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Microplastics and nanoplastics in soil, water, and air

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EXECUTIVE SUMMARY

Microplastics (MPs) and nanoplastics (NPs), collectively referred to as MNPs, are synthetic polymer particles originating from both the intentional manufacture of small plastic particles (e.g., glitter) and the fragmentation of larger plastic items. Due to their persistence, small size, and mobility, MNPs are now ubiquitous across all environmental compartments, including air, freshwater and marine systems, soils, sediments, and biota, resulting in widespread ecological and human exposure.

There is broad international agreement that MNPs represent an emerging risk to ecological integrity and human health. Evidence demonstrates a range of biological effects associated with MNP exposure, including physical impacts on organisms, chemical toxicity linked to plastic-associated additives and sorbed contaminants, and biological effects arising from plastic-microbe interactions. However, MNPs are highly heterogeneous, varying in size, morphotype, polymer type, degree of weathering, and associated chemical and biological components. This variability leads to substantial heterogeneity across studies, with effects often being system-, species-, and context-specific.

As a result, while the ubiquity of MNPs and many of their potential biological effects are well recognised, the overall state of knowledge regarding their impacts, particularly on human health, remains unresolved. The evidence base is established but incomplete, and current certainty regarding impact magnitude and mechanisms is best described as medium, with key knowledge gaps persisting.

Establishing routine and coordinated monitoring of MNPs across air, water, and soils, and key source pathways such as wastewater discharges, would substantially improve understanding of real-world exposure levels and particle types. Such monitoring would reduce uncertainty, improve comparability across studies, and support research that more accurately reflects environmentally relevant exposure conditions. Given the persistence of plastics and the lack of viable remediation options for MNPs once released, a precautionary focus on monitoring and source reduction remains central to managing future risks.

MICRO-/NANOPLASTICS

INTRODUCTION

Microplastics (MPs) and nanoplastics (NPs) are synthetic polymer particles typically defined as <5 mm and <1 µm in size [1, 2], respectively. From here on, MPs and NPs are referred to as MNPs, unless otherwise specified. MNPs are a multifaceted contaminant, not only presenting both a physical and complex chemical risk but also altering microbial risks due to the plastic-microbe interactions that occur. Particles originate from multiple sources [3], and are either produced at that size (primary MNPs) or formed by the mechanical abiotic fragmentation of larger plastic items (secondary MNPs), including, but not limited to, abrasion of synthetic textiles and clothing during wear and washing, as well as tyre and road wear. Plastic waste recycling processes, particularly mechanical recycling of post-consumer plastics (e.g., electronics, clothing, packaging) are an additional source of MNPs to the environment via atmospheric and wastewater discharge [4, 5]. Biotic fragmentation, for example through biting, has also been shown to be caused by a wide range of taxa and ecosystems [6]. MNPs have been identified in all environments (surface and groundwater, marine water and sediments, soil and air) and taxa examined [3], including humans. MNPs have also been identified in tissues (e.g. lung, brain, placenta) [7-10], and bodily fluids (blood and breastmilk) [11-13]. Their low density and durability enable MNPs to be transported long distances by wind and water, leading to widespread environmental distribution and accumulation on shorelines, the deep sea, the water column, soils and sediments. Uptake by organisms, from those at the base of the food web to apex predators, provides pathways for these particles to enter food webs, including those relevant to human food systems, thereby extending contamination across environmental compartments.

Plastic particles are complex contaminants composed of synthetic polymer matrices and a wide range of chemicals, either within the polymer matrix, but not covalently bonded (e.g., plasticisers) or resulting from surface treatments (e.g., stain protectants), as well as chemicals acquired from the environment [14, 15]. They can also act as vectors for microbial contaminants, including pathogens, antibiotic resistance genes, mobile genetic elements and other bioactive agents such as endotoxins, mycotoxins, glucans, and fungal spores. [16]. While there is a robust body of evidence of the adverse health effects of many plastic-associated chemicals [17, 18], including those in MNPs, and the microbial contaminants that become associated with them, understanding of the role of MNPs themselves and the combined effects of these different factors requires further study [19].

STATE OF KNOWLEDGE OF ‘MICRO-/NANOPLASTICS ATTRIBUTE

The potential impacts of MNPs on organisms and ecosystem health and function are an emerging concern globally [3]. There is broad international agreement that MNPs pose ecological risks; however, their high complexity and heterogeneity (including variation in size, shape, polymer type, ageing processes and associated chemical and biological contaminants) create significant challenges for accurate quantification across diverse environmental matrices. These difficulties are further exacerbated by methodological constraints and the absence of standardised analytical approaches [20-24]. Combined, these challenges hinder the robust assessment of biological impacts and the generation of consistent, comparable data on how MNPs affect organisms, ecological processes, and overall ecosystem health [3].

Similarly, evidence linking MNP exposure to human health impacts is emerging and, although limited, there is broad international agreement that they represent a credible and emerging risk to human health [25-28]. There is consensus that increased research effort is required to better understand the wide range of exposure pathways, interactions and potential impacts [29, 30]. This uncertainty warrants adoption of a precautionary approach while critical knowledge gaps are addressed. With the World Health Organisation (WHO) recommending that whilst the risks they pose are not fully understand it is agreed that they do not belong in the environment and “measures should be taken to mitigate exposure” [31].

Although it is well established that environmental MNPs are ubiquitous, and that they can have biological effects, the high variability in particle characteristics results in substantial variability across studies. This limits the ability to derive a fully generalised understanding, as observed responses are often system-, species- and context-specific. Consequently, the overall state of knowledge of the impacts of MNPs on environmental health, and to a greater degree human health, are considered to be unresolved, with medium certainty. While the evidence base is established but incomplete, the overall certainty regarding the impacts of MNPs on ecosystem functioning and human health may be described as medium, with the exact mechanisms and magnitude of the effect currently of poor certainty in some areas. Establishing routine and coordinated MNPs monitoring programmes across air, water and soils, and potentially major source pathways such as biowaste[1] discharge, would improve the state of knowledge by providing robust information on environmental exposure levels and particle type. This would reduce uncertainty, improve comparability between studies, and enable experimental studies to be better aligned with real-world exposure conditions.

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[1] Biowaste refers to biodegradable organic waste of plant and/or animal origin generated in the home and commercial environment. For example, food waste compost.

PART A: ATTRIBUTE & METHOD

A1. HOW DOES THE ATTRIBUTE RELATE TO ECOLOGICAL INTEGRITY OR HUMAN HEALTH?

Micro- and nanoplastics (MNPs) are pervasive contaminants that affect ecological integrity and human health through their widespread distribution, persistence, and interactions with biological systems. They are now recognised as global pollutants, ubiquitous across marine, freshwater, terrestrial (including soil) and air and atmospheric domains and interacting with organisms from the base of food webs to apex predators, including humans. While the occurrence of MNPs is widespread, key uncertainties remain. For example, the existence of synergistic effects of different chemical and physical characteristics, the effects of long-term exposure levels, cumulative effects, and dose-response relationships, particularly for chronic and low-level exposure.

MNPs influence ecological integrity by disrupting fundamental ecological processes and organism health across multiple ecosystems. Their physical presence can cause ingestion-related stress, physical damage, and altered feeding behaviour, while their chemical properties allow them to transport and release additives and sorbed environmental contaminants [32]. In addition, MNPs act as substrates for microbial communities, including pathogens and antibiotic resistance genes, creating novel ecological niches that may alter ecosystem structure and function [33-35] as well as influencing the dispersal of marine organisms affecting biodiversity and ecosystem function [36]. Emerging evidence indicates that MNPs also interact with climate systems. By absorbing and scattering solar radiation, they can alter the atmospheric radiation balance [37], and by acting as ice-nucleating particles they can induce cloud ice formation, driving changes in cloud development and precipitation patterns and thereby linking plastic pollution to broader climate processes [38]. The durability of MNPs leads to their accumulation in soils, sediments, and biotic tissues, reducing ecosystem resilience and potentially altering nutrient cycling, soil structure [39-42], and food-web dynamics [43]. These impacts compromise ecosystem health and function, particularly when combined with other environmental stressors such as chemical pollution and climate change.

Table 1: Examples of studies where plastic particles have been found to be present in human organs, tissues, and bodily fluids.

Organ/Tissue/Fluid	Reference
Blood	Brits *et al.,* 2024 [12]
	Leonard *et al.,* 2024 [11]
Urine	Song *et al.,* 2024 [44]
	Rotchell *et al.,* 2024 [45]
Liver	Hovartis *et al.,* 2022 [46]
	(Nihart et al. 2025) [7]*
Brain	(Li et al. 2026) [47]
	(Nihart et al. 2025) [7]*
	(Amato-Lourenço et al. 2024) [48]
Lung	(Jenner et al. 2022) [8]
	(Amato-Lourenço et al. 2021) [9]
	(Zhu et al. 2024) [49]
Gastrointestinal tract (incl. faeces)	(Hartmann et al. 2024) [50]
	(Özsoy et al. 2024) [51]
	(Zhu et al. 2024) [49]
Placenta	(Ragusa et al. 2021) [10]
	(Halfar et al. 2023) [52]
	(Zhu et al. 2024) [53]
Virgina	(Shim and Min 2025) [54]
Breastmilk	(Ragusa et al. 2022) [13]
Semen	(Montano *et al*. 2023) [55]
	(Zhao *et al*. 2023) [56]
Carotid plaque	(Marfella *et al*. 2024) [57]

* This study [7] has received feedback of substantive concerns about the validity of this study's findings, citing limitations in analytical specificity and potential artefacts associated with the methods used; accordingly, the results should be interpreted with caution [58].

There are multiple exposure pathways of MNPs for humans, including ingestion of contaminated food and water and inhalation of airborne particles [22, 59] and through medical interventions such as infusion therapy [60, 61]. MNPs have now been detected in human tissues and bodily fluids, indicating internal exposure and systemic distribution (Table 1). MNPs can act as combined physical, chemical, and biological stressors. Potential mechanisms relevant to human health include inflammation, oxidative stress, immune modulation, and the vectoring of plastic-associated chemicals [15, 62-64] and microorganisms [65-68] known to cause harm.

A2. WHAT IS THE EVIDENCE OF IMPACT ON (A) ECOLOGICAL INTEGRITY OR (B) HUMAN HEALTH? WHAT IS THE SPATIAL EXTENT AND MAGNITUDE OF DEGRADATION?

Current understanding of the impacts of MNPs on ecosystem integrity and organism health is good/established but incomplete. Due to the highly complex nature of this heterogeneous contaminant, the scientific community has faced significant challenges in testing its impact on organisms and ecosystems [3]. Although critical knowledge gaps exist, evidence to date broadly report consistent findings. MNPs affect ecological integrity by impacts on individual organism health and behaviour, altering species interactions, and impairing ecosystem functions. Effects across taxa include reduced growth and development of both plants and animals at different life stages [69, 70], altered feeding behaviour, physiological stress, immune disruption, and microbiome dysbiosis. These organism-level effects can scale up to influence food-web dynamics, nutrient cycling, and overall ecosystem resilience, particularly when MNPs interact with other stressors such as chemical pollution and climate change [71-74]. An example of the diversity and complexity of exposure routes and impacts is that of honeybees [75, 76]. This ecologically critical group is affected by airborne MNPs. Studies have identified the presence of MNPs in hives resulting from natural ventilation, and deposition of particles that have attached to bees' setae (fine hairs) that cover their bodies as they fly or those that have settled on the flowers and foliage that become attached to the setae or are gathered with pollen and nectar during foraging [76-78]. They have also been shown to be internalised within the bees, and may have both direct and indirect effects on bee health, including gut damage and microbiome dysbiosis [75, 77, 79-82], disease susceptibility, body condition, foraging and feeding behaviour [83, 84].

Evidence linking MNPs to human health impacts is emerging and although limited there is broad international agreement that they represent a credible and emerging risk to human health [25-28], warranting a precautionary approach whilst critical knowledge gaps are addressed. The spatial extent of potential human exposure is global due to the widespread environmental distribution of MNPs across air, food, water and soil, including in urban, rural, and remote environments. Laboratory studies indicate that MNPs, particularly NPs, can induce inflammation and oxidative stress, disrupt cellular membranes and signalling, and interfere with immune, metabolic, and reproductive functions (Figure 1). Experimental evidence also suggests that MNPs can cross biological barriers [24] and act as vectors for plastic-associated chemicals and microorganisms, resulting in combined physical, chemical, and biological stress responses. While these findings support the biological plausibility of human health impacts from MNP exposure, further research is required to characterise exposure-response relationships and determine the relevance and magnitude of these effects under real-world, long-term exposure conditions [21, 85].

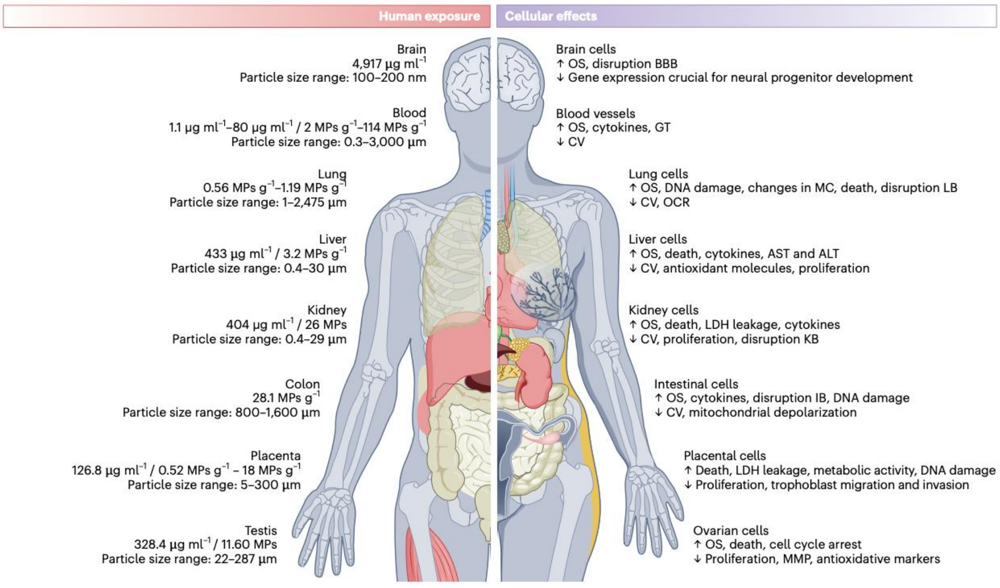

Figure 1: Human MNP exposure and cellular effects. A summary of information on recent detection of MNPs in human biofluid and tissue and observed cellular effects in model systems. ALT, alanine transaminase; AST, aspartate aminotransferase; BBB, blood–brain barrier; CV, cell viability; GT, genotoxicity; IB, intestinal barrier; KB, kidney barrier; LB, lung barrier; LDH, lactate dehydrogenase MC, morphology cells; MMP, mitochondrial membrane potential; OCR, oxygen consumption rate; OS, oxidative stress. Reproduced with permission from Springer Nature; from Lamoree *et al.,* (2025).

In addition to having direct effects on biological systems, MNPs in the atmosphere have been linked to processes such as cloud formation, precipitation, and interactions with Earth's radiation balance [37, 86-88]. Plastic particles can act as cloud condensation nuclei or ice-nucleating particles, enabling them to influence cloud formation, cloud albedo, precipitation patters and cloud lifetime. These interactions can alter the radiation balance, and wider weather and climate systems, although knowledge gaps exist regarding the magnitude of these effects.

A3. WHAT HAS BEEN THE PACE AND TRAJECTORY OF CHANGE IN THIS ATTRIBUTE, AND WHAT DO WE EXPECT IN THE FUTURE 10 - 30 YEARS UNDER THE STATUS QUO? ARE IMPACTS REVERSIBLE OR IRREVERSIBLE (WITHIN A GENERATION)?

Global evidence indicates the abundance of MNPs have increased in tandem with rising plastic production and use, however the pace and trajectory of change is difficult to quantify due to limited monitoring and a lack of standard methods [23]. For example, MPs detected in ombrotrophic peat (fed only by atmospheric precipitation) in the French Pyrenees demonstrated a ~3500% increase in MP abundance between the 1960s and 2015-2020 [89], aligning with the trend in European plastic production and waste management. Similarly, sediment cores worldwide consistently show strong increases in MPs deposition over time, typically beginning in the mid-20th century and accelerating into the 1990s–2010s [90-92].

Annually 10-40 Mt of MNPs are estimated to enter the global environment [3]. The equivalent of up to 2 million fully loaded garbage trucks. Under the status quo, with global plastic production projected to double by 2040 [93], MNP levels are expected to escalate significantly over the next 10-30 years, driven not only by the production, use and disposal of new plastics, but also the continued fragmentation of plastics already in existence. The resilient nature of plastic means that, without elimination of the use of primary MNPs (e.g., slow-release fertilisers that use synthetic polymer coatings [94]), suitable remediation of existing environmental MNPs, and management of whole plastic items (e.g. post-consumer waste) to mitigate the genesis of secondary particles, MNPs will accumulate and persist in the environment, posing ongoing risks to ecological integrity and human health. Currently, there are no viable remediation methods available to address MNP pollution.

A4-(I) WHAT MONITORING IS CURRENTLY DONE AND HOW IS IT REPORTED? (E.G., IS THERE A STANDARD, AND HOW CONSISTENTLY IS IT USED, WHO IS MONITORING FOR WHAT PURPOSE)? IS THERE A CONSENSUS ON THE MOST APPROPRIATE MEASUREMENT METHOD?

Globally, the monitoring of MNPs is dominated by research-led studies, rather than routine regulatory or compliance monitoring. International research efforts have focused primarily on water matrices (marine, freshwater, wastewater, and drinking water), with more limited and fragmented assessment of levels in air, soils, sediments, biota and sources to the environment, such as in biowaste. The European Commission is introducing requirements (Directive (EU) 2025/2360) for Member States to monitor soils for a range of emerging contaminants, including microplastics. The EU's *Marine Strategy Framework Directive* includes the provision for microplastics monitoring however currently only plastics >25 mm are included in monitoring [95], and the Arctic Council, which crosses over Nordic EU waters, is conducting MP monitoring in a range of environmental matrices, including sand, water, sediments terrestrial environments, freshwater systems, and organisms as part of the Arctic Monitoring and Assessment Programme: Litter and Microplastics Monitoring Plan [96].

A4-(II) ARE THERE ANY IMPLEMENTATION ISSUES SUCH AS ACCESSING PRIVATELY OWNED LAND TO COLLECT REPEAT SAMPLES FOR REGULATORY INFORMING PURPOSES?

It is not anticipated that there would be significant implementation issues associated with accessing sites or collecting repeat samples for MNPs, provided that monitoring is integrated into existing sampling programmes and infrastructure.

Logistically, MNP sampling could be co-located with established environmental and public-health monitoring activities, reducing the need for additional site access or the establishment of new monitoring networks. For example, sampling could be incorporated into routine shellfish monitoring programmes currently undertaken for food safety purposes (such as biotoxin and contaminant testing), provided that appropriate sampling, handling, and contamination-control protocols for microplastics analysis are applied. Similarly, sampling in water bodies could be integrated with existing drinking-water, wastewater, coastal, or freshwater quality monitoring programmes, avoiding the need for new permissions to access privately owned land. Accessing access to privately owned land for collecting soil samples for State of the Environment Monitoring is not necessarily problematic, obtaining access for regulation-informing sampling would be more challenging.

The main practical considerations relate not to site access, but to ensuring that sampling and sample handling meet the specific requirements for MNP analysis, including strict contamination controls, adequate sample volumes, and compatibility with downstream analytical methods. These requirements may place additional constraints on how samples are collected and processed, but they do not represent fundamental barriers to implementation.

A4-(III) WHAT ARE THE COSTS ASSOCIATED WITH MONITORING THE ATTRIBUTE? THIS INCLUDES UP-FRONT COSTS TO SET UP FOR MONITORING (E.G., PURCHASE OF EQUIPMENT) AND ON-GOING OPERATIONAL COSTS (E.G., ANALYSIS OF SAMPLES).

Costs for monitoring depend on the specific objectives, sample type (matrices[2]) type, sampling requirements (see A4-(ii)), processing requirements and analytical methods selected. Currently, the most accepted analytical methods for the identification of MNPs are spectroscopic methods (primarily micro-Fourier Transform Infrared spectroscopy (µFTIR), Raman spectroscopy and Laser Direct Infrared Imaging (LDIR)) and pyrolysis–gas chromatography–mass spectrometry (pyr-GC/MS). Both methods identify polymer types, but they differ in their approach and the level of qualitative and quantitative detail they provide (Table 2). The costs of these analytical instruments are in the range of ca. NZD $200,000-$450,000, depending on the model and accessories. Operating costs are minimal, but they require experienced technical staff to run and maintain equipment and interpret data. Additional accreditation costs may also be incurred should the testing facility require accreditation to support regulatory compliance and monitoring. Currently, the only formal microplastics-specific accreditation scheme is the *California Environmental Laboratory Accreditation Program*[3], which is the first accreditation programme for microplastics analysis and does so specifically for the monitoring of drinking water.

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[2] Indicative categories: food, water (freshwater/marine/groundwater/tap water), sediments, soils

[3] https://www.waterboards.ca.gov/drinking_water/certlic/labs/

Table 2: Comparison of the two most widely used analytical methods for nano- and microplastic quantification for soil, air and water sample analysis. The table summarises the particle-level information each method can provide, their analytical strengths and the key limitations and indicative costs. Instrument costs vary depending on model and configuration, which are determined by analytical requirements. Labour costs are presented as estimated hours per sample and depend upon the level of analysis and processing required. Consumable costs are not included as they vary considerably based on samples type.

	FTIR (Fourier Transform Infrared) spectroscopy	**pyr-GC/MS (pyrolysis-gas chromatography/mass spectrometry)**
Particle size analysis	Yes >20 µm	No
Particle shape/morphotype analysis	Yes	No
Particle number/count	Yes	No
Polymer mass	No	Yes
Advantages	• Data on key risk factors: size, number and morphotype	• No size limitations (includes NPs) • Provides polymer mass
Limitations	• Limited to MNP >20 µm • Labour intensive • Extensive processing increases contamination risk.	• No data on size, number or morphotype • Susceptible to interference from naturally occurring organic compounds in environmental matrices, which can complicate polymer identification and quantification.
Analysis available in NZ*	Yes[†]	No
Estimated instrument purchase cost	NZ$200k-450k	NZ$200k-450k
Labour per sample (soil, sediments, biosolids, air and water) [††]	6-12 hours	3-6 hours
Approx. cost per sample[#]	NZ$2500-5000	$1500-3000

* Commercial service. Research capability exists but not generally offered as a commercial service.

[†] The availability is contingent on the analytical requirements (e.g., detection limit required to obtain interpretable results for the sample).

[††] Development of bespoke protocols due to high heterogeneity in matrices resulting in greater labour costs.

[#] Cost may be reduced by doing samples in batches.

The closest commercial service with accredited laboratory capability for MNP analysis is Eurofins Environment Testing (Melbourne, Australia). The facility holds ISO/IEC 17025:2017 accreditation (via NATA) for MPs testing in water and offers analysis across a range of matrix types. Particle analysis is conducted by LDIR, with a particle size range of 20-5000 µm size. Use of this service from New Zealand may be constrained by Australian biosecurity requirements for the importation of certain sample types. Other international Eurofins laboratories are able to provide MNP analysis with a range of other analytical methods.

A5. ARE THERE EXAMPLES OF THIS BEING MONITORED BY IWI/MĀORI? IF SO, BY WHO AND HOW?

We are not aware of MNP monitoring being undertaken by iwi/hapū/rūnanga.

A6. ARE THERE KNOWN CORRELATIONS OR RELATIONSHIPS BETWEEN THIS ATTRIBUTE AND OTHER ATTRIBUTE(S), AND WHAT ARE THE NATURE OF THESE RELATIONSHIPS?

There is currently no evidence of MNPs being correlated with other attributes.

PART B: CURRENT STATE AND ALLOCATION OPTIONS

B1. WHAT IS THE CURRENT STATE OF THE ATTRIBUTE?

Evidence of the distribution and abundance of MNPs in all ecosystem compartments in New Zealand is extremely limited.

Soils from four urban sites in Auckland were analysed for microplastic contamination [97]. Polypropylene (PP) was the predominant plastic polymer identified (13.81 µg/g soil at stormwater outlet[4]), with a range of other polymers commonly used[5] in a range of items (polymethyl methacrylate (PMMA), styrene-butadiene rubber (SBR), polyethylene (PE), polycarbonate (PC), polyvinyl chloride (PVC), polyethylene terephthalate (PET) and nylon 66 (PA66)) also found. Two other studies have examined the MP load in biowaste routinely applied to New Zealand soils, therefore providing an indication of the input to soils.

Biosolids, compost and vermicompost contribute an estimated 1.10×10^7 to 2.71×10^7 microplastics particles, per hectare annually when applied to land, and these inputs consist predominantly of PP, PE and PMMA, with lesser abundance of polymers such as PET, polystyrene (PS), polyurethane (PU), nylon, PVC and a range of biodegradable[6] polymers (polylactic acid (PLA), polybutylene adipate terephthalate (PBAT), polycaprolactone (PCL) and poly(methyl vinyl ether-co-maleic anhydride) (PVA/MA) [98]. Liquid effluent from wastewater treatment plants with tertiary-level treatment in New Zealand have been estimated to discharge 8.7×10^7 MP particles annually and therefore present a major source of MPs to soils when discharged to land [99]. Polymer types were predominantly polyester, PE and PP, with a range of others also present (e.g., rayon, acrylic, PTFE, PA, PVC, silicone).

Limited data exists for the abundance of MNPs in biota, including food species, from New Zealand environments. Microplastics have been identified in a range of wild-caught commercial finfish species [100], shellfish [101] as well as in the stomachs of the common dolphin (*Delphinus delphis*) [102] and the faeces of baleen whales [103].

Microplastics have been documented in beach sediments in four regions in New Zealand (Canterbury, Waikato, Auckland and Northland) [104-106] although data is limited and highly heterogeneous. The most comprehensive study was that by de Lena *et al.,* (2025) which optimised isolation methods for both large and small MPs, and showed that small MPs (<300 µm) comprised >99% of detections with a mean abundance of 788 MPs kg^{-1} dry sand, highlighting the likely underestimation of previous studies where smaller particles are not measured. Plastic polymer types identified were representative of commonly used plastics, similar to those found in soils and biowaste.

Microplastics have been detected in freshwater environments in New Zealand, although published data is very limited with only two studies having been conducted both of which are limited to urban streams [107, 108]. Both studies found MPs to be present at all sites and were representative of commonly used plastics.

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[4] Analysis was carried pyr-GC/MS providing the mass concentration of the polymers.

[5] Examples of common uses: PP – food packaging (e.g., bottle lids); PMMA – acrylic paint; SBR – vehicle tyres; PE – food packaging (e.g., milk bottles); PC – headlights; PVC – guttering/pipes; PET – food packaging (e.g., drink bottles), and PA66 – tyre reinforcing.

[6] Biodegradable polymers undergo complete microbial remineralisation under optimal environmental conditions.

Airborne MNPs have been detected in both densely populated urban areas and remote regions of New Zealand. The first study, conducted in Christchurch in 2021 [109], focused primarily on sampling methodology, while subsequent studies in Auckland reported exceptionally high deposition rates equivalent to thousands of particles per square metre per day (estimated at 74 tonnes annually) [110]. More recent studies have identified airborne MNPs at Mt John Observatory in the Southern Alps [111] and the Southland coast [112], confirming long-range transport. Whilst limited, these results align with global studies which have demonstrated the presence across all major environmental compartments, including densely populated urban areas, remote wilderness regions, polar environments, and even the free troposphere, and therefore it is expected that the same would apply in New Zealand. However, due to the unique characteristics of New Zealand (e.g. population density, industry, geography and climate), international studies are not indicative of the levels of local airborne MNPs. A single study has also examined the levels of indoor MNPs, which demonstrated that levels were an order of magnitude higher than outdoors [113] aligning with global studies that have demonstrated that indoor environments represent hotspots for MNP exposure [114, 115]. Again, polymer type reflected common use plastics, in particular polyester which is used extensively in textiles and clothing.

There is currently no data on the levels of MNPs in food (other than some seafood species as mentioned above) or drinks in New Zealand, including drinking water sources waters such as groundwater and surface-water reservoirs. Data are also lacking for other environmental compartments, particularly marine water and benthic sediments.

B2. ARE THERE KNOWN NATURAL REFERENCE STATES DESCRIBED FOR NEW ZEALAND THAT COULD INFORM MANAGEMENT OR ALLOCATION OPTIONS?

Microplastics and nanoplastics are synthetic materials that do not occur naturally in the environment. Consequently, there is no natural reference state for these particles, and any detection of MNPs reflects contamination resulting from human activities.

B3. ARE THERE ANY EXISTING NUMERIC OR NARRATIVE BANDS DESCRIBED FOR THIS ATTRIBUTE? ARE THERE ANY LEVELS USED IN OTHER JURISDICTIONS THAT COULD INFORM BANDS? (E.G., US EPA, BIODIVERSITY CONVENTION, ANZECC, REGIONAL COUNCIL SET LIMIT).

There are currently no established numeric or narrative bands for MNPs. Studies have reported levels of abundance; however, these values vary widely depending on sampling and quantification methods, as well as location. No regulatory standards or guideline thresholds exist at national or international levels, and narrative descriptors such as “low” or “high” exposure have not been formalised. This gap reflects the emerging nature of research on environmental MNPs and the lack of consensus on ecological and human health impacts and measurement protocols. The establishment of any type of human or ecosystem health band or threshold (assuming a safe level) are therefore considered to be very far away.

B4. ARE THERE ANY KNOWN THRESHOLDS OR TIPPING POINTS THAT RELATE TO SPECIFIC EFFECTS ON ECOLOGICAL INTEGRITY OR HUMAN HEALTH?

Currently, no scientifically established thresholds or tipping points exist for MNPs in relation to ecological integrity or human health [21, 116].

B5. ARE THERE LAG TIMES AND LEGACY EFFECTS? WHAT IS THE NATURE OF THESE, AND HOW DO THEY IMPACT STATE AND TREND ASSESSMENT? FURTHERMORE, ARE THERE ANY NATURALLY OCCURRING PROCESSES, INCLUDING LONG-TERM CYCLES, THAT MAY INFLUENCE THE STATE AND TREND ASSESSMENTS?

Although lag times and legacy effects of MNPs are unknown, their abundance is expected to continue increasing substantial in the coming decades (see A3). Therefore, resulting in increased levels of exposure.

B6. WHAT TIKANGA MĀORI AND MĀTAURANGA MĀORI COULD INFORM BANDS OR ALLOCATION OPTIONS? HOW? FOR EXAMPLE, BY CONTRIBUTING TO DEFINING MINIMALLY DISTURBED CONDITIONS, OR UNACCEPTABLE DEGRADATION.

Māori identify MP pollution and the contamination of food and water as significant threats to whakapapa, mahinga kai, cultural identity, and intergenerational wellbeing [117]. This reflects a relational worldview in which harm to te taiao is experienced as harm to people and communities. Mātauranga Māori emphasises holistic, interconnected, and place-based understandings of environmental pressures. These perspectives highlight that plastics and MPs affect Māori not only physically but also culturally and spiritually, particularly through impacts on kaimoana, water health, and the integrity of customary food systems. Accordingly, bands and allocation options should be co-designed [117-119] with mana whenua and should incorporate Māori environmental outcomes alongside biophysical indicators of MP presence and associated contaminants. This approach aligns with Māori expectations of environmental stewardship and supports the restoration and protection of te taiao.

PART C: MANAGEMENT LEVERS AND CONTEXT

C1. WHAT IS THE RELATIONSHIP BETWEEN THE STATE OF THE ENVIRONMENT AND STRESSES ON THAT STATE? CAN THIS RELATIONSHIP BE QUANTIFIED?

Due to MNPs originating from a wide range of domestic and industrial sources across the biosphere (air, water, soils), and because of their high mobility, the limited studies available to date do not allow the specific origin of MNPs in New Zealand to be determined. It is expected that abundance will continue to increase with the projected increase in plastic production and use, both nationally and internationally.

International evidence indicates that policies or strategies aimed at reducing the use of plastic items that can become a source of secondary MNPs, phasing out products that contain primary MNPs, and improving waste-management practices can lead to a reduction in levels of MNPs entering the environment [120, 121]. For example, following the introduction of bans on the use of MPs in personal care products in the US and Canada, MP abundance Toronto wastewater effluent decreased by up to 86%. A corresponding reduction was also observed in MP levels in the receiving environment of Lake Ontario [122]. Reviews of global governance strategies highlight that stricter municipal and national regulations can lower plastic consumption and limit MNP generation at source, thereby reducing the volume of particles entering the environment. While direct empirical evidence demonstrating subsequent declines in local environmental MNP concentrations is sparse, it is widely agreed that source-reduction measures provide effective management strategies for the reduction of local airborne MNPs [123, 124]. However, caution is required when relying on voluntary actions such as phase-outs, as the effectiveness of these approaches have been found to be inconsistent and often ineffective [125].

C2. ARE THERE INTERVENTIONS/MECHANISMS BEING USED TO AFFECT THIS ATTRIBUTE? WHAT EVIDENCE IS THERE TO SHOW THAT THEY ARE/ARE NOT BEING IMPLEMENTED AND BEING EFFECTIVE?

C2-(I). LOCAL GOVERNMENT DRIVEN

There are currently no local government-led initiatives specifically addressing MNP release into the environment.

C2-(II). CENTRAL GOVERNMENT DRIVEN

Control of primary MNPs have been achieved through the *Waste Minimisation (Microbeads) Regulations 2017* which banned the manufacture and sale of wash-off products[7] containing plastic microbeads in New Zealand from 7 June 2018. The purpose

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[7] Wash-off product means a product that is intended to be rinsed off during or after use. Product types include personal care products (exfoliating cleansers, toothpaste), abrasive surface cleaners, and products where microbeads are added to alter visual appearance (e.g. glitter bubble bath).

of the ban was to prevent intentionally added microbeads (a microbead being a “water-insoluble plastic particle that is less than 5 mm at its widest point” (reg. 3)) from entering aquatic environments, where they pose risks to wildlife and human health. Products which use primary MPs that are not covered in this ban include wipe-off products such as cosmetic makeup, crafting materials and medicines and medical devices for therapeutic purposes. Regulation of a range of plastic products, including bans and upcoming product stewardship strategies, will also lead to a reduction in the sources of secondary MNPs. The product stewardship scheme for agrichemicals[8] will support the rural recycling of agrichemical containers and farm plastics[9], preventing the practice of disposal by burying or burning. The phasing out[10] of single-use-plastics (SUPs) considered to be hard-to-recycle[11], as part of the Waste Minimisation (Plastic and Related Products) Regulations 2022 (SL 2022/69) will prevent leakage of these items to the environment and the contamination of the waste plastic recycling stream.

Given the substantial knowledge gaps that persist around MNP toxicity, exposure pathways, fate and potential tipping points there are currently no established thresholds of reference values that would allow MNPs to be readily incorporated into existing regulatory frameworks. As knowledge gaps are filled it may become technically feasible to consider MNPs within instruments such as the NES-Contaminated Soils, the HSNO Act, or related mechanisms.

C2-(III). IWI/HAPŪ DRIVEN

There are currently no formal iwi or hapū-led initiatives specifically addressing MNP release into the environment.

C2-(IV). NGO, COMMUNITY DRIVEN

There are currently no NGO or community initiatives in New Zealand-focused specifically on addressing MNP release into the environment.

C2-(V). INTERNATIONALLY DRIVEN

International efforts to reduce the formation and release of MNPs are underway through several complementary mechanisms. A *Global Plastics Treaty* has the overarching aim of reducing plastic pollution, including in the marine environment, through the introduction of legally binding measures targeting MNPs, particularly those intentionally added to products or created during manufacturing, and the overall reduction in production of primary plastics. The United Nations Environment Assembly (UNEA) resolution on marine litter and MPs (UNEP/EA.3/Res.7) calls on countries to address land-based sources, strengthen monitoring, and improve research collaboration. The *Basel Convention* also indirectly contributes by tightening controls on the transboundary movement of plastic waste, reducing mismanaged plastics that would otherwise

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[8] Announcement made in December 2025 of plans for implementation. Farm plastics recycling scheme gets green light | Beehive.govt.nz

[9] Agrichemical containers, bale wrap and silage sheet, small seed and feed bags, large (0.5 & 1 tonne) fertiliser bags.

[10] Phasing out is occurring in three tranches, with completion scheduled by 2028.

[11] Examples of SUPs include drink stirrers, cotton buds, items made of plastics made with pro-degradants (oxo-degradable), food containers made from polyvinyl chloride or polystyrene, tableware and cutlery, straws, produce bags.

fragment into MPs. Regional agreements such as the *Baltic Sea Action Plan* (Helsinki Commission) implements targeted measures to limit MP emissions from wastewater, industrial sources, and the leakage of preproduction pellets. At the national scale, many countries have adopted bans on intentionally added MPs, beginning with the United States' *Microbead-Free Waters Act* of 2015, which prohibited the manufacture and sale of rinse-off cosmetics containing plastic microbeads. Similar bans have since been implemented in Canada, the United Kingdom, France, South Korea, Taiwan, and Australia, with the European Chemicals Agency progressing broader restrictions on intentionally added MPs. These mechanisms are further supported by policy approaches promoting advanced wastewater treatment and the role extended producer responsibility schemes, which help to reduce MP discharge and drive upstream design changes across plastic-intensive sectors, have been proposed.

PART D: IMPACT ANALYSIS

D1. WHAT WOULD BE THE ENVIRONMENTAL/HUMAN HEALTH IMPACTS OF NOT MANAGING THIS ATTRIBUTE?

Not managing the abundance of MNPs would be expected to result in a continued increase in their concentration and distribution across environmental compartments, driven by ongoing plastic production, fragmentation of existing materials, and sustained discharge from diffuse sources. Due to their persistence and mobility, unmanaged MNPs would continue to accumulate in air, water, soils, sediments, and biota, reinforcing their role as a long-lasting environmental contaminant.

Research on the direct impacts of MNP particles themselves on environmental and human health is still emerging, and it is not yet possible to fully quantify the magnitude of harm that would arise if this attribute were left unmanaged. However, uncertainty should not be interpreted as a lack of risk. There is already an extensive and well-established body of evidence demonstrating that many plastic-associated chemicals have adverse effects on both environmental and human health (Table 3).

Table 3: Examples of key plastic chemical groups, their common usage and the health effects that have been identified through meta-analysis reported by Symeonides *et al.,* 2024 [17]. The listed health effects reflect statistically supported associations across domains such as birth outcomes, reproductive and endocrine function, neurodevelopment, metabolic and nutritional status, circulatory and respiratory health, and cancer risk. For an up-to-date and interactive review of the impacts of plastic-chemicals on human health see the Plastic Health Aware dashboard [126].

Chemical Group	Common Uses in Plastic	Key Human Health Effects
Bisphenols (BPA)	Polycarbonate plastics, epoxy resins, food packaging	↑ Type 2 diabetes, insulin resistance. ↑ obesity ↑ hypertension and cardiovascular disease risk ↑ polycystic ovary syndrome
Phthalates	Plasticizers used to soften PVC; consumer products; food packaging	↑ spontaneous pregnancy loss ↓ birth weight ↓ sperm mobility and velocity ↑ sperm DNA damage
Polychlorinated biphenyls (PCBs)	Legacy contaminants; sometimes detected in plastics or plastic-contaminated environments	↓ birth weight ↑ endometriosis ↑ Type 2 diabetes ↑ hypertension and cardiovascular disease risk ↑ bronchitis in infants ↑ breast cancer ↑ non-Hodgkin lymphoma
Polybrominated diphenyl ethers (PBDEs)	Flame retardants in electronics, furniture foam, textiles	↓ birth weight ↓ IQ and cognitive scores after prenatal exposure
Per- and polyfluoroalkyl substances (PFAS)	Non-stick coatings, grease-resistant food packaging, textiles	↓ birth weight and length ↑ obesity and BMI in children ↑ ADHD risk in girls ↑ allergic rhinitis

If left unmanaged, MNP contamination would therefore be expected to increase environmental and human exposure over time. Taken together, current evidence supports a precautionary approach, with early management focused on monitoring and source reduction to limit future risks.

D2. WHERE AND ON WHO WOULD THE ECONOMIC IMPACTS LIKELY BE FELT? (E.G., HORTICULTURE IN HAWKE'S BAY, ELECTRICITY GENERATION, HOUSING AVAILABILITY AND SUPPLY IN AUCKLAND)

Given that this field of research is still developing, and significant knowledge gaps exist, it is uncertain where and who would feel the economic impacts of MNPs in New Zealand. However, the impacts are expected to occur across multiple sectors [127, 128]. The impact on primary industries such as agriculture and horticulture may include both impacts on production and contamination of export commodities. For example, reduced soil health due to MP-driven soil degradation [69, 129] or the impact on ecologically critical species, such as pollinators [130], which impede production levels. A recent study has estimated that the loss of agricultural productivity due to current soil MP contamination levels is resulting in an annual economic loss of ca. US$46.5 billion [131]. Similarly, fisheries and aquaculture are vulnerable to declining stock health and yield losses due to potential impacts on the reproduction, growth and quality of food species, and indirectly to impacts on the health of the ecosystems the industry depends upon [132-134]. Food exporters, including seafood, horticulture, meat and dairy, face risks to market access, brand value, and trade relationships if MNPs are detected in products, with potential burdens from increased testing and verification requirements. The economic costs of the impacts of plastic-associated chemicals on human health have been estimated at US$250–920 billion per year [14, 135] in the U.S. However, no studies have yet isolated the economic costs attributable specifically to MNPs.

D3. HOW WILL THIS ATTRIBUTE BE AFFECTED BY CLIMATE CHANGE? WHAT WILL THAT REQUIRE IN TERMS OF MANAGEMENT RESPONSE TO MITIGATE THIS?

Climate change is expected to significantly increase environmental MNPs [136]. Rising temperatures, increased UV radiation, and humidity will accelerate plastic polymer degradation, increasing fragmentation rates, thereby generating more MNPs. Extreme weather events such as storms, floods, and wildfires will mobilise plastics from terrestrial, soil and aquatic sources into the atmosphere, while stronger winds and altered circulation patterns will enhance long-range transport and redistribution. These changes may also create feedback loops with climate systems, for example, the resulting abundance and persistence of airborne MNPs have been shown to influence radiation and cloud formation [37, 86-88]. Climate change is driving greater reliance on agriplastics for food production, thereby substantially increasing plastic use in agricultural systems [137]. This creates more material that can degrade into MPs, adding to environmental contamination and long-term risks to soil health, water quality, and air and food safety.

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