Making the case for removing expanded polystyrene products from construction

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Executive Summary

This report investigates the potential classification of expanded polystyrene (EPS) as a contaminant under the Resource Management Act (RMA), focusing on its environmental impact and regulatory implications. The analysis comprises a literature review covering EPS production and usage, environmental repercussions, regulatory measures related to plastics, and the toxicological effects of EPS micro and nanoplastics.

EPS, derived from polystyrene, is extensively used in construction and packaging due to its insulation properties, lightweight nature, and cost-effectiveness. However, its widespread application poses environmental challenges, particularly regarding its contribution to micro and nanoplastic pollution. Studies indicate that EPS fragments easily, leading to the proliferation of microplastics in marine, terrestrial, and freshwater ecosystems. Moreover, EPS contains harmful additives like the flame retardant hexabromocyclododecane (HBCD), which can persist in the environment and bioaccumulate in organisms, posing risks to human health and the ecosystem.

Global regulatory efforts to address plastic pollution include proposed treaties, bans on single-use plastics, and restrictions on hazardous additives. In New Zealand, initiatives such as the ban on plastic microbeads and phased elimination of hard-to-recycle plastics underscore the government's commitment to mitigating plastic pollution. However, challenges persist in regulating EPS, particularly in the construction sector, where its fire retardant properties raise concerns about toxic emissions during fires.

The report concludes that EPS micro and nanoplastics meets some of the criteria for the RMA's definition of contaminants and may cause significant environmental harm. Recommendations are proposed to mitigate EPS-related environmental risks, including banning EPS from certain building applications and imposing fines for mismanagement on construction sites. In addition, education on the alternatives to EPS in construction is necessary.

Appendix 1 highlights some of the current alternatives to EPS that are available now.

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1. Introduction

A literature review was conducted to determine if expanded polystyrene (EPS) can be established as a contaminant under the Resource Management Act. The literature is split into the following sections:

- EPS and its uses
- How EPS escapes into the environment
- Ubiquitousness of micro and nano plastics
- Regulations related to plastics
- Contaminants as defined under the Resource Management Act
- Recommendations/conclusion

2. EPS and its uses

EPS is produced from polystyrene, a thermoplastic polymer made from styrene (vinyl benzene) monomer and air. It is one of the most widely used plastics and is used in construction, packaging and for food and medicine transportation. Approximately 24 million tonnes was used globally in 2020 (Statista, 2021).

In construction EPS is used for:

- insulation
- roofing tiles, and metal roofing systems
- in composite (multi-material) masonry and concrete blocks
- as packaging for many building products, such as doors, windows, and panels
- to create decorative elements such as architectural mouldings and columns
- as geofoam in soil stabilisation and lightweight fill applications, such as embankments and retaining walls
- in decorative facades made of concrete to help make this product lighter
- in landscape applications to save on topsoil, reduce weight on embankments, hillslopes and bulk out retaining walls (Atherton, T. 2023).

A paper commissioned by Auckland Council on the use of EPS in construction (Atherton, T, 2023) outlines the reasons this material is used in insulation and other construction applications including its thermal insulation properties, resistance to moisture absorption, lightweight and sound insulation properties, and cost-effectiveness. See table 1 for a comparison of insulation materials.

The paper listed the disadvantages of EPS used in construction as:

- poor onsite handling leading to the product entering the environment
- Being made from petrochemicals
- Lack of end of life options other than landfill once it has been used in construction
- Non biodegradability
- The toxicity of fire-retardant EPS.

Insulation materials					
Material	**Use**	**R value**	**Cost**	**Notes**	**End of life disposal**
Expanded polystyrene (i.e. Expol)	Ceilings Underfloor Walls (beads)	r1.4 for 60mm	approx $12/m2	Made from petrochemicals with fire retardant added so toxic if in a fire Not flexible so can be gappy around pipes/ penetrations etc. corrosive: Not compatible with electrical wires	Recyclable if not broken up, damaged or wet and in large quantities only Manufacturers can be specific about only taking back their own product Storage and disposal on tight residential sites, with no known take back collections mean this often ends up in landfill
Glass and mineral wools (i.e. Pink® Batts®)	Ceilings Underfloor Walls	r 3.6 for 180mm r2.6 for 110mm	approx $10/m2 approx $12/m2 approx $20/m2	Non toxic but can irritate eyes and skin of installers Slumps and poor moisture resistance so needs replacing after 15 years or so	Recyclable if dry
Polyester (i.e. Mammoth or Greenstuf®)	Ceilings Underfloor Walls	r 1.9 r2.5 (90mm) r4 (blanket)	approx $30/m2 approx $37/m2	Made from petrochemicals and toxic if in a fire. Airborne pollutants are emitted if chemical binders are used. Does not slump	Recyclable
Wool (i.e. Terra Lana)	Ceilings Underfloor Walls	r 4 for 190mm thick r2.0 for 115 mm r2.4 for 90mm of same thickness	Approx $34/m2	NZ made. Toxic free if 100% wool but depends on what it is blended with to make it pest, mould and slump resistant. Non irritating. Moisture wicking Made to order so minimal waste and off cuts. Does not slump	Zero waste - offcuts are taken back, and respun into insulation or weedmats if dirty.

Table 1: Comparison of different insulation types in NZ

3. EPS in the environment

The extremely lightweight and unstable nature of EPS means it quickly breaks down into microplastics while being used in marine products such as fish boxes, buoys, pontoons, surfboards and so on, as well as through its transportation, cutting of for construction, escape from a landfill, compaction of before or during the recycling process, deterioration or loss of structure, or illegal dumping of polystyrene waste (Frey, B 2021). A 2023 study found that a significant amount of EPS pollution near the coast of Antofagasta, Chile was the result of improper application and management of EPS used as expansion joints at a construction site (Zadjelovix, V et al 2023). Another study of an industrial site that produced EPS in Minsk, Belarus found that EPS microplastic was present in both the upper levels of soil and deeper levels to a depth of 20cm. The study also found that the soil pollution from the EPS plant went beyond the site and was also found in the floodplain of a small river located 500-600m from the plant (Kukharchyk, T and V Chernyk 2021).

Organisms can also contribute to the creation of EPS microplastics. One study based in Korea found EPS particles in the digestive tracts of burrowing polychaetes (marine worms) living on EPS debris. When the living conditions of polychaetes were replicated in a laboratory the study found that due to their burrowing behaviour, one single polychaete can produce hundreds of thousands of microplastic particles per year (Jang, M et al, 2018).

While there is no scientific literature on EPS microplastics produced in New Zealand there is solid anecdotal evidence of EPS being mismanaged and littered on building sites, leading to the creation of micro and nanoplastics.

Examples of mismanagement of EPS on building sites in Auckland

In addition, in the Christchurch Earthquakes of 2010 and 2011 approximately 100,000 buildings were damaged and about 10,000 buildings demolished.[1] The Auckland Anniversary Weekend flood event on 2023 had about 10,000 buildings damaged[2] and Cyclone Gabrielle caused damage to another 10,000 buildings.[3] It is unknown how many of these buildings contained EPS insulation.

[1] https://my.christchurchcitylibraries.com/canterbury-earthquake-2011-for-kids/
[2] https://www.nzherald.co.nz/nz/auckland-anniversary-floods-one-year-on-could-the-city-cope-with-another-storm-like-january-27/4X4TB4UDNRA7FOAKOBN2QPJ7FA/
[3] https://www.newshub.co.nz/home/new-zealand/2023/06/cyclone-gabrielle-buyout-for-worst-hit-homes-leaves-thousands-of-houses-in-other-categories-in-limbo.html

This photo of a house damaged during Cyclone Gabrielle clearly shows the exposure of EPS insulation to the environment. Photo credit: Tom Taylor, RNZ.

4. Ubiquitousness of micro and nano plastics

Microplastics are defined as plastic particles less than 5 mm in length that originate from a variety of sources including from larger plastic that degrades into smaller and smaller pieces, and from microbeads, which are a type of microplastic added to beauty products, cleaners and toothpastes.[4] Nanoplastics are defined as ranging in size from 1 to 1000 nanometers (Gigault, J et al 2018). Since 2004, when a team of researchers (Thompson, R et al, 2004) first highlighted the issue of microplastics, there has been a growing awareness of the problems caused by these tiny pieces of plastic in the environment. This source of environmental contamination is predicted to double by 2030 (Hale, Robert et al, 2020). Microplastics are now recognised as not only being a source of pollution in marine environments (Hale, Robert et al, 2020, Gola, D et al 2021), fresh water environments (Chaoran, L, 2019) but in the air (Sridharan, S et al 2021), terrestrial ecosystems (Zhang, J et al 2023), in animals (Prata, J.C. et al 2022), and in humans (Cox, K et al 201). One study estimates that humans ingest up to five grams or the equivalent of one credit card worth of plastic per week (Senathirajah, Kala et al, 2021). Another study of 22 anonymised, healthy adult volunteers that measured microplastics in the blood stream found that four widely used plastics, including expanded polystyrene, were the most widely present type of plastic (Leslie, H et al, 2022).

Microplastics are now found in some of the remotest parts of the world (Padha, S et al 2022) including in the Antarctic (Waller, C et al, 2017). New Zealand is not immune from the incidence of microplastics (Bridson, J et al, 2020; Ruffell, H et al, 2021; Van Gool, E, 2021). The abundance of microplastics directly causes animal deaths (Susanti, N.K.Y, 2020) and has been linked to immune function disruption, inflammation, neurotoxicity,

[4] https://oceanservice.noaa.gov/facts/microplastics.html

and reproductive toxicity (Prata, J et al 2020; Blackburn K and D Green, 2021) and also threatens food security (De la Torre, G, 2019).

5. Regulations related to plastics

The recognition of microplastics as an environmental contaminant has led to global action. Work on a United Nations Treaty to end Marine Plastic Pollution began in 2022 and 175 nations have contributed to it, including New Zealand.[5] Following the *X-Press Pearl* shipping incident off the coast of Sri Lanka in February 2021[6], the International Maritime Organization began work on a Proposed Regulation of Maritime Transport of Plastic Pellets, which is expected to be approved in 2024.[7] The New Zealand Maritime Organisation has contributed to this regulation. In addition, numerous countries have banned single use plastic bags and other single-use plastic items.[8]

Since 2013, the argument has been made that PVC, polyurethane, polycarbonate and PS are so hazardous they should be regulated by environmental protection agencies (Rochman, C et al 2013). In response, some towns in the USA, Canada, the Philippines, France and Taiwan prohibit the sale, possession and distribution of EPS. In addition, California has 64 local government laws or regulations on EPS based on its potential as an environmental hazard (Farrelly T and I Shaw, 2017).

The New Zealand government banned plastic microbeads (tiny plastic particles, including plastic-based glitter, that are added to products to increase their cleaning or scrubbing power or to make a product look fun)[9] in 2018. Among the reasons for banning the microbeads were:

- they are too small to be retrieved, are cumulative and do not biodegrade.
- can be mistaken by marine life as food, causing long-term damage to aquatic animals like fish and mussels. This in turn poses a potential threat to human health.
- there are suitable alternatives to plastic microbeads in personal care products that do not have adverse impacts on the environment.[10]

The Ministry for the Environment began work on phasing out hard to recycle plastics after the publication of the Office of the Prime Minister's Chief Science Advisor's report Rethinking Plastics (2019). Starting with the single use plastic bag ban in July 2019, the

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[5] https://www.un.org/en/climatechange/nations-agree-end-plastic-pollution and https://environment.govt.nz/what-government-is-doing/international-action/towards-a-global-treaty-to-combat-plastic-pollution/

[6] https://www.unep.org/resources/report/x-press-pearl-maritime-disaster-sri-lanka-report-un-environmental-advisory-mission

[7] https://www.imo.org/en/MediaCentre/HotTopics/Pages/FAQ-Plastic-pellets.aspx

[8] https://www.weforum.org/agenda/2020/10/canada-bans-single-use-plastics/ and https://www.statista.com/chart/14120/the-countries-banning-plastic-bags/

[9] https://www.epa.govt.nz/news-and-alerts/alerts/microbeads-ban-is-your-product-affected/

[10] https://environment.govt.nz/assets/Publications/cabinet-paper-microbeads-2017.pdf

Ministry for the Environment’s work on phasing out hard to recycle plastics has led to the following items being banned:

- Single use plastic drink stirrers
- Single use plastic cotton buds
- Plastics with pro-degradant additive
- PVC food trays and containers (plastic 3)
- Polystyrene takeaway food and beverage packaging (plastic 6)
- Expanded polystyrene food and beverage packaging
- Single use straws that contain any type of plastic
- Single use plastic tableware and cutlery
- Single use plastic produce bags
- Non-home compostable plastic fruit labels.

The Ministry for the Environment’s consultation on hard to recycle plastics, initially included the following proposal:

> “The Government is proposing a mandatory phase-out (a ban) on the sale and manufacture of PVC and polystyrene plastic packaging in two stages under section 23(1)(b) of the WMA. This allows for *controlling or prohibiting the manufacture or sale of products containing specified materials*.” (MfE, 2020, page 38).

This proposal was two-phase. Stage 1 of the proposal was to prohibit the sale and manufacture of all food and beverage items that contain PVC packaging and to prohibit the sale and manufacture of some food and beverage items that contain polystyrene packaging by January 2023.

Stage 2 was to prohibit the sale and manufacture of all food and beverage items that contain polystyrene packaging not captured under stage 1 AND a ban on all expanded polystyrene (EPS) packaging including but not limited to homeware, electronics and other consumer goods. The proposed phase-out of all EPS packaging reflected concerns about the environmental impact of EPS litter, as well as its difficulty in being recycled onshore in New Zealand.

There were 8000 submissions made to the consultation, with the majority in favour of the proposals. Plastics NZ submitted on behalf of its Expanded Polystyrene Sector Group and supported the phasing out of single-use EPS takeaway containers, beverage containers and tableware. It opposed the proposed phasing out of EPS used in cold-chain supply lines (i.e. seafood, pharmaceuticals, medical) and for protecting products (i.e. shellfish, lab samples, whiteware and large electronic goods), as Plastics NZ asserted that no alternatives meet the high level requirements of these supply chains (Plastics NZ, 2020, page 2). These latter EPS products were not included in the final phase out.

Not included in the proposal was polystyrene used in construction such as wiring, downpipes and insulation, because “These tend to have a much longer life cycle than food packaging, and are less likely to appear in kerbside recycling.” (MfE, 2020, p 40). This is despite there being many alternatives to EPS insulation being available and the government's own building.govt.nz noting that aside from choosing insulation that provides the highest insulation level, other issues to consider when choosing insulation include:

- whether the material can be recycled at the end of the building's life
- avoiding hydrochlorofluorocarbon (HCFC)-foamed insulation materials which may be used in polystyrene products.[11]

6. EPS microplastic as a contaminant under the RMA

Under the Resource Management Act, a contaminant includes:

> *any substance (including gases, odorous compounds, liquids, solids, and micro-organisms) or energy (excluding noise) or heat, that either by itself or in combination with the same, similar, or other substances, energy, or heat—*
>
> > *(a) when discharged into water, changes or is likely to change the physical, chemical, or biological condition of water; or*
> >
> > *(b) when discharged onto or into land or into air, changes or is likely to change the physical, chemical, or biological condition of the land or air onto or into which it is discharged*

Microplastics broadly fit into the above definition of a contaminant under the RMA.

In 2014 the International Agency for Research on Cancer (IARC) determined that styrene is a possible human carcinogen due to the metabolic system converting styrene into styrene oxide (Farrelly T and I Shaw, 2017). The 15th National Toxicology Programme's Report of Carcinogens states:

> *Styrene is reasonably anticipated to be a human carcinogen based on limited evidence of carcinogenicity from studies in humans, sufficient evidence of carcinogenicity from studies in experimental animals, and supporting data on mechanisms of carcinogenesis* (National Toxicology Program, 2021).

The report also notes that styrene oxide is reasonably anticipated to be a human carcinogen and that it was first listed in the Tenth Report on Carcinogens (National Toxicology Program, 2021). New Zealand's Environmental Protection Agency states that styrene "may cause cancer".[12] However, the polymerisation of styrene (the process that turns it into PS and EPS), if done properly, means that the styrene monomer cannot be released in an environmental context (Farrelly T and I Shaw, 2017). If not done completely

[11] https://www.building.govt.nz/getting-started/smarter-homes-guides/heating-cooling-and-insulation/insulation-materials/

[12] https://www.epa.govt.nz/database-search/chemical-classification-and-information-database-ccid/view/EB1CD562-C7F7-4FBF-AE03-01C36CEEB8E7

the styrene monomer can contaminate the PS and migrate into food and the environment.

6.1. The flame retardant HBCD

One of the issues with the use of EPS in construction is what happens to it in the event of a house or building fire. EPS in a housefire leads to incomplete combustion which produces up to 57 chemicals, including styrene, polycyclic aromatic hydrocarbon (PAHs) such as fluoranthene, which in mice studies has been found to be carcinogenic, carbon black (which can cause lung disease) and carbon monoxide (Gurman et al, 1987).

One of the most widely used brominated flame retardants was hexabromocyclododecane (HBCD), which was used for 50 years to fire-retard EPS insulation. However, HBCD was designated as a global elimination compound in the Stockholm Convention on Persistent Organic Pollutants (POPs) in 2013 with a 5-year exemption for building insulation. This means EPS from buildings prior to 2018 are likely to contain HBCD that could be released into the environment during renovation, demolition and damage due to natural disasters and fires.

A 2017 study that looked at the distribution of HBCD from an EPS plant in China found concentrations of HBCD in dust, soil, sediment, plant tissues and marine species from the environment around the plant. Plant tissue and marine animals showed increasing concentrations of HBCDs over a 5-year period demonstrating the seriousness of the release of polystyrene with HBCD and that its toxicity increases over time (Zhu, H et al 2017). Another study conducted in South Korea collected EPS debris from 12 other countries in the Asia-Pacific region and found high detections of HBCD in non-flame-retardant EPS. The same study identified debris on Alsakan beaches as most likely being the result of the 2011 Indian Ocean Tsunami, which indicates the long distance EPS debris can travel and implications for the transportation of hazardous materials (Jang, M et al 2017). A 2015 study pointed out that due to the persistent nature of HBCD the consequences of it go well beyond the phasing out of it, as the disposal of EPS with HBCD will continue to be badly managed with the resulting contamination of marine life from it (Zhiqiang, N, 2015). Indeed, a 2023 study investigated the occurrence and distribution of HBCDs and microplastics in aquatic organisms in different substrates. The study found measurable HBCD in seawater, sediment, EPS substrates and organism samples. EPS buoys were found to be the biggest source of HBCDs and contributed to the ingestion of HBCDs by aquatic organisms (Pan, Y-F et al 2023).

6.2. Release of chemicals and heavy metals from EPS

Aside from HBCD, many known land and water contaminants have been found to be present in EPS microplastics. A study carried out in Peter the Great Bay (Sea of Japan), found that the fluctuations in temperature, salinity, oxygen concentration, and UV found in costal zones aid the release of chemicals from synthetic polymers into the environment with dangerously toxic effects. It determined that high concentrations of mainly EPS plastic debris in this area changed the biochemical level in the digestive glands of the mollusc species studied and initiated oxidative stress processes in their tissues (Chelomin, V, 2023).

Another study in a laboratory in the Bay of Bengal, India, examined the impact of rigid polystyrene (PS) microplastics compared to the impact of EPS on the seastar - a keystone species, which plays an important role in maintaining the functional homeostasis of the coastal ecosystem. The study found that while both PS and EPS had an adverse effect on total count, phagocytic response, cytotoxicity and oxidative potential of the seastars, higher cytotoxicity was caused by the EPS MP in comparison to that of PS (Barua, A et al 2021).

A study of EPS microplastic litter on five islands beaches in the Pearl River Estuary, China, highlighted that EPS acts as a carrier for heavy metals such as cadmium, chromium, arsenic, copper, nickel, manganese, iron and aluminium and might pose a threat to biological and human health (Xie, Q et al, 2021). A 2023 study in the UK found that aqueous and particulate metals such as cadmium (Cd), copper (Cu), lead (Pb), antimony (Sb) and Zinc (Zn) interact with the surface of beached marine EPS through adsorption, precipitation and entrapment and end up inside the polymer. In at least one of the environments studied, EPS seemed to be a significant carrier and means of exposing these metals in the marine environment (Twyford, S and A Turner, 2023).

Microplastics are potentially a source of the bioaccumulation of heavy metals and other chemicals. A review commissioned by New Zealand Food Safety in 2019 concluded that while it is thought that microplastics in the environment pose a low risk to human health, the manufacturing additives or chemicals adsorbed from the environment have been associated with human health effects and that the risk to human health from nanoplastics is unknown. Research programmes are now underway in New Zealand to specifically investigate if microplastics are a food safety concern (Pantos, Olga, 2019).

6.3. Toxic impact of nanoplastics and photodegraded EPS

Due to their small size, EPS nanoplastics are able to pass through membranes, accumulate in organs and bring about physiological harm on immune cells (Rubio et al., 2020). A study of EPS nanoplastics in mice observed accumulation of nanoplastics in the liver, spleen, lung, kidney, small intestine, large intestine, testis and brain after oral exposure to nanoplastics, with toxic effects. The nanoplastics were also observed to negatively impact on the blood system and cause lipid metabolism disorders (Xu D et al 2021).

Beyond microplastics and nanoplastics, there is evidence that even when EPS is degraded to the point where it cannot be seen by the eye there are still toxic impacts. In one study, EPS floating on water was exposed to UV light and produced fine particles that visibly polluted the water. The polluted water was filtered and the following dissolved organic compounds were extracted: Catechol (pyrocatechol or 1,2-dihydroxybenzene), benzoic acid, salicylic acid, 4-hydroxybenzoic acid, phthalic acid, terephthalic acid and isophthalic acid. These compounds have human health impacts including dermatitis, anaphylactic shock, nausea, vomiting, tinnitus, dizziness, headaches, confusion, delirium, hallucinations, convulsions, coma, respiratory failure, cardiovascular collapse, damage to liver and blood and one of the compounds is classified as a carcinogen. The study concluded that the photodegraded products of EPS should be considered equally threatening as micro and nano EPS particles. The study also concluded that due to the enormous amount of EPS produced, and its low recycling rate a large amount of potentially hazardous chemicals will be generated by the degradation of EPS in the environment (Lee, S et al 2022).

6.4. Link between microplastics and negative health effects

6.4.1. Link between microplastics and auto immune diseases

A study of mice found that there is evidence that microplastic consumption induces a mild increase in gut inflammation, which then prolonged the viral arthritis present in the mice, similar to enteropathic arthritis (previously called irritable bowel disease), which is an auto-immune disease (Rawle, DJ et al 2022). Another study examined the potential impact of microplastics entering the human body through the respiratory and digestive tract as an aggravating factor for rheumatoid arthritis (RA), which is also an auto-immune disease. The study found that microplastics aggravated RA cartilage damage and thus promote sustained damage for those suffering from RA (Lihua, C and T Zhiyin, 2023).

6.4.2. Link between microplastics and negative impact on cardiovascular health

A 2024 prospective, multicentre, observational study of patients undergoing treatment for asymptomatic carotid artery disease, found that patients with carotid artery plaque in which micro-nanoplastics were detected had a higher risk of a composite of myocardial infarction, stroke, or death from any cause at 34 months of follow-up than those in whom micro-nanoplastics were not detected (Marfella, R et al, 2024).

6.4.3. Link between microplastics and early onset colorectal cancer

An epidemiological study of the increasing incidence of colorectal cancer in those born after 1960 explored the possible role of microplastics in this. In New Zealand for example, the incidence of distal colonic cancer in men has increased by 14% per decade, the incidence of rectal cancer in men by 18% and in women by 14%. The study found the increase in incidence of colorectal cancer correlates with the increased incidence of microplastics in the environment. The authors concluded that microplastics may disrupt the mucus layer of the colon and thus reduce its protective effect and increase the likelihood of colorectal cancer (Li, S et al 2023).

7. Conclusion

7.1. Summary of literature reviewed

Topic	Evidence	Type of study
Microplastics are a widespread source of environmental contamination	Microplastics are widespread in marine environments (Hale, Robert et al, 2020) and (Gola, D et al 2021)	Hale et al - Literature review of existing published studies Gola et al – Literature review of existing published studies
	Microplastics are present in freshwater environments (Chaoran, L, 2019)	Literature review of existing published studies
	Microplastics are found in the air (Sridharan, S et al 2021)	Literature review of existing published studies
	Microplastics are found in terrestrial ecosystems (Zhang, J et al 2023)	Microcosm study
	Microplastics are found in in animals (Prata, J.C. et al 2022)	Post-mortem study of urban companion animals
EPS is a widely spread micro and nano plastic	EPS breaks into microplastics and nanoplastics while being used in marine products, through transportation, cutting, disposal, the recycling process, deterioration or loss of structure, or illegal dumping of polystyrene waste (Frey, B 2021).	Masters Thesis
	EPS escapes into the environment as microplastics through improper application and management in construction (Zadjelovix, V et al 2023 and anecdotal evidence from Auckland Council)	Case studies
	Burrowing organisms can produce hundreds of thousands of EPS microplastic particles per year (Jang, M et al, 2018).	Laboratory study
	EPS microplastics were found in floodplain soil located 500-600m from an EPS plant (Kukharchyk, T and V Chernyk 2021).	Case study
	It is estimated that humans ingest up to 5 grams of plastic per week (Senathirajah, Kala et al, 2021)	
EPS is present inside the human body	EPS Is one of the most widely present types of plastic in the human blood stream (Leslie, H et al, 2022)	Meta-analysis
EPS is toxic	EPS is made of styrene which is reasonably anticipated to be a human carcinogen (National Toxicology Program, 2021) and (NZ EPA)	
	EPS in housefires produces 57 chemicals including ones that are carcinogenic (Gurman et al, 1987, cited in Farrelly, T and I Shaw, 2017)	Literature review and laboratory studies
	Plant tissue and marine animals near an EPS plant showed increasing levels of HBCD concentration over a 5 year period (Zhu, H et al 2017)	Case study
	Toxic HBCD was detected in non-flame retardant EPS	Multi-country case study
	Marine environments aid the release of chemicals from EPS into the environment	Case study

	with toxic effects on mollusc species (Chelomin, V 2023)	
	EPS has more of an adverse effect on total count, phagocytic response, cytotoxicity and oxidative potential of a keystone species of Seastar in the Bay of Bengal than PS does (Barua, A et al 2021).	Laboratory study
	EPS is a carrier for toxic heavy metals (Xie et al, 2021)	Multi-island case study
	EPS is a carrier and means of exposure of heavy metals in marine environment (Twyford and Turner, 2023)	Case study
	EPS nanoplastics in mice were observed to negatively impact on the blood system and cause lipid metabolism disorders (Xu D et al 2021)	Animal laboratory study
	Water that had contained EPS floating on water and exposed to UV light was filtered and found to contain 7 organic compounds that have toxic effects on humans (Lee, S et al, 2022)	Laboratory study
Direct link between microplastics and negative effects on human health	Microplastic consumption prolongs a viral arthritis present (Rawle, DJ et al 2022)	Mice laboratory study
	Microplastics aggravate rheumatoid arthritis cartilage damage (Lihua C and T Zhiyin, 2023)	Laboratory study
	Micro-nanoplastics are implicated in a higher risk of a composite of myocardial infarction, stroke or death for patients undergoing treatment for asymptomatic carotid artery plaque (Marfella et al, 2024)	Multicentre observational study
	The timeline between the increased presence of microplastics in the environment and the rising incidence of colorectal cancer correlates. It is proposed that microplastics disrupt the colon's mucus layer (Li, S et al 2023).	Epidemiological study

7.2. Conclusion statement

EPS micro and nanoparticles meet the RMA section 2 definition of being contaminants and nanoparticles from EPS and may in some circumstances cause significant adverse environmental effects, as indicated in the reviewed literature. In addition, some chemicals that leach from EPS, and whole leachate, are capable of causing ecotoxic effects. The extent of those will depend on specific circumstances of the source and receiving environment. If or when EPS is burned, it produces a concentrated range of toxic substances. Runoff from a housefire that contained EPS would be a major environmental problem (similar to runoff from a tyre-fire). However, the RMA does not consider future potential discharges. The following section explores some recommendations that could be implemented in the construction sector to minimise the environmental impact of EPS.

8. Recommendations

8.1. Banning EPS from vertical wall panel systems in multi-story buildings

In 2021, the Minister for Planning for the state of Victoria, Australia prohibited the use of the external wall cladding products ACP and EPS for any building work in connection with Class 2 to 9 buildings[13] of Type A and Type B construction.[14] This ban was made after the Commonwealth Scientific and Industrial Research Organisation (CSIRO) conducted a literature review on EPS in EIFS and Insulated Sandwich Panels and then commissioned an independent full scale fire test of EPS with fire-retardant. The EPS with fire retardant was found to result in rapid vertical fire spread and pool fires when exposed to a large fire source (such as from a window opening or an external fire source).

8.2. Imposing fines on mismanaged EPS left on construction sites

Australia has an expanded polystyrene stewardship scheme and accompanying code of practice for expanded polystyrene pods used in construction. Management of waste EPS on site is the responsibility of the builder and they can be subject to fines under littering/waste control bylaws. However, under the EPSA charter and code of practice there is an expectation that pod waste will be bagged and collected from the site within 24-48 hours of notification from the builder. If this expectation is not met the builder can mitigate any fines. Major and visible incidents of poor waste control such as pod waste being blown off the site in very strong winds ultimately have led to stakeholders including the supplier working together to investigate and rectify any systematic failure in pod waste control.

[13] Domestic apartment buildings, residential buildings providing long-term or transient accommodation for a number of unrelated persons, a single domestic dwelling within a non-residential building (ie caretakers residence), office buildings, retail buildings, warehouses and carparks, factories and public buildings. https://www.vba.vic.gov.au/building/regulatory-framework/building-classes

[14] https://www.vba.vic.gov.au/__data/assets/pdf_file/0014/123710/Advisory-note-Prohibition-of-High-Risk-Cladding-Products.pdf

Appendix 1: Alternatives to Expanded Polystyrene in Construction

Not all uses of EPS have an alternative, and the situation is currently changing. The information below was an environmental scan at the time of writing, and is not an exhaustive list of alternatives, or an endorsement of the alternatives shown, rather is designed to demonstrate current marketed alternatives to EPS. Builders, specifiers or owners should do their own research as to the best product to use in their situation.

Foundation Systems

Plastic pods systems replace the need for EPS in foundations. As the EPS adheres to concrete, it means that at end of life, all the foundation materials may end in landfill. As the plastic does not adhere to concrete, it can be separated for recycling, resulting in a 100% recyclable foundation.

The plastic pod systems are generally made from polypropylene. Some manufactures use recycled only content, but all claim 100% recyclable plastic at end of life.

The plastic is also stackable meaning it is easier to manage on site and can be transported on smaller vehicles. There is also less environmental damage from wind spread polystyrene.

There are a number of manufacturers/suppliers in the NZ market with pod systems. Below are a few:

- Cleavaco – Clevapod - https://clevaco.co.nz/clevapod-system/
- QPOD - https://www.qpod.nz/
- Cupolex - https://bowersbrothers.co.nz/products/cupolex-concrete-forming-system/
- Firth – Ribraft X-Pod - https://www.firth.co.nz/concrete/foundations/xpod/

Suspended Timber Floor Insulation

Suspended timber ground floors can be insulated using glasswool (fibreglass) or wool sheets fitted between the floor joists and securely fixed or strapped in place. Most manufacturers will have a specific product for under floor use, which will have different properties, this can be confirmed by checking specifications.

There are a large number of products for this use, not all will be suitable for every situation:

- Greenstuf - https://greenstuf.co.nz/
- Glasswool – Earthwool - https://www.knaufinsulation.co.nz/products/earthwool-glasswool-floorshield-underfloor-batt
- Pink Batts - https://www.pinkbatts.co.nz/product-library/pink-batts-insulation/underfloor/pink-batts-snugfloor-insulation/
- Wool Insulation - https://www.woolinsulation.kiwi/shop/product/521490/underfloor-insulation--r2-0/?variantId=1327617

Wall and Ceiling Insulation

As with suspended floors, glasswool (fibreglass) or wool sheets, rolls or even loose fill are the most commonly used insulation products. Façade sheets are also available made from similar products with treatments for external use. Products for these applications are numerous.

Metal Roofing Systems

The only alternative available to EPS in metal roofing systems is PIR insulated panels. Depending on installation location, access to the manufacturer's recycling schemes and use, PIR may or may not provide a better environmental choice.

Composite (multi-material) masonry and concrete blocks

EPS has been added to masonry and concrete blocks to reduce weight which can reduce costs in buildings as well as increase the speed of the build. It can also support better thermal and sound insulation.

- Traditional concrete blocks are still an alternative in many of these cases.

Packaging for many building products, such as doors, windows, and panels

As a short-lived and consumer facing use of EPS – packaging alternatives have grown in recent years.

- Corrugated cardboard is now commonly used, and can be manufactured as cradles or inserts as well as corrugated sheets. Custom designed fittings mean that it can minimise any disruption of products in transport.
- Cellulose, plant based, or starch foams and pops are becoming more common. Some advertise as being home compostable. - https://www.friendlypak.co.nz/Products/Foam-Protection-Products/Pop-Starch-Voidfill

Create decorative elements such as architectural mouldings and columns

- Plastic reusable mouldings are now also available for some decorative elements.

Geofoam in soil stabilisation and lightweight fill applications, such as embankments and retaining walls

- Pumice or Clay can be used instead in some situations.

Decorative facades made of concrete to help make this product lighter

Autoclaved Aerated Concrete (AAC) technology has been in use for over 70 years. A number of NZ manufacturers and suppliers have a range of panels and blocks on the market- typically used for exterior wall cladding, fencing and in some cases flooring.

- Enviro AAC Panel - https://mpb.co.nz/product/enviro-aac-panel-cladding
- Hebel panels - https://hebel.co.nz/aac/
- INTEGRA - https://reseneconstruction.co.nz/system/integra-lightweight-concrete-facade-system/

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