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Final

Hazardous Waste in Australia 2021

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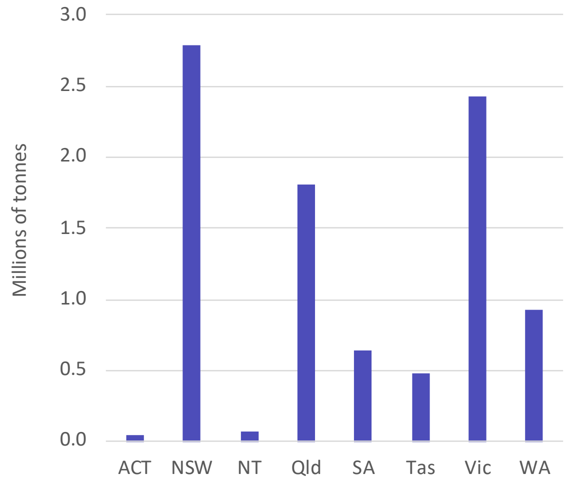
At a glance

In 2019-20 Australia generated around 7.4 million tonnes of hazardous waste[1], which is about 10% of all waste generated (74 million tonnes)[2]. Despite consolidating in 2019-20 about 1% lower than 2017-18, hazardous waste quantities are increasing, at a rate of 6.3% per year from 2014-15 to 2019-20.

Classified into more than 70 detailed types, these wastes include:

Generation of hazardous waste by state and territory, Australia 2019-20



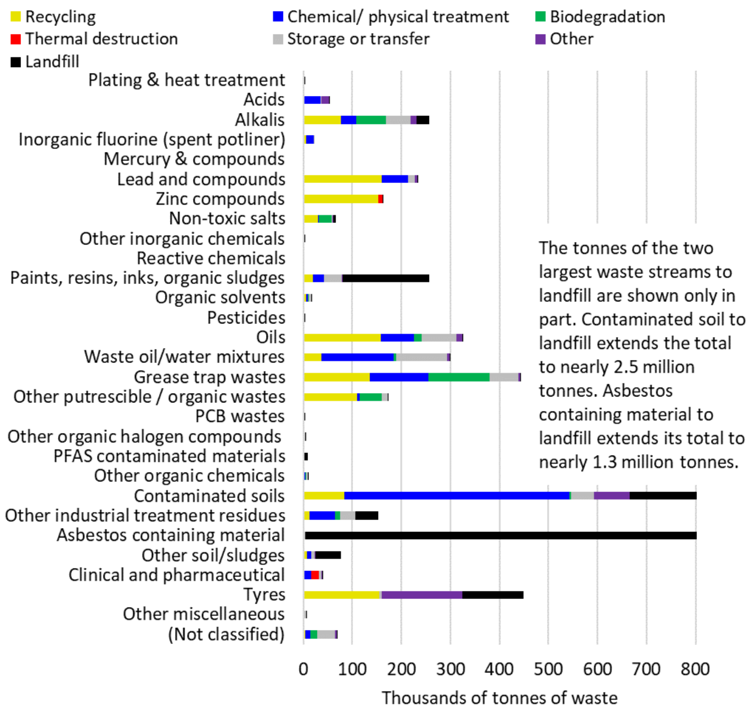
- contaminated soils and asbestos from development and demolition projects
- wastes from the chemicals, heavy manufacturing and mining industries
- emerging per- and poly-fluoroalkyl substances (PFAS) wastes
- a range of hazardous wastes that arise from everyday sources, such as –
  - tyres/oils/oily waters (motor vehicles)
  - grease trap waste (commercial cooking)
  - lead-containing wastes such as lead acid batteries (motor vehicles) and leaded glass (used TVs and computers)
- metal smelting and refining wastes containing lead and other heavy metals
- paint- and solvent-related wastes.

The top ten hazardous wastes produced by weight in 2019-20 were:

1. Contaminated soils [35%]
2. Asbestos [18%]
3. Tyres [6%]
4. Grease trap wastes [6%]
5. Waste oils [5%]
6. Oil/water mixtures [4%]
7. Paints, resins, inks organic sludges [4%]
8. Lead compounds [4%]
9. Alkalis [3%]
10. Animal effluent and residues [3%].

The majority of these wastes were sent to landfill (51%). Another 21% was recycled, 15% underwent treatment to reduce or remove the hazard, 7% was stored for accumulation and later release into management infrastructure and 6% went to other infrastructure (the biggest portion of which was tyres going to export markets).

Generation of hazardous waste by type and management, Australia 2019-20



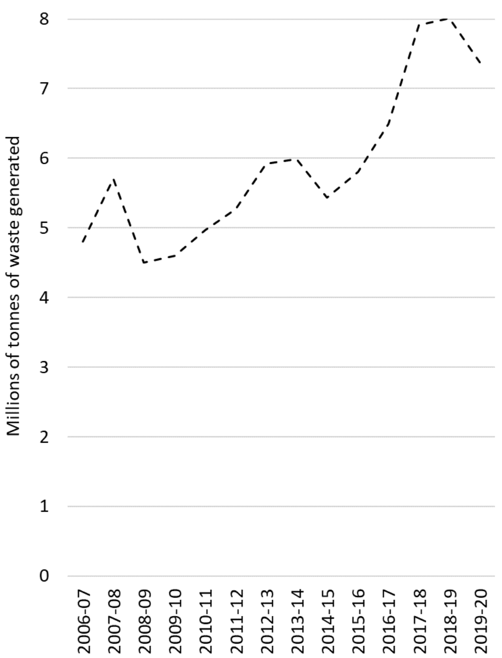
[1] Excluding biosolids, due to their large tonnage and the unresolved and variable nature of their hazard classification.

[2] The *National Waste Report 2020* reports waste data for the 2018-19 year, whereas this report draws data from 2019-20.

Hazardous waste in Australia moves in three sub-markets, each associated with different wastes and with distinct scales and issues of interest: 91% of waste is managed in infrastructure within the state/territory where it was generated; 7% crosses interstate borders; and ~2% is exported to or imported from overseas for management in specialised infrastructure unavailable or not viable within the generating jurisdiction.

Hazardous wastes have trended strongly upwards since 2006-07, increasing at a compound annual growth rate of approximately 6.3% per year since 2014-15, when the first edition of this report series[3] was published.

National generation of hazardous wastes in Australia, 2006-07 to 2019-20



The major contributors to this post-2014-15 surge were **asbestos** (almost all in NSW) and **contaminated soil** (mostly in Vic and Qld). The trend slowed in 2018-19 then slightly fell in 2019-20, due to reduced NSW asbestos volumes and a large 2019-20 drop in Qld contaminated soil, down 57% on that state's 2018-19 reported tonnages. Offsetting these 2019-20 falls was Vic's sharp growth in 2019-20, driven by its contaminated soil volumes, which grew a further 42% on 2018-19, on top of an already unprecedented growth period in that waste from 2014-15.

PFAS-contaminated waste has emerged dramatically since 2016-17 with the trend shown most clearly in Vic and Qld, those states that house the main national infrastructure for managing PFAS waste.

Australia's soil thermal treatment facilities, concentrated in Vic, have experienced major growth in 2019-20. This rise is almost certainly attributable to PFAS contaminated soils. A number of options for PFAS management in Australia were identified. However, there remains a large risk that PFAS contaminated soil, rubble and concrete will arise over the near term into a market that does not have sufficient capacity to deal with it.

Additional volumes of **COVID-19** personal protective equipment (PPE) placed a heavy demand on clinical waste infrastructure in Australia in 2020, creating more interstate flows to manage it. Industry sources indicated that facility licences in south eastern Australia had to be temporarily expanded to cope with the extra load. Operators and regulators appeared to act swiftly and cooperatively, particularly during Vic's Covid second wave, and coped well with the unprecedented volumes and circumstances.

An investigation into a range of potential **chemical additives in plastic** consumed in Australia in 2018-19 found that:

- polyvinyl chloride (PVC) has the highest risk of containing endocrine-disrupting chemicals (EDCs), potentially at high levels (phthalate plasticisers potentially make up 30% of the weight of PVC)
- over 100,000 tonnes of phthalate plasticisers were estimated to be used in plastics in 2018-19
- EDCs also have the potential to be present in high-density polyethylene (HDPE), low-density polyethylene (LDPE) and polystyrene, but at much lower concentrations than those used in PVC
- flame retardants are added to a wide range of plastics at around 0.5%-15% by weight, and as high as 35% if dechlorane plus, a potential new listing on the Stockholm Convention, was used, equivalent to over 200,000 tonnes of this emerging chemical in Australian plastics in 2018-19.

[3] *Hazardous Waste in Australia 2015.*

Abbreviations and glossary

ACM	asbestos containing material
AFFF	Aqueous film forming foams (containing PFAS, in the context of this report)
ANZBP	Australian and New Zealand Biosolids Partnership
ANZSIC	Australian and New Zealand Standard Industrial Classification
Basel Convention	*The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal*. The Convention puts an onus on exporting countries to ensure that hazardous wastes are managed in an environmentally sound manner in the country of import.
BFR	brominated fire retardant
Bisphenols	A group of chemicals often used as plastics additives, many of which disrupt the function of bodily endocrine systems. May include bisphenol A (BPA), bisphenol S (BPS) and bisphenol F (BPF),
BOD	biochemical oxygen demand
Controlled Waste	Waste that falls under the control of the *National Environment Protection (Movement of Controlled Waste between States and Territories) Measure 1998*. Generally equivalent to hazardous waste, although definitional differences of the latter exist across jurisdictions.
Controlled Waste NEPM	*National Environment Protection (Movement of Controlled Waste between States and Territories) Measure 1998*
COVID-19 (COVID)	A disease caused by a new strain of coronavirus ('CO' stands for corona, 'VI' for virus, and 'D' for disease), responsible for the worldwide pandemic from early 2020.
Contaminant	chemical contaminant within hazardous waste
CPT	chemical or physical treatment, a broad description of types of infrastructure that 'treat' the waste to remove or reduce the hazard, such as acid/ base neutralisation, de-watering or solid waste immobilisation.
CSG	coal seam gas - a form of natural gas (generally 95 to 97% pure methane, CH_4) typically extracted from permeable coal seams at depths of 300 to 1,200 m. Also called coal seam methane (CSM) or coalbed methane (CBM).
DecaBDE	decabromodiphenyl ether
DEHP	diethylhexyl phthalate
The Department	The Australian Government Department of Agriculture, Water and the Environment
DiNP	diisononyl phthalate
EDC	endocrine-disrupting chemicals
EPA	Environment Protection Authority
EU	European Union
e-waste	Any waste item that uses a plug, battery or power cord. For example, TVs, mobile phones and computers.
GAC	granular activated carbon
Halogenated organic compounds	chemical compounds containing a 'halogen' (typically fluorine, chlorine or bromine) in their chemical structure
Hazardous waste	A hazardous waste, as defined in the Australian Government's *National Waste Policy: Less waste, more resources* (2009), is a substance or object that exhibits hazardous characteristics, is no longer fit for its intended use and requires disposal. According to the Hazardous Waste Act, hazardous waste means: (a) waste prescribed by the Hazardous Waste Regulations, where the waste has any of the characteristics mentioned in Annex III to the Basel Convention; or (b) wastes covered by paragraph 1(a) of Article 1 of the Basel Convention; or (c) household waste; or (d) residues arising from the incineration of household waste;

	but does not include wastes covered by paragraph 4 of Article 1 of the Basel Convention.
Hazardous Waste Act	*Hazardous Waste (Regulation of Exports and Imports) Act 1989*
Hazardous Waste Regulations	Hazardous Waste (Regulation of Exports and Imports) Regulations 1996
HBCD	hexabromocyclododecane
HDPE	high-density polyethylene
HWiA 2015	Blue Environment, Ascend Waste and Environment, and Randell Environmental Consulting (2015) *Hazardous Waste in Australia*, prepared for the Department of the Environment, available at: www.environment.gov.au/system/files/resources/9ae68d42-d52e-4b1d-9008-111ad8bacfea/files/hazardous-waste-australia.pdf
HWiA 2017	Blue Environment and Ascend Waste and Environment (2017), *Hazardous Waste in Australia*, prepared for the Department of the Environment, available at: www.environment.gov.au/protection/publications/hazardous-waste-australia-2017
HWiA 2019	Blue Environment and Ascend Waste and Environment (2019), *Hazardous Waste in Australia 2019*, prepared for the Department of the Environment and Energy, available at: www.environment.gov.au/protection/publications/hazardous-waste-australia-2019
HWiA 2021	this report
IED	The EU's Industrial Emissions Directive: *Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)*, available at: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:334:0017:0119:en:PDF
kt	kilotonnes (thousands of tonnes)
LDPE	low-density polyethylene
LNG	liquefied natural gas
MRU	mercury removal unit
Mt	Megatonnes (millions of tonnes)
NATA	National Association of Testing Authorities
NEPC	National Environment Protection Council
NEPM	*National Environment Protection (Movement of Controlled Waste between States and Territories) Measure 1998*
NiCad	nickel cadmium
OctaBDE	octabromodiphenyl ether
PBDE	polybrominated diphenyl ether
PCB	polychlorinated biphenyl
PFAS	per- and poly-fluoroalkyl substances
PFAS NEMP	PFAS (per- and poly-fluoroalkyl substances) National Environmental Management Plan
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonate
Phthalates	A group of chemicals often used as plastics additives, many of which disrupt the function of bodily endocrine systems. May include dibutyl phthalate, butyl benzyl phthalate, dimethyl phthalate, diethyl phthalate (and many more).
PIC	products of incomplete combustion
POP	persistent organic pollutant
POP-BDE	persistent organic pollutants - bromodiphenyl ethers (various forms)
PPE	personal protective equipment
PVC	polyvinyl chloride
Re-entrainment	When a chemical contaminant is unintentionally migrated from one product/ material/context to another during recycling and re-production, remaining undiscovered for a period of time, causing environmental or health consequences.
SPL	spent potliner (a waste from the aluminium smelting industry)
Standard	*Australian hazardous waste data and reporting standard – 2019 revision*

Stockholm Convention	Stockholm Convention on Persistent Organic Pollutants (POPs)
TCLP	toxicity characteristic leaching procedure
Tracking system	Jurisdiction-based hazardous waste tracking systems, which are in place in NSW, Qld, SA, WA and Vic. These tracking systems can be either online, paper-based, or a combination of both these mechanisms.
Tracked data	Hazardous waste collected under the arrangements of a tracking system
Treatment	Treatment of waste is the removal, reduction or immobilisation of a hazardous characteristic to enable the waste to be reused, recycled, sent to an energy-from-waste facility or disposed.
ULABs	used lead acid batteries
US EPA	United States Environmental Protection Agency
Waste	(For data collation purposes) is materials or products that are unwanted or have been discarded, rejected or abandoned. Waste includes materials or products that are recycled, converted to energy, or disposed. Materials and products that are reused (for their original or another purpose without reprocessing) are not waste because they remain in use.
Waste arisings	Hazardous waste is said to 'arise' when it is delivered to infrastructure for management. Typically, arisings data is obtained from intrastate tracking systems. Arisings differ from 'generation' (a more common term in waste reporting) in that if a given mass of hazardous waste is transported to more than one site during a data period, it may 'arise' more than once in the tracking system data.
Waste code	Three-digit code typically used by jurisdictions to describe NEPM-listed wastes; for example, N120 (contaminated soils). These are also referred to as 'NEPM codes' although it is noted that the actual codes do not appear in the NEPM itself. These are detailed in the waste groups map of Appendix C.4.
Waste fate	Waste fate refers to the ultimate destination of the waste within the management system. Types of fate may include recycling, energy recovery, long-term storage and disposal, each of which categories can be divided into more specific fates. Treatment, transfer and short-term storage are not fates, but are rather part of the pathway leading to a fate.
Waste generation	The process of creating a waste. In this report generation is expressly different to arisings because it seeks to exclude the potential for double-counting, by subtracting the following (to the extent the relevant tonnes can be identified): 1. hazardous waste sent to facilities for short-term storage or transfer 2. hazardous waste outputs of hazardous waste infrastructure – only inputs are counted. Jurisdictional tracking systems are also examined for imports from other jurisdictions, which are reallocated to the source jurisdiction. Typically in Australia, waste is not recorded as generated until it leaves a site.
Waste groups	The classification system adopted for wastes outlined in this report (closely follows the NEPM category waste codes; (see Table 12, Appendix A). Waste groups have also been referred to as 'projection groups' in previous projects where the context refers to projections of hazardous waste arisings for the purpose of assessing demand on infrastructure.
Waste management	For the purposes of this report, management of hazardous waste comprises the activities through which it is dealt with in infrastructure approved to receive it. The types of management are recycling, energy recovery, long-term storage, disposal, treatment and short-term storage. The first four of these are a type of fate; the last two are a type of pathway. Therefore, for hazardous waste, tonnes 'managed' = tonnes sent to pathway infrastructure + tonnes sent to fate infrastructure.
Waste pathway	The pathway of hazardous waste covers the various steps in the route between hazardous waste generation and fate, potentially including transfer, storage and/or treatment.
Waste source	The source of a waste describes and categorises where it is generated, which could be the geographical location, the company, industry sector, or in some circumstances the jurisdiction that produced it.
WTC	waste transport certificate

1. Introduction

1.1 Project background and context

Hazardous Waste in Australia 2021 (HWiA 2021) was commissioned by the Australian Government Department of Agriculture, Water and the Environment (the Department) and prepared by Blue Environment and Ascend Waste and Environment. Building on the initial 2015 and subsequent 2017 and 2019 versions of the report, HWiA 2021 seeks to provide:

- an authoritative and current snapshot of hazardous waste generation and management in Australia that includes sources, amounts, trends, types, pathways and fates of hazardous waste in 2019-20
- analysis and commentary on issues with particular wastes and their management, to improve understanding of where policy and management systems work well and where barriers may exist to more effective management of Australia's hazardous wastes.

Appendix A provides definitions of key terms critical to understanding the data and interpretation applied in this project. These include conceptual, classification and coding approaches that will help explain the presentation of and meaning drawn from the information supplied in this report. In addition, abbreviations and a glossary are provided following the tables of contents.

1.2 Project outputs

This report includes:

- data on hazardous waste sources, for example by Australian and New Zealand Standard Industrial Classification (ANZSIC) codes
- data on hazardous waste management, which includes both fates and pathways (as defined in Appendix A)
- historical trend analysis of hazardous waste arisings
- commentary on the data.

The analysis is underpinned by the Microsoft Excel data file, *National hazwaste data collation 2019-20*. This compilation contains hazardous waste data from all states and territories including:

- tonnes by waste type and financial year covering 2019-20 and similar historical data spanning several years
- data on the source industries that generated the hazardous waste (NSW, Qld, SA and Vic only)
- data on the ways hazardous waste was managed (NSW, Qld, SA, Vic and WA only).

The state codes for waste type, source and management vary. The collation file transforms them to a common platform for analysis. The common platform and transformation methods are described in the *Australian hazardous waste data and reporting standard – 2019 revision* ('the Standard').

1.3 Report structure

This report is structured as follows:

- An introduction to the project, its scope and context amongst the other related data projects (**Section 1**). This covers the approach used for the project including any differences from its predecessor HWiA 2019 (Section 1.4.1).
- A national overview of the hazardous waste market, including players, pathways, waste flows and trends (**Section 2).**
- A national overview of hazardous waste arisings, sources and management for 2019-20 data, plus summary-level historical trends ranging as far back as jurisdictional data allows (**Section 3)**.
- Investigation into wastes for which there are current and emerging challenges, including some that are not well-covered by jurisdictional waste tracking systems (**Section 4**).
- Summary of findings in the form of the report's key messages (**Section 5**).

The appendices to this report provide:

- a summary (in **Appendix A**) of key definitions that are critical to understanding of the data, and interpretation applied to this project
- analysis of each of 29 waste groups in detail, describing the waste, its major sources, 2019-20 arisings, historical arisings trends, fate, and analysis and commentary to provide insight into issues that this data may uncover (**Appendix B**).
- underlying data for this report in detail (**Appendix C**)
- data sources, limitations and quality issues (**Appendix D**)
- a summary of Section 4.4.1's chemical additives in plastics investigation, in terms of the chemicals' full names, abbreviations and relevant references (**Appendix E**).

1.4 Project approach

Data from jurisdictional tracking systems was used extensively where available. Waste tracking systems in Qld, NSW, SA, Vic and WA require organisations generating, transporting and managing hazardous waste to provide a record to government of each transaction to which they are a party.[4] These systems were established to ensure hazardous waste is appropriately managed.

Data from these systems was collected, collated and analysed, together with other jurisdictional waste data. Data on quantities, sources and management were collated for 2019-20. Historical quantity data collected previously is also included.

Details about data, terminology, waste groups and how they have been applied are discussed in Appendix A**.** Data sources and their limitations are discussed in Appendix D.

[4] The NT Online Waste Tracking System was rolled out for use by all licensees in NT in mid-January 2021, with a transitional period (in parallel with the paper system) until 1 April 2021. The system operates from the NT EPA online platform (*https://www.ntlis.nt.gov.au/ntepa/auth/login?redirect=bjAIEwlYPasINWZpcilzpFOQPBSWkytj*). This system was not available for the data period of this report (2019-20).

1.4.1 Changes since the 2019 version

Hazardous Waste in Australia was first published in 2015 and updated in 2017 and 2019. As a commitment under Target 7 of the *National Waste Policy Action Plan 2019*[5], this fourth version is issued in accordance with the Department's planned biennial release schedule.

This report is largely aligned with the method of 2019 with the following incremental improvements:

- With the implementation of the *PFAS* (per- and poly-fluoroalkyl substances) *National Environmental Management Plan* (PFAS NEMP), HWiA 2021 includes a new waste group *M270 PFAS contaminated materials*, recognising the new waste code for this material (*M270 Per- and poly-fluoroalkyl substances (PFAS) contaminated materials, including waste PFAS- containing products and contaminated containers*). For data analysis purposes in Appendix B Section B19, the waste *M160 Other organohalogen compounds* has been combined with M270 as *PFAS and related POPs (M160 and M270)*. This is because an accurate reflection of historical PFAS wastes in tracking data can only be seen by looking at both of these waste codes together.
- There is an expanded focus on PFAS wastes, including a review of their emergence in tracking system data and a suggested management priority framework.
- An updated data compilation methodology is provided for *D220 lead and lead compounds waste*. As highlighted in earlier editions of HWiA, NSW tracking system data underestimates lead waste due to a waste tracking regulatory exemption for *spent lead acid batteries destined for reuse*[6]. The 2019-20 national hazwaste data collation estimates the NSW used lead acid batteries (ULAB) generation to account for this gap in tracking data.
- A historical record of Australian hazardous waste generation is given by financial year presenting an annual record from 2006-07 to 2019-20 that is, for the first time and to the extent achievable, consistent in scope and method to the Standard.
- A refreshed Australian hazardous waste market overview is presented in Section 2, accounting for new entrants since HWiA 2019. These new entrants are highlighted separately in Section 4.6, since there is a significant number of new infrastructure providers both in operation and emerging in the pipeline.
- Deeper insights are provided into the waste group-specific analyses of Appendix B.

1.4.2 Waste generation versus arisings

Two slightly different terms are used to describe tonnages of hazardous waste arisings and generation.

- **Waste arisings** include all wastes that are received by management infrastructure and recorded in tracking systems. This data may count some wastes more than once because it could include:
  - wastes that have been generated in one jurisdiction but sent to another for management (tonnages could be duplicated in sender-state and receiving-state tracking systems)
  - wastes that have been sent to pathway infrastructure, such as storage or chemical or physical treatment (CPT) and then subsequently sent to a (final) fate.

  Waste arisings are the best measure when assessing demand on management infrastructure, because 'multiple counting' is not problematic, since it is important to assess all impacts across the infrastructure set.

[5] Australian Government (2019), *The National Waste Policy Action Plan 2019*, Target 7: *Make comprehensive, economy-wide and timely data publicly available to support better consumer, investment and policy decisions*, Action 7.5 *Publish the national Hazardous Waste in Australia report*.

[6] See *http://www.epa.nsw.gov.au/wasteregulation/lead-acid-battery.htm.*

- **Waste generation** focuses on where the waste was created and seeks to exclude the potential for multiple counting by:
    - scouring jurisdictional tracking system data for imports from other jurisdictions and reallocating them to the source jurisdiction
    - estimating double-counting in and out of infrastructure by using proportions sent to short-term storage and (out of) CPT, then subtracting these from total arisings estimates.

  Waste generation is the best measure to use when assessing cause-mechanisms of waste – what type of facilities or activities produce it and where it comes from.

These terms and others critical to hazardous waste data understanding are further defined in Appendix A.

1.4.3 Data reported to the Basel Convention

The Department's engagement also required the delivery of the *Basel report 2019*, Australia's hazardous waste generation data from all jurisdictions reported to the Basel Secretariat in Geneva, Switzerland for the reporting year 2019. Common tonnage data was used for both reporting requirements, in different formats, and is summarised in Appendix C to this report.

Australia signed the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal* (referred to hereafter as the Basel Convention) in 1992. Under the Convention, the movement of hazardous wastes across international boundaries requires the prior informed consent of all countries involved in the movement, which can only be granted if it is demonstrated that the hazardous wastes are transported and disposed of in an environmentally sound manner. One hundred and eighty-seven other countries had ratified the Basel Convention as at July 2021.

The Australian Government is obliged to submit an annual report to the Basel Secretariat detailing the tonnages of hazardous wastes generated in the country each calendar year. This data provides a baseline and backdrop to discussions about Australia's progress with efforts to better manage its hazardous waste. The data must be reported using the Basel Convention's classification system known as 'Y-codes', which may differ from state and territory definitions for hazardous waste. State and territory governments collect this data as part of their regulatory role in managing hazardous waste and its potential for impact on the environment and human health.

2. Hazardous waste market overview

The Australian hazardous waste market is structured according to the following roles:

- Generators of hazardous waste - typically, but not exclusively, industrial, mining and infrastructure development operations. This is a diverse and geographically distributed group.
- Managers (sometimes known as treaters) of hazardous waste, comprising those businesses that manage certain hazardous wastes, either through –
  - intermediate activities, or pathways, en route to a fate, such as transfer, storage and/or CPT
  - fate infrastructure, the ultimate destination of the waste within the management system, where types of fate include recycling, energy recovery, long-term storage and disposal.
- Transporters of hazardous waste, made up of –
  - primarily, the logistics fleets of major hazardous waste management companies
  - distinct waste logistics operators, of typically smaller fleets and, on occasion, single vehicle operators.

State government regulators shape behaviours and structures through regulatory controls such as licensing waste producing and receiving facilities, licensing/permitting waste transport vehicles, and operating waste tracking and consignment authorisation systems. The Australian Government authorises hazardous waste movements into and out of the country, via the *Hazardous Waste (Regulation of Exports and Imports) Act 1989*.

This section introduces the Australian hazardous waste market, structures within it, key waste flow mechanisms, and high-level trends in the nature, volume and management of these wastes. Section 3 has some overlapping themes with this section, but focuses on the waste data aspects of market activity. The section opens with an assessment of companies and infrastructure, first nationally then in the states hosting the most infrastructure (NSW and Vic). It then assesses which wastes go where, concluding with an infographic showing major wastes and flows.

2.1 Companies and infrastructure

2.1.1 Market analysis – national

Following Cleanaway's purchase of Toxfree (including Daniels Health) in mid-2018, three major waste companies manage most of the hazardous waste tonnage generated in Australia, and tend to offer services for a broad range of wastes:

- Cleanaway Waste Management
- Veolia Environmental Services (Australia)
- SUEZ Recycling and Recovery.

At the time of writing, Suez and Veolia have reached a deal on a merger at the international level. It appears that Cleanaway may acquire a number of Suez's Sydney-based assets.[7] The Cleanaway purchase has not been officially confirmed because it is currently subject to approval by the

[7] *The Age*, 13 April 2021, *Cleanaway still expects to snap up Sydney Suez assets for $501m*, available at: *https://www.theage.com.au/business/markets/asx-set-to-rise-cleanaway-deal-scrapped-20210413-p57inv.html.*

Australian Competition and Consumer Commission[8], which will make its decision on 2 September 2021. The ramifications of these acquisitions are not yet clear so have been disregarded for the purposes of this market discussion.

Cleanaway has the most operations nationally (around 47 facilities that can receive hazardous wastes), mostly covering transfer and storage, CPT and some recycling (typically of oils/oily waters). Cleanaway also operates the Ravenhall landfill (Melbourne's largest) which accepts large quantities of wastes included as hazardous but having low hazard characteristics (mainly low-level contaminated soils and asbestos).

Cleanaway also runs other specialist infrastructure such as a persistent organic pollutant (POP) destruction facility, an e-waste reprocessor that can handle mercury, and a significant slice of the clinical waste management market.

Veolia has approximately 12 facilities nationally with hazardous waste management capability, with a focus on liquid waste treatment plants for oils and oily waters, grease trap waste and other industrial liquid wastes such as those from the food and meat processing industries. Veolia's sites are spread between CPT, transfer and storage, landfills (both hazardous and low-hazard wastes), clinical waste treatment and organics (biological treatment).

SUEZ has approximately six facilities equipped to specifically manage hazardous waste nationally. Importantly, these include the two largest dedicated hazardous waste landfills in Australia, at Lyndhurst in Vic and Kemps Creek in NSW. It also has some CPT capacity and two dedicated clinical waste facilities, and is a major player in non-hazardous wastes, operating seven advanced resource recovery facilities and eight major composting operations.

All three major waste management companies operate large fleets of waste transport vehicles.

In approximate terms, excluding the vast volumes of low-level contaminated soils and asbestos[9], these three major companies receive in the order of 80% of national hazardous waste flows (by tonnage) into their facilities. They also account for a large proportion of non-hazardous facilities in Australia. But the wide variability in hazardous waste types and technologies allows a relatively large number of facilities outside of the 'big three'. Previous work by the authors (Blue Environment et al 2017[10]) suggests that the big three cover just 30% of the number of hazardous waste sites.

Next tier (medium sized) operators tend to be either location-specific or technology/waste-specific and include:

- JJ Richards, which has multiple sites managing various wastes, including major waste oil re-refining capabilities
- large private landfill operators such as Hanson and Remondis
- specialised companies such as –
  - Ace Waste (clinical waste)

[8] Australian Competition and Consumer Commission website: *https://www.accc.gov.au/public-registers/mergers-registers/public-informal-merger-reviews/cleanaway-waste-management-limited-certain-suez-recycling-recovery-pty-ltd-post-collection-waste-assets-in-sydney*.

[9] While sites receiving these lower-hazard wastes may also be dominated by the 'big three', such landfills are numerous, very widely dispersed and receive predominantly non-hazardous waste, so are difficult to quantify in this market context.

[10] Blue Environment and Ascend Waste and Environment (2017), *Hazardous Waste in Australia 2017*, prepared for the Department of the Environment, available from: *http://www.environment.gov.au/protection/publications/hazardous-waste-australia-2017*.

- Geocycle (solvents, paints, oils, other liquid organics recycling into fuels)
- Renex (contaminated soils remediation)
- Regain and Weston Aluminium (spent potliner [SPL] and other aluminium smelting wastes)
- waste oil re-refining and treatment companies (such as Southern Oil Refining)
- various large composters
- specialist lead recovery facilities such as Nyrstar (from metal refining wastes) and Hydromet/DGL Environmental and Enirgi Power Storage Recycling (EPSR) (from used lead acid batteries)
- smaller specialists such as CMA Ecocycle and two new entrants in WA (mercury recovery) and solvent/paint recovery facilities such as Solveco and Planet Paints.

The remainder of the market is made up of many small players, with either specific niches (such as hazardous waste packaging recyclers, which deal largely in steel drums) or geographic coverages (such as the large number of small regional landfills, that typically may take limited hazard wastes, such as low-level contaminated soils or asbestos).

Some other industrial operations are important in hazardous waste management because, while not their main focus, they accept hazardous waste because it is useful to them or as a commercial adjunct. These include cement kilns, metal smelters, clinical waste incinerators and potentially steel and brick works, utilising various wastes for fuel value such as SPL, pesticide wastes, 'off-spec' paints and even tyres. These can be considered examples of industrial symbiosis at work, or part of the 'circular economy', a term more recently used to describe extracting maximum value from resources whilst in use, then recovering and regenerating products and materials at the end of each service life.

The last two to three years have seen the commissioning of infrastructure with the potential to provide significant extra capacity and, in some cases new capability, to further support the Australian hazardous waste management market. Those in Vic and NSW are touched on in the market overview specific to these jurisdictions (Sections 2.1.2 and 2.1.3).

The most significant new entrant outside of these states is Tellus Holdings, whose dual open-cut kaolin mine and arid near-surface geological waste repository commenced operations at Sandy Ridge, north-west of Kalgoorlie WA in October 2020. Tellus can accommodate up to 100,000 tonnes/year of a wide range of wastes in a form of long-term isolation, which qualifies as 'permanent isolation' in Australia under accounting standard AASB 137[11], enabling a contingent liability to be removed from a company's financial statements.

Two new mercury recovery facilities (BMT Mercury Technology, Kwinana and Contract Resources Karratha) have been commissioned in WA to receive mercury waste from the oil and gas industry, whose waste mercury recovery units can now be managed in an environmentally sound manner locally. These facilities respond to the *Minamata Convention on Mercury*, which came into force in August 2017.

A new CPT facility, Yatala Waste Treatment Services, run by the Hi-Quality group, was commissioned in southern Qld in 2020, and is expected to bolster treatment services for contaminated soil and liquid waste in Qld and northern NSW.

A detailed listing of all major hazardous waste management facilities in Australia is provided in the *Hazardous Waste Infrastructure Database 2018*, an output of the *Assessment of hazardous waste*

[11] https://www.aasb.gov.au/admin/file/content105/c9/AASB137_07-04_COMPjun14_04-14.pdf.

infrastructure needs and capacities in Australia 2018 project[12]. This project and its list of facilities will be updated in 2022.

2.1.2 Market analysis – NSW

The hazardous waste market in NSW follows a pattern similar to the national market, with Cleanaway prominent in terms of market volume share. In NSW, Veolia is a small player, reducing the big three to the big two. These plus other important players are summarised below:

- Cleanaway has 17 facilities, comprising various CPT operations (including the long-standing Homebush Bay liquid waste facility), basic oil recovery facilities, storage sites and those assets purchased from Toxfree and Daniels Health –
  - Cleanaway Operations at Albury (licence no. 1224)
  - Cleanaway Operations at Padstow (licence no. 2977)
  - Cleanaway Operations at Homebush Bay (licence no. 4560)
  - Cleanaway Operations at Glendenning (licence no. 6091)
  - Cleanaway Operations at Kooragang (licence no. 6124)
  - Cleanaway Operations at Unanderra (licence no. 10251)
  - Cleanaway Industrial Solutions at Unanderra (licence no. 10771)
  - Cleanaway Operations at Tamworth (licence no. 10804)
  - Cleanaway Equipment Services Orange (licence no. 6089)
  - Cleanaway Equipment Services Queanbeyan (licence no. 6090)
  - Cleanaway Ingleburn (licence no. 20076)
  - Cleanaway Wagga Wagga (licence no. 12945)
  - (former Toxfree) South Windsor (licence no. 4602)
  - (former Toxfree) St Marys 3 sites with licence nos. 12628 (Christie St), 12943 (Links Rd) and 20271 (Charles St)
  - (former Toxfree) Heatherbrae (licence no. 13255)
  - Cleanaway Daniels NSW Customer Centre, Matrix and Incineration Facility (licence no. 3245)
  - Cleanaway Daniels Waste Services (Autoclave) Silverwater (licence no. 12171).
- Suez has four facilities comprising –
  - Suez Elizabeth Drive Landfill, Kemps Creek (licence no. 4068), which is the only restricted solid waste landfill in NSW
  - Suez Forest Hill (licence no. 10060)
  - Suez's liquid waste facility at Rosehill (licence no. 12242)
  - Suez Revesby (licence no. 20026).
- Veolia has one facility – Veolia Environmental Services at Cameron Park (licence no. 13212).

Of the remaining NSW waste management operators, the most significant by remaining volume are:

- DGL Environmental, which operates on the Hydromet Unanderra site, offering new CPT capacity, particularly for the waste group B acids market

[12] Blue Environment, Randell Environmental Consulting and Ascend Waste and Environment (2019) *Assessment of hazardous waste infrastructure needs and capacities in Australia 2018*, prepared for the Department of the Environment and Energy, available at: https://www.environment.gov.au/protection/publications/hazwaste-infrastructure-assessment-2018.

- lead acid battery infrastructure, of which EPSR, formerly Renewed Metal Technologies (Bomen) is by far the largest and Hydromet (DGL) similar but more a 'breaker' of batteries rather than a refining/smelting operation
- a wide range of further waste oil processors, including CPT and oil/water treatment or recycling facilities
- BlueScope Steel and IXOM, which both use 'industrial symbiosis' to deal with acid and alkaline waste solutions
- a number of drum reconditioning companies
- niche market operators that deal with PCB wastes (Coopers Environmental), solvents and related liquid wastes (Solveco and Solvents Australia) and aluminium industry wastes (Weston Aluminium and Regain) and a small number of composters.

There are more than 100 local landfills scattered across the state, many of which are licensed to receive low level contaminated soils and asbestos. The facility analysis above excludes these landfills because their receipts of hazardous waste would typically be dwarfed by their non-hazardous waste volumes.

There has been a significant rise in the number of mobile plant for contaminated site work over the past two years. Eleven new licences for mobile waste treatment plants have been issued in NSW alone since 2018, most of which involve pump and activated carbon capture of PFAS from water such as contaminated groundwater, fire water and surface waters.

2.1.3 Market analysis – Vic

The hazardous waste market in Vic is also similar to the national market, with the three major players similarly placed in terms of market volume share. Key Vic hazardous waste infrastructure is provided via the following company/facility breakdowns:

- Cleanaway has 14 facilities comprising –
  - 3 CPT facilities, including one ex-Toxfree
  - 2 storage/ transfer facilities
  - 1 organics processing facility (grease trap specific)
  - 1 oil re-refining facility
  - 1 clinical waste incinerator (ex-Daniels)
  - 1 clinical waste non-thermal treatment facility (ex-Daniels)
  - 3 closed storage/transfer facilities, awaiting future management decisions
  - 1 closed CPT facility, awaiting future management decisions (ex-Toxfree)
  - 1 e-waste facility (ex-Toxfree).
- Veolia has three facilities comprising –
  - 1 CPT facility, which incorporates capability for thermal treatment of organic contaminants (including POPs)
  - 1 oil/water treatment facility
  - 1 organics processing facility (grease trap specific).
- Suez has two facilities, including the only dedicated Category B hazardous waste landfill in Vic (Taylors Rd, Lyndhurst) plus a separate thermal and CPT soil treatment facility at their Lyndhurst landfill, which became operational in 2020.
- Of the remaining waste managers there are –
  - 2 other CPT facilities
  - 2 clinical waste incinerators and 1 clinical waste (chemical treatment) facility
  - 3 other e-waste facilities (plus a number of much smaller facilities)

- 2 thermal technology facilities for treating contaminated soils, including those contaminated with POPs
- 4 tyre recyclers
- 7 other oil water treatment plants
- 11 drum recyclers (hazardous waste packaging facilities)
- 1 mercury recycler
- 5 more closed facilities awaiting future management decisions, including
  - 2 processing facilities related to aluminium smelting industry waste
  - 1 oil/water treatment facility
  - 1 storage/transfer facility
  - 1 drum recycler (hazardous waste packaging facility).

An important Victorian-specific aspect of the market is the number of developments in the past two years involving soil remediation facilities (for organic contaminants), using thermal technologies. Renex has a thermal waste treatment facility licensed to treat contaminated soils (mainly pyrolysis recovery of hydrocarbons); EnviroPacific has a new thermal contaminated soil treatment facility similar to Renex; and Suez has commenced operation of its major soil treatment plant at the Lyndhurst landfill site, for thermal desorption/cement stabilisation of contaminated soils. These are in addition to the thermal desorption capability at Veolia Laverton. All four have large design capacities.

All appear to have positioned as POPs thermal destruction facilities of scale, for feedstock such as PFAS-contaminated soils.

2.2 Geographic flows – what wastes go where?

While many hazardous wastes are managed close to where they are generated, markets for others may be national or even international, due to niches of technology or scale that do not lend themselves to local replication. Consequently, hazardous wastes en route to their management destination may require transport:

- within jurisdictional borders
- across jurisdictional borders
- via shipment to international facilities, both as exports out of Australia and imports into Australia.

These three hazardous waste sub-markets, with distinct scales and issues of interest in each case, are estimated in Table 1.

Table 1 Comparison of hazardous waste sub-market types, 2019-20

Sub-market type	Total arisings (tonnes)	Major wastes (and % of sub-market type)	
Total flows involving Aust hazardous waste producing and receiving facilities 2019-20			**6,810,000 tonnes**
Cross international borders[13]			
Imports 0.06% of total flows	3,940 tonnes	Waste oils unfit for their original intended purpose [1,000 tonnes, 25%[14]] Mercury contaminated sludge [1,000 tonnes, 25%[14]] Mixed non-halogenated organic solvents [790 tonnes, 20%[14]] Oily water [300 tonnes, 8%[14]] Mixed pesticide residue (organophosphate, organonitrogen based) [300 tonnes, 8%[14]] Cytotoxic clinical waste [200 tonnes, 5%[14]] Waste acids [100 tonnes, 3%[14]] Waste alkalis [100 tonnes, 3%[14]] Mixed household batteries incl. lithium-ion, nickel metal hydride [100 tonnes, 3%[14]] Misc. mercury-bearing waste incl. crushed lamps and fluorescent tubes [50 tonnes, 1%[14]]	
Exports 1.6% of total flows	107,000 tonnes[15]	Used lead acid batteries waste/scrap [73,000 tonnes, 68%[16]] Electric arc furnace dust [15,000 tonnes, 14%[16]] End-of-life ship (fully intact) contam. in various haz. substances [12,200 tonnes, 11%[16]] Lead scrap [6,000 tonnes, 6%[16]] Non-spillable nickel-cadmium batteries [500 tonnes, 0.5%[16]] Used lithium-ion batteries [360 tonnes, 0.3%[16]]	
Cross state/territory borders			
Total cross-border flows (2019-20)			**490,000 tonnes** 7.2% of total flows
Into ACT[17]	674 tonnes	599 tonnes from NSW: J120 [44%], R [41%], N codes [14%] 30 tonnes from Qld: J120 [100%] 45 tonnes from Vic: J120 [100%]	
Into NSW	105,000 tonnes	76,100 tonnes from Vic: D220 [42%], B [25%], J100 [17%], J120 [6%], D300 [4%] 13,900 tonnes from Qld: D220 [89%], F [3%], J100 & J160 [3%] 6,050 tonnes from ACT: K110 [43%], J100 [18%], D220 [16%], J120 [9%], R [5%] 6,150 tonnes from SA: D220 [69%], J100 [30%] 2,910 tonnes from WA: D220 [97%], J120 [1%], K110 [1%] 407 tonnes from NT: D220 [93%], J120 [5%] 42 tonnes from Tas: J100 [100%]	
Into NT[17]	418 tonnes	292 tonnes from WA : J [100%] 126 tonnes from Qld: J [100%]	
Into Qld	55,100 tonnes	49,500 tonnes from NSW: J100 [46%], N220 [10%], T140 [8%], N140 [7%], K110 [7%], M270 [4%], N205 [4%] 3,240 tonnes from NT: J100 [65%], D220 [17%], J120 [9%], C [3%], T140 [3%] 2,040 tonnes from Vic: F [47%], M270 [33%], M160 [14%], G [3%] 162 tonnes from SA: H [43%], G [36%], 'Other' [21%] 117 tonnes from WA: G [92%], F [8%] 61 tonnes from ACT: J100 [100%] 7 tonnes from Tas: M100 [100%]	
Into SA	309,000 tonnes	266,000 tonnes from Tas: D230 [56%], D220 [44%] 24,700 tonnes from NSW: D220 [39%], D230 [36%], N205 [19%], D300 [2%] 16,900 tonnes from Vic: N120 [33%], N205 [26%], D230 [22%], F [14%] 1,630 tonnes from NT: J100 [21%], C [20%], N100 [18%], F [12%], D220 [11%], J120 [8%], R [5%] 96 tonnes from WA: J100 [100%]	

[13] Data supplied by the Department for the 2019 year (as part of Australia's annual report to the Basel Convention).

[14] Percentage of total imports (3,940 tonnes).

[15] Excludes tyres, as these are specifically not deemed hazardous waste under the Basel Convention.

[16] Percentage of total exports (107,000 tonnes).

[17] Data taken from the NEPC Annual Report 2018-19 (*https://www.nepc.gov.au/publications/annual-reports/nepc-annual-report-2018-19*) because tracking data is not collected for these jurisdictions and 2019-20 NEPC report is not yet due.

Sub-market type	Total arisings (tonnes)	Major wastes (and % of sub-market type)
		49 tonnes from Qld: J120 [92%], G [8%]
Into Tas[17]	4,150 tonnes	3,890 tonnes from Vic: D230 [100%] 13 tonnes from NSW: D230 [100%]
Into Vic	14,900 tonnes	4,870 tonnes from WA: D220 [95%], R [4%] 3,880 tonnes from SA: N120 [62%], D220 [32%] 3,140 tonnes from NSW: D220 [21%], N120 [20%], Other K [14%], 'Other' [12%], J100 [6%], N220 [6%], F [4%] 2,660 tonnes from Qld: N120 [87%], M270 [4%], C [3%] 221 tonnes from ACT: D220 [100%] 107 tonnes from Tas: G [89%], B [9%]
Into WA	389 tonnes	389 tonnes from NT: J120 [72%], F [10%], K110 [10%], B [8%]
Within state/territory borders[18]		
	Total within-jurisdiction flows 2019-20	**6,210,000 tonnes** 91% of total flows
Produced and managed in jurisdiction		Top 10 wastes (by weight) produced and managed within jurisdictions: 1. Contaminated soils (N120) [40%] – 2,460,000 tonnes 2. Asbestos containing material (N220) [21%] – 1,320,000 tonnes 3. Grease trap wastes (K110) [6%] – 363,000 tonnes 4. Waste oil/water mixtures (J120) [5%] – 291,000 tonnes 5. Paints, resins, inks, organic sludges (F) [4%] – 262,000 tonnes 6. Alkalis (C100) [4%] – 256,000 tonnes 7. Waste oils (J100 & J160) [4%] – 244,000 tonnes 8. Other putrescible / organic wastes (Other K) [3%] – 195,000 tonnes 9. Industrial treatment residues (N205b) [3%] – 185,000 tonnes 10. Tyres (T140) [2%] – 131,000 tonnes

Table 1 shows that the bulk of the market volume (91%) was managed within the Australian jurisdiction in which the waste was generated. However, each sub-market type is different, with distinct scales and issues of interest in each case. Each can be summarised as:

- International imports –
  - small overall market and includes a narrow group of wastes (typically from regional neighbours, where suitable management facilities are not present).
- International exports –
  - relatively small overall market and also a narrow group of wastes largely focused on end-of-life batteries of one kind or another
  - individually, these can be sizeable, for example, there were 73,000 tonnes of lead waste and scrap derived from ULABs.
- Cross state/territory borders –
  - accounted for only 7% of 2019-20 waste flows but clear national market pathways exist for some wastes
  - large volumes of lead and zinc smelter wastes are sent from Tas to SA – these dwarf within-state management of these wastes and represent 54% of all hazardous wastes that move across borders in Australia
  - NSW infrastructure dominates national management of ULABs and salty wastes like metal smelting slags and dross; Vic alone sent 32 kt of these wastes to NSW in 2019-20 and Qld sent 12 kt

[18] Total (within jurisdiction) hazardous waste arisings = Total arisings - Cross state/territory borders arisings.

- despite re-refining infrastructure within its state, NSW sent 23 kt of waste oils to Qld in 2019-20
  - a significant proportion of acid wastes continue to be exported from Vic to NSW
  - PFAS wastes showed up in interstate movements to Vic (as contaminated soils to thermal infrastructure) and Qld (likely as higher concentration foams and waste filter media to plasma arc destruction)
  - paint wastes were sent from Vic to Qld, a new flow that may be in response to the 2019 closure of Bradbury Industrial Services, a major solvent recycler in Vic
  - total exports of hazardous waste from NSW to Qld reduced by 40% in 2019-20, compared to 2017-18
  - industrial treatment residue wastes (internal company movements from NSW and Vic to SA) and ULABs from WA to Vic, were new interstate flows for 2019-20
  - in summary, outside of Tas's extremely large exports to SA, Vic was the next biggest exporting jurisdiction at 20% of all interstate movements, followed by NSW at 16%, Qld at 3%, SA and WA at 2%, and NT and ACT about 1% each.
- Within state/territory borders –
  - the top 10 wastes by tonnage make up 91% of all waste produced and managed within a jurisdiction's border
  - this is the largest waste sub-market, and includes typical large-volume wastes, where economies of scale are large enough (and sophistication of technology is simple enough) to enable state-based markets to operate
  - these wastes are generally lower on the hazard scale (except for asbestos).

These characteristics are summarised in the infographic of Figure 1 overleaf, which uses visual approaches to approximate the relative scales of waste tonnages arising in each sub-market.

Figure 1 Major wastes and flows, Australia 2019-20

3. Data analysis – overview

The primary data for this report is provided in the accompanying Microsoft Excel data file, *National hazwaste data collation 2019-20*, which was compiled from jurisdictional data submitted from tracking systems (NSW, Qld, SA, Vic and WA) and Basel workbook templates (ACT, NT and Tas).

Data was collected in six-monthly blocks, allowing aggregation by either 2019-20 financial year or 2019 calendar year. The bulk of the analysis in this report is based on the 2019-20 financial year dataset, to align with historical trend data and to be consistent with the other financial year data needs laid out in Table 11 (in Appendix A). The difference between calendar year collation and financial year collation is typically minor overall, but can vary from waste to waste.

This section presents 2019-20 data collated for waste generation, sources and management (fate and pathway infrastructure), plus historical trends in arisings, as a national overview. Detailed investigation of this data for individual waste groups is provided in Appendix B.

3.1 Overall waste generation and arisings

Hazardous waste arisings data for Australia has been collected, transformed into consistent classifications, collated and presented in detail in Appendix C as follows:

- Section C1 provides 2019-20 national hazardous waste generation data, at the detailed classification level of 72 codes set out in the National Environment Protection (Movement of Controlled Waste between States and Territories) Measure (referred to here as 'the NEPM').
- Section C2 provides the 2019 Basel report data, in Basel Y-codes, as well as in six-monthly blocks to allow totals to be added by financial year.

A snapshot of national hazardous waste generation in Australia in 2019-20, by waste group for each jurisdiction, is given in Table 2. Biosolids are included in the table but, given the large tonnage they contribute and the unresolved and variable nature of their hazard classification, the totals at the bottom of the table are provided both inclusive and exclusive of biosolids.

Table 3 contains 2019-20 hazardous waste arisings as reported in state and territory tracking systems, noting that these figures may include double-counting but also exclude generation data reported by the ACT, NT and Tas, who did not operate intrastate electronic tracking systems during the 2019-20 period[19]. Arisings are provided for context, particularly since HWiA 2015 and earlier years' data compilations used hazardous waste arisings rather than adjusted generation to estimate annual waste production figures. Figure 2 reproduces the information of Table 2 in graphical form, allowing easier identification of the relative scale and contribution of each waste group, including jurisdictional proportions.

Figure 3 provides a similar graphical breakdown but at the finer grained level of the NEPM 72 waste types. Figure 4 and Figure 5 also present tabulated data in graphical form, as total hazardous waste generation per jurisdiction, both including and excluding biosolids.

[19] The differences between the terms 'arisings' and 'generation', and which situations each are best suited for, are explained further in Section 1.4.2 and summarised briefly in the glossary at the front of this report.

Table 2 Adjusted generation of hazardous waste by waste group, Australia 2019-20 (tonnes by jurisdiction)

Code	Description	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	AUSTRALIA
A	Plating and heat treatment	0	66	0	5,584	67	0	20	1,218	6,954
B	Acids	0	7,010	1,126	12,179	1,178	6	37,302	2,185	60,987
C	Alkalis	0	18,555	519	103,775	14,430	7	9,266	110,990	257,542
D110	Inorganic fluorine (spent potliner)	0	15,386	0	11,997	0	3,788	6,398	2	37,572
D120	Mercury and compounds	8	35	18	176	136	23	175	638	1,209
D220	Lead and compounds	57	44,169	1,926	39,931	7,409	123,181	41,587	8,190	266,450
D230	Zinc compounds	0	8,921	0	564	64	148,489	3,704	417	162,159
D300	Non-toxic salts	0	11,344	19	20,430	280	5	5,023	49,209	86,309
Other D	Other inorganic chemicals	0	412	35	3,669	159	0	926	148	5,350
E	Reactive chemicals	0	68	2	48	14	0	153	5	290
F	Paints, resins, inks, organic sludges	144	11,776	388	15,032	1,992	16	58,821	179,424	267,594
G	Organic solvents	17	2,023	20	3,217	417	144	6,824	2,902	15,564
H	Pesticides	0	536	7	334	444	0	1,729	1,127	4,177
J100 & J160	Oils	2,016	88,828	10,587	67,960	15,925	20,076	72,197	95,711	373,301
J120	Waste oil/water mixtures	485	52,021	9,379	107,956	18,782	178	52,348	34,029	275,178
K110	Grease trap wastes	2,614	86,850	2,633	145,227	18,926	5,778	116,014	62,802	440,845
Other K	Other putrescible / organic wastes	2,008	44,366	1,323	98,696	1,309	2,901	58,300	34,089	242,994
M100	PCB wastes	23	678	0	2,588	42	15	1,145	177	4,668
M160	Other organic halogen compounds	0	100	451	89	42	0	3,884	1	4,568
M270	PFAS contaminated materials	0	1,890	0	7,119	63	0	683	84	9,839
Other M	Other organic chemicals	6	2,918	7	8,680	25	0	3,544	2,630	17,811
N120	Contaminated soils	22,401	839,863	2,334	353,303	220,577	84,417	1,054,877	4,670	2,582,442
N205a	Biosolids	0	441,355	16,434	340,872	231,811	71,401	522,166	180,111	1,804,148
N205b	Other industrial treatment residues	1	14,418	15	86,645	33,045	0	38,396	23,471	195,991
N220	Asbestos containing material	12,417	904,498	17,435	150,137	36,083	3,258	178,502	24,172	1,326,503
Other N	Other soil/sludges	20	40,958	309	23,980	2,030	575	24,868	1,526	94,266
R	Clinical and pharmaceutical	265	10,971	1,216	12,699	5,152	53	17,541	3,126	51,025
T140	Tyres	5,500	136,638	4,900	102,000	31,200	11,000	113,400	61,400	466,038
Other T	Other miscellaneous	30	3,582	10	2,053	227	41	1,256	117	7,314
Other	(Not classified)	0	410	0	75,349	94	0	0	36,275	112,128
Totals (inclusive of biosolids)		**48,014**	**2,790,644**	**71,094**	**1,802,288**	**641,927**	**475,352**	**2,431,051**	**920,844**	**9,181,214**
		0.52%	30%	0.77%	20%	7.0%	5.2%	26%	10%	
Totals (exclusive of biosolids)		**48,014**	**2,349,289**	**54,660**	**1,461,416**	**410,116**	**403,951**	**1,908,885**	**740,734**	**7,377,065**
		0.65%	32%	0.74%	20%	5.6%	5.5%	26%	10%	

Table 3 Arisings of hazardous waste by waste group, Australia 2019-20, (tonnes by jurisdiction)

Code	Description	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	AUSTRALIA
A	Plating and heat treatment	0	4	0	5,646	67	0	20	1,218	6,954
B	Acids	0	26,041	0	12,217	1,194	0	18,273	2,175	59,901
C	Alkalis	0	19,029	0	103,790	14,501	0	8,830	110,972	257,122
D110	Inorganic fluorine (spent potliner)	0	15,386	0	5,932	0	3,788	453	2	25,561
D120	Mercury and compounds	0	43	0	178	139	0	175	638	1,172
D220	Lead and compounds	0	56,951	0	29,626	129,459	0	16,175	751	232,961
D230	Zinc compounds	0	14	0	564	161,097	0	67	417	162,159
D300	Non-toxic salts	0	13,530	0	20,461	807	0	2,286	49,209	86,292
Other D	Other inorganic chemicals	0	356	0	3,678	163	0	969	148	5,314
E	Reactive chemicals	0	64	0	55	16	0	149	5	290
F	Paints, resins, inks, organic sludges	0	12,558	0	15,757	4,588	0	54,930	179,381	267,213
G	Organic solvents	0	2,023	0	4,287	481	0	7,404	3,516	17,711
H	Pesticides	0	263	0	694	375	0	1,726	1,115	4,173
J100 & J160	Oils	0	43,466	0	92,314	14,955	0	40,189	95,579	286,502
J120	Waste oil/water mixtures	0	58,090	0	109,461	18,939	0	71,297	41,630	299,416
K110	Grease trap wastes	0	5,038	2,633	148,577	19,211	5,778	115,886	73,326	370,449
Other K	Other putrescible / organic wastes	0	1,430	1,323	100,224	1,309	2,901	57,466	34,089	198,743
M100	PCB wastes	0	1,038	0	2,388	8	0	1,047	177	4,658
M160	Other organic halogen compounds	0	60	0	365	42	0	3,649	1	4,117
M270	PFAS contaminated materials	0	0	0	9,585	63	0	116	84	9,848
Other M	Other organic chemicals	0	2,923	0	8,676	131	0	3,445	2,630	17,804
N120	Contaminated soils	0	838,866	0	351,522	223,699	0	1,054,610	4,668	2,473,365
N205a	Biosolids	0	441,355	16,434	340,872	231,811	71,401	522,166	180,111	1,804,148
N205b	Other industrial treatment residues	0	8,123	0	88,398	42,017	0	34,007	23,471	196,015
N220	Asbestos containing material	12,417	899,534	17,435	154,918	35,694	0	178,670	24,165	1,322,834
Other N	Other soil/sludges	0	37,649	0	27,441	2,051	0	24,746	1,525	93,412
R	Clinical and pharmaceutical	0	1,643	0	13,857	5,101	0	17,807	2,954	41,361
T140	Tyres	5,500	613	4,900	66,667	10,670	11,000	0	37,142	136,492
Other T	Other miscellaneous	0	3,608	0	2,062	227	0	1,256	117	7,269
Other	(Not classified)	0	0	0	75,412	0	0	441	36,275	112,128
Totals (inclusive of biosolids)		**17,917**	**2,489,695**	**42,725**	**1,795,624**	**918,814**	**94,868**	**2,238,254**	**907,489**	**8,505,387**
		0.21%	29%	0.50%	21%	11%	1.1%	26%	11%	
Totals (exclusive of biosolids)		**17,917**	**2,048,340**	**26,291**	**1,454,752**	**687,004**	**23,467**	**1,716,088**	**727,379**	**6,701,238**
		0.27%	31%	0.39%	22%	10%	0.35%	26%	11%	

Figure 2 National hazardous waste generation, 2019-20 (tonnes) – by waste group and jurisdiction (including biosolids)

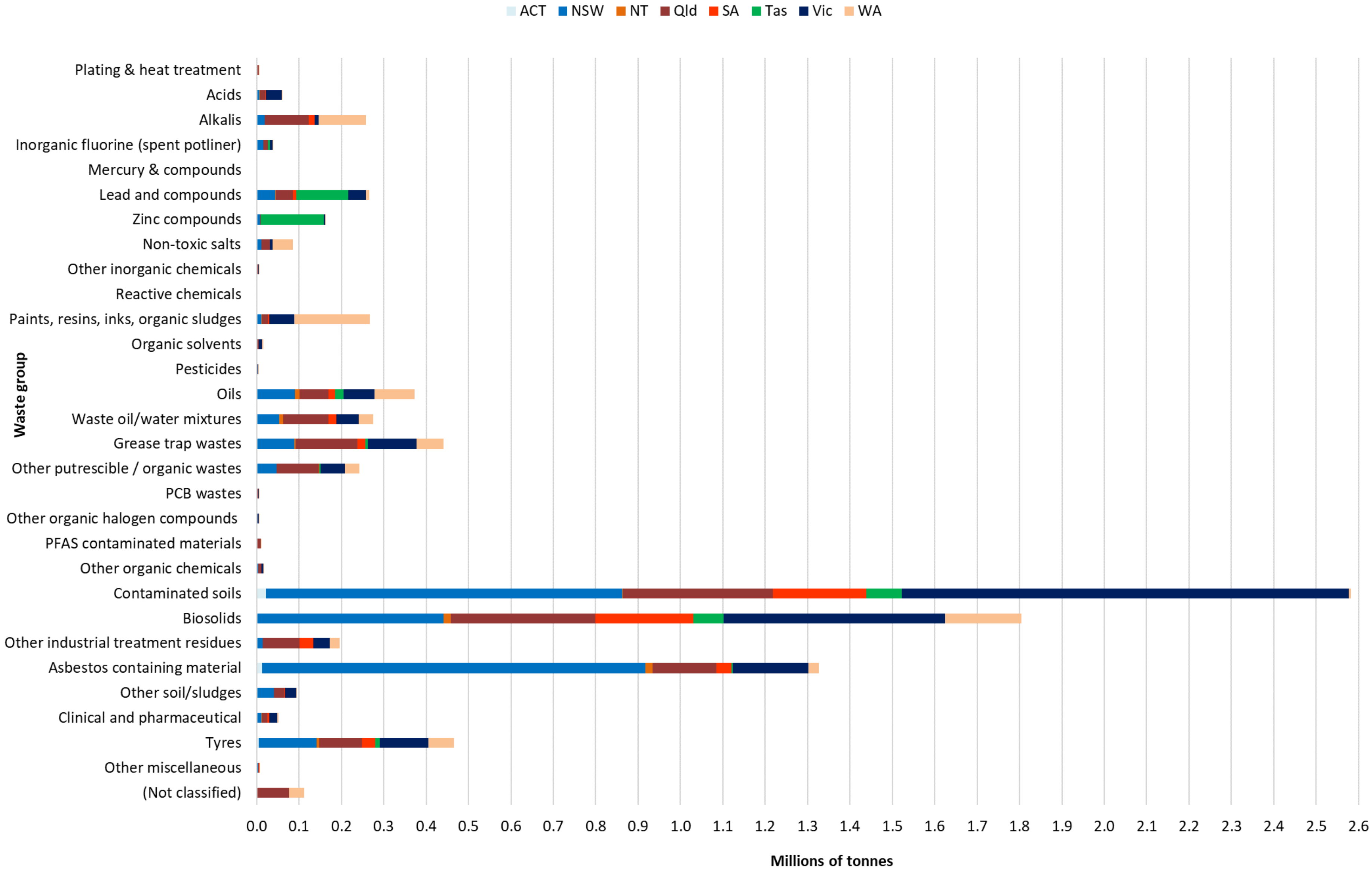


Figure 3 National hazardous waste generation, 2019-20 (tonnes) – by NEPM 72 waste types (top half of chart: linear display; bottom half: logarithmic display)

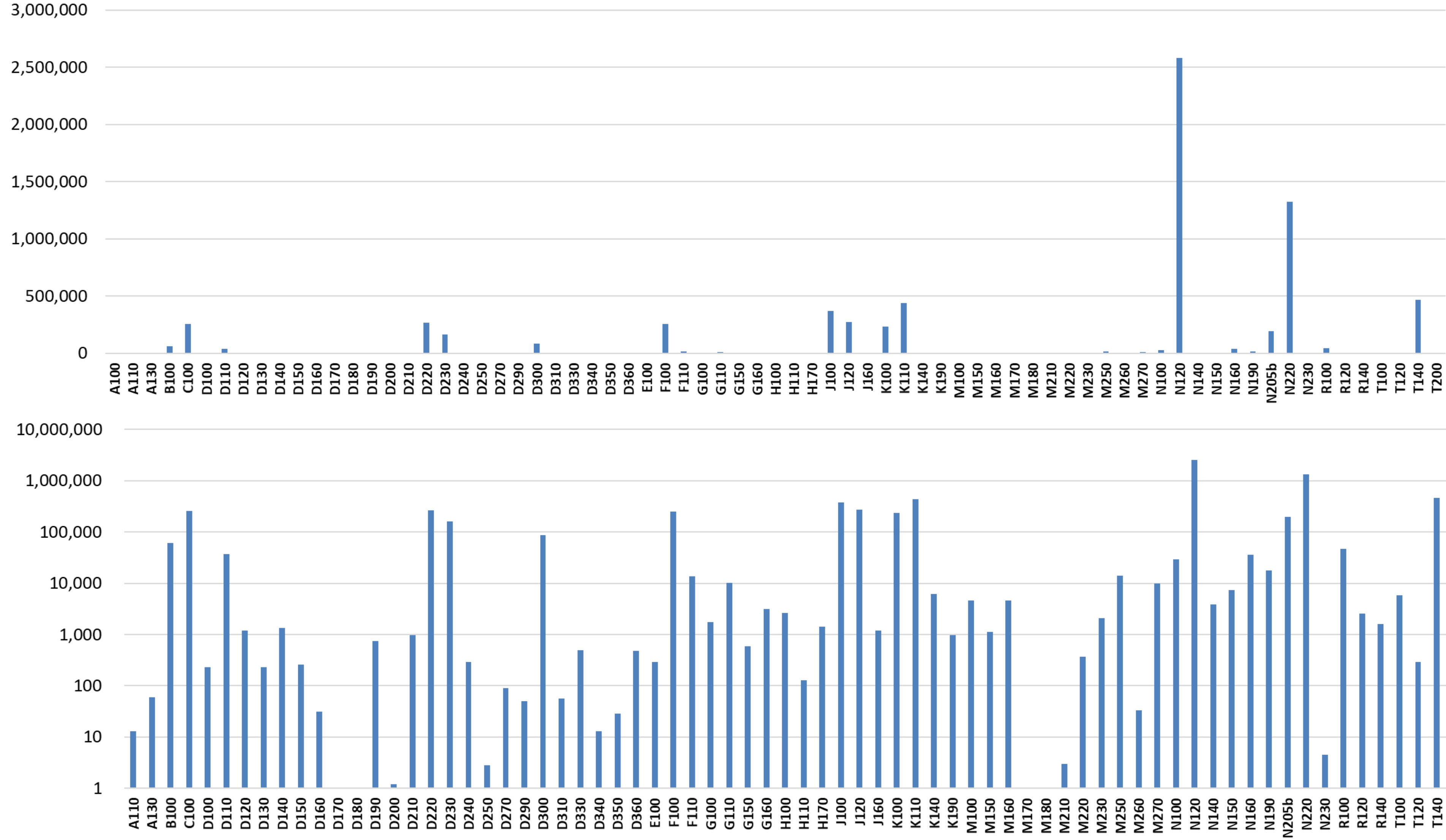


Figure 4 National hazardous waste generation, 2019-20 (tonnes) – by jurisdiction (including biosolids)

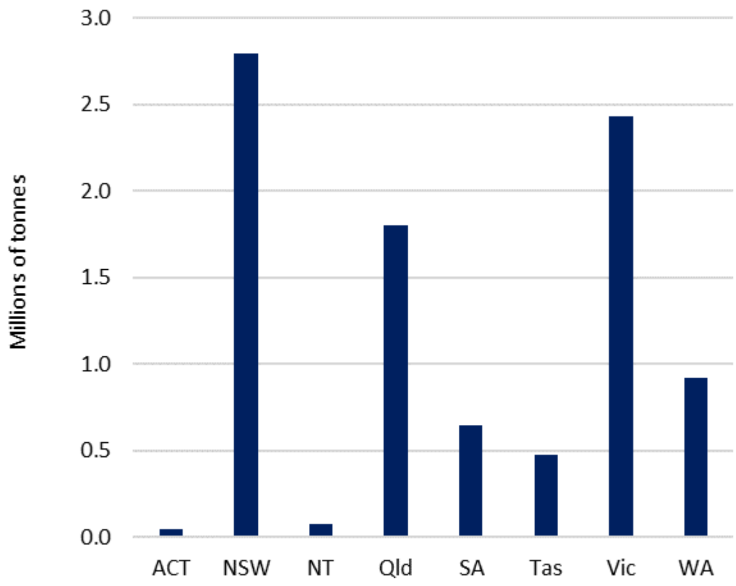
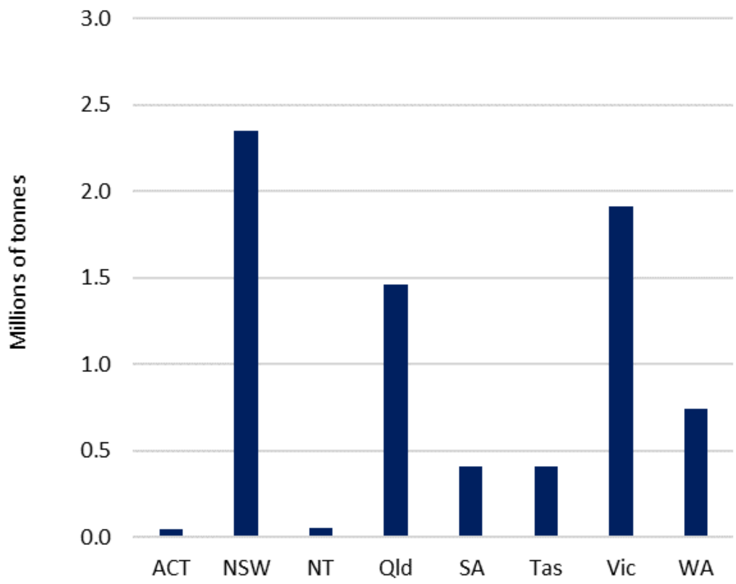


Figure 5 National hazardous waste generation, 2019-20 (tonnes) – by jurisdiction (excluding biosolids)



3.2 Sources of waste arisings

Source industry sector data, in the form of Australia and New Zealand Standard Industrial Classification (ANZSIC) codes, shows which industries generate each waste. This is vital to understand the nature of the market, what might be driving future trends (to enable meaningful projections), and where to focus policy initiatives designed at reducing waste at the source.

ANZSIC code data – generally called 'waste origin codes' on waste transport certificates- was sparingly provided in 2019-20, according to Table 4.

Table 4 Total percentage of tonnes for which source sector is known

Jurisdiction	% tonnes that has source data	Comment
ACT	Not available	No intrastate tracking system
NSW	-	Not completed for 2019-20 as virtually no data is available
NT	Not available	No intrastate tracking system
Qld	-	Incomplete dataset for 2019-20 so not analysed for sources
SA	79	Best jurisdictional coverage of source sector data available for 2019-20
Tas	Not available	No intrastate tracking system
Vic	12	Source sector data insufficiently populated to be useable
WA	0	No source data supplied at all

Only SA data was of sufficient coverage to attempt quantitative analysis in 2019-20, with 79% of all tonnes generated provided with an ANZSIC code identifier. This means that outside SA, source data recorded in 2019-20 waste transport certificates was not useful for analysis purposes. To counter this, we have re-used a manual method of sorting tracking data for Vic and NSW, and carried out on 2017-18 data for HWiA 2019. Specifically:

- For NSW and Vic 2017-18 data, (for key wastes) we manually sorted through individual waste transport certificates by major waste generator company names, sufficient to account for around 80% of the tonnes, then allocated ANZSIC codes to these key generators using research and industry knowledge. Since this has been derived from a highly manual data-parsing method, some waste groups' sources have been described in qualitative terms only. This has been re-used as indicative for 2019-20 data.
- For Qld data, semi-quantitative analysis of waste transport certificate raw data, with a focus on correlating waste generating company names with their likely industry sectors, listing industry sources in approximate order of highest to lowest arisings tonnages.
- For SA data, used source analysis directly from waste transport certificates for 2019-20, listing industry sources in order of highest to lowest arisings tonnages.
- For WA data, no source data is supplied so no analysis can be undertaken, apart from that obtained from existing industry knowledge (which is discussed in text where known and appropriate).
- National summary, a collation of the four state source sector lists, with indicative ordering of relative tonnages across the four jurisdictions.

Since Tas, NT and the ACT do not have intrastate tracking, no breakdown of their data by source was possible, other than from existing industry knowledge (which is discussed in text where known and appropriate).

This approach has provided a reasonable level of clarity around source sectors. Appendix B Sections B1 to B28 provide detailed analysis on a waste group by waste group basis and uses this state-based approach to list main sources, in tabular form. An example for *C. Alkali waste* is shown below.

Table 5 Example summary source analysis for C Alkalis, 2019-20

NSW	Vic	Qld	SA	National Summary
• 78% Industrial gas manufacturing • 10% Iron smelting and steel manufacturing • 3% Petroleum refining and petroleum fuel manufacturing	• Petroleum refining and petroleum fuel manufacturing • Metal coating and finishing • Motor vehicle parts manufacturing • Waste collection, treatment and disposal services	• Ready-mixed concrete manufacturing • Asphalt manufacturing • Oil and gas extraction (CSG/LNG) • Aluminium refining	• 91% Basic chemical manufac-turing	• Ready-mixed concrete manufacturing • Asphalt manufacturing • Oil and gas extraction (CSG/LNG) • Aluminium refining • Basic chemical manufacturing • Industrial gas manufacturing • Petroleum refining and petroleum fuel manufacturing

The sources of arisings data at the ANZSIC division, sub-division and group levels, as recorded in jurisdictional tracking systems, are provided for NSW, Qld, SA and Vic in the underlying data file, *National hazwaste data collation 2019-20*, in the worksheets labelled '[State] in'. However, as noted in the discussion in this section, jurisdictional input industry source data is mostly unreliable, and so is not presented in this report.

3.3 Historical trends

This section discusses national trends of reported national hazardous waste quantities, while Appendix B lays out trends in waste arisings at a waste group-specific level.

Previous editions of HWiA have provided a summarised view of the national trend in hazardous waste arisings, but this is an incomplete picture because:

- arisings are from tracking system data only, which means data from jurisdictions lacking tracking systems (Tas, ACT and NT) is not included
- some wastes not well collected by tracking systems (such as tyres and grease trap waste) are absent
- NSW's historical record of quality-assured data only goes back to 2010-11, which is a shorter period than data available for other states and shortens the historical window for all data.

Plotting a reliable historical trend is further complicated by more contemporary issues:

- Qld tracking data is only verified as complete up to October 2016. This caveat is discussed in detail in Appendix B and means that Qld arisings trendlines from 2016-17 onwards are not necessarily reliable.
- The methods adopted in 2019-20, for adjustments from arisings to generation and a number of other data additions, corrections and calculations, are different to how data was treated historically across the period because of improvements and iterations. This has been the overarching reason of why arisings have been chosen to illustrate trends, because raw tracking data is mostly unaffected by these method changes, however arisings suffer the shortfalls mentioned above.

To solve these difficulties, HWiA 2021 provides, for the first time, a 'back-cast' of the historical record of hazardous waste generation by financial year, constructed to be method-consistent as much as can practically be achieved with available historical data and knowledge. The *Hazwaste generation historical data set 2019-20* (provided as an accompanying Excel workbook to this report) is a definitive historical record of hazardous waste generation from 2006-07 to 2019-20, encompassing all states and territories and all hazardous wastes currently reported.

The Qld data caveat has led to instances of data adjustment, according to the method described in Appendix B, for some Qld data that met the adjustment criteria from 2016-17 to 2019-20. These adjustments are included in the historical record.

A historical record of hazardous waste generation is plotted in Figure 6, showing the long-term national trend and jurisdictional contributions. Since 2006-07, hazardous waste generation has exhibited a strong upward trend nationally, with Vic and NSW experiencing the most rapid growth, particularly in the more recent period (2014-15 onwards). This trend calculates to a compound annual growth rate of 3.4% per year over the entire period (2006-07 to 2019-20) and 6.3% per year from 2014-15 to 2019-20.

The rate of growth in hazardous waste numbers is higher than for non-hazardous waste: when expressed as a total increase from 2006-07 to 2019-20, hazardous wastes grew by 54%, while all waste in Australia grew by 18% according to the *National Waste Report 2020* [20].

The major contributors to this post-2014-15 surge were asbestos (almost all in NSW) and contaminated soil (mostly in Vic and Qld). Figure 7 segments the historical record into three groups: contaminated soils, asbestos and other, which corresponds to all other hazardous wastes combined.

Another notable feature of all three charts is the slowing of the trend in 2018-19 followed by a fall in 2019-20. This is largely a function of NSW asbestos volumes, but this reduction in 2019-20 volumes was also caused by a large fall in Qld contaminated soil quantities, down 57% on that state's 2018-19 reported tonnages. Offsetting these 2019-20 falls was Vic's sharp growth in 2019-20, driven by its contaminated soil volumes, which grew a further 42% on 2018-19, on top of an already unprecedented growth period in that waste from 2014-15.

While hazardous waste quantities overall declined in 2019-20 (which is not surprising given the levels of sustained increases since 2014-15) the long-term growth trend remains unaffected.

These waste and jurisdiction-specific trend aspects are examined in detail in Appendix B Sections B1 to B28.

Figure 8 shows the national trend with contaminated soils and asbestos removed. It also suggests a rising trend, with some fluctuation along the way, but less pronounced than in Figure 6. The compound annual growth rate when contaminated soils and asbestos are excluded (2006-07 to 2019-20) is 2% per year.

The near-future market is likely to see significant further change due to emerging wastes (discussed in Section 4), and a tightening regulatory setting in response. This has already been seen in recent years with respect to PFAS wastes.

[20] Blue Environment (2020) National Waste Report 2020, prepared for the Department of Agriculture, Water and the Environment, available at: *https://www.environment.gov.au/protection/waste/national-waste-reports/2020*.

Figure 6 Historical record of national generation of hazardous wastes in Australia, 2006-07 to 2019-20 (excluding biosolids)

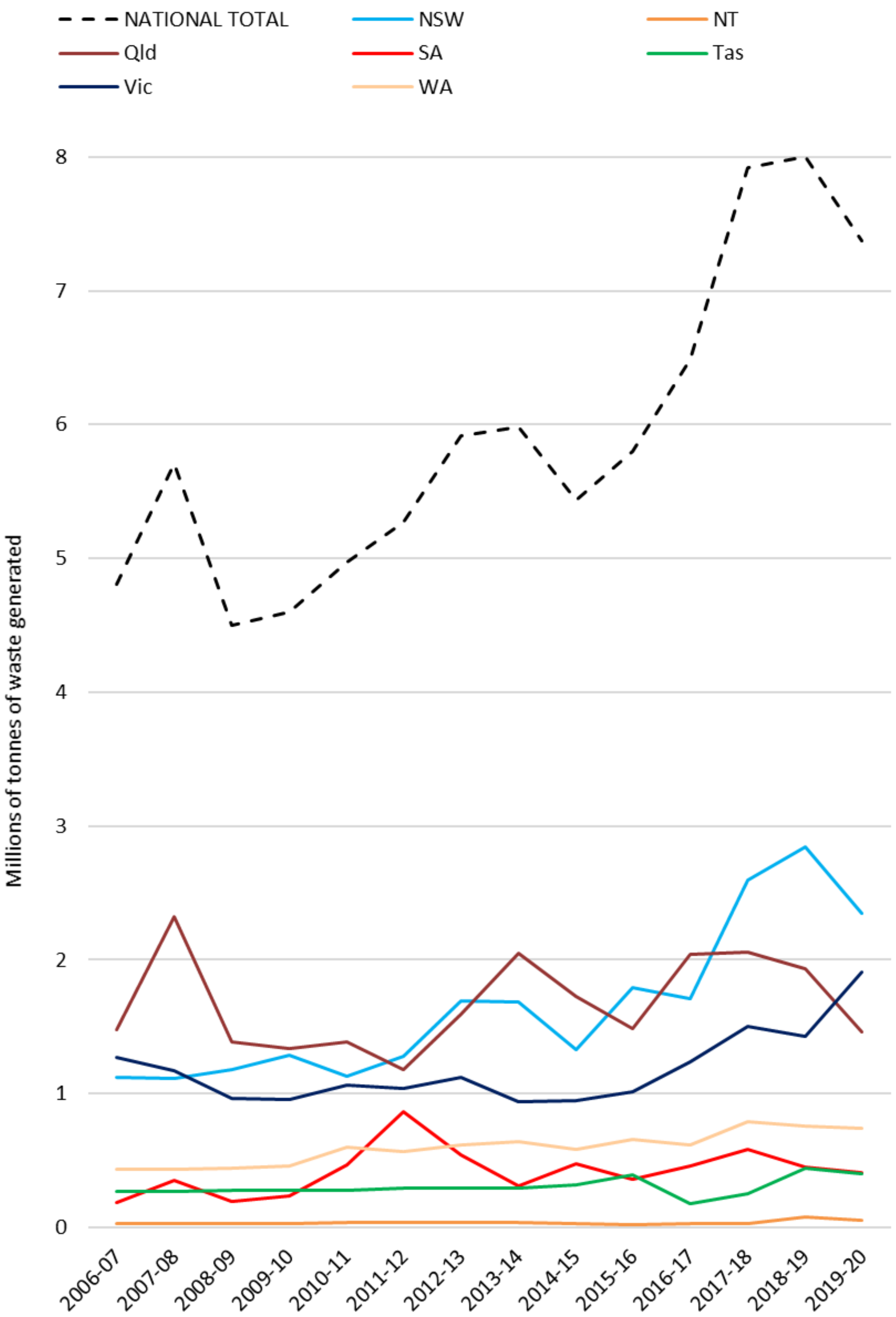


Figure 7 Historical record of national generation of contaminated soil, asbestos and other (hazardous) wastes in Australia, 2006-07 to 2019-20 (excluding biosolids)

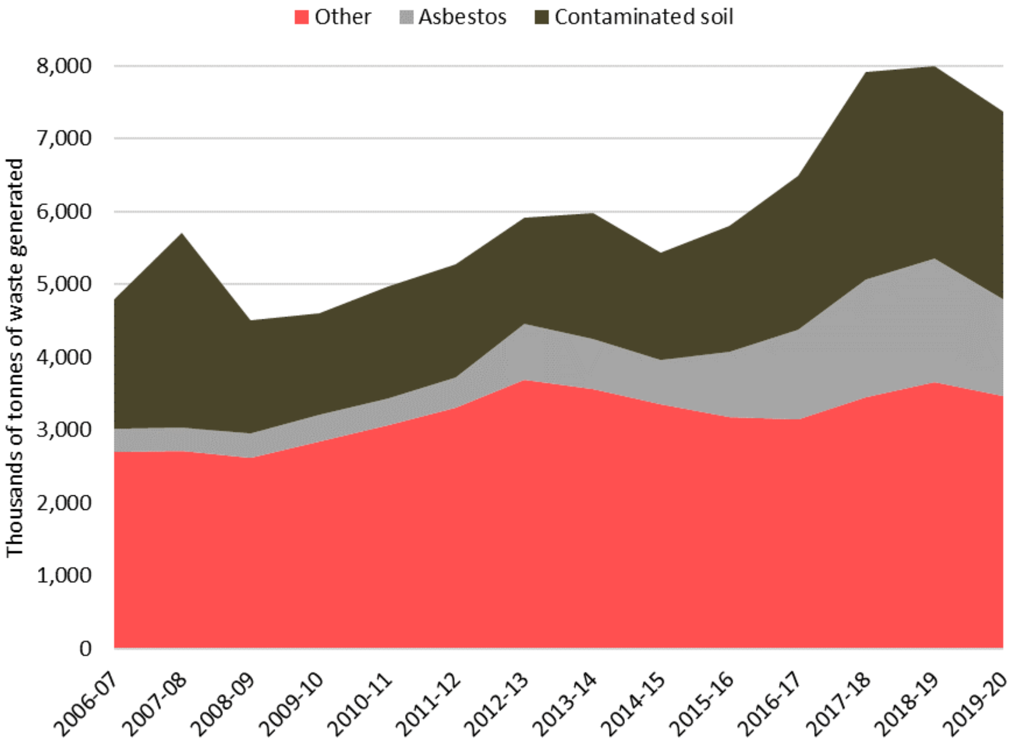
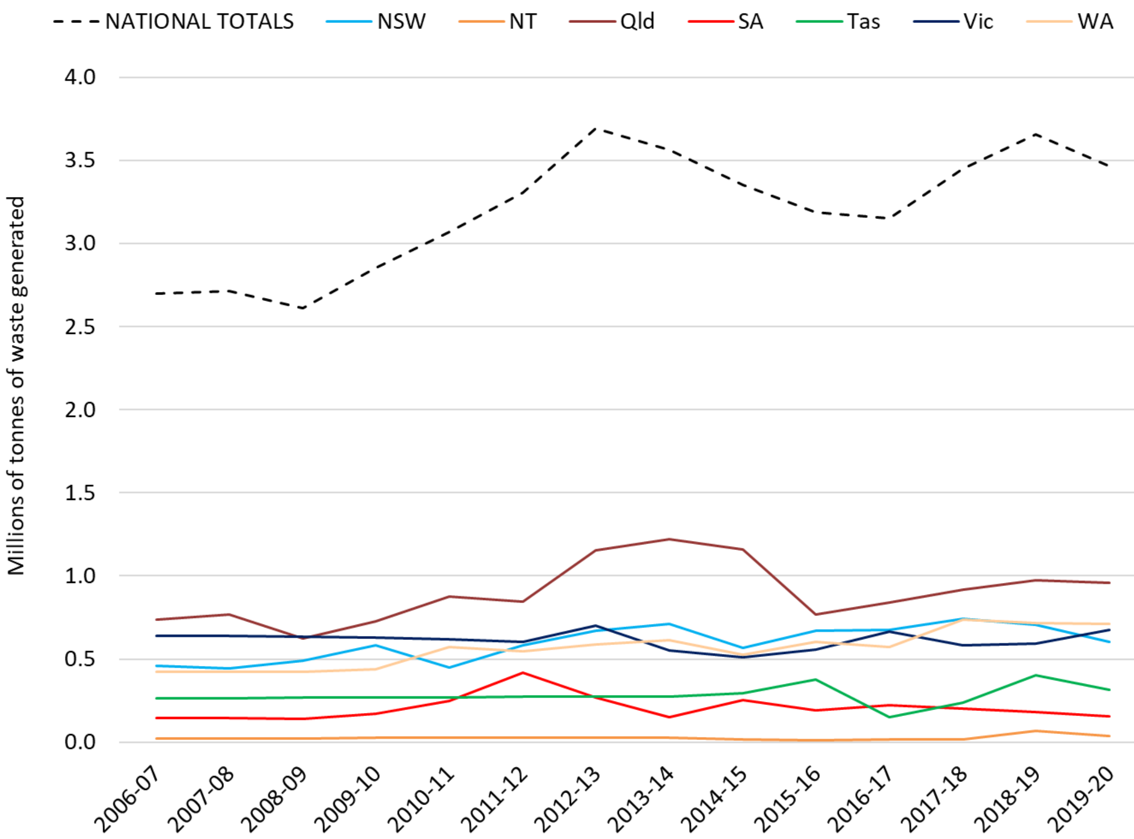


Figure 8 Historical national arisings of hazardous wastes tracked in Australia, by jurisdiction (excluding contaminated soils and asbestos)



3.4 Management of hazardous wastes (NSW, Qld, SA, Vic and WA)

Jurisdictional tracking system data was analysed to determine the management types (fates and pathways to them) recorded for each waste group in the data. Management data was comprehensively available from NSW, Qld, SA, Vic and WA. The overall tonnes by management in these jurisdictions was compiled for 2019-20 and is presented in Table 6 and Figure 9. These tonnages, in relative percentage terms within each waste group, are charted in Figure 10.

Although assembled at a much greater level of detail, some manipulation of Qld and Vic data was needed to transform management data to uniform national categories, which are based on the NSW and SA systems, the lowest common denominator of categories tracked. These management categories do not align neatly with those reported in national waste reporting (recycling, energy recovery and disposal).

The potential for multiple counting should be considered in interpreting the data. For example, waste that is sent to CPT may be landfilled after treatment and the tonnage would be included under both management categories in the figure below.

Figures 12-16 plot overall tonnage by management for each of the five jurisdictions where this data is tracked, compiled for 2019-20. Note that the scale for each of these figures differ, to ensure appropriate detail can be seen in each.

Management data is examined in more detail by waste group in Appendix B, where a greater understanding can be gained about the management of each waste for Qld and Vic in particular, which track management type to a much finer degree of categorisation than other jurisdictions.

Table 6 The management of tracked hazardous waste in NSW, Qld, SA, Vic and WA, 2019-20 (tonnes)

Code	Description	Recycling	Chemical/ physical treatment	Biodegradation	Landfill	Thermal destruction	Storage or transfer	Other
A	Plating and heat treatment	66	1,300	6	422		710	
B	Acids	400	34,309	49	107	610	1,919	14,252
C	Alkalis	77,433	29,832	60,597	25,453		51,676	12,132
D110	Inorganic fluorine (spent potliner)	5,705	15,553	206	0		310	0
D120	Mercury and compounds	30	141	0			835	0
D220	Lead and compounds	160,011	53,578	197	1,080		13,847	4,247
D230	Zinc compounds	153,490	224		24	7,893	85	0
D300	Non-toxic salts	28,973	2,612	25,379	6,351		1,646	1,551
Other D	Other inorganic chemicals	79	1,179	25	107		747	9
E	Reactive chemicals	2	99				152	5
F	Paints, resins, inks, organic sludges	19,159	22,223	283	177,290	84	37,014	1,194
G	Organic solvents	5,491	4,370	130	87	88	5,501	688
H	Pesticides	1,085	727	42	1,406		749	79
J100 & J160	Oils	157,688	67,877	15,002	510	6	71,427	12,328
J120	Waste oil/water mixtures	36,263	147,622	5,499	1,163	61	103,687	5,122
K110	Grease trap wastes	135,502	119,572	125,238	2,587	76	58,414	2,579
Other K	Other putrescible / organic wastes	110,056	4,843	44,824	807	19	11,469	177
M100	PCB wastes	340	1,882		633	1	186	179
M160	Other organic halogen compounds	118	938		53	20	2,063	925
M270	PFAS contaminated materials	20	207		8,540	269	477	188
Other M	Other organic chemicals	537	4,075	186	25		5,041	33
N120	Contaminated soils	83,010	459,436	3,331	1,807,260		47,966	72,363
N205b	Other industrial treatment residues	13,091	51,164	10,737	46,051		31,749	83
N220	Asbestos containing material	19	2,484		1,260,461		941	493
Other N	Other soil/sludges	8,001	8,383	48	52,401	21	6,690	893
R	Clinical and pharmaceutical	49	15,777	1	426	15,810	5,608	1,513
T140	Tyres	155,006			125,547		4,967	163,952
Other T	Other miscellaneous	303	989	90	1	15	4,166	36
Other	(Not classified)	3,866	9,995	14,255	240	34	35,898	3,643
Total		**1,155,794**	**1,061,390**	**306,124**	**3,519,031**	**25,007**	**505,941**	**298,664**

Yellow shading indicates management types where a majority (the largest proportion) of a waste type has been sent

Figure 9 Management of tracked hazardous waste in NSW, Qld, SA, Vic and WA, 2019-20 (tonnes)

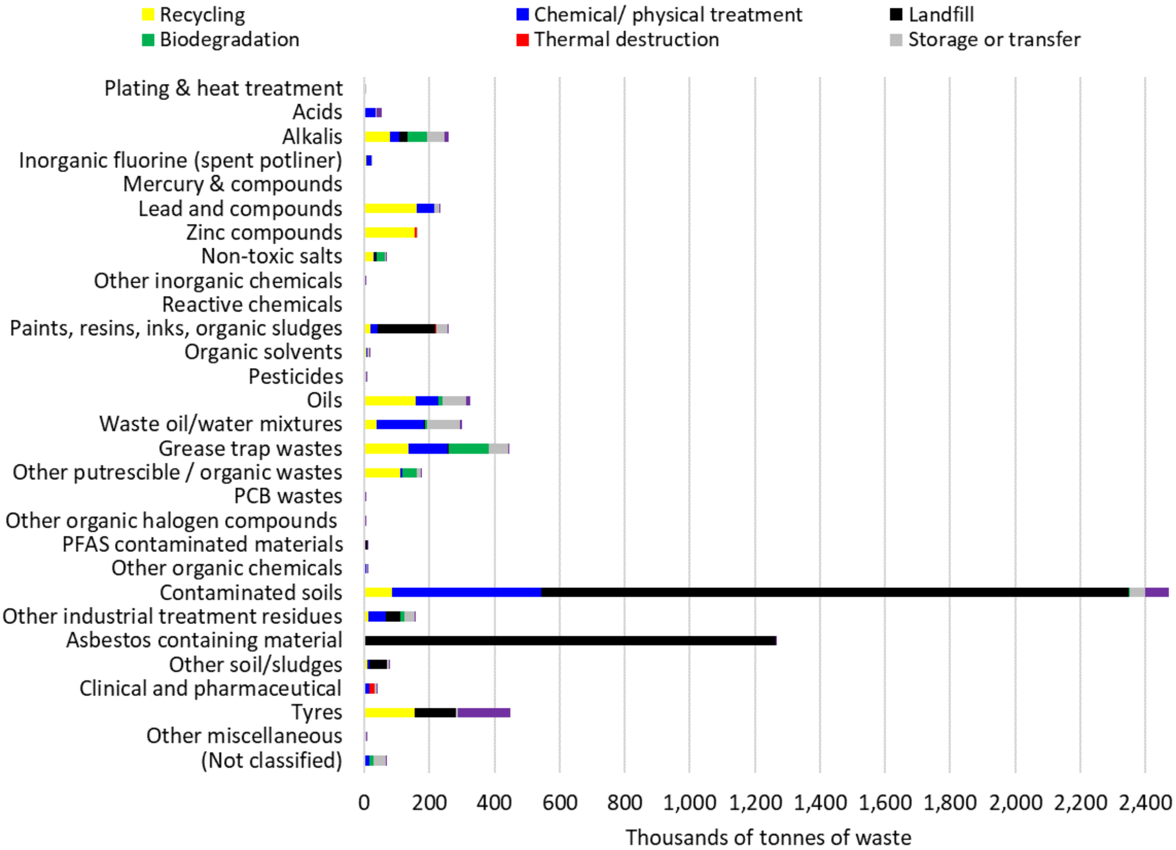


Figure 10 Management of tracked hazardous waste in NSW, Qld, SA, Vic and WA, 2019-20 (percentages)

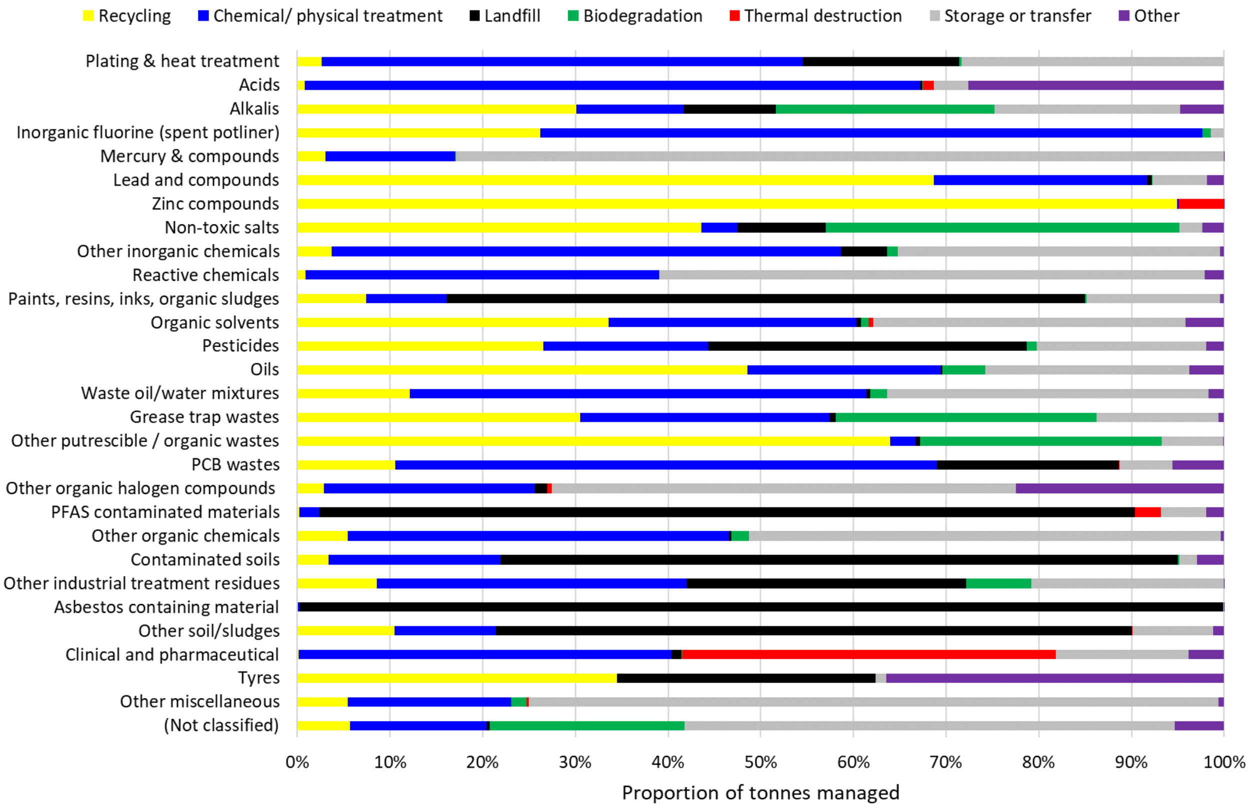


Figure 11 The management of tracked hazardous waste in NSW, 2019-20 (tonnes)

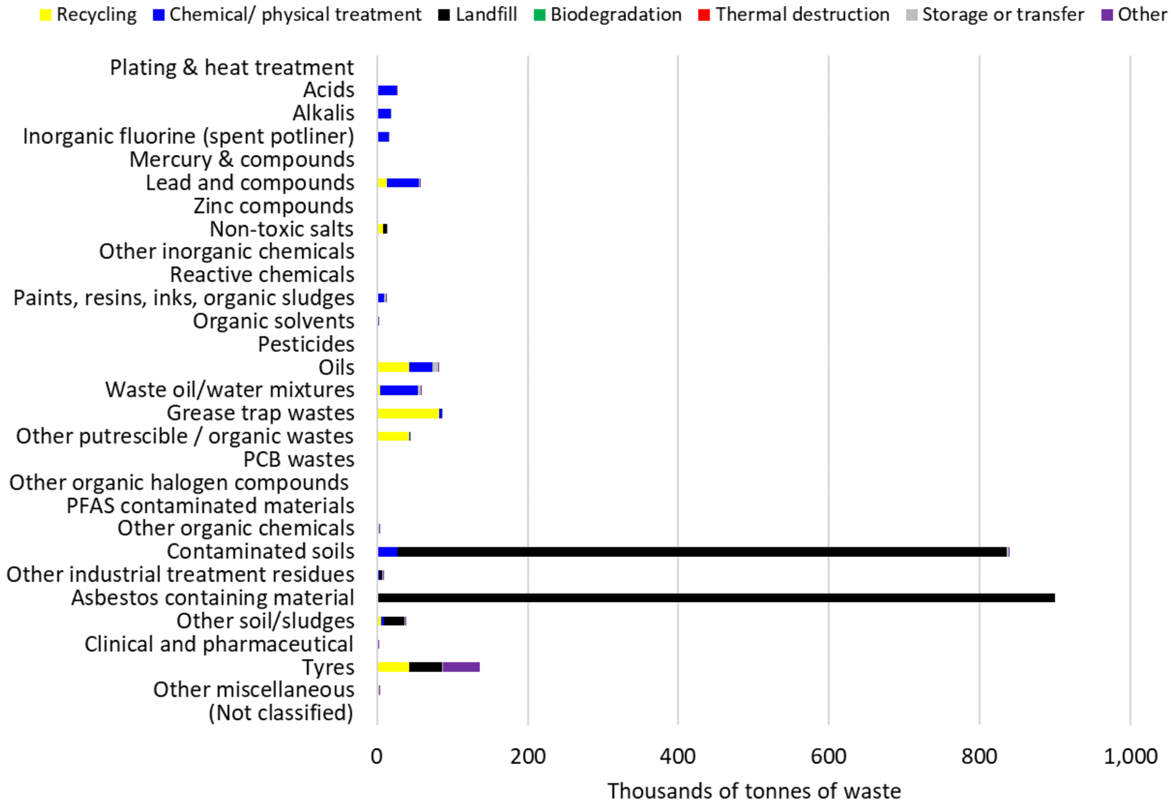


Figure 12 The management of tracked hazardous waste in Qld, 2019-20 (tonnes)

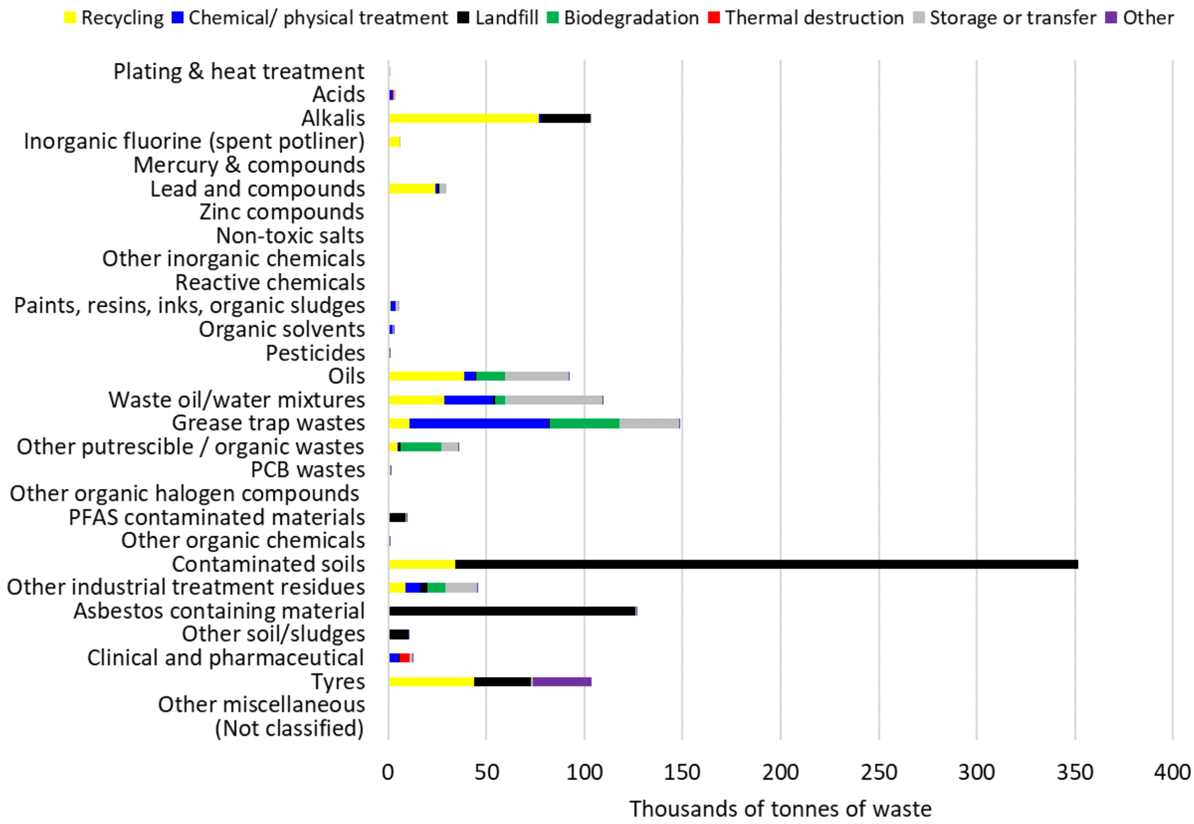


Figure 13 The management of tracked hazardous waste in SA, 2019-20 (tonnes)

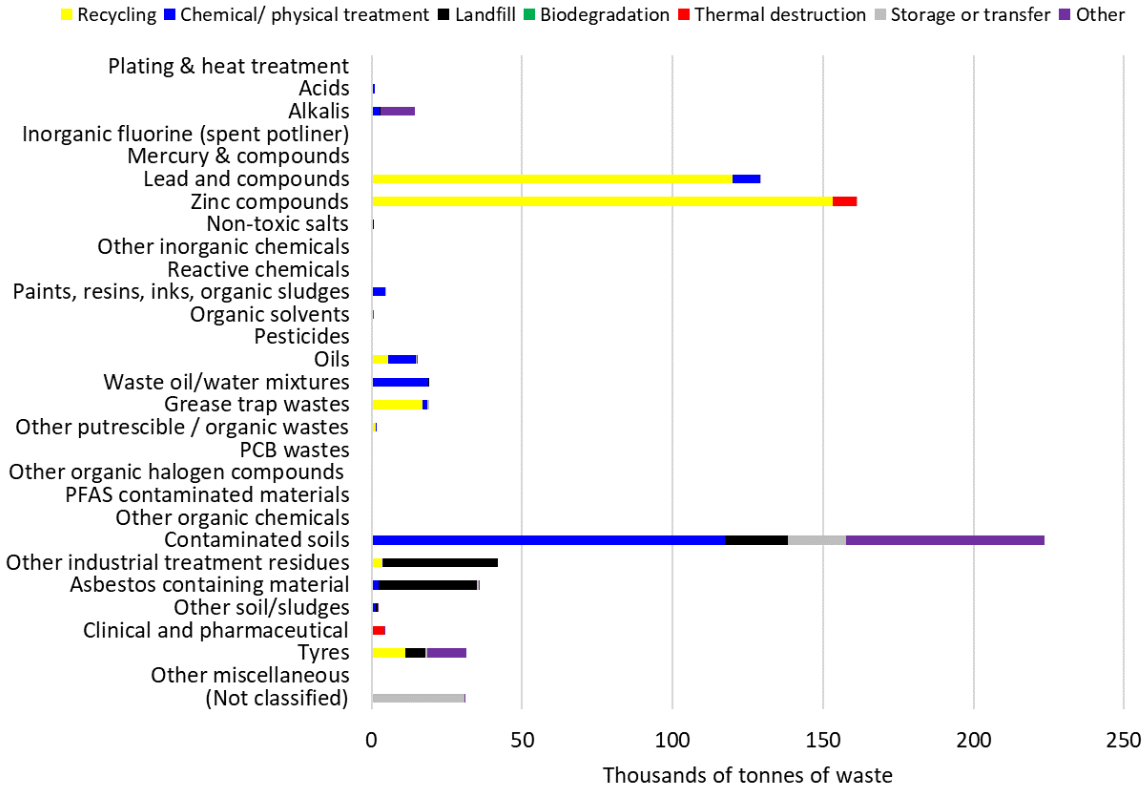


Figure 14 The management of tracked hazardous waste in Vic, 2019-20 (tonnes)

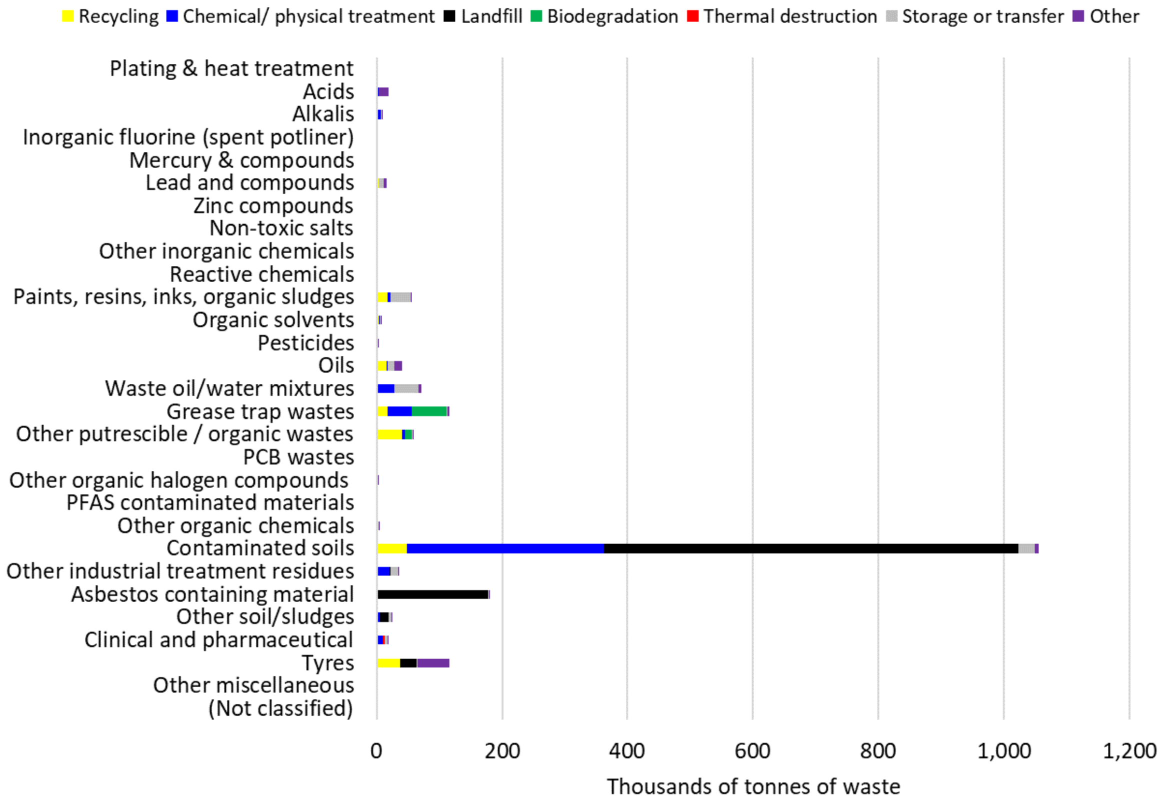
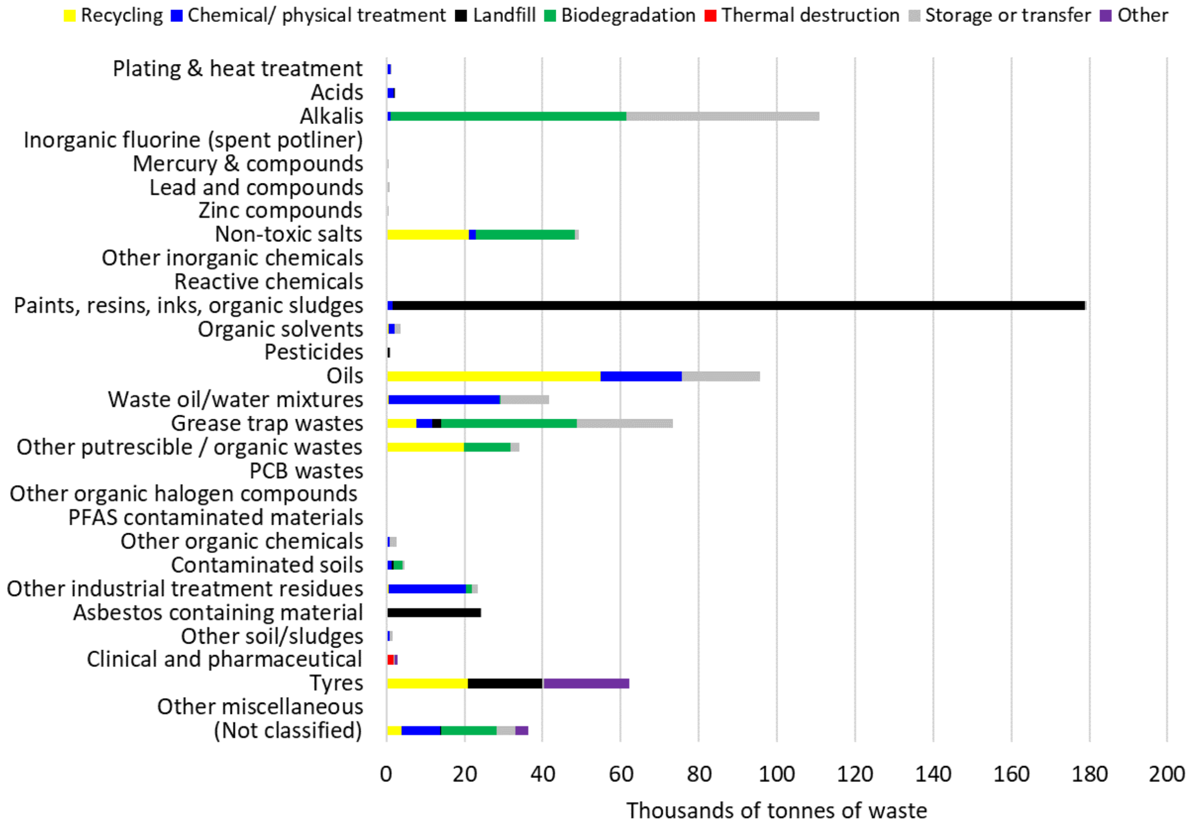


Figure 15 The management of tracked hazardous waste in WA, 2019-20 (tonnes)



4. Current and emerging challenges

This section considers some of the challenges currently facing the hazardous waste management system, as well as some emerging concerns deserving of greater attention. Content discussed includes:

- how COVID-19 has impacted hazardous waste management, albeit caveated by the fact that the data reporting year (2019-20) coincided only with the beginning of the pandemic
- various contemporary issues regarding the emergence of PFAS wastes in the hazardous waste management system and challenges facing their management
- the consequences of unintended contaminants in waste and their potential for re-entrainment in products or pollution of the environment
- a specific focus on the contaminants found in plastics, which can find their way into the environment through waste disposal
- lithium-ion batteries – a waste problem that has not been solved and will not go away
- the ageing of current, and the emergence of new and planned, infrastructure for hazardous waste management in Australia over the last two years, and how these changes might relate to other issues discussed above
- a brief look to the medium-term future of other emerging hazardous waste issues.

4.1 COVID-19 impacts to hazardous waste management

The COVID-19 pandemic has touched virtually everyone on the planet in some way, from early 2020 to the time of writing. The hazardous waste system, both generation-side and management-side have felt COVID-19 related impacts. The data collected for this report covers 2019-20, which only captures the early stages of the pandemic.

The most obvious impacts to consider were clinical waste volumes, from healthcare and aged care facilities in particular, where discarded COVID-19 personal protective equipment (PPE) added significantly to business-as-usual volumes disposed into clinical waste collection bins. These are deemed direct impacts.

However, there were also other impacts that affected the sector, such as reduced waste supply due to shutdown impacts on waste generating industries and other disruptive impacts to particular industries creating knock-on effects relevant to hazardous waste management. As with other workplaces, some waste infrastructure staff moved to work from home arrangements.

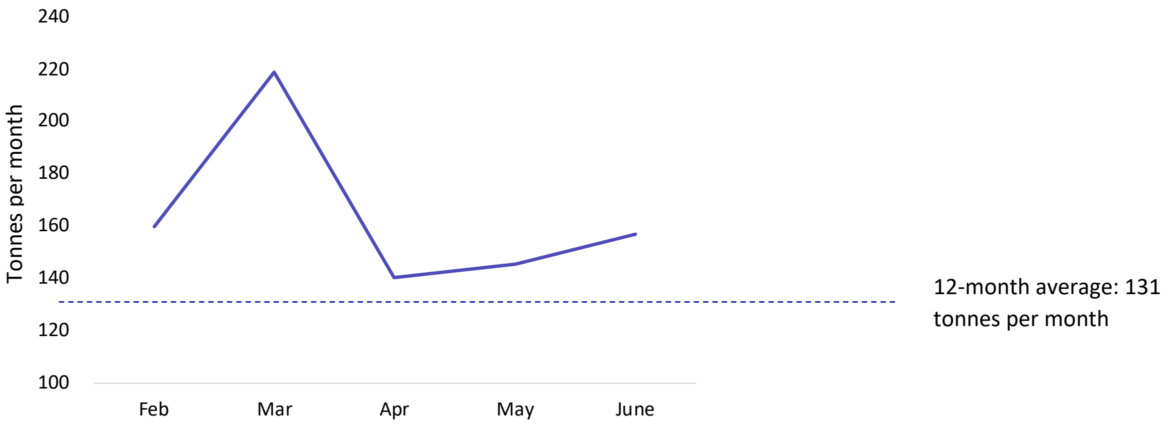
4.1.1 Direct impacts – how the clinical waste management industry coped

The waste group *R Clinical and pharmaceutical* includes those potentially infectious wastes that arose during the pandemic, with large quantities from healthcare and aged care settings, but also from quarantine facilities, COVID-19 testing locations, corporate and retail settings, and throughout the wider community.

From the start of the pandemic until the end of the data collection period (30 June 2020), NSW and Vic were the hardest hit states in terms of infection numbers, with NSW dominating infection numbers in the early part of the pandemic. Late February to early April 2020 coincided with NSW's largest case numbers, with its lockdown restrictions easing from around late April. Vic's first lockdown began around mid-March 2020 and continued through into April, when restrictions were eased. Victorian restrictions were re-imposed on 20 June 2020, with the second full lockdown introduced from early July, after a sharp rise in infections.

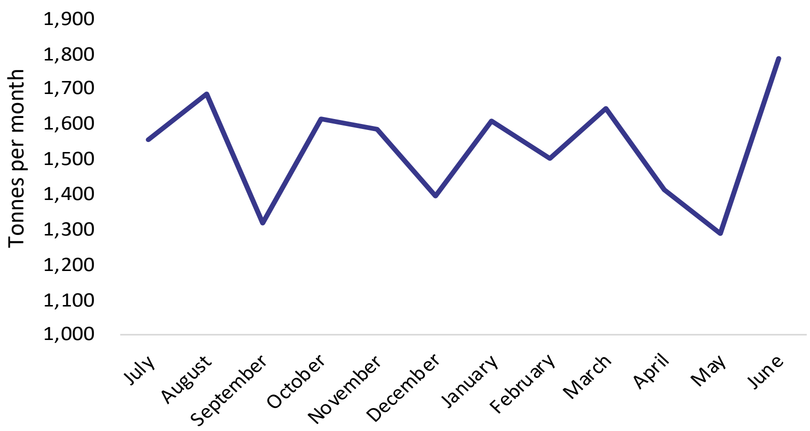
From a data perspective, NSW tracking data is unhelpful, because R wastes are covered by a tracking exemption. The small amount of data tracked in NSW (despite the exemption) is charted by month, over the pandemic period-data year intersection, in Figure 16. This analysis is by no means definitive, given the amount of R waste actually tracked in NSW is around 10% of what might be expected. But assuming the proportion of R waste that is put through the tracking system (compared to what is not) remains constant over the period, a qualitative pattern can be inferred. Tracked arisings for March (219 tonnes) are significantly higher than other months, and around 70% higher than the NSW 2019-20 monthly average (131 tonnes). March corresponds to NSW's peak infection numbers, and all February to June months (the pandemic-tracking data intersection) are above the 2019-20 monthly average for R wastes tracked in NSW.

Figure 16 NSW clinical and pharmaceutical waste arisings 2019-20, tonnes (selected months)



Vic tracking data is more complete for R wastes than NSW, but the peak infection period does not align as well to 2019-20 as NSW's, with its relatively small first wave (March-May 2020) dwarfed by the biggest outbreak in Australia, the second wave (around late June to early November 2020). Despite this limitation, Vic's monthly arisings of R wastes is charted in Figure 17. The notable feature is that June, the month corresponding with the beginning of the second wave, is the largest monthly arising of the year at 1,783 tonnes and 17% above the 12-month average (1,530 tonnes).

Figure 17 Vic clinical and pharmaceutical waste arisings 2019-20 by month, tonnes



R waste data in other tracking system-jurisdictions is less helpful, for various tracking completeness reasons and the fact that COVID-19 infection numbers were low outside of the most populous states in 2019-20.

Anecdotes from industry suggest that additional volumes of COVID-19 PPE placed a heavy demand on thermal and autoclave clinical waste infrastructure in Australia in 2020, creating more interstate flows to manage it. These discussions indicate that facility licences in south-eastern Australia had to be temporarily expanded to cope with the extra load; as 2020 wore on and Vic infections in particular increased, the industry and regulators acted swiftly and collegiately, and coped well with the unprecedented quantities.

The volume of R wastes, on a more quantitative level, was also a factor. COVID-19 PPE is lighter and more bulky than other clinical wastes, filling bins quickly. This decreased density per load increased demands on clinical waste collection staff, transport logistics and site bin storage.

Waste from COVID-19 hospital wards was, out of caution, more likely to be treated as clinical waste due to the infectiousness of the virus, which would also be a factor in increased volumes. Other R wastes may also have declined due to major reductions in other medical procedures, such as elective surgeries.

The 2020-21 tracking data will be more helpful than 2019-20 data with respect to COVID-19 waste data, in bearing out more visible impacts to the clinical waste management sector from the pandemic. At this stage, it appears that the industry rallied to cope with the unusual waste volumes and circumstances.

4.1.2 Indirect impacts – how did COVID affect the management of other hazardous wastes

Apart from the obvious issue of increased clinical waste volumes, there were other disruptive impacts that affected hazardous waste arisings and management in Australia due to the pandemic.

For example, the Australian Government moved in September 2020 to regulate for increased payments to used oil recyclers[21], under the Product Stewardship for Oil scheme. The scheme is crucial for the viability of waste oil re-refining in Australia and the temporary increase in payment per litre of re-refined oil was necessary to ensure their survival, due to a significant drop in waste oil collections in mid to late 2020. Much of the industry spent the latter half of 2020 in 'care and maintenance' shutdown due to the drop in the market prior to Government intervention.

In addition, the NSW Environment Protection Authority (EPA) granted permission for Cleanaway to send waste-derived fuel to landfill without paying the waste levy, due to COVID-19-driven disruption of the normal practice of using it in cement kilns.[21]

4.2 PFAS waste

PFAS describes a range of per- and polyfluoroalkyl substances, which includes perfluorooctane sulfonic acid (PFOS), its salts (perfluorooctane sulfonates) and perfluorooctane sulfonyl fluoride (PFOSF). These chemicals were listed on the *Stockholm Convention on Persistent Organic Pollutants* in 2009, as part of a suite of new POP listings. PFOS is likely to arise in waste with other PFAS chemicals, such as perfluorooctanoic acid (PFOA) and perfluorohexane sulfonate (PFHxS), the former recently listed under the Convention (May 2019) and the latter currently under review for potential listing.

The environmental and potential human health impacts from exposure to PFAS are of increasing concern worldwide. The Heads of EPAs Australia and New Zealand collaborated to develop the PFAS NEMP[22] and

[21] Footprint News (8/9/20), *COVID disruption prompts bigger payments to struggling oil recyclers*, available at: https://www.footprintnews.com.au/news/plastics-to-oil-trial-covid-disrupts-oil-recycling-and-waste-derived-fuel-use-80577.

[22] PFAS NEMP January 2018, available at https://www.epa.vic.gov.au/your-environment/land-and-groundwater/pfas-in-victoria/pfas-national-environmental-management-plan.

its 2020 update (PFAS NEMP v2.0[23]), which is designed to achieve a nationally consistent approach to the environmental regulation of PFAS.

PFAS chemicals have been widely used for many decades in household products such as non-stick cookware, stain protection and food packaging as well as industrial and commercial applications, such as firefighting foams, mist suppressants and coatings. PFAS are persistent and highly resistant to degradation. PFOS, the compound of most concern, was used extensively in fire-fighting foams, was the key ingredient in Scotchgard, a fabric protector made by 3M, and had numerous stain repellent/surface coating uses. Under the Stockholm Convention domestic treaty-making process, Australia must determine whether to ratify the listing of PFOS after considering the costs and benefits of ratification. This decision has not yet been made.

4.2.1 Data

PFAS-containing wastes that arise in the Australian hazardous waste market include PFOS-containing aqueous film-forming foam (AFFF, or firefighting foam), spent granular activated carbon (GAC) or similar absorbents used in filtration of water contaminated by PFAS, PFAS-contaminated soils and PFAS-contaminated wastewaters. This list is not exhaustive, as PFAS is increasingly being shown to be a ubiquitous contaminant. PFAS-contaminated biosolids are not explicitly managed within the hazardous waste market, but contamination in this stream is a growing concern.

PFAS waste has historically not been present in tracking systems because it was not recognised as hazardous. From 2016-17 onwards, PFAS-contaminated waste began appearing in waste tracking data, often under M160 *Organohalogen compounds—other than substances referred to in this Table or Table 2*. The M270 NEPM code[24] was introduced in February 2018 within the PFAS NEMP.

Any pre-2018 PFAS history was (mostly) reflected under the M160 code, potentially along with other POP-wastes, but from 2018-19 onwards the M270 code has been specifically available for PFAS wastes. Implementation of the M270 code across jurisdictions has been inconsistent (for reasons described in Appendix B Section B19), so this report has chosen to analyse both M160 and M270 as one waste group, *PFAS and related POPs (M160 and M270)*, as the most practical means of representing those POPs which are volumetrically dominated by PFAS wastes.

PFAS data, as generation and arisings into infrastructure in 2019-20 and historically, is described in Appendix B Section B19. The key takeaway from that analysis is that PFAS wastes have appeared in tracking systems since 2016-17, accelerating the trend identified in HWiA 2019. Figure 18 duplicates Figure 49 from Appendix B Section B19, and shows the most prominent trend (Vic).

Although an order of magnitude higher again than Vic's, Qld is excluded from Figure 18 because its PFAS waste classification approach adds in the much larger tonnage PFAS-contaminated soils with other PFAS wastes, under M160/M270 codes, which other jurisdictions do not appear to do. Inclusion of this Qld data would swamp all other jurisdictions' amounts, falsely conveying a message that PFAS wastes were only arising in Qld.

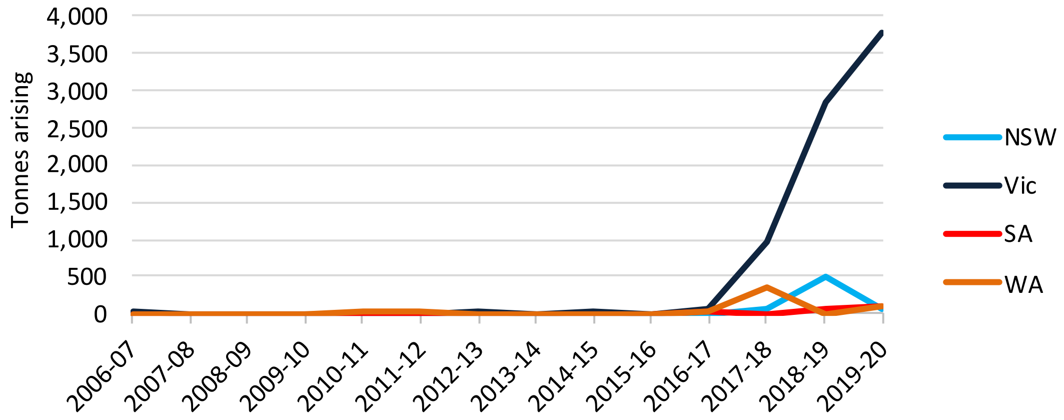
Vic guidance instructs tracking system users to report PFAS-contaminated soils under N120 contaminated soils, with all others codified as M160/M270. The reason that Vic (non-soil) PFAS waste is

[23] PFAS NEMP Version 2.0 - January 2020, available at https://www.environment.gov.au/system/files/resources/2fadf1bc-b0b6-44cb-a192-78c522d5ec3f/files/pfas-nemp-2.pdf.

[24] M270: Per- and poly-fluoroalkyl substances (PFAS) contaminated materials, including waste PFAS-containing products and contaminated containers.

so much higher than other states (except Qld) is probably because of the concentration of soil thermal treatment facilities in Vic that do not exist elsewhere.

Figure 18 Historical arisings of PFAS and related POPs wastes (excluding Qld)



4.2.2 PFAS management infrastructure

Management of PFAS contaminated waste in Australia is guided by the PFAS NEMP. The PFAS NEMP draws acceptable management methods from the Stockholm Convention, its stated contaminant limits (low POP content limits) and specific technical guidance documents published by the United Nations Environment Program.

Broadly speaking, management of POPs waste under the Stockholm Convention needs to either destroy or irreversibly transform the chemical. The Convention allows for POPs wastes to be '... otherwise disposed of in an environmentally sound manner when destruction or irreversible transformation does not represent the environmentally preferable option...' (Article 6 1. (d) (ii)). No recycling, recovery or reuse options are allowed for these wastes, and landfill is not acceptable for wastes above the low POP content limit of 50 mg/kg of PFOS.

The PFAS NEMP adopts landfill acceptance criteria of up to 50 mg/kg (0.7 µg/L leachable concentration) for single composite liner landfill, the only landfills likely to be large enough to accept significant quantities of low-level PFAS contaminated soil/ sludge/ rubble, which is the only PFAS waste likely to be landfilled in Australia.

NSW EPA employs more stringent controls than in the NEMP: up to 1.8 mg/kg (0.05 µg/L leachable concentration) for single-lined landfill and up to 7.2 mg/kg (0.2 µg/L leachable concentration) for double-composite landfill.

At the time of writing, Vic provides only quantitative guidance in the form of its *Interim position statement on PFAS*[25], where anything above 0.004 mg/kg cannot undergo re-use and must be classified for management by Vic EPA. The hazard category (A, B, C) framework, is used by Vic EPA in determining a PFAS waste classification, but definitive concentrations do not appear in classification guidelines, including the newest version[26] developed for the rollover into a new regulatory framework on

[25] EPA Vic (2020) *Interim position statement on PFAS*, Publication 1669.4, available at: https://www.epa.vic.gov.au/about-epa/publications/1669-4.

[26] EPA Vic (2021) *Waste disposal categories - characteristics and thresholds*, Publication 1828.2, available at: https://www.epa.vic.gov.au/about-epa/publications/1828-2.

July 1 2021. Vic EPA's website suggests that any PFAS contaminated soil that EPA directs to thermal treatment is classified as Vic code N119, Category A contaminated soil[27].

Queensland's regulated waste categorisation carries a threshold concentration of zero for PFAS in waste, which is taken to mean than any waste with any measurable quantity of PFAS (above the NATA-accredited test method level of reporting) is classified as Category 1 regulated waste, the highest hazard category available. No general guidance concentrations for soil are provided, although acceptance criteria for individual landfills are specified in their licence (environmental authority).

Elsewhere the baseline numbers and guidance of the PFAS NEMP apply for landfill acceptance of PFAS wastes.

In terms of non-landfill options for PFAS waste management in Australia, Vic is the primary location of thermal treatment infrastructure, and includes:

- Renex, EnviroPacific and more recently Suez (onsite at Taylors Road landfill) thermal soil treatment plants, designed to volatilise and destroy organic contaminants in soil, including PFAS.
- Veolia's Brooklyn thermal desorption plant for separation of organic contaminants in waste, such as PFAS, prior to their thermal destruction.

In Qld, Cleanaway operate a dedicated plasma arc POPs destruction facility at Narangba, although its capacity is relatively small. Some PFAS wastes are also blended and fed into cement kilns, one in Qld and one in Tas.

In WA, Tellus Holdings opened its geological repository facility at Sandy Ridge (near Kalgoorlie) in 2020 (as discussed in Section 4.6), and is licensed to accept PFAS wastes up to 50 mg/kg.

Site-based approaches to PFAS contamination using mobile treatment plant have expanded in recent years, with most focused on groundwater clean-up via pump and treat techniques, using GAC or related absorbents. In addition, Ventia is currently introducing its 'SourceZone' soil washing technology[28] into the market, specifically for PFAS soil remediation, in the form of onsite soil washing and recovery for reuse.

Despite the apparent set of choices for PFAS management in Australia, there remains a large risk that PFAS contaminated soil, rubble and concrete will arise over the near term into a market that does not have sufficient capacity to deal with it. This issue will be examined in the forthcoming *Hazardous waste infrastructure needs assessment project 2021*.

The scale of PFAS soil arisings will be driven by the intersection of:

- the nature and scale of development activity, thus volumes of contaminated soil arising
- concentration levels in the soil
- regulatory limits of PFAS concentration allowed (for different forms of management), and
- regulatory, contingent liability and other drivers to have it removed from sites.

Availability of PFAS waste management infrastructure, at the time, place, scale and price that is needed, will likely determine how much PFAS contaminated soil will arise in the market. Victoria's West Gate

[27] https://www.epa.vic.gov.au/for-community/environmental-information/pfas/pfas-and-waste.

[28] Ventia SourceZone treated 11,500 tonnes of sand and clay soil and removed up to 99% of PFAS (90% average PFOS + PFHxS removal efficiency for the treatment of clay soils), at the Australian Department of Defence RAAF Base Edinburgh in South Australia. Source: https://www.ventia.com/capabilities/pfas-remediation.

Tunnel Project provides a window into the scale of what PFAS contaminated soil arisings could be from just a single infrastructure project.

Box 1 PFAS contaminated soil from the West Gate Tunnel Project, Vic

Major tunnel boring works for the West Gate Tunnel project, west of Melbourne, have been extensively delayed due to the existence of large quantities of PFAS contaminated soil. The major issue is the scale – around 3 Mt of PFAS contaminated soil (known as Tunnel Boring Machine Spoil or tunnel boring soil) are estimated to be generated across the life of the project. The worst of the contamination is attributable to firefighting during the 1991 Coode Island fire, where around 200 tonnes of PFAS-containing firefighting foam was used.[29]

While the spread of contamination levels across the entire 3 Mt is not clear, the EPA generally expects levels of PFAS to be low. The project's website[30] quotes expected PFAS levels (in terms of leachate or toxicity characteristic leachate procedure [TCLP] testing) to be 0-0.7 µg/L. Regardless, once the tunnel boring machine is operating, around 10,000 tonnes per day will need to be removed from site, since an urban road project like this one does not have the space for onsite processing or treatment.

The sheer scale of this single project has meant that even if they had the EPA's approval, all of the largest Melbourne landfills combined do not have sufficient space in-cell to receive it. Efforts to date to solve the problem have included new regulation – the *Environment Protection (Management of Tunnel Boring Machine Spoil) Regulations 2020* – which allows landfill operators to submit environmental management plans for EPA's approval that detail how they will handle the volumes, essentially circumventing the lengthy process of applying for approval to build additional in-cell capacity. At the time of writing, neither decisions about final fate of the soil, nor the enabling works required of sites bidding to take the waste, have occurred. These delays to tunnelling have pushed up the project's costs by at least $1 billion[31].

HWiA 2019 estimated the number of sites that housed likely PFAS contaminated soil, due to the nature of historical activities there (defence, airports, fire and rescue facilities and major hazard facilities). The total estimate across Australia was 1,911 sites. The West Gate Tunnel project is possibly an outlier in the scale of soil it will produce, but HWiA 2019 reported other single projects with known quantities of very high scale (for example 900,000 m^3 of PFAS contaminated soil stockpiled on a Forrestfield WA industrial site from airport expansion pre-construction works).

If volumes of PFAS contaminated soil arisings approach the scale that is clearly possible, it is likely that a patchwork of management options will have to be considered. Availability of infrastructure, environmental risk assessment and clear policy thinking will be important in dealing with this looming volume on a project-by-project basis.

[29] *The Age*, 6 March 2020, *Worst of PFAS contamination revealed on West Gate Tunnel*, available at: https://www.theage.com.au/national/victoria/worst-of-pfas-contamination-revealed-on-west-gate-tunnel-20200306-p547l0.html.

[30] West Gate Tunnel Project website, *Expected PFAS levels*, available at: https://westgatetunnelproject.vic.gov.au/construction/soil-management/expected-pfas-levels.

[31] *The Australian Financial Review*, *Zoom won't do for West Gate Tunnel soil talks*, available at: https://www.afr.com/companies/infrastructure/west-gate-tunnel-consultations-shift-to-zoom-20200703-p558td.

4.2.3 The effectiveness of PFAS thermal destruction

In addition to their shared environmental chemical properties of persistence, bioaccumulation and toxicity, POPs listed on the Stockholm Convention share a more direct chemical commonality – they are all organic compounds that include halogens in their molecular structure. Halogenated organic compounds are those that include fluorine, chlorine, bromine or iodine atoms in their organic-bonded molecules. The first tranche of chemicals on the Convention were chlorinated compounds. In 2009 a new group of POPs were added, including more chlorinated chemicals, a group of brominated chemicals and two new types of compound again, the fluorinated organics PFOS and PFOA.

Prior to 2009, destruction of POPs has been the preferred management (to eliminate the risk of further exposures), and thermal techniques have been highlighted as the most effective. This preference has continued beyond 2009, and into the time of the listing of brominated and fluorinated POPs: for example, thermal destruction is recommended by technical guidance under the Stockholm Convention[32] as the best method of managing POP waste.

However, most of the brominated and fluorinated POPs are highly flame-retardant, which is the reason for their past commercial use and successful application. They are very hard to burn.

The EU's Industrial Emissions Directive (IED)[33] has been referred to in environmental approvals for thermal processes in Australia and elsewhere as the benchmark for pollution control practices and emission limits. One of the key reference points taken from it is the residence time in the flame of the furnace/device and the temperature of that residence: the IED specifies a temperature of at least 850 °C for at least two seconds. This temperature/time combination is specified to ensure complete combustion of organics chemicals in the flame, such as organohalogens like the POP chemicals. The UNEP POP guidelines[32] describe hazardous waste incineration as requiring more aggressive flame conditions, greater than two seconds at a temperature greater than 1,100 °C, if the feed waste contains more than 1% halogenated organics substances (for their complete destruction).

Questions are beginning to be asked about whether the prevailing understanding of 'traditional POP' destruction applies as well to PFAS, relating to the efficacy of destruction of PFAS chemicals in thermal processes such as incineration. These include:

- If PFAS (and potentially brominated flame retardants) are more resistant to being burnt than chlorinated POPs, do the same residence time/temperature conditions completely combust and therefore destroy PFAS?
- If these conditions are indeed suitable to enable complete combustion of PFAS, are they being required, demonstrated and monitored by thermal plant regulators? In other words, are these plants operating to the specifications required to destroy PFAS?
- What is the evidence that products of incomplete combustion (PICs) containing fluorinated species are not produced from incomplete combustion of PFAS or reformation of combustion by-products?
- In trying to solve one environmental problem (destroying AFFF and related PFAS wastes) are we creating a new one in PFAS or related chemical dispersal into the air environment, from thermal (incomplete) combustion?
- What studies or monitoring are being carried out to answer these questions?

[32] UNEP (2015), *Updated general technical guidelines for the environmentally sound management of wastes of wastes consisting of, containing or contaminated with persistent organic pollutants*, available at: *http://www.basel.int/Portals/4/Basel%20Convention/docs/pub/techguid/tg-POPs.pdf*.

[33] EU 2010, *Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)*, available at: *https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:334:0017:0119:en:PDF*.

- In light of these questions, are traditional thermal treatment facilities fit for purpose for complete PFAS waste destruction, particularly with higher concentration wastes?

This line of inquiry has surfaced primarily in the USA, where incineration is a common existing form of municipal solid waste management. The US Defense Department has contracted several commercial incinerators to destroy stocks of AFFF since 2016. Following a range of reports in the US press questioning the safety of disposing of AFFF by incineration, specifically about the potential for PFAS and related air emissions impacting nearby communities, a lawsuit was filed against the Department in February 2020[34].

The lawsuit alleges that the Department of Defense was irresponsible in contracting a number of incineration facilities, violating the *National Defense Authorization Act 2019*, which spelled out guidelines for safely incinerating AFFF. The Act requires the Defense Department to ensure that incineration is conducted at sufficient temperature to ensure the maximum degree of emission reduction. The plaintiffs argue that no specification of operating temperatures was made by Defense, and no due diligence was carried out to demonstrate adherence to these operating conditions as evidence of likely PFAS destruction.

The lawsuit stops short of claiming actual harm to communities surrounding the incinerators that disposed of Defense's AFFF, but infers this based on the lack of oversight of the facilities' operations.

Monitoring data and studies that show airborne emissions of PFAS and related PICs from PFAS waste combustion are difficult to find. One April 2020 study[35] however, from Bennington College Vermont, found elevated PFAS levels in soil and water samples near the Norlite incineration facility in Cohoes, New York, a facility that incinerated AFFF. Levels measured declined with distance from the incinerator. The pattern of PFAS contamination in the soil and water around the site resembled known AFFF contamination, such as air force bases and firefighting training centres. The study noted that 'contamination at both Norlite and these legacy AFFF sites is marked by the prevalence of sulfonic and butanoic varieties of PFAS. This pattern differs from composition of PFAS contamination elsewhere in the region.'

As recently as December 2020, the US Environmental Protection Agency (US EPA) published interim guidance on this very subject: *Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances*[36]. The document considers the types of PFAS wastes discussed in this section, and reviews the following types of management for suitability of managing each of these waste types:

- thermal treatment
- landfills
- underground injection (considered for liquid PFAS wastes)
- storage.

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[34] EarthJustice (20 February 2020), *Department of Defense Illegally Burning Stockpiles of Toxic "Forever Chemicals"*, available at: https://earthjustice.org/news/press/2020/department-of-defense-illegally-burning-stockpiles-of-toxic-forever-chemicals.

[35] Bennington College, Vermont USA (27 April 2020), News Release: *First in the Nation Testing Reveals Toxic Contamination in Soil and Water Near Norlite Incinerator,* available at: https://www.bennington.edu/sites/default/files/sources/docs/Norlite%20News%20Release%20%5Bdb%20final%20updated%5D.pdf.

[36] US EPA (2020), *Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances*, available at: https://www.regulations.gov/document/EPA-HQ-OLEM-2020-0527-0003.

The guidance provides 'the best up-to-date information on potential releases during the destruction and disposal of PFAS and PFAS-containing materials and identifies data gaps to be filled that can inform future EPA guidance.'

Below, we reiterate concluding statements from the guidance relevant to Australian agencies tasked with making informed decisions in the evaluation of existing destruction and disposal options, noting the significant uncertainties that apply:

> Managers of PFAS materials could consider the following existing destruction and disposal options **in the order of lower uncertainty to higher uncertainty** while considering the other factors mentioned above to come up with a decision that is as protective of the environment as possible.
>
> **1. Interim storage**. While not a destruction or disposal method, interim storage may be an option if the immediate destruction or disposal of PFAS and PFAS-containing materials is not imperative. In general, interim storage (estimated to be anywhere from 2 to 5 years) would be utilized until research reduces the uncertainties associated with other options.
>
> **2. Permitted deep well injection** (Class I). Underground injection would be limited to liquid-phase waste streams.
>
> **3. Permitted hazardous waste landfills** (RCRA Subtitle C). These have the most stringent environmental controls in place and higher potential capacity to manage the migration of PFAS into the environment.
>
> **4. Solid waste landfills** (RCRA Subtitle D) that have composite liners and leachate collection and treatment systems. These landfills receive non-hazardous waste and tend to have environmental controls commensurate with the waste they receive. These controls can vary from state to state.
>
> The following options have higher levels of uncertainties regarding their capacity to manage the migration of PFAS into the environment. In order to reduce the uncertainties, interim storage may be considered for PFAS or PFAS-containing materials before these options are selected…
>
> **5. Hazardous waste combustors**. These would include commercial incinerators, cement kilns, and lightweight aggregate kilns, subject to the considerations outlined in this guidance.
>
> **6. Other thermal treatment**. This would include carbon reactivation units, sewage sludge incinerators, municipal waste combustors, and thermal oxidizers, subject to the considerations outlined in this guidance.'

The guidance notes that the carbon–fluorine bond is much stronger than the carbon–chlorine bond, and that breaking the carbon–fluorine bond requires 1.5 times more energy and therefore higher temperatures and reaction times. However, it also makes it clear that specific types of thermal treatment are likely to destroy PFAS if these flame conditions are met. The reasons for its caution and uncertainty around thermal destruction technologies can be summarised as:

1. A lack of definitive evidence of complete PFAS destruction in real-world conditions ('few experiments have been conducted under oxidative and temperature conditions representative of different field-scale incineration devices used for PFAS destruction').
2. A poor understanding and evidence base on the potential formation/reformation of PICs.
3. The current lack of standardised methods to measure PFAS and PFAS-PIC emissions ('lack of validated sampling and measurement methods for the potentially large number of fluorinated and mixed halogenated organic compounds that might be formed').
4. Uncertainty whether air pollution control devices (used at thermal plants) are adequately controlling fluorinated PICs (which EPA recognises to be 'inevitable').

5. Poor field data from existing thermal operations that destroy PFAS wastes, in terms of PFAS/fluorinated PIC emissions characterisations against feed waste concentrations and types.

The guidance describes current research into PFAS thermal treatment conditions and PIC characterisation and behaviour through pollution control processes for various PFAS-containing materials, as well as methods for sampling and analysing PFAS in air emissions and ambient air. Planned areas of future research by US EPA are identified in three broad areas:

1. Research to better characterise PFAS-containing materials targeted for destruction or disposal, so that management methods can be better tailored to which material streams.
2. Research to measure and assess the effectiveness of existing methods for PFAS destruction, improve existing methods, and/or develop new methods for PFAS destruction.
3. Research to measure and assess the effectiveness of existing methods for PFAS disposal, improve existing methods, and/or develop new methods for PFAS disposal.

Concluding the discussion, it seems that destruction of PFAS in thermal plants commonly used in Australia (soil thermal treatment facilities, cement kilns and plasma arc facilities) is likely to destroy the vast majority of PFAS, but significant uncertainty remains:

- Fluorinated PICs may pass through the combustion and air pollution control stages to be released, at some level, in the surrounding air. This uncertainty is enhanced by the unresolved nature of what fluorinated PICs might be formed and how to standardise testing for them.
- There is limited field-based evidence that either PFAS or fluorinated PICs are completely destroyed in operational facilities, and therefore do not migrate to surrounding communities, either by air emission or solid residual waste pathways.
- A profile of PFAS-containing wastes that may be more or less suitable to thermal destruction than others, in terms of PFAS speciation and concentrations, would be a helpful policy and risk management tool.

4.2.4 Elements of a prioritised PFAS waste management framework

In light of the issues raised in Section 4.2.3, the options for PFAS waste management in Australia, excluding intermediary pathways, are collated in Table 7. Alongside these management types are the main categories of PFAS waste encountered in Australia. For each waste type/management type combination, a subjective assessment has been made regarding the environmental soundness of each option – essentially fit for purpose suitability in the author's opinion. This is not intended to be definitive, but rather aims to start a conversation in the Australian PFAS management context to build on the concrete starting points of the PFAS NEMP and various jurisdictional policy positions on the environmentally sound management of PFAS wastes.

This assessment is subject to a range of uncertainties of its own, particularly in light of the US EPA's precautionary approach to PFAS thermal destruction. It attempts to translate the current body of knowledge to the Australian infrastructure context, suggesting types of management that are likely to be suitable for a particular PFAS waste and, within this, prioritising those that appear best-suited to a particular PFAS waste. This assessment makes no reference to practical issues such as gate fees, levies, transport costs and logistics of movement, nor does it assess existing jurisdictional policy and regulations.

Table 7 Suggestions for a framework for management of PFAS waste into Australian infrastructure

PFAS contaminated waste type	Management type: Thermal	Plasma arc	Single lined landfill	Hazwaste landfill	Geological repository	Site based treatment/ reuse	Comment
AFFF	?	✓	x	x	✓	x	High concentration waste, limits management options. Assessment of 'thermal' impacted by US EPA interim guidance. Highly contaminated wastes and alignment with US EPA's 'interim storage'-favoured precautionary approach - both favour geological repository.
GAC	?	✓	x	x	✓	x	
Wastewaters	✓	✓	x	x	✓	✓	Site-based pump and treat with GAC filtration is widely adopted for PFAS groundwater remediation.
Contaminated soil:							Wastes with high levels of contamination favour geological repository. Assessment of 'thermal' for highly contaminated soil impacted by US EPA interim guidance. 'Plasma arc' unlikely to be practical for large volume wastes like soil. Single lined landfill prioritised over other suitable management for low level soils due to the potential for very large volumes, and their scalability.
High	?	✓	x	x	✓	?	
Intermediate	✓	✓	x	✓	✓	✓	
Low	✓	✓	✓	✓	✓	✓	
Biosolids	?	?	✓	✓	x	?	Uncertainties about levels of contamination and volumes of this waste. May not be suitable for thermal, plasma arc or 'soil washing' due to potential odour, water content, volume and other waste-related aspects.
Comment	US EPA uncertainty notwithstanding, thermal methods are likely to be suited to intermediate and low levels of soil contamination, but incomplete combustion uncertainty raises questions for higher levels of PFAS.	Plasma arc is assumed to be suitable for highly concentrated PFAS waste, due to its exceptionally high temperatures, but more evidence is required re any PIC reformation.	Suitable only for low levels of contamination. Advantages include potential scale and low cost.	Suitable only for low and intermediate levels of contamination, although price and capacity constraints limit this option.	Suitable for all levels of contamination. Permanent isolation certificates (from the biosphere) legally remove liability from waste producer. Not suitable for off-gassing wastes, such as organics like biosolids.	Prioritised for water remediation. New entrant to market for 'soil washing' remediation – further detail required to assess effectiveness in different contexts.	

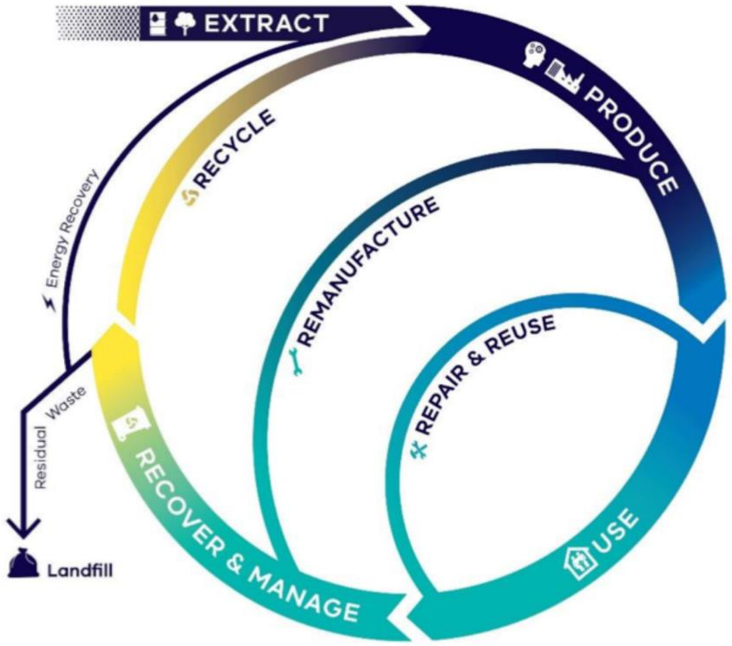
Notes:

1. *AFFF = aqueous film-forming foams; GAC = granular activated carbon; wastewaters include ground, surface, industrial and leachate waters*
2. *Thermal excludes plasma arc but includes high temperature incineration, gasification and cement kilns*
3. *Hazwaste landfill is taken to mean the highest form of engineered landfill (includes double-lining); site-based treatment includes both GAC filtration of waters and soil washing.*
4. ✓ *= prioritised management type for this waste type*
5. ✓ *= suitable management type for this waste type*
6. x *= management type unsuited to this waste type*
7. ? *= uncertainty about the environmental soundness of this management type for this waste.*

4.3 Unintended contaminants – the wrong kind of circular economy

A circular economy continually seeks to reduce the environmental impacts of production and consumption and gain more productive use from natural resources. The circular nature of retaining and recultivating value, while minimising waste, is shown in Figure 19.

Figure 19 Depiction of a circular economy



Source: Victorian Department of Environment, Land, Water and Planning (2019), Circular Economy Policy Fact Sheet[37]

Hazards present in waste must be understood and considered within this recovery framework, particularly chemical contaminant hazards, which may not be as evident as other types of hazards, such as corrosivity or infectiousness. Ultimately of course, the purpose of a circular economy is for manufacturing to occur fully cognisant of, and responsible for, a product's end-of-life, therefore avoiding the downstream environmental impact of hazard by designing it out of products wherever possible.

However, problems can arise when the hazard is unknown or unexpected, and can be made worse when it remains undiscovered as an unintentionally re-entrained chemical hazard in a completely different product context, or directly in the environment itself. Figure 20 depicts a schema where manufactured product A undergoes an end-of-life waste management decision of recycling in reasonable accordance with circular economy (and waste hierarchy[38]) principles, but an unexpected hazardous contaminant is unknowingly re-entrained in product B, resulting in unintended environmental harms from any of:

- product B manufacturing, where product B serves a different purpose to product A
- product B use

[37] Available at: https://s3.ap-southeast-2.amazonaws.com/hdp.au.prod.app.vic-engage.files/9715/6222/7831/Circular_Economy_Policy_Fact_Sheet_July_2019.pdf.

[38] A set of priorities for the efficient use of resources, where avoidance of the waste is the most preferable and disposal of the waste the least. The waste hierarchy is applied in policies of environmental regulators throughout Australia.

- end-of-life product B/waste B management or
- residual waste B disposal.

Residual waste A is managed successfully in terms of its known hazards, whereas B product/waste/residual waste can only be managed according to its known or reasonably expected hazards, resulting in the potential for mismanagement. Figure 20 shows only one cycle of re-entrainment.

Resulting harms are unintended and potentially significant, because they could occur unnoticed for years or even decades, since it may take time for science to trace the consequence back to the unintended contaminant.

Figure 20 Hazardous contaminant re-entrainment in the product-waste-product cycle

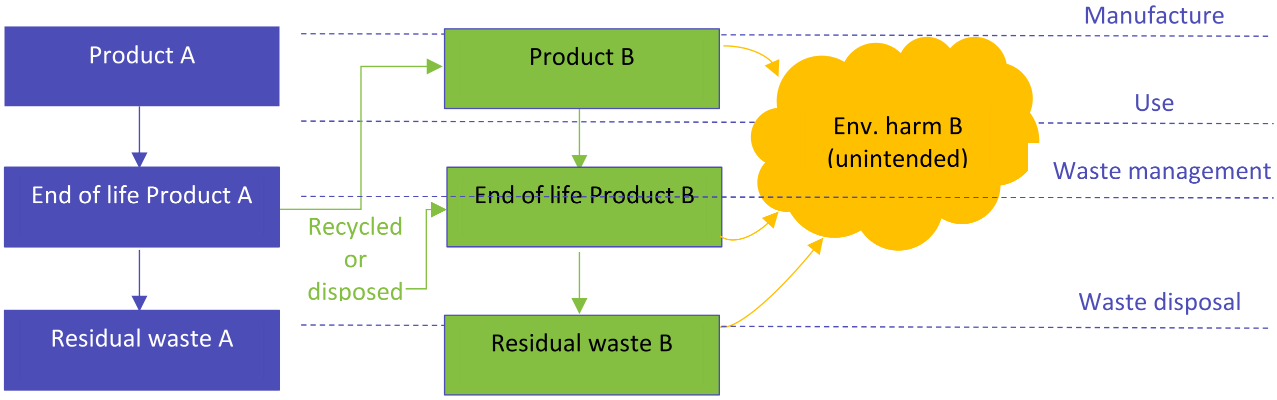


Table 8 highlights some examples of products/ wastes known to have (or historically have had) the potential for unintended contaminant re-entrainment in downstream product or waste contexts.

Table 8 Examples of the re-entrainment of unintended contaminants in the product/waste cycle

Product A	Waste A	Product B	Waste B	Unintended contaminant	Product/ waste cycle impact point
E-goods	E-waste hard plastic	Plastic baby toys	Landfill leachate	Brominated flame retardants	Product B use Waste B disposal
-	Biosolids	Soil improver	Contaminated land/ groundwater	PFAS or other micro pollutants	Product B use
-	Green waste	Compost	-	herbicides	Product B use
Vehicle lubricant oils	Waste oil	Re-refined oil	Refinery discharges (air or solid waste)?	PFAS	Product A use Waste A management Product B manufacture
Take-away food wrappers	Litter	-	Polluted surface water Landfill leachate	PFAS	Waste A disposal Waste B disposal
Textiles (carpet, clothing)	Waste textiles	Recycled carpets, recycled clothing	Chemical contamination in indoor dust, wastewater discharges from washing	PFAS, brominated flame retardants, phthalates	Product B use Waste B disposal
Tyres	Used tyres	Rubber crumb for playgrounds/sport fields	Run-off from outdoor playgrounds, sport fields	Lead, zinc, chromium, quinones	
Plastic packaging	Plastic litter	-	Microplastic marine debris	Bisphenols, phthalates, other EDCs[39]	Waste A disposal
Plastic food packaging and consumer products	Municipal solid waste	-	Landfill leachate Biosolids	Bisphenols, phthalates, other EDCs[39]	Product A use Waste B disposal

4.3.1 POPs unintentionally recycled from e-waste plastics

The potential for unintended contamination from the recycling of e-waste plastics was discussed in HWiA 2017. Brominated flame retardants (BFRs) are added to hard plastic product casings (such as TVs and computers) at high concentrations to protect against fire. While plastic recycling is an otherwise good environmental option, if plastics containing BFRs are mixed with non-BFR plastics and on-sold as recyclate for new (completely different) product manufacturing, re-entrainment of BFRs can inadvertently occur back into products where flame retardancy is not required, creating potential human health problems and perpetuating the cycle of environmental pollution.

A 2015 study of children's toys[40] (made from materials that included recycled plastics) found exactly this – 43% of toy samples tested contained either octa or deca BDE above 50 mg/kg, the low POP content limit adopted for a number of POPs.

Article 6(1)(d)(iii) of the Stockholm Convention requires that POPs are generally not to be recovered, recycled or reused. Yet in 2010, after the original POP-BDEs were listed, the Convention's Parties

[39] EDC = endocrine disrupting chemicals

[40] DiGangi J, IPEN, and Strakova J, ARNIKA (2015), *Toxic toy or toxic waste: recycling POPs into new products, Summary for Decision-Makers*, available from: https://ipen.org/sites/default/files/documents/toxic_toy_or_toxic_waste_2015_10-en.pdf.

agreed to an exemption that permits recycling of materials such as foam and plastics that contain these substances until 2030. Practically, the Convention strongly recommends separation of POP-BDE containing plastics from those that do not, to enable recycling of the latter only, but this pre-recycling separation advice comes with a caveat that is unambiguous about the consequences of not doing so:

> *"Failure to do so will inevitably result in wider human and environmental contamination and the dispersal of brominated diphenyl ethers into matrices from which recovery is not technically or economically feasible and in the loss of the long-term credibility of recycling."*[41]

4.3.2 Micropollutants in biosolids

HWiA 2017 discussed the issue of persistent, bioaccumulative and toxic micropollutants in biosolids, and HWiA 2019 updated the state of knowledge with some further Australian studies on pollutant concentrations in biosolids and the movement of regulation, mostly pertaining to PFAS chemical contaminants.

POPs such as PFAS are potentially problematic in this context because biosolids can act as a 'sink' for pollutants that are non-polar or hydrophobic (tending to repel or fail to mix with water); in other words, these chemicals have a strong tendency to avoid water and adhere to organic solids in the wastewater stream. There is further complexity in the properties of some of these chemicals; for example, PFOS is not 'non-polar' because the perfluorinated group is both hydrophobic and lipophobic (tending to repel or fail to mix with oils). PFOS bioaccumulates through a distinctive tendency to bind to proteins, the most likely mode of adherence to biosolids. These attractive forces cause biosolids to act like a sponge to these pollutants, concentrating them in a similar manner to how they bioaccumulate in the environment.

While further work has been done, none of these emerging chemical contaminants are currently listed in Australian jurisdictional biosolids guidelines. You cannot find what you are not looking for. Protocols for sampling, testing and sharing of results for PFAS and related persistent, bioaccumulative and toxic micropollutants in wastewaters and biosolids are not yet in place. Regulations and guidelines should move faster to incorporate these contemporary pollutants into their contaminant screening requirements.

4.3.3 Herbicide-contaminated compost

In the second half of 2020, 'hundreds of Victorian gardeners'[42] reported unusual death rates of their anticipated summer vegetable crops. The common thread was a batch of commercial compost from a Suez recycling facility in Melbourne, bought from retail garden centres. Investigations by Suez and EPA Vic revealed that the compost was contaminated with the agricultural herbicides dicamba, 2,4-D, MCPA, triclopyr and picloram, and came from Council-supplied garden waste. Not surprisingly, the composting process is unable to break down these contaminants, which 'can cause serious damage at levels of just three or four parts per billion'[43].

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[41] UNEP/POPS/POPRC.6/13 (2010): *Report of the Persistent Organic Pollutants Review Committee on the work of its sixth meeting*, p.19, available at: *http://chm.pops.int/TheConvention/POPsReviewCommittee/Meetings/POPRC6/POPRC6ReportandDecisions/tabid/1312/Default.aspx*.

[42] ABC News 14 February, 2021, *Hundreds of Victorian home gardeners angry and out of pocket after using toxic compost from major recycler Suez*, available at: *https://www.abc.net.au/news/2021-02-14/toxic-garden-compost-kills-vegetables-victorian-gardeners-angry/13152164*.

[43] ABC News 21 February, 2021, *Recycler Suez says herbicides in contaminated compost came from Melbourne council waste*, available at: *https://www.abc.net.au/news/2021-02-21/suez-herbicides-contaminated-compost-melbourne-council/13175200*.

The problem is two-fold:

- these chemicals are available for use in urban and commercial settings
- Australian standards for compost quality do not regulate for the presence of these types of chemicals.

The latter is the same problem as with biosolids guidelines: unexpected contaminants are not present in the contaminant testing requirements imposed by standards, which means this problem is probably not isolated and may have occurred in the past, but without leading to a detailed investigation to uncover its cause.

4.3.4 PFAS in lubricant oils: product-waste-product

PFAS testing, as part of classification of wastes for landfill or other management acceptance criteria, has expanded enormously over the last 3-5 years in Australia. Soil, ground and surface waters, even industrial wastewaters, have been tested. As many of these tests have found PFAS, waste managers and regulators continue to expand the scope of their testing.

For example, a recent study[44] found significant levels of PFAS chemicals in automotive lubricant oils, purchased off the shelf in the USA. PFAS were reported to be used as additives to reduce surface tension, protect from fire and prevent evaporation, although this use of PFAS has not been widely alluded to in literature. Consequently, regulators and waste managers have not been looking at waste oils for PFAS contamination.

Used engine oils are predominantly recycled in waste oil re-refining facilities, through the Australian Government Product Stewardship for Oil program. Anecdotal evidence from within the waste industry suggests that PFAS has also been found in re-refined oil output products, as well as in other liquid wastes from industries where PFAS has not previously been suspected.

If lubricant oils contain PFAS chemicals for product performance purposes, and this is not widely recognised by those re-refining spent oil wastes, it is likely that the thermal conditions employed will be neither designed for nor monitored to ensure PFAS destruction. There is also the question of the potential for PFAS losses from engine oil in vehicular use.

The presence of PFAS chemicals in engine oil product, as well as refinery-recovered output from waste oil, suggests the potential for PFAS emissions or leaks to the environment in the refining process. This links to the discussion in Section 4.2.3 about the possibility of incomplete thermal destruction of PFAS – could the chemicals' ubiquity be leading to unexpected environmental releases from thermal processes not even intended for PFAS destruction?

As with every PFAS issue, the potential for concern is reliant on whether the concentration in the waste or product is sufficient to cause any environmental impact and, as is also regularly true, whether the speculation is supported by data and evidence. We are very much in the speculation stage for questions of more widespread sources and releases of PFAS; much more research is required.

[44] Hongkai Zhu, Kurunthachalam Kannan, *A pilot study of per- and polyfluoroalkyl substances in automotive lubricant oils from the United States*, Environmental Technology & Innovation, Volume 19,2020, available at: https://www.sciencedirect.com/science/article/abs/pii/S2352186420307240.

4.4 Plastics – a hazardous waste issue?

The *National Waste Report 2020*[45] estimates that 2.5Mt of plastic waste was generated in 2018-19. A little less than 13% was recycled and a little less than 3% used for its energy value, mostly in solid recovered fuels for energy recovery. The remainder was deposited in landfill.

In January 2021, changes were introduced to the Basel Convention, which classified some plastic wastes as presumed to be hazardous, and therefore subject to the Convention's control of transboundary movements between parties[46]. Hazardous plastic waste A3210, *Plastic waste, including mixtures of such waste, containing or contaminated with Annex I constituents, to an extent that it exhibits an Annex III characteristic*, was added to the Convention's Annex VIII. A corresponding Y code Y48, *Plastic waste ..*, was also added to Annex II, which essentially elevates plastic waste to be added to future Australian hazardous waste generation tonnages required under the Convention's country-level reporting regime.

A number of plastics are also identified as exclusions by the definition of Y48, particularly if they are uncontaminated by other plastics or hazardous constituents. These are further clarified by a new entry to Annex IX, B3011, *Plastic waste*, which lists those plastic wastes deemed not to be hazardous. In short, any plastic waste that cannot be recycled by Basel 'disposal operation' *R3 Recycling / reclamation of organic substances that are not used as solvents*, which would typically include polyurethane foam, polyvinyl chloride and polytetrafluoroethylene (commonly branded as Teflon), would fall under the control of the Basel Convention[47]. In addition, many plastic mixtures and those known to be contaminated with hazardous constituents will also be captured.
Plastic waste physically breaks up upon weathering. Such plastic debris can be classified as nanoplastics (<0.001 mm), microplastics (≥0.001 mm and <5 mm), mesoplastics (≥5 mm and <25 mm), and macroplastics (≥25 mm)[48]. Micro- and nanoplastics may be made that size for specific product purposes (primary micro/nanoplastics) or result from the disintegration of macro- and mesoplastics, as they degrade.

Much has been written about the physical impacts of plastics pollution, particularly once it enters the marine environment. The public's awareness of marine animals mistaking larger plastic fragments for food or becoming trapped in plastic debris is widespread. Regulatory and stewardship campaigns are gathering pace to both clean up oceans and reduce or eliminate single-use plastics. The problem is clearly identified in Australian-specific data on the macro-effects of plastics on marine wildlife, highlighted by CSIRO's Marine Debris Research Hub[49].

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[45] Blue Environment (2020) *National Waste Report 2020,* prepared for the Department of Agriculture, Water and the Environment, available at: *https://www.environment.gov.au/system/files/pages/5a160ae2-d3a9-480e-9344-4eac42ef9001/files/national-waste-report-2020.pdf.*

[46] Basel Convention Plastic Waste Amendments, *BC-14/12: Amendments to Annexes II, VIII and IX to the Basel Convention*, available at: *http://www.basel.int/Implementation/Plasticwaste/PlasticWasteAmendments/FAQs/tabid/8427/Default.aspx#LiveContent[BC-14/12]*.

[47] Scottish Environment Protection Agency (December 2020), International Waste Shipments – Guidance on the Basel Convention Amendments on plastic waste, available at: *https://www.sepa.org.uk/media/539014/basel_convention_amends_plastic_waste.pdf*.

[48] W.J. Shim, S.H. Hong, S. Eo, *Marine microplastics: Abundance, distribution, and composition*, Microplastic Contamination in Aquatic Environments, Elsevier (2018), pp. 1-26.

[49] CSIRO (2021), Marine pollution: sources, distribution and fate, available at: *https://www.csiro.au/en/research/natural-environment/oceans/Marine-debris*.

This report focuses on hazardous waste, which does not include plastics. But should it? Chemicals in some plastics are hazardous in nature, and plastics can weather into fragments in the marine environment, causing a range of harms. But are they a problem for consumers too?

Plastics contain additive chemicals to make them rigid or soft, to shape them, to colour them, to stabilise them or reduce brittleness, to name a few applications. Some of these chemicals are proven to have deleterious effects on brain development, fertility and reproductive function and many more health indicators. These effects apply to both people and the environment, because exposures occur from product use (human impacts) and waste disposal (animal impacts). These additives may leach from the plastic they are added to, resulting in environmental contamination.[50]

The chemicals most under the microscope in plastics are bisphenols and phthalates – both endocrine disrupting chemicals (EDCs), alongside other contaminants discussed in this report, such as BFRs. EDCs interfere with the normal functioning of the hormonal system. While the PFAS group are sometimes referred to as 'the forever chemicals', because they are so persistent, bisphenols and phthalates could be called 'hormone imposters', because they mimic the key sex hormones oestrogen (bisphenols) and testosterone (phthalates).

Bisphenols are present in some hard polycarbonate plastic products (such as water bottles, food storage containers and food packaging), epoxy resin liners of aluminium cans and cash register receipts. Bisphenol A (BPA) has received the most regulatory attention, but there are many other bisphenols.

Phthalates can be found in some flexible plastic products, usually made of PVC (for example plastic wrap, food packaging/containers, labels on packaging, vinyl flooring, toys), glues, paints, personal care products and air fresheners.

Low-dose effects are another phenomenon likely to be at play with the hormone imposter chemicals. The Institute for Sustainable Futures at UTS, in its report on consumer product chemicals for a private client[51], described the meaning of low-dose effects:

> "*Traditional approaches to regulatory toxicology follow the axiom that 'the danger is in the dose'. Tests to determine the toxicity of a substance assume that substances will always be more toxic at higher doses, and less toxic at lower doses. Consequently, allowable dose limits are established for many substances that are toxic at high doses. However, emerging research has found that some chemicals are more harmful at low doses. For example, some EDCs fool the body at low doses into thinking they are hormones, thus allowing them to disrupt the function of the hormonal system. At higher doses, these same chemicals are recognised by the body as foreign, and don't have the same impact.*"

EDCs such as these two groups of chemicals are certainly a product use/chemical exposure issue, in terms of human health effects, but their impacts as contaminants in wastes make them ecologically problematic as well. The same sorts of reproductive, development and behavioural problems observed in humans have been observed in laboratory animals at doses similar to studies done on wildlife[52].

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[50] Marturano V, Cerruti P, Ambrogi V, *Polymer Additives*. Physical Science Review 2017, 2 (6).

[51] Dubash, J., Wakefield-Rann, R., Prentice, E., Giurco, D., and Latimer, G. (2018): *Chemical Management for Consumer Products – Company Evaluations for (confidential client)*. Institute for Sustainable Futures, UTS.

[52] Maria Cristina Fossi, Cristina Panti, Cristiana Guerranti, Daniele Coppola, Matteo Giannetti , Letizia Marsili and Roberta Minutoli, *Are baleen whales exposed to the threat of microplastics? A case study of the Mediterranean fin whale (Balaenoptera physalus)*, Marine Pollution Bulletin, DOI.org/10.1016/j.marpolbul.2012.08.013, 2012.

Because of the ubiquity of plastic products, bisphenols and phthalates can be found throughout the environment and via waste pathways including landfill leachate, sewage treatment discharges and biosolids. The latter act as something of a 'leaky sponge', for both adsorption of organic chemicals like these (in the wastewater influent, treatment and effluent stages) but also as a carrier and releaser of these chemicals into soil and water, since the primary use of biosolids in Australia is for land application, either for agricultural nutrient benefit or for site rehabilitation purposes.

Box 2 Are endocrine disrupting chemicals contributing to a decline in fertility rates?

Shanna Swan, a noted environmental and reproductive epidemiologist at Mount Sinai School of Medicine in New York City, has studied rising levels of infertility for more than two decades. She points to[53] a reproductive health crisis in which EDCs play a 'major causal role'. By mimicking testosterone, Swan argues, phthalates mislead the body's mechanism for regulating concentration of the hormone, and production declines. This diminishes sperm count on the male side, decreases libido on the female side and has a range of other reproductive effects. Bisphenols, the oestrogen mimics, have a similar impact on female fertility as well as male libido and other effects.

In an interview in *The Guardian*[54], Swan notes that "if you follow the curve from the 2017 sperm-decline meta-analysis[55], it predicts that by 2045 we will have a median sperm count of zero. It is speculative to extrapolate, but there is also no evidence that it is tapering off. This means that most couples may have to use assisted reproduction."

Swan also warns against marketing claims that products are free of BPA ("you could still be getting bisphenol S or F, which are regrettable substitutes") or phthalates ("while it might be free of the old, well-known actors, it may not be free of newer ones").

Tim Moss of Monash University's Department of Obstetrics and Gynaecology is more cautious, arguing[56] that correlation between declining fertility and exposure to EDCs does not establish causation. While significant decline in sperm count in North America, Europe, Australia, and New Zealand is widely accepted[57], he notes it has not been demonstrated in South America, Asia or Africa.

Given the critical significance of the issue, the role of environmental chemicals in driving infertility requires more research.

4.4.1 What plastics contain which chemicals?

More immediately, and in the Australian context, decisions are difficult to make without information. How much plastic do we consume? Which plastics contain EDCs? Are they in sufficient concentration (or sufficiently low as the case may be) to cause environmental harm?

[53] *COUNT DOWN. How Our Modern World Is Altering Male and Female Reproductive Development, Threatening Sperm Counts, and Imperilling the Future of the Human Race*, by Shanna H. Swan with Stacey Colino, Scribner 2021.

[54] *The Guardian* newspaper, 28 March 2021, *Shanna Swan: 'Most couples may have to use assisted reproduction by 2045'*, available at: *https://www.theguardian.com/society/2021/mar/28/shanna-swan-fertility-reproduction-count-down?CMP=share_btn_fb&fbclid=IwAR0KuS6q99AvqCno4zHtcY4b__UqT58FhM7nD8HzWns_djynS9bAjATy7IQ*.

[55] Swan et. al. (2017), Temporal trends in sperm count: a systematic review and meta-regression analysis, Human Reproduction Update, Volume 23, Issue 6, November-December 2017, Pages 646–659, *https://doi.org/10.1093/humupd/dmx022*, available at: *https://academic.oup.com/humupd/article/23/6/646/4035689*.

[56] The Conversation, 4 May 2021, *Are chemicals shrinking your penis and depleting your sperm? Here's what the evidence really says*, available at: *https://theconversation.com/are-chemicals-shrinking-your-penis-and-depleting-your-sperm-heres-what-the-evidence-really-says-160007*.

[57] Chris Barrett, Professor of Reproductive Medicine at the University of Dundee, The Conversation, 27 July 2017, *Huge drop in men's sperm levels confirmed by new study – here are the facts*, available at: *https://theconversation.com/huge-drop-in-mens-sperm-levels-confirmed-by-new-study-here-are-the-facts-81582*.

According to the 2018-19 *Australian Plastics Recycling Survey*, 3.5 million tonnes of plastics are consumed in Australia each year[58]. It is certain that these plastics contain a range of chemicals that function as plasticisers, antioxidants, flame retardants, stabilisers, etc. What is not certain is which particular chemicals are added to Australian consumer goods to perform these functions and in what quantities.

Potential concentrations and total tonnes of a range of potential chemical additives in plastic consumed in Australia in 2018-19, such as currently identified EDCs[59], flame retardants, antioxidants and stabilisers have been estimated in Table 9.

The chemicals analysed are not an exhaustive representation of all potentially hazardous chemicals that can be found in plastic, but were rather selected due to concerning hazard characteristics that include environmental persistence, bioaccumulation, toxicity and endocrine disruption. Many of the chemicals selected are also of high international concern, including several that are listed as POPs under the Stockholm Convention.

The following equation was used to estimate the volumes of hazardous additives:

$$\frac{(Hazardous\ additive\ concentration\ \%)}{100} \times volume\ of\ plastic\ consumed\ (tonnes/\ year)$$

The plastic volumes in Table 9 are from the 2018-19 *Australian Plastics Recycling Survey*. Typical chemical additive concentrations were obtained from previous chemical assessments conducted by the Department, chemical assessments published by international government agencies, published scientific literature and information published by plastics manufacturers.

Due to the limitations of the data, several assumptions were made when generating the estimated volume data:

- For most hazardous plastic additives, multiple different possible concentrations were reported throughout the available literature, with little to no clarification as to what concentration is used for specific plastic types or applications. The hazardous additive quantity estimates are presented as ranges to reflect the range of possible additive concentrations. In some cases, no reported additive concentration for certain plastics was available. Where possible, these volumes were estimated from other plastic types.
- It was assumed that each plastic contained all of the possible hazardous additives that can be found within that plastic, regardless of the plastic's potential use, as use-specific compositions of the various plastic additives in each sector are not available. As a result, the estimates of hazardous additive volumes are likely to be an overestimation.
- It was assumed that all plastics reported as textiles were made of nylon unless otherwise stated, as in the survey, nylon represented all polyamide plastics within Australia.

All chemicals investigated are listed by their chemical abstract series (CAS) numbers, names and their abbreviations (used in Table 9) in Appendix E alongside all literature references used in additive estimations. Those chemicals that fall into the category of known endocrine disruptors are listed in **bold red** in the table, with ready reference to their abbreviations beneath it.

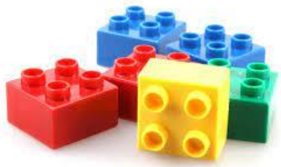
[58] Department of Agriculture, Water and the Environment 2018-19 Australian plastics recycling survey.

[59] *UN list of identified endocrine disrupting chemicals* (2017), available at: https://www.chemsafetypro.com/Topics/Restriction/UN_list_identified_endocrine_disrupting_chemicals_EDCs.html.

Table 9 Estimated amounts of additive chemicals by plastic type consumed, Australia 2018-19

Plastic type	Product uses	Plastic consumed (tonnes/year)	Potential chemical additive	Functional use	Typical concentration of potential additive (%)	Estimated additive quantity (tonnes/year)
Polyethylene terephthalate, PET 	Flexible bottles for water, soft drink, juices, cleaners 	360,000	TPP	Flame retardant	0.3 – 10	1,100 – 36,000
High density polyethylene, HDPE or PE-HD 	Milk bottles, shampoo bottles, detergents, pipes, houseware, toys 	650,000	**BHT**	Antioxidant	0.055	330
Polyvinyl chloride, PVC 	Window frames, vinyl flooring, pipes, cable insulation, garden hoses, toys, medical tubing 	410,000	**DEHP**	Plasticiser	30	122,000
			DBP	Plasticiser	30	122,000
			BPA	Antioxidant	0.12	410
			4NP	Antioxidant	0.26 - 0.42	1,100 – 1,700
			NP	Antioxidant	0.26 - 0.42	1,100 – 1,700
			OBPA	Biocide	0.6 - 5	2,400 – 20,000
			TPP	Flame retardant	0.3 - 10	1,200 – 41,000
			MCCP	Flame retardant	15	61,000
			UV 328	UV stabiliser	0.1 - 1	400 – 4,000
			DBTDL	Heat stabiliser	1 - 2	4,000 – 8,000
			TTS	Heat stabiliser	1 - 4	4,000 – 16,000
			PbDS	Heat stabiliser	1 - 4	4,000 – 16,000

Plastic type	Product uses		Plastic consumed (tonnes/year)	Potential chemical additive	Functional use	Typical concentration of potential additive (%)	Estimated additive quantity (tonnes/year)
Low density polyethylene, LDPE or PE-LD 4	Re-useable bags, trays, containers, food packaging film	 	350,000	**BHT**	Antioxidant	0.055	180
Polypropylene, PP 5	Food packaging, snack wrappers, microwave containers, bottle tops		500,000	**BHT** HBCD Dechlorane plus	Antioxidant Flame retardant Flame retardant	0.055 0.5 3 - 35	250 2,500 15,000 - 180,000
Polystyrene, PS 6	food packaging, meat trays, drinking cups, electronic equipment, eyeglass frames		77,000	**4NP** **NP** HBCD	Antioxidant Antioxidant Flame retardant	0.09 - 0.19 0.09 - 0.19 0.51	69 - 140 69 - 140 390
Polystyrene foam, expanded, PS-E 6 PS-E PLASTIC	Food packaging, meat trays, 'clam shell' take away containers, other packaging	 	58,000	HBCD	Flame retardant	0.5 - 3	300 - 2,000
Nylon 7 OTHER	Variety of sturdy product uses		120,000	HBCD decaBDE Dechlorane plus	Flame retardant Flame retardant Flame retardant	0.5 8.5 - 14 3 - 35	600 10,000 - 17,000 4,000 - 43,000

Plastic type	Product uses		Plastic consumed (tonnes/year)	Potential chemical additive	Functional use	Typical concentration of potential additive (%)	Estimated additive quantity (tonnes/year)
Polyurethane foam, PUR No recycling symbol (not recyclable)	Building insulation, pillows and mattresses, fridge foams, many other foam products		81,000	TCPP TCEP TDCPP TPP Dechlorane plus UV 328	Flame retardant Flame retardant Flame retardant Flame retardant Flame retardant UV stabiliser	2 -15 2 -15 2 -15 0.3 - 10 3 - 35 0.1 - 1	2,000 - 12,000 2,000 - 12,000 2,000 - 12,000 200 - 8,000 2,000 - 29,000 80 - 800
Acrylonitrile butadiene styrene (ABS), Acrylonitrile styrene acrylate (ASA), Styrene-acrylonitrile (SAN) 	Hard plastics used in electronic product casings (e.g. computers and TVs) plus hard plastic crockery/ cups		90,000	HBCD decaBDE TPP Dechlorane plus UV 328	Flame retardant Flame retardant Flame retardant Flame retardant UV stabiliser	0.5 8.5 - 14 0.3 - 10 3 - 17 0.1 - 1	500 7,700 - 13,000 300 - 9,000 3,000 - 32,000 90 - 900

Known endocrine disruptor chemicals listed in red above

- *DEHP: diethylhexyl phthalate, a phthalate used as a plasticiser in polyvinyl chloride (PVC)*
- *DBP: dibutyl phthalate, a phthalate used as a plasticiser in PVC*
- *BHT: butylated hydroxytoluene, an alkyl phenol used as an anti-oxidant (preservative) in PVC, high-density polyethylene (HDPE), polypropylene (PP) and low-density polyethylene (LDPE)*
- *BPA: bisphenol A, a bisphenol used as an anti-oxidant (preservative)/plasticiser in PVC*
- *4NP: branched nonylphenol, an alkyl phenol used as an anti-oxidant (preservative)/plasticiser in PVC and polystyrene (PS)*
- *NP: nonylphenol, an alkyl phenol used as an anti-oxidant (preservative)/plasticiser in PVC and polystyrene (PS).*

Significant figures used above:

- *Plastics consumed are rounded to 2 significant figures*
- *All other numerical data is unrounded, the inherent uncertainties are large and incalculable.*

Table 9 is by no means a definitive data source on chemicals in plastics in Australia, but is instructive about which plastics are at most risk of containing large quantities of additive chemicals, noting that reliable data about which chemicals are used in the Australian context is not publicly available.

The following can be observed from the data in Table 9:

- HDPE, the plastic used in milk bottles, shampoo bottles, detergents, pipes, housewares and toys, was consumed in the highest quantity in Australia in 2018-19, closely followed by polypropylene and PVC.
- PVC is the plastic with the highest risk of containing additive chemicals, particularly EDCs, potentially at very high levels. Other observations about PVC were that –
    - phthalate plasticisers, according to the literature, potentially make up 30% of the weight of PVC, which is more a major component than an additive
    - over 100,000 tonnes of phthalate plasticisers such as DEHP or DBP were estimated to be used in plastics in 2018-19, the highest levels of EDCs recorded in all plastics
    - around 40,000 tonnes of flame retardants were estimated to have been added to PVC
    - all three choices of heat stabiliser chemicals used in PVC are organometallic compounds, which are estimated to account for around 1,000 to 3,000 tonnes of lead (assuming TTS or PbDS are used)
    - biocide OPBA contains arsenic, and if it was used in Australian PVC would account for between 300 and 3,000 tonnes of this heavy metal in 2018-19.
- EDCs such BHT, 4NP and NP also have the potential to be present in HDPE, LDPE and polystyrene, although their concentrations are much lower than those used in PVC.
- Flame retardants such as decaBDE, HBCD and the organophosphates (TCPP, TCEP, TDCPP and TPP) are added to a wide range of plastics in typical concentration ranges of 0.5% to 15% of the weight of the plastic.
- These could correspond to very large quantities, but if dechlorane plus was used for flame retardancy that proportion could be as high as 35% of the total plastic it is added to, which could account for over 200,000 tonnes of the chemical in Australian plastics in 2018-19.

As of January 2021, dechlorane plus and UV 328 were before the 16th meeting of the Persistent Organic Pollutants (POPs) Review Committee (POPRC-16) to the Stockholm Convention for potential listing on the Convention.[60]

EDCs and other chemical contaminants in non-plastic waste streams are discussed in Section 4.7.2.

4.4.2 Better regulation of dangerous chemicals in products and wastes

The science on the hazards posed by these plastic additives, in the case of BPA, phthalates and related chemicals, is clear. While the focus of public health protection should be product design, formulation and use, waste management must be cognisant of the hazard and risks that inherent chemical contaminants pose for animal ecologies. Solving environmental chemical problems at the product end eliminates them as a waste problem, so elimination of these chemicals in-use is the most efficient strategy. The problem is, while plastic use remains widespread and diverse, this is not easy.

Because the health and environmental effects of chemicals such as these tend to be chronic, it has taken time, often decades, before causal links have been established. Regulatory intervention then follows sometime after that, if at all, after lengthy legal and lobbyist battles play out. Ozone-depleting substances, dieldrin (and other organochlorine pesticides), PFAS, BFRs and even

[60] https://sdg.iisd.org/news/stockholm-committee-reviews-three-pops-for-screening-listing/.

asbestos are just a few examples that have followed this delayed trajectory of scientific (hazard/risk) recognition and regulatory response. Finally, alternative chemicals are substituted to provide the same function (assuming the product itself is not eliminated).

Firstly, this approach is painfully long, leaving a human health and environmental toll. History tells us that the process of chemical replacement can turn out to be a cycle of 'regrettable substitution'. Regrettable substitution describes the practice of chemical manufacturers and formulators replacing chemicals that are discovered to be harmful with other chemicals that have been inadequately researched, and are later discovered to be harmful in similar or different ways.

Both bisphenols and phthalates have followed this path. BPA has received the most attention so was banned and replaced with bisphenols S and F. Similarly, diethylhexyl phthalate (DEHP) was replaced with diisononyl phthalate (DiNP). All replacements have been proven to have many of the same problems[61,62].

Solving the problems caused by an omnipresent material like plastics is complex and will require different ways of thinking and regulating. One of those ways is to regulate by chemical classes, assuming the similarly-structured 'cousins' of a known problem chemical could cause similar problems. This can avoid regrettable substitution risk. This approach takes known toxicology science (for one chemical) and applies the precautionary principle to a class of chemicals similar to it, using a 'guilty until proven innocent' philosophy.

The Green Science Policy Institute promotes the idea of the six classes[63] for potential regulation but, more accessibly, for companies and individuals to make purchase decisions that minimise the use of harmful chemicals. The six classes are:

1. PFAS – PFOS, PFOA and ~ 3,000 related highly fluorinated compounds
2. Antimicrobials – triclosan, triclocarban, nanosilver, quaternary ammonium salts, benzalkonium chloride
3. Flame retardants – polybrominated diphenyl ethers, other BFRs, chlorinated tris (TDCPP)
4. Bisphenols and phthalates – BPA, BPS, BPF, dibutyl phthalate, butyl benzyl phthalate, dimethyl phthalate, diethyl phthalate (and many more)
5. Some solvents – aromatic hydrocarbon solvents (e.g., toluene, xylene, benzene) and halogenated organic solvents (e.g. methylene chloride, perchloroethylene, trichloroethylene)
6. Certain metals – heavy metals like mercury, arsenic, cadmium and lead.

Legacy problems from plastics are very large, which creates policy inertia. Regulatory action needs to move up the product-waste cycle to be effective, in line with circular economy thinking. The impact of these contaminants is felt during use, disposal and waste management. For a wholistic approach to gain momentum, such as action at the level of chemical class, environmental regulators may need to collaborate more with their health, industrial chemicals and product approval counterparts. Complicating all of this is the reality that most additive chemicals are not added in Australian manufacturing processes, but rather imported in plastic materials or products already formulated overseas. This makes it difficult to a) know what has been added, and b) apply regulatory controls to eliminate problematic chemical additives.

[61] Rochester J. R., Bolden A. L. (2015). *Bisphenol S and F: A systematic review and comparison of the hormonal activity of bisphenol A substitutes*. Environ. Health Perspect. 123, 643–650.

[62] Gray L. E., Ostby J., Furr J., Price M., Veeramachaneni D. N., Parks L. (2000). *Perinatal exposure to the phthalates DEHP, BBP, and DINP, but not DEP, DMP, or DOTP, alters sexual differentiation of the male rat*. Toxicol. Sci. 58, 350–365.

[63] The Six Classes Approach to Reducing Chemical Harm. Green Science Policy Institute, available at: http://www.sixclasses.org.

4.5 Lithium-ion batteries – an unresolved problem

Lithium-ion batteries are the most prevalent rechargeable battery technology used today in applications ranging from handheld batteries (typically 5 kg or less), such as those used in home electronics and power tools, to electric vehicle automotive batteries, through to domestic and industrial application of large batteries for grid storage. Their use has been increasing strongly in the last decade.

The CSIRO[64] reports that Australia produced around 3,300 tonnes of lithium-ion battery waste in 2016 – not a large volume but a serious waste problem. According to CSIRO the waste is currently growing at 20% per year and forecasts over 100,000 tonnes per year by 2036. In 2016, only 2% of waste lithium-ion batteries were collected and exported for offshore recycling, with the majority disposed of in landfill or stored, in the absence of a preferred domestic fate.

Although lithium-ion batteries are not regulated as hazardous waste for transport within Australia, they have significant hazardous potential. They are very energy-dense when compared to other types of batteries and can contain flammable electrolytes. That is why these batteries are strictly prohibited by airlines and are not allowed in checked luggage. While these factors are not typically a concern in the operational battery, damage or puncture during collection, sorting or disposal, as a waste, can result in the crossing of battery terminals, creating excessive heat that causes fires. Clearly, this can be a major problem within waste collection and management infrastructure.

In February 2021, *The Age* newspaper[65] reported that Brisbane City Council had collected 225 tonnes of waste lithium-ion batteries from kerbside landfill collection bins in 2020, and these discarded batteries were believed to have caused eight Council garbage truck fires in the first 6 months of 2020-21. Visy Recycling, which manages the Council's resource recovery centres, said that 'dozens of battery-related fire incidents' had occurred in processing infrastructure throughout 2020. This is likely to be happening at all Australian landfills and waste infrastructure that finds itself inadvertently dealing with lithium-ion battery waste.

A significant industrial fire burned at the MRI (Aust) Pty Ltd, e-waste and battery recycling facility in Campbellfield, Vic, on 9 August 2020. The facility disassembled and processed e-waste, such as computers and TVs, as well as nickel-cadmium (NiCad) batteries. It also accepted lithium-ion batteries. The site was under EPA investigation prior to the fire, for allegedly amassing 'an inappropriately large stockpile' of batteries and e-waste[66].

The economics of lithium-ion battery recycling, as well as safe handling and insurance aspects, have not seen it take shape yet in Australia, at least not in a true value-recovery sense. Six companies are listed on the ABRI[67] website as providing a collection and recycling service for lithium-ion batteries: CMA Ecocycle, Envirostream, PF Metals, Powercell (Australia), SIMS Recycling Solutions and TES-AMM Australia. Of these, Envirostream is the only company in Australia that undertakes a form

[64] CSIRO (2018), *Lithium-ion battery recycling in Australia. Current status and opportunities for developing a new industry*, available at: *https://www.csiro.au/en/research/technology-space/energy/Energy-storage/Battery-recycling*.

[65] *The Age* Newspaper, February 23, 2021, *Household batteries blamed for spate of Brisbane garbage truck fires*, available at: *https://www.theage.com.au/national/queensland/household-batteries-blamed-for-spate-of-brisbane-garbage-truck-fires-20210223-p57519.html*.

[66] *The Age* Newspaper, August 12, 2020, *E-waste recycler under pressure from EPA before fire erupted*, available at: *https://www.theage.com.au/national/victoria/e-waste-recycler-under-pressure-from-epa-before-fire-erupted-20200812-p55l2z.html*.

[67] ABRI – Australian Battery Recycling Initiative.

of initial domestic pre-processing. However, valuable cathodic powders are exported offshore for recovery, as evidenced in Basel export permits, which means the value is realised by other countries.

The problem of fire hazard is likely to get worse without dedicated industry support, potentially via product stewardship arrangements.

4.6 Infrastructure – challenges and changes

4.6.1 Ageing infrastructure

While three companies control the majority of hazardous waste volumes managed in Australia (as discussed in Section 2), absolute tonnage received is not the full story. The hazardous waste management industry is not really a single industry sector, but rather a collection of facilities offering different management and infrastructure types, some quite specialised for specific wastes. For many wastes, national markets supply limited receiving infrastructure – in some cases there may be only one facility nationally dedicated for environmentally sound management of a particular waste.

Some of this infrastructure is ageing, some is running out of capacity and some are nationally-critical for the management of certain wastes, at least for environmentally preferred forms of management. Therefore some market sub-sectors are more vulnerable than others. This creates challenges for regulators to ensure wastes are managed efficiently and safely, while striving for the retention of value in a broader circular economy where possible.

Hazardous waste landfills, designed with the highest levels of engineering, are limited in Australia, and those in both Vic and NSW have identified an approximate lifespan until around 2030[68,69].

Non-hazardous waste landfills, typically designed with single-liner barrier protection, also face airspace constraints, particularly where PFAS wastes are concerned. As discussed in Section 4.2.2 (Box 1), landfills in Vic do not have sufficient space to accept low-level PFAS contaminated soils from a single project, the West Gate Tunnel project.

Cement infrastructure is used in Australia for thermal destruction purposes, where high calorific wastes combined with small quantities of waste hazardous chemicals like POPs provide fuel replacement value in the process. At least some of these facilities are ageing, but their role in hazardous waste management is currently important, even crucial for some wastes.

Bradbury Industrial Services, a key national provider of waste solvent recycling infrastructure, closed in 2019 after major licence breaches and a factory fire and later connection to 'undoubtedly the biggest illicit dumping operation in the city's history.'[70] The series of events are chronicled in HWiA 2019. Bradbury was critical to the recycling of solvent and related flammable wastes nationally and its loss has put additional pressure on other infrastructure in Vic, NSW and Tas.

The NSW Homebush Bay liquid waste facility, a key and longstanding piece of NSW infrastructure, faces expiry of its lease in 2025. The facility has traditionally taken a variety of liquid wastes, including waste non-aqueous solvents, paints, other flammable wastes and wastewaters

[68] Tonkin + Taylor (2016), *Needs Assessment - Melbourne Regional Landfill*, prepared for Landfill Operations Pty Ltd, available at: *https://www.planning.vic.gov.au/__data/assets/pdf_file/0024/4794/1.-Tonkin-and-Taylor-Needs-Assessment-12-02-2016.PDF*.

[69] Suez Australia website: *https://www.suez.com.au/en-au/news/elizabeth-drive-landfill-expansion-proposal*.

[70] *https://www.theage.com.au/national/victoria/up-to-19-million-litres-of-toxic-waste-dumped-in-eight-suburban-warehouses-20190315-p514lm.html*.

contaminated with PFAS and other oxidisable organic compounds. This capability is not well-catered for elsewhere.

In addition, the waste management industry is reportedly finding insurance harder to get due to recent incidents, such as the Bradbury fire, the battery fire at MRI and media attention on unscrupulous activity regarding waste more broadly. This could put pressure on existing operators. All of this creates the backdrop of an infrastructure set that, in some areas, is in need of investment.

4.6.2 New infrastructure built or in the pipeline

Recently there has been an encouraging number of proposals and developments that offer new capacity for some of these market segments. The last 2-3 years has seen some major infrastructure commissioned that should provide significant extra capacity and, in some cases new capability, to further support Australian hazardous waste management. A number of proposed facilities have also been approved by environmental regulators, and are in various stages of design and construction.

Table 10 lists new hazardous waste infrastructure that has been publicly announced and is somewhere on the project development cycle from regulator-approval to fully constructed and operational.

In addition, there has been a substantial recent rise in the number of mobile plants for contaminated site work. Eleven new licences have been issued in NSW alone since 2018 for mobile waste treatment plants, most of which involve pump and activated carbon capture of PFAS from water such as contaminated groundwater, fire water and surface waters. All licences expressly forbid the treatment of AFFF concentrates/solutions and one specifically mentions a maximum concentration of PFAS able to be treated by this method, of 45 mg/L total PFAS compounds.

Pump and treat mobile water treatment plants have been excluded from national assessments of hazardous waste infrastructure because the mechanics of the infrastructure pumps, pipes and filter media, are readily expandable, so their capacity is not strongly constrained.

Further to those developments listed in Table 10, Victoria's West Gate Tunnel project's massive PFAS-contaminated tunnel boring machine spoil (contaminated soil) volumes (approximately 3 Mt) have created a management dilemma – even if approvals are given to Vic's largest (non-hazardous waste) landfills to accept this waste, they do not have the space to take it all.

Consequently, Transurban's builder CPB John Holland is running a tender process to choose a site for the safe disposal of this soil. Cleanaway Ravenhall, Hi-Quality Bulla, Maddingley Brown Coal Bacchus Marsh and a potential back-up site in Wyndham Vale are all in the mix. Once a final decision about the fate of the soil is made, this will expand hazardous waste (low level contaminated soil) infrastructure capacity in Australia.

Several facilities to recovery energy from municipal solid waste, using high temperature thermal processing, are planned or under development. The Kwinana Avertas Energy from Waste plant in WA is expected to commence operations in 2022, and will be the first of what is likely to be several of these facilities over the next 5-10 years. The impact to the hazardous waste infrastructure set from these operations is not their acceptance of hazardous wastes, but their likely creation of it; fly ash is expected to contain sufficient levels of heavy metals to categorise it as hazardous. If so, upwards of 2% of the feedstock to these plants will be a new hazardous waste stream, N150 *Fly ash, excluding fly ash generated from Australian coal fired power stations*, which will require management in infrastructure such as landfill or the emerging geological repository sector.

Alternatively, if contaminant levels are lower than expected, diversion into construction-related uses may be possible.

Table 10 Regulator-approved new hazardous waste infrastructure (since HWiA 2019)

Facility	Jurisdiction	Infra. group	Estimated capacity increase (per year)	Project stage/ comment
Regain Spent Potlining Reprocessing Facility, Tomago	NSW	Spent potlining facility	Expansion (+40 kt), est. 2022	SSD EIS approved, currently in design/preconstruction
EPSR Bomen	NSW	Lead facility	Expansion (+50 kt), est. 2022	SSD EIS approved, currently in planning stage
Ledox Lead Acid Battery Recycling Facility, Ingleburn	NSW	Lead facility	New facility (18 kt)	Approved but no clear plans to proceed
Pymore Recyclers Battery Recycling Facility, Kurri Kurri	NSW	Lead facility	New facility (60 kt)	Approved but no clear plans to proceed
DGL Environmental, Unanderra	NSW	CPT plant	Expansion (+130 kt)	Undergoing Development Approval – site previously operated as Hydromet
Tellus Blue Bush Storage and Isolation Facility, Broken Hill	NSW	Long-term isolation facility	New facility (200 kt)	At SEARs Scoping Report stage, with EIS process to follow
Yatala Waste Treatment Services	Qld	CPT plant	New facility (unknown kt)	Commenced operational waste acceptance in 2020
EnviroPacific, Altona	Vic	POP thermal destruction facility	New facility (unknown kt)	Operational in 2018
Suez Recycling and Recovery, Lyndhurst	Vic	POP thermal destruction facility	New facility (unknown kt)	Operational in late 2019
Chunxing ULAB facility, Hazelwood North	Vic	Lead facility	New facility (50 kt)	Approved and in pre-construction
Tellus Sandy Ridge Geological Repository	WA	Long-term isolation facility	New facility (100 kt)	Commenced operational waste acceptance in 2020
Contract Resources, Karratha	WA	Mercury facility	New facility (unknown kt[71])	Operational in 2019, built to serve mercury waste from oil and gas industry
BMT Mercury Technology, Kwinana	WA	Mercury facility	New facility (2 kt)	Operational in 2019, built to serve mercury waste from oil and gas industry

While not traditionally hazardous waste infrastructure, there are several landfills in Vic that may accept large quantities of PFAS contaminated soil in the immediate future. The West Gate Tunnel

[71] 'The plant is the largest hazardous waste recycling and processing facility in the southern hemisphere, and is capable of treating all of Australia's mercury contaminated waste.' From: https://www.pilbaranews.com.au/news/pilbara-news/largest-mercury-treatment-plant-in-aus-opens-in-karratha-ng-b88904619z.

project will generate an estimated 3 Mt of PFAS contaminated soil. This has created a management dilemma – even if approvals are given to Vic's largest (non-hazardous waste) landfills to accept this waste, they do not have the space to take it all.

The number and nature of new hazardous waste facilities recently built and in the pipeline suggest that the industry is changing - this degree of flux and investment has probably never been seen in Australia.

The plant capacity increases described in Table 10, plus others indicated (but not in the public domain), will be important in assessing the capacity of hazardous waste infrastructure, the subject of the forthcoming *Hazardous waste infrastructure needs assessment project 2021*.

4.7 Other emerging hazardous waste issues

This section collects together a status report of some issues that raised in previous editions of HWiA.

4.7.1 Coal seam gas industry wastes

The coal seam gas (CSG) industry is concentrated in SW Qld due to deposits in the Surat Basin. The Qld CSG industry grew markedly during the mid to late 2000s and was known to produce large volumes of salty wastes, in the form of drilling muds (C100) produced during the establishment of wells and water raised to the surface as part of the gas extraction process. The latter is now desalinated in large scale reverse osmosis plants to produce large volumes of water suitable for a range of uses. This desalination process also leaves large residues (D300) in the form of salts or brines.

Qld's approach to regulating the salty wastes from reverse osmosis treatment has evolved to require disposal in 'regulated structures'[72]and, since the vast majority of this is managed onsite, it has largely disappeared from tracking data. The question this approach raises is common with other extractive industries – what will happen to these waste structures and the large volumes of salt they contain once the resource is expended and it is time for site rehabilitation and remediation?

CSG wastes remain contentious due to the large waste volumes they generate, particularly salty wastes. NSW has issued planning approval for Santos to develop a CSG field in the Gunnedah Basin in NSW. This project could supply half of NSW's gas needs but is predicted to produce around 33,000 tonnes/year of salty wastes, 'which could be reused or sent to a licensed landfill for disposal'[73]. Definitive plans for salt waste management are not yet available.

4.7.2 Understanding contaminants in biosolids and related wastes

As described in Section 4.4, landfill leachate, wastewaters from sewage treatment and biosolids are examples of wastes with high potential to contain trace level EDCs, as well as other micropollutants. Since they are likely to be lower in EDCs, these waste streams may be of secondary interest compared to the direct impacts of plastic pollution, but low-dose effects may still render these streams environmentally significant. There are also other pollutant concerns with biosolids, including

[72] Qld Department of Environment and Science (2019), *Structures which are dams or levees constructed as part of environmentally relevant activities*, available at: https://environment.des.qld.gov.au/__data/assets/pdf_file/0031/89383/era-gl-structures-dams-levees-eras.pdf.

[73] NSW Department of Planning, Industry and Environment (DPIE) (2020), *Narrabri Gas Project State Significant Development SSD 6367*, DPIE Final Assessment Report, p.14, available at: https://majorprojects.planningportal.nsw.gov.au/prweb/PRRestService/mp/01/getContent?AttachRef=SSD-6456%2120200611T101108.126%20GMT.

metals, PFAS and BFR chemicals. The interest in biosolids, in particular, is due to their 'capture and concentrate' effect during wastewater treatment and their common application as a soil conditioner on agricultural land.

Hazardous wastes are managed according to various jurisdictional regulatory frameworks, each typically with a list of contaminants to assess via laboratory testing of the waste, and comparison against corresponding concentration criteria for each contaminant, including for leachability testing. This classification approach generally considers around 50-80 chemical contaminants in waste.

Wastes that are derived from domestic, commercial and industrial activities that typically are not handled directly by the hazardous waste management industry, or within its infrastructure, do not undergo the same rigour of contaminant regulation (and therefore testing). These waste streams include:

- inputs to wastewater treatment plants (influent sewage, wastewater and trade waste)
- landfill leachate that is destined for wastewater treatment plant disposal
- wastewater treatment plant effluent waters
- biosolids.

These four waste streams are depicted in Figure 21.

Beneficial use of biosolids is managed according to biosolids guidelines developed and applied at the state or territory government level. As pointed out in previous editions of HWiA, the chemical contaminant coverage of these guidelines appears deficient with just 11 chemical species listed (at most), with none of the more contemporary organic chemicals included. Similar limitations apply to trade waste discharges to sewage treatment plants, which can include leachate from landfills.

In addition to limited contaminant coverage, there is a lack of consistent testing requirements, methods and coordination in sharing results amongst wastewater treatment managers, government agencies and regulators.

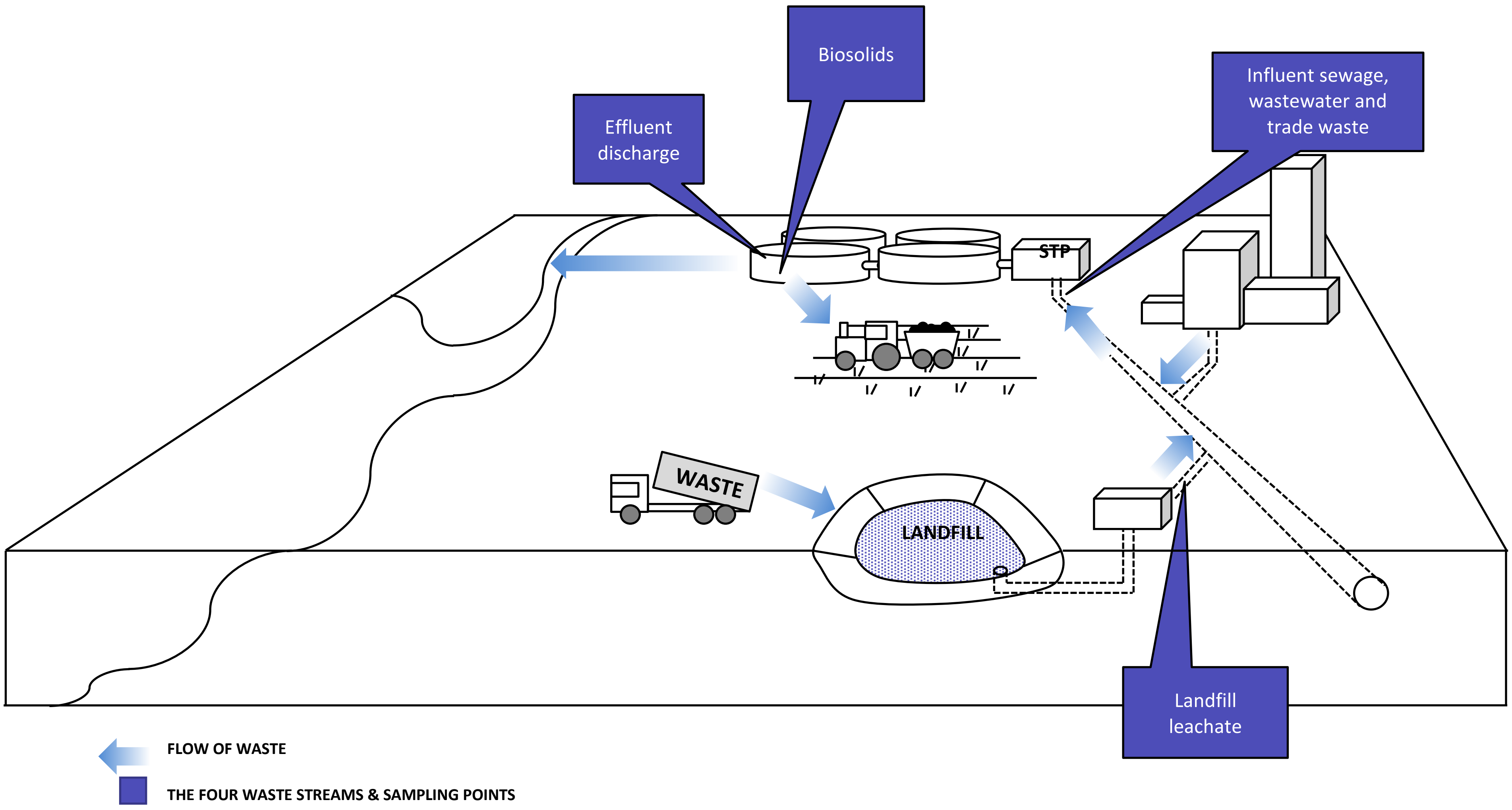
This fragmented approach means the significance of the new chemicals of concern discussed in previous sections, and how they relate to waste waters and biosolids, is not well understood in Australia.

A national agreement or protocol is needed to establish:

- a common set of contaminants that could be present in these streams
- an agreed regime of testing frequency for these contaminants
- an agreement to pool results data to maximise value and minimise collective investment
- an agreed set of sampling and testing methods to assure quality and rigour in the data obtained
- a commitment to look forward to the science of emerging pollutants of concern that may be relevant to these waste streams.

Once the nature of the problem of wastewater solid and liquid phase micro-contaminants in Australia is better understood, better waste and resource management decisions can be made.

Figure 21 Biosolids and related waste streams



Source: Ascend Waste and Environment and Blue Environment (2017), National contaminant sampling and testing protocol for waste, prepared for the Department of the Environment and Energy

4.7.3 Public disclosure of hazardous waste data?

HWiA 2019 recommended that the merits of 'community right to know' public disclosure of hazardous waste tonnages and information be considered by governments. This is controversial, because disclosure has historically been limited to reports and data collations (such as this one), in which data is presented only in aggregated form. The case against has always been built around the commercial sensitivity of such information, but the question of disclosure was raised in light of media reports about fraudulent activity in the waste sector.

The case for public disclosure of site-specific waste movements and management was put by the authors of this report in *Inside Waste* magazine[74]:

> *"There is a clear social benefit in providing public information about the movement and management of waste. Waste management often relies on good individual practices, and these are buttressed by public confidence in the sector. Transparency makes it easier for investors to identify infrastructure gaps, improves the standard of public and political debate, and means community groups, neighbours and governments can more easily identify risks and poor practices. Generators of hazardous or large waste streams will keep a more careful eye on their waste management if they know the public can see it too. Easily available data means secret stockpiles and criminal activity are less likely."*

Current policy attributes less importance to this social benefit than to commercial sensitivities. This contrasts with the National Pollutant Inventory, which has disclosed detailed information about discharges of pollutants without confidentiality issues for 20 years.

Public disclosure of hazardous waste information may be uncomfortable for some operators but is not without precedent. The Scottish EPA produces quarterly online data on waste types, amounts and capacities at a site level[75]. This interactive tool allows users to access, visualise, extract and download information about waste management sites in Scotland that are regulated by SEPA. It is, in a sense, the National Pollutant Inventory of waste data.

The *Inside Waste* article concluded:

> *"We maintain that weakness in reporting requirements and subservience to industry preferences is undermining appropriate public oversight of waste generation and management. Given the recent failings of waste governance, it is time for a rethink. The public interest would be better served if data on waste types, quantities, sources, facilities, processes, pathways and fates were much more publicly transparent. The default position of state and territory governments should be to require this information from significant waste generators and waste operators above some low threshold level of throughput. Reporting exemptions should be available on a case-by-case basis where a sound rationale is provided. Governments should report this information in disaggregated and aggregated forms."*

[74] Inside Waste Issue 95, April-May 2020, *Managing waste data for the public good*, Joe Pickin (Blue Environment) and Geoff Latimer (Ascend Waste and Environment), available at: https://issuu.com/primecreativemedia-2016/docs/iw0420_lr.

[75] Scottish EPA (SEPA), *Scotland's waste sites and capacity data tool*, available at: https://www.sepa.org.uk/data-visualisation/waste-sites-and-capacity-tool/.

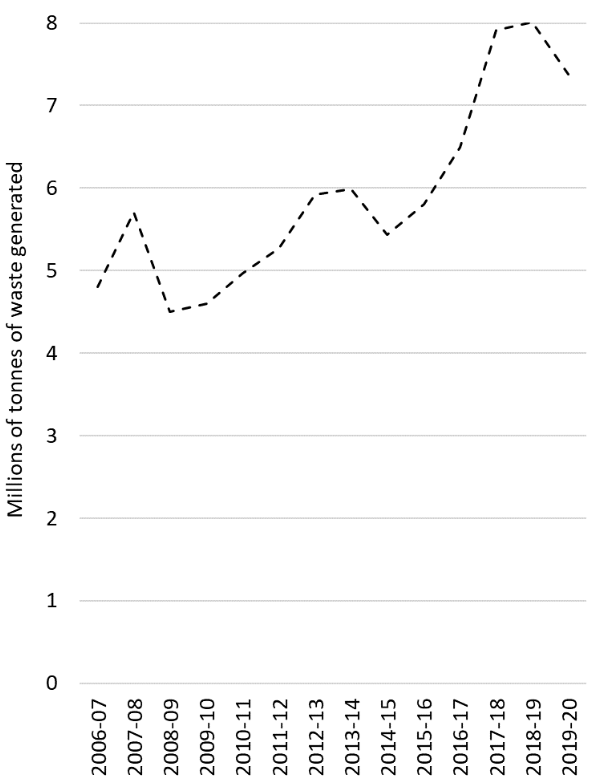
5. Key messages

Preceding sections feed into the findings of this section. These include Section 2, which describes the hazardous waste market in Australia and Section 3, which takes a 'helicopter' view of hazardous waste data, providing a high-level picture of where hazardous waste is coming from, where it is going and how this has changed in recent history. Section 4 examines those wastes, issues and challenges, both current and emerging, that provide the most pressing concerns for policymakers and those in the industry. Appendix B backs up these preceding sections by providing more detailed data analysis and commentary on each of the 29 waste groups.

The discussion below builds on these preceding chapters to draw out eight key messages.

5.1 Despite consolidating in 2019-20, the quantities of hazardous waste are increasing

Figure 22 National generation of hazardous wastes in Australia, 2006-07 to 2019-20 (excl. biosolids)



Historical hazardous waste generation from 2006-07 to 2019-20 has exhibited a strong upward trend nationally, with Vic and NSW experiencing the most rapid growth, particularly in the more recent period (2014-15 onwards). This trend calculates to a compound annual growth rate of 3.4% per year from 2006-07 to 2019-20 and 6.3% per year from 2014-15 to 2019-20.

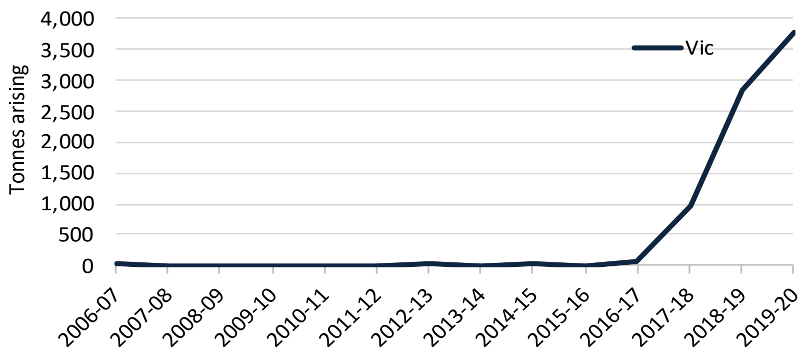
The major contributors to this post-2014-15 surge were asbestos (almost all in NSW) and contaminated soil (mostly in Vic and Qld), The trend slowed in 2018-19 then actually fell in 2019-20, due to reduced NSW asbestos volumes and a large 2019-20 drop in Qld contaminated soil, down 57% on that state's 2018-19 reported tonnages. Offsetting these 2019-20 falls was Vic's sharp growth in 2019-20, driven by its contaminated soil volumes, which grew a further 42% on 2018-19, on top of an already unprecedented growth period in that waste from 2014-15.

Hazardous waste quantities overall went through a consolidation in 2019-20, which is unsurprising given the sustained increases since 2014-15. Nonetheless, the long-term growth trend remains unaffected.

5.2 PFAS waste quantities are increasing sharply

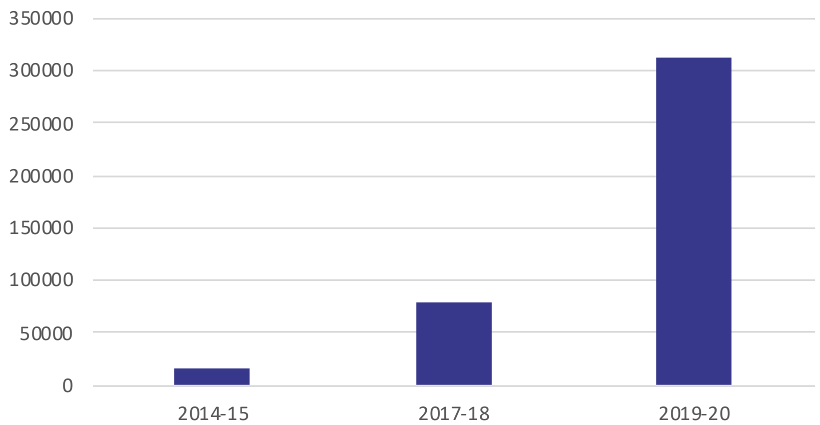
PFAS-contaminated waste has emerged dramatically since 2016-17 with the trend shown most clearly in Vic non-soils data; probably because of the concentration of soil thermal treatment facilities in Vic that do not exist elsewhere. Qld, the other main location of infrastructure for managing PFAS waste, has also shown dramatic rises, particularly with respect to PFAS contaminated soils.

Figure 23 Historical arisings of PFAS and related POPs wastes (Vic)



Australia's soil thermal treatment facilities, concentrated in Vic, have experienced major growth in 2019-20. In contrast to other forms of contamination, PFAS is not a visible contaminant in Vic contaminated soil data, due to its recent emergence in the classification system, although this may change with the implementation of a new tracking system in 2021. However, this rise is almost certainly attributable to PFAS as a contaminant, because of its timing and the fact that Category A (Vic classified) soil follows the same sharp increase, and thermal treatment is the only allowable management in Vic for PFAS soils classified as Category A.

Figure 24 Contaminated soil sent to thermal treatment, Vic (tonnes)



Despite an apparent set of choices for PFAS management across Australia, there remains a large risk that PFAS contaminated soil, rubble and concrete will arise over the near term into a market that does not have sufficient capacity to deal with it.

5.3 The effectiveness of complete thermal destruction of PFAS is not yet proven

As recently as December 2020, the US EPA published 'the best up-to-date information on potential releases during the destruction and disposal of PFAS and PFAS-containing materials.' [76]

The guidance notes that the carbon–fluorine bond is much stronger than the carbon–chlorine bond (common to many other POPs), and that breaking the carbon–fluorine bond requires 1.5 times more

[76] US EPA (2020), *Interim Guidance on the Destruction and Disposal of Perfluoroalkyl and Polyfluoroalkyl Substances and Materials Containing Perfluoroalkyl and Polyfluoroalkyl Substances*, available at: https://www.regulations.gov/document/EPA-HQ-OLEM-2020-0527-0003.

energy and therefore higher temperatures and reaction times. However, it also makes it clear that specific types of thermal treatment are likely to destroy PFAS, if these flame conditions are met. The reasons for its caution and uncertainty around thermal destruction technologies can be summarised as:

- a lack of definitive evidence of complete PFAS destruction in real-world conditions
- a poor understanding and evidence base on the potential formation/reformation of fluorinated products of incomplete combustion (PICs)
- the current lack of standardised methods to measure PFAS and PFAS-PIC emissions
- uncertainty of whether air pollution control devices (used at thermal plants) are adequately controlling fluorinated PICs (the occurrence of which EPA recognises to be inevitable)
- poor field data from existing thermal operations that destroy PFAS wastes, i.e. a lack of emission characterisations linked to feed waste concentrations and types.

It seems that destruction of PFAS in thermal plants commonly used in Australia (soil thermal treatment facilities, cement kilns and plasma arc facilities) is likely to destroy the vast majority of PFAS, but significant uncertainty remains. There is limited evidence that either PFAS or fluorinated PICs are completely destroyed in operational facilities, and therefore may make it past the combustion and air pollution control stages to be released, at some level, in the surrounding air.

A profile of PFAS species and concentrations that may be more or less suitable to thermal destruction than others could be a helpful policy and risk management tool while such evidence is being gathered. An example management framework is provided in Section 4.2.2.

5.4 The clinical waste management industry coped well with increased volumes caused by COVID-19

The 2019-20 data collection period reported in this document did not coincide particularly well with the worst of the pandemic:

- the bulk of NSW's cases occurred prior to 30 June 2020 but NSW clinical waste is subject to a regulatory tracking exemption, so data is poor
- Vic's first wave of infections coincided with the 2019-20 year, but its second wave of far greater infection numbers occurred after 30 June 2020, outside the data collection period for this report
- COVID-19 infection numbers were low outside of the major states in 2019-20.

However, selected industry conversations suggested that additional volumes of COVID-19 PPE placed a heavy demand on thermal and autoclave clinical waste infrastructure in Australia in 2020, creating more interstate flows to manage it. These discussions indicate that facility licences in south eastern Australia had to be temporarily expanded to cope with the extra load; as 2020 wore on and Vic infection numbers increased, industry feedback suggests that operators and regulators acted swiftly and collegiately, and coped well with the unprecedented volumes.

2020-21 tracking data should be more helpful than 2019-20 data in bearing out more visible impacts to the clinical waste management sector from the pandemic. Information obtained to date indicates that the industry rallied to cope with the unusual waste volumes and circumstances, perhaps as an economic benefactor from the crisis.

5.5 The hazardous potential of plastics deserves more attention

Plastics contain additive chemicals to improve various properties, such as flexibility, form or stability. The chemicals most under the microscope in plastics are bisphenols and phthalates – both EDCs, alongside other contaminants discussed in this report, such as BFRs. EDCs interfere with the normal functioning of the hormonal system. While the PFAS group are sometimes referred to as the forever chemicals because they are so persistent, bisphenols and phthalates could be called hormone imposters, because they mimic the key sex hormones oestrogen (bisphenols) and testosterone (phthalates).

According to the 2018-19 Australian Plastics Recycling Survey[58], 3.5 million tonnes of plastics are consumed (within products) in Australia each year. It is certain that these plastics contain a range of chemicals that function as plasticisers, antioxidants, flame retardants, stabilisers, etc. What is not certain is which particular chemicals are added to Australian consumer goods to perform these functions and how much.

Potential concentrations and total tonnes of a range of potential chemical additives in plastic consumed in Australia in 2018-19 have been estimated in this report, using literature-based assumptions about chemical additive proportions per plastic type, since plastic products are mostly imported from overseas, it is difficult to know exactly which chemicals have been added and the respective quantities of each chemical. Salient observations from this work were:

- PVC is the plastic with the highest risk of containing additive chemicals, particularly EDCs, potentially at exceptionally high levels. Other observations about PVC were that –
  - phthalate plasticisers, according to the literature, potentially make up 30% of the weight of PVC, which is more a major component than an additive
  - over 100,000 tonnes of phthalate plasticisers such as DEHP or DBP were estimated to be used in plastics in 2018-19, the highest levels of EDCs recorded in all plastics.
- EDCs such BHT, 4NP and NP also have the potential to be present in HDPE, LDPE and polystyrene, although their concentrations are much lower than those used in PVC.
- Flame retardants such as decaBDE, HBCD and the organophosphates (TCPP, TCEP, TDCPP and TPP) are added to a wide range of plastics in typical concentration ranges of 0.5% to 15% of the weight of the plastic.
- However, if dechlorane plus was used for flame retardancy that proportion could be as high as 35% of the total plastic it is added to, which could account for over 200,000 tonnes of this chemical in Australian plastics in 2018-19.

As of January 2021, dechlorane plus and UV 328 were before the 16th meeting of the Persistent Organic Pollutants (POPs) Review Committee (POPRC-16) to the Stockholm Convention for potential listing on the Convention.

Also from January 2021, changes came into effect to the Basel Convention, clarifying some plastic wastes as presumed to be hazardous, and therefore subject to the Convention's control of transboundary movements between parties. In short, any plastic waste that cannot be recycled by Basel 'disposal operation' *R3 Recycling / reclamation of organic substances that are not used as solvents*, which would typically include polyurethane foam, poly vinyl chloride and polytetrafluoroethylene (commonly branded as Teflon), would fall under the control of the Basel Convention[77]. In addition, many plastic mixtures and those known to be contaminated with hazardous constituents will also be captured.

[77] Scottish Environment Protection Agency (December 2020), International Waste Shipments – Guidance on the Basel Convention Amendments on plastic waste, available at: *https://www.sepa.org.uk/media/539014/basel_convention_amends_plastic_waste.pdf*.

5.6 A number of old and new infrastructure issues remain, but new capability is emerging

Hazardous waste management in Australia is a relatively mature industry, but several unresolved infrastructure problems remain:

- Used lithium-ion batteries are forecast to reach 100,000 tonnes/year by 2036, yet in 2016 only 2% were collected and exported for offshore recycling; the majority were disposed of in landfill or stored, with no clear domestic management fate available. Damage or puncture can result in explosion and fire, and the number of these incidents in Australian waste infrastructure is growing. Highlighted in previous editions of this report, this problem persists and is likely to increase in significance without dedicated industry support, potentially via product stewardship arrangements.
- Hazardous waste landfills, those designed with the highest levels of engineering, are limited in Australia, and those in both Vic and NSW have identified an approximate lifespan until around 2030. Non-hazardous waste landfills, typically designed with single-liner barrier protection, also face airspace constraints, particularly where PFAS contaminated soils concerned.
- Some of Australia's cement infrastructure is used for thermal destruction of hazardous waste, where high calorific wastes containing small quantities of hazardous chemicals provide fuel replacement. At least some of these facilities are ageing, but their role in hazardous waste management is currently important, even crucial for some wastes.
- Bradbury Industrial Services, a key national provider of waste solvent recycling infrastructure, closed in 2019. Bradbury was critical to the recycling of solvent and related flammable wastes nationally and its loss has put additional pressure on other infrastructure in Vic, NSW and Tas.
- NSW's Homebush Bay liquid waste facility, a key and longstanding piece of NSW infrastructure, is facing expiry of its lease in 2025. The facility has traditionally taken a variety of liquid wastes, including waste non-aqueous solvents, paints, other flammable wastes and wastewaters contaminated with PFAS and other oxidisable organic compounds. This capability is not well-catered for elsewhere.
- The waste management industry is reportedly finding insurance harder to get due to recent incidents (for example lithium-ion battery fires) and media attention on unscrupulous activity regarding waste more broadly. This could put pressure on existing operators to close.

All of this creates the backdrop of an infrastructure set that, in some areas, will need future investment.

The last 2-3 years have seen some significant infrastructure commissioned that has the potential to provide significant extra capacity and, in some cases, new capability to further support the Australian hazardous waste management market. Significant infrastructure development has occurred since HWiA 2019 was written, with major new facilities opened in WA, large expansions underway in NSW and a major block of soil thermal treatment plants coming online in Vic. Qld has also added a new CPT plant. A number of proposed facilities have also been approved by environmental regulators and are in various stages of design and construction.

The number and nature of new hazardous waste facilities recently built and in the pipeline suggest that the industry is changing. This degree of flux and investment has probably not been seen for some time in Australia.

5.7 Public confidence in hazardous management is low – is it time for more public disclosure?

The case against public disclosure of hazardous waste tonnages and information has always been built around the commercial sensitivity of such information, but this report raises this question again, in light of media reports about fraudulent activity in the waste sector.

There is a balance of perceived risks of exposure of commercially sensitive information (through publication of company-specific waste volumes) versus this social benefit, but is it justified, in light of the experience of the National Pollutant Inventory, which has disclosed similar information without major confidentiality issues for 20 years?

While such a move would be uncomfortable for some operators in the sector, it is not without precedent. The Scottish EPA make available quarterly, online, its waste sites and capacity data tool[78], an impressive collection of detailed data on waste types, amounts and capacities at a site level. It includes the numbers and types of sites, the amounts and kinds of waste they handle, and what their capacity is to accept waste and all data is fully downloadable. It is, in a sense, the National Pollutant Inventory of waste data.

Given the recent failings of waste governance, is it time for a rethink?

5.8 Data quality, access and classification issues must be improved

This is the fourth biennial report in this series since the first was published in 2015. Hazardous waste data and understanding, at least in the public domain, has improved significantly over that period, and yet many issues and weaknesses in data provided by jurisdictional governments remain.

Data

- Electronic tracking systems are not available in all jurisdictions for within-jurisdictional waste movements, while paper recording systems are used for the most part in cross-border transactions. Paper-based systems create a myriad of data quality problems.
- One of those paper-system problems is the heavy resourcing burden of data entry and quality assurance. This issue has manifested most in Qld, which reports a backlog of approximately 430,000 paper waste transport certificates that have not been processed/verified, meaning paper data is only complete up to October 2016.
- Data on waste source was insufficient for quantitative analysis in 2019-20. Only SA produces a dataset with a reasonable level of completion.
- Vic and WA provided only aggregated waste tracking data for 2019-20, with no visibility of waste sources, treatment facilities or waste contaminants. These details are collected in tracking systems but withheld due to confidentiality concerns (see Section 5.7).
- The quality of data available to this project on interstate movements of waste, particularly in some jurisdictions, is questionable due to the patchwork of approaches used in its implementation.
- Regulatory exemptions in NSW cause some shortcomings in the data.

[78] Scottish EPA (SEPA), *Scotland's waste sites and capacity data tool*, available at: https://www.sepa.org.uk/data-visualisation/waste-sites-and-capacity-tool/.

Access

- In addition to the lack of public disclosure, each state's tracking data is maintained as confidential and not shared with other jurisdictions, other than the Commonwealth.
- Data is only supplied for national analysis purposes (such as this report) annually. Compilation, collation, quality assurance and interpretation adds several months again, so any worthwhile issues that may be identified in this process could be 1-2 years after they occurred, hampering the potential for follow-up action.
- A perfect example of this data access delay is that data-visible impacts of clinical waste volumes from the COVID-19 year of 2020 will not be evident until analysis of 2020-21 data, which will not occur (at the earliest) until late 2021 or early 2022, long after the value of this information has passed.

Classification

- There are difficulties identifying PFAS wastes caused by lack of data clarity – the new management code M270 is used differently across jurisdictions, while high-concentration PFAS wastes (such as foams and adsorbents) and low concentration PFAS wastes (such as PFAS contaminated soil) are indistinguishable in tracking data. This is unacceptable for such a prominent, new and critical waste stream.
- The reporting of wrapped asbestos containing material, separately from soil and rubble contaminated with asbestos containing material, is an important distinction from policy and management perspectives, but the N220 classification is applied inconsistently in this respect, across jurisdictions.
- Classifying management method within only six categories limits capacity to interpret and report on what happens to hazardous wastes. Not only are they too restrictive, in many cases they overlap – for example, CPT, recycling and thermal treatment are variously used to describe the same management method, while recycling and biodegradation are routinely confused.

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In addition to the list of references above, Appendix E contains a list of references specifically used in estimating additive concentrations in plastics (Section 4.4.1).

Appendix A Key terms and definitions

Key terms and definitions

The primary source of information about hazardous waste terms and definitions in Australia is the *Australian hazardous waste data and reporting standard*[79] (referred to in this and subsequent appendices as 'the Standard'). Some of the most pertinent terms for this report are defined below.

Hazardous waste

Hazardous waste is waste that, by its characteristics, poses a threat or risk to public health, safety or to the environment. In national reporting this term is taken to correspond with:

- wastes that cannot be imported or exported from Australia without a permit under the *Hazardous Waste (Regulation of Exports and Imports) Act 1989*
- wastes that any jurisdiction regulates as requiring particularly high levels of management and control, namely: regulated waste (Qld); trackable waste (NSW); prescribed waste (Vic); listed waste (SA and NT); or controlled waste (ACT, Tas and WA)
- additional wastes nominated as hazardous by the Australian Government[80].

NSW (along with the ACT[81], due to their adoption of NSW classification procedures) uses the term 'hazardous waste' in a specific regulatory sense. The NSW *Protection of the Environment Operations (Waste) Regulation 2005* and associated guidance defines hazardous waste as one of six classes of waste – and it typically cannot be disposed at landfill without hazard reduction treatment such as immobilisation. Hazardous waste in this strict NSW (and ACT) regulatory interpretation is equivalent only to those hazardous wastes (in national reporting terminology) that would be categorised at the higher hazard end of the range.

Regulating and tracking hazardous waste in Australia

Whereas the Australian Government has responsibilities in relation to hazardous waste under the *Hazardous Waste (Regulation of Exports and Imports) Act 1989* (the Hazardous Waste Act) and the *National Waste Policy,* regulation of hazardous waste management is mainly the responsibility of the states and territories (the jurisdictions). In order to ensure appropriate management of these wastes, the five largest jurisdictions (NSW, Qld, SA, Vic and WA) operate systems for 'cradle to grave' tracking of the movement of each consignment of hazardous waste from point of generation to treatment or disposal. Tracking certificates include the type and quantity of waste, the dates, and the producer, transporter and details of the receiving facility. A copy is sent to the government. The jurisdictions agreed to allow the use of the large data sets generated by their tracking systems in this study, under confidentiality agreements. ACT and Tas do not have intrastate tracking systems in place, although much of their waste is sent to infrastructure across borders, which is tracked under Controlled Waste NEPM requirements. While NT waste movements are similarly dominated by exports to other jurisdictional infrastructure, this jurisdiction implemented its own electronic waste tracking system in July 2020. In addition, the NT require reporting of amounts of controlled waste handled by producers, transporters and receivers, for the operating year of their licence.

The *National Environment Protection (Movement of Controlled Waste between States and Territories) Measure* (the Controlled Waste NEPM) is the legal agreement shared by all jurisdictions

[79] Available at: https://www.environment.gov.au/protection/waste-resource-recovery/publications/australian-hazardous-waste-data-reporting-standard.

[80] For example, the Australian Government has considered waste lithium-ion batteries as hazardous in assessing the adequacy of hazardous waste infrastructure.

[81] Environment ACT (2000) *ACT Environmental Standards: Assessment and Classification of Liquid & Non-liquid Wastes,* June, available from: http://www.environment.act.gov.au/__data/assets/pdf_file/0005/585500/wastestandards.pdf.

and the Australian Government that governs the movements of controlled waste (equivalent to hazardous waste in the context of this report) across state and territory borders. This requires these movements to be tracked, although this is commonly maintained as a multiple copy paper-based system.

The reporting year used for data in this report

The Standard identifies five purposes for reporting quantities of hazardous waste at a national level in Australia. These are reproduced in Table 11 (overleaf). Basel and OECD reporting use calendar year format while the *National Waste Report* (which incorporates hazardous waste), reporting under the Controlled Waste NEPM and HWiA all use financial year format.

The reporting year used in this report is the 2019-20 financial year, the most recent financial year for which data was provided or available for all jurisdictions.

Appendix C Section C1 includes hazardous waste generation data at the 'NEPM 75' level (the most detailed waste categorisation level obtainable from tracking data, as described in this Appendix under '*The NEPM and its waste classification systems*'). Data in this appendix is presented to enable either financial year or calendar year viewing. Appendix C Section C2 includes hazardous waste generation data in Y code format (as required by Basel) submitted for the Basel report for calendar year 2019, alongside the two six-monthly blocks it was collected in.

The meaning of waste arising

The term 'arise' is used in relation to hazardous waste data derived from tracking systems. Waste arises when it is delivered to hazardous waste processing, storage, treatment, or disposal infrastructure. This is distinct from 'generation', a term commonly used in waste reporting, in that if waste is transported to more than one site it may arise more than once in the tracking system data.

Some of the data presented in this report is waste arising, which is consistent with data from the jurisdictional tracking systems. This differs for the Basel report (Appendix C), which specifically requires waste generation as defined below.

It should be noted that until a waste is moved offsite, it does not arise. Waste that is created on a site and remains stored there has not arisen.

The meaning of waste generation

Waste generation is the process of creating a waste. For data purposes, generation of non-hazardous waste is normally taken as the sum of waste disposed of, recycled or sent for energy recovery. Generation of hazardous waste is more difficult to estimate because data on the tonnages to each of these fate types is not always readily available, and additional pathways, such as storage or treatment, may be taken by hazardous waste on route to its final fate. Inclusion of tonnages to these additional pathways would result in multiple counting of the same waste, which was generated only once.

Table 11 National reporting of hazardous waste data

Report	Rationale	Period	Frequency	State and territory data needed by	Content
Report to the Basel Secretariat	Requirement of the Basel Convention	Calendar year	Annually	By end of previous calendar year	Quantities generated nationally by waste type
Hazardous Waste in Australia	Government commitment under the *National Waste Policy Action Plan 2019* (Action 7.5)	Financial year	Every two years	Not yet fixed	Quantities, trends in quantities, sources, pathways and fates, potentially with sub-analyses by jurisdiction
National waste reports	Government commitment under the *National Waste Policy Action Plan 2019* (Action 7.3)	Financial year	Not yet fixed	Not yet fixed	Quantities, pathways and fates by jurisdiction
Other international: - OECD reports - Stockholm Convention - Minamata Convention	Requirement of membership for each	Calendar year	Various	Varied	Various. Note that Stockholm and Minamata Conventions are chemical contaminant rather than waste-based, but reporting requirements include wastes that contains these chemicals.
NEPM reports	Requirement of the NEPM and its implementation agreement	Financial year	Annual	Not fixed	Collated summary information on the: (i) movement of controlled waste into each jurisdiction, indicating jurisdiction of origin, waste code and quantity of waste; (ii) level of discrepancies (e.g. non-arrival of a consignment) as a percentage of total authorised controlled waste movements; and (iii) benefits arising from the implementation of the Measure.

Source: Blue Environment, Ascend Waste and Environment and Randell Environmental Consulting (2016). Australian hazardous waste data and reporting standard, prepared for the Australian Government Department of the Environment and Energy for distribution to the Australian states and territories, Appendix H Table 6.

In using arisings data to estimate hazardous waste generated for the purpose of this report (and related work such as Basel reporting), the following is subtracted (to the extent the relevant tonnes can be identified):

- hazardous waste sent to facilities for short-term storage or transfer
- hazardous waste outputs of hazardous waste infrastructure – only inputs are counted.

This method seeks to avoid multiple counting in waste generation. Conversely, waste arisings have no adjustments applied for multiple counting.

The meaning of waste source

The source of waste is where it is generated, which could be the location (geographical source) or the company or industry sector that produced it. This report, like others, describes geographical source at the jurisdictional level. However, to provide a greater level of understanding of the data, this report focuses on the industry source sector where possible. Reporting industry source is not always provided, or even collected, by jurisdictional tracking systems. Where it is collected, some jurisdictions do not provide it for the data analysis purposes of this report, due to sensitivity concerns about identifying individual waste-producing companies, even though these names are not published as part of the scope of this work.

Industry sectors are shown in this report using the ANZSIC code system where quantitative data exists. Jurisdictional tracking systems typically allow for inclusion of waste origin in transport certificates, which is generally equivalent to ANZSIC code, but both provision of this information and its accuracy is typically limited.

The meaning of waste fate

Waste fate refers to the ultimate destination of the waste within the management system. Types of fate may include recycling, energy recovery, long-term storage and disposal, each of which categories can be divided into more specific fates. Treatment, transfer and short-term storage are not fates, but are rather part of the pathway leading to a fate.

The meaning of waste pathway

The pathway of hazardous waste covers the various steps in the route between hazardous waste generation and fate, potentially including transfer, storage and/or treatment.

The meaning of waste management

For the purposes of this report, management of hazardous waste comprises the activities through which it is dealt with in infrastructure approved to receive it. The types of management are recycling, energy recovery, long-term storage, disposal, treatment and short-term storage. The first four of these are a type of fate; the last two are a type of pathway.

Therefore, for hazardous waste, tonnes managed = tonnes sent to pathway infrastructure + tonnes sent to fate infrastructure.

In this report, management data was available from states (NSW, Qld, SA, Vic and WA), but the categories of management used were not entirely consistent. Consequently, a lowest common denominator approach was taken to categorise management methods, to allow comparative analysis between these states. The categories applied to enable all three states' data to be used were:

- recycling

- CPT
- landfill
- biodegradation
- incineration
- storage or transfer.

This approach, and the way primary data is recorded in these tracking systems, introduces a level of ambiguity that limits the value of the management/fate assessment. For example:

- Recycling includes resource recovery, reclamation and energy recovery, since there is no energy recovery category. This can lead to mapping of an incineration process, for example, not to incineration but to recycling, because the thermal treatment process may either recover energy or use the waste (in some small or large part) as recovered fuel.
- Biodegradation is a category on its own, but composting of organic material could be coded as either biodegradation or recycling, because the biodegradation process produces another beneficial use for the waste.
- CPT processes typically describe chemical processes (e.g. oxidation, reduction, precipitation, neutralisation, etc.) and physical treatments (e.g. sedimentation, filtration, adsorption, immobilisation, etc.). If the outputs from simple CPT find a further use, the management/fate could also be described as recycling.
- Incineration is an unnecessarily narrow categorisation – thermal destruction would be more useful – because POPs destruction facilities such as those that use plasma arc are left without an accurate fate category – under the current headings they could be deemed to reside in CPT, which is not the purpose of that category.

These are limitations of the tracking system data and its interpretation. The Standard seeks to address and unify these different jurisdictional approaches to recording management types over time as systems are reviewed and updated. The Standard's longer term proposed categorisation of fate and pathway management types (outlined in the Standard's Appendix H *Hazardous waste management typology (long-term)*) is consistent with that provided in Annex IV 'Disposal Operations' of the Basel Convention, organised as Disposal Codes D1 – D15 and Recovery, Recycling or Re-use Codes R1 – R13.

International imports and exports of waste

Waste arisings/generation data should include:

1. waste that is generated within a jurisdiction and destined for management infrastructure located within that jurisdiction
2. waste that is generated within a jurisdiction and destined for management infrastructure located outside that jurisdiction, in another Australian state or territory
3. waste that is generated within a jurisdiction and destined for management infrastructure located out of the country, via international export under the permit system of the Hazardous Waste Act.

The first two types of arisings are intended to be captured by this project. Internationally exported/imported wastes, via the Hazardous Waste Act's permitting system, are not included in this project explicitly as part of generation and arisings, because they are generally not captured in underlying jurisdictional tracking data. However, they are provided in waste flows (Table 1) to provide context to the hazardous waste market in Australia. The relative contributions of imports and exports to Australia's hazardous waste tonnages are very small.

The NEPM and its waste classification systems

Hazardous waste produced in a particular jurisdiction may move to another for storage, treatment or disposal. The NEPM was established to ensure that hazardous wastes transported between jurisdictions are properly identified, transported, and otherwise handled. Among other things, the NEPM established a coding system to be used for these wastes. Many of the jurisdictions' own waste classification systems have been subsequently updated to fully or mostly mirror the NEPM list. The NEPM classification system has two levels:

- the NEPM 75[82] list contained in Schedule A, List 1 of the NEPM
- the NEPM 15 list, which aggregates the NEPM 75 and is used for reporting purposes.

The NEPM 15 and 75 lists provide the foundation for the waste groups used in this project.

Basel Convention Y-codes

Basel Y-codes (see Appendix C Section C2) are a pre-determined waste classification system for reporting under the Basel Convention. For Australian data, which is collected by states and territories first using their own classification systems, this must undergo a two-stage translation: to NEPM codes (common Australian system) and then further to Basel Y-codes. This translation process was established by the authors in a 2012 project for the Department and is further described in jurisdictional guidance developed as part of that work (Blue Environment *et al*., 2014).

After the translation process outlined in this guidance was applied, a number of NEPM codes remained that were suitable for reporting but could not be readily mapped to Basel Y-codes. The answer was to create eight new descriptions for reporting to the Basel Secretariat, referred to as 'Y+8' codes (Y+1 through to Y+8), made up from groupings of the outstanding NEPM codes as described in Appendix C Section C3.

Three Basel Y-codes stand out as different from the rest, in the context of Australia's report:

- Y46 Wastes collected from households are not considered in this report's analysis, although it has been estimated by the authors of this report and is included in Appendix C Section C2 for completeness.
- Y47 Residues arising from the incineration of household wastes have not been either estimated or included in any part of this report. Energy-from-waste incineration technologies (of mixed waste) are only in their infancy in Australia, and while they should generate volumes for Y47, this data is likely to be captured by NEPM codes such as N205 (residues arising from industrial waste treatment/disposal operations) and N150 (fly ash, excluding fly ash generated from Australian coal fired power stations) which makes it difficult to isolate.
- Y48 Plastic waste, a recent addition to the Basel Convention (implemented January 2021)[83], to be added to Australia's Basel report for 2020, as available data allows.

[82] There are 75 waste categories listed in Schedule A List 1 of the NEPM. The alpha-numeric codes (A100 for example) do not actually exist in the NEPM but have been adopted to practically represent Schedule A of the NEPM, and do not include oxidising agents, reducing agents or reactive chemicals, presumably because these descriptions are generic and better covered by existing more specific categories, such as perchlorates or peroxides. Also, oxidising and reducing agents could be grouped as types of reactive chemicals, which introduces another level of overlap. Therefore, in reality, only 73 coded wastes are used in NEPM tracking (and therefore in this and similar reports), but the 'NEPM 75' term is still used to describe the list of 73 wastes, since it reflects what the NEPM actually prescribes.

[83] Discussed previously in Section 4.4.

Classifications of waste applied in this project

Hazardous waste data could be grouped or codified for analysis purposes in a number of ways. Fundamental is the most detailed level of disaggregation, such as the NEPM 75 levels or the Y codes adopted by the Basel Convention. Since Australian data is routinely captured in NEPM-like codes and descriptions, this is used by data underlying this report.

However, in compiling the original version of this report (HWiA 2015*)* it became apparent that the NEPM 75 approach was too detailed for useful analysis. Consequently, HWiA 2017 and beyond use a more condensed classification system, defining 'waste groups' that are mostly consistent with the NEPM 15 heading level list, but with some categories disaggregated where a component waste was likely to arise in large or highly uncertain amounts, had particular management requirements, or was of particular interest for some other reason. These 30 waste groups are shown in Table 12.

Table 12 Waste groups used for Hazardous Waste in Australia 2019

Waste groups summarised	
A	Plating and heat treatment
B	Acids
C	Alkalis
D110	Inorganic fluorine (spent potliner)
D120	Mercury and compounds
D220	Lead and compounds
D230	Zinc compounds
D300	Non-toxic salts (including coal seam gas wastes)
Other D	Other inorganic chemicals
E	Reactive chemicals
F	Paints, resins, inks, organic sludges
G	Organic solvents
H	Pesticides
J100 & J160	Oils
J120	Waste oil/water mixtures
K110	Grease trap wastes
Other K	Other putrescible / organic wastes
M100	PCB wastes
M160	Other organohalogen compounds
M270	PFAS contaminated materials
Other M	Other organic chemicals
N120	Contaminated soils
N205a	Contaminated biosolids
N205b	Other industrial treatment residues
N220	Asbestos containing material
Other N	Other soil/sludges
R	Clinical and pharmaceutical
T140	Tyres
Other T	Other miscellaneous
Other	(Not classified)

Data analysis in HWiA follows both the detailed (NEPM 75) and condensed (waste groups) categorisations, as follows:

- Waste arisings and generation
  - Section 3 and Appendix B of this report list waste arisings (or generation) by the waste groups of Table 12.
  - Appendix C Section C1 provides 2019-20 national hazardous waste data, broken down in a detailed NEPM 75 level of collation. All data analysis is carried out on foundation NEPM code data, with aggregation to the condensed waste groups as described above for management (fate and pathway) analysis and waste trends.
  - Appendix C Section C2 provides the 2019 Basel report data, in Basel Y-codes. This report does not conduct further analysis of this data in the Basel Y-code format.
- Waste sources
  - Where source data is available, this is described for each waste at the waste group level.
- Fate and pathway (management) of wastes
  - Management is presented in this report based under the six fate and pathway headings described in 'The meaning of waste management' above, and by the waste group.
- Waste trends
  - Where data exists, historical trends are provided in this report based on the waste group level by jurisdiction.

Waste groups strike a sensible balance for this analysis between complexity (the 75 NEPM classifications) and overly-aggregated simplicity (the 15 NEPM headings).

Biosolids in a hazardous waste context

Biosolids are a product of sewage sludge (the sludge collected from wastewater treatment) once it has undergone further treatment to reduce disease-causing pathogens and volatile organic matter, producing a stabilised product. Biosolids may be contaminated above guideline levels or recovered as a resource for various beneficial uses.

The concepts of biosolids and contaminated biosolids, and how they fit into the context of hazardous waste, have the potential to be confusing. The following describes how biosolids have been differently interpreted and applied in related Departmental projects:

- Basel Reporting (see Appendix C Section C2) – All biosolids are reported as a hazardous waste (as a subsection of 'Y+4 Putrescible/organic waste'), as a conservative measure in line with reporting of other wastes not typically deemed hazardous in Australia, such as (Basel code) *Y46 Wastes collected from households*. This is because we do not have comprehensive testing and quality data to confirm an exact amount of biosolids that is hazardous (due to contaminants), from the total, therefore we report the total amount.
- National Waste Report – Biosolids are mostly assumed to be uncontaminated, following the reporting for the Biosolids Partnership.
- HWiA 2017, 2019 and 2021 (this report) – Typically includes biosolids in hazardous waste arisings and generation, using the N205a biosolids waste group, other than for
  - Historical trends of arisings: which does not include biosolids, as they are not regulated as hazardous in jurisdictional tracking systems.
  - Management: Actual fate and pathway data (from Vic, NSW and Qld) did not include biosolids, therefore attributions of arisings to fate do not include biosolids.

Sections 4.3.2 and 4.7.2 of this report explore potential resource and hazard aspects of biosolids from the perspective of emerging contaminants, due to some uncertainties and complexities that need to be considered in its environmental management from both operational and regulatory perspectives.

Confidential and commercial-in-confidence information

The tracking system data used in this project was submitted to the jurisdictions under legal commitments to protect confidentiality. The jurisdictions, in turn, agreed to provide tracking system data for this project under agreements that required the project team to maintain commercial confidentiality. Tracking system data was analysed to examine tonnages of waste arisings by waste code, year and jurisdiction – if this was made publicly available, in some cases companies might be able to work out the scale of rival's operations.

To prevent this, arisings, historical trends, sources and fates were presented at the waste group level, which is definitionally aggregated more broadly than what has been published in past years' Basel reporting and related data projects.

This report breaks down national hazardous waste tracking data to a level of source information that identifies industry sectors, although in most cases data quality limits quantitative assessment at this level. This largely qualitative approach further protects confidentiality (it is noted that the Standard states that 'state and territory data collated by NEPM or Basel Y-code is not considered confidential' (p.21)).

Appendix B Data analysis – by waste group

Data analysis – by waste group

This section analyses and comments on the data presented in Section 3 and detailed in Appendix C (Section C1) National hazardous waste data 2019-20 and 2019 – by NEPM code, for each of the 30 waste groups.

Each waste group's analysis is structured by:

- waste sources (by dominant industry sector) and some discussion of the nature of the waste
- tonnages generated
- historical trends in waste group arisings
- management approaches adopted for the waste group.

Beyond absolute tonnage quantities, all remaining analysis above requires a detailed breakdown in the data, which is what tracking systems can provide. Since the ACT, NT[84] and Tas did not have electronic tracking capability in 2019-20, only data from NSW, Qld, SA, Vic and WA is available for analysis.

Waste sources

In the case of waste sources, the non-tracking jurisdictions are not included in tabulations because no breakdown by source is possible, and neither is WA as no level of source identification is provided in its collated tracking data. Where significant sources in these jurisdictions are known and relevant they are included in analysis text.

The summary tables analysing the sources of each waste group by state show the contributing industry sectors in approximate order from highest to lowest contributing tonnages. SA continued to provide good quality source data for 2019-20, with source sectors recorded for 79% of SA tonnes reported. The remaining jurisdictions provided no useful source information at all in 2019-20 data. This continues a recent history of poor recording of waste generation sources by ANZSIC code in tracking systems.

More detailed analysis of raw data was undertaken for NSW and Vic data in HWiA 2019 (using 2017-18 data), to determine percentage breakdowns of their source industries. This analysis has typically been retained in this report, since categorised raw data was not made available in 2019-20.

Good quality SA source data allowed for quantitative analysis for 2019-20 in the most part, while Qld's qualitative source data analysis is based mostly on 2015-16 data, the last dataset provided without a caveat on data completeness.

Historical trend charts

In the case of historical trends in waste arisings, ACT, NT[84] and Tas are not included in charts because they do not have a history of electronic tracking capability. Trends are typically charted for NSW, Qld, SA, Vic and WA, although occasionally some of these are missing for reasons such as the waste group (e.g. Vic A waste) is not fully tracked or because the main source does not exist in that jurisdiction (e.g. spent pot liner D110 – no aluminium smelting operations are present in SA or WA).

[84] The NT Online Waste Tracking System was rolled out for use by all licensees in NT in mid-January 2021, with a transitional period (in parallel with the paper system) until 1 April 2021. The system operates from the NT EPA Online platform (*https://www.ntlis.nt.gov.au/ntepa/auth/login?redirect=bjAIEwlYPasINWZpcilzpFOQPBSWkytj*).

Management data

Similarly, management data is collated and discussed below for NSW, Qld, SA, Vic and WA. The ACT, NT and Tas do not record management data due to the absence of intrastate tracking systems in these jurisdictions in 2019-20.

Where 2019-20 analysis figures are quoted, such as percentage contributions by jurisdiction or waste type, waste generation figures have been used. When discussing trends, arisings data is typically used – unadjusted to generation because the information required to make such multiple-count adjustments is not always available for the historical record. This approach allows trends to be viewed consistently over time.

Although biosolids are presented in the waste group analysis below (Appendix B Section B22), national percentages (waste group to total waste) quoted in the respective discussions of each waste group exclude biosolids. This is due to the swamping effect of this large waste stream and the fact that biosolids are not expressly captured by jurisdictional hazardous waste regulations (although they may exhibit hazardous characteristics).

The Qld data caveat

Tracking data from Qld was supplied with the following caveat:

> *'There is currently a backlog of approximately 430,000 paper waste transport certificates [WTCs] which have not been processed/verified, and the data associated with these WTCs is not available in WTS [Qld's waste tracking system]. Therefore, paper WTC data is only complete up to October 2016.'*

This caveat means that tracking data after October 2016 is incomplete, with the extent of that under-report dependent on how significant paper WTC transactions (as opposed to online transactions) were for any particular waste group. Since this is unknown, we have adopted a modelling decision for the years 2016-17 onwards, that if annual data subsequent to 2015-16 is less than the 2015-16 value multiplied by 60%, it is replaced with the 2015-16 value multiplied by the proportional increase in population. This decision framework is applied on a NEPM waste code basis, which means that a waste group made up of several waste codes could be a combination of supplied data and data estimated according to this method.

Because this decision resulted in adjusted data estimates, we have chosen to include them in all tonnage-based figures throughout the report, but exclude them from trend charts. Consequently, where this adjustment decision has been made for a waste group, Qld trendlines are not shown for those years in the trend charts below.

B1 A: Plating and heat treatment

This group includes:

- *A100 Waste resulting from surface treatment of metals and plastics* – Overspray of coating materials together with excess material removed in cleaning of equipment – the latter includes sandblast cleaning and surface protection of metal surfaces, including shipping hulls.
- *A110 Waste from heat treatment and tempering operations containing cyanides* – Molten inorganic salts are used to 'case harden' or 'face harden' iron or low-carbon steel or to control temperature in the tempering process.
- *A130 Cyanides (inorganic)* – Solutions of sodium and potassium cyanides are used in processes that do not result in their complete transformation or destruction and they are present in wastes from such processes.

Sources

Table 13 provides a summary of the main sources of waste in each jurisdiction.

Table 13 Plating and heat treatment summary source analysis 2019-20

NSW [85]	Vic (A130 only) [85]	Qld	SA	National summary
1% of national total for waste group	0.3% of national total for waste group	• Shipyards and slipways • Metal coating and finishing • Waste collection, treatment and disposal services • Coal mining	1% of national total for waste group • Waste collection, treatment and disposal Services • Oil and gas extraction	• Shipyards and slipways • Metal coating and finishing • Waste collection, treatment and disposal services • Coal mining

The majority of the source data (by tonnes) presented in Table 13 is generated in Qld (mostly A100) from the following sources:

- shipyards and slipways (from ship hull cleaning and protective coating)
- metal coating, finishing and surface blasting (such as electroplaters, galvanisers and metal cleaning via sandblasting).

The other notable feature of 2019-20 data for this waste group is that WA contributed 18% of the national total, along with Qld's 80%, leaving only 2% coming from all other jurisdictions combined. No source data is available for WA.

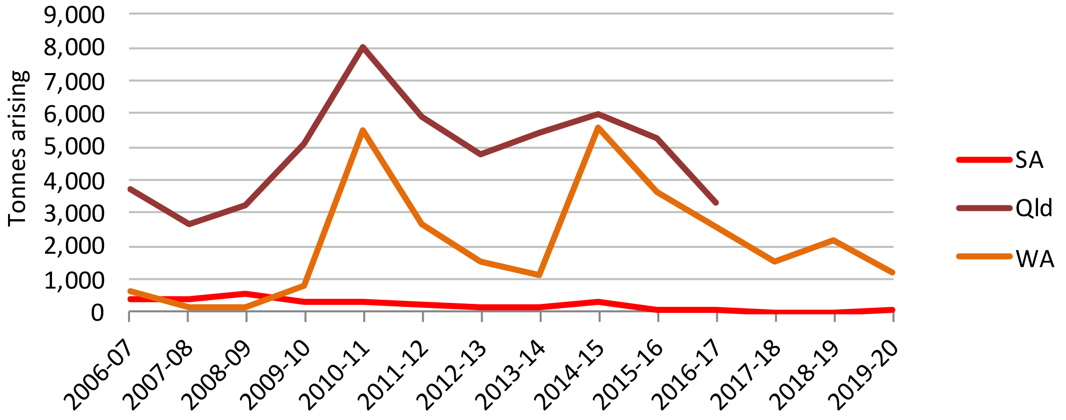
Analysis

This waste group is small by volume in Australia, making up only 0.1% of the national total in 2019-20. It is dominated by *A100 Waste resulting from surface treatment of metals and plastics* and derives from overspray of coating materials together with excess material removed in cleaning of equipment. This waste is generated from either metal surface cleaning and protection, such as barnacle removal from ship hulls, cleaning, blasting and other surface finishing techniques in metal manufacturing/finishing industries and industrial cleaning and protection of heavy equipment, such as is used for mining applications.

[85] Detailed source analysis undertaken on 2017-18 data.

Historical trends in arisings for this waste group, predominantly for Qld and WA, are shown in Figure 25. The trends for both states fluctuate markedly at times, but overall can be characterised as increasing.

Figure 25 Historical arisings of plating and heat treatment waste



Management

Management approaches for this waste group differ between Qld and WA. In Qld, 55% goes to storage and 32% to landfill, although in Qld's case management data in incomplete. In WA 96% is recorded as going to CPT. This difference is likely to be attributable to the different types of materials used in these differing surface treatment processes. Marine anti-fouling technologies are likely to use quite different approaches and materials to land steel applications.

B2 B: Acids

This group comprises the single NEPM code *B100 Acidic solutions or acids in solid form*. It can take a large variety of forms including, but not limited to sulfuric acid, hydrochloric acid, nitric acid, phosphoric acid, chromic acid, hydrofluoric acid, mixed inorganic and organic acids.

Sources

Table 14 provides a summary of the main sources of waste in each jurisdiction.

Table 14 Acids summary source analysis 2019-20

NSW [85]	Vic [85]	Qld	SA	National summary
• 47% Iron smelting & steel manufacturing • 40% Petroleum refining & petroleum fuel manufacturing • 2% Copper, silver, lead and zinc smelting & refining	• 41% Structural metal product manufacturing • 35% Petroleum refining & petroleum fuel manufacturing • 3% Petroleum product wholesaling • 1% Motor vehicle parts manufacturing	• Copper refining • Metal coating & finishing • Coal mining • Alumina refining • Waste collection, treatment & disposal services	• 55% Cement, lime, plaster & concrete product manufacturing • 23% Motor vehicle parts manufacturing • 15% Residential building construction 2% of national total for waste group	• Structural metal product manufacturing • Petroleum refining • Copper refining • Iron smelting & steel manufacturing • Petroleum product wholesaling • Metal coating & finishing • Coal mining • Alumina refining

Vic produced the largest quantities of acid wastes in 2019-20 (61%), followed by Qld with 20%. Their main sources (and those of NSW) were steel and metal related industries such as metal product manufacturers, foundries, metal refiners, electroplaters, galvanisers, and other metal product manufacturing industries, as well as petroleum refining.

Analysis

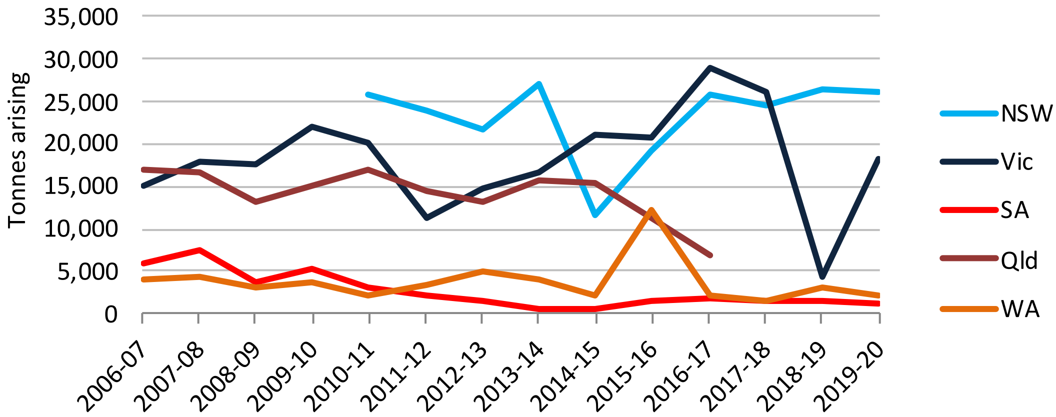
This waste group is relatively small by volume in Australia, making up 0.8% of the national total in 2019-20. Liquid is the dominant waste form.

Historical trends in arisings for this waste group are shown in Figure 26. While there is some historical fluctuation, Vic arisings have usually been within the 15,000–25,000 tonnes/year band. The 2018-19 low Vic arising may be more to do with data quality, since interstate tracking data from that state has been questionable in the past, probably to do with the use of paper WTCs.

Acidic spent pickle liquor from steel making is a key component of this waste stream in NSW, but tonnages are likely to be under-reported in NSW due to the regulatory exemption for spent pickle liquor reuse that has applied there since 2006.

Another important aspect of acids waste is that a large proportion of the waste stream appears as exports from Vic to NSW.

Figure 26 Historical arisings of acids waste



Management

The management of this waste group is listed as:

- 99% CPT in NSW
- 21% CPT and 78% 'other' in Vic
- 42% CPT and 32% storage in Qld (noting that Qld management data is only attributed to 32% of its tonnes reported for B Acids)
- 100% CPT in SA
- 87% CPT and 32% storage or transfer in WA.

While neutralisation via CPT is historically a typical pathway, analysis of NSW tracking data shows that Vic companies send their B100 waste to spent-acid regeneration infrastructure in NSW. These WTCs record the management as CPT although it would appear to more accurately recorded as (the Basel disposal operation) *R6 Regeneration of acids or bases*, which would best be described as a form of recycling. This highlights a broader issue (discussed in HWiA 2019), where the restricted system of only 6 management type headings in NSW and SA can result in blurred distinction between recycling and CPT, the latter often used as a broad catch-all category.

The 78% other management category in Vic is most likely capturing export to NSW recycling, with a lack of clear management categorisation. This demonstrates a weakness in closing the loop of the interstate transport system, where such a transaction is not being fully reflected back in the tracking system of the state of origin of the waste (Vic in this case).

B3 C: Alkalis

This group comprises the single NEPM code *C100 Basic solutions or bases in solid form*.

Sources

Table 15 provides a summary of the main sources of waste in each jurisdiction.

Table 15 Alkalis summary source analysis 2019-20

NSW [85]	Vic [85]	Qld	SA	National Summary
• 78% Industrial gas manufacturing • 10% Iron smelting and steel manufacturing • 3% Petroleum refining & petroleum fuel manufacturing	• Petroleum refining and petroleum fuel manufacturing • Metal coating and finishing • Motor vehicle parts manufacturing • Waste collection, treatment and disposal services	• Ready-mixed concrete manufacturing • Asphalt manufacturing • Oil & gas extraction (CSG/LNG) • Aluminium refining	• 91% Basic chemical manufacturing	• Ready-mixed concrete manufacturing • Asphalt manufacturing • Oil & gas extraction (CSG/LNG) • Aluminium refining • Basic chemical manufacturing • Industrial gas manufacturing • Petroleum refining & petroleum fuel manufacturing

WA produced the biggest portion (43%) of alkali wastes in 2019-20, followed by Qld with 40%.

WA C100 is entirely red mud from the aluminium refining industry, which is a significant contributor to Qld tonnages as well. Red mud is produced in exceptionally large quantities during aluminium refining, but only those volumes that move to dedicated offsite residue storage areas, such as happens at scale in WA, are captured by tracking systems.

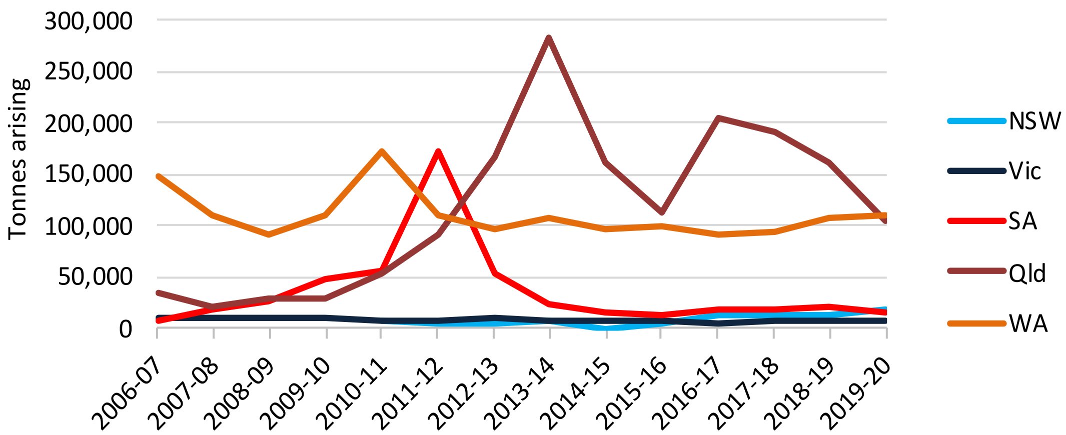
Historically the main Qld source was CSG extraction but this has changed markedly through 2017-18 and now in 2019-20, where just 3% of Qld's alkali waste came from this industry. As discussed in Analysis below, Qld alkalis in tracking data are now dominated by concrete manufacturing.

C100 is also produced in small quantities across Australia as waste from surface cleaning/degreasing in a range of industries as diverse as metal coating and finishing to fast food.

Analysis

Historical trends in arisings for this waste group are shown in Figure 27. This waste is moderately significant nationally, at 3.5% of all hazardous waste arising in 2019-20.

Figure 27 Historical arisings of alkalis waste



Qld arisings from the pre-mix concrete industry

Following on from recent years, 2019-20 Qld tracking data includes large representation from the concrete production (and aligned asphalt production) industries, sectors that were essentially absent from data prior to 2016-17. Approximately 67%[86] of all Qld C100 waste in 2019-20 was from these sectors. There appears to have been some form of regulatory or industry policy change post-2015 that has captured concrete washout (presumably with high pH) to be C100 regulated waste, and subject to tracking in Qld. These industry sectors are not represented at all as C100 sources in NSW or Vic.

The waste is alkaline material from concrete washout areas, 'used to contain concrete slurry and liquids when the chutes of concrete mixers and hoppers of concrete pumps are rinsed out after delivery to a site. The washout facilities are used to consolidate solids for easier disposal or reuse and to prevent runoff of contaminated liquids.'[87]

Qld arisings from the CSG industry

Qld C100 waste that is produced by the CSG industry is mostly drilling mud (in liquid form), the waste output of the use of drilling fluids to access the coal seams, described in HWiA 2017 as containing mostly brine/water (76%), barium sulphate (14%) and bentonite clay/polymer (6%). This has dropped as a proportion of total Qld C100 dramatically in recent years – 120,000 tonnes in 2014-15 down to just 1,500 tonnes in 2017-18.

The reason for the disappearance of Qld CSG drilling mud from tracking data is almost certainly the new 'End of Waste Code' for coal seam gas drilling mud[88], which became effective in January 2019. This new industry requirement is designed to enable a waste to be reclassified as a resource, and therefore avoid administrative requirements such as waste tracking, as long as contaminant limits are demonstrated to be met and the material is managed according to one of the approved uses (essentially as input to composting to produce compost or conditioned soil product). These contaminant limits and the specifics of the approved uses are spelled out in the code. Although the End of Waste Code is silent on the issue, this change in classification has largely seen drilling muds no longer tracked in Qld. The small residual drilling muds tonnage still tracked probably represents those wastes not in compliance with the code, potentially due to exceedance of a contaminant threshold or simply because of impracticalities in sending the material to composting, with distance/cost potentially a factor.

End of Waste Codes, like NSW's regulatory exemptions (from tracking) may result in wastes 'disappearing' from national collations like this one, because they are no longer tracked as moving into infrastructure. This would appear to be the case for Qld CSG-based C100 waste in 2019-20.

This significant reduction in tracked drilling mud in Qld is shown in Figure 27 as a somewhat jagged but clear decline from the peak of 2013-14.

Management

Qld data indicates that 74% of alkali waste is recycled, which captures mostly concrete washout, with the 24% categorised as landfill mostly reflective of red mud going to a residue storage area. The

[86] On a gross mass basis, unadjusted for density.

[87] NSW Government Transport for NSW 2015, Concrete Washout Guideline 3TP-SD-112/2.0, available at: https://www.transport.nsw.gov.au/sites/default/files/media/documents/2017/concrete-washout-guideline%20-3tp-sd-112.pdf

[88] QDSE 2019: Queensland Government Department of Environment and Science, *End of waste code Coal Seam Gas Drilling Mud (ENEW07543018),* 01 January 2019, available at https://environment.des.qld.gov.au/assets/documents/regulation/wr-eowc-approved-drilling-mud.pdf

remainder includes some 'surface impoundment' of drilling muds (translated as 'storage' in the management headings in this report) and chemical physical treatment.

C100 concrete washout was sent to Qld management codes R5 (recycling/reclamation of inorganic substances), carried out by concrete recyclers or quarries. These facilities may not be licensed as hazardous waste management facilities in other jurisdictions but would appear to be captured in Qld due to recent changes to 'environmentally relevant activities' legislation.

Red mud residue storage areas are a form of regulator-approved storage that is essentially long-term or indefinite.

B4 D110: Inorganic fluorine (spent potliner)

This group comprises the single NEPM code *D110 Inorganic fluorine compounds excluding calcium fluoride*. This NEPM code is used in the Australian dataset virtually exclusively to describe spent potliner (SPL), a waste material generated from aluminium smelters, of which there are four in current operation (in Vic, NSW, Qld and Tas) and two recently closed (in Vic and NSW).

SPL can exhibit the following hazards:

- toxicity – leachable fluoride and cyanide compounds, with fluoride levels often around 10%
- corrosiveness – high pH due to the presence of alkali metals and oxides
- reactivity with water – producing toxic, explosive and inflammable gases.

SPL is sometimes heat-treated prior to transport to recycling/re-processing fates to remove cyanides and flammability risk, but not fluorides, hence the convention to record it in tracking systems as *D110 Inorganic fluorine compounds excluding calcium fluoride*.

Sources

Table 16 provides a summary of the main sources of waste in each jurisdiction.

Table 16 Inorganic fluorine (SPL) summary source analysis 2019-20

National summary (in Vic, NSW, Qld & Tas only)
100% Aluminium smelting

Analysis

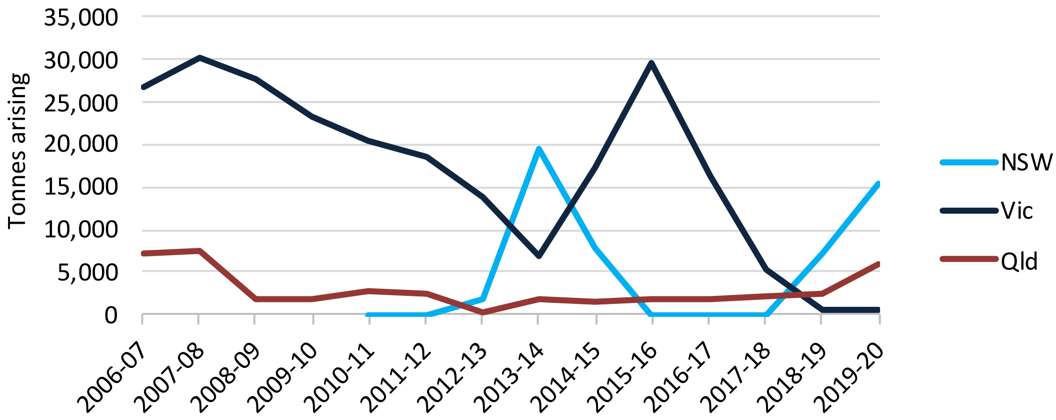
This waste group is relatively small by volume in Australia, making up 0.5% of the national total in 2019-20. However it is a good example of why annual volume (tonnage) is not an accurate indicator of the significance of a waste. SPL is problematic because:

- it contains a number of different and significant hazards
- it is produced from a potentially declining industry sector in Australia (which increases the risk of stranded infrastructure with legacy environmental liabilities)
- management solutions have proved difficult for decades
- large stockpiles around Australia, summing to approximately 700,000 tonnes, are held in either above-ground (shed) or below-ground (landfill) storages around Australia (REC *et al*. 2016), dwarfing the 38,000 tonnes annual generation estimate in Table 2.

Historical trends in arisings for this waste group are shown in Figure 28 which provides some value from an indicative trend perspective, but is limited by two issues:

1. Annual aluminium production figures are used to derive generation figures instead of tracking system data, on the basis that this is a better estimate of tonnages produced due to the prevalence of onsite storage (that is not visible in tracking systems). When SPL is intermittently released from these storages (and into tracking data) trends can appear in spikes, which is not a true indicator of waste generation. The arisings trends in Figure 28 are based on tracking systems.
2. The other state with an operational aluminium smelter (Tas) is not represented because it does not have a tracking system.

Figure 28 Historical arisings of inorganic fluorine (SPL) waste



However, Figure 28 does indicate that:

- SPL arisings in Vic have declined over the last decade, culminating in a low when Alcoa Point Henry closed down in February 2014 and rebounding the year after that due to some movements of previously stored material. The other smelter in Vic (Portland) stores its SPL onsite, so it was not tracked in 2019-20.
- NSW data shows a spike when SPL was taken out of onsite storage in 2013-14 and again in 2019-20; although aluminium (and SPL) production has continued in the intervening period, virtually none has moved offsite for treatment/disposal.

Management

Tracking data shows that SPL in NSW was exclusively sent to CPT when it arose in 2019-20, noting that this could be otherwise described as recycling, since the process employed involves recycling some of the post-treatment outputs. Qld management of SPL in 2019-20 was exclusively recycling, via an industrial symbiosis arrangement with a nearby cement kiln where the waste is used as an alternative fuel substitute. A similar cement kiln application also applies with SPL generated in Tas, although it is likely that the quantity able to be accepted is less than the quantity generated, resulting in some onsite storage. Negligible Vic arisings of SPL in tracking data confirm onsite storage in 2019-20.

B5 D120: Mercury & compounds

This group comprises the single NEPM code *D120 Mercury; mercury compounds*. While volumes are small, this waste is addressed separately in this analysis due to its inherent hazard, as evidenced by the Minamata Convention on Mercury.

Sources

Table 17 provides a summary of the main sources of waste in each jurisdiction.

Table 17 Mercury & compounds summary source analysis 2019-20

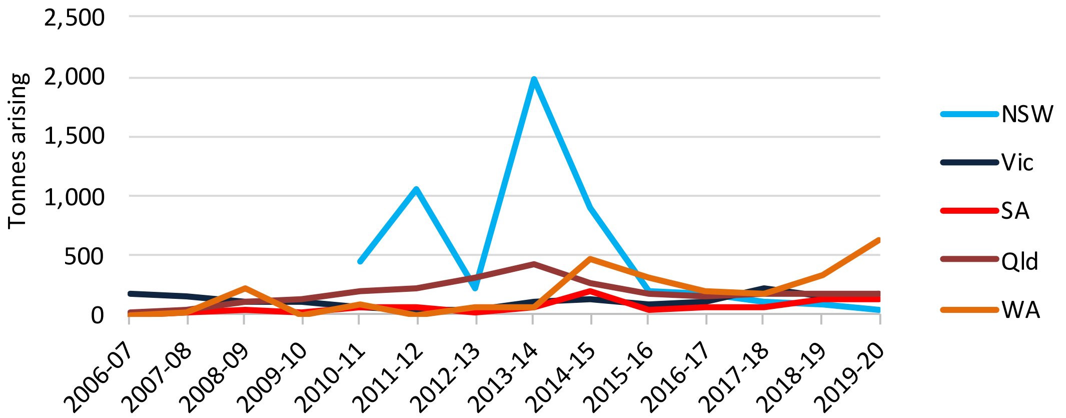
NSW [85]	Vic [85]	Qld	SA	National summary
• Waste treatment and disposal services • Various manufacturing • Lighting (retail)	• 53% Waste treatment and disposal services • 18% Non-residential building construction[89] • 11% Aluminium smelting	Disparate sources	• 42% Oil & gas extraction] • 45% Motor vehicle parts manufacturing • 7% Other transport equipment manufacturing	• Oil & gas extraction • Waste collection services • Lighting (retail)

Mercury volumes are small but appear to be growing in recent years, namely in WA. Often the waste industry is listed as the producer, given its role in fluorescent lighting collection programs, but oil and gas extraction has emerged in 2019-20 data as a source relevant to some jurisdictions.

Analysis

Historical trends in arisings for this waste group are shown in Figure 29 below. While extremely small by tonnage (0.02% of all hazardous waste arising in 2019-20), this waste presents a very high hazard waste with limited long-term management options.

Figure 29 Historical arisings of mercury waste



The major spike in NSW in 2013-14 was due to isolated movements of a large volume of mercury waste rehabilitated from a closed waste management operation. Other spikes in data could be miscoded soil whose contaminant was mercury, and should have been coded as N120 contaminated soil (not D120 mercury). This could also be a simple typographical error, given the commonality of the '120' part of the code (D120 v N120). This has also been observed in Qld data previously, and the Vic source 'Non-residential building construction' is evidence of such a mistake in 2017-18 data.

However, fluctuations that appear as spikes from year to year are also common for those wastes that are sent to storage then later released back into the market when either volumes become more economic or better management options emerge. Mercury wastes are a candidate for this sort of storage/release activity, as discussed in Management.

[89] Attribution of mercury waste to this source is likely to be in error, see 'Analysis' beneath Figure 29.

WA has recorded a significant rise in mercury waste since 2017-18 (as shown by Figure 30) and, while WA-supplied tracking data does not enable source industries/companies to be visible, this increase may be due to the release of spent mercury recovery units[90] from the oil and gas sector, given the implementation of the Minamata Convention on Mercury in August 2017.

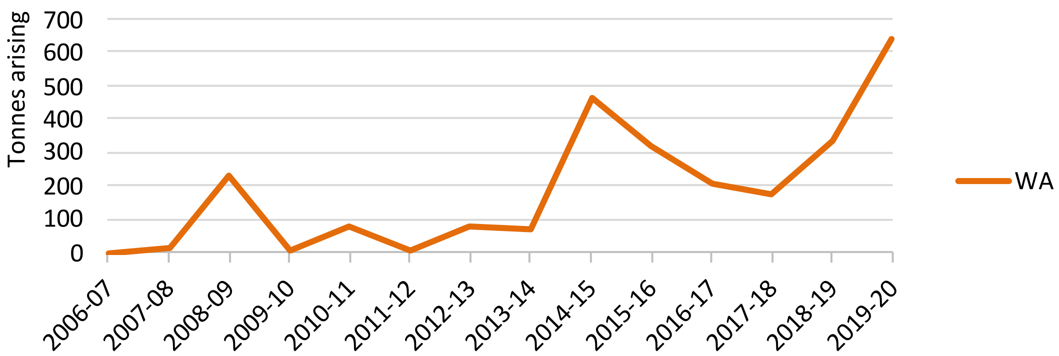
HWiA 2019 noted with respect to mercury recovery units:

> 'Mercury is present in all hydrocarbon reservoirs at trace levels, and is concentrated in waste from mercury removal units (MRUs) in the form of spent mercury adsorbents (usually activated carbon) or contaminated hydrocarbon sludges... In the absence of a pressing need for processing, these wastes have traditionally been held in onsite stockpiles. *(p.60)*'

Apart from the obvious environmental and work health and safety issues concerning mercury, there is a specific risk that mercury-entrained petroleum feedstock can damage metal components of processing plant equipment (particularly aluminium), through a form of corrosion, which can lead to catastrophic equipment failure.

The Minamata Convention appears to be offering a new incentive for companies to eliminate this contingent liability from site, at least in SA and potentially WA. It is also likely this may apply to oil and gas infrastructure in Qld and Vic, but issues to do with completeness and source quality of data respectively limit visibility.

Figure 30 Historical arisings of mercury waste in WA



Management

Eighty-three percent of mercury waste nationally was sent to storage in 2019-20. This is linked to its small volumes, hazardous nature and consequent management challenges. High storage rates have been a feature of mercury waste noted in past HWiA editions. The remaining 17% is mostly recycled in the limited mercury infrastructure available in Australia (sometimes referred to in data as CPT). Perhaps important to the rise in mercury wastes in the WA data is the opening of two new treatment facilities in 2019 (see Section 4.6.2, Table 10).

[90] A mercury recovery unit, or mercury removal unit, is mercury 'clean-up' equipment specific to the sector, which separates mercury from oil/ gas streams by absorbing onto capture media and filtration.

B6 D220: Lead & compounds

This group comprises the single NEPM code *D220 Lead; lead compounds*.

Sources

Table 18 provides a summary of the main sources of waste in each jurisdiction.

Table 18 Lead & compounds summary source analysis 2019-20

NSW [85]	Vic [85]	Qld	SA	National summary
• 72% Motor vehicle parts retailing • 12% Metal and mineral wholesaling • 8% Motor vehicle dismantling & used parts wholesale • 2% Copper, silver, lead and zinc smelting and refining	• 61% Motor vehicle dismantling & used parts wholesale • 19% Motor vehicle parts retailing • 13% Copper, silver, lead and zinc smelting and refining	• Lead acid battery collection • Scrap metal collectors and recyclers • Waste collection, treatment and disposal services	• Other motor vehicle parts manufacturing	• Zinc smelting & refining (Tas only) • Motor vehicle parts retailing and dismantling & used parts wholesale • Lead acid battery collection • Scrap metal collectors and recyclers • Waste collection, treatment and disposal services

Australia has the world's largest deposits of both lead and zinc, and processing of lead ore in Australian primary metal smelters and refineries led to around half of lead wastes generated in 2019-20. Most of this occurs in Tasmania, but there are also smaller more specific arisings of lead waste from smelting and refining of metals, mining and scrap metal recyclers.

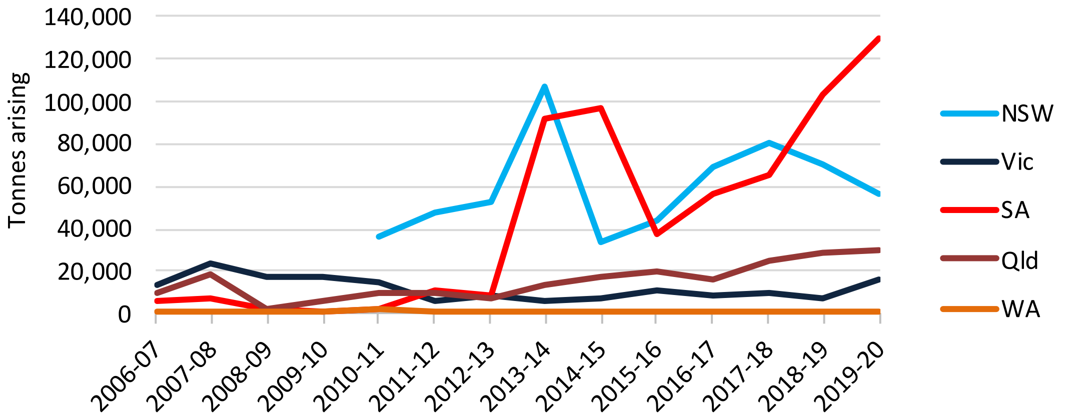
The other half was from used lead acid batteries (ULABs) from vehicle and related battery applications. ULABs originally come from a broad range of industries, including vehicle intensive ones such as mining and transport-related businesses, but usually via collection programs facilitated by metal and other resource recovery companies.

Analysis

This waste was quite significant nationally by tonnage in 2019-20, coming in 8th highest at 4% of all hazardous waste generated, according to data evident in tracking systems. The majority of this was generated in Tas (46%), with 17%, 16% and 15% generated in NSW, Vic and Qld respectively, while WA and SA had 3% each and the NT and ACT less than 1% combined.

Historical trends in arisings for this waste group are shown in Figure 31.

Figure 31 Historical arisings of lead waste



Note: SA's 2018-19 data point has been corrected to include Tas-reported generation of D220 (that is sent to SA), due to SA's omission of interstate import data in that year.

Tas D220 lead generation

While not directly present[91] in the data of Figure 31 due to its lack of a tracking system, Tas generated the largest tonnage of lead waste in Australia from the zinc refining industry in that state. Over 123,000 tonnes were generated from Tas in 2019-20, which is the highest tonnage recorded since SA began collecting and reporting interstate import data in national collations (2013-14).

While there were extremely high levels of generation in 2013-14 and 2014-15, these dropped back in 2015-16 (probably due to stockpiling) and then rose rapidly again over the last four years. These metal refining industry by-products/wastes are further processed to recover metal commodities such as lead in smelting infrastructure in SA.

ULAB lead waste generation

ULABs are produced from batteries disposed by motor vehicle parts retailers, car wreckers and other collection centres, often run by third parties. But, as highlighted in earlier editions of HWiA, NSW generation of lead waste in the tracking system-generated data set is an underestimate, due to its waste tracking regulatory exemption for spent lead acid batteries destined for reuse[92]. As part of assembling an accurate and method-consistent historical hazardous waste generation record (see Section 3.3), the 2019-20 national hazwaste data collation estimates the NSW ULAB generation to account for this gap in tracking data.

A more accurate ULAB market/generation estimation method

Two studies were used to quantify the ULAB market in Australia: Warnken[93] identified the total market arisings in 2009-10 to be 122,200 tonnes, of which 100,300 tonnes were processed within Australia. The difference (21,900 tonnes or 18%) accounted for double-counting of ULABs sent into breaking infrastructure and out again as broken up scrap, on-sent to domestic smelting (recycling). ISF UTS[94] then

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[91] Tas tonnages are actually contained within the SA red chart line of Figure 31, because their generation tonnage is sent to SA (via ship), so it is said to 'arise' in SA.

[92] See *http://www.epa.nsw.gov.au/wasteregulation/lead-acid-battery.htm.*

[93] Warnken ISE (2010) *Analysis of Battery Consumption, Recycling and Disposal in Australia*. Report for Australian Battery Recycling Initiative (ABRI) November 2010.

[94] ISF, UTS (2014), available at: *https://www.environment.gov.au/system/files/resources/b72944c5-4479-4bb3-89bd-740079c06743/files/lead-acid-batteries-entering-australia.pdf*.

estimated the 2012-13 Australian total market to be 137,000 tonnes. Assuming the same proportion (18%) was double-counted in 2012-13, about 112,400 tonnes of ULABs were processed that year. These two data points were used to indicate an annual growth rate for ULABs in Australia of 3.8% per year.

Extrapolating these figures to the present day gives the estimates of total ULABs arising in Australia shown in Table 19.

Table 19 Estimated national ULAB market (processed in Aust), tonnes

Year	Tonnes/year
2009-10	100,300
2010-11	104,131
2011-12	108,109
2012-13	112,448
2013-14	116,743
2014-15	121,203
2015-16	125,833
2016-17	130,639
2017-18	135,630
2018-19	140,811
2019-20	146,190

Tracking data reported directly by individual jurisdictions except NSW, from 2019-20, was then summed together and subtracted from the total market estimate, yielding an estimate of NSW's contribution. These NSW generation calculations were then backdated in the historical record (*Hazwaste generation historical data set* Excel workbook).

The jurisdictional breakdown of ULAB generation in 2019-20 is shown in Table 20.

Table 20 Estimated ULAB generation by jurisdiction 2019-20

Year	Tonnes/year	% of national
ACT	57	0.04%
NSW	44,169	31%
NT	1,926	1%
Qld	39,931	28%
SA	7,409	5%
Tas	2,921	2%
Vic	41,587	30%
WA	8,190	6%
Total	**146,190**	**100%**

Management

As expected, recycling dominates the management of arisings of lead waste in Australia, but this is heavily influenced by the large Tas-SA flows into metal smelting and refining infrastructure.
A misleadingly high proportion of batteries imported into NSW (75% in 2019-20) nominate CPT as the management infrastructure, when they are clearly received within secondary lead smelting (recycling). Adjusting for anomalies such as this suggests around 92% of all D220 (lead) waste managed in Australia is recycled, with the remainder accumulated in storage.

ULAB lead waste exports

There is a complex interplay between the market, its capacity and the *Hazardous Waste (Regulation of Exports and Imports) Act 1989* ('the Hazardous Waste Act'). The market in 2021 is made up of a single smelter-based recycler in NSW – the only full recycler of ULABs in Australia – while the remaining players employ battery breaking, followed by either further processing in the NSW smelting facility or, when this capacity is exhausted, export to smelters overseas.

The Hazardous Waste Act and subordinate regulation implements the Basel Convention in Australia. This means that the Australian Government must consider available Australian (full recycling) infrastructure capacity first, before granting a permit to export hazardous waste such as ULAB scrap (the output of breakers). Large quantities of lead paste and grid derived from ULABs have been exported in recent years[95], as Table 21 demonstrates, which hides the fact that domestic ULAB recycling capacity is, nowadays, significantly exceeded by market supply.

Table 21 Australian ULAB scrap exports, 2014-2019

Year	Quantity of ULAB scrap exported (tonnes)
2014	48,700
2015	19,500
2016	71,500
2017	61,600
2018	61,700
2019	73,000

Source: Australia's annual reports to the Basel Convention from 2014 to 2019: Department of Agriculture, Water and the Environment

This domestic market imbalance is likely to be stabilised in the near future, with construction underway of around 50,000 tonnes/year of extra capacity at EPSR in Wagga Wagga, NSW and the beginning of pre-construction works for a new 50,000 tonnes/year facility in Hazelwood North, Vic (see Section 4.6.2).

Several incidents where illegal movements of ULABs have been prevented or were returned to Australia have occurred in recent years – particularly to countries such as Malaysia[96].

[95] Around 2013 the former ARA smelter in Alexandria, Sydney closed down and a similar facility in Laverton North, Melbourne paused its thermal operations and operated as a breaker only. These 'closures' led to a reduction in domestic smelter-recycling capacity of 65,000 tonnes per year.

[96] Batteries International (2020), FIVE ILLEGAL CONTAINERS OF USED LEAD BATTERIES PREVENTED FROM ENTERING MALAYSIA, available at: https://www.batteriesinternational.com/2020/04/23/five-illegal-containers-of-used-lead-batteries-prevented-from-entering-malaysia/.

B7 D230: Zinc compounds

This group comprises the single NEPM code *D230 zinc compounds* and is analysed separately because of the significant tonnage generated in Tas and forwarded to SA.

Sources

Table 22 provides a summary of the main sources of waste in each jurisdiction.

Table 22 Zinc & compounds summary source analysis 2019-20

NSW [85]	Vic [85]	Qld	SA	National summary
• 100% Metal and mineral wholesaling – exported to SA	• 100% Metal and mineral wholesaling – exported to SA	<0.5% of national total for waste group	• Iron smelting & steel manufacturing <0.5% of national total for waste group	• Zinc smelting & refining (Tas only) • Metal & mineral wholesaling

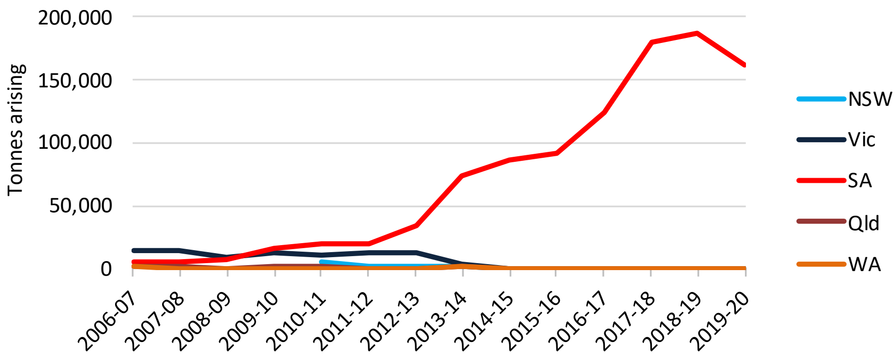
This waste was quite significant nationally by tonnage in 2019-20, at 2% of all hazardous waste generated. The vast majority of this was generated in Tas (92%), with the only other significant generation from NSW 6% and Vic 2%.

As discussed in Appendix B, in the case of historical trends in waste arisings and waste source analysis, Tas is not explicitly included in charts because it does not have an electronic tracking system.

Analysis

The Tas-produced zinc waste, like its lead waste, comes exclusively from zinc refining. Historical trends in arisings for this waste group are shown in Figure 32.

Figure 32 Historical arisings of zinc waste



Note: SA's 2018-19 data point has been corrected to include Tas-reported generation of D230 (that is sent to SA), due to the omission of interstate import data in that year.

The most notable aspect of Figure 32 is the SA (red) line, which shows large growth from 2010-11 onwards. Like lead waste this is not produced in SA but entirely in Tas. That state's zinc refining industry has been sending large shipments of zinc waste (and lead waste) to smelting infrastructure in SA for recycling over the last decade. These show up as SA arisings in raw SA tracking system numbers because they arise in the SA waste management system. Because Tas has no tracking system, it is not obvious that this comes from Tas exports, but this fact is borne out in SA tracking data which makes imported waste transactions clearly visible. Similarly, Vic and NSW export quantities of zinc waste, slag, dust and sludges from steel mills in each state.

The rate of zinc arisings into SA appears to have increased, firstly around 2012-13 then substantially again from about 2015-16. This is likely to be due to major upgrades of the Port Pirie lead smelter, with the top submerged lance furnace commissioned in late 2017 increasing throughput by 70% and enabling the treatment of internal residues across their smelter network[97]. The lower volumes accepted in 2019-20 probably reflect plant shutdowns that occurred in 2019[98].

Management

As described above, all of the zinc waste is received into metal smelting infrastructure in SA for recycling.

B8 D300: Non-toxic salts

This group comprises the single NEPM code *D300 Non-toxic salts*. In Qld this was historically dominated by highly saline solid, liquid and sludge by-products of CSG extraction, but these are not the main types of D300 appearing in tracking systems in 2019-20.

Significant non-CSG related sources of this waste are dominated by liquid wastes from WA, followed by salty slags leftover from the smelting or refining of aluminium, steel, lead and other metals.

Sources

Table 23 provides a summary of the main sources of D300 non-toxic salts in each jurisdiction.

Table 23 Non-toxic salts summary source analysis 2019-20

NSW	Vic [85]	Qld	SA	National summary
• 55% Aluminium smelting • 38% Copper, silver, lead and zinc smelting and refining	• 72% Aluminium smelting • 13% Metal and mineral wholesaling	Limited 2019-20 data available for useful analysis	<1% of national total for waste group	• Other non-metallic mineral product manufacturing (WA only) • Aluminium smelting • Copper, silver, lead and zinc smelting and refining • Metal and mineral wholesaling

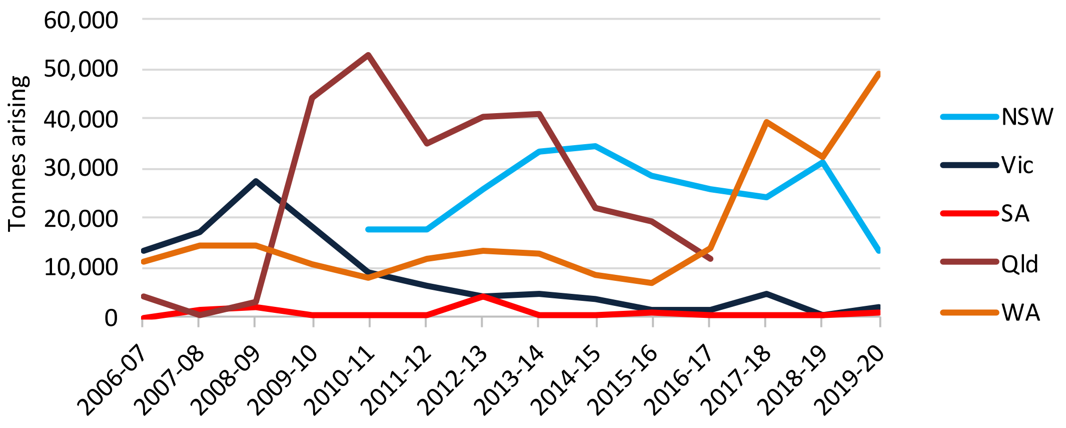
Analysis

Historical trends in arisings for this waste group are shown in Figure 33.

[97] Nyrstar Investor Presentation, 2018. Available at: https://www.readkong.com/page/nyrstar-investor-presentation-1091707.

[98] INDaily 13 August 2019, Nyrstar Port Pirie smelter shuts down again, available at: https://indaily.com.au/news/business/2019/08/13/nyrstar-port-pirie-smelter-shuts-down-again/

Figure 33 Historical arisings of non-toxic salts waste



In total this waste made up 1% of all hazardous waste generated nationally by tonnage in 2019-20, with WA generating 57%, Qld 24%, NSW 13% and Vic 6%. However, as discussed below, the contribution from Qld in 2019-20 may be significantly over-estimated.

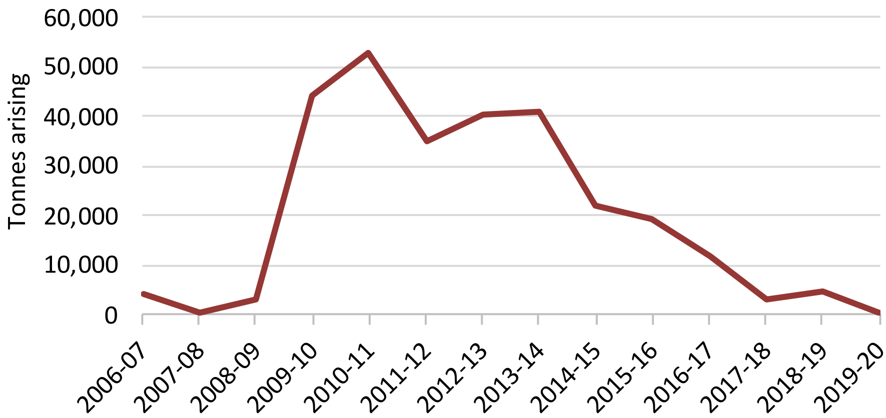
Qld CSG-produced non-toxic salts waste

The CSG industry in Qld's Surat Basin grew markedly in the mid to late 2000s and produced large volumes of salty wastes, in the form of drilling muds (C100) in the establishment of wells and water brought to the surface in the gas extraction process. The latter is now required to be desalinated in large scale reverse osmosis plants, yielding large volumes of water suitable for a range of uses. This desalination process also leaves substantial residues (D300) in the form of salts or brines.

However, the quality of Qld data supplied in recent years is accompanied by a key caveat that infers incompleteness, as described in Appendix B. Accordingly, Blue Environment has implemented procedures to assess whether any particular annual quantity for a waste is likely to be affected (under-reported) by this caveat and if so, replace the number provided with an alternative estimate drawn from the last year verified, complete data was received from Qld (the 2015-16 year), multiplied by population growth. The procedure assesses whether each waste's annual data point is less than 60% of the 2015-16 value, with 60% nominally chosen to take into account that quantities can vary significantly from year to year. While the estimated values cannot be confirmed as accurate, it is considered likely that, on average, across all waste types, they are more accurate than the incomplete data received.

From 2017-18 to 2019-20, Qld D300 data supplied was below this threshold, so it has been adjusted according to the method described. Surprisingly, perusal of 2019-20 waste transport certificates finds no CSG industry producers of D300 waste and a vastly reduced arising of just 680 tonnes – a far cry from the peak in tracking data above 50,000 tonnes in 2010-11. Figure 34 shows the Qld historical D300 trend without any adjustment in response to the data caveat.

Figure 34   Unadjusted historical arisings of non-toxic salts waste in Qld



Qld's approach to regulating the CSG industry's wastes has been somewhat fluid since the Coal Seam Gas Water Management Policy[99] was introduced in 2012, which also required that salt and brine waste must be managed according to two priorities:

1. Brine or salt residues are to be treated to create useable products wherever feasible.
2. After assessing the feasibility of treating the brine or solid salt residues to create useable and saleable products, brine and salt residues must be disposed of in accordance with strict standards that protect the environment.

The disposal requirements were later referred to as regulated structures and detailed in guidelines in 2014 (revised in 2019[100]). Requirements for desalination emerging from the 2012 water policy also began to be operationally deployed around 2014-15, across the southwest Qld CSG industry region.

Even with an incompletely compiled tracking dataset, if the Qld CSG industry was still producing significant quantities of D300 into the waste management market, some CSG company representation would be expected to be identifiable in 2019-20. Combining the policy driver of managing salt wastes in onsite regulated structures with the observed (unadjusted) trend in Figure 34, it seems probable that D300 arisings in Qld are more accurately represented without adjustment, despite the data caveat, to be at very low levels of arisings, with the vast majority of the waste managed in onsite regulated storage structures.

The obvious question this approach raises is common with other extractive industries – what happens to these waste structures once the resource is expended and it is time for site rehabilitation and remediation, given the extremely large volumes of salt contained within them?

WA-produced non-toxic salts waste

Given the lack of access to source information in all WA data, analysis of the largest D300 non-toxic salts contribution in national data in 2019-20 reveals little other than a major rise in tonnes generated since 2015-16, a trend that accelerated to a new high in 2019-20.

[99] Qld Department of Environment and Heritage Protection (2012), the Coal Seam Gas Water Management Policy 2012 – ESR/2016/2381, available at: https://environment.des.qld.gov.au/__data/assets/pdf_file/0034/89386/rs-po-csg-water-management-policy.pdf.

[100] Qld Department of Environment and Science (2019), *Structures which are dams or levees constructed as part of environmentally relevant activities*, available at: https://environment.des.qld.gov.au/__data/assets/pdf_file/0031/89383/era-gl-structures-dams-levees-eras.pdf.

HWiA 2019 linked WA D300 and F100 wastes (as well as N205), via their near identical growth profiles since 2015-16, concluding that virtually all WA's D300 waste was likely to be from a single non-metallic mineral product manufacturer newly introduced to the tracking system, with very large volumes of slurried treatment solid residues from the process' neutralisation plant. This remains the case for 2019-20 data.

Non-toxic salts waste from metal manufacturing

These are made up of:

- aluminium smelting industry wastes, mostly aluminium dross but also other salty wastes (often called salt cake) from ingot rolling in the final stage of production
- other metal smelting and refining industry slags, mostly furnace slags from lead acid battery recycling processes.

Arisings of D300 aluminium smelting salt cake into NSW remained level from 2017-18 to 2019-20 but furnace slag from lead acid battery recycling reduced by around half. The latter could be explained by significantly reduced production at the NSW ULAB smelter due to disruption during a major expansion in furnace capacity. This suggests potentially increased volumes of unprocessed ULABs were held in storage, awaiting the new capacity to be operational, or perhaps greater levels of export of D220 ULAB-related waste (either would result in less D300 slag generation in Australia). Perusal of Australian Government export permit approvals granted in 2020 specifically for ULAB scrap totals 79,200 tonnes and Table 21 indicates 2019 exports, at 73,000 tonnes, was around 20% higher than the previous two years. This would suggest that both higher storage and higher exports of ULAB-related wastes could have occurred due to reduced smelter activity in 2019-20.

Management

Aluminium dross is recycled in specific aluminium recovery infrastructure, with subsequent low value (secondary) dross material sent to hazardous waste landfill. Furnace slag from lead acid battery reprocessing and related metal smelting operations is also sent to hazardous waste landfill. Qld CSG salt waste appears to be predominantly managed in regulated storage structures (essentially engineered dams), although this is not apparent in tracking data since these wastes are kept onsite.

B9 Other D: Other inorganic chemicals

This group includes wastes contaminated with metal carbonyls; inorganic sulphides; perchlorates; chlorates; arsenic, cadmium, beryllium, antimony, thallium, selenium and tellurium; compounds of copper, cobalt, nickel, vanadium, boron, barium (excl. barium sulphate), chromium (hexavalent & trivalent) and phosphorus (excl. mineral phosphates)[101].

Sources

Other D wastes are small nationally by tonnage, at around 0.07% of all hazardous waste generated in 2019-20. Table 24 provides a summary of the main sources of waste in each jurisdiction.
Qld generated 69% of this waste and Vic 17% in 2019-20. In Qld, waste treatment activities were a source of arsenic wastes (D130), steel and foundry related industries produced chromium waste (D140) and copper wastes (D190) came from metal refining. Selenium waste (D240) from industrial chemical manufacturing was a significant contributor to NSW Other D wastes. In all jurisdictions, small quantities

[101] Also including compounds containing these elements.

of batteries such as NiCad and metal hydride were observed in the data, either from government or corporate collection programs.

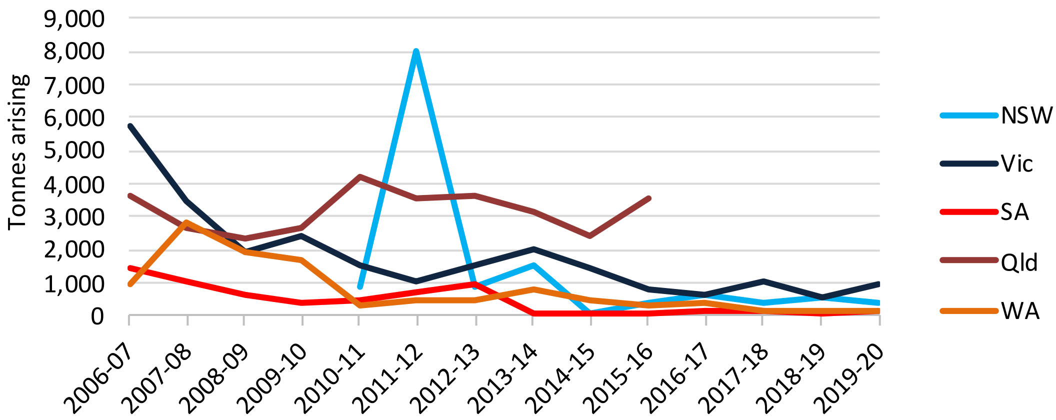
Table 24 Other inorganic chemicals summary source analysis 2019-20

NSW	Vic	Qld	SA	National summary
• Industrial chemical manufacturing • Waste treatment and disposal services • Defence, cruise ships, aviation	Not determined	• Waste treatment and disposal services • Copper, silver, lead and zinc smelting and refining • Foundries and steel product manufacturing	• 40% Paper stationery manufacturing • 25% Cement, lime, plaster and concrete product manufacturing • 18% Construction services	• Waste treatment and disposal services • Copper, silver, lead and zinc smelting and refining • Foundries and steel product manufacturing

Analysis

This group of wastes made up only 0.07% of all hazardous waste generated nationally by tonnage in 2019-20. Historical trends in arisings are shown in Figure 35.

Figure 35 Historical arisings of other inorganic chemical waste



Trends are difficult to decipher in the arisings data, which appears to show what may be a storage release spike for NSW in 2011-12 or, perhaps, a miscoded contaminated soil, contaminated with one of the metals in this group.

Qld's obvious spike in 2015-16 was from tellurium waste and is from a number of waste movements out of a single earth moving/demolition/civil contracting company, sending solid waste to landfill. This is probably another example of miscoded contaminated soil.

Management

Management data are as varied as the wastes themselves with the majority in Qld listed as going to storage, followed closely by CPT and then landfill. Both CPT and storage are the dominant forms of management of these wastes in Vic.

B10 E: Reactive chemicals

This waste group comprises the single NEPM code: *E100 Waste containing peroxides other than hydrogen peroxide*, although it shares similar strong oxidising properties to *D340 Perchlorates* and *D350 Chlorates*, which were not grouped together in this category to preserve NEPM E reporting alignment and because the contributions from D340 and D350 are similarly small.

Sources

Table 25 provides a summary of the main sources of waste in each jurisdiction.

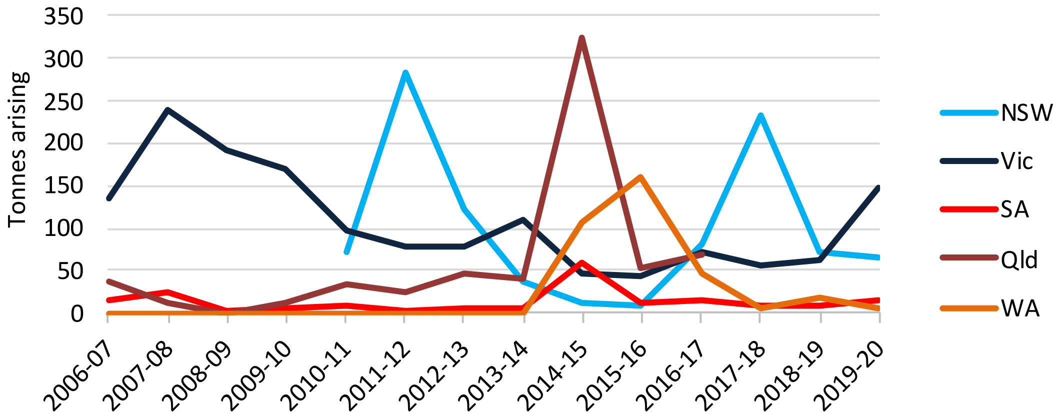
Table 25 Reactive chemicals summary source analysis 2019-20

NSW [85]	Vic [85]	Qld	SA	National summary
• Pharmaceutical industry • Waste treatment and disposal services • Defence • Laboratory services	• 43% Waste treatment and disposal services • Other basic non-ferrous metal manufacturing	• Aluminium smelting	Insufficient source information available	• Waste treatment and disposal services • Aluminium smelting • Other basic non-ferrous metal manufacturing

Analysis, including management

This waste was extremely small nationally by tonnage in 2017-18, at 0.004% of all hazardous waste generated. The majority of this was generated in Vic (53%), NSW (23%) and Qld (16%). Historical trends in arisings for this waste group are shown in Figure 36.

Figure 36 Historical arisings of reactive chemicals waste



This waste is produced in very small quantities and is difficult to characterise because the source of much of it is listed as the waste industry. This is typical of difficult-to-manage high hazard wastes that often default to storage, as is the case here, with 59% of all E waste going to storage and 38% to CPT in 2019-20.

An observation from Figure 36 is the number of jurisdictions that have shown sharp peaks in arisings. Given the small tonnages involved and the high hazard nature of the waste, this is likely to be storage release spikes.

A known waste that sometimes appears in this category is expired marine flares. State government guidance indicates they must be handed over to police, while in summer (in NSW at least) there have previously been dedicated collection systems. This also supports 'lumpy' arisings patterns.

B11 F: Paints, resins, inks, organic sludges

This group includes:

- *F100 Waste from the production and use of inks, dyes, pigments, paints, lacquers & varnish*
- *F110 Waste from the production & use of resins, latex, plasticisers, glues and adhesives.*

F100 includes polymeric material such as polyacrylates and methacrylates, together with mineral pigment processing wastes and small quantities of substances like plasticisers and anti-oxidants. F110 includes monomers used in production of polymers, waste products from the production site, or waste generated in or after use of the products.

Sources

Table 26 provides a summary of the main sources of this waste in each jurisdiction.

Table 26 Paint, ink, resin and organic sludge summary source analysis 2019-20

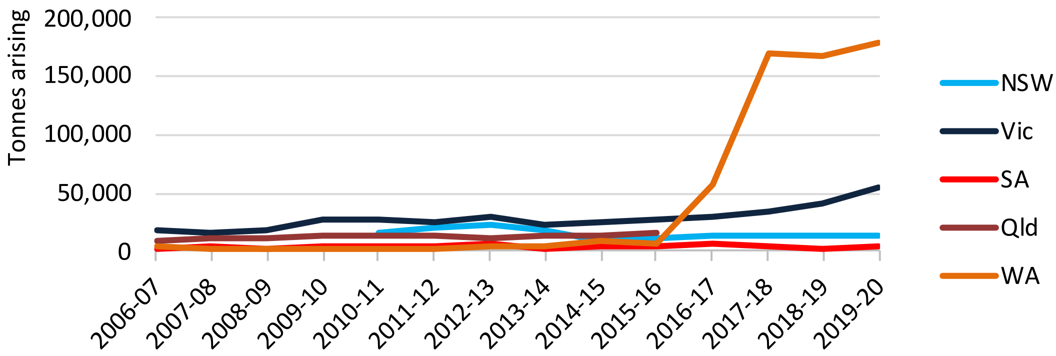
NSW [85]	Vic [85]	Qld	SA	National summary
• 40% Waste treatment and disposal services • 14% Paint and coatings manufacturing • 11% Basic organic chemical manufacturing • Printing, other 35%	• 40% Waste treatment and disposal services • 14% Paint and coatings manufacturing • 2% Motor vehicle manufacturing	• Paint and coatings manufacturing • Chemical and chemical product manufacturing • Printing • Metal product manufacturing • Pulp and paper manufacturing • Aircraft manufacturing	• 78% Other motor vehicle parts manufacturing • 10% Motor vehicle and motor vehicle part manufacturing • 5% Beer manufacturing	• Paint and coatings manufacturing • Waste treatment and disposal services • Chemical and chemical product manufacturing • Printing • Motor vehicle and motor vehicle part manufacturing

Although not included quantitatively in the source summary of Table 26, WA generated 67% of this waste, followed by Vic at 22%, Qld 6% and NSW 4%, in 2019-20. A supplier of raw material to the paint and coating manufacturing sector was responsible for the large WA arising, while the sector itself was a key source in other states, along with the waste industry.

Analysis

In total this waste makes up 4% of all hazardous waste generated nationally by tonnage in 2019-20, which ranks it surprisingly highly as the 7th highest. Historical trends in arisings for this waste group are shown in Figure 37. WA arisings swamp all other jurisdictions combined. The WA waste in question is *F100 Waste from the production, formulation and use of inks, dyes, pigments, paints, lacquers and varnish*.

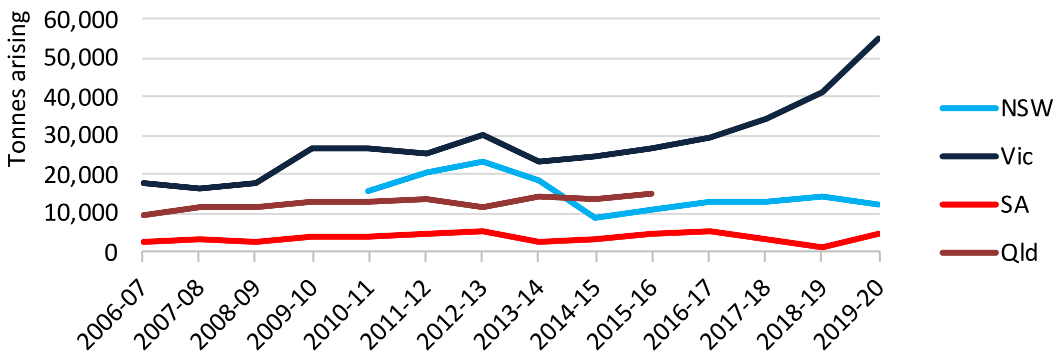
Figure 37 Historical arisings of paint, ink, resin and organic sludge wastes



As identified in HWiA 2019, the WA tonnage is a relatively recent occurrence, from a single company that has been in existence for some time, but has only begun using the controlled waste tracking system in WA since 2016, probably in correcting a previous oversight.

Another key observation in 2019-20 data is the more than doubling of Vic arising tonnages, following an exponential increase from around 2014-15, shown more clearly in Figure 38, in which WA arisings are excluded. The reasons for this are discussed in Management below.

Figure 38 Historical arisings of paint, ink, resin and organic sludge wastes, excluding WA



Management

WA F100 waste is slurried treatment solid residues from a pigment processing facility's neutralisation plant, which bears little resemblance to other wastes in the F description, such as solvent-based coating by-products, resin, adhesive and paint sludge wastes. Unusually, this slurry is sent to landfill, in a specific cell, with the resulting leachate returned back to the original facility's neutralisation plant (by road tanker again) for further treatment and subsequent discharge via ocean outfall. HWiA 2019 discussed this WA waste in detail, in discussions related to F, D300 and N205 waste groups, noting that landfilling of liquid/slurry waste was unexpected and unique in the Australian context.

Vic's large tonnages in 2019-20, increasing further on the recent annual trend, was managed as 57% into storage, 33% recycling and 8% CPT. Table 27 shows Vic's receipts of F waste into key management types across the last three editions of HWiA, in tonnage terms.

Table 27 F wastes received into dominant management types, Vic

Management type	2014-15	2017-18	2019-20
Recycling			
Tonnes of F waste	10,289	15,418	17,898
Storage			
Tonnes of F waste	10,752	10,915	31,234
All management types			
Total tonnes of F waste	24,961	34,132	54,930

A couple of observations can be drawn from this, in addition to the rising trend:

1. quantities recycled in Vic have increased over the period
2. quantities stored jumped markedly in 2019-20.

Along with G wastes (solvents), F wastes were a significant part of the warehousing and illegal disposal activity uncovered in late 2018 and early 2019, culminating in the Bradbury Industrial Services fire in Campbellfield in April 2019. Once Bradbury, the dominant player in the solvent recycling market in Australia, stopped operating, this created a shortage of infrastructure to deal with these wastes. In the short term, it is logical that this would lead to higher levels of storage.

Additionally, infrastructure pivotal to processing calorific liquid wastes Australia-wide, via co-firing as fuel substitute in thermal plant, appears to have taken some of this waste in lieu of Bradbury. However, the size of the jump in stored tonnes compared to the more modest increase in recycled tonnes suggests that an infrastructure shortage for these types of wastes remains, possibly on a national scale. This issue will be examined in the forthcoming *Hazardous waste infrastructure needs assessment project 2021*.

B12 G: Organic solvents

This waste group includes:

- *G100 ethers*
- *G110 organic solvents excluding halogenated solvents*
- *G150 halogenated organic solvents*
- *G160 waste from the production, formulation and use of organic solvents.*

Solvents have three principal areas of use; as cleaning agents, as raw materials or feedstock in the production and manufacture of other substances; and as carrying and/or dispersion media in chemical synthesis processes. They are often distinguished on the basis of halogenation in their chemical structure, with halogenated organic solvents more of a health and environmental concern than non-halogenated organic solvents. As a result, both usage and waste from halogenated organic solvents tend to be declining in favour of non-halogenated alternatives.

Sources

Table 28 provides a summary of the main sources of this waste in each jurisdiction.

Table 28 Organic solvents summary source analysis 2019-20

NSW [85]	Vic [85]	Qld	SA	National summary
• 25% Waste treatment and disposal services • 11% Printing & packaging Remainder made up of: • Dry cleaning; chemical and chemical product manufacturing; automotive and other machinery servicing, laboratory services, other manufacturing	• 35% Waste treatment and disposal services Remainder made up of: • Pharmaceutical manufacturing; printing; oil & gas extraction; motor vehicle manufacturing; organic chemical manufacturing	• Automotive and other machinery servicing • Waste collection, treatment and disposal services • Dry cleaning • Oil refining • Asphalt production • Motor vehicle manufacturing • Defence • Paint manufacturing	• 39% Other motor vehicle parts manufacturing • 29% Scientific research services • 17% Mineral, metal and chemical wholesaling	• Waste treatment and disposal services • Printing & packaging • Pharmaceutical • Dry cleaning • Automotive and other machinery servicing • Motor vehicle parts manufacturing

Generation of this waste was relatively evenly spread in 2019-20: Vic 44%, Qld 21%, WA 19% and NSW 13%. The waste industry is one of a number of major contributors to arisings, probably due to its role in distributed collection arrangements, such as from automotive servicing, dry cleaning and other individually small but highly represented waste generating businesses.

Analysis and management

This waste group is small by volume in Australia, making up 0.2% of the national generation total in 2019-20. Around 35% of all G waste nationwide was recorded as stored, the largest management percentage, with as much as 61% stored in NSW in 2019-20. Recycling (33%) and CPT (27%) are the other main management methods for this waste nationally.

Storage can dominate as a form of management for a number of reasons: difficulty of treatment due to limited infrastructure; complex management requirements due to high-hazard; small volumes per transaction (leading to efficiencies in accumulation for subsequent transport); or storage awaiting an interstate consignment authorisation. While all of these explanations may apply, limited infrastructure is also a likely driver, which supports a similar assertion for F waste infrastructure in Australia.

Historical trends in arisings for this waste group are shown in Figure 39. Figure 40 takes the same information and charts a national total over the top (broken line). This suggests that waste volumes have fallen quite consistently from around 2013-14, for reasons that are not clear. After the revelations of widespread mismanagement of this waste in Vic and SA in 2019 (see HWiA 2019, Section 4.3.1), volumes tracked would have been expected to have increased again by now. The fact that they have not, may be evidence that sufficient replacement capacity has not yet emerged in the solvent treatment market, which could mean that significant quantities of this waste remain at generation-facilities. This is only speculative but, given the environmental and health impacts from criminal activity in this sector in the recent past, a better understanding of G waste sources, volumes, market capacity and destinations is warranted.

Figure 39 Historical arisings of organic solvents wastes

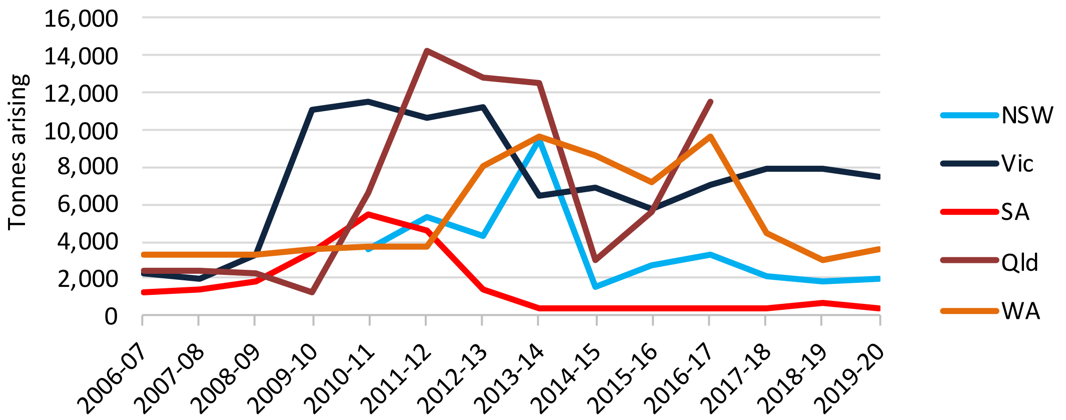
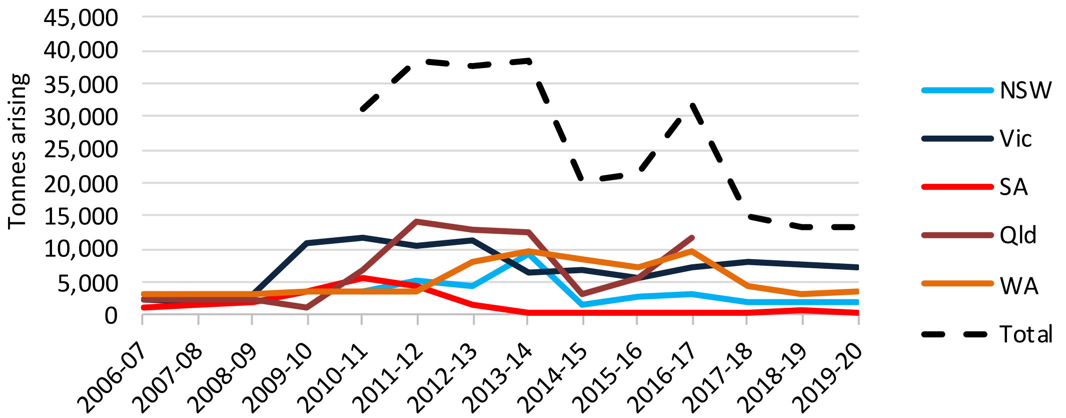


Figure 40 Historical arisings of organic solvents wastes – national summary



B13 H: Pesticides

This group includes three potentially diverse types of waste:

- *H100 waste from the production, formulation and use of biocides and phytopharmaceuticals*
- *H110 organic phosphorous compounds*
- *H170 waste from manufacture, formulation and use of wood-preserving chemicals*.

H100 is the major pesticide heading although it also includes the relatively unrelated phytopharmaceuticals, which are plant-derived pharmaceutical products such as alkaloids.

H110 includes wastes from organic phosphorus compounds used as lubricants, plasticisers, flame retardants and, most notably, organophosphate pesticides.

H170 is different again – it covers wastes from timber preservation which, in Australia, has historically been dominated by chromated copper arsenate treatment. Its overlap in this NEPM category is presumably due to the function of this timber preservation process, where the copper acts as a fungicide, the arsenic an insecticide (both types of biocide) and the chromium chemically fixes these to the wood to stabilise them.

Over 8,000 pesticide and veterinary products have been registered for use in Australian agriculture, horticulture, livestock, forestry, commercial premises, parks, homes and gardens (Immig 2010). Pesticide wastes can arise due to historical activities where the active ingredients may be mixed or perhaps unknown, due to weathered container labelling. It also arises from manufacturing and formulating of these chemicals, such as agricultural chemical suppliers, wood preserving chemical supply and chemical manufacturing.

Sources

Table 29 provides a summary of the main sources of this waste in each jurisdiction.

Table 29 Pesticides summary source analysis 2017-18

NSW [85]	Vic [85]	Qld	SA	National summary
• 53% Waste treatment and disposal services • 17% Pesticide manufacturing • 2% Basic organic chemical manufacturing • Shipyards & slipways	• 72% Waste treatment and disposal services	• Wood product manufacturing • Electricity supply • Waste treatment and disposal services • Shipyards & slipways	• 83% Motor vehicle and motor vehicle part manufacturing • 9% Pulp, paper and converted paper product manufacturing	• Waste treatment and disposal services • Pesticide manufacturing • Wood product manufacturing • Motor vehicle and motor vehicle part manufacturing

Vic generated 41% of pesticide wastes nationally in 2019-20, followed by WA (27%) and the remainder spread relatively evenly between NSW, SA and Qld. The waste sector is regularly mentioned as a source, possibly due to their role in household or farm collection programs. The waste sector in this case is the collector rather than the true generator.

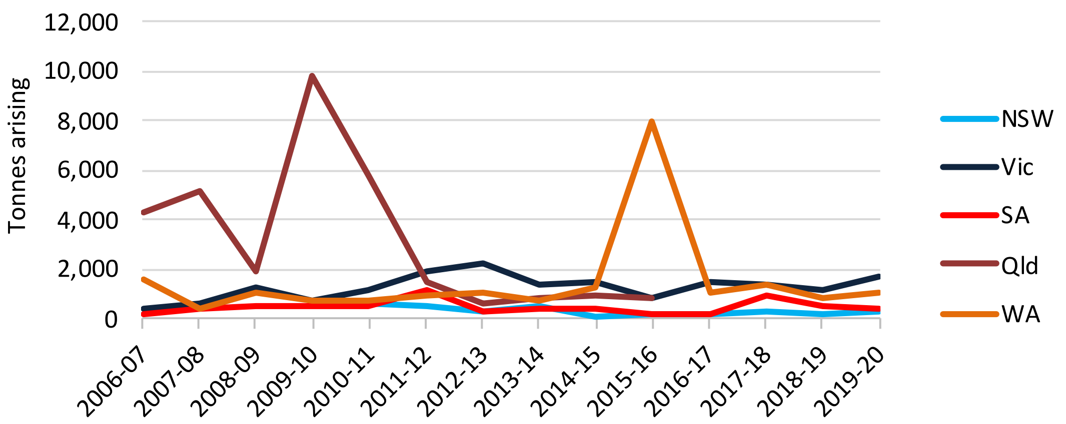
In the case of H170, sources of this waste are quite specific, arising from the preservation chemicals used by the wood product manufacturing industry. For H100 and H110 sources are more variable.

Analysis

This waste group was very small nationally by tonnage in 2019-20, at 0.06% of all hazardous waste generated. Historical trends in arisings for this waste group are shown in Figure 41.

The very large historical spikes recorded in Qld and WA data are either due to miscoding (for example pesticide contaminated soil coded as H100 instead of N120) or are large releases from cumulative storage or possibly stockpiling, perhaps in response to campaigns such as site post-closure or collection programs. Perusal of the large spike of 2018-19 Qld H arisings shows significant quantities of contaminated soil recorded as H100 (much of it contaminated with tributyl tin), while the 2015-16 WA spike cannot be explained within the constraints of WA data, from which source information is absent.

Figure 41 Historical arisings of pesticide wastes



Management

The major management types for H wastes vary, but the surprise is that the second largest tonnes nationally are recorded in tracking as landfilled, at 34% of all H wastes. This is driven by high landfill proportions in SA (92%), WA (75%) and Qld (37%), while Vic and NSW have zero tonnes of this waste to landfill. At face value, no pesticide waste should be managed in landfill.

Thermal destruction is the main Stockholm Convention-sanctioned treatment for POPs such as pesticides, but is the only one of the six national management categories against which no waste was recorded in 2019-20. As HWiA 2019 pointed out, the limitations of the six-category system are partly to blame. The main management outside of landfill is recycling (in Vic) – the waste is blended into a fuel and subsequently burnt for energy recovery in industrial processes, hence the use of the recycling-based (Victorian) management code R1 *Use as a fuel (other than in direct incineration) or other means to generate energy*. The waste component of concern – pesticides – is thermally destroyed (not recycled), even if it is a (very small) part of a fuel blend. In Qld, CPT tends to be used to describe a plasma arc (thermal destruction) facility for reasons that are not clear. The net result is that, in the case of the H waste that contains organohalogen-based pesticides, most of it (44% of all H waste in 2019-20) is actually thermally destroyed in Australia, despite not being classified this way in tracking systems.

As discussed in HWiA 2019, virtually all of SA's H waste is identified as 'copper-chrome-arsenate' in liquid form, being sent to an SA landfill. Waste liquids from this treatment would not typically be accepted at landfill, but it is noted that waste transport certificates do not reveal all of the information about a waste.

B14 J100 and J160: Oils

This waste group comprises two NEPM codes:

- *J100 Waste mineral oils unfit for their original intended use*
- *J160 Waste tarry residues arising from refining, distillation and any pyrolytic treatment.*

J100 is dominated by used oil from transport vehicles and off-road machinery, while a small proportion of (mostly Vic) data also includes the used oil filters themselves. J160 is a much smaller contributor, produced in the refining of petroleum, re-refining of lubricating oils, production of metallurgical coke or town gas by pyrolysis of coal.

Sources

Table 30 provides a summary of the main sources of this waste in each jurisdiction.

Table 30 J100 & J160 (oils) summary source analysis 2019-20

NSW [85]	Vic [85]	Qld	SA	National summary
• 19% Basic organic chemical manufacturing • 19% Water passenger transport • 12% Coal mining • 9% Waste treatment and disposal services • 6% Petroleum refining & petroleum fuel manufacturing • 2% Fossil fuel electricity generation • Others including: other automotive repair and maintenance; metal ore mining; road freight transport	• 80% Waste treatment and disposal services	• Mining • Manufacturing (various, including food, petroleum & metal coating) • Transport • Automotive repair and maintenance • Waste sector	• 38% Motor vehicle and motor vehicle part manufacturing • 47% unaccounted (likely collection from automotive repair and maintenance)	• Waste treatment and disposal services • Basic organic chemical manufacturing • Mining • Petroleum refining & petroleum fuel manufacturing • Automotive repair and maintenance • Transport

Arisings of oily wastes are distributed across industries in jurisdictions quite similarly, with differences related mainly to variations in industrial mix, such as the prevalence of mining in WA and Qld.

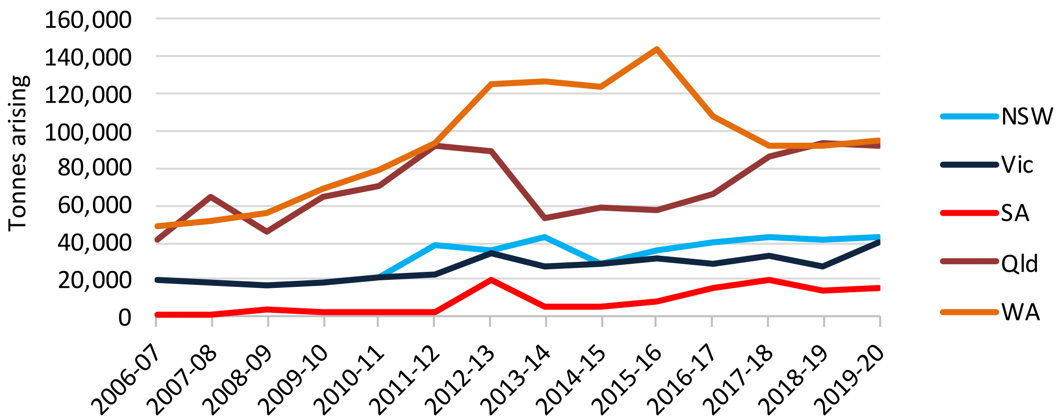
The Product Stewardship for Oil program was introduced by the Australian Government in 2001 to provide incentives to increase recycling of used oil. The program aims to encourage the environmentally sustainable management and re-refining of used oil and its reuse. The arrangements comprise a levy-benefit system, where an 8.5 cents per litre levy on new oil helps to fund benefit payments to used oil recyclers.

Analysis and management

This waste was quite significant nationally by tonnage in 2019-20, coming in 5th highest at 5% of all hazardous waste generated. WA generated 26% of oily wastes nationally, followed by NSW (24%), Vic (19%), Qld (18%) and SA (4%).

Historical trends in arisings for this waste group are shown in Figure 42. WA and Qld have historically trended much higher in arisings than other states, although both curves have flattened since about 2013-14. In both cases, this could be due to a slowdown or consolidation in mining activity. NSW, Vic and SA have followed more sedate growth patterns, as would be expected from population-linked growth in motor vehicle ownership.

Figure 42 Historical arisings of waste oils



While the Product Stewardship for Oil program results in large volumes of recycled oil, significant quantities still go to more rudimentary oil treatment facilities or options lower on the waste hierarchy. In Qld for example, 16% of oils are sent to composting, whereas no other state records this form of management. Storage tends to be a relatively highly-used management pathway, consistent with the centralised distribution of oil re-refining infrastructure, located predominantly in NSW and Qld.

B15 J120: Waste oil/water mixtures

This waste group comprises the NEPM code *J120 Hydrocarbons/water mixtures or emulsions* and, like its ‘oilier’ counterpart waste J100, is dominated by used oil/ water mixtures from vehicles or, more specifically, vehicle washwater pump-out liquids.

Sources

Table 31 provides a national summary of the main sources of waste.

Table 31 Oil/water mixtures summary source analysis 2019-20

NSW [85]	Vic [85]	Qld	SA	National summary
• 10% Waste treatment and disposal services • 8% Motor vehicle parts retailing • 2% Copper, silver, lead, zinc smelting & refining • 2% Iron smelting and steel manufacturing • Highly varied sources repair and maintenance; metal ore mining; road freight transport	• 72% Waste treatment and disposal services	• Mining • Manufacturing • Automotive repair and maintenance • Waste treatment and disposal services	• 56% Motor vehicle and motor vehicle part manufacturing • 21% Photographic, optical and ophthalmic equipment manufacturing	• Waste treatment and disposal services • Motor vehicle parts retailing • Mining • Various manufacturing • Copper, silver, lead, zinc smelting & refining • Iron smelting and steel manufacturing

Sources for this waste are similar to J100 – places that handle lubricating oils through vehicle and other machinery servicing and cleaning. The difference between J120 and J100 is that the former also has large contributions from dedicated vehicle washing facilities, such as commercial car washes and truck bays, as well as similar forecourt wash-down collection systems found on retail vehicle refuelling stations, and industrial process waters where oil/water mixtures are collected.

Analysis

This waste was significant nationally by tonnage in 2019-20, coming in 6th at 4% of all hazardous waste generated. The majority of this was generated in Qld (39%), followed by NSW and Vic at 19% each, WA 12% and SA 7%. Historical trends in arisings for this waste group are shown in Figure 43, while Figure 44 is the same chart with a national tonnage overlaid.

Figure 43 Historical arisings of waste oil/water mixtures

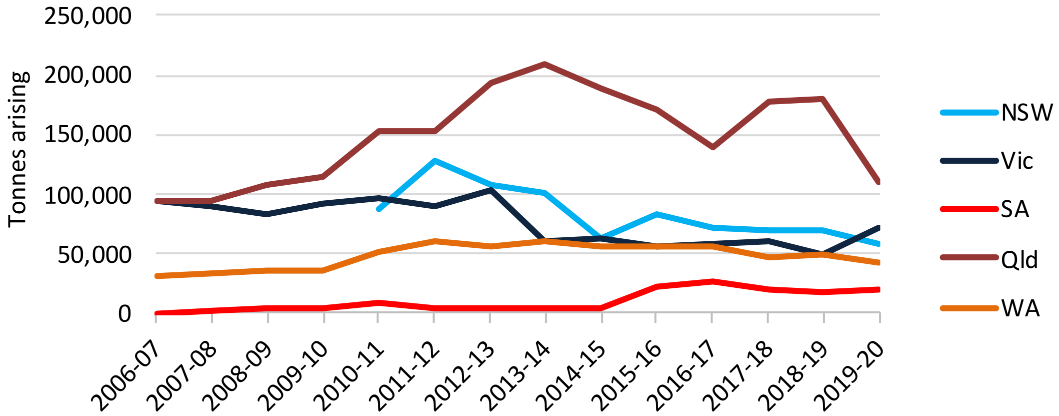
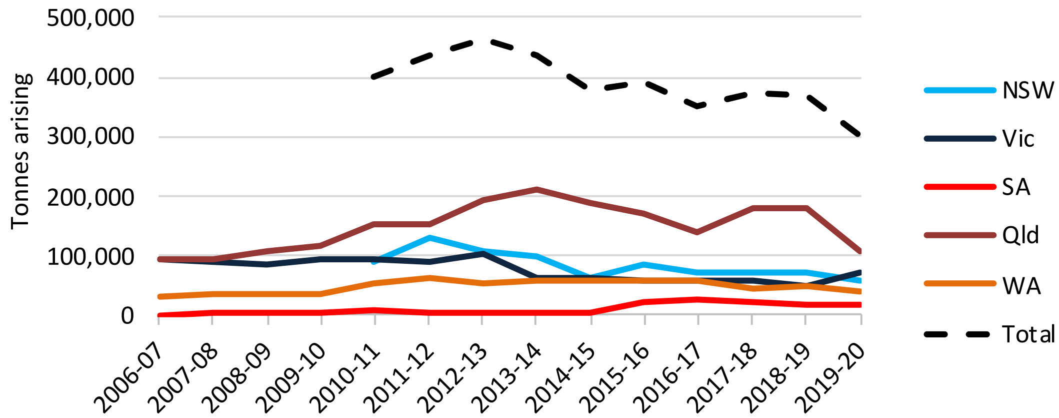


Figure 44 Historical arisings of waste oil/water mixtures – national summary



Nationally, from a peak of around 460 kt in 2012-13, arisings of oily waters have declined significantly, by about 160 kt or 35% in 2019-20. The reason is unclear. Given Qld's dominant tonnage and its data quality uncertainties post 2015-16, this trend may be inaccurate.

Management

CPT dominates management of J120 at 49% nationally, while storage is also prominent at 35%. The high CPT tonnage correlates with the large number of simple oil/water separation and storage facilities.

Storage of this waste is particularly high in Vic (54% vs 35% nationally). This could be due to double-counting from the accredited agents' system, where multiple pick-ups are tracked individually and brought back to central facilities and accumulated, then on-sent to further management.

B16 K110: Grease trap wastes

K110 Grease trap waste is waste from grease interceptors used for capturing food, grease and solids before entry to the sewer, including any solids derived from the treatment of this waste. It is primarily sourced from retail food business, such as restaurants and fast-food outlets.

Grease trap is separated from sewer discharges because it can cause blockages. Once collected, its potential hazards include odour amenity issues and water pollution. Grease trap waste can turn acidic if left standing too long in a tank due to the presence of food scraps, which produces sulfides that combine with water to produce sulfuric acid.

Sources

Table 32 provides a summary of the main sources of this waste in each jurisdiction.

Table 32 Grease trap waste summary source analysis 2019-20

National summary
• Cafes, restaurants and takeaway food services • Supermarkets and grocery stores • Waste sector (as collectors and aggregators from cafes and restaurants)

Grease trap waste is typically collected by waste transporters under a 'milk run' style accredited agents' system. This system is used for other wastes generated by large numbers of small producers, where multiple pick-ups are tracked as a single 'job lot' waste transport certificate and a list of all of the pick-up points is attached for detail.

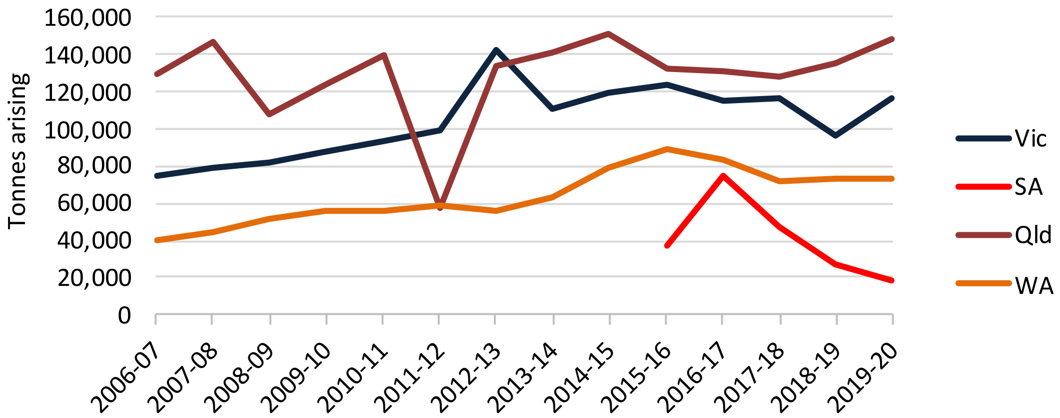
Like other K wastes, grease trap is not tracked in NSW due to the presence of a NSW EPA regulatory exemption based on pre-treatment[102]. SA has only begun tracking it in recent years.

Analysis

Historical trends in arisings for this waste group are shown in Figure 45.

[102] https://www.epa.nsw.gov.au/-/media/epa/corporate-site/resources/waste/rro14-grease-trap.pdf?la=en&hash=4627D6229194E793B771928548DED4DCCD68B63D.

Figure 45 Historical arisings of grease trap waste



This waste was the 4th highest national contributor of hazardous waste by tonnage in 2019-20, at 6% of all hazardous waste generated. From a hazard perspective, it poses risks at the lower end of the scale. Impacts could include odour and environmental impacts similar to the more viscous and solid petroleum fractions, such as waste mineral oils and waste tarry residues. Primarily though, large amounts of oil and grease can congeal on the surface of tanks and clog pipes, due to their insolubility in water, and can hamper effective treatment at wastewater treatment plants. The indirect nature of these potential environmental impacts, in a related vein to tyres, are the reason some jurisdictions do not view them as hazardous waste.

Generation is roughly proportional to population size, as can be seen from the generally even inclining trends over the last 5-10 years in Figure 45, noting that NSW is excluded due to its lack of tracking and SA did not historically track it.

Management

Management data for grease trap waste across those states that track it is shown in Table 33.

Table 33 Management of grease trap waste, % of all management per jurisdiction (2019-20)

Jurisdiction	Biodegradation	Recycling	CPT	Storage
Qld	24 %	7 %	48 %	21 %
SA	0 %	88 %	9 %	3 %
Vic	48 %	18 %	34 %	1 %
WA	48 %	11 %	6 %	33 %

Note: K110 waste is not tracked in NSW so no management data is included above

The categorisation system for management types used at the national level is unhelpful in this case, because the term biodegradation (composting) is often interchanged with recycling, so they are better described in combination as a recycling process. In the case of grease trap specifically, CPT can often be put into the same category. This is because grease trap waste is best managed via a two-stage process:

1. physical screening followed by gravity separation, leaving three distinct layers – floating oil/fat, aqueous liquid waste beneath and settleable sludge at the bottom
2. removal of the 'float' and typically recombination with the sludge layer (often with lime added) to be used in composting or soil injection/amendment, while the aqueous phase is sent to sewer (sometimes with polishing treatment to reduce biochemical oxygen demand (BOD) to lower sewer disposal costs).

The first stage is typical for liquid CPT plants, which may then on-send the treated non-aqueous phase to composters. In some regional areas, where infrastructure is more limited, the entire grease trap waste may go directly to composting, although this is not preferred. Alternatively, some composters may have sufficient equipment onsite to do both treatment and composting steps.

It is not entirely clear in tracking data where separation and treatment is carried out prior to composting, and where it is not. Even the storage category, in the case of K110, may be describing gravity separation (hence treatment).

NSW tracking data may not be of assistance for grease trap waste, but the nature of their regulatory exemption ensures that the same treatment followed by soil amendment/composting process applies.

Vic has a regulatory ‘classification for reuse’ in place that requires grease trap to be kept separate from other similar wastes to ensure recycling and reuse outcomes, which are mandatory. Consequently, biodegradation/recycling and CPT (pre-treatment) make up 99% of management in that state.

SA’s data, upon closer inspection of waste transport certificates, indicates that virtually all grease trap waste goes to composting. It is unclear whether gravity pre-treatment is also undertaken.

B17 Other K: Other putrescible/organic wastes

This waste group aggregates together the non-grease trap K wastes:

- *K100 Animal effluent and residues (abattoir effluent, poultry and fish processing wastes)*
- *K140 Tannery wastes (including leather dust, ash, sludges and flours)*
- *K190 Wool scouring wastes.*

Sources

Table 34 provides a summary of the main sources of this waste in each jurisdiction.

Table 34 Other putrescible/organic waste summary source analysis 2019-20

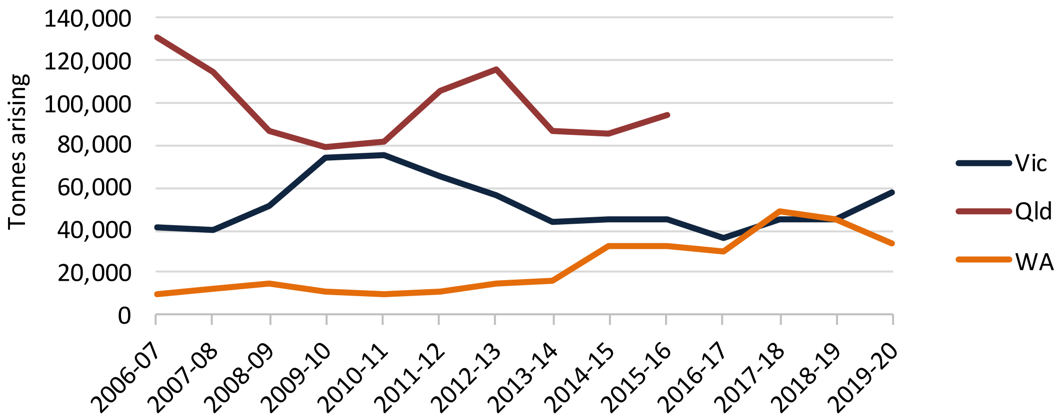
National summary
• Meat and meat product manufacturing
• Leather and leather product manufacturing
• Textile product manufacturing.

Analysis

This waste group is dominated by K100, comprising wastes from the meat and seafood processing industries, which are typically high in organic material content. It is significant by tonnage at 3% of all hazardous waste generated in Australia in 2019-20, coming in at 10th on the list of largest generating wastes.

Historical trends in arisings for this waste group are shown in Figure 46. NSW and SA are excluded because their respective tracking systems do not track these wastes. The national data estimates NSW and SA arisings from the average per capita arisings in other states.

Figure 46 Historical arisings of other putrescible/organic wastes



Management

Unsurprisingly due to its high-nutrient organic nature, management of Other K wastes in Vic, Qld and WA is mostly recycling and biodegradation, with composting the major activity.

B18 M100: PCB wastes

This group comprises the single NEPM code *M100 Waste substances and articles containing or contaminated with polychlorinated biphenyls, polychlorinated naphthalenes, polychlorinated terphenyls and/or polybrominated biphenyls*, which is separately considered due to its highly hazardous nature and specific management requirements. It includes any materials contaminated with polychlorinated biphenyls (PCBs) but primarily comprises waste oils from electricity distribution infrastructure.

PCBs were removed from service in the 1980s and 1990s but paraffin oil contaminated with PCB mixtures remain. Polychlorinated terphenyls and polybrominated biphenyls are not known to have been used in Australia.

Sources

Table 35 provides a summary of the main sources of this waste in each jurisdiction.

Table 35 PCB waste summary source analysis 2019-20

NSW [85]	Vic [85]	Qld	SA	National summary
• 62% Fossil fuel electricity generation • 14% Waste treatment and disposal services	• Fossil fuel electricity generation • Waste treatment and disposal services	• Fossil fuel electricity generation • Waste treatment and disposal services	Not identified	• Fossil fuel electricity generation • Waste treatment and disposal services

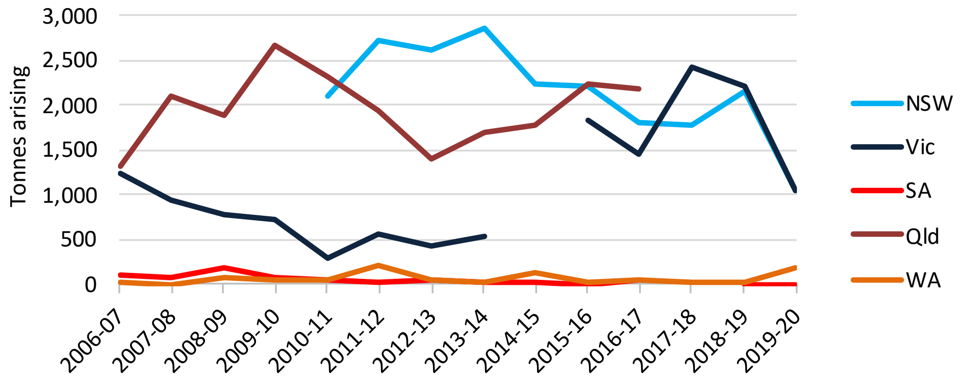
PCB-containing wastes are typically sourced from transformer oils recorded as from the electricity supply or waste industries.

Analysis

This waste was small nationally by tonnage in 2019-20, at 0.06% of all hazardous waste generated. The majority (55%) was generated in Qld, followed by Vic (25%) and NSW (15%).

Historical trends in arisings for this waste group are shown in Figure 47.

Figure 47 Historical arisings of PCB waste



HWiA 2019 assessed and dismissed as errors two very large spikes, one in Vic (2014-15) and one in SA (2017-18), each above 15,000 tonnes – as miscoded contaminated soil and a units mistake, respectively. These two data points have been removed from Figure 47 to allow a more useful view of the chart's scale.

Qld, NSW and Vic typically generate PCB waste in similar quantities, although Vic's generation halved in 2019-20.

Management

PCBs in oils, at significant concentrations, are managed in Australia through two types of technologies:

- destruction technologies, such as plasma arc furnace, incineration, cement kilns or related thermal treatment
- solvated electron chemistry technology[103], which uses a solution of ammonia and an alkali metal (such as metallic sodium) to create a powerful reducing agent that chemically transforms PCBs, and potentially other POPs like pesticides, into relatively benign substances.

However, the management data from tracking systems does not reflect this very well. This is another example of the problems with the restrictive six national management type headings (as mentioned elsewhere in this report) and inconsistent or incorrect interpretation by tracking system users of the management code to use.

In NSW data, CPT and recycling management types are used interchangeably, despite the receiver being the same facility that performs the solvated electron process. This is probably best described as chemical treatment (therefore CPT) although it is quite unlike traditional CPT. Recycling is understandably chosen because, after separation of PCBs, the oil component is recycled. However, the PCB component is destroyed (not thermally but through chemical transformation), which is not recycling. Even the longer form Basel-based D and R type management codes do not provide an ideal fit – a process of irreversible chemical transformation probably can only be coded as D9B *Chemical treatment and solidification or solidification* only, which is still a poor fit. A small quantity of M100 solid waste (68 tonnes) was recorded as going to landfill in NSW in 2019-20. Further inspection of waste transport certificates shows this to be obsolete/failed transformers with low-level PCB contamination, sent not to landfill but to a facility undertaking chemical transformation.

103 http://www.cpeo.org/techtree/ttdescript/solvelectr.htm.

Vic data confuses M100 management similarly, because of related issues. PCB waste is blended into a fuel for energy recovery and sometimes coded as recycling, but the hazard of interest (PCB) is destroyed so sometimes coded as CPT. Neither are accurate and thermal destruction would be a better code choice. There were also 565 tonnes (54%) of M100 waste sent to landfill in 2019-20 in Vic. This may be miscoded contaminated soil, with PCBs as the contaminant, but the lack of transparency in Vic-supplied data makes this difficult to confirm.

Qld data refers to a thermal destruction process (plasma arc) as CPT, which is also not an accurate reflection of what occurs.

Translating these management codes into a more useful framework for PCBs gives the breakdown in Table 36.

Table 36 Adjusted management of PCB waste, per jurisdiction (2019-20)

Jurisdiction	Management 2019-20, tonnes and (%)					
	Thermal destruction	Irreversible chemical transformation	Landfill	Storage	Other	Total
NSW	-	1,030 (99%)	-	9 (1%)	-	1,039
Qld	915 (96%)	-	-	30 (3%)	5 (1%)	950
Vic	163 (16%)	-	565 (54%)	145 (14%)	174 (17%)	1,047
National (ex SA & WA)	1,078 (36%)	1,030 (34%)	565 (19%)	184 (6%)	179 (6%)	3,036

Notes:
1. SA recorded only 8 tonnes of M100 managed in within-state (to traditional CPT plants) so has not been included above.
2. WA recorded 175 tonnes M100 to CPT and 1 tonne to storage. The lack of transparency in WA-supplied data makes the definitive choice of a more descriptive management method unclear.

The high proportion of 'other' management in Vic is likely to represent paper WTC use, where management types are often unreliably recorded. Some or all of this could be M100 sent to Qld's thermal destruction (plasma arc) facility, because interstate movement data (from Vic) is recorded on paper certificates.

B19 M160 and M270: PFAS and related POPs

M160 Organohalogen compounds—other than substances referred to in this Table or Table 2, is waste that contains some form of organohalogen compound not elsewhere mentioned on the NEPM list. Prior to 2018, this waste code was the most logical home for tracking movements of PFAS-containing wastes, amongst other POPs.

M270 PFAS-contaminated materials, including waste PFAS-containing products and contaminated containers, is waste specifically contaminated with or measurably containing PFAS. The M270 NEPM code designation was introduced in February 2018 within the PFAS NEMP, which was further updated in January 2020 (NEMP V2)[104]. The PFAS NEMP was established by the National Chemicals Working Group of the Heads of EPAs Australia and New Zealand, and is Australia's jurisdictionally-agreed fundamental guidance on the management of PFAS in the environment. Jurisdictions may individually prescribe tighter requirements for managing PFAS, but the PFAS NEMP represents the minimum standard.

Any pre-2018 PFAS data was (mostly) recorded under the M160 code, potentially along with other POP wastes, but from 2018-19 onwards the M270 code has been specifically available for PFAS wastes. This

[104] https://www.environment.gov.au/system/files/resources/2fadf1bc-b0b6-44cb-a192-78c522d5ec3f/files/pfas-nemp-2.pdf.

has not always provided the classification clarity intended because it bundles some very different wastes together, including PFAS-containing AFFF, PFAS-contaminated soil and PFAS-contaminated wastewaters. This has led to fractured implementation of the M270 code across jurisdictions, with NSW not adopting it at all until uniformity is established, and other jurisdictions taking different approaches as to what falls into the category.

Consequently this report has chosen to analyse both M160 and M270 as one waste group, *PFAS & related POPs (M160 plus M270)*, as the most practical means of representing those POPs which are volumetrically dominated by PFAS wastes. It is noted that in some jurisdictions, PFAS wastes can also be tracked under M250 Surface active agents (surfactants), N140 Fire debris and fire wash waters or N120 contaminated soil.

The common characteristic of this waste type is its inclusion of organic chemicals with halogen elements (usually fluorine, chlorine, bromine) forming a significant structural component. It has similarities with other waste types such as chlorophenols (M150), halogenated solvents (G150), dioxins and furans (M170 and M180), PCB-like compounds (M100) and organochlorine pesticides (within H100).

The presence of the halogen species is usually the issue of interest and the reason for the toxicity. Examples of organohalogen active ingredients are the Stockholm Convention-listed pollutants polybrominated diphenyl ethers (PBDE) and hexabromocyclododecane (HBCD), and the most scrutinised of all organohalogens in recent years, the PFAS group of chemicals.

PFAS waste issues are significant in Australia at present, largely because of historical use of PFAS in firefighting foams, but more ubiquitously due to other uses, including in food and other product packaging. A dedicated discussion of the various PFAS wastes and issues is provided in Section 4.2.

Sources

Table 37 provides a summary of the main sources of this waste in each jurisdiction.

Table 37 PFAS & related POPs wastes summary source analysis 2019-20

NSW [85]	Vic [85]	Qld	SA	National summary
• 63% Waste treatment and disposal services • 36% Fire protection and other emergency services	• 51% Defence • 18% Waste treatment and disposal services • 11% Fire protection • 7% Oil & gas extraction	• Defence • Waste treatment and disposal services • Petroleum and coal product manufacturing	< 1% of national total for waste group	• Defence • Waste treatment and disposal services • Fire protection and other emergency services • Oil & gas extraction

PFAS waste sources are either directly AFFF firefighting foams (being removed for destruction), or wastes contaminated from the use of these foams, such as contaminated soils, biosolids, groundwaters or media used in their clean-up, such as contaminated GAC adsorbent.

These foams have been heavily used at defence bases, major hazard facilities, airports and fire protection facilities, all locations where fire training procedures using AFFFs have historically taken place.

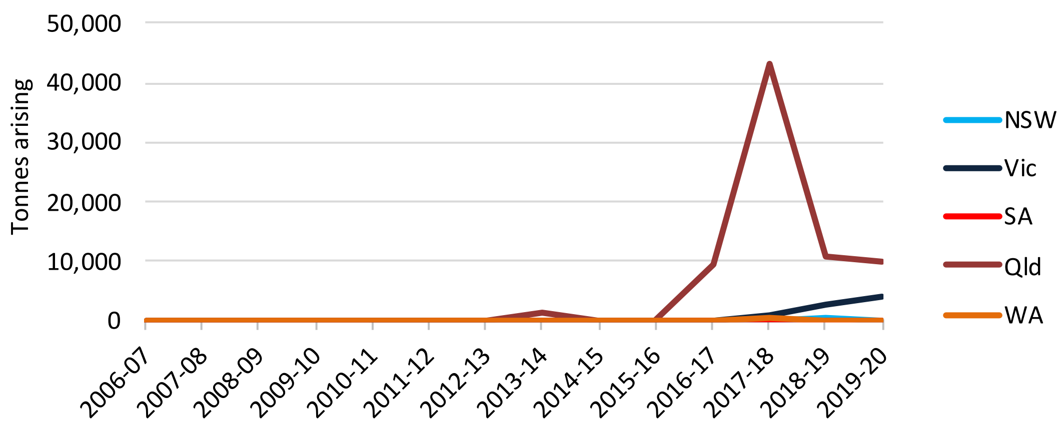
Consequently the Department of Defence or its contractors are the main sources of combined M160 and M270 waste in 2019-20, with AFFF, PFAS-containing wastewater and PFAS-contaminated soil commonly described in tracking datasets with good visibility. The waste industry is commonly mentioned as a source, as a collector, sometimes processor and on-sender to fates such as thermal destruction.

Analysis

PFAS and related POPs waste was small nationally by tonnage in 2019-20, at 0.2% of all hazardous waste generated, but this has greatly increased from 2014-15 figures, where it accounted for just 0.001%. Qld generated the most at 50%, followed by 32% in Vic and 14% in NSW.

Domination of this waste group's tonnage by PFAS waste began around 2016-17 and has intensified into 2019-20. Raw tracking numbers do not always show this, because of the differing approaches to the use of the M270 code. The trend in the sum of M160 and M270 is charted in Figure 48, noting that M270 has only been notable in tracking since 2018-19.

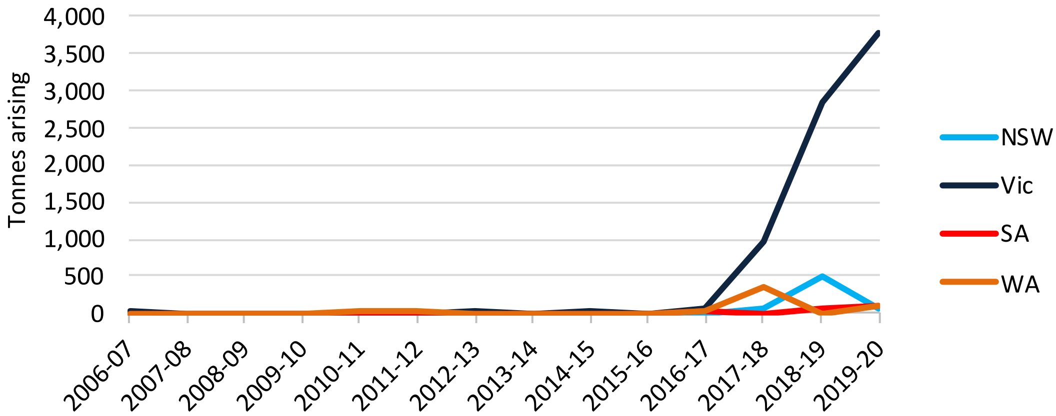
Figure 48 Historical arisings of PFAS & related POPs wastes



Qld PFAS data has swamped other states since 2016-17, but this is because the majority of M160 and M270 WTCs in that time have been for PFAS-contaminated soil, a high-volume arising with much lower PFAS concentration than, say, AFFF. In other jurisdictions, PFAS-contaminated soils are more likely to be recorded as N120 contaminated soil, with the notification of PFAS contamination left to the contaminant field. Qld does not track contaminated soils in its tracking system, but rather collects that data separately through a system that does not record soil contaminants. So for Qld, including PFAS soils under the M270 code implements the code's description accurately, but clouds the capacity to distinguish materials with very different stream concentrations.

Figure 49 removes Qld data so as to provide a better sense of scale for other states' M160+M270, where PFAS contaminated soils are, in the main, not recorded in either of these codes.

Figure 49   Historical arisings of PFAS & related POPs wastes (excluding Qld)



Vic data, in particular, shows striking growth since 2016-17. Growth is also evident in NSW, SA and WA, but not to the same scale as Vic (or Qld). This is because these trends indicate arisings into a state's management infrastructure set, rather than where it was generated. Vic and Qld host the major operators that provide PFAS thermal destruction capacity of contaminated soils and other matrices such as AFFF, PFAS-contaminated adsorbents (from contaminated groundwater filtration treatment) and contaminated waters.

Management

PFAS-contaminated soil in Qld was sent to landfill, which would suggest that contaminant levels were low. AFFF foams (nationally) were sent to thermal destruction infrastructure mostly identified as CPT in Vic, recorded as a combination of CPT and thermal destruction in Qld. Across the eastern seaboard at least, there is a significant amount of storage for subsequent interstate transport.

B20 Other M: Other organic chemicals

This waste group includes the broad catch-all of:

- *M150 phenols, phenol compounds including chlorophenols*
- *M170 & M180 polychlorinated dibenzo-furan and polychlorinated dibenzo-p-dioxin, respectively*
- *M210 cyanides (organic)*
- *M220 isocyanate compounds*
- *M230 triethylamine catalysts for setting foundry sands*
- *M250 surface active agents (surfactants) containing principally organic constituents*
- *M260 highly odorous organic chemicals (including mercaptans and acrylates).*

Sources

Table 38 provides a summary of the main sources of this waste in each jurisdiction.

Table 38 Other organic chemical wastes summary source analysis 2019-20

NSW [85]	Vic [85]	Qld	SA	National summary
• ~ 42% Defence, fire protection services, airport operations • Waste treatment and disposal services • Human pharmaceutical & medicinal product manufacturing • Cosmetic & toiletry preparation manufacturing • Cleaning compound manufacturing	• Aircraft manufacturing and repair services • Organic chemical manufacturing • Oil & gas extraction	• Waste treatment and disposal services • Fire services • Various other manufacturing	0.1% of national total for waste group	• Waste treatment and disposal services • Defence, fire protection services, airport operations • Aircraft manufacturing and repair services • Various manufacturing industries

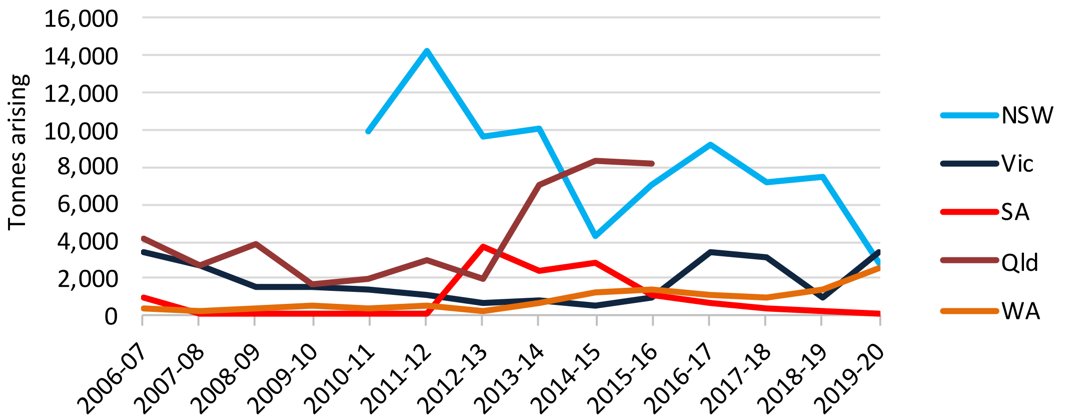
Outside of WA, this waste was almost exclusively *M250 surface active agents (surfactants) containing principally organic constituents* (99% in NSW, 96% in Vic). WA was unique in that *M230 triethylamine catalysts for setting foundry sands* made up 67% of this group.

The presence of defence, fire protection and airport operations as sources of M250, particularly in NSW, indicates the inclusion of AFFF foams (which would be better classified as M270).

Analysis

This waste was small nationally by tonnage in 2019-20 at 0.2% of all hazardous waste generated. Historical trends in arisings for this waste group are shown in Figure 50.

Figure 50 Historical arisings of other organic chemicals waste



The majority of Other M was generated in Qld (49%), followed by Vic (20%), NSW (16%) and WA (15%). But Qld's data is an extrapolated estimate based largely on 2017-18 data. Qld 2019-20 waste transport certificate-reported arisings were 766 tonnes, just 9% of the 8,680 tonnes our data caveat-driven adjustment method estimates it to be. An explanation for the scale of this discrepancy may be more to do with the fact that in 2017-18, the majority of Qld arisings of M250 were transported from NSW, a practice that has now ceased completely. This suggests that a figure of around 766 tonnes is probably closer to the mark (than 8,680 tonnes) in 2019-20 for Qld, but its data caveat does not allow a firm conclusion.

Management

Other M wastes are sent to storage in surprisingly high levels in Vic (76%) and WA (63%), which can suggest a management hurdle exists, such as insufficient local infrastructure. Beyond storage, this predominantly liquid waste is almost exclusively sent to liquid treatment plant CPT.

Of the 766 tonnes of M250 reported as managed in Qld, 24% was sent to a composting facility. Nowhere else in Australia was this waste managed this way in 2019-20. This appears to be an unusual choice for a surfactant liquid that is not particularly prone to biodegradation and may contain active ingredients like metals or organic chemicals, potentially even PFAS. Such a practice risks contamination of compost products, an issue similar to the discussion in Section 4.3.3. Alternatively this could simply be a case of miscoded management.

B21 N120: Contaminated soils

This group comprises *N120 Soils contaminated with a controlled waste*. NSW and Qld do not specifically track contaminated soils in their tracking systems, although both have regulatory definitions of this waste and collect and supply data from landfill records.

Sources

Table 39 provides a summary of the main sources of this waste in each jurisdiction.

Table 39 Contaminated soil wastes summary source analysis 2019-20

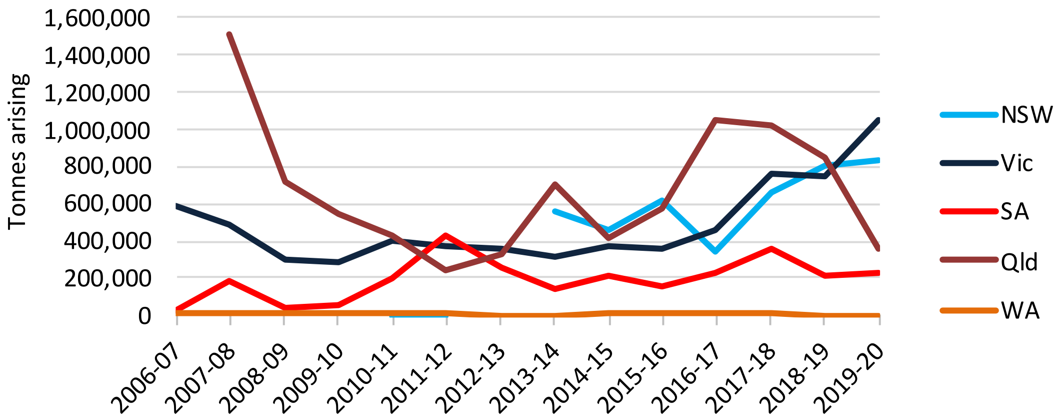
NSW [85]	Vic [85]	Qld	SA	National summary
• Construction, demolition and related development activity • Waste treatment and disposal services	• Construction, demolition and related development activity • Waste treatment and disposal services • Asbestos removal contractors	• Construction, demolition and related development activity • Waste treatment and disposal services	• Construction, demolition and related development activity • Waste treatment and disposal services	• Construction, demolition and related development activity • Waste treatment and disposal services • Asbestos removal contractors

Contaminated soils arise exclusively from construction and development (including demolition) activities that require the excavation of contaminated material. The contamination is mostly an historical legacy issue, whereas the quantity produced in any given year fluctuates with the level of development activity in contaminant-prone geographical areas, which are mostly industrial areas in large cities.

Analysis

Contaminated soils are the largest hazardous waste in national data, making up 35% of the tonnages in 2019-20. Vic was the highest contributor of arisings at 41%, followed by NSW at 33%, Qld at 14% and SA at 8%. WA appears unusually low at only 0.2%, but only tracks high level contaminated soil. Historical trends in arisings for this waste group are shown in Figure 51.

Figure 51 Historical arisings of contaminated soils



Although contaminated soils rose sharply around 2016-17 and 2017-18, in all states apart from WA, there are perhaps two striking features of contaminated soils data in 2019-20:

- Qld's dramatic fall of around 500 kt (58%) from the previous year
- Vic's resurgent tonnages, building further on the historical highs of the previous two years (~ 750 kt) to over 1 Mt (a 42% increase on 2018-19).

NSW also surpassed their historically large volumes from the last couple of years.

Qld contaminated soils

In 2019-20, Qld contaminated soil tonnages decreased to their lowest level since 2012-13, a drop of 495 kt from 2018-19. A declining trend had established itself after a peak in 2016-17, but the fall of 2019-20 was far steeper. A number of factors could have contributed to this:

- A set of levies were introduced in Qld on 1 July 2019, on waste going to landfill, which includes contaminated soil ('*Earth contaminated with a hazardous contaminant from land recorded on the environmental management register or contaminated land register*', $85/tonne in 2021-22 [105]). This would be expected to constrain wastes previously sent to landfill, of which soil is the major contributor from all hazardous wastes.
  - In support of the levy's impact, the amount of contaminated soil received from interstate sources reported in 2019-20 was down by 90% compared with the previous year [106].
- An economic downturn in Qld beginning late in 2018-19 [107].
- A more specific economic aspect related to point number 2, a decline in major project activity in Qld in 2019-20 [108].

This decline went against contaminated soil increases in NSW and Vic in 2019-20, the other large-volume contributing states, and was the primary factor restricting the generation of all hazardous wastes in Australia in 2019-20, to be slightly below 2017-18 figures.

[105] Queensland Government 2021, *Levy rates*, available at: https://www.qld.gov.au/environment/pollution/management/waste/recovery/disposal-levy/about/levy-rates.

[106] Pers. Comms. With Laurie Knight, DES 26 July 2021.

[107] Conus Business Consultancy Services, 2 September 2020, *Second quarter GDP falls by 7.0% q/q; Qld domestic economy down 5.9% q/q*, available at: https://www.conus.com.au/2020/09/second-quarter-gdp-falls-by-7-0-q-q-qld-domestic-economy-down-5-9-q-q/.

[108] Queensland Major Contractors Association (QMCA) and the Infrastructure Association of Queensland (IAQ), *2019 Queensland Major Projects Pipeline*, available at: https://qmca.com.au/wp-content/uploads/2019/03/QldMPP_2019.pdf.

Vic contaminated soils

Vic's striking 2019-20 increase, on top of already historically high tonnages from 2017-18, is probably the ongoing result of its unprecedented infrastructure project activity. HWiA 2019 p.45 explored the nature of some of these projects, and commented as follows on the increase in Vic N120 to that point:

> '*Another important consideration is that projects like Metro Tunnel and level crossing removals cannot use cut and fill techniques to manage significant excavated volumes onsite – all contaminated soil from these specific projects must be exported offsite, which results in high project volumes compared to projects that are less physically constrained, such as non-inner city road projects. Industry sources also contended that "we have only seen 10-15% of the contaminated soil that will come out of these major projects," predicting that 2018-19 and beyond will likely see even greater increases in contaminated soil volumes coming out of Vic major infrastructure projects.*'

Vic data is provided without visibility to identify either the sources or receivers of wastes, including contaminated soils. However, it allows excellent breakdown of the levels of contamination: high-level contamination is called Category A, intermediate-level Category B and low-level Category C. Table 40 shows long-term trends in contaminated soil broken down by these hazard categories, while Figure 52 charts this data.

These trends show that Category A soil (the most contaminated) has risen 20-fold since 2015-16, the time that the recent overall growth period began, and that in 2019-20 it was 2½ times larger than in 2018-19. The extraordinary scale of the growth in highly-contaminated soil is illustrated by comparison with the growth of Category B soil and the long-term proportions of contaminated soil by hazard category in Vic, where the volume of Category A has outstripped Category B for the first time in the available record:

- Average 2007-08 to 2015-16
  - Category C, 91%
  - Category B, 8%
  - Category A, 1%
- 2019-20
  - Category C, 86%
  - Category B, 5%
  - Category A, 9%.

Marked increases in contaminated soil can be explained by high rates of infrastructure and other development projects, but what of the sudden increase in highly contaminated soil? Highly urbanised tunnelling and road projects inevitably lead to higher levels of contamination than rural or urban fringe developments, which could explain the rising trend over the last 4-5 years. But level-crossing removals, Metro Tunnel and West Gate Tunnel projects, as large-scale examples, have been ongoing over the last few years, not just 2019-20 where the most dramatic increase has occurred.

Either something in the market has changed in 2019-20, or something was changed that affected the market, or both. The former could be a project or projects that have thrown up a large quantity of unusually contaminated soil, while the latter could be a regulatory change, such as a tightening of what might constitute a Category A soil.

Contaminated soil is typically managed in landfill, but this has been changing in Vic. Table 41 looks at the management of contaminated soil over the data-years corresponding to HWiA's last three editions (including this one).

Table 40 Vic historical arisings of contaminated soils, by hazard category

Contaminated soil category	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Cat A	3,509	5,988	6,028	5,695	5,041	1,955	4,516	3,950	4,689	13,442	29,939	36,636	92,327
Cat B	45,571	25,463	20,387	15,550	22,002	8,803	26,032	35,109	35,012	45,071	58,846	49,125	48,700
Cat C	445,834	268,552	254,869	377,104	339,517	184,782	219,909	299,379	311,584	393,084	668,252	638,398	875,006
Total	**494,915**	**300,003**	**281,284**	**398,349**	**366,559**	**195,540**	**250,458**	**338,438**	**351,285**	**451,597**	**757,037**	**724,159**	**1,016,032**

Figure 52 Vic historical arisings of contaminated soils, by hazard category

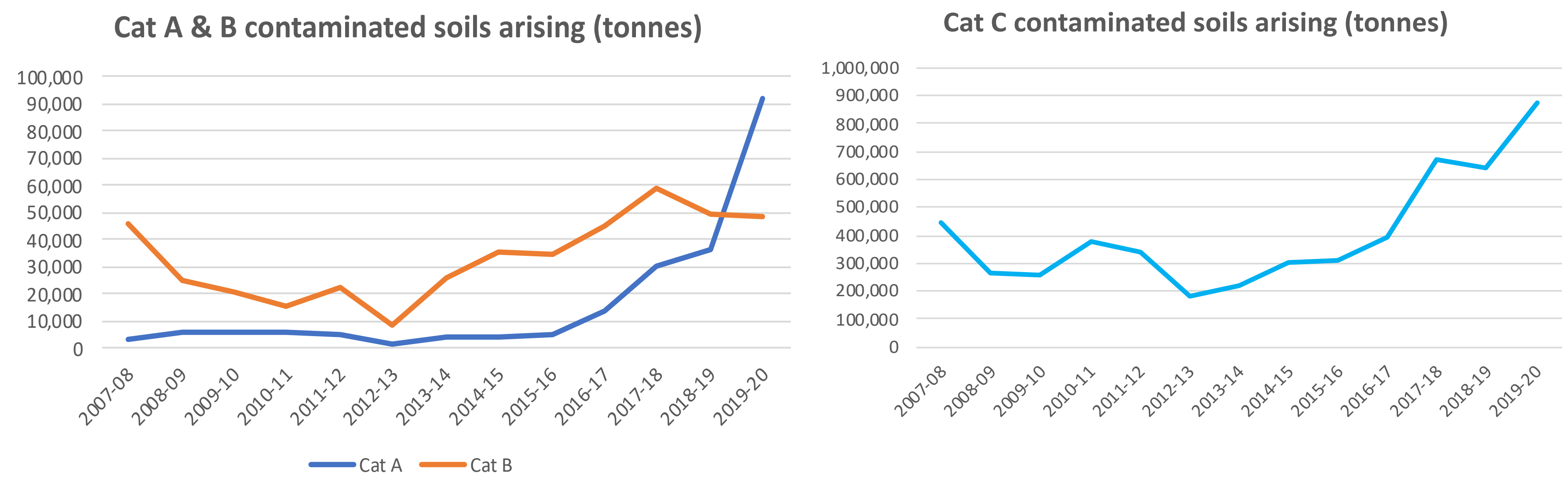


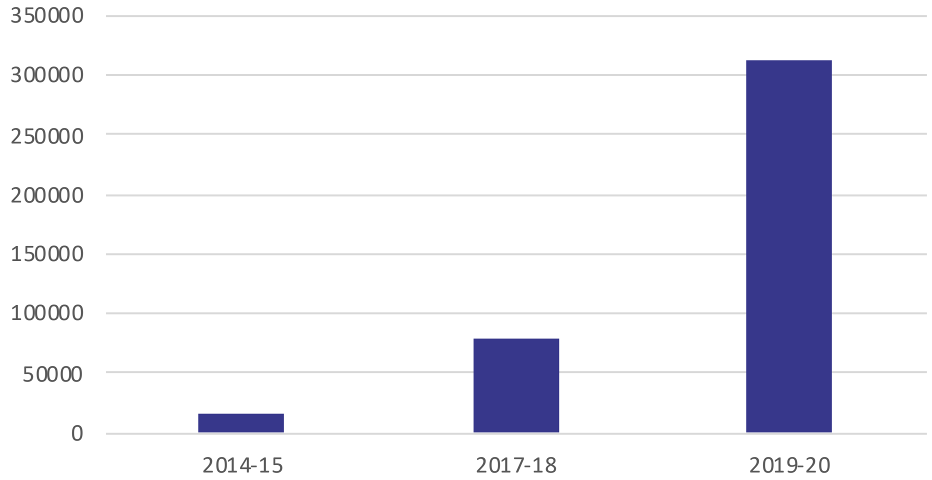
Table 41 Contaminated soil sent to key management types, Vic (tonnes, % of total tonnes managed)

Data year	Landfill	'CPT'
2014-15	307,653 (84%)	15,523 (4%)
2017-18	659,158 (86%)	78,923 (10%)
2019-20	660,328 (63%)	313,334 (30%)

Vic is now a hub for thermal treatment of soil contaminated with organic chemicals, hosting Australia's only large-scale facilities. Certificate users delivering material to these facilities mostly use the D9C Vic management category (*Physical treatment not otherwise specified in this Table*), but occasionally also D9D (*Thermal treatment to remove contaminants*), both of which translate to CPT in the national management nomenclature.

Figure 53 plots this rise in contaminated soil going into thermal infrastructure.

Figure 53 Contaminated soil sent to thermal treatment, Vic (tonnes)



A clear observation from this data is that contaminated soil management in thermal infrastructure has increased markedly since 2014-15, with around 300,000 additional tonnes received, a 20-fold increase in 2019-20. Further, almost three-quarters of Category A contaminated soil was sent for this treatment in 2019-20.

So what might this be telling us? The relatively smooth but increasing growth of Category C contaminated soil over the last 7 years (shown in Figure 52) is a good indicator of overall infrastructure project activity in Vic over this period, which is known to have grown substantially. The rapid rise of Category A soil in 2019-20, relative to Category B soil shows that the level of contamination of this soil has increased sharply. Soil in 2019-20 managed through thermal infrastructure increased by 234 kt on 2018-19, which is most of the total increase in contaminated soil (292 kt). A possible reason for all of these things is a large increase in PFAS-contaminated soil, because:

- PFAS is the only contaminant for which regulation is known to have changed over this period in terms of how it is regulated, with the PFAS NEMP (and later, in October 2020, EPA's interim position statement on PFAS[109]) dictating that even low levels of contamination (particularly leachability) require careful management. While EPA's hazardous waste classification guidelines[110] do not

[109] https://www.epa.vic.gov.au/about-epa/publications/1669-4.

[110] https://www.epa.vic.gov.au/about-epa/publications/1828-2.

directly provide PFAS contaminant level translations to Categories A, B or C, it is very likely that the low thresholds provided could result in greater proportions of PFAS-contaminated soil classified as Category A, compared to other contaminants.

- Like other POP wastes, EPA Vic encourages management of PFAS-contaminated soil by thermal destruction[111] in preference to landfill.
- PFAS-contaminated soil is categorised in Vic as either N119, N120 or N121 (not M160 or M270).
- Growth in PFAS wastes such as AFFF and PFAS adsorbents (seen in M160 and M270) mirrors Vic Category A contaminated soil in the last three years (see Figure 49).

This conclusion is speculative only, since the available data does not reveal the nature of contaminants or their source projects.

Management

Landfill has historically been the dominant fate recorded for contaminated soil throughout Australia and continues to be, at 73% in 2019-20. CPT accounted for 19% of contaminated soils managed in 2019-20, largely on the back of Vic's thermal treatment infrastructure. A significant amount of SA contaminated soil (116 kt or 52% of SA's N120) goes to storage infrastructure for subsequent use in suitable development projects, and is recorded in the data as recycled.

B22 N205a: Biosolids

Biosolids are not typically considered hazardous waste in tracking systems, but are included in this report and annual hazardous waste data collations at the national level, which underpin this report. This is because they have, in recent years, been included in annual data reported to the Basel Convention, as a precautionary approach, and coded to N205. Basel reported data is also included in this report (Appendix C). Appendix A includes a detailed definition of how we classify biosolids in a hazardous waste context.

Consequently, there is a split in this code, for the purposes of this report:

- *N205a Biosolids*
- *N205b Other industrial treatment residues.*

This waste group considers *N205a biosolids* in totals that are produced in Australia.

Sources

Wastewater treatment plants around Australia are the sole source of biosolids. Biosolids generation is not collated from tracking systems but provided from a biennial survey of wastewater treatment plants commissioned by the Australia and New Zealand Biosolids Partnership (ANZBP).

Analysis and management

When included in the totals, biosolids are the second largest hazardous waste behind contaminated soils and asbestos in national data, making up 20% of the tonnages in 2019-20. Recorded quantities in 2019-20 align approximately with the relative populations of the jurisdictions, with Vic the highest contributor at 29%, followed by NSW at 24% and Qld at 19%.

[111] https://www.epa.vic.gov.au/for-community/environmental-information/pfas/pfas-and-waste.

Historical trends in arisings for this waste group are not available as they are not taken from tracking records. However, when adjusted for an assumed national average solids content of 21%[112] for dewatered biosolids (their equilibrium state of water retention), national figures can be estimated in line with how other water-containing wastes are reported. Total figures from the last five ANZBP national surveys, adjusted to a dewatered basis, are shown in Table 42.

Table 42 Dewatered biosolids produced in Australia over the last 5 survey collection periods

Year	2010	2013	2015	2017	2019
Total biosolids (tonnes)	1,428,571	1,585,714	1,476,190	1,557,143	1,766,667

Source: Vero C, Pollution Solutions and Designs (2020), Biosolids Production and Use Survey Summary 2010 to 2019, prepared for the ANZBP, based on an average of 21% water in dewatered biosolids, consistently applied to data expressed by Vero as dry solids, from 2010-2019.

Management categories collected in detail by the ANZBP survey for 2019 are provided in Table 43.

Table 43 Biosolids arisings going to biosolids-specific management categories, 2019 (percent)

Management options	ACT	NSW	NT	Qld	SA	Tas	Vic	WA	National
Stockpile	n/a	1%	17%				5%	17%	3%
Agriculture	n/a	48%	59%	92%	98%		61%	59%	67%
Land rehabilitation	n/a	22%		8%			31%		16%
Landfill	n/a	9%	12%			1%		12%	4%
Landscaping (compost)	n/a	17%	6%		1%	99%	3%	6%	8%
Ocean discharge	n/a	3%							1%
Other	n/a		6%		1%			6%	1%

ACT biosolids are incinerated onsite, so are not 'generated' as a waste

Table 43 indicates that the majority (67%) of biosolids are managed through application to agricultural land in Australia. A total of about 91% is applied to land (when ‘land rehabilitation’ and ‘landscaping’ are combined with ‘agriculture’).

B23 N205b: Other industrial treatment residues

This category covers the single NEPM code *N205 Residues from industrial waste treatment/disposal operations*. For this project, we rebadge this material as *N205b. Other industrial treatment residues* to distinguish it from biosolids, which are not typically reported in jurisdictional tracking systems, and which we characterise as N205a. Therefore, in this section we consider N205b, industrial treatment residues, not including biosolids.

This group captures a variety wastes such as:

- solid or liquid residues from chemical/physical treatment (CPT) processes
- landfill leachate
- wastewater treatment plant residues, liquids and sludges
- industrial washwaters and treatment residues
- waste recycling process residues.

[112] Biosolids solids content varies in ANZBP annual survey reports (16-25% across the last five reports). The average of these five years (21%), has been used in each year’s data for this report (and previous versions), to ensure consistent trend analysis.

Sources

Table 44 provides a summary of the main sources of this waste in each jurisdiction.

Table 44 Other industrial treatment residues waste summary source analysis 2019-20

NSW [85]	Vic [85]	Qld	SA	National summary
• 60% Waste treatment and disposal services • 9% Veterinary pharmaceutical and medicinal product manufacturing • 7% Coal mining • 3% Explosive manufacturing	• 82% Waste treatment and disposal services	• Waste treatment and disposal services • Oil & gas extraction (CSG/LNG) • Copper, silver, lead and zinc smelting and refining	• 60% Motor vehicle and motor vehicle part manufacturing • 29% Other transport equipment manufacturing • 9% Soft drink, cordial and syrup manufacturing	• Waste treatment and disposal services • Oil & gas extraction (CSG/LNG) • Copper, silver, lead and zinc smelting and refining • Motor vehicle and motor vehicle part manufacturing

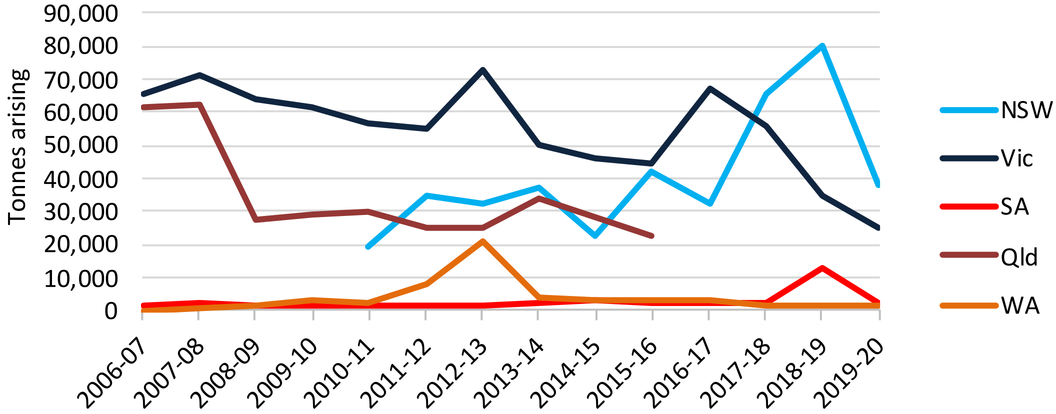
Analysis and management

This waste was significant nationally by tonnage in 2019-20 (12th by weight), at 3% of all hazardous waste generated. Qld was the largest contributor to national generation with 44% of industrial treatment residues in 2019-20, followed by Vic with 20%, Vic with 20% and SA with 17%.

SA is a significant receiver of this waste through interstate transport, from Vic and NSW – if arisings are considered instead of generation, 21% of the waste nationally arises in SA infrastructure (landfill).

Historical trends in arisings for this waste group are shown in Figure 54.

Figure 54 Historical arisings of other industrial treatment residues



N205b is catch-all in nature, and its management varies across Australia. CPT is the dominant management overall, and this applies in all jurisdictions except SA, where landfill accepts 91% of N205 arisings. Landfilling of this waste is recorded in other states, but only in low proportions. Qld is the only state that accepts any significant quantity into composting facilities, which at 20% is the highest form of N205 management outside of storage, which is quite high at 36%. Storage of this waste is generally high nationally, at 21% of all N205.

B24 N220: Asbestos containing material

This waste group captures the single NEPM code of *N220 Asbestos*, including products that contain asbestos and wastes contaminated with them. Asbestos is the name given to a group of naturally occurring minerals found in rock formations. Inhalation of asbestos fibres can cause respiratory problems that can be fatal. Asbestos-containing building products are classified as either 'friable' (soft, crumbly) or 'bonded' (solid, rigid, non-friable). Friable asbestos products may be as much as 100% asbestos fibres and can become airborne and inhalable very easily. Bonded products such as asbestos cement sheet (otherwise known as 'fibro') contain approximately 15% asbestos fibres, bonded with cement and do not normally release fibres into the air when in good condition.

Houses built between the 1930s and 1980s are likely to include asbestos-containing products.

Asbestos is one of the largest flows of hazardous waste in Australia and poses significant health risks. Asbestos waste includes both end-of-life asbestos containing materials (ACM) as well as soil or building rubble that has been tested to demonstrate asbestos contamination. Since the latter may contain very low concentrations of asbestos fibre and very high soil volumes, this greatly contributes to reported asbestos waste volumes.

Sources

Table 45 provides a summary of the main sources of this waste in each jurisdiction.

Table 45 Asbestos containing material waste summary source analysis 2019-20

NSW	Vic	Qld	SA	National summary
• Asbestos removal contractors • Construction, demolition and related development activity	• 33% Waste treatment and disposal services • 19% Pulp, paper and paperboard manufacturing • Remainder (48%) – unidentified asbestos removal & construction	• Asbestos removal contractors • Construction, demolition and related development activity	• Asbestos removal contractors • Construction, demolition and related development activity	• Waste treatment and disposal services • (specifically) Asbestos removal contractors • Construction, demolition and related development activity • Pulp, paper and paperboard manufacturing

Sources of asbestos are construction/demolition related as well as any residential, commercial or industrial buildings that are involved in removal of asbestos containing material.

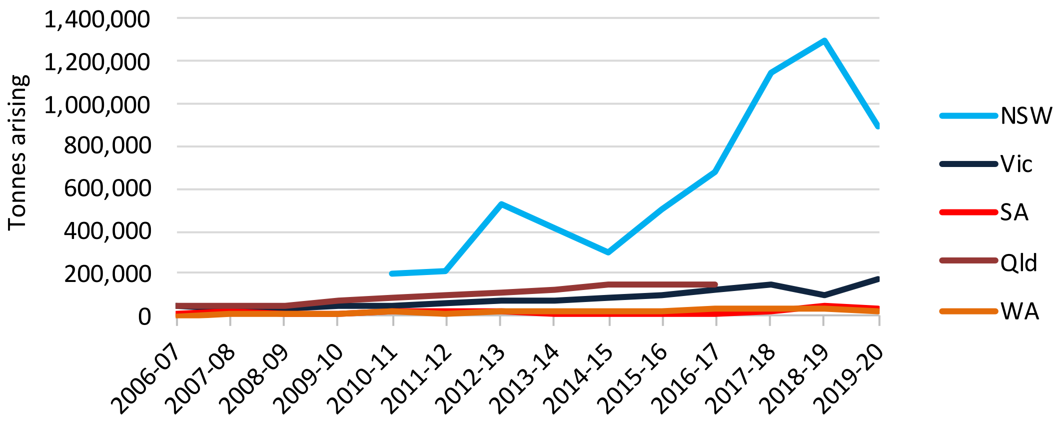
Jurisdictional tracking systems in the past have often not differentiated between ACM and asbestos-contaminated soils/rubble but this is changing. The split under the N220 asbestos group is discussed in this section, but broader data compilations in this report must default to the total asbestos figure (ACM plus asbestos-contaminated soil/rubble), because that is the lowest common data denominator across jurisdictions.

Analysis

Asbestos was the second largest contributor to national hazardous waste quantities in 2019-20, making up 18% of generation tonnages. NSW reported by far the highest quantity in 2019-20, with 68% of national tonnages, followed by Vic with 13%, Qld 11%, SA 3%, WA 2% and Tas 1%. The ACT, which reported 6% of national generation in HWiA 2019, has shrunk to 0.9%, due to the effective conclusion of asbestos clean-up work from residential housing affected by Mr Fluffy roofing insulation asbestos contamination.

Historical trends in arisings for this waste group are shown in Figure 55.

Figure 55 Historical arisings of asbestos containing material



Quantities vary significantly between years and jurisdictions. Spikes in the data are often associated with particular large development projects, such as the Barangaroo redevelopment in Sydney. NSW consistently produces the most asbestos waste.

The national quantity of asbestos waste in 2019-20 was 22% less than the previous year due to a large drop in asbestos generated in NSW. The long-term trend still appears to be rising levels of asbestos waste.

What is reported under 'N220'?

Blue Environment[113] conducted a study for the Asbestos Safety and Eradication Agency in 2020, focusing on asbestos data and trends to that time, using the same tracking and other data sources used for this report. Blue Environment reported significant variability in what jurisdictions classify as N220:

- Tas, SA and WA include only ACM (e.g. asbestos cement sheets).
- Vic previously included ACM plus soil or rubble contaminated with asbestos alone; i.e. if any other contaminants are also present above threshold limits for fill material, then the waste is not classified as N220, but as N120 contaminated soil. However, since 1 July 2021, Vic separates ACM (N220) from asbestos contaminated soil (N120), but does not separate asbestos contaminated soil from other forms of contamination in soil (both N120).
- ACT, NSW, NT and Qld include ACM and any soil or rubble contaminated with asbestos, even if it also contains other types of contamination.

To better understand the waste in this category, it would make sense to report a split of ACM and asbestos-contaminated soil/rubble. However, Blue Environment found that states and territories have different capacities to make this distinction in their data reports:

- Tas, SA and WA reported ACM separately
- NSW and Qld, despite reporting both ACM and asbestos contaminated soil/rubble as N220, can now distinguish the two in their landfill data because they are subject to different levy rates (both of which were recently established)

[113] Blue Environment (2020), *Asbestos waste data update 2020*, prepared for the Asbestos Safety and Eradication Agency.

- ACT and NT were unable to differentiate ACM from soil or rubble contaminated with ACM
- Vic did not differentiate ACM from soil or rubble contaminated with ACM but will do so from 1 July 2021[114].

Further complicating these inconsistencies, NSW (for example) appears to take a particularly risk-averse position on the extent of contamination required to classify soil/rubble as asbestos-contaminated, while Vic (for example) less so, deeming that soil does not contain asbestos if 'all visible asbestos-containing material … has been removed, so far as reasonably practicable, from the soil by the person proposing to supply, store, transport, sell, use or re-use the soil.'[114]

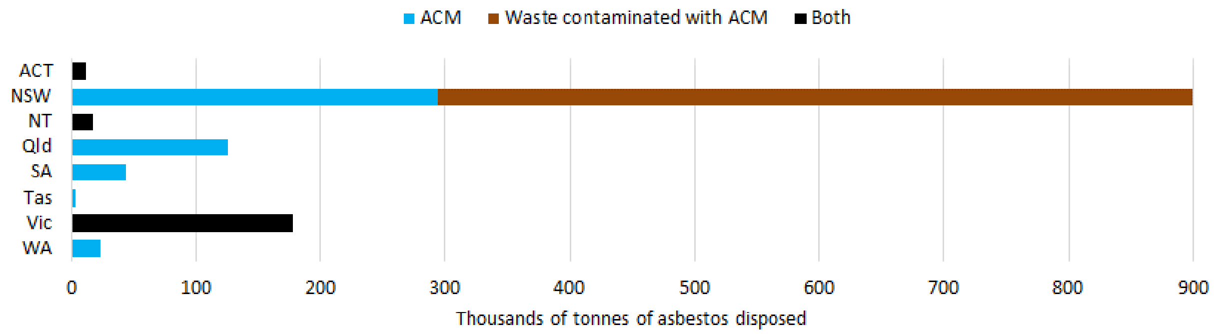
Blue Environment concluded, with respect to reporting of asbestos waste:

> '*There is a need for accurate and consistent reporting of waste data to support a nationally coordinated approach to asbestos. States and territories should be encouraged to report wrapped ACM separately from soil and rubble contaminated with ACM.*'

Asbestos waste quantities disaggregated

Figure 56 shows the 2019-20 data disaggregated, to the extent data is available, into ACM and waste (soil or rubble) contaminated with ACM. NSW produces the most of each category.

Figure 56 Jurisdictional asbestos waste quantities disaggregated, 2019-20



Source: Blue Environment 2020

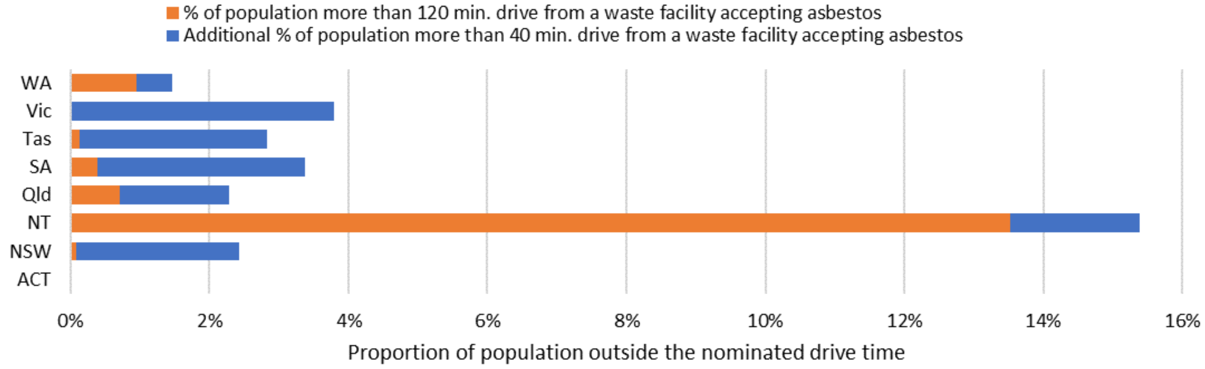
Management

100% of asbestos waste was disposed of at landfills licensed by environmental regulators to receive asbestos waste in 2019-20. These landfills differ from 'hazardous waste landfills' in that they are licensed to receive a very selective suite of low-hazard wastes. In the context of this report, wastes typically accepted at these facilities are asbestos, low-level contaminated soil and, potentially, tyres. Such landfills are numerous and widely dispersed throughout Australia.

A key issue for asbestos disposal, to avoid illegal dumping, is the extent to which these landfills are geographically accessible to the community, particularly for receipt of wrapped asbestos cement sheets. Blue Environment's report[113] also developed a series of maps indicating the accessibility of these facilities through reference to benchmark drive times. The results are shown in Figure 57.

[114] EPA Victoria (2021), *Waste disposal categories – characteristics and thresholds*, Publication 1828.2 (Applies from 1 July 2021), available at *https://www.epa.vic.gov.au/about-epa/publications/1828-2*.

Figure 57 Proportion of the population outside nominated drive times from a waste facility accepting asbestos, by state and territory



Source: Blue Environment 2020

In relation to access within a 120-minute drive-time, access is least available in larger jurisdictions with a relatively high remote population, particularly NT (13.5%) but also WA and Qld. In relation to access within a 40-minute drive-time (but less than 120 minutes), access is least available for Vic (3.8%) and followed, in order, by SA, Tas and NSW. All of the ACT's population is within 40 minutes of a waste facility accepting asbestos, hence they are not represented in Figure 57.

Overall, Blue Environment estimated that:

- 2.8% of the Australian population lives more than 40 minutes from a waste facility that accepts domestic asbestos waste
- 0.4% of the Australian population lives more than 120 minutes from a waste facility that accepts commercial asbestos waste.

B25 Other N: Other soils/ sludges

This waste group collects those remaining N group codes including:

- *N100 containers & drums contaminated with residues of substances referred to in the NEPM 15 list*
- *N140 fire debris and fire wash waters*
- *N150 fly ash, excluding fly ash generated from Australian coal fired power stations*
- *N160 encapsulated, chemically-fixed, solidified or polymerised wastes in the NEPM 15 list*
- *N190 filter cake contaminated with residues of substances referred to in the NEPM 15 list*
- *N230 ceramic-based fibres with physico-chemical characteristics similar to those of asbestos.*

Sources

Table 46 provides a summary of the main sources of this waste in each jurisdiction.

Table 46 Other soils/sludges waste summary source analysis 2019-20

NSW	Vic [85]	Qld	SA	National summary
3.5 kt of northern NSW 2019-20 fires waste (N140 solid fire debris) was sent to Qld landfill	• Waste treatment and disposal services • Chemical product manufacturing • Pulp, paper and paperboard manufacturing • Machinery & equipment manufacturing	• Most of N150 is from alumina production	0.1% of national total for waste group	• Waste treatment and disposal services • Chemical product manufacturing • Metals manufacturing • Petroleum refining • Paper & paper product manufacturing

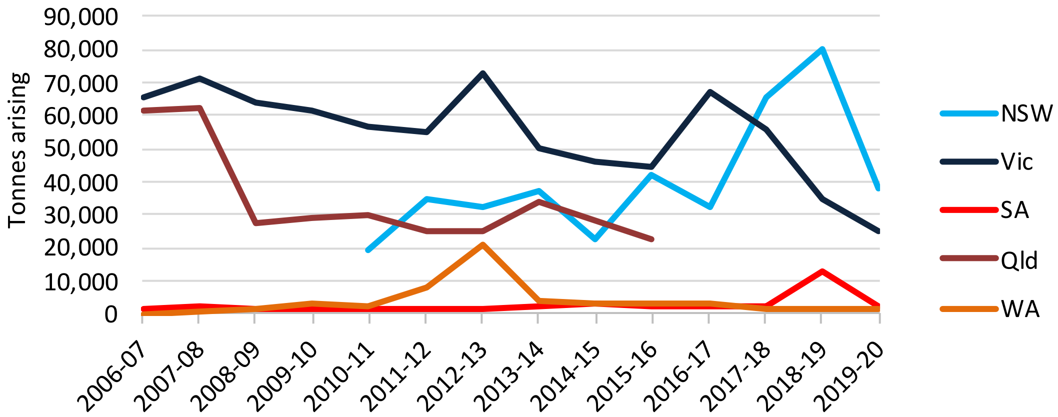
N160 Encapsulated waste is waste that has been treated to reduce its hazard by various CPT facilities in the waste industry. Chemical product and related manufacturing and petroleum refining contribute to drums (N100) and N190 filter cake is from a variety of industrial processes, including chemical product manufacturing, metals manufacturing, paper and paper product manufacturing and machinery and equipment manufacturing.

N150 fly ash is contributed from various forms of thermal processing, including from incineration, alumina refining, meat processing, cement kilns, coal-fired power stations (despite the waste classification name), non-coal derived power plants, asphalt plants, iron and steel manufacturing and petroleum refining.

Analysis

This group is another collation of disparate wastes, most of which arise in small quantities. The whole group contributes 1% to national generation figures, making it 15th highest in 2019-20. Historical trends in arisings for this waste group are shown in Figure 58.

Figure 58 Historical arisings of other soil/sludges waste



NSW generated 43% of these wastes in 2019-20, followed by Vic (34%) and Qld (25%). The caveat on the completeness of Qld's data makes it hard to accurately gauge the relative contributors in the group, but NSW and Vic data (shown in Table 47) indicate that N100 drums and N160 encapsulated waste provide the largest quantities, the sum of each making up exactly 82% of the group both in NSW and Vic.

Table 47 Composition of other soil/sludges waste in NSW and Vic, 2019-20

Waste in 'Other N' group	NSW		Vic	
	Tonnes	%	Tonnes	%
N100 containers & drums contaminated with residues of substances referred to in the NEPM 15 list	14,145	35%	9,450	38%
N140 fire debris and fire washwaters	3,479	8%	97	0%
N150 fly ash, excluding fly ash generated from Australian coal fired power stations	1	0%	383	2%
N160 encapsulated, chemically-fixed, solidified or polymerised wastes in the NEPM 15 list	19,116	47%	10,837	44%
N190 filter cake contaminated with residues of substances referred to in the NEPM 15 list	4,217	10%	4,098	16%
N230 ceramic-based fibres with physico-chemical characteristics similar to those of asbestos	0	0%	2	0%
Total Other N	40,958	100%	24,867	100%

This waste group was estimated by the data caveat method in Qld, due to the much lower quantities recorded in tracking as generated in Qld compared to the quality assured baseline year of 2015-16. Using raw data alone, alumina refining makes up virtually all of it (as N150 fly ash). Another feature of Qld data is the presence of bushfire debris waste (N140) from the fires in northern NSW in late 2019 and January 2020, much of which was contaminated with asbestos (from destroyed buildings).

Management

The main form of management in 2019-20 tracking data for this whole waste group is landfill (69%), with recycling, CPT and storage each around 10% each.

B26 R: Clinical and pharmaceutical waste

This waste group is made up of:

- *R100 Clinical and related wastes*
- *R120 Waste pharmaceuticals, drugs and medicines*
- *R140 Waste from the production and preparation of pharmaceutical products.*

Clinical and related wastes are wastes arising from medical, nursing, dental, veterinary, laboratory, pharmaceutical, podiatry, tattooing, body piercing, brothels, emergency services, blood banks, mortuary practices and other similar practices, and wastes generated in healthcare facilities or other facilities during the investigation or treatment of patients or research projects, which have the potential to cause disease, injury, or public offence, and includes clinical sharps and non-sharps clinical waste.

Other wastes are also generated within health care settings. Waste pharmaceuticals, drugs and medicines are waste pharmaceutical products that have: passed their recommended shelf life; been discarded as off-specification batches; been returned by patients or been discarded. These wastes are often generated directly from pharmacies, hospitals, medical centres and hospital dispensaries.

A particularly notable pharmaceutical waste is waste cytotoxic drugs, or waste (including sharps) contaminated by cytotoxic drugs. A cytotoxic drug has carcinogenic (cancer-causing), mutagenic (increase mutations of genetic material) or teratogenic (birth defect) potential, and is commonly used in the treatment of cancer.

Lastly, waste from the production and preparation of pharmaceutical products, R140, is similar to R120. The key difference is the setting for its generation – at the pharmaceutical product manufacturing stage rather than the point in the lifecycle where the product is sold, administered or used (pharmacy or health care facility). Another difference is that, as a manufacturing waste, R140 may include process wastes that may be raw materials-based rather than wastes of final manufactured products.

Sources

Table 48 provides a summary of the main sources of this waste in each jurisdiction.

Table 48 Clinical and pharmaceutical waste summary source analysis 2019-20

NSW	Vic [85]	Qld	SA	National summary
Not determined (waste exempt from tracking)	• 78% Waste treatment & disposal services • 6% Human pharmaceutical & medicinal product manufacturing	• Waste treatment & disposal services • Health care sector • Human pharmaceutical & medicinal product manufacturing	• Waste treatment & disposal services • Health care sector	• Waste treatment & disposal services • Health care sector • Human pharmaceutical & medicinal product manufacturing

NSW does not track any of the R group wastes, because clinical waste is exempt from tracking[115]. Therefore, the national data includes estimates of NSW arisings, derived from per capita comparison with other jurisdictional arisings. While clinical wastes should arise somewhat proportionally to population, the NSW arisings estimate introduces uncertainty.

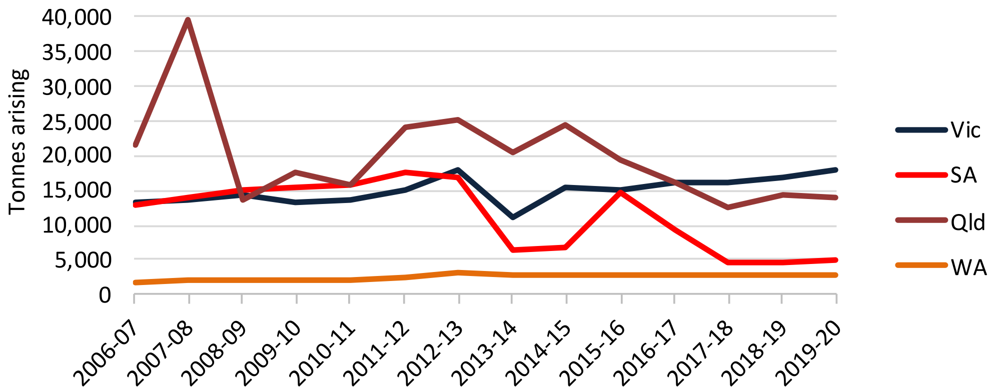
Sources of R100 are health care and allied sectors at the core, with waste businesses heavily identified because of their role as waste collection agents from these facilities. R120 is quite specific to hospitals and pharmacies, while R140 is specific to pharmaceutical manufacturing.

Analysis

The R waste group made up 0.7% of Australia's hazardous waste in 2019-20, with *R100 clinical and related waste* making up almost all of it. Historical trends in arisings for this waste group are shown in Figure 59.

[115] https://www.epa.nsw.gov.au/your-environment/waste/tracking-transporting-hazardous-waste/waste-tracking-exemptions.

Figure 59 Historical arisings of clinical and pharmaceutical wastes



Trends in arisings over the last five to ten years are flat to decreasing, even though one would expect incremental growth in hospital bed days as the population ages. The trend may reflect the success of efforts by hospital administrators to reduce staff use of clinical waste disposal bins for normal wastes, which has been an expensive problem historically. Data quality may also be an issue, with NSW not represented at all and SA data only tracked accurately in recent years.

Management

For this type of waste, the following management techniques are routinely carried out in Australia:

- incineration
- autoclaving and shredding (which may also include chemical disinfection).

Management data gathered for 2019-20 shows thermal destruction (via clinical waste incinerators) and CPT (via autoclaving) share the highest management proportion nationally, with 40% of R waste going to each, followed by storage at 14%. Small quantities of landfill of clinical waste are recorded in Qld and WA, but these are likely to be re-arisen clinical waste after treatment by a clinical waste company, such as by autoclave and shredding. Once the hazard has been treated, landfill can be an acceptable final management.

The issue of COVID 19-related impacts on clinical waste volumes and management in Australia in 2020 is explored in Section 4.1.

B27 T140: Tyres

This group is the sole NEPM category *T140 Tyres*. Tyres are used, discarded or rejected tyres that have reached the end of their useful life, i.e., when they can no longer be used for their original purpose, and are subsequently removed from a vehicle.

Tyres are included in Qld and WA tracking systems, and NSW tracks them in their WasteLocate system, which is specific for tyres and asbestos. WasteLocate aside, tracking-recorded arisings indicate that they are significantly under-reported, when compared with credible recent estimates of arisings (REC 2020)[116]. Consequently, in reporting to Basel and the 2019-20 dataset for this report, data from REC 2020 was used to estimate arisings.

[116] Tyre Stewardship Australia (2020), *Used tyres supply chain and fate analysis*, prepared by Randell Environmental Consulting in association with Envisage Works and Brock Baker Environmental Consulting.

Sources

The bulk of this waste nationally is produced from tyre and motor vehicle retailing and motor vehicle servicing industries.

Analysis

Using REC 2020 data, tyres are a large national waste, making up 6% of national hazardous waste generation and coming in 4th in the list of largest tonnages.

Management

REC (2020) data shows that domestic tyre recycling has increased from a reported 10% in HWiA 2019 to 34% in 2019-20. Recycling outputs are high-value commodities such as crumb rubber and granules. The share of exports, as low-value materials, has increased from 27% to 36%, while landfill has reduced sharply, from 60% in 2017-18 to 28% in 2019-20.

These significant changes in reported management are largely associated with improved data quality. Data on waste tyres quantities and management has been notoriously fraught but is now much improved due largely to investigative work undertaken by the Tyre Stewardship Australia.

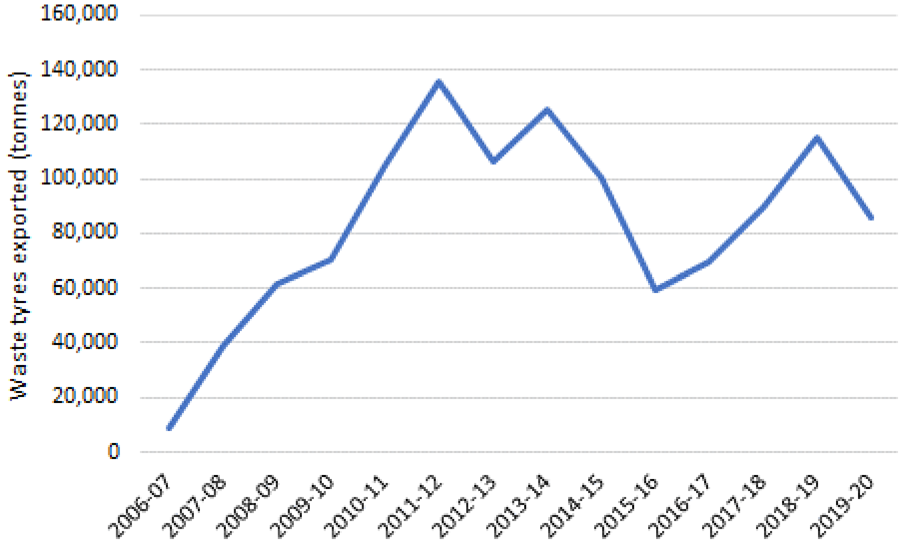
Exports data show increasing quantities of waste tyres exported overseas in the early 2000s, peaking in 2011-12 (see Figure 60). This data set is incomplete as it is apparent that exports of waste tyres have historically often been miscoded, and included in codes meant for new or re-treaded tyres. Exports have been of two main types:

- tyre-derived fuel manufactured to a specification for use in cement kilns in South Korea and other countries
- whole tyres exported for use in pyrolysis mainly in Malaysia and India.

The second of these export types has been shown to be environmentally problematic, resulting in high levels of urban pollution. The Australian Government has legislated for a ban on the export of whole tyres from 1 December 2021, as part of its range of broader bans on the export of environmentally problematic wastes. The impact of the ban on the waste tyre market remains uncertain, but Tyre Stewardship Australia (pers. comm.[117]) reports that a number of exporters of whole tyres have invested in shredding machinery.

[117] Tyre Stewardship Australia (Lina Goodman, personal communication with Joe Pickin of Blue Environment, Feb 2021).

Figure 60 Recorded exports of waste tyres by financial year



Source: ABS export data in HS codes 400400, 401220 and 401290.

B28 Other T: Other miscellaneous

This waste group includes:

- *T100 waste chemicals from research and development or teaching activities*
- *T120 waste from the production & use of photographic chemicals and processing materials*
- *T200 waste of an explosive nature not subject to other legislation.*

This waste group is a collection of relatively unrelated wastes that are produced in small quantities and are made up of mostly T100, with smaller quantities of T200 and T120.

Sources

Table 49 provides a summary of the main sources of this waste in each jurisdiction.

Table 49 Other miscellaneous waste summary source analysis 2019-20

NSW	Vic	Qld	SA	National summary
• Public administration & other education • Domestic chemical collections	• Waste treatment & disposal services • Public administration & other education • Domestic chemical collections	• Public administration & other education • Domestic chemical collections	• Public administration & other education • Domestic chemical collections	• Waste treatment & disposal services • Public administration & other education • Domestic chemical collections

This waste group is small nationally, making up 0.1% of Australia's hazardous waste in 2019-20. NSW generated 49%, followed by Qld (28%), Vic (17%) and SA just 3%.

This waste was primarily T100 from research and development, university or teaching institutions, as well as from domestic chemical collections. The waste industry often acts as the producer through collection of these wastes.

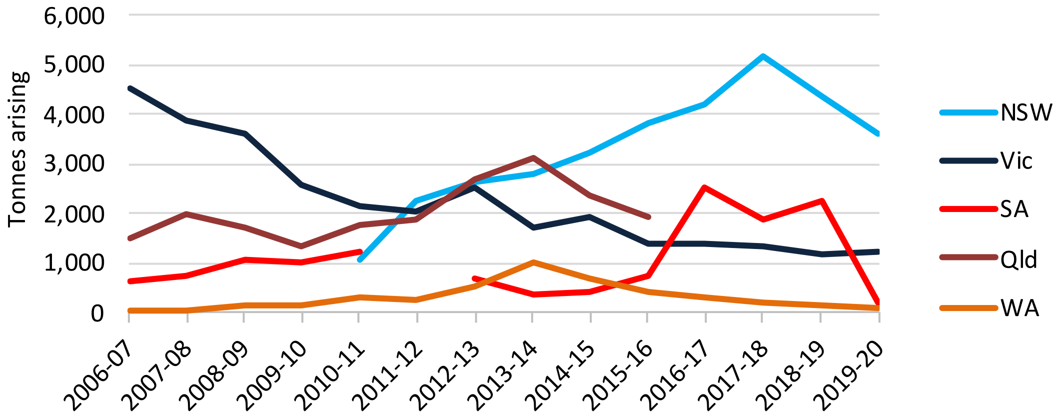
T120 is a specialty waste from the printing industry, but also includes x-ray photography activities from dentists and other health practitioners.

T200 is produced by the mining industry from the use of mine explosives, but also from manufacturers and suppliers of these explosives. Expired marine flares may also be captured in this waste code, and some jurisdictions appear to operate a collection system for these, or they may come into the waste management system via police accumulation from public disposal. Qld recorded most of this waste nationally in 2019-20 (334 tonnes from raw tracking data, unadjusted), while WA recorded a very small amount (16 tonnes) as 'highly reactive chemicals not otherwise specified'.

Analysis

Other T miscellaneous wastes made up just 0.1% of all hazardous waste generation nationally in 2019-20. Historical trends in arisings for this waste group are shown in Figure 61.

Figure 61 Historical arisings other miscellaneous waste



A likely data error in SA data in 2011-12 (discussed in HWiA 2019 and recorded as a 51 kt spike) has been removed from Figure 61. This allows more visibility, although the trend is not particularly consistent nationally, which may reflect different jurisdictional priorities with chemical collection programs from time to time.

Management

Storage is the largest management type nationally (74%, mostly in NSW and Vic), with CPT making up most of the rest at 18%. Storage is typical of a waste group collation of small quantities of 'rats and mice' chemicals and materials, some of it of potentially unknown origin.

Appendix C Underlying data to this report

C1 National hazardous waste data 2019-20 and 2019 – by NEPM code

Adjusted generation (tonnes) by NEPM code					
NEPM group	Waste group	NEPM code	NEPM code description	2019-20	2019
A	Plating and heat treatment	A100	Waste resulting from surface treatment of metals & plastics	6,881	7,273
		A110	Waste from heat treatment & tempering operations containing cyanides	13	13
		A130	Cyanides (inorganic)	60	76
B	Acids	B100	Acidic solutions or acids in solid form	60,987	43,081
C	Alkalis	C100	Basic solutions or bases in solid form	257,542	281,367
D	Inorganic chemicals	D100	Metal carbonyls	230	199
		D110	Inorganic fluorine compounds excluding calcium fluoride	37,572	31,506
		D120	Mercury; mercury compounds	1,209	716
		D130	Arsenic; arsenic compounds	230	167
		D140	Chromium compounds (hexavalent & trivalent)	1,357	1,809
		D150	Cadmium; cadmium compounds	260	228
		D160	Beryllium; beryllium compounds	31	26
		D170	Antimony; antimony compounds	0	0
		D180	Thallium; thallium compounds	1	0
		D190	Copper compounds	755	589
		D200	Cobalt compounds	1	37
		D210	Nickel compounds	968	1,087
		D220	Lead; lead compounds	266,450	357,277
		D230	Zinc compounds	162,159	288,550
		D240	Selenium; selenium compounds	294	434
		D250	Tellurium; tellurium compounds	3	3
		D270	Vanadium compounds	90	62
		D290	Barium compounds (excluding barium sulphate)	50	206
		D300	Non-toxic salts	86,309	97,005
		D310	Boron compounds	56	81
		D330	Inorganic sulfides	499	471
		D340	Perchlorates	13	12
		D350	Chlorates	29	31
		D360	Phosphorus compounds excluding mineral phosphates	483	480
E	Reactive chemicals	E100	Waste containing peroxides other than hydrogen peroxide	290	239
F	Paints, resins, inks, organic sludges	F100	Waste from production, formulation & use of inks, dyes, pigments, paints, lacquers & varnish	253,744	245,227

Adjusted generation (tonnes) by NEPM code					
NEPM group	Waste group	NEPM code	NEPM code description	2019-20	2019
		F110	Waste from the production, formulation & use of resins, latex, plasticisers, glues & adhesives	13,850	10,358
G	Organic solvents	G100	Ethers	1,730	2,603
		G110	Organic solvents excluding halogenated solvents	10,128	12,392
		G150	Halogenated organic solvents	595	670
		G160	Waste from the production, formulation & use of organic solvents	3,110	3,609
H	Pesticides	H100	Waste from the production, formulation & use of biocides & phytopharmaceuticals	2,615	3,381
		H110	Organic phosphorous compounds	129	138
		H170	Waste from manufacture, formulation & use of wood-preserving chemicals	1,434	1,301
J	Oils	J100	Waste mineral oils unfit for their original intended use	372,125	407,076
		J120	Waste oil/water, hydrocarbons/water mixtures or emulsions	275,178	327,206
		J160	Waste tarry residues arising from refining, distillation, & any pyrolytic treatment	1,176	1,366
K	Putrescible/ organic waste	K100	Animal effluent & residues (abattoir effluent, poultry & fish processing wastes)	235,915	252,361
		K110	Grease trap waste	440,845	434,288
		K140	Tannery wastes (incl. leather dust, ash, sludges & flours)	6,103	6,195
		K190	Wool scouring wastes	976	1,117
M	Organic chemicals	M100	Waste substances & articles containing or contaminated with polychlorinated biphenyls, polychlorinated naphthalenes, polychlorinated terphenyls and/or polybrominated biphenyls	4,668	5,876
		M150	Phenols, phenol compounds including chlorophenols	1,117	1,182
		M160	Organohalogen compounds—other than substances referred to in this Table or Table 2	4,568	7,737
		M170	Polychlorinated dibenzo-furan (any congener)	0	0
		M180	Polychlorinated dibenzo-p-dioxin (any congener)	0	0
		M210	Cyanides (organic)	3	0
		M220	Isocyanate compounds	369	328
		M230	Triethylamine catalysts for setting foundry sands	2,070	918
		M250	Surface active agents (surfactants), containing principally organic constituents & which may contain metals & inorganic materials	14,218	16,487

Adjusted generation (tonnes) by NEPM code					
NEPM group	Waste group	NEPM code	NEPM code description	2019-20	2019
		M260	Highly odorous organic chemicals (including mercaptans & acrylates)	33	14
		M270	PFAS-contaminated materials including waste PFAS-containing products and contaminated containers	9,839	4,107
N	Soil/ sludge	N100	Containers & drums that are contaminated with residues of substances referred to in this list	28,974	29,906
		N120	Soils contaminated with a controlled waste	2,582,442	2,729,800
		N140	Fire debris & fire wash waters	3,811	3,334
		N150	Fly ash, excluding fly ash generated from Australian coal fired power stations	7,310	7,456
		N160	Encapsulated, chemically-fixed, solidified or polymerised wastes referred to in this list	36,444	58,069
		N190	Filter cake contaminated with residues of substances referred to in this list	17,723	16,216
		N205b	Other industrial treatment residues (excludes biosolids)	195,991	179,556
		N220	Asbestos	1,326,503	1,388,954
		N230	Ceramic-based fibres with physico-chemical characteristics similar to those of asbestos	5	84
R	Clinical and pharmaceutical	R100	Clinical & related wastes	46,907	46,640
		R120	Waste pharmaceuticals, drugs & medicines	2,536	2,774
		R140	Waste from the production & preparation of pharmaceutical products	1,582	1,487
T	Miscellaneous	T100	Waste chemical substances arising from research & development or teaching activities, including those which are not identified and/or are new & whose effects on human health and/or the environment are not known	5,868	5,411
		T120	Waste from the production, formulation & use of photographic chemicals & processing materials	289	1,058
		T140	Tyres	466,038	457,647
		T200	Waste of an explosive nature not subject to other legislation	1,157	1,157
Other		Other		112,128	0
Totals				7,377,065	7,788,512
Notes					
1	The Basel data set (2019 calendar year) does not subtract or add inter-jurisdictional transfers. Due to flaws in the underlying data, this is likely to skew the total quantity upwards relative to the financial year data set.				
2	The Basel data ignores 'other'. The financial year data set presented includes 'other'.				

C2 2019 Basel data (in Y codes)

(See 'Basel Convention Y-codes' definition in Appendix A)

Basel Convention		Tonnes generated, National, 2019
Code	Waste description (Annex 1)	
Total amount of hazardous wastes under Art. 1 (1)a (Annex I: Y1-Y45) generated		5,508,920
Total amount of hazardous wastes under Art. 1 (1)b generated		9,556,960
Total amount of other wastes (Annex II: Y46 - Y47)		11,393,992
Y1	Clinical wastes from medical care in hospitals, medical centres and clinics	46,640
Y2	Wastes from the production and preparation of pharmaceutical products	1,487
Y3	Waste pharmaceuticals, drugs and medicines	2,774
Y4	Wastes from the production…… of biocides and phytopharmaceuticals	3,381
Y5	Wastes from the manufacture…… of wood preserving chemicals	1,301
Y6	Wastes from the production, formulation and use of organic solvent	3,609
Y7	Wastes from heat treatment and tempering operations containing cyanides	13
Y8	Waste mineral oils unfit for their originally intended use	407,076
Y9	Waste oils/water, hydrocarbons/water mixtures, emulsion	327,206
Y10	Waste substances …. containing or contaminated with PCBs, PCTs, PBBs	5,876
Y11	Waste tarry residues … from refining, distillation and any pyrolytic treatment	1,366
Y12	Wastes from production…… of inks, dyes, pigments, paints, etc	245,227
Y13	Wastes from production……resins, latex, plasticizers, glues, etc	10,358
Y14	Waste chemical substances arising ….. environment are not known	5,411
Y15	Wastes of an explosive nature not subject to other legislation	1,439
Y16	Wastes from production, formulation and use of photographic chemicals…	1,058
Y17	Wastes resulting from surface treatment of metals and plastics	7,273
Y18	Residues arising from industrial waste disposal operations	2,013,613
Y19	Metal carbonyls	199
Y20	Beryllium; beryllium compounds	26
Y21	Hexavalent chromium compounds	1,809
Y22	Copper compounds	589
Y23	Zinc compounds	288,550
Y24	Arsenic; arsenic compounds	167
Y25	Selenium; selenium compounds	434
Y26	Cadmium; cadmium compounds	228
Y27	Antimony; antimony compounds	0
Y28	Tellurium; tellurium compounds	3
Y29	Mercury; mercury compounds	716
Y30	Thallium; thallium compounds	0
Y31	Lead; lead compounds	357,277
Y32	Inorganic fluorine compounds excluding calcium fluoride	31,506
Y33	Inorganic cyanides	76
Y34	Acidic solutions or acids in solid form	43,081
Y35	Basic solutions or bases in solid form	281,367
Y36	Asbestos (dust and fibres)	1,388,954
Y37	Organic phosphorus compounds	138
Y38	Organic cyanides	0
Y39	Phenols; phenol compounds including chlorophenols	1,182
Y40	Ethers	2,603
Y41	Halogenated organic solvents	670
Y42	Organic solvents excluding halogenated solvents	12,392
Y43	Any congenor of polychlorinated dibenzo-furan	0
Y44	Any congenor of polychlorinated dibenzo-p-dioxin	0
Y45	Organohalogen compounds other than …(e.g. Y39, Y41, Y42, Y43, Y44)	11,844

Basel Convention		Tonnes generated, National, 2019
Code	Waste description (Annex 1)	
Y46	Wastes collected from households	11,393,992
Y47	Residues arising from the incineration of household wastes	0
	Additional waste categories not included in Y-Codes	
1	Other metal compounds	1,393
2	Other inorganic chemicals	98,037
3	Other organic chemicals	17,747
4	Putrescible/ organic waste	693,961
5	Waste packages and containers containing Annex 1 substances in concentrations sufficient to exhibit Annex III hazard characteristics	29,906
6	Soils contaminated with residues of substances in Basel Y-codes 19-45	2,729,800
7	Sludges contaminated with residues of substances in Basel Y-codes 19-45	19,550
8	Tyres	457,647

Y48 Plastic waste, a recent addition to the Basel Convention (implemented January 2021) is discussed previously in Section 4.4 and will be added to Australia's Basel report for 2020, as available data allows.

C3 Adopted Y-code translations from additional NEPM codes (Basel 'Y+8')

Additional waste categories not included in Y-Codes (Y+8 codes)		NEPM code	
Y+1	Other metal compounds	D200	Cobalt compounds
		D210	Nickel compounds
		D270	Vanadium compounds
		D290	Barium compounds (excluding barium sulphate)
Y+2	Other inorganic chemicals	D300	Non-toxic salts
		D310	Boron compounds
		D330	Inorganic sulfides
		D360	Phosphorus compounds excluding mineral phosphates
Y+3	Other organic chemicals	M220	Isocyanate compounds
		M230	Triethylamine catalysts for setting foundry sands
		M250	Surface active agents (surfactants), containing principally organic constituents and which may contain metals and inorganic materials
		M260	Highly odorous organic chemicals (including mercaptans and acrylates)
Y+4	Controlled putrescible/ organic wastes	K100	Animal effluent and residues (abattoir effluent, poultry and fish processing wastes)
		K110	Grease trap waste
		K140	Tannery wastes (including leather dust, ash, sludges and flours)
		K190	Wool scouring wastes
Y+5	Waste packages and containers containing Annex 1 substances in concentrations sufficient to exhibit Annex III hazard characteristics	N100	Containers and drums that are contaminated with residues of substances referred to in this list
Y+6	Soils contaminated with residues of substances in Basel Y-codes 19-45	N120	Soils contaminated with a controlled waste
Y+7	Sludges contaminated with residues of substances in Basel Y-codes 19-45	N140	Fire debris and fire wash waters
		N190	Filter cake contaminated with residues of substances referred to in this list
Y+8	Tyres	T140	Tyres

C4 Waste groups map

NEPM code	Waste group	Waste group description
A100	A	Plating & heat treatment
A110	A	
A130	A	
B100	B	Acids
C100	C	Alkalis
D100	Other D	Other inorganic chemicals
D110	D110	Inorganic fluorine (spent potliner)
D120	D120	Mercury & compounds
D130	Other D	Other inorganic chemicals
D140	Other D	
D150	Other D	
D160	Other D	
D170	Other D	
D180	Other D	
D190	Other D	
D200	Other D	
D210	Other D	
D220	D220	Lead and compounds
D230	D230	Zinc compounds
D240	Other D	Other inorganic chemicals
D250	Other D	
D270	Other D	
D290	Other D	
D300	D300	Non-toxic salts (including coal seam gas wastes)
D310	Other D	Other inorganic chemicals
D330	Other D	
D340	Other D	
D350	Other D	
D360	Other D	
E100	E	Reactive chemicals
F100	F	Paints, resins, inks, organic sludges
F110	F	
G100	G	Organic solvents
G110	G	
G150	G	
G160	G	
H100	H	Pesticides
H110	H	
H170	H	
J100	J100 & J160	Oils
J120	J120	Waste oil/water mixtures
J160	J100 & J160	Oils
K100	Other K*	Other putrescible / organic wastes
K110	K110	Grease trap wastes
K140	Other K*	Other putrescible / organic wastes
K190	Other K*	
M100	M100	PCB wastes
M150	Other M	Other organic chemicals
M160	M160	Other organohalogen compounds
M170	Other M	Other organic chemicals

NEPM code	Waste group	Waste group description
M180	Other M	
M210	Other M	
M220	Other M	
M230	Other M	
M250	Other M	
M260	Other M	
M270	M270	PFAS contaminated materials
N100	Other N	Other soil/sludges
N120	N120	Contaminated soils
N140	Other N	Other soil/sludges
N150	Other N	
N160	Other N	
N190	Other N	
N205	N205b	Other industrial treatment residues
N220	N220	Asbestos containing material
N230	Other N	Other soil/sludges
R100	R	Clinical and pharmaceutical
R120	R	
R140	R	
T100	Other T	Other miscellaneous
T120	Other T	
T140	T140	Tyres
T200	Other T	Other miscellaneous
Other	Other	(Not classified)

* Although recognised in five jurisdictions (WA, Qld, SA, Tas and NT) code K130 (often used for sewage or sewage sludge) is not recognised under the Controlled Waste NEPM, and so was not analysed in this project.

Appendix D Data sources, limitations and quality issues

D1 Data sources

This report is supported by current and historical data, predominantly sourced from confidential hazardous waste tracking data (waste transport certificates). This data covers the 2019-20 financial year, the focus of this report, but also includes tracking data reaching as far back as 1999-2000 (in the case of Qld) to provide trends and historical context.

Data was supplied by the states as comprehensive tracking system 'data dumps', encompassing hundreds of thousands of individual transactions per year. Additional data from landfill reports was provided in some cases where a hazardous waste is not tracked, such as for contaminated soil and asbestos in NSW. Additional data from other studies was also applied in some cases where a hazardous waste is not tracked, nor recorded in landfill data, to fill obvious gaps. The ACT, NT and Tas provided completed Basel data workbooks.

The data supporting this report is housed in the *National hazwaste data collation 2019-20* workbook. The NEPM data from the National Environment Protection Council Annual Report 2018-19 was also reviewed, to inform data and discussion involving interstate management of waste.

The data collection method

Methods of data collation used for this work follow the *Australian hazardous waste data and reporting standard*[118], in particular Section 4 of this standard.

A 'waste receival end' approach, instead of a 'waste arising end' approach to collating waste data was used in this project (and HWiA 2017), because it offers potential data quality improvements over the first HWiA approach (HWiA 2015) such as:

- more reliable capture of interstate movement data, which could subsequently be apportioned back to the jurisdiction that generated it
- easier elimination of double-counting, through subtraction of tonnages going into short-term storage or transfer management infrastructure
- better alignment with NEPM implementation reporting, which also reports hazardous waste received into its borders from other jurisdictions, on a calendar year basis
- a theoretically easier compilation task for jurisdictions.

This approach has several jurisdiction-specific limitations, which involves a patchwork of data collection methods to arrive at the highest data quality outcome. The approach taken in each jurisdiction and relevant characteristics of the data provided in each case are analysed in Table 50.

[118] Blue Environment, Randell Environmental Consulting and Ascend Waste and Environment 2017, *Australian hazardous waste data and reporting standard – 2017 revision*, prepared for the Australian Department of the Environment and Energy (and available at: http://www.environment.gov.au/protection/waste-resource-recovery/publications/australian-hazardous-waste-data-reporting-standard

Table 50 Data collection approach for HWiA 2021

	Expected data status in relation to inter-jurisdictional transfers	Main receiving jurisdiction(s) based on NEPC 14-15 ann. rpt.	Comments on the corresponding data in jurisdictions receiving or exporting waste	Conclusions and adjustments to data received from this jurisdiction	Change in approach from 14-15
ACT	Assumed to receive no waste from outside ACT. ACT data except asbestos is from NEPM transport certificates and so should be represented in the receiving jurisdiction's data.	NSW (based on NEPC data and ACT staff advice)	Transformed NSW data (9,551 t) is greater than quantities reported by ACT (8,441 t) for 2017-18.	ACT data to be used. Subtract ACT waste recorded in other jurisdictions' data.	As per the information to the left
NSW	Data identifies jurisdiction where waste is produced	Qld, Vic, SA		Subtract waste recorded in NSW data as produced elsewhere. Add data from other states recorded as produced in NSW.	As per the information to the left
NT	Assumed to receive no waste from outside NT. NT data except asbestos is from NEPM transport certificates and should therefore be represented in the data of the receiving jurisdiction.	NSW, Qld, SA, WA		NT data to be used. Subtract NT waste recorded in other jurisdictions' data.	As per the information to the left
Qld	Data identifies jurisdiction where waste is produced	NSW, NT, SA, Vic		Subtract waste recorded in Qld data as produced elsewhere. Add data from other states recorded as produced in Qld.	As per the information to the left
SA	Data identifies jurisdiction where waste is produced	NSW, NT, Vic		Subtract waste recorded in SA data as produced elsewhere. Add data from other states recorded as produced in SA.	
Tas	Assumed to receive no waste from outside Tas. All Tas data except asbestos is from NEPM transport certificates and so should be represented in the receiving jurisdiction's data.			Tas data to be used. Subtract Tas waste recorded in other jurisdictions' data.	Tas data to be used. Subtract Tas waste recorded in other jurisdictions' data. Estimate this amount for SA as shown above.
Vic	Data identifies jurisdiction where waste is produced	NSW, SA, Qld, WA		Subtract waste recorded in Vic data as produced elsewhere. Add data from other states recorded as produced in Vic.	As per the information to the left
WA	Data identifies jurisdiction where waste is produced			Subtract waste recorded in WA data as produced elsewhere. Add data from other states recorded as produced in WA.	Add data from other states recorded as produced in WA.

D2 Data limitations

All of the tracking data and other arisings estimates used in this report are subject to limitations. Ultimately, waste transport certificates capture only those hazardous waste movements that legally occur. If a transport movement occurs without an accompanying waste transport certificate, such activity is illegal and would not be captured as part of the waste arisings assessed in this report. Waste transport certificates suffer from the vagaries of choices made by the certificate users, such as choice of waste and code, or choice of management code, as two examples, which can result in miscoded data. There may also be more than one code (for wastes or management types) that could be justified as appropriate, which could result in wastes allocated across different categories. It is noted however that online tracking systems go some way to controlling many of these potential user errors.

Data gaps

Although generically similar, there is some variation in hazardous waste classification, tracking and data collection throughout the states and territories. This leads to significant gaps in hazardous waste data that need to be filled in collating a credible national dataset. In accordance with the Standard, the project's team's approach in this (and previous annual data collations) has been to fill these gaps where possible, using alternative data sources and estimation methods. Expertise, judgement and potentially consultation are needed to determine whether a jurisdictional datum or an empty cell should be adjusted with data from an alternative source. In undertaking the assessment, the following principles were considered:

1. Is a waste for which no data is provided likely to have been generated in significant quantities?
2. Are there other reasons, such as policy priorities, existing programs or particular hazards posed, that justify seeking data that a jurisdiction was not able to provide?
3. Is a reasonable data source or estimation method available (such as a nationally consistent dataset or average quantity per capita) that is likely to produce a more accurate or more consistent national figure than the data (or blank entry) collected from a jurisdiction?

Various adjustments are provided for in the *National hazwaste data collation workbook*, in the 'Gap data' worksheet based on:

- Using figures from various sources and reports to estimate waste quantities (tyres, biosolids and wastes collected from households [Basel code Y46])
- Calculating the average quantity of the waste generated per capita in jurisdictions providing the data. This figure is applied to population data to estimate the quantity generated in a jurisdiction that did not provide data for that waste type.

Various adjustments have been applied by the project team to 2019-20 (and 2019) data, while other gaps are left uncorrected, due to a lack of reasonable estimation method. Table 51 compiles these along with some suggested reasons as to why the data gaps and weaknesses still prevail.

Table 51 Gaps and weaknesses in jurisdictional tracking system data and methods for adjusting them

Waste	Adjusted	Adjustment method	Possible reason for gap
All jurisdictions			
Biosolids (N205a)	Yes	Remove tracking data where reported and replace with estimations from biosolids data (latest ANZBP survey) reported on a 'wet' basis	The state-based K130 is unreliably tracked in WA, Qld, SA, NT and Tas and not at all in the remaining jurisdictions. This is not an official NEPM code – biosolids are not uniformly recognised across jurisdictions as hazardous (or trackable) waste.
Tyres (T140)	Yes	Remove tracking data where reported and replace with estimates from REC 2016	Unreliably tracked since tyres are not uniformly recognised across jurisdictions as hazardous (or trackable) waste.
Several jurisdictions: NSW, Vic, Qld, Tas			
Spent potlining (D110)	Yes	Derived as a proportion of aluminium produced in NSW, Qld, Tas and Vic (22kg/t Al produced based on Holywell et al 2013)	Onsite stockpiling is commonplace, so tracking only shows sporadic releases from these stockpiles, which is a poor guide to annual generation. Estimation method is more reliable.
Several jurisdictions: NSW, SA, NT			
Animal effluent and residues (K100)	Yes	Use average of data reported by other states to obtain a t/capita figure. Multiply t/capita by population in NSW, SA and NT respectively.	Wastes not tracked in these jurisdictions – probably due to perception that hazard is not as acute as other tracked wastes.
Grease trap waste (K110)	Yes	Use average of data reported by other states to obtain a t/capita figure. Multiply t/capita by population in NSW, SA and NT respectively.	Wastes not tracked in these jurisdictions – probably due to perception that hazard is not as acute as other tracked wastes.
Tannery wastes (K140)	No	No estimates made - no defensible principle-based method available	Limited tannery and wool scouring operations in Australia – largely historical industry so waste not as relevant today.
Wool scouring wastes (K190)	No	No estimates made - no defensible principle-based method available	
NSW			
Acids (B100)	No	No defensible principle-based method to estimate so data reporting in tracking is used.	This waste (in the specific form of spent pickle liquor that is destined for reuse) is not tracked in NSW, on account of a regulatory exemption (from tracking).
Lead and compounds (D220)	No	No defensible principle-based method to estimate so data reporting in tracking is used. It is suggested that NSW examine non-tracking approaches to data gathering as this waste is large and important.	This waste (only in the specific form of lead acid batteries that are destined for reuse) is not tracked in NSW, on account of a regulatory exemption (from tracking).
Zinc compounds (D230)	No	No defensible principle-based method to estimate so data reporting in tracking is used.	This waste (only in the specific form of zinc wastes destined for reuse) is not tracked in NSW, on account of a regulatory exemption (from tracking).
Waste oils (J100)	Yes	Uses data from the Product Stewardship for Oil program to estimate NSW (and some Vic) data missing from tracking systems due to tracking exemptions	This waste (only in the specific form of non-hazardous waste hydrocarbon oil destined for reuse) is not tracked in NSW, on account of a regulatory exemption (from tracking).

Waste	Adjusted	Adjustment method	Possible reason for gap
			Vic, through their accredited agents program, appear to also be missing significant tonnages in tracking data.
Clinical and related wastes (R100)	Yes	Use average of data reported by other states to obtain a t/capita figure. Multiply t/capita by population in NSW.	This waste is not tracked in NSW, on account of a regulatory exemption (from tracking).
Waste pharms., drugs and medicines (R120)	Yes	Use average of data reported by other states to obtain a t/capita figure. Multiply t/capita by population in NSW.	This waste is not tracked in NSW, on account of a regulatory exemption (from tracking).
Qld			
Cobalt compounds (D200)	No	No defensible method to estimate.	No information to suggest this waste is generated in Qld
Ceramic-based fibres (N230)	No	No defensible method to estimate.	No information to suggest this waste is generated in Qld
Tas and WA			
Asbestos (N220)	N220	Use average of data reported by other states to obtain a t/capita figure. Multiply t/capita by population in Tas and WA respectively.	Tas and WA do not track or otherwise record asbestos waste generation.

Note: 1. No data gaps specific to the ACT and Vic were identified so they are not included in Table 51

Limitations caused by the six-category national management system

NSW and SA use a six-category system of allocating waste tonnages to fate and pathway types (management types), while WA use a different categorisation again, covering 11 management types. These limited choices for describing what is happening at receival infrastructure can be ambiguous compared to Qld and Vic, which categorise hazardous waste management activities in over 30 categories, in line with the Basel Convention. This simplicity leads to other complications in national data, from a market understanding perspective.

The situation is made worse by the fact that even within these six categories there is major ambiguity for certificate users, who frequently choose the wrong management types. For example, using NSW categories, a cement kiln POPs destruction facility could be classified as incineration (which it technically is not), recycling (since the waste matrix such as the solvent carrying pesticide waste will displace fuel in the kiln, resulting in energy recovery), CPT (since the solvent containing pesticide waste will be blended with other wastes of calorific value first, before entry into the kiln) or ‘other’ since it is neither of these things. Underwhelmingly, ‘other’ is probably the most accurate choice in this example.

These limitations skew interpretation of what is happening to hazardous waste. NSW data has many instances where legitimate recycling activities (like lead acid battery recycling) are recorded under the CPT heading, causing misunderstanding and under-representation of recycling activity.

Gaps in waste tracking systems

Section 4 of the *Australian hazardous waste data and reporting standard* (the Standard) describes weaknesses in the comprehensiveness of data supplied from jurisdictional tracking systems. Appendix E from the Standard is reproduced below, which shows the extent of coverage that these intra-state tracking systems provide.

Status of waste tracking by jurisdiction tracking system

(blank)	Tracked
(grey)	Not tracked
(hatched)	Not fully tracked

15 code & description		75 code and description (NEPM Schedule A, List 1)		NSW	Qld	SA	Vic	WA
A	Plating and heat treatment	A100	Waste resulting from surface treatment of metals & plastics				Not tracked	
		A110	Waste from heat treatment & tempering operations containing cyanides				Not tracked	
		A130	Cyanides (inorganic)					
B	Acids	B100	Acidic solutions or acids in solid form	Not fully tracked				
C	Alkalis	C100	Basic solutions or bases in solid form					
D	Inorganic chemicals	D100	Metal carbonyls					
		D110	Inorganic fluorine compounds excluding calcium fluoride					
		D120	Mercury; mercury compounds					
		D130	Arsenic; arsenic compounds					
		D140	Chromium compounds (hexavalent & trivalent)					
		D150	Cadmium; cadmium compounds					Not fully tracked
		D160	Beryllium; beryllium compounds					
		D170	Antimony; antimony compounds					
		D180	Thallium; thallium compounds					
		D190	Copper compounds					
		D200	Cobalt compounds		Not tracked			
		D210	Nickel compounds					
		D220	Lead; lead compounds	Not fully tracked				Not fully tracked
		D230	Zinc compounds	Not fully tracked				
		D240	Selenium; selenium compounds					
		D250	Tellurium; tellurium compounds				Not tracked	
		D270	Vanadium compounds				Not tracked	
		D290	Barium compounds (excluding barium sulphate)					
		D300	Non-toxic salts					
		D310	Boron compounds					
		D330	Inorganic sulfides					
		D340	Perchlorates					
		D350	Chlorates					
		D360	Phosphorus compounds excluding mineral phosphates					
E	Reactive chemicals	E100	Waste containing peroxides other than hydrogen peroxide		Not tracked			
F	Paints, resins, inks, organic sludges	F100	Waste from production, formulation & use of inks, dyes, pigments, paints, lacquers & varnish					
		F110	Waste from the production, formulation & use of resins, latex, plasticisers, glues & adhesives					
G	Organic solvents	G100	Ethers					
		G110	Organic solvents excluding halogenated solvents					
		G150	Halogenated organic solvents					
		G160	Waste from the production, formulation & use of organic solvents					
H	Pesticides	H100	Waste from the production, formulation & use of biocides & phytopharmaceuticals					
		H110	Organic phosphorous compounds					
		H170	Waste from manufacture, formulation & use of wood-preserving chemicals					
J	Oils	J100	Waste mineral oils unfit for their original intended use	Not fully tracked				
		J120	Waste oil/water, hydrocarbons/water mixtures or emulsions					
		J160	Waste tarry residues arising from refining, distillation, & any pyrolytic treatment					
K	Putrescible/ organic waste	K100	Animal effluent & residues (abattoir effluent, poultry & fish processing wastes)	Not tracked				
		K110	Grease trap waste	Not tracked				
		K140	Tannery wastes (incl. leather dust, ash, sludges & flours)	Not tracked		Not tracked		
		K190	Wool scouring wastes	Not tracked		Not tracked		
M	Organic chemicals	M100	Waste substances & articles containing or contaminated with polychlorinated biphenyls, polychlor					
		M150	Phenols, phenol compounds including chlorophenols					
		M160	Organo halogen compounds—other than substances referred to in this Table or Table 2					
		M170	Polychlorinated dibenzo-furan (any congener)				Not tracked	
		M180	Polychlorinated dibenzo-p-dioxin (any congener)				Not tracked	
		M210	Cyanides (organic)				Not tracked	
		M220	Isocyanate compounds					
		M230	Triethylamine catalysts for setting foundry sands					
		M250	Surface active agents (surfactants), containing principally organic constituents & which may contai					
		M260	Highly odorous organic chemicals (including mercaptans & acrylates)					
		M270	Per- and poly-fluoroalkyl substances (PFAS) contaminated materials, including waste PFAS- contain					
N	Soil/ sludge	N100	Containers & drums that are contaminated with residues of substances referred to in this list	Not tracked	Not tracked			
		N120	Soils contaminated with a controlled waste	Not tracked	Not tracked			
		N140	Fire debris & fire wash waters					
		N150	Fly ash, excluding fly ash generated from Australian coal fired power stations					
		N160	Encapsulated, chemically-fixed, solidified or polymerised wastes referred to in this list					
		N190	Filter cake contaminated with residues of substances referred to in this list					
		N205	Residues from industrial waste treatment/disposal operations					
		N220	Asbestos					Not tracked
		N230	Ceramic-based fibres with physico-chemical characteristics similar to those of asbestos		Not tracked			
R	Clinical and pharmaceutical	R100	Clinical & related wastes	Not tracked				
		R120	Waste pharmaceuticals, drugs & medicines	Not tracked				
		R140	Waste from the production & preparation of pharmaceutical products					
T	Miscellaneous	T100	Waste chemical substances arising from research & development or teaching activities, including t					
		T120	Waste from the production, formulation & use of photographic chemicals & processing materials					
		T140	Tyres				Not tracked	
		T200	Waste of an explosive nature not subject to other legislation					

Data shortcomings caused by regulatory exemptions in NSW

An issue that is unique to NSW warrants explanation in the context of data quality and completeness: waste tracking exemptions, which are a NSW subset of the tracking status table above. NSW exempts the following waste types and recovery outcomes from tracking:

- waste batteries destined for reuse and spent lead acid battery waste (within D220)
- zinc waste destined for reuse (within D230)
- spent pickle liquor wastes destined for reuse (within B100)
- clinical and other specified wastes (within R)
- non-hazardous hydrocarbon oil waste destined for reuse (within J100).

In addition to these reuse exemptions, K (putrescible) wastes are not required to be tracked in NSW. Adjustment methods applied in national data collations to fill the data gaps these exemptions cause, where alternative data is available. All wastes crossing borders into NSW must be tracked regardless, but those generated from and sent to NSW facilities (in the categories above) are added-in to tracking system numbers to produce a more comprehensive estimate of what is actually received within NSW infrastructure.

Major volumes that go to recycling as a form of management are invisible to the NSW tracking system due to regulatory exemptions and other reasons for not tracking wastes included in the scope of national hazardous waste collations.

Grease trap waste arises at over 100 kt each in Qld and Vic, but without a requirement for tracking it appears as 9 kt in NSW. The Commonwealth Product Stewardship for Oil program data indicates as much as 80 kt of J100 is probably generated beyond that tracked in NSW. Lead is likely to be a very similar story – 14 kt is recorded as generated in NSW but Vic (for example) sends 44 kt to NSW alone. The same under-tracked scenario applies to spent pickle liquor (B100) and zinc waste (D230), which are also both recycled.

Not only does this add up to large volumes of hazardous waste unrecorded (in the NSW tracking system) and potentially unaccounted for in collations like the one for this project, it underplays the significant role that recycling plays in hazardous waste management in NSW.

Although these exemptions are typically for a recovery/recycling management purpose, the reason why such an exemption is applied and how it might better facilitate such recovery (if that is indeed the exemption's purpose) is not clear or publicly accessible.

Interstate transport data

It appears that once a waste shipment leaves the sending jurisdiction, with consignment authorisation in place, the information of its arrival in the receiving jurisdiction is regularly either not forwarded (by the receiving jurisdiction) or not recorded (by the sending jurisdiction). This results in patchwork information that makes identifying cross-border movements and collating national data about them 'hit and miss'.

This could lead to large quantities of exported wastes unaccounted for if a sending jurisdiction's system was relied upon for the data – this is borne out through comparison of certificate records in sender/receiver jurisdictional databases; the latter typically shows much larger volumes.

Paper based certificates

This issue leads to major data quality issues (Section D3) but it is discussed here because it is a systemic limitation rather than a direct quality issue.

Jurisdictions have poor control over data integrity when paper certificates are used instead of electronic certificates. Two issues define this inadequacy:

- the certificate-user is much more likely to make significant data recording errors and leave data gaps, given the lack of controls and restrictions that come with an open access paper form
- paper certificates bring problems with subsequent data entry
  - cost, time-lag, loss of records
  - legibility, resulting in mis-entered information
  - data entry mistakes.

This is the single biggest factor in tracking system data quality. Vic, Qld and WA still rely heavily on paper-based certificates, while the ACT, NT and Tas use only paper-based certificates for interstate movements.

A fully electronic system, or as close as is practical to one, could vastly improve the quality of data within it, as well as provide real-time potential.

Long-term onsite stockpiles and storages are not captured in tracking systems

Some wastes that are significant in hazard are generated in significant quantities, but a high proportion remains in storage onsite, due to unavailability of infrastructure or other reasons. In these cases, limited volumes are captured by tracking systems. Spent potliner waste from the aluminium industry is a rare example where quantities that arise each year are included in the data compiled for this report, via a calculation estimate that is reasonably reliable. However, historical amounts remaining in onsite storages/stockpiles are not reported.

Interjurisdictional data sharing

Information from other jurisdictions' tracking systems, which is not routinely made available to cross-border state and territory government agencies, would enable a clearer picture of the waste management system in any particular jurisdiction, through a clearer understanding of interstate waste movements and comparison with like activities for benchmarking purposes. This lack of data sharing is an unnecessary disconnect for good policy analysis.

Adjusting for multiple counting of wastes generated

The Standard's item 14 describes how to convert waste arisings data to waste generation data. The method attempts to adjust for multiple counts by removing:

1. wastes recorded as going to short-term storage (or, in the absence of data, the average proportion of wastes sent to these management types in jurisdictions where it is recorded) – the idea is that these wastes will be captured when they leave their short-term storage for their final management
2. outputs of treatment – the idea is that these wastes are already counted on their way into the treatment facility.

In practice, this has not worked out well because:

- the accuracy of management reporting in this category is poor – some large quantities of waste are missing from generation data because they are classified as going into short-term storage from which they may never be removed. A review of Qld and NSW data found that of selected wastes going to short-term storage, the proportion coming back out (in a 12-month period) was less than 10% for D120, D300, F100, F110, G110 and N150, and less than 25% for J120 and K110.

- The proportional management of wastes in states lacking the ability to differentiate short-term from long-term storage data (NSW, SA, WA) is not necessarily the same, or even similar, to those states that have this data (Qld and Vic).
- There is user demand for treatment outputs data (waste code N160 *Encapsulated, chemically-fixed, solidified or polymerised wastes*) and surprise that it is eliminated from the data set.
- The difference between the two methods is small. In 2017-18, generation of tracked codes is 1% less than arisings – is this difference worth the additional complexity and potential confusion?

While multiple counting certainly occurs in the hazardous waste management system, there is probably too much uncertainty in the current approach to warrant its continued use. Should it be dropped, arisings and generation would still be distinguished:

- arisings would describe all wastes under movement in the hazardous waste management system that were managed within a particular jurisdiction
- generation would account for wastes generated that were sent interstate for management, by removing them from the receiving jurisdiction's generation numbers and placing them against generation numbers for the jurisdiction they emanated from.

The latter method is currently applied, as a means of eliminating interstate transport double-counts (or non-counts).

D3 The quality of jurisdiction-provided data

Item 25 of the Standard states (with respect to jurisdictional validation of the quality of hazardous waste data it submits to the Australian Government for various reporting purposes) –

> '*Prior to provision to the Australian Government, states and territories should ensure hazardous waste data is validated through data quality checks and cleaning. The checks should consider completeness, accuracy, consistency and reasonableness. In particular, checks should be made to look for:*
> - *unit errors (such as mistaking kilograms for tonnes)*
> - *inconsistent coding of wastes from the same company or of the same type*
> - *major gaps (for example, hazardous wastes that are not included in tracking systems)*
> - *major differences from previous years (e.g. in the quantity of a particular waste type)*
> - *use of historical reporting codes (these should be converted to modern codes).*
>
> *Significant errors should be identified and removed, and significant gaps should be filled to the extent practicable. Suspect data should be identified in the submission.*'

Overall jurisdictional data quality

The reliability of the data presented varies by jurisdiction. An assessment of data quality by jurisdiction, sorted as both strengths and weaknesses in different data categories, is summarised in Table 52.

In the main, 2017-18 data quality was a significant improvement on the 2014-15 dataset used for HWiA 2017. Historical Qld data quality was notably better than in HWiA 2017, because the historical record has now been cleansed of some major errors that were previously present. However, 2017-18 Qld data was largely unusable, not because of errors but incompleteness – departmental resourcing was not sufficient to have all of the data quality assured in time for release, so only a partial dataset was provided. This resulted in the need to use population-based adjustment from past years' data for many wastes which led to difficulty in drawing conclusions.

Table 52 Quality characteristics of jurisdictionally-supplied data

Data type	Strengths	Weaknesses
General	Qld, NSW, Vic, SA and WA have tracking systems which provides exceptionally rich detail of data. Tas, ACT and NT use data from interstate transport certificates, which is quite accurate given the lack of hazardous waste facilities in these jurisdictions. Qld, NSW, Vic, SA: Complete dataset supplied – allows 'full window' for interpretation, finding anomalies. ACT and NT data supplied in full from collated interstate paper tracking dockets. SA 2017-18 data improved significantly from that provided in HWiA 2017, due to the use of their new online tracking system, which is based NSW online waste tracking (OWT) system. Vic 2017-18 data improved dramatically on previous years – not because quality assurance was better but because all previous years' releases have been of a dataset that has been aggregated to exclude source company detail, due to confidentiality concerns. 2017-18 was the first time a full data set was provided. The NSW and SA datasets are well-organised and complete for core data, due to their use of an essentially the same online tracking system (OWT).	Tas, ACT and NT do not have tracking systems, making compilation labour-intensive. WA deny access to key data details. Vic & Qld have poor control of data integrity when paper certificates are used. Qld, NSW, SA do not use pre-set user fields as routinely as it could, which allows for inconsistency and errors.
Waste arisings	Vic provide the most sophisticated data on contaminants by virtue of their system of collecting up to 4 contaminants per certificate, and enforcing that (for contaminated soils at least). NSW data sometimes contains descriptive fields which helps in assessing the waste type, and includes contaminants as a summarised free text field. All 'receiving jurisdictions'' data contains reliable records of wastes imported from other jurisdictions. ACT supplied accurate asbestos data. SA supplied interstate imports into SA for the first time.	All data contains a number of waste coding errors. WA did not supply asbestos data (asbestos is not tracked in WA and landfill data was not supplied due to confidentiality concerns). WA does not supply contaminants data and SA has limited information in the contaminants fields. NSW regulatory exemptions results in under-reporting of D220, J100, B100, D230 and R wastes, and do not track others, such as grease trap and other K wastes.
Source data	SA source data recording was excellent in 2017-18, with 82% of all tonnes recorded against an ANZSIC code.	Vic source data coverage has dropped from 80% to 14% of all tonnes making it unusable. Qld source data coverage in 2017-18 was unusable. NSW source data continues to be unusable (2% of all tonnes). WA source data is absent.

Data type	Strengths	Weaknesses
Management data	Qld and Vic management codes are based on Basel so are more detailed than NSW and WA, allowing clearer identification of management types Reliable and comprehensive SA management data was provided for the first time in 2017-18 data.	NSW, SA and WA management codes are too narrow which leads to confusing allocations and limits the value of the entire national management analysis.
Historical arisings trends		NSW data only goes back 8 years and for contaminated soils, which is typically in the top two largest wastes generated, it only goes back five years.

Reporting of metadata

The purpose of tracking waste movements is mostly about core information: what was it, when did it leave, where was it sent to, how much was there and did it all end up there safely? When it comes to using tracking data for more long-term strategic analysis purposes, some of what might be called metadata (in the core waste tracking sense) becomes very important. Key metadata is source data (the industry that is producing the waste) and chemical contaminants information (what causes the waste to be hazardous). Reporting of these two fields (or in the case of contaminants in the Vic system, four) is typically poor in Australian tracking systems, but need not be. The fields in the waste transport certificate are already there, but no attention is paid by either certificate users or regulators to ensure they are filled out.

This is particularly confounding in the case of contaminants, since laboratory testing of waste for contaminants and subsequent EPA approval of the classification outcome happens as a matter of course, yet this information is not being connected into tracking systems to the extent that it could.

Difficulties identifying PFAS wastes caused by lack of data clarity

Contaminants are also an issue for PFAS, which has made direct identification of PFAS wastes from 2017-18 onwards difficult. Notes in the waste description field in Qld data have helped identify PFAS wastes, although contaminated soils in Qld and NSW are not part of the regular tracking system but provided as a simple annual tonnage figure. NSW's contaminants field (and sometimes other descriptive text fields) have also helped identify PFAS wastes. Vic has an extensive system of contaminants, with pre-set codes applied to 90 different contaminant chemicals. However, PFAS chemicals are not yet included in this list. So even though Vic contaminant information is well populated (at least for contaminated soils), PFAS identification becomes a guessing game between some commonly chosen contaminants, namely:

- Contaminant no. 53: *Hydrocarbons and its oxygen nitrogen or sulfur compounds NOS*
- Contaminant no. 17: *Fluoride compounds NOS* (an incorrect choice).

If a contaminant code was available for PFAS, Vic data would be a rich opportunity to identify PFAS contaminated soils. It is noted that in 2019-20 Vic data supplied, despite the fact that they are recorded, no contaminants data was provided.

Jurisdictional tracking systems have begun to respond to the requirements of the PFAS NEMP (which was published in February 2018), so the PFAS NEMP's mandated new NEPM code M270 *Per- and poly-fluoroalkyl substances (PFAS) contaminated materials*, including waste PFAS-containing products and contaminated containers, has been implemented in tracking data, albeit inconsistently.

M270 is used differently across jurisdictions:

- NSW does not use the M270 code at all, but appears to adopt M160, M250, J120 and N140 for different types of PFAS waste and, while N120 is probably used for PFAS-contaminated soil, this is not clear in data, because contaminated soils are not tracked within the NSW tracking system (which includes contaminant information).
- Qld appeared to report PFAS-contaminated soils under M270 in 2019-20, although in 2017-18 and 2018-19 PFAS soils were reported against M160. Foams and adsorbents appear to be reported under both M160 and M270.
- Vic appears to use M160 (and M270) for non-soil PFAS wastes and N120 for PFAS-contaminated soils. This approach was unhelpful for 2019-20 data, because unlike previous years, all wastes (including contaminated soils) were reported without any contaminant information, which means that PFAS-contaminated and non-PFAS contaminated soils cannot be distinguished.
- SA appears to use M160 (and M270) for non-soil PFAS wastes and N120 for PFAS-contaminated soils, the latter including the potential for separate contaminant recording, but there are limited entries in the contaminants field for 2019-20 soils data.
- WA appears to use the M270 code instead of M160, but PFAS-contaminated soils are not evident in their dataset at all.
- It is not clear what convention of PFAS waste codification is used elsewhere.

This patchwork approach is unacceptable for such a prominent, new and critical waste stream.

Even if the M270 classification code was implemented consistently, on the surface at least, it seems like it would not be very helpful, because it does not distinguish between the different waste matrices that PFAS can contaminate. For example, without further alterations, M270 would appear to lump together AFFF, PFAS soils, PFAS waters, PFAS absorbent media, PFAS end of life products and PFAS-contaminated biosolids. Unless some sub-heading codes are introduced, this looks like a lost opportunity for better understanding PFAS waste volumes.

Appendix E Chemicals of high concern in plastics

Table 53 List of chemical additives to plastics considered in Section 4.4.1

	CAS RN	Inventory Name	Common Name	Abbreviation
1.	117-81-7	1,2-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	Diethylhexyl phthalate	DEHP
2.	84-74-2	1,2-Benzenedicarboxylic acid, dibutyl ester	Dibutyl phthalate	DBP
3.	128-37-0	Phenol, 2,6-bis(1,1-dimethylethyl)-4-methyl-	Butylated hydroxytoluene	BHT
4.	80-05-7	Phenol, 4,4'-(1-methylethylidene)bis-	Bisphenol A	BPA
5.	84852-15-3	Phenol, 4-nonyl-, branched	Nonylphenol	4NP
6.	25154-52-3	Phenol, nonyl-	Nonylphenol	NP
7.	58-36-6	10H-Phenoxarsine, 10,10'-oxybis-	10,10 oxybisphenoxarsine	OBPA
8.	3194-55-6	Cyclododecane, 1,2,5,6,9,10-hexabromo-	Hexabromocyclododecane	HBCD
9.	1163-19-5	Benzene, 1,1'-oxybis[2,3,4,5,6-pentabromo-	Decabromodiphenyl ether	decaBDE
10.	13674-84-5	2-Propanol, 1-chloro-, 2,2',2''-phosphate	Tris(1-chloro-2-propyl) phosphate	TCPP
11.	115-96-8	Ethanol, 2-chloro-, phosphate (3:1)	Tris(2-chloroethyl) phosphate	TCEP
12.	13674-87-8	2-Propanol, 1,3-dichloro-, phosphate (3:1)	Tri(1,3-dichloro-2-propyl) phosphate	TDCPP
13.	115-86-6	Phosphoric acid, triphenyl ester	Triphenyl phosphate	TPP
14.	13560-89-9	1,4:7,10-Dimethanodibenzo[a,e]cyclooctene, 1,2,3,4,7,8,9,10,13,13,14,14-dodecachloro-1,4,4a,5,6,6a,7,10,10a,11,12,12a-dodecahydro-	Dechlorane Plus	-
15.	85535-85-9	Alkanes, C14-17, chloro-	Medium-chain chlorinated paraffins	MCCPs
16.	25973-55-1	Phenol, 2-(2H-benzotriazol-2-yl)-4,6-bis(1,1-dimethylpropyl)-		UV 328
17.	77-58-7	Stannane, dibutylbis[(1-oxododecyl)oxy]-	Dibutyltin dilaurate	DBTDL
18.	12202-17-4	Lead oxide sulfate (Pb4O3(SO4))	Tetralead trioxide sulphate	TTS
19.	1072-35-1	Octadecanoic acid, lead(2+) salt	Lead distearate	PbDS

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