National Environmental Science Program

Sustainable Communities and Waste Hub Research Plan 2023 – Attachment B project plans - IP3

Project IP3.02 – Management of hazardous waste, substances and pollutants

Project type: Hub research project	
Project status: Existing proposal seeking amendment to scope and budget	
Cross-cutting initiative:	No
Project start date: 1 April 2023	**Project end date**: 31 March 2025
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Project description

Project summary

Chemicals in our waste streams pose undefined risks, which inhibit our ability to safely move towards achieving National and State policy action targets to divert materials from landfill and accelerate reuse. The presence of chemicals of potential concern (CoPC) can impact recyclability of waste and the safe reuse of materials in the economy, and the establishment of robust circular economies. Through the generation of high-quality data related to the mass and potential availability of chemicals in our waste streams, this project will assist safe recovery and reuse of resources obtained from wastes and enable national resource recovery targets.

Project description

The overall aim of Impact Priority 3 (IP3) is to assist safe recovery and reuse of resources obtained from wastes, and to bridge the gaps in knowledge that allow adequate risk characterisation. In RP2023, we expand on the IP3 multi-year research that commenced in RP2022 to:

- progress waste sampling, characterisation, reporting and risk assessment;
- address challenges around analytical data gaps and quality;
- validate sampling approaches for complex waste materials; and
- enable the pragmatic regulatory control of potentially hazardous recovered resources as we increase their reuse in our economy.

IP3.02.01 Quantifying mass and potential release of chemicals of potential concern in our wastes and recovered resources

The problem

End of Life (EOL) tyres and e-wastes can contain chemicals of concern (e.g., heavy metals like lead, cadmium and mercury, bisphenol A (BPA), per- and poly-fluoroalkyl substances (PFAS), *N*-(1,3-dimethylbutyl)-*N'*-phenyl-p-phenylenediamine (6PPD; which can form a quinone (6PPD-quinone) toxic to some fish species), polybrominated diphenyl ethers (PBDE), and other fire retardants), shown to impact human and ecosystem health. Some of these chemicals are also of international concern. Australia is required to manage and account for these chemicals in accordance with our international obligations outlined under the Basal, Stockholm and Minamata Conventions.

The findings of the IP3 RP2021 co-design process were detailed in a summary report presented to the SCaW Hub in early 2022 [1]. Key issues for focussing investigations on e-waste and EOL tyres included:

1) A lack of quantitative data on their composition and potential hazard as wastes or on reuse;
2) Significant arisings of both e-waste and EOL tyres in urban, remote and regional settings [2, 3, 4] with the bulk of these wastes ending up in landfill or exported from Australia; and,
3) Local waste export bans, alongside import bans by some of Australia's key waste management partners (e.g., China and the National Sword Policy banning the importation of recyclable materials).

These issues have resulted in significant and compounding environmental, economic and policy drivers to ensure that we manage, recycle and reuse wastes domestically [5, 6].

Our response

Through the co-design process during RP2021 and RP2022, with the Department of Climate Change, Energy, the Environment and Water (the Department), regulatory agencies, industries, and other partners, IP3 developed a research agenda focused on electronic waste (e-waste) and EOL tyres. EOL tyres and e-waste were chosen as priority exemplars of waste streams where addressing knowledge gaps was urgent. The outcomes and methodologies adopted and developed for investigation of these specific waste streams were considered transferrable to other waste types, such as those that will result from our transition to renewable energy (photovoltaic cells, batteries) and other complex waste streams such as textiles and organics (e.g., biosolids and food and organic wastes).

In seeking to advance the required science, IP3 has also sought to develop national capability to address such hazardous waste challenges, and to transfer knowledge of value and use to regulatory and other stakeholder groups. The time horizon foreseen to address hazardous waste challenges related to IP3 is shown in Figure 1.

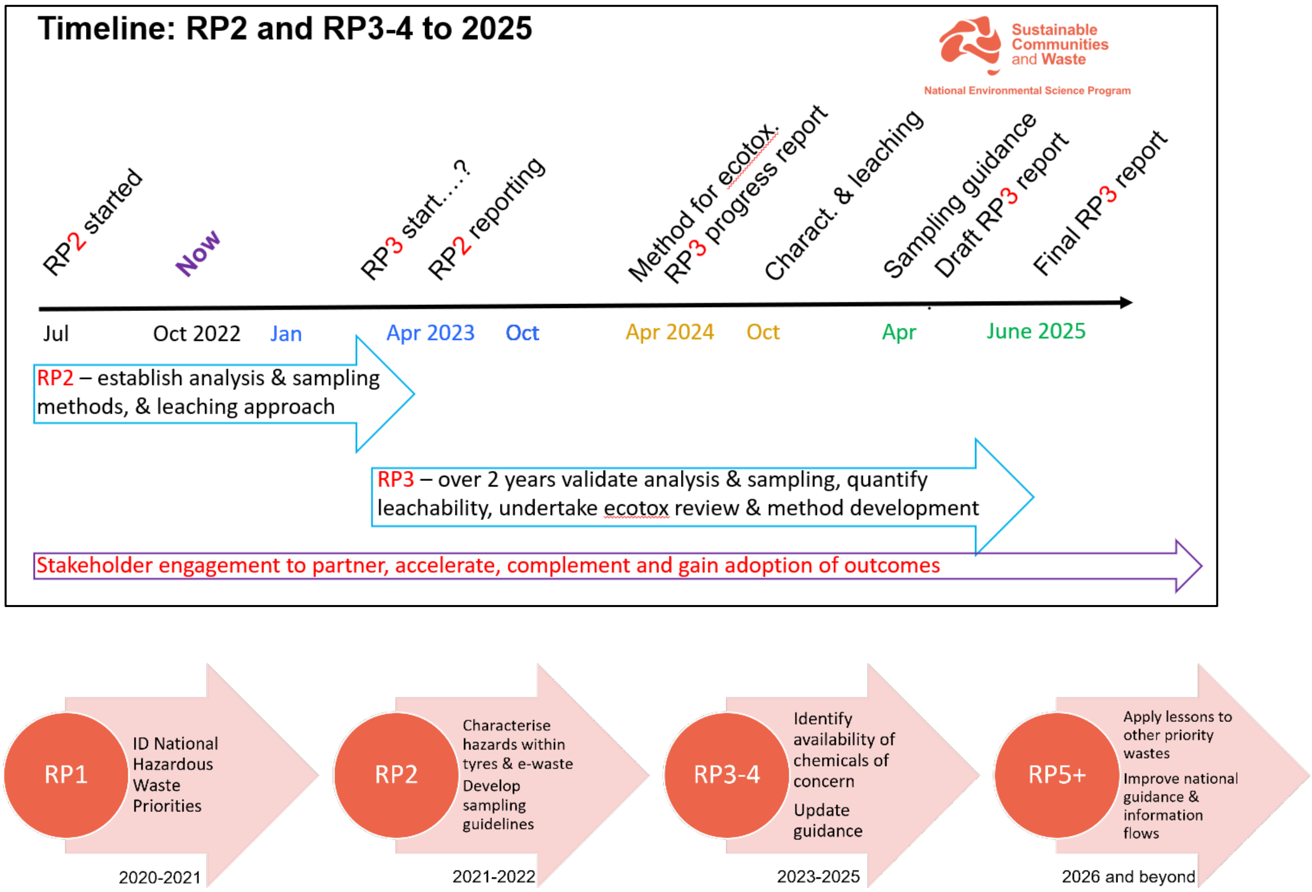

Figure 1 Time horizon for Impact Priority 3 (Hazardous Waste, Substances and Pollutants). The Top image shows the linkage between RP2 and RP3-4 (current proposal scope). The Bottom image puts RP3-4 in context with the earlier codesign stage of RP1 and intentions for RP5 and beyond.

This project (IP3.02.01) extends a further 2 years and builds on work undertaken under RP2021 and RP2022.

In RP2021, through partner, stakeholder and Department engagement, we co-designed three key questions/themes for prioritisation of research for IP3:

1) What's in our waste? - understanding the chemicals in current and emerging wastes;

2) What's the risk profile of our wastes? - de-risking the future through safe waste reuse and resource recovery; and
3) How do we better inform stakeholders? - enhancing information flows and assessment for improved outcomes and governance for hazardous wastes.

During RP2022 currently underway, IP3.02.01 will identify compounds and concentrations to frame efforts to quantify availability and risk associated with identified CoPC in EOL tyres and e-waste to be undertaken in RP2023 and RP2024 (early 2023 to 2025). RP2022 was framed to address Question 1 – to establish sampling strategies for priority waste elements of electronic waste (e-waste) and EOL tyres, to undertake method development and representative chemical analysis to screen waste stream hazards, and to establish a methodology for determining the potential for CoPC to be released from e-waste and EOL tyres to start to address Question 2. RP2022 also builds national capability and ensures knowledge outcomes can generate methods and guidance more broadly applicable for sampling and analysis of complex waste streams, enabling evidence-based risk management of CoPC identified in our wastes and in repurposed materials (i.e., to begin addressing Question 3). The concluding steps within RP2022 overlap in time with, and feed directly into the proposed RP2023 and 2024 activities, which concurrently build the knowledge base required to address all research themes for IP3.

The RP2023 and RP2024 activities for IP3.02.01 aim to consolidate and build on the research undertaken in RP2021 and RP2022 to develop robust and representative sampling and reporting methods, waste characterisation, and environmental and ecotoxicological risk definition for CoPC identified in EOL tyres and e-waste. We will generate data that are discoverable, accessible, and reusable, can easily be integrated and interpreted for other applications, and used to inform risk-based decisions regarding the management, treatment, and safe reuse of these wastes.

Methodology

IP3.02.01 seeks to provide the underpinning data and methodologies to define total and actual risk associated with identified CoPC in EOL tyres and e-waste. To do this, IP3.02.01 has three focus areas:

1) To validate sampling and analytical strategies by intensifying analysis of targeted e-waste and EOL tyre components focused on quantification of CoPC concentrations and mass in such waste components.
2) To establish the leachable (and/or releasable) CoPC fractions from the waste streams and/or repurposed materials to inform risk assessments and handling.
3) To establish methodologies for ecotoxicological studies that may be warranted based on leachable CoPC from e-waste and EOL tyre components.

1. Quantify concentrations and mass of chemicals in waste components

Under RP2023 and RP2024, IP3.02.01 will further validate the sampling strategy and quantify leachable fractions from the waste streams and build hazard assessments for identified CoPC from EOL tyres and e-wastes. Once priority CoPC have been identified (through RP2022), a more rigorous and targeted sampling campaign is planned in RP2023 and RP2024 to focus on specific points along the e-waste and tyres waste-handling flow paths that represent the greatest total risk or priority for waste handlers, regulators or other identified research-users. Here, the targeted characterisation of specific CoPC from EOL tyres and e-waste will occur with higher sample numbers but targeting fewer analytes so sampling programs can be statistically validated and confidence in the data can be assured. CoPC for targeted characterisation in waste streams will be determined based on results generated by bulk characterisation studies in RP2022, and in consultation with research-users and stakeholders.

End-of-life tyres

EOL tyres are a problematic waste stream in Australia and represented the third largest hazardous waste category by weight (6%) in 2017-18 [3]. Significant arisings occur in urban, remote and regional settings, linked to heavy industry and transport. Historically, EOL tyres have been stockpiled, sometimes posing a fire threat, or have been exported as a waste management solution.

EOL tyres are increasingly being recycled and reused in new materials. The Circular Economy Roadmap produced by CSIRO [9] indicated that the major reuse markets for EOL tyres in Australia for the next 2 years were crumb rubber in spray seals (20 kilotonnes/year, kt/y) and crumb and shreds incorporated into binders, adhesives and glues (18 kt/y), and in soft-fall, playground, turf and asphalt applications. The use of shredded and crumbed rubber as tyre derived fuel and as lightweight aggregate for use as fill was also predicated to increase in the next 10 years. There is an increasing concern arising that the behaviour and risk of contaminants within these reprocessed materials is not fully understood. The US EPA, for example, have invested in the characterisation of tyre crumb rubber, specifically as it is used in synthetic field turf to address potential exposure to CoPCs present in these materials [10]

For EOL tyres (Figure 2), crumbed (<1 mm) and shredded (50-150 mm) tyre material will be assessed for target analytes and leachability of identified CoPC (Figure 2). This will also inform ecotoxicological work on the potential environmental and human health impact of these materials. The selected materials span tyre size reduction ranges and data will enable consideration of crumb/shred tyre variability and heterogeneity when subsampled and analysed appropriately. In addition, these size fractions have known reuse pathways in Australia, and provide an opportunity to understand risks associated with current reuse pathways of secondary materials generated from tyres.

As aforenoted, analytes will be determined based on screening outcomes of RP2022, but a broader suite of analytes may also be explored should additional CoPC be detected. Table 1 lists some of the CoPCs that could be analysed for EOL tyres.

In future, we also expect to consider how the CoPCs identified in EOL tyre fractions might relate to stockpiles, which could trigger further risk assessment of the storage and reuse of whole tyres in civil engineering or silage applications.

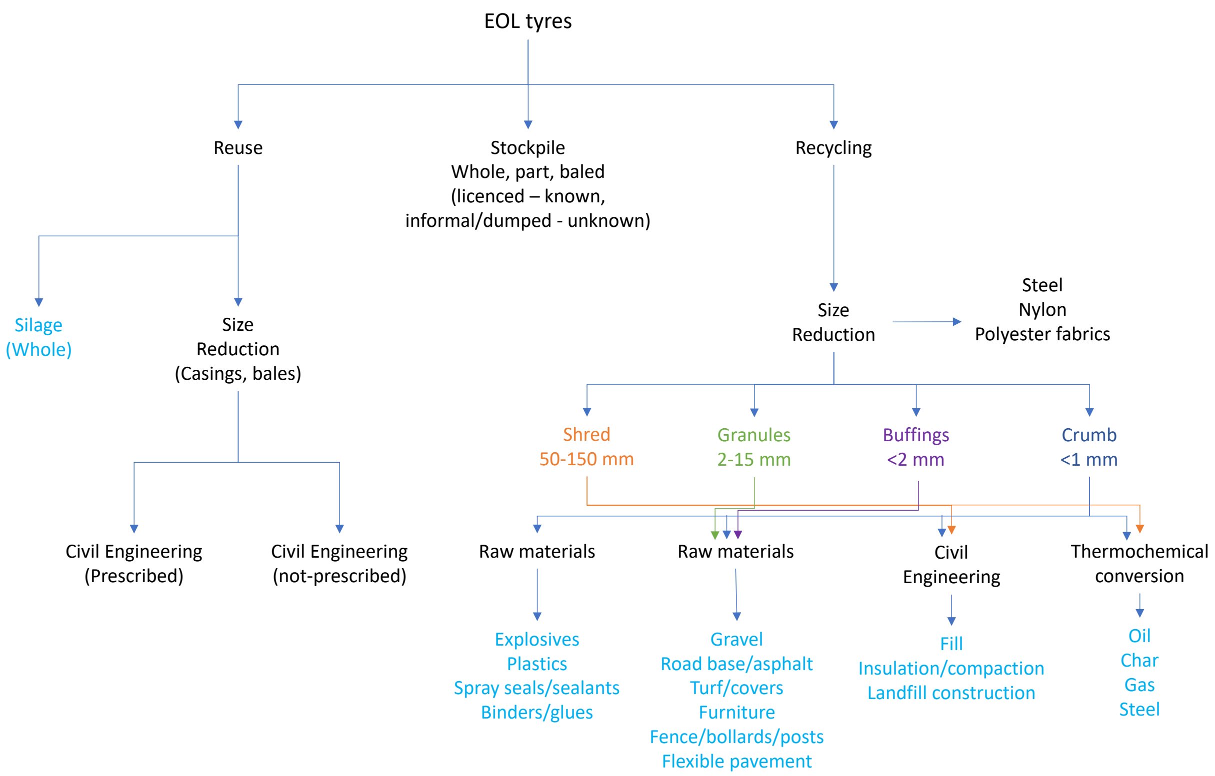

Figure 2 Indicative material handling flow sheet for end-of-life (EOL) tyres

<u>Electronic waste</u>

The Australian Bureau of Statistics Waste Account approximates 466 kt of e-waste was generated in Australia in 2016-17 [4]. Improper handling and disposal of these wastes can cause pollution and risk to human and environmental health, and the loss of critical resources from the economy.

For e-waste, the indicative waste management flow sheet is complex (Figure 3), a direct consequence of the wide range of products consumed and disposed of, and the complex design of these products.

E-waste often consists of multiple individual components that contain problematic chemicals that are included because of a functional requirement, such as insulating plastics in cables and flame-retardant plastic housing. The large number of e-product types, their components, product and component volumes in waste streams, and any identified pathways for reuse, will dictate sampling and analytical regimes in RP2022, RP2023 and RP2024. However, e-waste plastics (also known as black plastics) and multi-component e-products with metallic and non-metallic fractions such as cables and wires, batteries or printed circuit boards could be some of the first targets for e-waste characterisation.

E-waste plastics are used to mitigate the risk of fire in all e-products and assessing the risk associated with the presence of chemicals, including brominated flame retardants, would help to address management of these persistent organic pollutants as part of Australia's international obligations [11]. There are also new risks identified related to the occurrence of synthetic antioxidants used in e-products to prevent the oxidative degradation of these products over time [12]. Additionally, understanding the availability of identified chemicals associated with multi-component e-wastes such as cables and wires, printed circuit boards, could be transferred to the characterisation of other multi-component e-waste streams including batteries or photovoltaic cells, which are of growing concern related to the waste liabilities of the renewable energy transition in Australia [13].

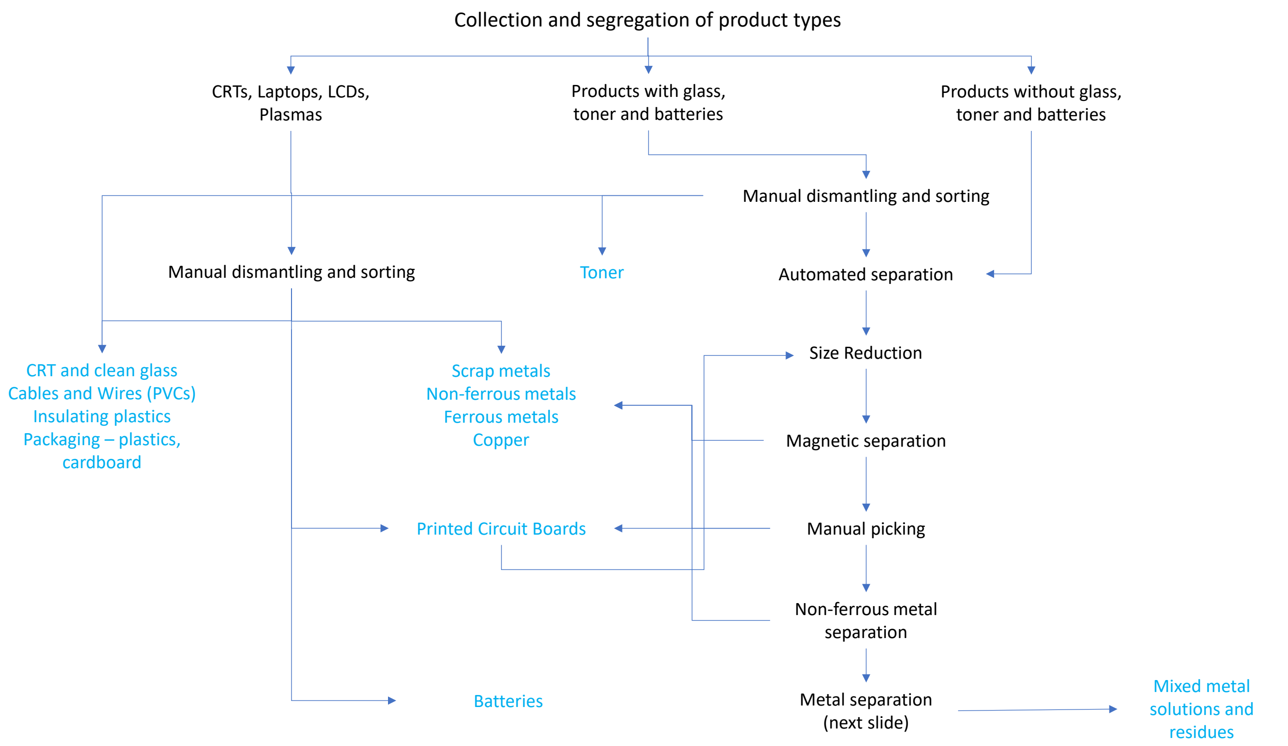

Figure 3 Indicative material handling flow sheet for e-waste (consumer products)

The data generated throughout RP2022 and RP2023 and RP2024 will sharpen the focus for characterisation and availability studies related to complex e-waste streams. The methodology will be developed through co-design with the Department and other stakeholders (including inter- and intra-Hub efforts) and will drive R&D directions and efforts in relation to this complex waste stream. Table 1 lists some of the CoPCs that will be analysed in RP2022 and used to build availability assessments through leaching and ecotoxicology studies in RP2023 and RP2024.

Table 1 Examples of CoPC reported for tyres and e-waste.

Tyres*	E-waste
PAHs [14]	2,4,6-tribromophenol and chlorophenol and dichlorophenol [17]
Phthalates [15]	Flame retardants [17]
Benzotriazoles and benzothiazoles [14]	PFAS [18]
Bisphenol A/S/F [15]	Phthalates [18]
6PPD (6PPD-quinone) [16] N,N'-Diphenylguanidine (DPG) [14] Hexamethoxymethyl-melamine [19]	Inorganics (e.g. Pb, Zn, Cr, Cd, Co) [18]
Inorganics (e.g., Pb, Zn, Cr, Cd, Co) [15]	Synthetic antioxidants [12]
Microplastics14	

*Includes CoPCs covered in the US EPA & CDC/ATSDR 2019 report [10]

<u>Consolidation and capability development for waste stream characterisation</u>

In RP2023 and RP2024, we will consolidate the data and analytical methods developed in RP2022 to best determine the chemical composition and availability of CoPC in EOL tyre and e-wastes. This will be supported by the knowledge base related to the management and analysis of waste and other materials held by the Department. Data generated across RP2022, RP2023 and RP2024, will be used to frame further characterisation of CoPC as required. This will include contextual metadata for recovered samples (e.g., sources of wastes, typical volumes recycled, holding and handling conditions, environmental parameters).

Characterisation of EOL tyres and e-wastes will be undertaken targeting a broad range of analytes and quantified as a screen across the range of compounds (identified in RP2022) that may be hazardous and leachable (Figure 4). Methods for extraction (i.e., solvent-based extraction) and preconcentration of the organic contaminants followed by Liquid Chromatography-Mass Spectrometry (LC-MS) or Gas Chromatography-Mass Spectrometry (GC-MS) analysis will be undertaken. Inorganic contaminants will be quantified following sample digestion, and Inductively Coupled Plasma Optical Emission Spectroscopy/Mass Spectrometry (ICP-OES/MS) analysis. Solution pH, electrical conductivity (EC), particle size and plastic/polymer type will also be measured/determined. Considering the range of possible analytes, strategies for prioritisation and screening will be undertaken to maximize project resources.

Methods for priority analytes will be optimised at CSIRO and/or Curtin University for both waste types, guided by protocols that have been previously reported for the selected organic contaminants in solution. For EOL tyres, the research protocols published by the USEPA on tyre crumb characterisation (as used in synthetic turf field recycled tyre crumb rubber) will be used as a point of reference [20]. Where appropriate, students will also be engaged to facilitate development of methods for CoPCs that are not covered in Table 1 and Figure 4, but are considered important from the literature (e.g., amines and ureas, reported by Muller et al. [16]) and following advice from the Department and other research partners and stakeholders.

Collectively, CSIRO and Curtin University have analytical methodologies for a range of organic chemicals (e.g., PFAS, plasticisers, PAHs, benzothiazoles, 6PPD-quinone) in aqueous and solid samples, which are relevant CoPC reported for these wastes, as well as the ability to modify, develop and validate other methods as appropriate. Analysis for most of these compounds are also available in commercial laboratories (e.g., NMI, Eurofins). To ensure reliability of results, interlaboratory comparison will be conducted on a limited set of samples as part of quality assurance/quality control. All samples will be appropriately stored/preserved to enable future analysis (e.g., HRMS). A Bayesian decision framework will be implemented for the sampling design, to determine the number of samples to be analysed, the endpoint of broad-based analyses and the selection of analytes for targeted analyses. Orthodox and Bayesian statistical methods will also be used to test hypotheses and assess the uncertainty of the targeted analyses [21].

Outcomes from this work include a comprehensive assessment of the availability of identified CoPC in EOL tyres and e-waste when exposed to relevant conditions associated with reuse pathways. The data generated will begin to build the evidence base to support decision making processes related to safe waste reuse to support and encourage establishment of circular economies. In addition, methodology to assess and measure the ecological risk for identified CoPC will be developed. As the science matures, outcomes will feed development of national capability on analytical and methodological approaches for commercial laboratories and others and enable unifying guidance on waste characterisation for future industry and regulatory consideration.

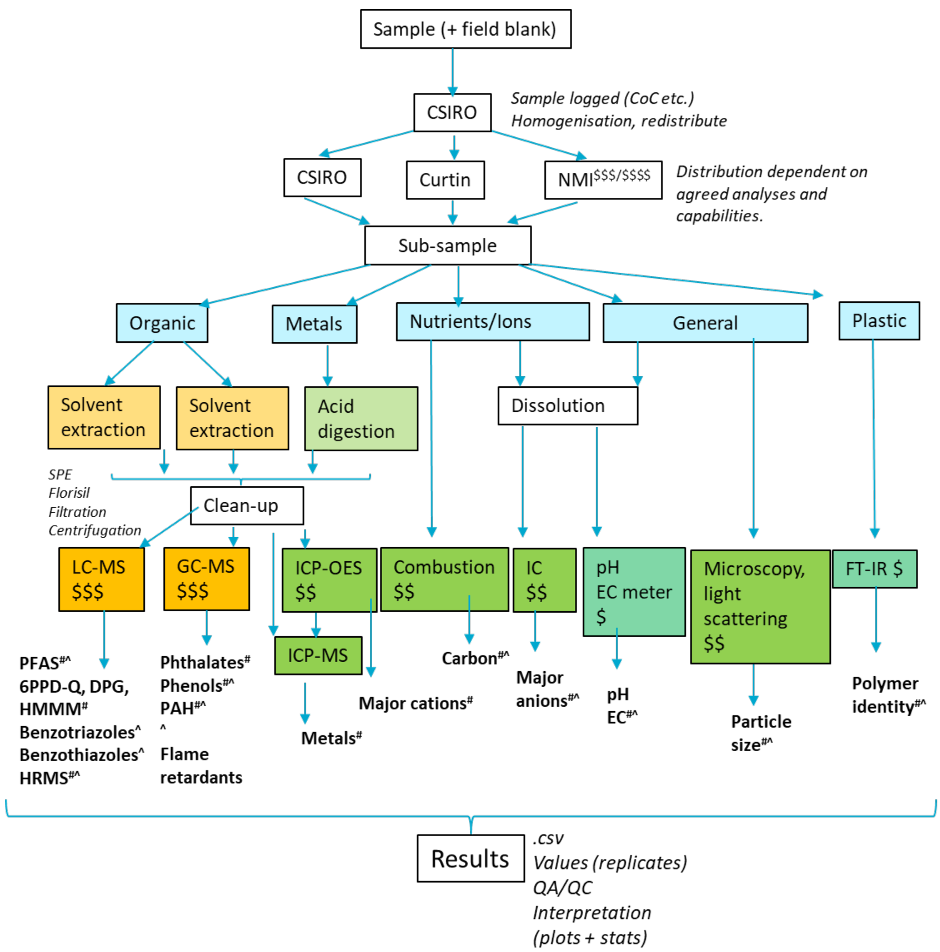

Figure 4 Workflow for analysis/characterisation of EOL tyres and e-waste. Analytical capability is shared between CSIRO (#), and Curtin University (^) to ensure that a greater suite of relevant analysis can be undertaken. Approximate costs per sample are provided to assist in budget prioritisation: $ ~ $10s/sample; $$ ≤$100; $$$ ~ $100s; $$$$ ~$1000s

2. Determine leachable (and/or releasable) chemical fractions from the waste streams and/or repurposed materials

The concentration of a chemical or its mass within a waste stream defines whether it is a CoPC, but it does not define its potential for release from the waste matrix into the environment. Understanding this is critical to defining the waste-chemicals risk profile and any threat they may pose to human and environmental health.

We can measure the likely chemical exposure related to the release of a CoPC from the waste matrix that may occur when waste is resident in the environment or as stockpiles, or when in contact with water. Contact with water is a potential exposure pathway for release of chemicals associated with secondary materials, including soft fall play surfaces and asphalt that incorporate recycled rubber.

For soils and other materials there are national and international standards and guidance such as the Australian Standard Leaching Procedure (ASLP,[22]) and the US EPA Leaching Environmental Assessment Framework (LEAF) method (LEAF, [23, 24, 25]). Similar batch leaching methods using aqueous solutions have been applied for crumbed tyre rubber [26, 27], and e-waste [28, 29]. Note that ASLP/LEAF standard methods are not specifically designed for EOL tyres or e-waste, and mostly have been applied to leachable fractions from contaminated soils and solid waste disposed to landfill. Even for soils, these 'standards' are being re-evaluated and challenged as to their applicability where soil is *in situ* or reused [30, 31].

We note too that volatilisation or vapour release to air of CoPC from waste might also occur during treatment or reuse such as during waste to energy or thermal treatment. Though we are not directly assessing the risk associated with air emissions associated with reprocessing of wastes in the proposed work for RP2023 and RP2024, we will link with IP4 to consider priorities across this aspect of hazardous waste processing. The data generated in RP2022, RP2023 and RP2024 and engagement with IP4 will help to identify potential points of uncontrolled release of CoPC that could inform future research in this space.

In assessing the leachability of identified CoPC from the EOL tyre and e-waste components, representative subsamples will be obtained, and physically and chemically characterised. The samples will be evaluated along with duplicate, triplicate, and appropriate blank tests for leachability. The leaching methods below are proposed based on the different leaching scenarios EOL tyres and e-waste may encounter during their reuse or recycling.

To determine leaching of CoPCs, the following methods (1 and 2) could be applied:

1) ASLP to identify/characterise the CoPC that may be readily released from the waste/repurposed materials This standard test is designed for waste disposal, typically simulated leaching conditions (i.e., pH) associated with landfills. In this study, the exact pH condition to be used will be guided by what is relevant for reuse/recycling of a particular waste.

2) LEAF 1313 to assess leaching at a lower liquid/solid (L/S) ratio than ASLP, a longer agitation/tumbling time and variable pH (typically 5 pH values covering 2-12). The LEAF methods have been designed to consider key environmental conditions and waste properties on leaching. The exact pH condition used will be guided by what is relevant for reuse/recycling of a particular waste. For example, pH is a key parameter dictating behaviour of metals. Furthermore, extreme pH can promote dissolution of e-waste components and affect the integrity/stability of EOL tyres, which can lead to release of CoPC.

To determine leaching under ambient conditions that could potentially simulate leaching of CoPC in reuse scenarios such as surfaces and asphalt, the following methods (3 and 4) will be considered:

3) LEAF 1315 to assess leaching from larger volumetric/mass components of the EOL tyres and e-waste.

4) A static batch test under minimal liquid/soil ratio (non-standard) to assess leaching from materials with smaller particle sizes.

The leaching assessment will follow a staged approach. Stage 1 will focus on conducting standard leaching conditions, followed by Stage 2 which will focus on non-standard leaching conditions that may reflect more relevant conditions associated with waste disposal, reprocessing and reuse. Stage 1 leaching will inform Stage 2 with respect to key CoPC that should be analysed. To enable comparison of results, for example, ASLP and Method 4 will be undertaken on replicate samples. Workflow for the Stage 1 leaching is shown in Figure 5. A summary of the leaching conditions is provided in Table 2.

Other conditions that may be relevant to reuse/recycling of a particular waste, following discussion with the Department and other partners, will be considered as the project progresses. For example, the effect of particle size, temperature and salinity on leaching of CoPC could also be investigated by modifying ASLP. Size and temperature could be important for EOL tyres which would be crumbed or granulated and may experience extreme temperature conditions (e.g., tropical vs temperate; summer vs winter; ambient reuse scenarios vs high temperature processing). Temperature changes could also facilitate weathering and affect the integrity/stability of EOL tyres which can lead to release of CoPC. Salinity changes would potentially identify availability of chemicals under saline or seawater conditions that may be relevant for some reuse pathways.

Where practical and agreed between researchers and research users, assessment of availability of CoPC from reformed materials incorporating recycled rubber crumb or shred, or e-waste plastics will also be assessed.

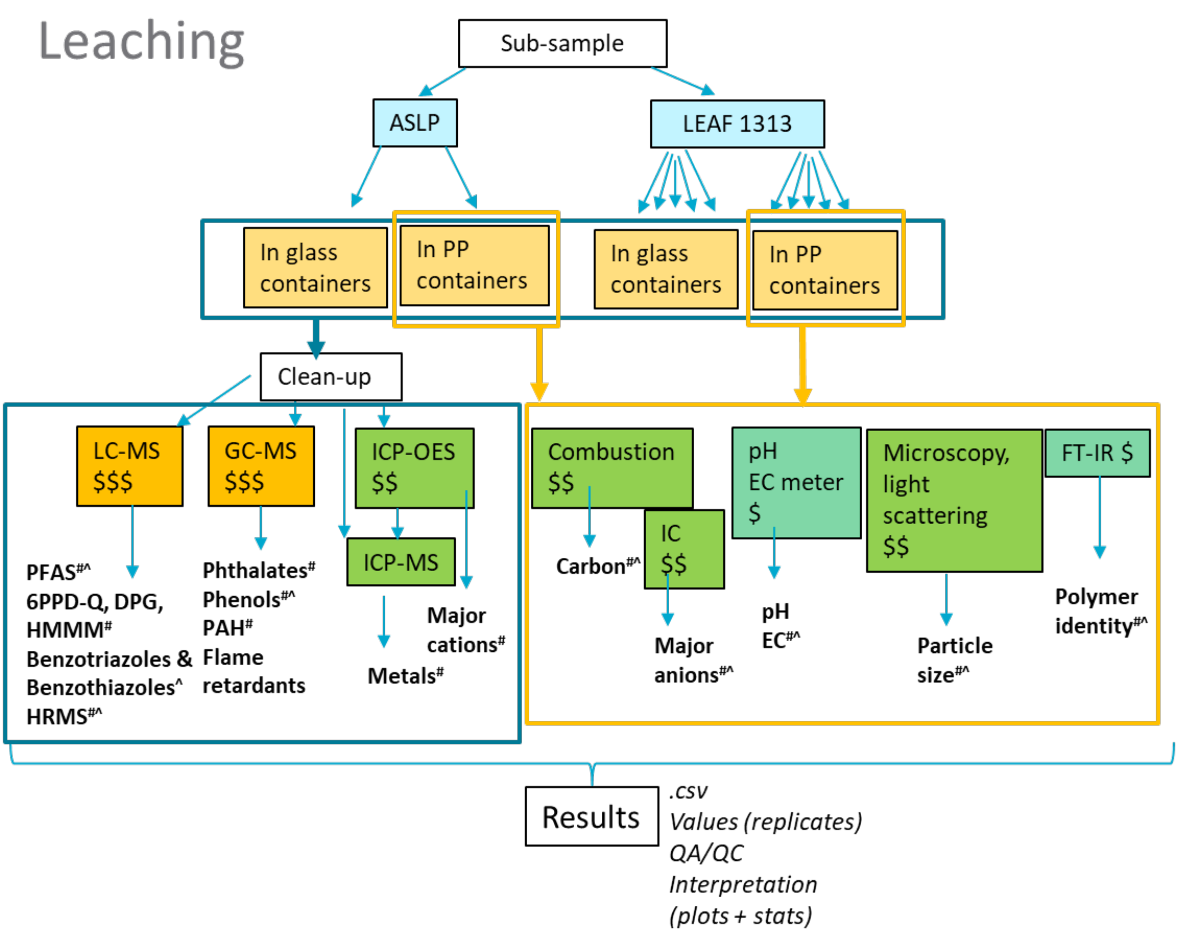

Figure 5 Workflow for Stage 1 leaching assessment of EOL tyres and e-waste focussing on aggressive leaching conditions. Leaching investigations will be undertaken at CSIRO, with analytical capability shared by CSIRO (#), and Curtin University (^). Approximate costs per sample are provided to assist in budget prioritisation: $ ~ $10s/sample; $$ ≤$100; $$$ ~ $100s; $$$$ ~$1000s.

The leaching assessments will be conducted at CSIRO and/or Curtin University. Some assessments could be conducted via a commercial laboratory (e.g., ALS, ChemCentre and Eurofins offer ASLP as fee-for-service); however, commercial laboratories are unlikely to have extensive experience with leaching waste samples. The analysis of CoPC in the leachates will focus on priority chemicals identified in RP2022, RP 2023 and RP2024, with other analyses undertaken based on an iterative review of data and co-design with research partners in consideration with available literature. To address potential chemical compatibility issues (e.g., potential sorption of CoPC to laboratory materials), leaching may need to be performed in both glass and plastic (e.g., polypropylene (PP) and high-density polyethylene (HDPE), for PFAS) containers. To ensure reliability of results, interlaboratory comparison will be conducted on a limited set of samples as part of quality assurance/quality control. All samples will be appropriately stored/preserved to enable future analysis (e.g., HRMS).

Table 2 Summary of leaching conditions proposed

Method Number	Method Name	Liquid: Solid ratio	Tumbling time (hrs)	Equilibration time (hrs)	pH initial solution	Comment
1	ASLP - Saturate, tumble and spin [22]	20:1	18	18	3, 5, 7 or 9	Standard; no pre-titrations involved; typically assessed at 1 pH condition
2	LEAF 1313 - Saturate, tumble and spin [23]	10:1	24	24, 48 or 72h depending on max particle size	2 to 12	Standard; pH of the material is adjusted using pre-titration data; typically assessed at 5 pH conditions
3	LEAF 1315 – monolith [24]	Liquid-to-surface area ratio (L/A) of 9 mL/cm^2.	0	Sequential Intervals of 2, 23 h, 5, 7, 14, 14, 7 and 14 d	7	Undertake if seeking to scale up towards whole tyres
4	Saturate and spin [31]	3:1	0	4, 8, 24	7	Non-standard, a static batch test under minimal liquid/soil ratio (non-standard) to assess leaching from materials with smaller particle sizes

3. Review and establish methodologies for ecotoxicological studies

To enable accurate assessment of the environmental risks for chemicals contained in EOL tyres and e-waste, ecotoxicological data are needed, to augment the leachability and exposure parameters that have been determined or are available. For example, there are a few already identified chemicals for which ecotoxicology and ecological response data are available and factored into regulatory criteria and guidelines [32]. However, data are lacking for local species and ecosystems, and critical or yet-to-be identified CoPC from wastes, including those that may leach within a complex mixture of compounds – such as a range of organic compounds that might leach from crumbed tyres. As a result, there is an urgent need to assess and mitigate risks to human health and the environment from these chemicals as more waste-derived materials are recovered and reused.

In parallel with the analytical and leachability studies outlined above for EOL tyres and e-waste, we will aim to deliver a comprehensive review of available ecotoxicological data and methodologies related to identified CoPC in EOL tyres and e-wastes. These findings will be used to design targeted studies (some to be undertaken within RP2023 and RP2024, but others proposed for RP2025) for relevant Australian aquatic and terrestrial receptors and chemicals for which data gaps exist.

Ecotoxicology investigations are expected to broadly follow OECD guidelines for testing chemicals [33, 34, 35, 36], and will also make best use of behavioural ecotoxicology endpoints that can serve as more sensitive and ecologically relevant bio-indicators of exposure and sublethal environmental impacts [37, 38, 39]. Suitable plant and/or invertebrate (i.e., earthworm, water flea) or possibly fish bioavailability and behavioural ecotoxicology studies may be proposed, and initial experiments are planned as part of RP3-4. The focus will depend on the likely contact and exposure scenarios that best represent environmental conditions and segments (e.g., terrestrial vs aquatic) where the waste or repurposed wastes are found (whether by design or by poor waste management practices).

The data, knowledge base and associated methodology generated in the proposed ecotoxicology of CoPC in EOL tyres and e-wastes in RP2023 and RP2024 and into RP2025 will be reviewed and distilled via co-design and interaction with the Department and other stakeholders (including the

Victoria Environmental Protection Authority and Department of Water, Environment, Land and Planning, Victoria) to ensure priorities to enable regulatory decisions are aligned with research efforts.

Outputs and Outcomes

Information sharing and development of waste guidelines

Information flows are critical in the current dynamic waste and contaminant context in Australia. There is a need to rapidly access the latest nationally and internationally relevant information on waste stream types, chemicals, and technologies to assess current and emerging issues related to waste management, treatment, and safe waste reuse in Australia. Reuse of materials in Australia relies on enhanced networks for information sharing between and across research, jurisdictional and industry boundaries. Information flows and distillation of sourced information for use needs greater automation and activation.

In RP2021 and RP2022, it was recognised that a long-term ambition of IP3 should be to establish a national set of principles, approaches, methods, and techniques for reference and use by jurisdictions and industry to assess Australia's ever-expanding waste stream and material types for their chemical content, hazardous nature, and their potential for safe reuse. Methods developed as part of RP2023 and RP2024 will create a basis for such an ambition. This can then be updated from time to time in keeping with knowledge advances, akin to the National Environment Protection Measure (NEPM) reviews/updates. Currently discussions are being had with state environmental regulators and the National Waste Working Group to assess a relevant vehicle to undertake such a role. The eventual development of a nationally acceptable and consistent set of guiding principles related to the characterisation, categorisation and safe reuse of waste is likely to be an important step to further enable resource recovery and reuse of materials in Australia.

The data, outcomes and outputs, including a draft set of waste sampling and characterisation guidelines, generated in this project will provide the basis for initiation of a transferrable framework for characterisation of other emerging wastes and reuse applications, and this will continue in development through the life of the Hub.

Further to the creation of nationally consistent guidance on sampling and analytical methodologies, RP2023 and RP2024 will also look to further explore the creation of automated living reviews. These will aim to provide government and private-sector decision-makers alike with a readily viewable and accessible account of relevant research activity and publications delineated by waste and contaminant type. This will also help to identify where there are true research gaps and, alternatively, where improved communication of findings is required.

Outcomes of this work will be shared as appropriate through stakeholder and research partner workshops throughout the life of RP2023-2024 and beyond, and this will ensure that networks are formed for multi-way conversations and co-design of future research plans.

Linkages

The data, outcomes and outputs generated in this project will be assessed in the context of projects in IP5, related to impacts of hazardous waste on remote and regional communities; for IP2, related to the characterisation and reuse of problematic plastics (e.g., e-waste plastics, and ecotoxicology of microplastics from EOL tyres); inform IP4, concerning possible air emissions from reprocessing of wastes; and IP5 projects related to exploring opportunities for value recovery from used tyres and conveyor belts, and the management of wastes (including e-wastes) in remote and regional communities.

Is this a cross-hub project? No.

Does this project contribute to a cross-cutting initiative?

No, apart from ongoing discussions and providing underpinning data for the Waste Initiative.

Also, the CoPC being investigated here are likely to have relevance to discussions underway with the NESP Marine and Coastal Hub on assessment and monitoring of nutrients, chemicals, antimicrobials and microplastics in the marine environment, and these linkages will be further explored, with the guidance of the Knowledge Broker and Initiative Leads from both Hubs. Aspects of the work would be relevant to the cross-Hub Swan River Basin riparian zone initiative.

Pathway to impact

Outcomes
The expected outcomes and value from IP3.02.01 include: **Informing policy and frameworks:** • Input to waste sampling, characterisation, and risk assessment methodologies to frame waste management policies around products and articles in Australia. **Community benefits:** • Reducing community exposure to hazardous chemicals from waste stockpiles and potentially unsafe management practices. **Economic Benefits:** • Providing industry and non-government stakeholders confidence and evidence to make decisions regarding business and investment for treatment, resource recovery and product development from hazardous wastes. **Environmental Benefits:** • Accelerating the diversion of hazardous waste from the environment and ensuring safe reuse of waste in new products in ecological settings. **Partnerships & Collaboration:** • Expanded and connected national network of key groups to create greater momentum in addressing state and federal hazardous waste diversion (from landfill) and resource recovery targets. Specific short-term outcomes include: • Datasets of the composition and availability of chemicals in certain e-wastes and EOL passenger vehicle tyres; • Identification of high priority CoPC from the total composition and leaching activities; • Quantitative extraction and analytical method descriptions for waste-CoPC combinations; • Critical review of existing ecotoxicological studies related to identified CoPCs; • Method/s to assess the ecotoxicological impacts from CoPCs identified in e-wastes and EOL tyres; • Input to a framework for waste sampling, characterisation and risk assessment that is sought to be transferrable to other emerging wastes and re-purposed materials in the future; • Input into guidance for information sharing for waste management outcomes; and • Facilitation of strategic management and reuse of wastes and their hazardous components, leading to economic environmental and social benefit, which is a long-term outcome we expect of the Hub.

Research-user	Engagement and communication	Impact on management action	Outputs
DCCEEW (Chemicals Management Branch, Environmental	Key DCCEEW personnel linked regularly via IP3 and Project lead.	Outcomes will be used to assist regulator/s identify and frame waste management policies around products, articles,	Final report identifying mass, concentration and availability of chemicals associated with e-waste and EOL tyres, and

Research-user	Engagement and communication	Impact on management action	Outputs
Protection Division; Sarah Stone Glen Walker) (Waste Policy and Planning Branch, Jason Dunn, Amanda Watson, Rebecca Drown, Lara Martin) (Waste Action and Modernisation Branch, Rob Quinn, Elaina Lobendahn)	Input across Government priorities and initiatives. Engaged in the development and design of the assessment program of activities and outputs. Research plan and recommendations will be communicated to DCCEEW regularly as required. IP3 plans to work with DCCEEW and other state jurisdictions to release appropriate non-technical summaries of outcomes that are factual and do not cause undue apprehension. Premature and ill-crafted release of chemical hazard information may generate undue angst, and not allow coordination of messaging across all jurisdictions.	and e-waste and EOL tyres in Australia.	preliminary assessment of ecotoxicology investigations. Co-designed sampling and analytical methodologies for waste characterisation. Categorisation of data in line with Environmental Information Standards. Guidance for information sharing.
Waste managers and partners. (Industry and non-industry) Examples: Mining companies Oil and gas industry Tellus Holdings Department of Defence Veolia	Via the Hub Steering Committee and otherwise we will establish links across regulators, industry, researchers, and community. Will work to establish common methodologies for assessing proposed risk values related to management, disposal, and safe reuse of resources from e-wastes and waste tyres, and how guidelines could be transferred to other priority wastes. The network will assist with co-design and help to guide the project and provide feedback through the co-design process in relation to the stakeholder engagement, identified research priorities and key outcomes of RP2023 and RP 2024. Via workshops partners and research-users will be engaged to develop and co-design project and outputs. Findings and outputs to be communicated to project contributors via project workshops, informal communication, and presentations.	Will assist industry and non-government stakeholders to make decisions regarding business and investment for treatment and resource recovery from hazardous wastes. Will identify new market pathways and quantify risks to existing market pathways for priority hazardous wastes in Australia. Will create symbiosis between industry stakeholders across material and resources supply chains, jurisdictions, researchers, and departments.	Final report identifying mass, concentration and availability of chemicals associated with e-waste and EOL tyres, and preliminary assessment of ecotoxicology investigations. Co-designed sampling and analytical methodologies for waste characterisation.
National, State, Regional and	Will continually engage project reference group of	Research outcomes will be used to assist	Final report outlining:

Research-user	Engagement and communication	Impact on management action	Outputs
Local Government All state and territory EPAs and/or Depts of Environment. Sustainability Victoria WA Waste Authority Department of Defence Department of Biodiversity, Conservation and Attractions	representative stakeholders to guide the project, who will provide feedback through the co-design process in relation to the stakeholder engagement, identified research priorities and key outcomes of RP2023 and RP 2024. Partners and research-users will be engaged to develop and co-design project and outputs. Findings and outputs to be communicated to project contributors via project workshops, informal communication, and presentations.	regulator/s identify and frame waste management policies around identified key hazardous waste priorities across Australia.	Data related to the mass, concentration and availability of CoPC from EOL tyres and e-wastes; Preliminary assessment of ecotoxicology assessments; Input to transferrable guidelines for sampling, characterisation, and reporting regarding waste management and safe waste reuse; and, Recommended assessments from data gaps existing for identified CoPC; and Methodology for determining total leachable components, leachable components under reuse scenarios and ecotoxicological assessment.
Indigenous communities	Research needs will be identified through engagement with appropriate Indigenous research-users identified through RP2023 and RP2024, in accordance with the Indigenous Partnerships Strategy of the Hub. Representation will be linked via the Hub Indigenous Facilitator, and via appropriate advisory panels. Exploration of involvement of Indigenous Knowledge and/or researchers	Research findings will identify key waste priorities impacting Indigenous communities in Australia, including the identification of harm caused to regional communities by poor hazardous waste management practices.	A final report identifying transferrable guidelines for sampling, impact of CoPCs in EOL tyres and e-waste management and safe waste reuse, with reference to the impacts on Indigenous communities, harm caused by hazardous waste management practices. Identification of Indigenous research-users, research priorities and pathways for Indigenous engagement.
NESP SCaW Hub	Engaged in the development and design of project and outputs. Findings and outputs to be communicated to project contributors via project workshops, informal communication, and presentations. Cross-hub communications to inform IP1, IP2 and IP5 as appropriate. Engagement with the knowledge broker will be ongoing to crystalise announcables and appropriate products from the work	Research results will be used by the SCaW Hub and IP3 to identify short-, medium- and long-term R&D effort in relation to e-waste, tyre wastes and other priority wastes. Inform the development of strategy for the Hazardous Wastes, Substances and Pollutants Impact Priority Area.	Final report outlining: Data related to the mass, concentration and availability of CoPC from EOL tyres and e-wastes; Preliminary assessment of ecotoxicology assessments; Input to transferrable guidelines for sampling, characterisation, and reporting regarding waste management and safe waste reuse; and, Recommended assessments from data gaps existing for identified CoPC; and

Research-user	Engagement and communication	Impact on management action	Outputs
			Methodology for determining total leachable components, leachable components under reuse scenarios and ecotoxicological assessment.

Additional outputs

List project-generated outputs that aren't specific to an identified research-user.

- Development and iterative review of nationally consistent guidance on how to characterise waste streams to minimise environmental and human health risks and ensure safe reuse of potentially hazardous materials. Will develop presentation and educational materials as the project progresses.
- When paired with RP2022 outcomes, we will begin to build risk profiles of the waste tyres and e-waste, based on its leachability and potential ecological impacts.
- Expanded national network of key groups to create greater momentum in addressing state and federal waste diversion (from landfill) and resource recovery targets.
- Findable, accessible, interoperable, and reusable data that can be shared between stakeholders related to waste management outcomes.

Indigenous consultation and engagement

The effect of hazardous wastes on the health, cultural, social, and economic well-being of Indigenous communities needs to be quantified and offers a significant research opportunity. The research undertaken in IP3 has an emphasis on characterising the human and environmental risks of wastes that may be in and near to remote and regional communities, including Indigenous communities. Tyres and e-wastes can be particularly difficult waste streams to manage in remote and regional communities and the impacts associated with improper handling and disposal can impact land, water, and communities.

Using the high-quality waste characterisation data that will be generated, including the concentration of CoPCs contained in waste streams, availability under disposal and reuse conditions and preliminary ecological risk assessments related to identified CoPCs, IP3 will seek to link with other Hub projects related to material flow, disposal pathways and waste management to build a better understanding about how these identified CoPCs may impact (positively and negatively) remote and regional communities. We also recognise the potential to link with the IP5 project related to the management of wastes in remote and regional communities (including e-wastes; IP5.02.04), and the development of market pathways for reuse of tyres in remote and regional Western Australia (IP5.02.02).

Given the laboratory-based nature, early status and regulatory drive of the work proposed, during RP2023 and RP2024, IP3.02.01 would still be considered a Category 3 Project under the NESP2 SCaW Hub Indigenous Partnerships Strategy, where data and outcomes generated will be communicated and shared to relevant Indigenous organisations. As information sharing is critical to ensuring accessibility of research findings and data, it is likely this component of work will consider how to best link in with identified Indigenous associations to communicate findings, further identify Indigenous waste research priorities and enable co-design of future work to address these priorities.

Our current research team have completed the training related to Indigenous Cultural and Intellectual Property. All engagement, regardless of the content or intent, will be guided through the SCaW Hub Senior Indigenous Facilitator, and any traditional knowledge and intellectual property will be managed in accordance with the Indigenous Partnerships Strategy and Data Management Strategy.

We have also indicated interest to participate in an Indigenous researcher/student Expression of Interest program with the Senior Indigenous Facilitator. The program is still being developed but hope this allows us to include Indigenous peoples more directly in our laboratory-based research, which we believe is a significant opportunity to provide training and capability development to Indigenous researchers.

Which Three-category approach the project meets	**Co-design** ☒	**Collaborate** ☐	**Communicate** ☐

Project milestones

Milestones	Due date	Responsible person
Milestone 1 – Anticipated signing of contract.	30 April 2023	UNSW
Milestone 2 – Scope refined for IP3.02.02 for RP2023 and RP2024.	30 April 2023	Leaders of analytical chemistry and leaching projects with Boxall and IP co-leads
Milestone 3 – Methodology framework for analytical and leaching tests.	30 June 2023	Divina Navarro, Mike Williams, Cynthia Joll, Anna Heitz
Milestone 4– Scope review for IP3.02.01 for RP2024	30 June 2023	Naomi Boxall, Mitzi Bolton, project team and research users
Milestone 5 – Progress update for characterisation and leaching work.	31 October 2023	Divina Navarro, Mike Williams, Cynthia Joll, Anna Heitz
Milestone 6 – Progress report for IP3.02.01 for RP2023	30 April 2024	Naomi Boxall, Mitzi Bolton, project team
Milestone 7 - Critical review of ecotoxicology methodologies for CoPCs.	30 April 2024	Bob Wong, Robert Niven with input from the project team
Milestone 8 - Methodology framework for preliminary ecotoxicology assessments.	30 April 2024	Bob Wong, Robert Niven with input from the project team
Milestone 9 – Draft priorities for next research plan (RP2025)	30 June 2024	Project team
Milestone 10 – Preliminary data for ecotoxicology assessments.	28 February 2025	Bob Wong, Robert Niven, Divina Navarro
Milestone 11 – Updated sampling guidance for waste	30 April 2025	Robert Niven, Naomi Boxall, Mitzi Bolton and project team
Milestone 12 – Draft IP3.02.01 report	30 April 2025	Project team
Milestone 13 – Final IP3.02.01 report	30 June 2025	Naomi Boxall, Greg Davis, Mitzi Bolton and project team

Data and information management

Data and knowledge products from this project will be made publicly available in a findable, accessible, interoperable, and reusable (FAIR) manner through the Hub website and in accordance with the Hub Data Management Strategy, with the guidance of the Data Wrangler. Through the engagement with the Hub Data Wrangler, and the Department (primary research-user), we will identify means of categorising and managing data that is consistent with the government's *National Principles for Environmental Information*, and translatable to relevant outputs that align with the Hub's Data Management Strategy. We will engage early regarding data management to ensure consistent and quality data is captured, delivered, and curated.

Information from private sources and partners may need to be held in confidence if negotiations and the importance of the data/information warrant it. Regardless, it will be managed ethically and respecting obligations to NESP and to stakeholders.

Project output	Data management and accessibility
Report	Will be made publicly available on the Hub website. Will be derived from scientific and other publicly available information. Information from private sources and partners will be managed ethically in accordance with the Hub Data Management Strategy, with guidance from the Hub Data Wrangler.
Data	Where appropriate, data generated will be FAIR (discoverable, accessible, and re-useable) to enable integration and interpretation of data gathered from different sources, and the rapid incorporation into many applications, products and decision making. Where valued, publication of data will be in open source, re-usable electronic formats, in a manner that is consistent with the government's *National Principles for Environmental Information*. Information and data from private sources and partners may need to be held in confidence if negotiations and the importance of the data/information warrant it. This data will be managed ethically, and respecting obligations to NESP and to stakeholders.
Co-designed transferrable guidelines for waste sampling, characterisation, and reporting	Will be made publicly available on the Hub website. Will be derived from scientific and other publicly available information.

Location of research

Research will be undertaken by researchers located in Western Australia, Victoria, South Australia, and Australian Capital Territory.

The proposed project is a national scale project, and as such the project will have scaled benefits. It is also envisioned that the outcomes of this project could be used as a baseline for the development of a new set of national methodologies and reporting tools for hazardous wastes.

The co-design process will largely take place on-line across Australia with various stakeholders and aims to include research-users across urban and regional Australia, other states and territories of Australia and a range of government and industry agencies, and communities.

The table below describes the scale at which the project will be working, and the location/s where most of the project research will be conducted.

At which spatial scale is the project working	**National** ☒	**Regional** ☐	**Local** ☐
Location(s) – gazetted region /place name	**Perth, Melbourne, Adelaide, Canberra**		
Aboriginal or Torres Strait Islander nation or traditional place name(s)	**Whadjuk, Kulin, Kaurna, Ngunnawal**		

Project keywords

Hazardous waste, chemicals of concern, tyre waste, e-waste, characterisation.

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