Polystyrene Pollution in the Yarra River

Deep Dive

2022

CLEANWATER GROUP

YARRA RIVERKEEPER

VICTORIA State Government Australia

Environment, Land, Water and Planning

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Disclosure Statement

Cleanwater Group (CWG) acknowledges that some of the recommendations made herein (particularly regarding the protection of stormwater infrastructure in hotspot areas) could be construed as in the interest of the company, as CWG provides such services and stands to gain financially if an employment opportunity should arise. In light of this, all possible efforts have been made to ensure impartiality in all recommendations and discussions provided. Cleanwater Group does not promote their business practices in this document, nor one technology or supplier over another. The advice they put forward in this document is therefore meant to be taken as general in nature. It is also acknowledged that the company will only participate in any possible future action that may be taken in this space if the process of involvement is deemed to be fair, unbiased and based on merit.

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The Yarra Riverkeeper Association

The Yarra Riverkeeper Association (YRKA) is the credible and authoritative voice for the Yarra, Melbourne's own beautiful, resilient, iconic river. The Association is an independent community of citizen advocates that works solely in the interest of the river with the advocacy strategy built around the motto: 'Our Yarra, healthy, protected and loved'. The Yarra Riverkeeper team monitor the river by boat and on foot, by bike and by canoe. That enables the Association to build a detailed understanding of the complex interactions of the ecology of river and its role in the City of Melbourne. This understanding is shared with the community through the Association's educational programs, website, and social media. YRKA's aims are to protect the Yarra from mouth to source, to revitalise the river and to foster love for the river by current and future generations.

The Cleanwater Group

The Cleanwater Group is a profit-for-purpose business with a mission to reduce the amount of plastic and other pollutants entering our ocean. We do this by focusing on prevention, data collection, source reduction, and community engagement. Our vision is a world where plastic is valued so much so that it no longer pollutes the environment.

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Executive Summary

Polystyrene is pervasive in the Yarra River. Since 2018, expanded polystyrene (EPS) has consistently been found to be the highest littered macroplastic found. Being both a light and brittle material, means that the ecological impacts of polystyrene, which can unfold gradually over time, can be widespread and devastating for the river and Port Phillip Bay.

This report presents the findings of a study to quantify the relative contribution of potential sources of polystyrene pollution. It estimates the amount of polystyrene pieces caught by the bandalong litter traps every year, and identifies solutions that can be implemented to prevent polystyrene from entering the Yarra River. Data was gathered over the period from December 2020 to October 23, 2021. Both desktop research, a feasibility study and field observations were conducted.

The project confirmed the conclusions of the previous report, finding construction sites contributed the highest amount of EPS pollution (an average of 43L per month, each month over the 6 cycles), followed by retail (31L), then markets / produce (26L), manufacturers (13.8) and lastly, recyclers (8L).

A deep dive into construction sites found that of the 80 sites inspected, polystyrene pollution was widespread, with 71% of sites inspected having some form of pollution.

Of those, 98% were confirmed to have polystyrene pollution either on site, just outside the site, on the nature strip, or in a drain within a few houses of the site.

On the river, the five audit cycles of the Yarra River's 16 bandalong litter traps estimate that more than 92 million pieces of EPS are caught by the traps every year. When added to the Clean bay Blueprints estimation of EPS escaping into the Port Phillip Bay, it is estimated that more than 382 million pieces enter the Yarra River every year. This figure is an underestimate due to limitations with sorting the litter trap samples and the amount of EPS sitting in reedbeds which are unreachable and unquantifiable.

Analysis of the data suggested the effects of COVID-19 restrictions likely created a downward trend in pollution from the source sites investigation and the bandalong trap audits. This suggests the closure of construction sites and businesses reduced litter at the source and in the river.

Finally, a study was conducted into the feasibility of tracing EPS pollution back to the source. RMIT confirmed that this study is possible with further funding.

Immediate attention must be taken on handling and containment practices of EPS as pollution is constant and continuous, rather than a once-off occurrence across all industries that manufacture, transport, distribute and handle polystyrene.

Increased monitoring and control measures implemented by the EPS industry needs to be met with improved legislation and stronger enforcement from both local and state governments to stop the flow of this material into our waterways.

Recommendations

INDUSTRY

- Phase out unnecessary packaging and rethink Packaging design
- Eps industry associations To include eps pollution material online
- Expand and improve the polystyrene collection and recycling network
- Monitor and strengthen Current containment for eps waffle pod and cladding, & Enforce compliance
- Take immediate action to ensure whitegoods stores docks prevent EPS escaping their sites and entering stormwater drains.
- Support the development of an EPS circular economy market
- Lead product stewardship and create drop off point programs
- Expand the use of environmentally-friendly alternatives

GOVERNMENT

- Review current legislation and revise where needed
- Strengthen current control measures for waffle pod/ cladding pollution
- Increase the 'State of Knowledge' amongst EPS handlers.
  - Industry guidance
  - Add EPS handling guidance to General Environmental Duty
- Support the expansion of environmentally-friendly alternatives

EDUCATION

- Develop educational material and programs for major source industries
- Expand the use of environmentally-friendly alternatives
- Improve consumer education
- Train retail staff on EPS pollution and good practice waste management

1 Introduction

The Yarra River traverses an enormous range of habitats from pristine forested catchments to a range of agricultural lands and dense urban areas. The Yarra flows 242 kilometres from headwaters to sea – from its source on the flanks of Mt Baw Baw in the Yarra Ranges National Park, north-east of Melbourne, through the Yarra Valley and greater Melbourne into Port Phillip Bay at Newport.

Where the Yarra meets Port Phillip Bay

More than one-third of Victoria's population lives in the Yarra catchment, which spans about 4000 square kilometres and includes 50 rivers and creeks (Melbourne Water Corporation, 2018).

The Yarra River corridor is 22% urbanised, 21% natural vegetation and 57% agricultural (Melbourne Water Corporation, 2018). Historically, the Yarra River was treated as a large, open dumping site, transporting human detritus out of sight and out of mind. In 2018, the State of the Yarra and its Parklands investigation reported 18 of the 25 environmental health indicators were 'poor'. Only 1 of the overall 36 indicators scored in the 'good' category, which was the indicator for "post settlement colonial heritage" (Victoria, 2018). The three main issues facing the Yarra today are overdevelopment, invasive species and habitat loss, as well as poor water quality. Water quality has been adversely affected by litter, pollution incidents, sewerage, stormwater quality, and climate change.

The Yarra River discharges into the northern most section of Port Phillip Bay, Hobsons Bay. Port Phillip Bay is the largest marine embayment in Victoria, with an area of approximately 1,930 square kilometres, a coastline of 333 kilometres and a catchment area close to 10,000 square kilometres. Melbourne, with a population in 2018 of 4.9 million people, surrounds much of the Bay. The Yarra River provides most of the freshwater inflow into the Bay and is the largest litter contributor.

Litter in the Yarra River

Waterways such as rivers act as a major transport pathway for all sizes and types of litter. High plastic litter loads in rivers, including both macro and microplastics, are due to high levels of mismanaged plastic waste arising from population-rich river catchments. The State of the Bays 2016 report highlighted the impact of waterway litter on Port Phillip Bay beaches, including the potential for litter to cause injury, high toxicity in biota and even death. The State of the Yarra 2019 report further identifies litter as a key threat to our waterways and highlights an increasing trend in litter volumes along the river corridor.

Through YRKA's Litter and Flows and the Yarra River Blitz projects, it was identified that polystyrene, especially expanded polystyrene (EPS), is the most prevalent and pervasive macro litter item in the Yarra River.

Since April 2018 and following 7 Blitz events approximately 38,000 kg of polystyrene contaminated soil and general waste have been removed from the Yarra's riverbanks and reedbeds. Microplastic trawl sample analyses also indicated at the time, that over 828 million litter items flow into Port Phillip Bay annually from the Yarra's surface waters, and over 612 million (74%) of these are microplastics, including polystyrene fragments (Charko et al, 2018).

This project (Phase 2) aimed to track down key sources of polystyrene pollution and identify potential solutions to contain this material at the source. This report has been prepared in order to present the results of this study and provide recommendations on source reduction actions that can be implemented to prevent polystyrene from entering our iconic waterways and Port Phillip Bay.

Expanded Polystyrene in Australia

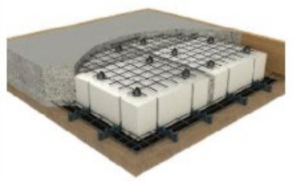
EPS, derived from the addition polymerization of phenyl ethane (styrene monomer), is produced in white beads consisting of a number of closed cells, solidly supported and heat-sealed tangentially to each other, which contain still air occluded inside (Tsivintzelis et al., 2007). PS foam is produced by treating crystalline PS with a blowing agent, typically a hydrocarbon or carbon dioxide, to produce a cellular structure in the material, which reduces the brittleness, making it an excellent cushioning and insulating material. Its use in food and electronics packaging, airplane and automotive parts, and sporting equipment (among other applications), has increased in the last few years due to its advantages of being lightweight, easy to form, acoustic and thermally insulating, inexpensive to produce, cushioning, dimensionally stable, and heat and moisture resistant (Castro et al. 2017).

In Australia, the expandable polystyrene manufacturing industry produces and markets long life-cycle products, such as geoblocks, cornices, insulation systems for construction, and refrigerators, as well as short life-cycle products, such as multipurpose boxes and packaging systems for the transport of fragile goods and foods, to name a few. According to Expanded Polystyrene Australia (EPSA), the national industry body for all manufacturers and distributors of EPS products across Australia, an estimated 71,000 tonnes of EPS is consumed annually, growing at a rate of 5% per annum. This consists of:

- 47,000 tonnes, which is domestically manufactured from imported resins. Of this, 70% is used in the built environment, in long-term use such as waffle pods used in housing construction and engineering/ manufacturing components (Metropolitan Waste and Resource Recovery Group, MWRRG, 2018). Approximately 30% of this is used for packaging, typically single-use or short-term packaging that can be recycled after use. Of the 30%, approximately half is exported as fresh food packaging;

- 24,000 tonnes imported as packaging with products;

- 3,000 tonnes, which is the estimated amount of EPS reprocessed and used locally.



Example of EPS waffle pod used in the construction of a concrete slab (WPMA, 2017)

It is also estimated that the total amount of EPS used in packaging is 44,000 tonnes, distributed into the following applications (Australian Packaging Covenant Organisation, APCO, 2018):

20,000 tonnes for electrical and electronic products;

24,000 tonnes for other packaging,

Of the EPS that is being used in construction (which constitutes 70% of all EPS used in Australia), it is estimated that more than 90% is consumed as waffle pods, with the remainder going into composite structure insulated wall panels and other building products (One Planet Consulting, 2018; Expanded Polystyrene Australia, EPSA, 2019a). Waffle pods are used in the construction of concrete slabs for both residential homes and commercial industrial buildings (Waffle Pod Manufacturers of Australia, WPMA, 2017).

They are made from EPS, and act as void formers for concrete slabs. They are known to reduce construction costs, provide insulation, reduce soil disturbance and improve the time-efficiency of building sites (WPMA, 2017). "Waffle pods are EPS blocks incorporated into building foundation slabs to significantly reduce the amount of concrete (along with other benefits) required (One Planet Consulting, 2018:8)."

In practice, waffle pods are laid out according to the site's foundation plan and are evenly placed in a grid-like pattern using spacers between each pod (EPSA, 2014c). Each pod is around 1.09m wide by 1.09m long, with thicknesses ranging from 150mm, 225mm, 300mm, and 375mm depending on the site specifications (EPSA, 2014c). Reinforcing mesh is then placed on top of the pods, prior to concrete being poured on top of and between the pods to complete the foundation (EPSA, 2014c). It is common practice to over-order waffle pod material in order to ensure that there is enough on hand during construction. In addition, there are also off-cuts generated on site during the installation process (One Planet Consulting, 2018).

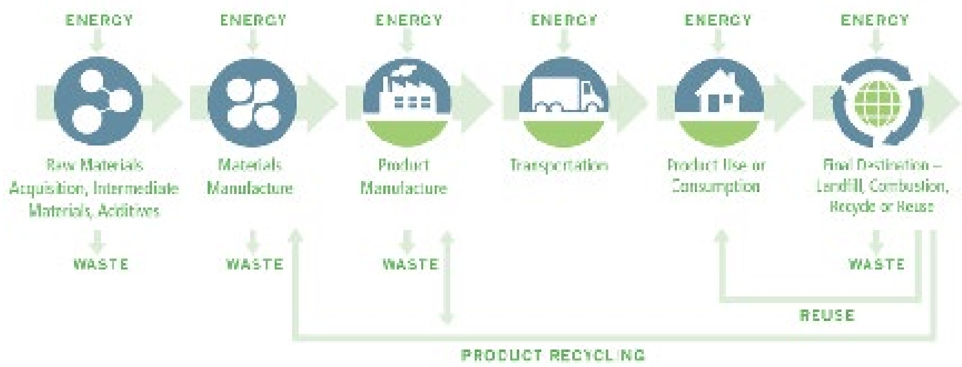
EPS Recycling

While EPS is reported to be 100% recyclable (EPSA, 2014b), it is estimated that "almost all EPS in Australia currently goes in general waste to landfill (One Planet Consulting, 2018:15)." This is largely due to polystyrene being excluded as an acceptable form of recyclable material in residential kerbside collections, as well as the lack of a consistent EPS recycling collection and drop off services for most users apart from isolated cases run by bulk-goods retailers (e.g. Harvey Norman and the Good Guys) or local councils.

In terms of EPS recycling, there are different figures reported for the amount of polystyrene recycled in Australia. EPSA (2014b) reports that during the 2018/19 period, over 5,800 tonnes of EPS was recycled, which is in line with One Planet Consulting (2018)'s reported recycling rate of 12.1% for EPS across all applications over the 2015-2016 period. More recently, however, according to the 2017-18 Australian Plastics Recycling Survey commissioned by the Australian Government Department of Environment and Energy, New South Wales Environment Protection Authority, and others, the national recycling rate for expanded polystyrene is now lower, at 7.6% with the major end-market use being for waffle pods (Envisage Works, 2019). In terms of EPS packaging, according to a 2018 EPSA study, the national recycling rate is relatively low with approximately 3,000 tonnes of EPS recycled locally and 6,000 tonnes exported for recycling (EPSA, 2018). This forecasts a recycling rate for EPS packaging in Australia at 29% (Envisage Works, 2016). This is in contrast to the NSW EPA, which reported that less than 10% of EPS was recycled in NSW (being one of the most poorly recycled plastics in the state).

It estimated that 12,000 tonnes of EPS is disposed to landfill each year, taking up 240,000 cubic metres of landfill space.

A report by One Planet Consulting (2018:15) that was commissioned by ACT NoWaste, summarises the problem for EPS: "EPS is inert in landfill and lasts for hundreds of years. However, it occupies a large volume (space) in landfill for a long time. Positively, it is recyclable and there is a market demand for it in Australia and offshore; however, collection costs are often greater than landfill costs."



General material flows for EPS Packaging (Source: EPS Industry Alliance Packaging, 2019).

The key challenges summarised by APCO (2018) for recycling and recovering EPS and other foamed plastics include:

Challenges in landfill:

EPS makes up a small percentage of solid waste to landfill, but takes up a lot of space and inhibits the compaction of waste.

Collection network:

EPS is rarely collected through kerbside systems and drop-off points are fragmented and not accessible by all consumers. Logistics are expensive due to the high volume-to-weight.

Quality of collected materials:

High levels of contamination in many commercial and industrial sources reduce its commercial value.

End markets:

There are limited local markets for recovered EPS (most is exported at present).

Impacts in litter:

In the litter stream, EPS is a problem because it is lightweight and easily breaks down into small pieces.

Economics of disposal:

It is cheaper for a consumer to landfill EPS than pay for recycling.

Alternative materials:

Some users are switching from EPS to alternative foams such as expanded polypropylene (EPP) polyethylene (EPE) which are less recyclable.

Consumer engagement:

There is a high level of consumer frustration as they do not know if or how to recycle EPS

Phase 1 - Investigation Recap

The YRKA partnered with the Cleanwater Group to research, map and conduct field inspections of potential sites around the inner-city and suburban reaches of the Yarra, where high volumes of polystyrene were thought to be leaking into the environment and finding their way into the river. The project aimed to track down key sources of polystyrene pollution and identify potential solutions to contain this material at the source.

The first polystyrene pollution investigation found that of the 107 site visits and observations recorded, 92 observations (or 86%) found some level of polystyrene pollution.

Of the 17 observations that were rated as having significant and very significant amounts of polystyrene pollution (Categories 4 and 5, respectively), 6 of the sites can be attributed to users of EPS, 2 to producers (National Polystyrene Systems and Auspod Styrene Industries Pty), 1 to recyclers (Eco Solutions (AUST)), and 1 to distributors (Omega Packaging).

From the 92 observations that found a presence of polystyrene pollution, 31 were located in shopping precincts, 20 were located in stand-alone commercial areas, and 18 were located in industrial areas. Although the second highest number of observations were cited as having a source industry of building and construction, 7 of these were observed in residential areas (at residential development sites using EPS insulation or waffle pods) while 9 were observed in industrial areas (associated with manufacturers of EPS insulation or waffle pods), indicating that both users and producers have role to play in reducing pollution from the construction industry.

Phase 1	Phase 2
Rated the amount of EPS pollution at each of the 30 sites cleaned in the Yarra River Blitz project.	Field audit deep dive of 80 construction sites
Created a user-friendly Polystyrene Hotspot Rating Tool	Re-designed the Rating tool
Interviewed Key Experts	Feasability study of analysing EPS in a lab to trace back to source
Field observations identified sources of polystyrene leakage within reach of the Yarra	Audited 25 source sites over 5 industries to estimate their relative contribution over time
Produced a report summarising the findings and a list of potential actions that can reduce EPS pollution	Audited 15 River Litter traps to estimate amount of EPS caught per year

EPS in the Yarra
Why continue the study?

While the first project achieved its aims and created a solid foundation for recommendations, there were still some unanswered questions regarding pollution over time and quantifying the full scale of pollution in the river. These questions formed the basis for this further investigation into polystyrene pollution.

The aim of this further investigation is to gain deeper knowledge of the relative contribution from sources, and to quantify the amount of polystyrene in the Yarra, all backed by quantifiable evidence. The data will then illustrate the current EPS pollution problem facing Victoria.

This report has been prepared in order to present the results of this study and provide recommendations on source reduction actions that can be implemented to prevent polystyrene from entering our iconic waterways and Port Phillip Bay.

Environmental Impacts of EPS

Worldwide, EPS is commonly reported as one of the top items of debris recovered from riverbanks, shorelines and beaches (Thaysen et al., 2018). It's widespread distribution and persistence have resulted in EPS being found in the gut contents of freshwater invertebrate and vertebrate wildlife (Jianann et al., 2018). In addition to physical EPS material, styrenes, the building blocks of the polymer, are found in marine and freshwaters and sediments globally (Kwon et al., 2015, 2017). Because polystyrene plastic is thought to be one of the only sources of styrenes in the environment, the styrene contamination is likely a result of polystyrene weathering and leaching in marine and freshwater systems (Kwon et al., 2017).

In 2015, the European Union banned HBCD (hexabromocyclododecane), the brominated flame retardant used in polystyrene building insulation, arguing that the health and environmental hazards associated with HBCD were significant. HBCD is not manufactured in Australia but is imported in EPS resin, as liquid dispersions and as a component of the EPS in finished articles, (Australian Government, Department of Health-Hexabromocyclododecane (HBCD)).

Polystyrene is more harmful than other types of plastic because it is composed of relatively hazardous chemicals (Lithner et al., 2011). Under certain conditions, EPS leaches styrene and benzene, chemicals that have known toxic properties (Gibbs and Mulligan, 1997; Niaz et al., 2017). Laboratory toxicity studies suggest polystyrene microspheres can impact feeding behaviour (Besseling et al., 2012; Cole et al., 2015), cause weight loss (Besseling et al., 2012), and affect reproduction (Cole et al., 2015; Sussarellu et al., 2016) in invertebrate species. More research into the impact of EPS and associated chemicals in vertebrates are needed to confirm broadscale negative ecological impacts.

Although inconclusive, these results highlight potential environmental impacts of large volumes of EPS within the Yarra River. Many governments have now accepted the recommendation from the science community that society should not wait until there is more quantified evidence of the degree of damage before acting to reduce marine plastic pollution impacts (Lavers and Bond, 2017, Gall and Thompson, 2015). In their report 'Marine Plastic Debris and Microplastics', the United Nations stated that there is a moral argument that we should not allow the ocean to become further polluted with plastic waste, and that marine littering should be considered a "common concern of humankind" (UNEP, 2016).

Locally, the wildlife living in and around the Yarra River is diverse, with one-third of Victoria's animal species found in the Yarra catchment. The river and local surrounds are home to 22 species of fish, 190 bird species, 10 frog species, 16 reptile species and 38 species of mammals, with several of these listed as endangered. Hence, immediate measures to manage plastic pollution at all stages of its life, particularly at the early stages where plastic sources are known and can be more easily contained, need to be addressed.

2 Aims

The aims of this study were to extend the initial research done by the first Phase of the Polystyrene Pollution investigation. This phase aims to collect evidence on the relative contribution of EPS sources, explore the nature of polystyrene and the awareness of the material in more depth, and quantify how much is ending up in the Yarra every year.

The project's main aims were to:

- Investigate relative contribution of EPS Sources
- Build on previous data to identify biggest contributor over time
- Gather evidence to show the extent of polystyrene pollution
- Seek opportunities for improvement
- Understand relative contribution from source industries
- Quantify extent of polystyrene pollution on the River:
- Estimate how much polystyrene's caught in the litter traps per year & how much flows down the Yarra
- Educate about the amount of pollution in the river
- Engage citizen scientists to help audit samples
- EPS fingerprinting study - feasibility check - Minor aim

Area of Study

The area of study for this research covered the inner city and the suburban reaches of the Yarra River. Both reaches have been designated and described by Melbourne Water Corporation (2018b) in the Yarra Strategic Plan Map Book.

The first, suburban reach, extends from Warrandyte which sits at the edge of metropolitan Melbourne, to Dights Falls in Abbotsford. This reach primarily consists of a near-continuous network of parklands and conservation areas as it transitions from rural at the metropolitan edge to suburban once it gets closer to central Melbourne (Melbourne Water Corporation, 2018b).

The second, inner city reach, starts at Dight's Falls which marks a clear transition from the suburban to the inner city and is also the transition point between tidal and freshwater flows. The reach then extends through industrial areas on the river flats, well-established residential neighbourhoods, the Melbourne CBD, parklands and recreation spaces down to the central city where it ends (at Webb Bridge). While the precincts of Docklands, Fishermans Bend and the Port of Melbourne are not technically considered part of the inner city reach by Melbourne Water Corporation (2018b), they were included in this study.

Lastly, an extension on the melbourne metropolitan region was made for monitoring construction sites, where new residential estates are more frequent in construction.

3 Methods & Objectives

In order to find 25 source sites to monitor, a map of the previously investigated sites was collated with a new list of assessed sites using desktop research and field audits. This map was then narrowed down to a selected number of sites, and subjected to monthly field inspections according to a methodology.

To quantify the level of EPS pollution in river litter traps, a detailed methodology was developed and reviewed by external stakeholders. This guided the sampling process on the river and the auditing of those samples.

Objectives	Methods
Map the distribution and flow of stormwater drains and pipes linking key sources to the Yarra River	Desktop research with geographical information system (GIS) analysis, paired with LGA engagement and map output
Locate and map all residential and commercial building sites that are likely to use waffle slabs or foamed insulation within the Yarra Catchment	Desktop research with geographical information system (GIS) analysis and map output
Integrate field data collected in Phase 1 with the Yarra River Atlas	Desktop work with geographical information system (GIS) analysis and map output
Assess technical and economic feasibility of analysing polystyrene river samples in the lab	Desktop research with literature review; Phone and email contact with local labs and Uni's to assess analytic capabilities and costs
Determine the relative contribution of EPS pollution from each industry type to the polystyrene problem on the Yarra River	Periodic field observation using mobile GIS data capture tools of 3 selected sites from each industry type; periodic data collection using the AMDI Stormwater Pollutant Auditing Method from 2 at-source litter traps installed at each site
Establish a consistent monitoring program to assess polystyrene loads in the Yarra River over time, and assess the effect of coronavirus lockdown on the amount of pollution entering the Yarra River	-Periodic field observation using mobile GIS data capture tools -Document the 16 Bandalong Litter Traps in the Yarra River and compare with field data sourced from VicParks of the Bandalong Traps before and after February 2020.
Develop digital and print educational pamphlets on polystyrene pollution for the public, retail and construction industries	Literature review on the prevalence and ecological impacts of polystyrene paired with graphic design
Investigate the difference between imported vs local polystyrene and current recycle rates.	Use desktop research to form notes and potentially interview/ talk with recyclers of EPS.

Summary of objectives and methods

Field Investigations

Field investigations were conducted from Dec 30, 2020 to Oct 23, 2021 covering two separate deliverables. Observations collected in the field were guided by the results of the first project, and a new round of site visits to construction sites.

Field data was collected using a digital smart-form in the same geographical information system as the map of potential sources and hotspots of polystyrene, in order to ensure that each observation (or record) could be geo-referenced for easy visualisation in the final project map. Data collected ranged from the location of the site to specific information on the amount of pollution, status, type and condition of stormwater drains inspected.

The following methodologies were developed for each key deliverable.

Source Site Method

This monitoring program has been established in order to gather additional evidence on the amount of polystyrene pollution from source sites over time. The results of this monitoring program are intended to provide comparison and deduce which of the five industries contribute the most to EPS pollution. Sample Procedure

The following method is to be followed when Auditing the selected source sites. The field technician will:

1. Arrive at the site and start the digital survey, ensuring the location is the same and the conditions allow them to safely audit the outside of the site.
2. Complete the survey form, documenting the EPS pollution
3. Clean the site, by hand or with a vacuum to remove all material before the next cycle.

Trap Methodology

This monitoring program has been established in order to gather additional evidence on the amount of polystyrene entering the Yarra River each year. The results of this monitoring program are intended to provide estimated quantities of polystyrene using both in situ and ex situ (lab-based) measurement methods. The findings will supplement Port Phillip Eco Centre's current estimates of polystyrene loads published in the Clean Bay Blueprint 2020 (Charko et al., 2020). In that study, based on monthly river trawls conducted between January 2015 and February 2020, the total estimated amount of litter items entering Port Phillip Bay from the surface waters (upper 200mm) of the Yarra River each year is 1,934,208,000. Polystyrene was the second highest litter type found (behind hard plastic fragments), accounting for 15% of the total, or 290,131,200 pieces per year.

Aspects of this monitoring program have been set up following discussions with Parks Victoria, Port Phillip Eco Centre and AUSMAP. Periodic samples will be drawn from 16 Bandalong litter traps (diagram below) managed by Parks Victoria along the Yarra River and audited for polystyrene content. While the traps are each in a fixed location, the amount of polystyrene captured varies between traps and over time. Parks Victoria cleans the traps by mechanical claw only after major rainfall events or if the trap is visually observed as full, therefore there is no consistent frequency of emptying the contents of the trap.

Note that using a cluster random sampling method such as this may not fully characterise the amount of polystyrene pollution captured in each trap. Due to the size and nature of the trap and the flow of pollutants, getting an accurate figure for the number of quadrats with polystyrene is likely to be difficult and impractical. This makes extrapolating to estimate the total amount of polystyrene in the trap unlikely to be accurate based on this method.

Therefore, the number of pieces and volume of polystyrene in each sample will be linked to an estimate of total volume of polystyrene in the trap which is based on a visual estimate of polystyrene pollution occurring as a percentage of the total trap volume. All effort will also be made to sample from traps that have been completely cleaned by Parks Victoria after the last sampling event, to ensure that samples are not drawn from the same pollutant load twice. As Parks Victoria continues to clean each trap only once they are full, this study can only indicate the net flux of polystyrene captured in each trap (in units of #items/m2/time), and assumes that the rate of debris accumulation is uniform between sampling events.

METHODS & OBJECTIVES

Images are examples, not actual sample taken for study
Image: Karin Traeger, 2021

Purpose of sampling: is to estimate both the number of pieces and the volume of polystyrene in each trap over each cycle of pollutant collection, thereby allowing us to extrapolate the total amount of polystyrene entering the Yarra River per year.

Sampling Method

Summary: Break up the collection chamber into even zones and draw a random sample from randomly selected zones amongst those that contain polystyrene. Note that based on the average volume of polystyrene in the traps, 2 samples which, when combined, roughly equate to 32L per trap per cycle is equal to or better than 80% confidence level and 10% margin of error when representing the total population.

1 Break up each trap into 1m zones on longest edge, including only zones that contain EPS

2 If there is only 1 zone with visible EPS pollution, then draw 2 random samples from that zone following steps 5-7 below. If there are only 2 zones, then draw 1 random sample from each zone.

3 If there are more than 2 zones with visible EPS pollution, use a random number generator to generate 2 numbers to select the 2 zones to sample from.

4 Visually break up the first zone into 3 sections (beginning, middle, end), which should be roughly 1m in width as traps range from 2m to 3.5m in width

5 Use a random number generator to select 1 section in the zone (by generating a random number between 1 and 3). If polystyrene only occurs in 1 section of a selected zone, then random sample from that section.

As the quadrat size is 0.25m2 (500mm x 500mm), use a random number generator to generate a number from 1 to 4 in order to select the quadrat within the section. Sections should be roughly 1m x 1m 6

Generate a random number again from 1 to 4 in order to select the square to draw the sample of 0.125m2 (250mm x 250mm, or 15.6L) from the quadrat. Refer to the diagram provided in the sampling data sheet. 7

Repeat steps for the next zone that was randomly selected in step 3. 8

Audit the samples by separating, counting and recording the volume of polystyrene and the number of pieces of polystyrene in each sample 9

Extrapolate to total pieces of EPS in the trap based on estimated volume of EPS present (in L) (based on visual estimate of percentages full as outlined below) 10

Estimate the percentage of litter as a proportion of the total capacity of the trap 10a

Multiply the percentage by the volumetric capacity of the trap to get the volume of litter in Litres (L) 10b

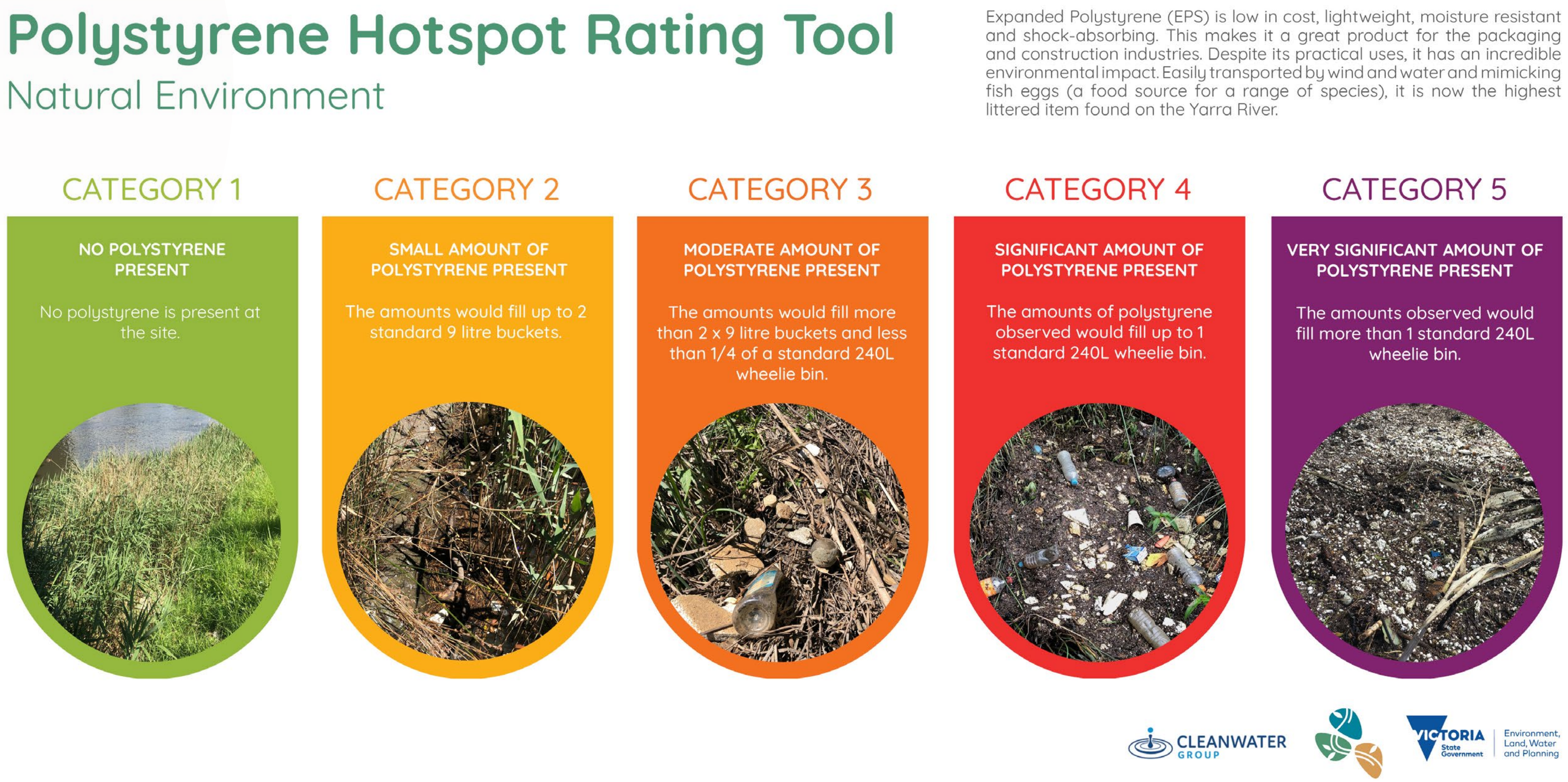
Estimate the percentage of polystyrene as a proportion of the total litter present 10c

Multiply the percentage by the volume of litter to get the volume of polystyrene (L) 10d

If it is found that the random samples are too onerous to audit within the scope of this project, then the size of the subsamples will be reduced (and possibly the number of subsamples then increased), whilst trying to maintain a statistically-sound representation of the population.

Hotspot Rating tool
Redesign

In preparation for the field investigations in Phase 1 (and used again in Phase 2), a polystyrene litter rating system was developed to assess sites based on the concentration of polystyrene observed. This rating system followed the model developed by the Victoria Litter Action Alliance in their “Litter Hotshots Rating Tool,” however, was made specific to polystyrene instead of all types of litter. Categories were assigned and assessed using field data and photos collected during the Yarra River Blitz. While the example photos provided in the tool are taken in a riparian environment, it is intended that this rating tool be applied when assessing polystyrene concentrations in both natural areas as well as in developed areas such as parking lots, nature strips, streets, footpaths, etc. where leakage has occurred. A larger scale version provided in Appendix A.



4 Results

Tracing EPS back to the source - feasibility study

Aim

The broad aim of this proposal is to provide 'proof-of-concept' that Raman spectroscopy and/or electron microscopy can be used for routine identification of polystyrene source when analysing samples drawn from a riverine environment. In that context, specific objectives are:

1. To understand whether spectroscopic methods can distinguish between polystyrene based on physic-chemical structure (by screening virgin polystyrenes provided by YRKA and CWG using Raman spectroscopy and/or electron microscopy).

a. If so, to identify the unique 'fingerprinting' characteristics that each type of polystyrene holds that can be linked to its source industry

2. To estimate the per sample / per batch cost of laboratory analysis of polystyrene samples.

3. To provide a report on the results and the indicative costs of carrying out this work on environmental samples of EPS as part of a long-term monitoring program

Outcome

The Plastics Lab @ RMIT leader A/Prof. Graeme Allinson has many years of research experience using the tools necessary to complete this task (as evidenced by the awarding of national competitive and contract research grants for the Plastics Lab, for analytical chemistry and environmental chemistry in Australia).
Tracing EPS in the Yarra River is a feasible study that can be conducted with further funding.

Field Audits

Using the data obtained from the desktop study and the interactive GIS map that could be accessed remotely, Field Audits were conducted from Dec 30, 2020 to Oct 23, 2021.

The locations of potential sources were informed by the GIS map of users, producers, recyclers and distributors, which ranged from manufacturers of EPS in industrial areas, and high volume users such as white and brown goods suppliers, to recycling centres that accept EPS and residential development sites that use EPS products for insulation and concrete foundations.

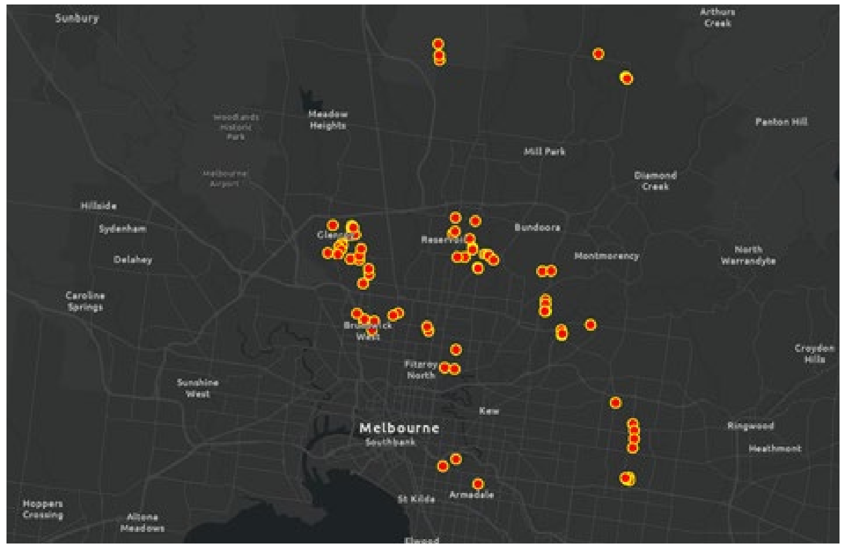
The types of sites where observations were recorded ranged from retail loading docks, border fences, footpaths and nature strips and stormwater drains.

Construction Deep Dive

Phase 1 of the EPS investigation identified construction sites as a possible major contributor to EPS pollution. In this phase, the project required monitoring construction sites over time, which was difficult due to the speed of construction (Right).

To find suitable sites for monitoring, a large sample of construction sites were audited, forming a wide snapshot of construction in Melbourne.

From Dec 30, 2020 - Feb 4, 2021, building and construction site inspections were conducted across 8 LGA's and included 80 sites - ranging from single dwelling construction to multi residential townhouses. Sites were found through desktop research and visited in the field, audited and added to a GIS map. It was unknown whether sites would use or have used EPS products for insulation and concrete foundations prior to arriving for the inspection.



Of the 80 sites inspected, the range of polystyrene pollution was vast and common, with 71% of sites inspected having some form of pollution. Of those, 98% were confirmed to have polystyrene pollution either on site, just outside the site on the naturestrip, or in a drain within a few houses of the site. Recording the level of EPS pollution, 24 had no EPS pollution, 36 ranked at Rating 2, 8 at Rating 3, 11 at Rating 4, and 1 at Rating 5. The large amount of no EPS ratings is likely due to assessing sites that had not yet started construction, and were recorded as sites with the potential for EPS pollution for the later source monitoring component.

Example of how quickly construction sites install EPS cladding - 2021

The sites varied in the stage of construction, from pre-construction to complete. The distribution was relatively even, with representation from pre-slab sites, post-slab sites, frame stage sites and lock-up stage sites.

There was little regard for EPS material, with only two sites storing off cut polystyrene in bags, and even those sites had polystyrene escaping the site. 320 photos were taken during the inspections, capturing evidence of waffle pod, EPS cladding and dumping pollution. Polystyrene confirmed as result of the site's activities found waffle pod use was only 7%, cladding 20%, and 60% was from unknown sources (though likely EPS cladding due to the stage of construction) with the remainder from packaging.

This is likely due to the way polystyrene was left on sites. Most commonly, polystyrene was left in a pile either in the site's bin or off to the side - both unenclosed. Polystyrene was often disregarded and left all over the site, in small chunks and individual beads, with 70% of pollution being widespread, and 30% clustered.

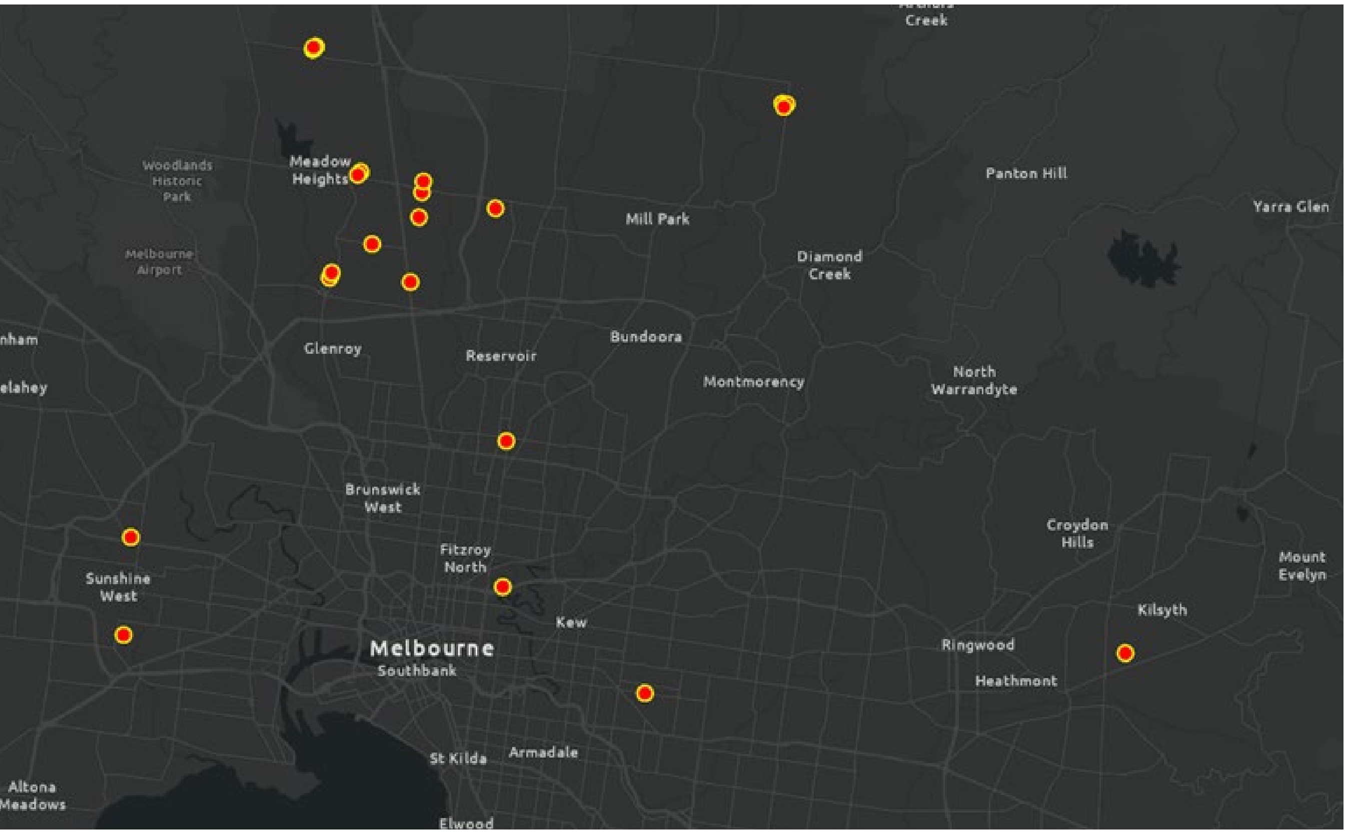
Polystyrene was recorded and/or photographed in the drains of 15 sites (18.5%), though a number of sites were visited after moderate weather events, and could have skewed the representation.

Whilst not all sites use polystyrene, it made up the largest percentage of cladding material observed onsite.

Source Audits

The source site audits took place at 25 locations around Melbourne, and occurred across 8 LGA's for 6 months. The audits were conducted by Clean Water Group once a month, and the sites cleaned after each visit.

The results of this study clearly indicate that polystyrene leakage is widespread and prevalent within every industry that manufactures, distributes, handles and/or uses the material. The results show this to be true over a 6 month period, and affirms that there are a high number of sources with widespread distribution around Melbourne that are leaking category 2-3 amounts of polystyrene (around 88% of total observations recorded), and only a handful of sources leaking category 4 or 5 amounts. All together though, over 90% of audits found some level of polystyrene leakage, indicating that there is a systemic problem with the material, the control measures we currently have in place, and the ease to which this material breaks apart.



Locations of the monitoring study

Cycles 1-6 of Source site audits by hotspot rating

Sites	C1	C2	C3	C4	C5	C6	
Markets	3	3	3	3	2	1	2.50
	2	3	2	2	2	2	2.17
	2	3	2	2	2	2	2.17
Retail	3	3	2	2	2	2	2.33
	2	2	3	3	3	3	2.67
	2	2	2	1	1	1	1.50
	3	3	3	3	3	2	2.83
	3	3	2	2	2	4	2.67
	3	3	3	2	2	2	2.50
	4	2	2	2	2	2	2.33
Construction	2	4	4	4	3	2	3.17
	2	2	2	1	2	1	1.67
	2	2	2	1	2	1	1.67
	3	2	2	2	2	2	2.17
	2	3	5	2	3	4	3.17
Recyclers	2	2	1	2	2	1	1.67
	2	2	2	2	2	1	1.83
	2	3	3	2	2	2	2.33
	2	2	2	2	2	2	2.00
Manufacturers	2	3	3	2	2	3	2.50
	2	2	2	2	2	2	2.00
	3	2	3	2	3	2	2.50
	3	3	2	2	2	2	2.33
	2	2	2	2	2	2	2.00
	2	2	2	2	2	2	2.00
	2.4	2.52	2.44	2.08	2.16	2	

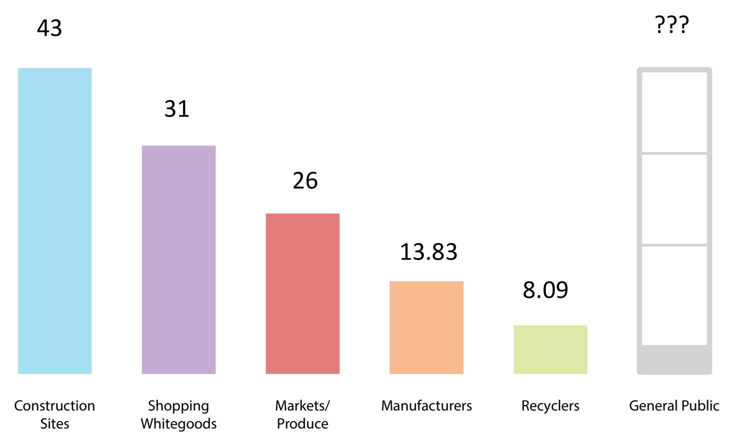
Cycles 1-6 of Source site audits by Volume

Sites	C1	C2	C3	C4	C5	C6	
Markets	25	75	5	10	0.5	2	23.1
	100	40	20	20	10	0	38
	20	30	15	7	10	1	16.4
Retail	90	40	5	15	10	1	32
	25	15	30	45	35	90	30
	5	2	7	0	0	0	2.8
	50	90	30	40	35	5	49
	70	50	5	0.5	0.5	100	25.2
	100	30	40	2	0.5	10	34.5
	200	2	10	10	5	25	45.4
Construction	30	150	100	100	40	20	84
	25	4	15	0	5	0	9.8
	10	5	10	0	1	0	5.2
	25	10	20	0.1	7	1	12.42
	10	50	425	10	30	80	105
Recyclers	1	5	0	0.1	1	0	1.42
	0.5	2	3	0.2	1	0	1.34
	2	10	5	0.5	0.5	0.5	3.6
	10	30	40	15	5	0.5	20
Manufacturers	10	20	25	10	10	25	15
	5	5	10	1	2	2	4.6
	35	15	30	10	40	15	26
	25	40	10	15	2	15	18.4
	10	10	10	10	10	1	10
	10	10	10	10	5	10	9
	893.5	740	880	331.4	266		

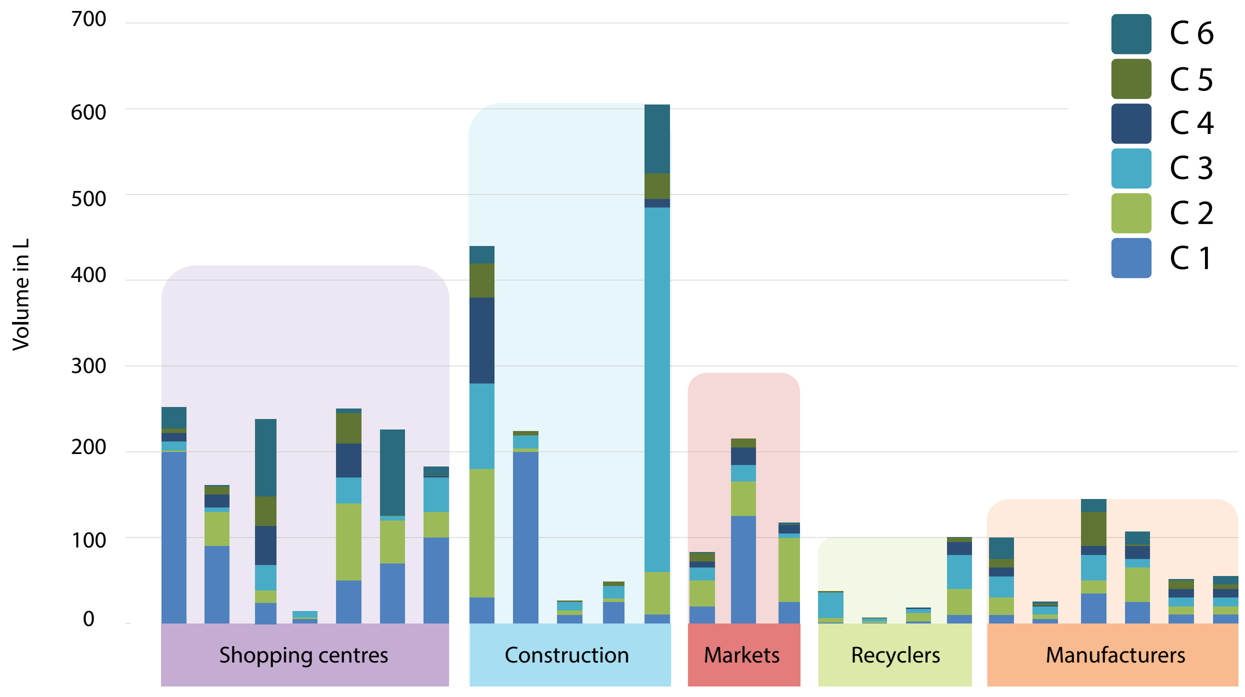
Whilst the results show that there is no one industry responsible for polystyrene pollution, over the monitoring period, construction averaged 50L of pollution, Retail/whitegoods 31L and markets 26L, whereas manufacturers averaged 13.8L and recyclers 8L.

It would be of interest to know the relative contribution from the general public, as many residential homes were observed to have left EPS out on the naturestrip. Whilst it would be difficult to quantify, it is suspected that they are also a sizable source of EPS pollution.

Average volume per Industry



Total volume of EPS pollution by industry



By volume, construction and retail were each responsible for 33% of the total amount of pollution collected. These results are consistent with the hypothesis of the first investigation, that construction and retail/whitegoods contribute higher amounts of EPS pollution than other industries.

It is worth noting, however, that polystyrene quickly fragments, and if counted by the number of pieces, it is likely the results would look different. Manufacturers were observed with a higher ratio of single balls to chunks around their sites, when compared to construction, retailers and markets.

The amount of pollution from each site over the monitoring period fluctuated. Only four sites recorded no change in hotspot rating, and stayed consistently at category 2.

One construction site recorded categories 2, 3, 4 and 5 over the 6 cycles, and another 2, 3, and 4, which is consistent with the rapid changes in their use of polystyrene. Shopping centres also saw high fluctuation, but on the most part were more stable as an industry.

The forms of polystyrene differed slightly across the industry types. Large packaging EPS from appliances or goods was mostly found at shopping and retail sites, where construction had small chunks of foam board, waffle pods and broken pod pieces, and manufacturers mostly had chunks and individual beads.

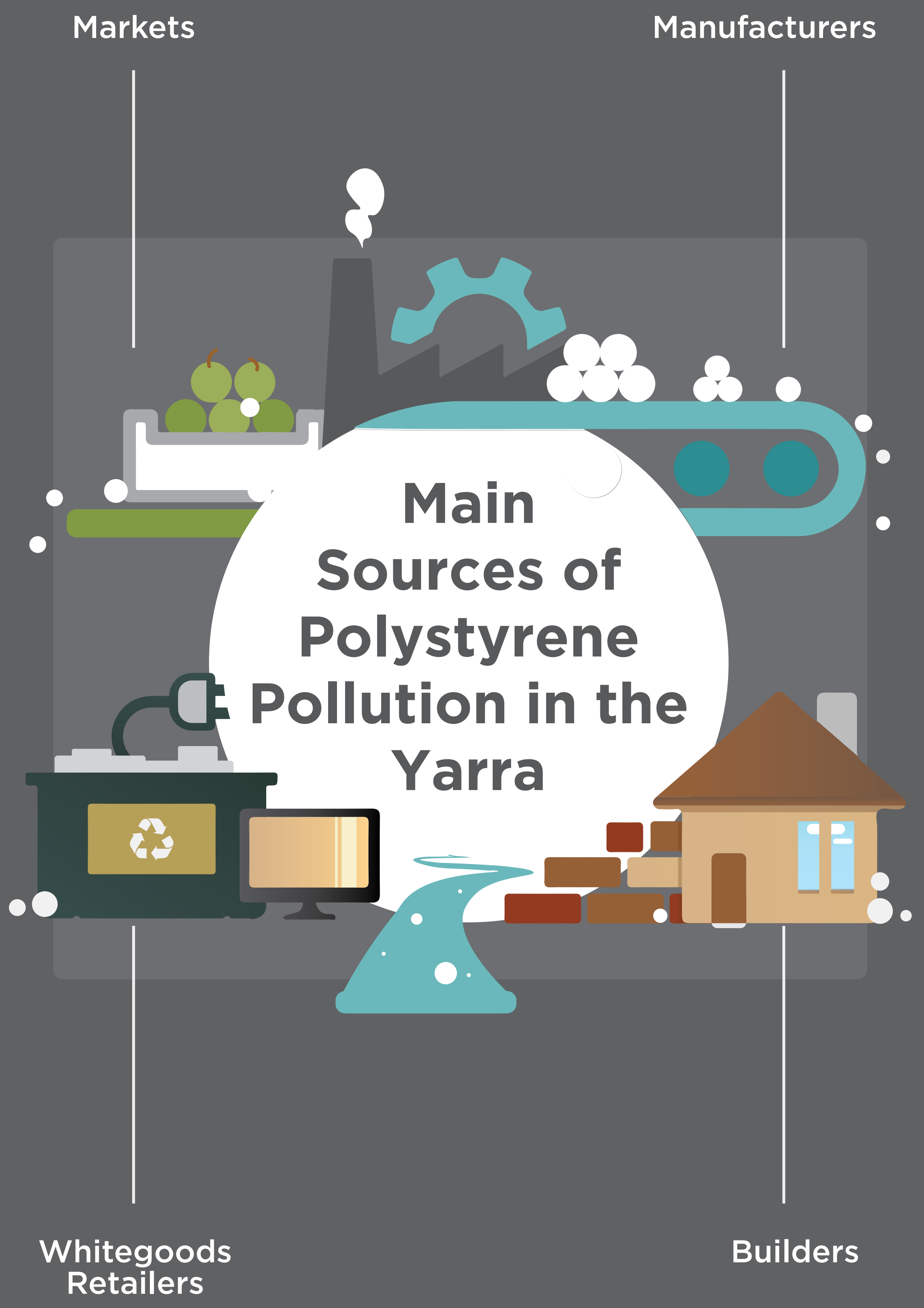
Distribution of Hotspot ratings across 6 Cycles

Covid-19 Lockdown

The results show a downward trend in polystyrene pollution over the 6 cycles. While the reasons for this might be intuitive, it is important to discuss here as they can apply to most cases and can also highlight limitations to the method of monthly monitoring cycles.

When compared against large rainfalls and the Covid-19 lockdowns, it is clear Cycles 3, 4, 5 and 6 occurred directly after or during substantial rain events in Melbourne, and Cycles 5 and 6 coincided with lockdowns. In the case of Cycle 6, the data was collected directly after the 2-week construction industry shut down. These factors; high rainfall washing away polystyrene into the stormwater system, and certain industries and their activities being shutdown, combined could account for the decrease in polystyrene found, and therefore the reduced hotspot rating.

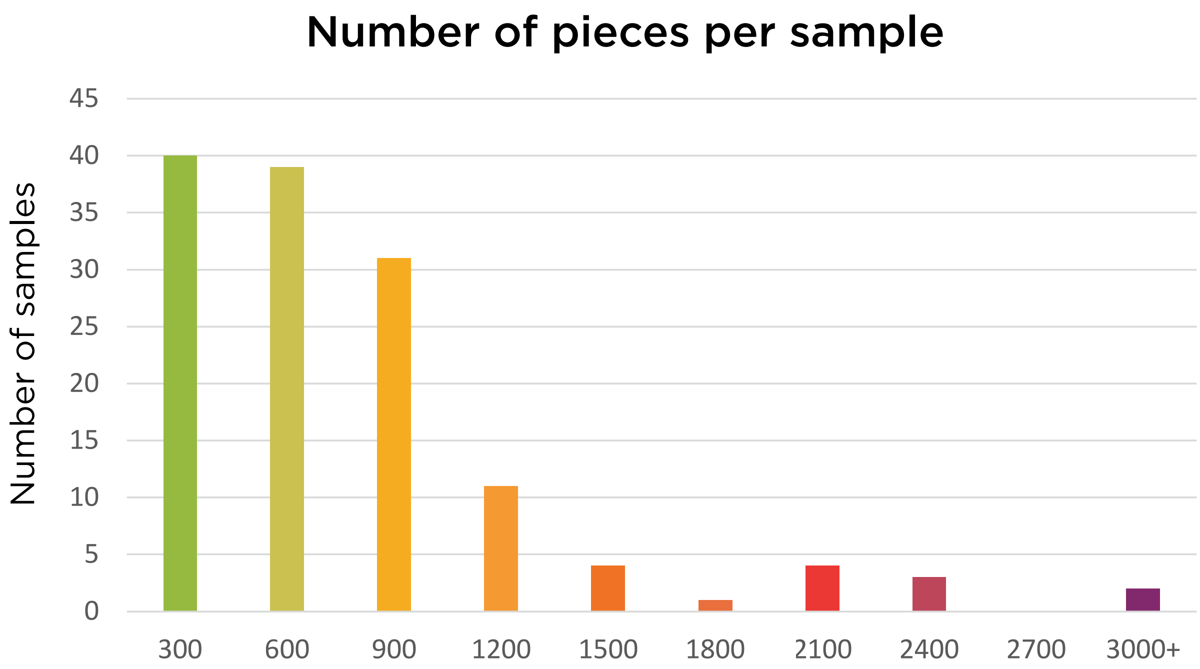
“The results show this to be true over a 6 month period, and affirms that there are a high number of sources with constant widespread distribution around Melbourne that are leaking category 2-3 amounts of polystyrene (around 88% of total observations recorded), and only a handful of sources leaking category 4 or 5 amounts.”

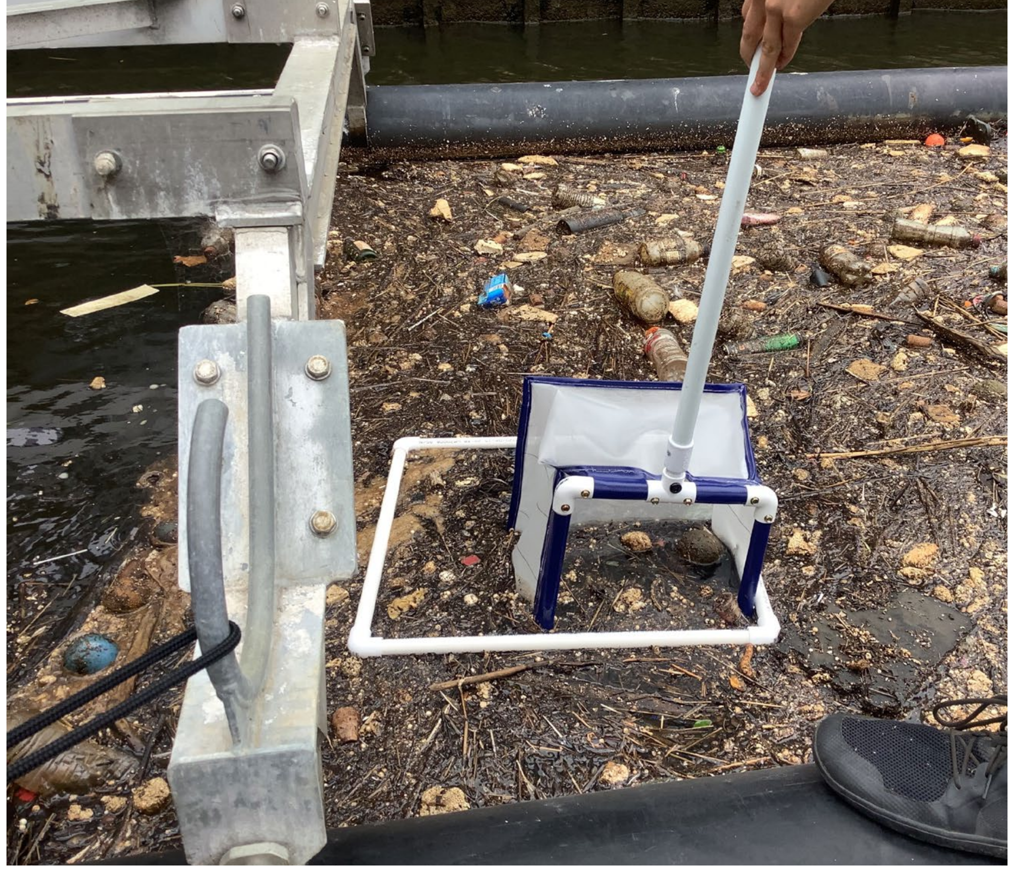


Litter Trap Audits

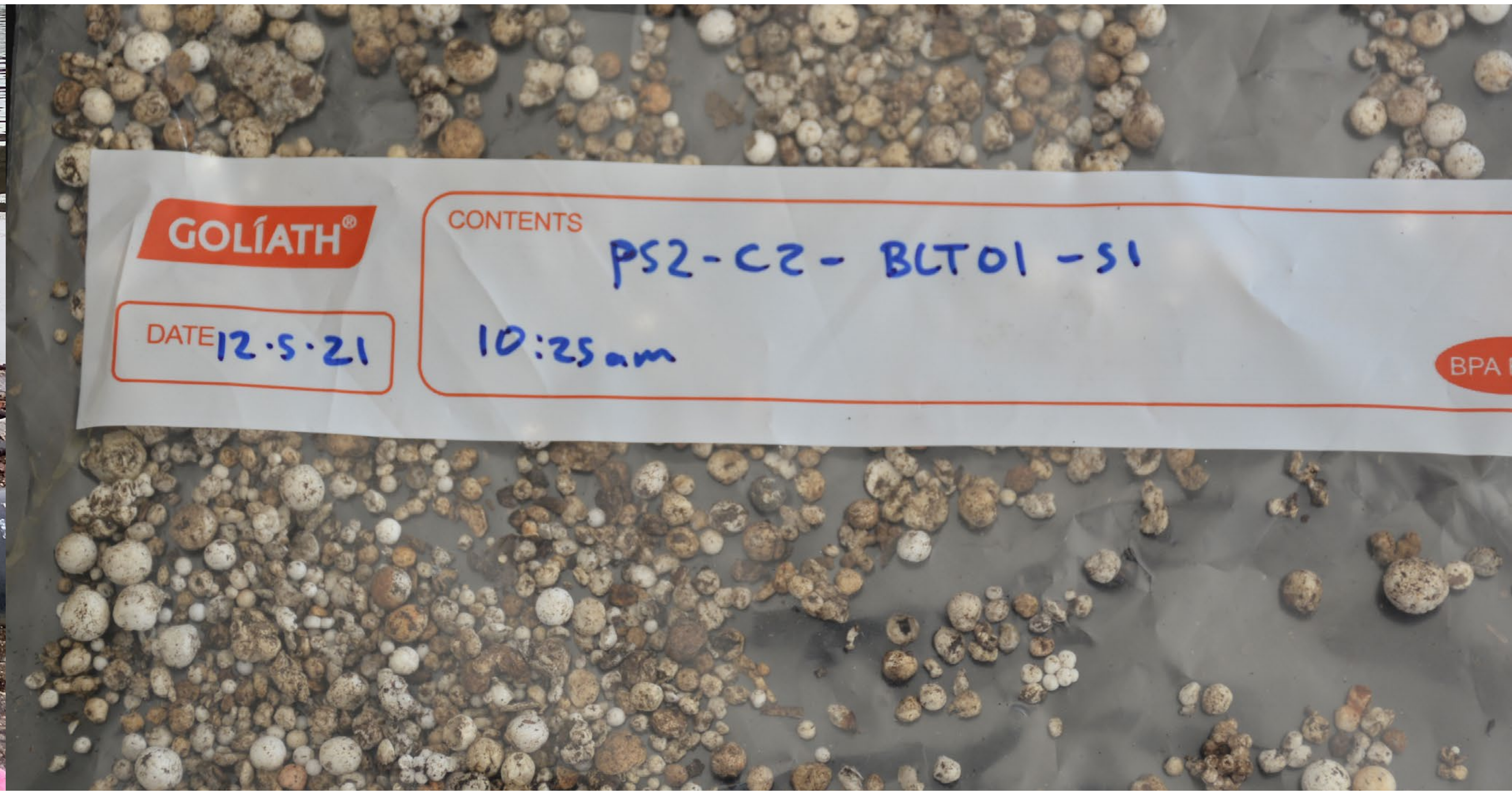
Auditing 152 samples with an average piece count of 648 was a monumental task. It involved over 50 volunteers, and over 330 hours of sorting. Well done to all involved, and thank you!

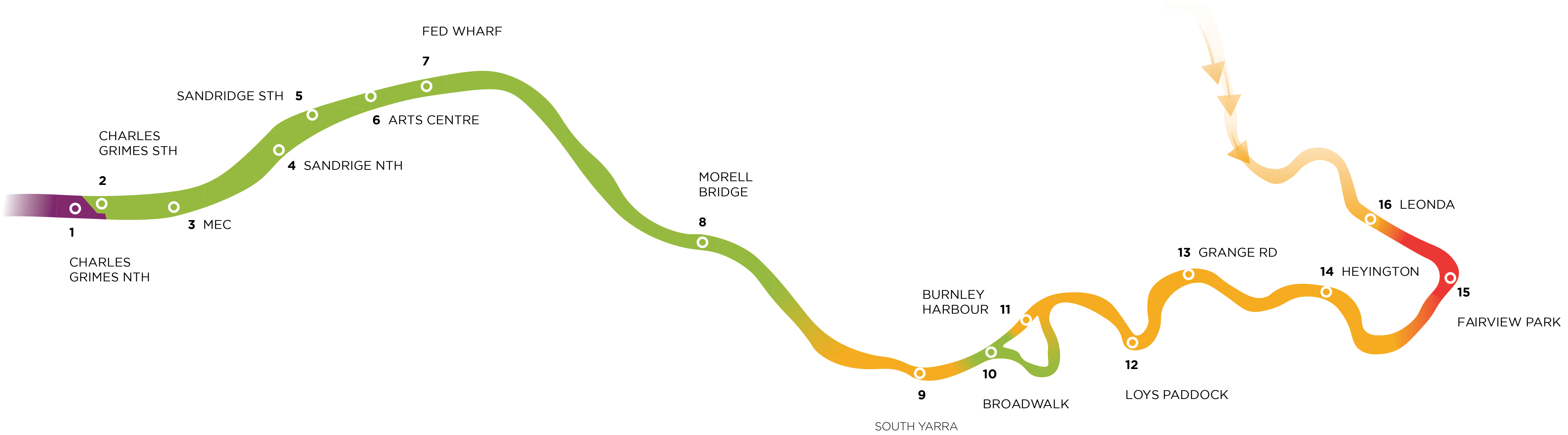
The amount of polystyrene pieces per sample for all 5 cycles ranged from 30 to 3193 for microplastics, and 0 to 873 for macroplastics. The frequency of pieces per sample, and an average piece count of 648 pieces, shows that there is some level of consistency in the amount of pollution between the traps over time.



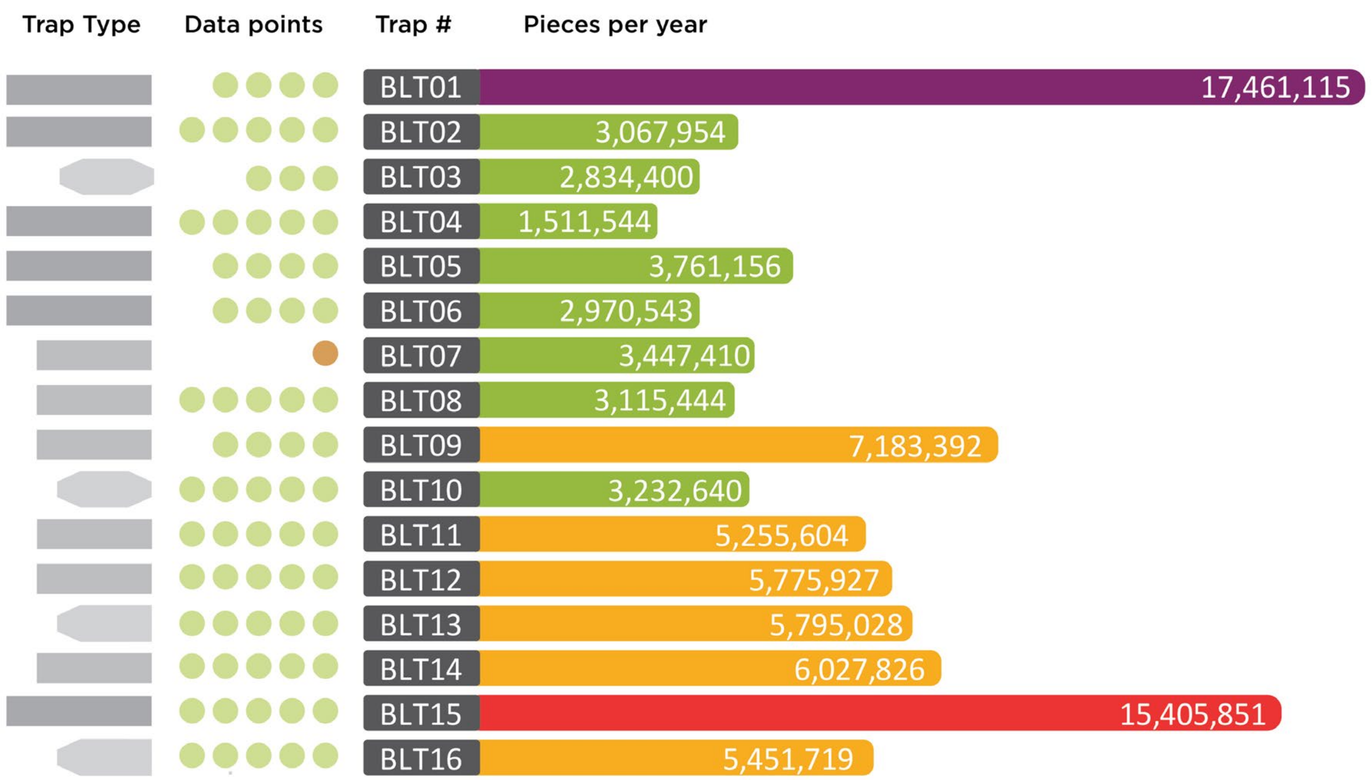



A little litter goes a long way.
Keep the Yarra River clean. Bin your litter.
UV849


GOLIATH
CONTENTS
PS2-C2- BLT01 -S1
DATE 12.5.21
10:25 am
BPA



Estimated number of EPS pieces per trap per year



The average estimated amount of EPS per trap per year is 5,768,597 pieces (underestimate). Two samples from each trap and from each cycle were used to calculate the above amounts, extrapolated from the results of the sample audits. The traps showed a range of 1.5 Million to 17.5 million pieces per trap per year. The total calculated amount of EPS pieces caught by the 16 litter traps on the Yarra is **92,297,562 pieces per year** (underestimate).

When compiled with the results from the Clean Bay Blueprint's results for polystyrene in the Yarra (290,131,200 pieces per year), the quantifiable amount of polystyrene in the Yarra every year becomes **382,428,770 p/y.** The results show a slight correlation between the trap size and EPS count. However, trap positioning has an impact on how quickly the trap fills up, and could skew the data.

It appears that the upper half of the traps on average collect more EPS than the downstream ones. This could be due to their forward position on the river, receiving the full amount of litter from multiple tributaries that join the Yarra further upstream.

Visually, it is very difficult to notice this difference when observing the trap's contents. It is of interest to note, that the visual estimates seem to follow the trend of the extrapolated results from the sample audit.

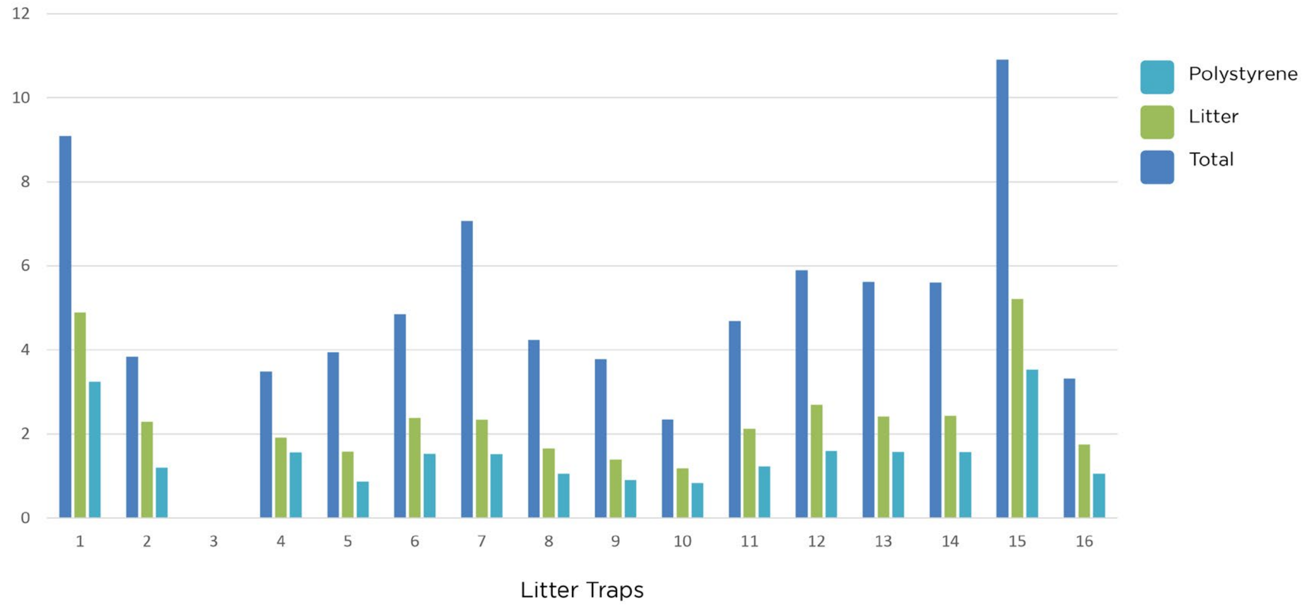
Extrapolation workflow

The total estimates per cycle shows a drop in number of eps pieces, which may be attributed to weeks of prior lockdown, and the 2 week construction lockdown taking place right before the samples were taken.

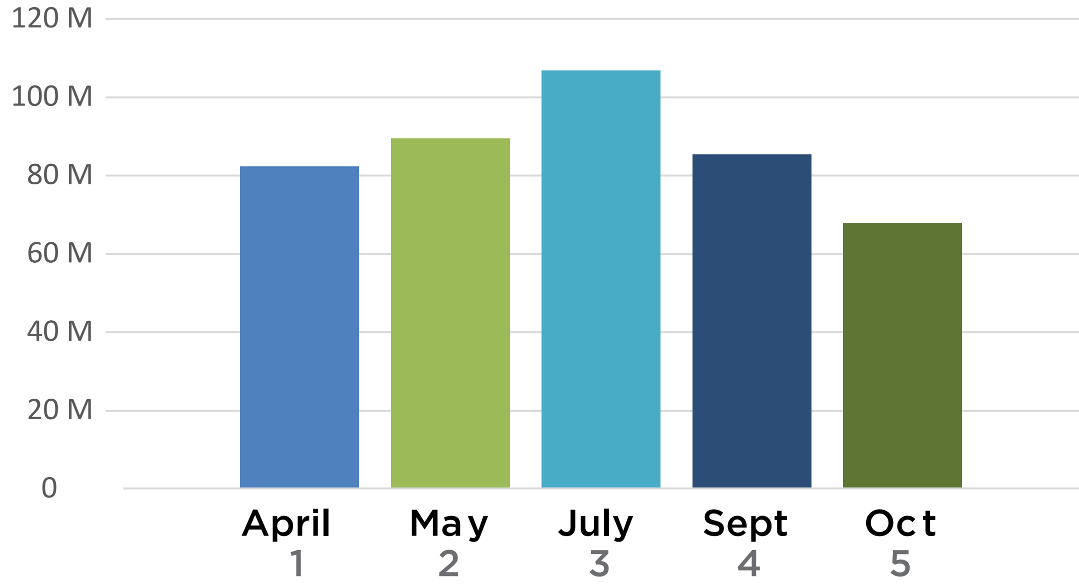
Trap 15 was most frequently in the top 5 largest amounts of EPS, no lower than 3rd highest over the entire study, and had the most consistent numbers across the cycles. Traps number 1, 11 and 13 also had three top five highest amounts over the 5 cycles.

The distribution of microplastics to macroplastics was 8.7% macroplastic pieces and 91.3% microplastics. This clearly shows the issue with polystyrene and why it is so pervasive, difficult to control the most common macroplastic in the Yarra River.

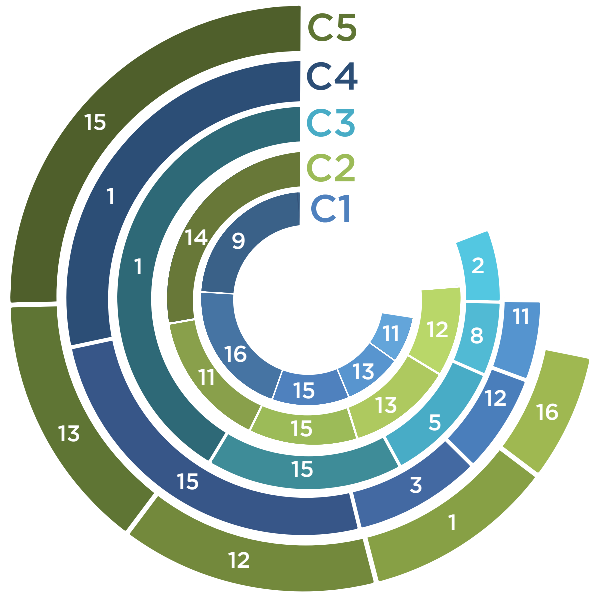
Average visual trap content estimates



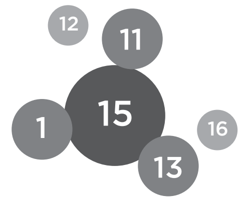
Total estimates per Cycle



Top 5 traps per Cycle



Frequency of top 5 traps



5 Discussion

Construction Deep Dive

Waffle pods

Polystyrene pollution from waffle pods was somewhat uncommon (7%), though this is likely due to the stage of construction the sites were at when visited. Of the sites that were constructing suspended slabs, the majority had EPS pollution. This was also further backed by the results of the monitoring phase later on.

Cladding

Cladding is the process of adding foam-based cladding to the exterior wall surfaces. Polystyrene cladding has become very popular in the last 20 years and is the most commonly used of all foam due to its comparatively low cost, versatility, ease of use, and "saves considerably more energy, than is consumed during its manufacture, use and disposal." - Unipod.

However, the previous report did not highlight the seriousness of the use of EPS cladding in residential home construction and its role in polystyrene pollution. Large blocks of cladding foam were found outside site fences, broken down into varying sized chunks that escaped under fences and were the most common sighting of polystyrene on site.

A group of Housing developments on Eley road in Burwood East, built by Burbank homes, were a good example of polystyrene cladding's role in pollution. Workers were observed cutting polystyrene cladding blocks with a hand saw on scaffolding, for at least 8 town houses. Subsequently, the nature strip was littered with polystyrene balls and the sites with chunks. The drains were blocked, but had polystyrene in them.

On many sites, cladding was left against the front fence, rubbing up against other construction waste and with no mesh fencing to prevent it escaping the site. EPS blocks of cladding were commonly left to break up and become a part of the site's ground, or be taken by the wind or rain.

Dumping

Lastly, dumping EPS from construction is a key entry point of polystyrene pollution in our waterways. Dumping was mostly observed in and around large housing developments like new estates, where empty blocks are common and few people live in the area. Waffle pods were the most commonly dumped EPS item, with 4 instances being recorded, and 5 pods the highest amount in a single location.

Dumping is a "common occurrence" on construction sites according to a conversation with a site manager, where empty lots are taken advantage of by builders who do not want to pay, or don't want to take the leftovers to recycling or landfill.

Dumping seemed to encourage more of the same behaviour, where the dumping sites had a large assortment of waste types from many individuals and grew very large in area.

Source Monitoring

Monitoring the different industry types over a regular period has affirmed the hypothesis set out in the first EPS pollution project. What was captured as a 'snapshot' of the different industries in the first investigation, has according to the new data, now been confirmed to be the business as usual rankings for those industries.

Construction

Despite residential construction sites being the most difficult industry to monitor due to the stop - start nature of using EPS in homes, and the speed of construction, the study was still able to document the reality of the situation. Following on from the 80 Construction site audits, it is unsurprising that construction sites had the largest amount of pollution over the study period.

It is especially important to note that all of the sites monitored were at the slab pouring stage of construction. This means the monitoring did not capture the entire building process, including the use of cladding foam. If the monitoring continued to the cladding phase of building, it is predicted that the size and nature of the EPS pollution would change to smaller pieces and individual balls, rather than chunks that result from waffle pods.

Large residential estates are of particular concern as they often are built by large companies who favour EPS waffle pods and cladding to keep costs down. EPS easily escapes their wire fences and the sites are mostly messily kept and with few best practice measures when it comes to containing litter. These locations also develop dumping cultures seen in the previous 80 site investigations, and there is little to no policing of litter pollution in these rural areas.

In construction, the onus is on manufacturers to voluntarily inform their clients - the users - of the best practice standards, following the "Pod Scrap Bag Program", they have put in place as part of an industry-led product stewardship scheme (Australian Government, 2012). There are two major problems with this system. The first is that, unfortunately, all responsibility and liability is transferred to the user, who has to comply with the rules established by the standards in order to participate, with seemingly no requirement and no incentive.

The second problem is that it appears that this practice only applies to recycling off-cuts of pod waste on-site. It does not apply to containing possible leakage when cutting and handling the material at any stage.

There is also a major issue when it comes to reclaiming EPS cladding from construction sites as "there is no return scheme or policy for EPS cladding" - Unipod. Clean pieces can be taken to recyclers, however, there is little incentive for builders to do so and it is most often mixed with other waste or dumped. This is consistent with the observation that - out of the 80 sites inspected, EPS cladding offcuts being stored in bags (presumably for recycling) was observed at one site.

“One challenge is to educate end users of waffle pods, such as builders and concreters, on the correct use of the pod scrap bags to ensure the EPS offcuts are segregated without contamination from other building site waste.” - National waste policy, 2011

From the observations made, after 10 years, builders and concreters are still very unsure about segregating clean EPS off cuts from other building materials.

Ideally, the project would have monitored the construction sites for 12 months, however this was financially impossible for the study. The 6 month monitoring provides a stronger understanding and allows for fluctuation in pollution amounts. The 6 months also, uniquely, occurred over non-lockdown and strong lockdown settings, which appears to have had a measurable impact on the data.

Retail

Retail (whitegoods and browngoods) made up the 2nd highest contributing industry by volume. The loading docks and surrounding areas are hotspots for polystyrene pollution, specifically because they tend to also be within close proximity to drains.

Kmart in Craigieburn showed good practice and regularly tried to contain their polystyrene in large 3m wide bags, however, they also were the highest and most consistent polluter in the retail category. This suggests either they need to upscale their containers to fit all of the EPS resulting from business, or that the storage bags are not 100% effective at holding the material. The same bags or large bins were present at retail sites, but large amounts of EPS are not being contained or retained in the secure storage containers. There is a clear disregard or lack of knowledge for EPS and its role as a pollutant amongst the staff, thus, litter training (in particular about EPS) is a crucial recommendation for retail workers who handle EPS in store.

Some users and manufacturers appear to employ preventative measures and others do not. Future research must build on the understanding of why, how and what measures are being used by some and not others, in order to develop industry wide standards on handling polystyrene.

It would also be advantageous for large retailers of whitegoods to become EPS drop-off points for the general public, as there has been similar success with REDcycle at supermarkets, diverting 900 million pieces of soft plastics from landfill and our waterways. This would also serve as a strong education campaign to highlight the amount of EPS that results from consumerism.

Markets

Markets are a relative to retail loading docks. The size, type and distribution of EPS is similar, although less frequent and mostly limited to fresh produce boxes.

Manufacturers

While Manufacturers as an industry had the 4th largest amount of EPS pollution, their contribution to the issue is not to be understated. Where retailers had large packaging pieces of polystyrene, manufacturers mostly had individual beads, and small chunks. Some of sites monitored operate at all hours of the day, and little beads litter the front of their fences.

Foamex in Bayswater had mesh along their fence line, however there was EPS found in small pieces and larger chunks all the way along their fence line. Trucks were observed coming in and out of the site constantly, and the gates stayed open for them to enter and leave. This is likely a major escape route for polystyrene at manufacturing sites. A large amount of EPS was observed in the stormwater pit outside Foamex.

Similarly, Vic foam had mesh along their fence line, and EPS was documented in small pieces and small chunks on the outside. This is believed to occur because there may be ways for EPS to get under the mesh on the fence, or they blow out through the gates where trucks move in and out.

A number of location had no mesh protecting their fence, though while it is an important start for sites who don’t have it along their fences, it is not the only requirement to contain EPS. Daily cleaning / vacuuming routines would help reduce the amount of polystyrene escaping their sites, as well as better skirting strips to ensure polystyrene cannot get under the fences. Drain traps would also be a priority for manufacturing sites as EPS is leaking from the sites constantly, and ensures minimal amounts of EPS flow into the stormwater system.

Recyclers

Recyclers had the lowest amount of pollution out of the five industries investigated. Greenwheel recycling was the only site to score category 3 hotspot ratings, a site which had no mesh along their perimeter fence. While there was evidence of EPS pollution at all sites monitored, it is a positive outcome nonetheless, to see that recyclers are not major contributors to EPS pollution, and with the adoption of regular cleaning practices and mesh along fences, could be mostly negligible contributors.

It is important to note that the 25 sites are a representation of their subsequent industries, and not a full representation of what is occurring. It is likely that there are sites within these industries that have less EPS pollution than recorded, or more.

Polystyrene in the River Traps

The state of polystyrene pollution in the Yarra River is very poor. It is the most common macroplastic in the river, and one of the most difficult to contain / catch once in the water.

Whilst the study was as thorough as could be, the results of this study are an underestimate of the true amount of EPS flowing down the river for 3 reasons.

The first factor is the limitation of using the bandalong litter traps as measuring devices. At any given time, a percentage of polystyrene is trapped and sitting in the reedbeds along the river's banks. This material falls outside the quantifiable amount of EPS in the river, however, based on visual observations, makes up a small percentage of the total amount.

Secondly, the litter traps are a maximum of 3m wide, and polystyrene can easily flow past them, around them or even through them (due to the back size of the holes in the gate on the back of the trap). The addition of the results from the Clean Bay Blueprint for EPS in the Yarra helped bridge this gap, but it is still a limitation for the results of this study.

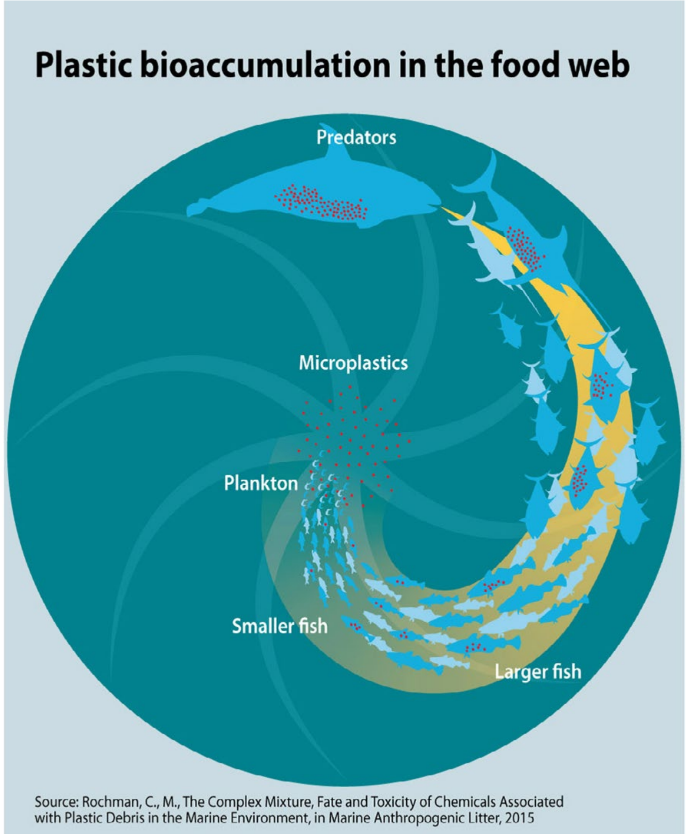
Lastly, the sample audits were completed by dedicated volunteers. It is certain that polystyrene pieces were missed during the audit procedure. Polystyrene microplastics under 1mm were problematic in samples so large and numerous as this study produced. Even missing 50 pieces will result in an average of 374,552 pieces missing from the final extrapolation.

These three factors are why the quantifiable value of 382,428,770 p/y (the results of this study and the Clean Bay Blueprint added together) is still an underestimate of the total number of EPS pieces in the river.

What does 382,428,770 pieces per year entering the bay mean?

Wildlife from plankton (Wang et al., 2020), to sea urchins (Messinetti et al., 2018), to fish and birds (Roman et al., 2019) have all been documented to ingest polystyrene or similar plastics.

A 2019 study showed that relevant concentrations of 10 Qm polystyrene microplastics for 60 days not only led to microplastic accumulation in the gill, intestine, and liver of the marine medaka (Oryzias melastigma), but also caused oxidative stress and histological changes (Wang et al., 2019).



There are numerous studies that have documented the effects of plastics on marine life, and a few discussing the bioaccumulation impact on humans.

Once the impacts of polystyrene and other plastics on marine life are understood, it becomes clear that the hundreds of millions of polystyrene pieces flowing into the port Phillip Bay annually is a serious issue for our marine life, food source and ecosystem. Working with the sources to reduce EPS pollution is of vital importance to the millions of dollars spent annually on litter removal, but mainly for the impact it has on our ecosystems.

Limitations of the Study

This investigation and the results both had limitations to completing an ideal study. The nature of investigating pollution in a waterway environment is already complex, and some of the methods used had never been done before.

Despite this beeing the deepest study into EPS pollution to date, it is still a baseline from which more work could be done if the evidence is deemed not enough.

The Investigation

The investigation was limited in scope by funding, accessability with covid-19 and time constraints. It is acknowledged that given more resources, the study could have:

- Included more sites to monitor, building out a more complete image of contributers to EPS pollution.

- Allowed more monitoring cycles of source sites and samples of the river traps, making the extrapolations more accurate

- Had better accuracy counting EPS pieces used in extrapolations

Data Collection

Sampling the bandalong litter traps revealed further limitations. The methodology created for this study was the best option given the resources and based on few existing studies, but could have been stronger with more than 2 sub-samples per sampling event.

Ideally, the number of cycles given to each site audit would have been higher in order to gain more solid evidence, but funding prohibited this.

The samples were sent to volunteers for sorting, which occured due to covid 19 lockdowns. Training volunteers to sort through the data was also a limitation to highly accurate data analysis.

A Way Out

Practices

There are two main pathways to physically reduce polystyrene pollution in the Yarra. Handling and containment practices can improve, or we can stop using EPS in favour of alternative materials.

Leaving Polystyrene uncovered / unattended

Polystyrene must not be left uncovered and uncontrolled outdoors. There is no doubt polystyrene will leak if left to the elements.

To reduce polystyrene pollution across the board, handling practices need urgent attention and action. If handlers can move the use, cutting and storing of polystyrene indoors, undercover or bagged up; dispose of EPS in sealed bins when outdoors and uphold cleaning schedules, EPS pollution in Melbourne will decrease.

It was outside the scope of this work to interview sources to discuss current best practices, environmental standards and where gaps can be filled. Reduction strategies would benefit from engaging industry and business to develop and implement a best practice polystyrene handling guide wherever EPS is being used.

Best practice

Best practices work effectively when tailored to the businesses engaging in litter reduction. Thus, there are a mix of methods and strategies that can and will need to be adopted. These are explored further in the recommendations section.

EPA General Environmental Duty

The general environmental duty (GED) is at the centre of the Environment Protection Act 2017 and it applies to all Victorians. All victorian must reduce the risk of harm from their activities:

to human health and the environment

from pollution or waste.

The approach to protection of human health and the environment has changed and it is now expected that all persons will manage their activities to avoid the risk of environmental damage. They must also respond if pollution does occur.

The GED are criminally enforceable, meaning it is now possible to see large EPS polluters held to account for their failure to properly control polystyrene pollution. .

Materials

Mycelium

Mycelium is quickly growing in popularity, and manufacturers are starting up around the world. Melbourne now has its very own manufacturer. There is a strong correlation and crossover between the material properties of mycelium and Polystyrene, which makes it a strong candidate to replace EPS in many areas of use.

Projects have been developed to start mycelium on its journey to certification for building sites, and consumer demand for sustainable packaging is growing. The ultimate way out of polystyrene pollution is to stop using it, and materials like mycelium provide a pathway forwards to a future where our waterways are free of millions of EPS fragments.

Fungi Solutions - A local business creating myco products:

Waste sourced from local businesses is recycled and turned into new products. The waste is fused together by the mycelium (the root network) of the fungi, which will take the form of the mould the waste is placed into.

The resulting composite material is lightweight, fire retardant, buoyant and insulating. We accept industrial, agricultural and manufacturing offcuts for processing and produce grown to order Mycomaterials for packaging, insulation and products.

The process of neutralising pollutants with fungi involves training their highly adaptive digestive systems to break down the hydrocarbon bonds of a specific toxic pollutant or waste material. This organic recycling method offers a unique opportunity to address the growing waste challenges facing Australia and develop cleaner circular materials.

Wool

"Woolpack, at its core, borrows from nature: just as wool keeps sheep warm in winter and cool in summer, so too does Woolpack technology for the contents of its boxes and pouches.

The specifically chosen fibres are incredibly effective at absorbing moisture from the air, minimising humidity and condensation to maintain stable temperatures"

Wool packaging can be flat-packed, is non-toxic, could replace refigerated transport, doesn't break and can be customised easily to suit needs.

Planet Protector

Planet Protector aims to remove polystyrene from packaging by providing cost effective, sustainable, eco-friendly packaging. They design with the circular economy in mind, utilising waste materials and giving them new life through our products.

Woolcool

Woolcool® was launched in 2008 and the innovative, sustainable design has scooped an impressive haul of awards in the packaging, business and environmental arenas. Woolcool, using patented technology, produce high performing insulated packaging.

Fungi Solution - Mycelium packaging

Material Comparison Table

Mycelium	Wool	Polystyrene
Lightweight	Lightweight	Lightweight
Mouldable	Somewhat Mouldable	Mouldable
Naturally flame retardant	flame retardant	Chemicals added
Thermally insulating	Thermally insulating	Thermally insulating
Buoyant		Buoyant
Suited to wide range of ap-plications	Suited to wide range of applications	Suited to wide range of applications
Medium cost	Small - Medium cost	Cheap
Biodegradable	Biodegradable	Non-biodegradable
No harm from pollution	No harm from pollution	Harm from pollution
Available/bespoke	Available/bespoke	Widely available
Captures twice its weight in c02 during cultivation.	Captures no carbon during production	Captures no carbon during production
Infinitely recyclable	Recyclable	Recyclable if clean
Home compostable	Compostable	Not compostable
Acoustically insulting		Somewhat acoustically insulating
Produced from waste and non virgin organic materials	Produced from waste and non virgin organic materials	Produced from waste virgin materials

RECOMMENDATIONS

INDUSTRY

Phase out unnecessary packaging & rethink packaging design

Ensure that all EPS-derived products are designed for recycling and utilise a minimum of 30% recycled content in line with the 2025 National Packaging Targets (APCO 2018).

EPS industry associations to include EPS pollution material online

Currently, the only education about polystyrene pollution comes from scientific studies and environmental groups. EPS industry associations need to help raise awareness about handling with their stakeholders.

Expand and improve the polystyrene collection and recycling network

Champion product stewardship practices and create drop off point facilities and programs for ALL types of EPS

Monitor and strengthen current containment for EPS waffle pod and cladding, & enforce compliance

EPS is sold cheaply, it is expensive to recover, difficult to contain and leads to a high environmental impact. Despite this, there is a lack of regulation, enforcement and industry responsibility around its distribution and disposal.

Retail/whitegoods store's docks need immediate action for EPS escaping their sites and entering stormwater drains.

Whitegoods docks recorded the second highest level of EPS pollution, and require immediete action to reduce leakage, protect drains and clean bin areas.

Support market development

Support the development of local end markets, e.g. waffle pods and pelletisation, to enable local manufacture of skirting board, picture frames, concrete panels, or commodity export.

Large retailers should lead product stewardship and create drop off point programs

Similar to Red-cycle and supermarkets, Consumers require easier acces to EPS drop off points. Large retailers are well placed to offer this service, connecting themselves and the public to EPS recyclers.

Expand the use of enviro-friendly alternatives

Fast track the expansion of alternative materials such as mycelium products, wool packaging, PHA, Plantable packaging made of fibre board and cellulose materials.

GOVERNMENT

Review current legislation and revise where needed

Following the addition of EPS to the National Plastics Plan 2021, a new review of the remaining gaps in EPS pollution is required. Areas to review include manufactuering, construction and fresh produce.

Strengthen current control measures for waffle pod/cladding pollution

Waffle pods and EPS cladding were among the highest contributers to EPS pollution in the study, for which any commitment to future reduction pathways is still lacking.

Increase the 'State of Knowledge' amongst EPS handlers.

- Industry guidance (VBA, EPSA)
- Add EPS handling guidance to GED

Without EPS mentioned in: the EPA's GED documents and industry documents and guidance, those responsible cannot be assumed to have a "State of Knowledge" about EPS pollution and how to reduce it - and therefore creates difficulties when taking action.

Support the expansion of environmentally friendly alternatives to EPS

Fast track the expansion of alternative materials such as mycelium products, wool packaging, PHA, Plantable packaging made of fibre board and cellulose materials.

EDUCATION

Develop educational programs and material for major source industries

Free, easy to understand and actionable material needs to be developed and spread to educate handlers of EPS about the importance of reducing pollution.

Key persons include:

- Retail staff
- Construction workers
- Manufacturers
- Recyclers
- General public

Topics include:

- Recycling services
- Correct sorting
- Containment methods & products
- Importance of cleaning

Expand the use of environmentally-friendly alternatives

We now have viable alternatives to EPS, and all efforts should be made to help these alternatives up-scale and open pathways for them to be put into widespread use. This includes awareness, funding and legislative support.

EPS Drop-off Location

Household quantities of polystyrene can be dropped off for recycling at the locations listed below.

Boroondara Recycling and Waste Centre
648 Riversdale Road, Camberwell
T: 92784444
*For residents only

Brooklyn Transfer Station
12 Old Geelong Road, Brooklyn
T: 93142297

Clayton Transfer Station
Cnr Fraser Rd and Deals Rd,
Clayton South
T: 95512351

Greenwheel Recycling
Factory 2, 67 Proximity Drive, Sunshine West
T: 1300289894

Monash Waste Transfer Station and Recycling Centre
380 Ferntree Gully Road, Notting Hill
T: 95183767
*For residents only

Moonee Valley City Council Transfer Station
188 Holmes Road, Aberfeldie
T: 83251730
*For residents only

Unipod Engineering Performance, Truganina site
Access is via 8 Foundation Road,
Truganina, Victoria, 3029.
T: +61 3 93945516

Complete Pod Solutions
17/21 Freight Drive
Somerton 3062
*Refer to the EPSA drop off requirements on the home page of this website
T: (03) 9308 8455

AndPak
731/733 Koorlong Avenue
Irymple 3498
*Refer to the EPSA drop off requirements on the home page of this website
T: (03) 5024 5819

FOAMEX
31-33 Gatwick Road
Bayswater North 3153
*Refer to the EPSA drop off requirements on the home page of this website
T: (03) 9720 4200

Polyfoam
32 Dandenong Street
Dandenong 3175
*Refer to the EPSA drop off requirements on the home page of this website
T: (03) 9794 8320

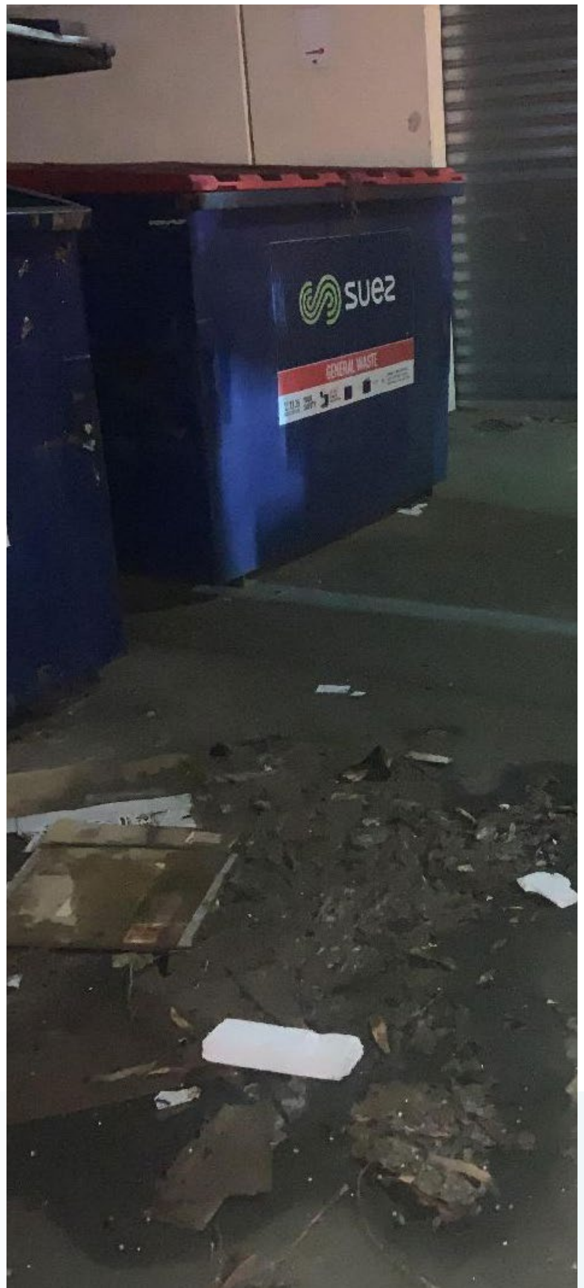
National Polystyrene Systems
329 St Albans Road
Sunshine 3020
*Refer to the EPSA drop off requirements on the home page of this website
T: (03) 8326 8080

Yarra City Council Recycling Drop-off Centre
168 Roseneath St, Clifton Hill
T: 9205 5555
*For residents only

Gallery


AIM
9720





suez
GENERAL WASTE


Conclusion

Research by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) shows that the vast majority of marine debris in Australia derives from land-based sources (Hardesty et al., 2016). With 98% of its volume as air (EPSA 2014a), EPS that is moved and used all over Melbourne daily, can easily be leaked into the environment it can have a damaging effect on Yarra River's rich and diverse ecological system.

This project aimed to document the relative contribution of potential sources of polystyrene pollution and identify any further solutions that can be implemented to prevent polystyrene from entering the Yarra River. The study started by continuing a desktop analysis of users, producers, distributors and recyclers of expanded polystyrene (EPS) around Melbourne, with a field investigation specifically into 80 construction sites.

A feasibility study was conducted into lab tracing EPS pollution back to the source, with RMIT confirming the study is feasible with further funding.

25 sources for monitoring were then selected from 5 different industries based on previous research and subjected to a 6 month monitoring period. The study found construction sites contributed the highest amount of EPS pollution, followed by retail (whitegoods and browngoods), then markets / produce, manufacturers and lastly, recyclers. Immediate attention needs to be paid to handling and containment practices of EPS at all industries as pollution is constant and continuing.

Finally, the 5 auditing cycles of the Yarra River's 16 bandalong litter traps estimate that 92,297,562 pieces of EPS are caught by the traps every year. When added to the Clean bay Blueprints estimation of EPS escaping into the Port Phillip Bay, it is estimated that 382,428,770 enter the Yarra River every year. This figure is an underestimate due to limitations with sorting the 152 litter trap samples and the amount of EPS sitting in reedbeds - unreachable and unquantifiable.

The effects of Covid-19 lockdown might have effected the data collected from the source sites investigation and the bandalong trap audits, suggesting the closure of construction sites and businesses reduced litter in the river.

The findings of this study suggest that stronger action can and must be taken across all industries that manufacture, transport, distribute and handle polystyrene. While a step in the right direction, voluntary product stewardship schemes have not gone far enough to contain this material from entering the environment and becoming the highest littered item on the Yarra River. Increased monitoring and control measures implemented by the EPS industry therefore needs to be met with improved legislation and stronger enforcement from both local and state governments in order to stop the flow of this material into the iconic Yarra River and eventually Port Phillip Bay.

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Appendix

Appendix A Polystyrene Hotspot Rating Tool – Natural Environment

Polystyrene Hotspot Rating Tool

Natural Environment

Expanded Polystyrene (EPS) is low in cost, lightweight, moisture resistant and shock-absorbing. This makes it a great product for the packaging and construction industries. Despite its practical uses, it has an incredible environmental impact. Easily transported by wind and water and mimicking fish eggs (a food source for a range of species), it is now the highest littered item found on the Yarra River.

CATEGORY 1

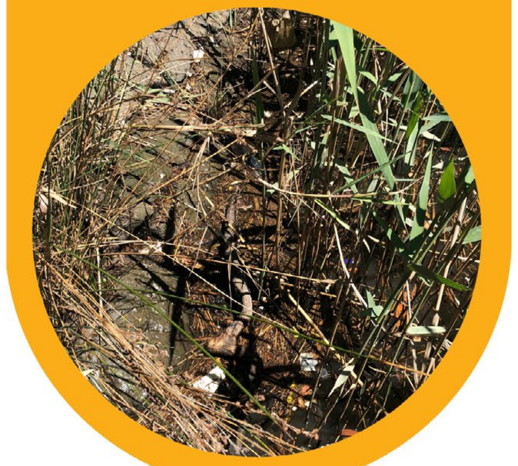
NO POLYSTYRENE PRESENT

No polystyrene is present at the site.

CATEGORY 2

SMALL AMOUNT OF POLYSTYRENE PRESENT

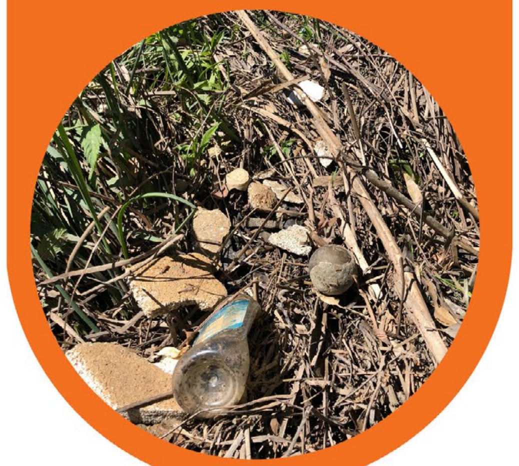
The amounts would fill up to 2 standard 9 litre buckets.



CATEGORY 3

MODERATE AMOUNT OF POLYSTYRENE PRESENT

The amounts would fill more than 2 x 9 litre buckets and less than 1/4 of a standard 240L wheelie bin.



CATEGORY 4

SIGNIFICANT AMOUNT OF POLYSTYRENE PRESENT

The amounts of polystyrene observed would fill up to 1 standard 240L wheelie bin.

CATEGORY 5

VERY SIGNIFICANT AMOUNT OF POLYSTYRENE PRESENT

The amounts observed would fill more than 1 standard 240L wheelie bin.

CLEANWATER GROUP

VICTORIA State Government | Environment, Land, Water and Planning