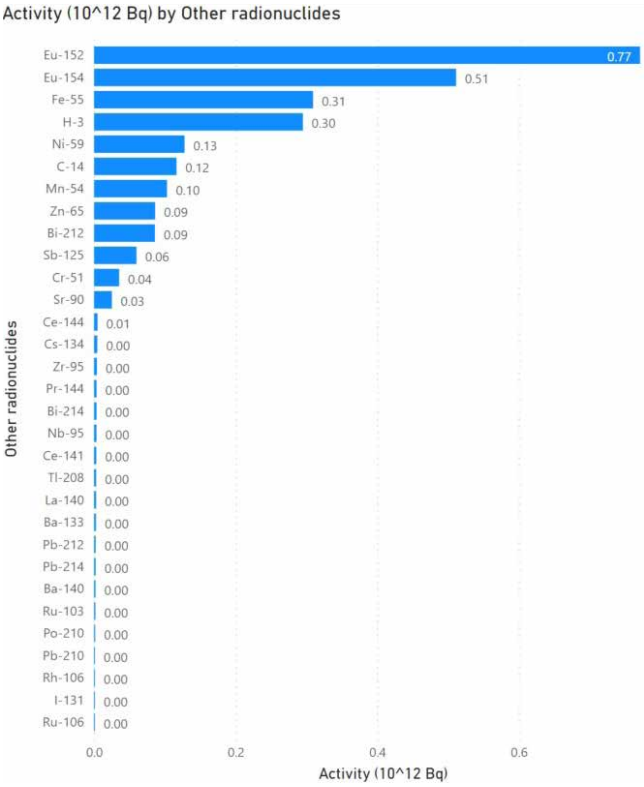


Figure 2: LLW activity (10^{12} Bq) by Other radionuclides in 2021 inventory



ARWA

ILW inventory 2021

ILW description and classification

Australia's intermediate level waste is largely associated with the production of nuclear medicine. The waste is predominantly generated from operation of the OPAL research reactor (and its predecessors) and the ANSTO Nuclear Medicine (ANM) facility.

ILW generally requires purpose-built containers that provide shielding during transport or storage, and may also require additional shielding in a storage facility.

The total volumes of intermediate level waste (ILW) reported are summarised in Table 6, while the total activity levels are summarised in Table 8. Waste volume estimates were not provided for some reported waste streams, and many waste streams with estimated volume do not have estimated activity.

Note that the volumes shown are packaged waste volumes (where available) based on the waste holder's current packaging and conditioning assumptions for storage, to enable comparison with 2018 inventory data which also reported packaged volumes.

ILW inventory details

The ILW inventory for 2021 presented in Table 6 does not include nuclear materials, which are reported later in this report. By comparison, the 2018 inventory included nuclear materials within the ILW volume. The ILW activity is based on reported activities. Not all ILW volumes were accompanied with activity estimates. Waste volumes are waste holder estimates. ARWA will work with waste holders in future to improve the completeness of the information.

Table 6: ILW volume in 2021 inventory, packaged (m^3)

ORGANISATION / GROUP	FUTURE	LEGACY	TBD	TOTAL
ANSTO	2,198	1,555	-	**3,753**
CSIRO	62	12	-	**74**
Defence	2	21	-	**23**
ARPANSA	-	22	-	**22**
Industry	3	-	-	**3**
Hospital	-	-	1	**1**
Other Commonwealth govt	-	1	-	**1**
Research and education	-	-	-	**-**
Total	**2,265**	**1,611**	**1**	**3,877**

Table 7: ILW volume in 2018 inventory (m^3)

ORGANISATION / GROUP	FUTURE	LEGACY	TOTAL
ANSTO	1,849	1,211	**3,060**
CSIRO	62	419	**481**
Defence	9	60	**69**
ARPANSA	43	1	**44**
Total	**1,963**	**1,691**	**3,654**

Note: where volume is less than $1m^3$ in above table, it is rounded up to $1m^3$.

Table 8: ILW activity in 2021 inventory (MBq)

ORGANISATION / GROUP	FUTURE	LEGACY	TBD	TOTAL
ANSTO	18,000,000,000	178,000,000,000	-	**196,000,000,000**
Other Commonwealth govt	-	2,600	-	**2,600**
Hospital	-	-	40	**40**
Research and education	-	1	-	**1**
Total	**18,000,000,000**	**178,000,002,601**	**40**	**196,000,002,641**

Figure 3 and Figure 4 show the proportion of total ILW activity contributed by each radionuclide, where Figure 4 shows the radionuclides included in the 'Other' group in Figure 3. The figures only represent the waste streams where radionuclide activity values have been provided. The activity values are expressed as multiples of ten to the power *n*. This means that $2x10^3$ is 2x10x10x10 = 2000 etc.

There are approximately 45 other radionuclides (with activity less than $4×10^{13}$ Bq) that are not shown in Figure 4 due to chart size limitations.

The Figures show that cobalt-60 is also the biggest contributor of radioactivity in the ILW waste streams as a whole.

Figure 3: ILW activity (10^{15} Bq) in 2021 inventory by main radionuclides

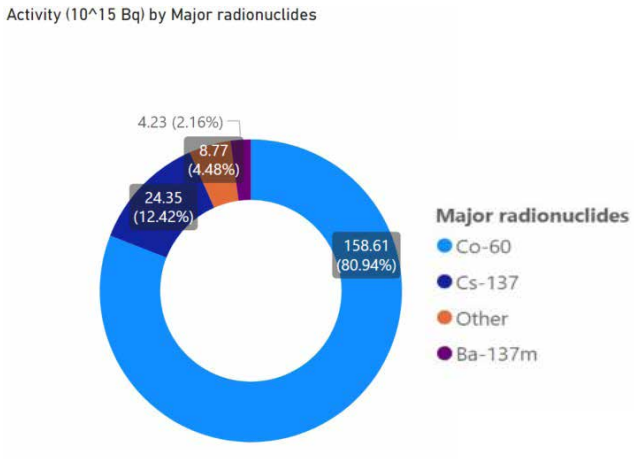
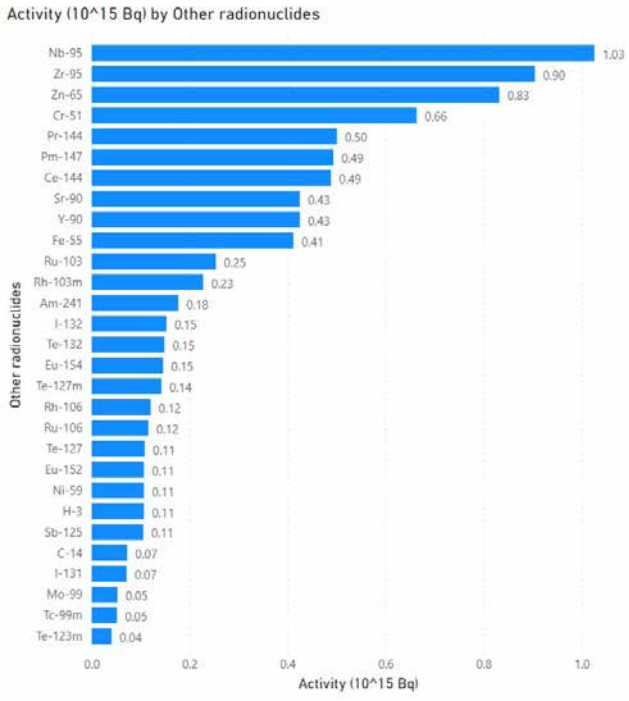


Figure 4: ILW activity (10^{15} Bq) in 2021 inventory by other radionuclides



ARWA

Short-lived and long-lived sealed sources 2021

Description and classification

Information on short-lived sealed sources (SLS) and long-lived sealed sources (LLS) was collected as individual categories in the 2021 inventory update, separate from the LLW and ILW categories.

ARWA has specified that for a source to be categorised as short-lived, its activity should decay to below exemption levels within 300 years. Otherwise, the source should be categorised as long-lived. Exemption levels are thresholds of radionuclide activities and activity concentrations defined by ARPANSA, below which the radioactive material is exempt from regulatory control.

Examples of sealed sources are shown in the images on this page.

Cobalt-60 disc source, original activity of 1 µCi (37000 Bq), half-life of 5.27 years. Image courtesy of Industrial Equipment and Control Pty Ltd

Inventory details

The data arising from the new request to categorise disused sources has, in some cases, been problematic, and needs substantial additional effort to reduce uncertainties for the next iteration. This is at least partly due to some states not passing on the request for information to their licence holders.

ARWA recognises that further work is required to improve the overall reporting of these wastes (about half the number of the sources in the ARPANSA Joint Convention report), and to clarify the categorisation of disused sealed sources / further clarify the residual activity values. This will occur during future inventory information collection.

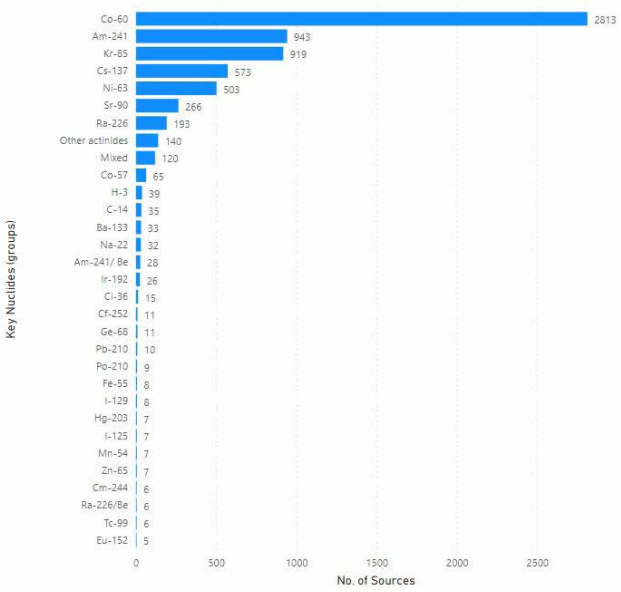
Given the data, at this stage the information on sealed sources is better combined, and is presented in this way in Table 9. The total number of the sources reported are shown in Table 9, by organisation/ group.

Table 9: Number of sealed sources in 2021 inventory

ORGANISATION / GROUP	FUTURE	LEGACY	TBD	TOTAL
ANSTO	-	3,014	-	**3,014**
Defence	730	1,335	-	**2,065**
Research and education	119	149	82	**350**
CSIRO	36	280	-	**316**
Hospital	5	30	47	**82**
State or territory gov	-	662	99	**761**
Industry	117	7	94	**218**
ARPANSA	-	66	-	**66**
Other Commonwealth gov	6	26	-	**32**
Total	**1,013**	**5,569**	**322**	**6,904**

Figure 5 provides an indication of the relative proportion of sources by type/ radionuclide. The large majority of reported short-lived sources contain cobalt-60 (2,813 items), while the large majority of reported long-lived sources contain americium-241 (943 items). Many of the americium-241 sources are disused smoke detectors. There are some sources with fewer numbers than those shown below, that are not included due to chart size limitations.

Figure 5: Number of sealed sources by radionuclide in 2021 inventory



Many of the reported sources do not have an associated measurement date for the activity, and many of the reported activity values are the original source activity, with few having been measured recently. Therefore, the true current activity values for some sources are likely to be much lower, especially for short-lived sources. For these reasons, activity information is not reported here.

Nuclear materials inventory 2021

Description and classification

Nuclear materials (NM) are being reported as a separate category in the 2021 inventory update. They are defined as safeguarded materials subject to the *Nuclear Non-Proliferation (Safeguards) Act 1987* and held under a permit from ASNO.

Safeguards material is defined as "any uranium, thorium or plutonium held in Australia under ASNO permits or otherwise subject to the *Nuclear Non-Proliferation (Safeguards) Act 1987*, with limited exceptions as described in the Nuclear Non-Proliferation (Safeguards) Regulations 1987". Specific items of nuclear material may not be subject to Part II of the Safeguards Act (by virtue of the exceptions the Safeguards Regulations) and these items may be treated as LLW.

Inventory details

Waste streams containing safeguards material were previously reported as ILW in the 2018 inventory, but are presented in their own category in this 2021 update.

About 50m^3 of nuclear material is estimated to be produced in the next 50 years and 450m^3 is already in storage.

The total activity of the safeguarded materials are dominated by one waste stream from nuclear medicine production, which will have a total activity in the order of 10^{22} Bq for legacy and anticipated future waste combined. The majority of this radioactivity is attributable to short lived radionuclides and so will decline rapidly, in proportion to the time in storage (and so the activity reported is also expected to change with time).

Naturally occurring radioactive materials 2021

Description and classification

There are a few organisations that reported naturally occurring radioactive materials (NORM) in their inventories. These are items such as ore and mineral samples held by schools and universities.

Inventory details

Almost 80 individual NORM items were reported, most of which are no longer being used. The total waste volume associated with NORM is very small and so is not reported.

Recommendations/actions for the next update

Response rate

Improving the response rate from waste holders is a priority for ARWA ahead of the next annual update.

ARWA will further explore and address any legislative and process barriers that are preventing waste holders from sharing their inventory data, and consider a variety of options to assist waste holders provide their data, with a view to streamlining the collection process.

Data submission

Reducing the incidence of common data submission issues associated such as errors in data collation, completeness, accuracy and formatting is a priority for future annual updates. For this report, where possible, ARWA resolved or corrected the data issues.

For future reports ARWA will also seek to better understand existing waste holder plans for waste management and disposal.