National Institute for Public Health and the Environment
Ministry of Health, Welfare and Sport

Knowledge brief

Microplastics in the air

RIVM

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The air we breathe contains billions of miniscule invisible plastic particles, microplastics and nanoplastics (MNPs). Too small to see, yet all around us. These tiny fragments of plastic originate from various sources and are part of particulate matter. Studies have demonstrated that we ingest these microplastics through our food. In addition, more research reveals that we are also exposed to them through the air we breathe. However, the negative impact of these plastic particles on our health, animals, and the environment is not yet fully understood.

In this knowledge brief, we summarise what is currently known concerning exposure to microplastics through the air. There is still much that we do not know. Most experimental studies assess the effects of short-term exposure to large quantities of microplastics. Yet we are constantly inhaling small quantities over the long term. Moreover, microplastic emissions in the Netherlands have only been examined on a small scale. To really understand the impact of microplastics on human health, we need to conduct more research. This includes research into the effects of exposure to microplastics in combination with other hazardous substances in the air.

The benefits of using polymers mean that we cannot live without plastics. We therefore need to make wise choices. Which plastics do we allow to be used? Which plastics are fully biodegradable or reusable? We need more knowledge to develop effective policy, address concerns and assess the risks.

Introduction

Plastics exist in various forms and compositions and consist largely of polymers. These are chains of molecules of natural or synthetic origin. Microplastics are plastic particles smaller than five millimetres, with the smallest measuring only a few nanometres. Microplastics and nanoplastics (MNPs) originate from various sources and can be present in the air as part of particulate matter. We are becoming increasingly aware of potential human exposure to MNPs. This awareness is accompanied by concerns about the negative impact on humans, animals, and the environment. This knowledge brief was commissioned by the Sustainable Living Environment and Circular Economy Directorate, part of the Ministry of Infrastructure and Water Management, as part of Programme 24 DLO.22 Air quality and health assignment, and summarises the current knowledge about MNPs in the air.

Definition of microplastic particles

The European Commission has defined microplastics as ‘synthetic polymer particles smaller than five millimetres in diameter that are organic, insoluble and resist degradation’[1]. In this knowledge brief we assume ‘a material consisting of more than 1% synthetic polymers (≥1 mass percentage), often with additives (deliberately added or that occur during the lifetime of the plastics)’.
MNPs conform to the following dimensions 1) all dimensions fall within a range of 0.1 to 5 millimetre or 2) a length of 0.3 to 15 millimetres with a length-to-diameter ratio greater than 3 (fibres). The definitions of particulate matter are based on their aerodynamic behaviour, the inhalability or respirability.

Many characteristics of MNPs resemble those of airborne particles and nanomaterials, which can be a cause for concern in multiple ways:

- **Particle size:** The smaller the particles, the more easily they enter various environmental compartments (water, air and soil), subsequently disperse and ultimately end up in the air we breathe and/or the food we eat. The smaller the particles, the higher the risk that the particles can spread throughout the body after they are inhaled. Their small size means that MNPs have the potential to enter tissue and organs, where they can cause oxidative stress[2], inflammation, and eventually induce harmful effects in the body.
- **Toxicity:** Although MNPs themselves can already be harmful due to their particulate or fibrous nature, they can also adsorb or already contain harmful chemicals from the environment (such as plasticisers). When they are inhaled by humans, these chemicals can potentially be released in the body, leading to negative health effects.
- **Accumulation:** MNPs have the potential to accumulate in the body, because the polymers are often hydrophobic and inert to acids or enzymes present in the body. They are also insoluble or only very poorly soluble in blood or other body fluids. This makes it difficult for the body to break down or remove MNPs. Despite relatively low MNP concentrations in the air, higher concentrations can eventually occur in the body.

Little is known about the health effects of MNPs caused by exposure through inhalation. The lack of high-quality measurements of MNPs in the air we breathe hinders the progress of research into their impact on our health. The World Health Organization has also noted this [WHO 2022]. The European Commission’s Scientific Advice Mechanism has also published a statement on the growing concerns about MNPs in our environment [EU 2019]. A number of countries have issued reports on MNPs in food and the environment, the need for an adequate risk assessment and concerns about the potential impact on our health [GEA 2020, Health Canada 2020, COT 2021, VKM 2019]. All these reports highlight the major knowledge gaps concerning the distribution and risks of MNPs in our environment and in particular for airborne particles.

[1] https://environment.ec.europa.eu/topics/plastics/microplastics_en
[2] Oxidative stress = a reaction that occurs when there is an imbalance between substances that can trigger an oxidation reaction and the antioxidant capacity of our cells.

In order to ultimately make an assessment of the human health risks associated with airborne MNPs and to issue policy advice on potential actions, we need to answer the following questions:

1) Which MNPs can be found in the air we breathe; which polymers are they made of, what is their size distribution and what are their sources?
2) In what quantities are MNPs present in the air and how much MNPs are people exposed to?
3) What quantity of MNPs do people actually inhale, what is our internal exposure?
4) What makes MNPs harmful to humans?

Sources, polymer types, chemical substances and micro-organisms

Our air contains a mixture of MNPs from various sources. MNPs are usually generated as a result of wear and tear or the degradation of plastic products (secondary sources). There are also products to which MNPs are intentionally added (primary sources).

MNP source
Primary: particles that are intentionally made small such as microbeads in toiletries or that are the waste products of industrial processes.
Secondary: particles generated during use that end up in the environment as a result of the degradation of larger plastic objects such as bottles, bags and packaging. This is often caused by exposure to UV light, friction and ambient temperature.

Sources
New regulations mean that emissions from primary sources (Table 1) will be further reduced in the future. In September 2023, the European Commission adopted a regulation that restricts the intentional use of MNPs in products[3]. Beginning in October 2023, this will gradually lead to a complete ban on this type of primary MNP use. The timeline of the phase-out will vary depending on the sectors (up to five to ten years longer). Products such as medical devices, special equipment and paint or coatings are excepted from the rule. The restriction applies to products with an MNP concentration of ≥ 0.01 mass percentage.

The main source of secondary MNPs is through the wear and tear of tyres, textiles and construction materials (including paint) [Quik 2021, Quik 2024, Wright 2021, O'Brien 2023].

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R2055

Table 1 Examples of primary and secondary microplastic sources [Thompson 2024]

	Category	**Capacity**	**Application**
Primary	Pre-production materials	Pellets, flakes, powders	
	Intentionally synthesised for direct use	Glitter, confetti	Reflective effect
		Research, medical devices, special equipment	
	Intentionally synthesised and added to products	In cosmetics	Controlled release, consistency, as an abrasive
		In paint	Addition to protect against wear and tear, moisture and increased chemical and mechanical resistance
		In farming products	Controlled release of fertilisers and pesticides
Secondary	Generated during wear and tear	Tyres	Degradation of tyres caused by rolling and friction resistance on the road
		Textiles	Microfibres released during washing and daily use
		Construction materials	Material released by weathering and sanding
	Generated during waste processing	Recycling of plastic	
	Generated during degradation of larger products (in the environment)	Straight into the air	Larger plastic objects such as bottles, bags and packaging degrade into smaller particles that can end up in the air
		Into the air through water	Waves and wind can transport MNPs from water masses to the air

Commonly used polymers

An estimated 1200 to 5700 tonnes of MNPs are released into the air in the Netherlands every year. Most synthetic polymers that can be found in MNPs originate in the petrochemical industry. By far the largest source of emissions to the air is tyre rubber, which makes up around 60% of total emissions (Figure 1). The remaining emissions from construction materials and clothing consist mainly of MNPs composed of the following polymers: Acrylic (~13%), PET, (~11%), PA (~10%), PP (~4%), PVC (~1%) and HDPE (<1%) [Quik 2024].

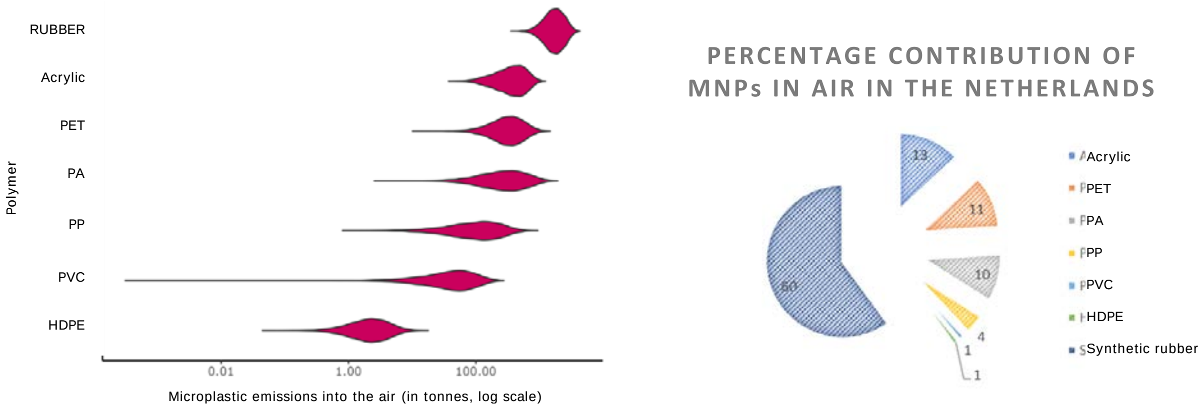

Figure 1 Graphs showing the distribution of polymers in microplastic emissions into the air in the Netherlands from tyre wear and tear, construction materials and clothing. Left: expressed in tonnes per polymer type. Right: expressed as a percentage of total emissions. Data: [Quik 2024]

Secondary MNPs consists of a mixture of MNPs that come about through degradation as well as through the wear and tear of plastic products [Tirkey 2021]. Processes that result in the formation of secondary MNPs are UV, heat, oxidation, biodegradation, wind, and waves. Both chemicals and micro-organisms can attach themselves to MNPs and can, in this way, spread further in the environment or find their ways into humans. There is a risk that our immune system will fail to recognise them due to embedding, leading to health problems [Yang 2023].

Presence in the air: composition, distribution and degradation of MNPs

Airborne MNPs can be transported over long distances by wind currents and eventually be (re)deposited on the ground or end up in bodies of water. They can enter the food chain if they are absorbed by organisms and therefore pose a risk to the environment as well as the health of humans and animals. Research is being done to better understand the sources, distribution and health effects of airborne MNPs on humans and animals. The composition, distribution and degradation of the polymer mixture must be determined in order to draw conclusions on the quantities and types of MNPs present.

Measuring the presence of MNPs in the air

MNPs can be found in the air in various forms, including as part of the mixture of particulate matter. Air quality monitoring currently takes place at roughly 100 locations in the Netherlands[4]. The presence of MNPs is not yet monitored at any of these locations. The percentage of MNPs in particulate matter in the Netherlands is therefore still unknown. To estimate the contribution of MNPs to particulate matter and the impact of these MNPs as accurately as possible, we need a systematic approach that identifies the composition and distribution of the particles. This includes the difference between locations where degradation products are actively released (e.g. along motorways) and the more rural areas where the particles can transport passively through air circulation. Apart from measuring the mass of MNPs, it is also important to determine their dimensions because these largely determine the chance of inhalation, the absorption into the body and also how harmful the particles are.

[4] https://www.luchtmeetnet.nl/

Modelling of the distribution of MNPs through the air

Besides taking measurements, the distribution of particles can also be modelled based on its known relationships with various particle properties and environmental factors. The distribution of MNPs in the air is the result of transport, dispersion, and deposition [Wright 2021]. These processes are dependent on the particle properties (size, shape, and length) and environmental factors (air pressure, air humidity, air velocity and wind direction). Examples of these relationships are:

- Smaller, low-density particles are found more often and remain in the environment for longer than larger, high-density particles.
- Shorter fibres are more easily transported than longer fibres.
- The season affects which polymers are found. For instance, the total quantity of particles in the air is lowest in autumn. (this is influenced by storms, rain and snow)
- Low air pressure leads to turbulence and thus favourable conditions for (re)distribution of MNPs and lower peak concentrations.

To effectively predict the distribution of MNPs in the various environmental compartments, it is important that reliable measurements are carried out to record particle identity, shape, size and volume. To improve these predictions, we also require information on as many different human aspects (population density, industrial activities, transport activities and buildings) and ecosystems (coast, lakes, mountains, forests, plains) as possible.

Finally, a proper estimate of the composition of the MNP mixture in the air is also related to the available information on MNPs in the other environmental compartments. Water in particular can be a significant factor because particles can easily end up in the air due to turbulence.

Composition

No standardised methods are available to directly measure the percentage of MNPs in the air. This means that MNPs present in the air must first be collected on filters and separated from the remaining particulate matter in the laboratory. The analytical techniques that can be used to identify the polymers involved are currently still limited to MNPs that are larger than a few micrometres.

Other techniques are based on determining the components of the polymers, regardless of the dimensions of the MNPs. Optimal processes for the separation of MNPs from of other materials are still being developed. Overall, larger MNPs are easier to identify than the smallest MNPs. Finally, there are measurement inconsistencies in relation to reporting, experimental design and the endpoints used, which makes it challenging, if not impossible, to compare the results obtained by different authorities and countries [Wright 2021, O'Brien 2023, Thornton Hampton 2022].

It is important to optimise and harmonise the study design and measurement techniques used in order to obtain comparable results at different measurement stations, regions, and labs. International collaboration also plays a key role in allowing an accurate estimate of the contribution of microplastic pollution from our neighbouring countries.

Modelling of polymer fragmentation and degradation
To predict the composition of the polymer mixture formed by degradation, the degradation processes must be well understood. That includes the fragmentation of the polymers into smaller particles and their degradation into molecules.

The Dutch National Institute for Public Health and the Environment (RIVM) is involved in modelling activities to identify these degradation products. The degradation process takes place throughout the life cycle of a polymer: during production, use and recycling. It is therefore important to determine which components of the large plastic products eventually become so small they become part of the particulate matter fraction (e.g. PM10) and therefore inhalable. The Netherlands Organization for Applied Scientific Research (TNO) has proposed an approach for assessing the MNPs formed based on the properties of the original polymer material [Boersma 2023]. This involves determining a MicroPlastic Index (MPI) which indicates the expected probability of a polymer fragmenting into particles in the micro range. This index takes into account various forms of ageing such as friction, which result in particles of varying sizes.

Quantitative data on degradation products are required in order to predict the association between polymer life cycle and human health. This is a crucial step in eventually linking health effects to polymer sources and advising on the most effective policy interventions.

Measurements during all phases of the polymer life cycle are required to support the prediction of degradation products. These can be measurements in the vicinity of polymer production locations, so as to gain more insight into the contribution of pre-production materials. Samples obtained during and around recycling activities also play an important role in assessing the different alterations that can occur in polymer composition during recycling. The effect of various ageing situations (e.g., heat, friction, UV light, impact, etc.) can be investigated under controlled conditions in laboratories.

Presence in the body

The quantities in which MNPs occur in the air (external concentration) do not always correlate exactly with the actual amounts in the airways or in the rest of the human body (internal concentration). The reason for this is that the body often poorly absorbs, metabolises, or eliminate MNPs, which may lead to accumulation in organs.

Internal concentration
Health risks arise when MNPs interact with or disrupt processes in our external barriers (epithelium in the lungs and intestines) or end up in our internal environment (bloodstream and organs). Long-term exposure or exposure to high concentrations can potentially lead to irreversible damage to the body. It is important to clearly identify whether and how external concentrations can be used to estimate internal concentrations. Research into internal exposure in humans has been conducted on samples such as tissue from patients and healthy volunteers. In recent years, scientists have reported finding MNPs in various organs including the lungs and brain.

The detection of MNPs in tissue using the current techniques can give a misleading impression. The techniques lack precision, particularly for small particles. In particular the extraction and degradation of MNPs at elevated temperatures, followed by mass spectrometry, can be impeded by fats, particularly when analysing PE and PVC. The choice of technique can therefore affect the results. Although dispersion through the body is likely, accurate quantification and identification requires methods to be further developed, harmonised and standardised.

Lung tissue
Jenner and colleagues were the first to demonstrate that a wide range of polymers can be found in lung tissue [Jenner 2022]. The distribution in the lungs varies considerably for each polymer. When the lungs were compared with the small intestine, colon and tonsils, the highest particle concentration per gram of tissue was found in the lungs. In all tissue, more than 50% of the MNPs were smaller than 100 µm (but larger than 20 µm, because that was the lower limit of what could be measured) [Zhu 2024]. Other researchers found smaller polymers in the lungs (measuring 2-17 µm) using different techniques [Amato-Lourenço 2021]. It is important to consider that polymers can also enter the body and ultimately the bloodstream through food and drinking water. Once in the blood, the MNPs can be pumped around the entire body and thus also reach the lungs.

Sputum
Another way to take samples is by collecting sputum through lung lavage. Sputum is responsible for removing all particles that enter our lungs and is therefore representative of the MNPs that are inhaled. Results from a number of studies have shown that over 90% of the polymers in sputum were between 10-300 µm in size [Özgen Alpaydin 2024]. Relatively long, (probably very thin) plastic fibres can therefore also be inhaled. Other researchers have measured MNPs in coughed up sputum and reported MNPs smaller than 500 µm. Half of the number of particles were also larger than 75 µm [Huang 2022].

Exposure in volunteers
Information originating from subjects whose exposure to airborne MNPs is measured can give an indication of the effects of exposure by inhalation. As yet unpublished studies such as the EU POLYRISK project[5][6] and the British IONA project[7] have brought volunteers to various traffic-intensive locations with an expected relatively high or low exposure to airborne MNPs (primarily from tyre wear and tear, which is higher when braking and accelerating at an intersection compared to at a constant speed such as on a motorway). Researchers within the POLYRISK[8] project[9] are also looking at exposure in volunteers exercising on sports pitches made of rubber granulate and those working with the polymer mixtures inside a textile factory. An initial, as yet unpublished analysis of the data originating from the exercising volunteers reports that the rubber particles have no detectable impact on a set of health indicators. All cases involve acute effects that can occur after a few hours of increased exposure.

As the study subjects are also exposed to factors other than MNPs in their daily lives, it will be difficult to establish in detail the specific impact of the MNPs on their health. Consequently, although there are certainly indications that polymers end up in the body through the air or otherwise, it is not clear whether the limited quantity in comparison with the overall particulate matter exposure can cause additional acute effects. It is also not known whether this exposure can eventually lead to irreversible health effects and whether the particles accumulate in the lungs due to long-term exposure. The lack of exposure data means that it is still impossible to conduct large-scale epidemiological research.

[5] https://www.uu.nl/organisatie/faculteit-diergeneeskunde/actueel/meedoen-aan-onderzoek/microplastics-research
[6] https://polyrisk.science/2023/11/02/investigating-the-link-between-traffic-related-air-pollution-microplastics-and-health/
[7] https://www.qmul.ac.uk/wiph/centres/centre-for-primary-care/primary-care-unit/iona-study/
[8] https://polyrisk.science/2023/06/28/new-polyrisk-study-examines-the-health-impact-of-microplastics-from-artificial-sports-pitches/
[9] https://polyrisk.science/2023/12/11/examining-occupational-exposure-to-micro-and-nano-plastics-in-the-textile-industry/

Accumulation in lung tissue
The accumulation of MNPs in the lungs is affected by their composition and size, but most importantly by their poor solubility. The expectation is that non-soluble plastic particles that are not eliminated by physical mechanisms (sputum displacement) or active degradation (immune system) will accumulate in our lung tissue over months and years. Although the MNPs or the additives they carry may not themselves be capable of causing acute damage, years of exposure may still have negative effects.

Harmfulness to humans

The risk of negative effects on human health from exposure to MNPs depends not only on the exposure to MNPs but also on the harmfulness of the polymers of which the particles are composed.

Toxicology
The harmfulness of MNPs is assessed under laboratory conditions in animal studies (*in vivo*) and in cells (*in vitro*). These studies seek to determine whether MNPs can interact with the tissues in our body and/or pass through natural barriers. It is important to determine which properties of the polymers play a role in this process (type, size, shape), what dose leads to effects and how this dose can be related to human exposure.

Animal studies can be used to estimate internal exposures that cannot be measured in healthy volunteers. In addition, they can be used to assess the relationship between exposure levels and inflammation and tissue damage. A limited number of studies have been conducted in which animals were exposed to polymers via inhalation. They concluded that inhaled polymers can accumulate in lung tissue and cause inflammation [Li 2022, Lim 2021, Han 2022]. Considerable effort has recently been devoted to research involving isolated lung cells. A large number of *in vitro* models are available that simulate various regions (nose, bronchi, and alveoli) and natural processes (including sputum production and immune responses) in our airways.

The *in vivo* and *in vitro* studies conducted to date with MNPs have a number of major limitations that mean that they cannot easily be used to estimate the risks for humans. Many researchers do not work with the types of MNPs to which humans are typically exposed to in day to day life. The MNPs studied are often synthetic polymers, usually polystyrene (PS), whose use provides no information on the effects of ageing or the presence of chemical or organic pollutants. Attempts are being made to produce MNPs from larger plastics in the laboratory. To date these attempts show that it is exceedingly difficult to produce sufficient MNPs. Finally, *in vitro* studies often work with truly short exposure periods. This means that potential effects of long-term exposure and thus accumulation of polymers or the additives/biological pollutants present can be missed.

Toxicity of substances associated with polymers
Various groups of harmful substances are included in the manufacture of plastics. For example, plastic stiffeners (such as bisphenol A) and plasticisers (phthalates) are associated with hormonal imbalances and are therefore a potential cause of various diseases[10]. Limits on the presence of these additives in plastics are based on their harmfulness, but also the method of use. It is important to be aware that MNPs can be released at various times in a product's life cycle and still indirectly end up in the air. The effects of long-term exposure to small amounts of MNPs are not yet known.

[10] https://www.nvwa.nl/onderwerpen/weekmakers

There are a number of Dutch and international initiatives aimed at improving the toxicological assessment of polymers. On the one hand, they are working on obtaining better MNP test material to carry out realistic exposure scenarios. And on the other hand, they are standardizing test methods and developing guidelines, a process which should take advantage of experience gained with nanomaterials[11].

Epidemiology
Epidemiological studies can help to assess the harmfulness of MNPs for humans, by examining associations between the presence of MNPs and the impact on human health. To date, no studies have been published about a potential link between airborne MNPs and health risks. This is due to the lack of usable measurements of airborne MNPs.

Quantification of health risks

The health risk of exposure to MNPs is determined by exposure to MNPs on the one hand and the toxicity of MNPs on the other. On the one hand, the risk is low if high exposure to MNP causes no health effects. On the other hand, if an MNP is highly toxic, but exposure (for example via inhalation) is negligible, the risk is also low. The main way of identifying risks to a population is through epidemiological research. This requires measurements or accurate estimates of the concentrations and characterisation of airborne MNPs, which are currently lacking. No direct correlation has been established between inhaled MNPs and airway-related symptoms or other health problems. The primary reasons for concern in the case of exposure through the air can only be addressed by systematic research into exposures to MNPs and at the same time can also give an indication of what this means for human health. When it comes to linking knowledge acquired through toxicological research using the previously mentioned *in vitro* models, it is also essential to know how many MNPs can end up in the target organ in question. For epidemiological research, it must be clear whether MNPs can be distinguished from all other types of particulate matter. Only then is it possible to accurately determine what proportion of health effects associated with air pollution can be attributed to MNPs.

Dutch and international projects

A number of projects have been set up in the Netherlands and around the world with the aim of develop scientific knowledge about MNPs in the environment (including in the air) and the human body (internal exposure). Attention is also being paid to the harmfulness of MNPs and the health risk they can pose for humans. A Dutch research partnership in this area falls under the MNP & Health programme of the Netherlands Organisation for Health Research and Development (ZonMw)[12,13,14]. The RIVM is contributing to this partnership by taking part in the MOMENTUM project and its follow-up MOMENTUM-2. The European Commission has also financed five projects that have been grouped together under the European Cluster on the Health Impacts of Micro- and NanoPlastics (CUSP). Within CUSP, 21 European countries are working with the European Commission's Joint Research Centre in five projects (AURORA, IMPtox, Plasticheal, PlasticsFatE, POLYRISK) to shed light on exposure to, and the dangers of, MNPs[15]. The RIVM's involvement in these projects is limited. Research into the emissions and harmfulness of sources that make a relatively large contribution to air pollution such as

[11] https://echa.europa.eu/nl/regulations/nanomaterials
[12] https://www.zonmw.nl/en/article/discover-microplastics-research
[13] https://www.zonmw.nl/sites/zonmw/files/typo3-migrated-files/Verkenning_microplastics_NL_2020.pdf
[14] Verkenning_microplastics_NL_2020.pdf Larger agenda of which the MOMENTUM project is part.
[15] https://cusp-research.eu/

tyres is being carried out through initiatives including the Horizon-2020 LEON-T project[16]. European projects such as POLYRISK[17], ATHENA[18], Py-Harmony[19] and MLIdent[20] aim to standardise data and develop better methods of identifying polymers in different environmental compartments and human samples.

Conclusions

There are signs that MNPs are harmful to our body. Various studies have demonstrated that the particles can penetrate deep inside the body, but there is still a great deal of uncertainty as to whether they pose a risk for our health.

Air quality is currently monitored at around 100 locations in the Netherlands. However this does not yet include MNPs. Investing in monitoring our exposure to airborne MNPs will provide information that can be used to determine limit values and help guide policy development. Measurements of MNPs in the air can be combined with distribution and exposure models to estimate negative health effects at the population level. This first requires a targeted measurement campaign that also identifies the contributions from different sources in order to advise on potential mitigating actions. An assessment of whether the MNPs in particulate matter pose a threat to human health can be obtained through experimental research. The use of representative material and harmonised and standardised testing methods is an important requirement.

The major benefits of polymer applications including synthetic rubber mean that simply banning these substances is not a feasible option in the short term. Developments such as the electrification of our vehicles will only lead to a relative increase in our exposure to polymers (rubbers) over the coming years. If it becomes clear what level of exposure or MNP use leads to negative health effects, alternatives can be developed that do not cause such effects.

It is currently still too early to identify policy interventions and quantify their potential impact. First, we need to gain more insights and decrease the uncertainties. This requires not only an effort from the academic world, but also knowledge building and integration by institutes that can inform and advise on policy and regulations in this area, such as the RIVM. These efforts will make it easier to distinguish between the perceived risks and actual health risks of exposure to MNPs in the air.

[16] https://cordis.europa.eu/project/id/955387
[17] https://polyrisk.science/
[18] https://projecten.zonmw.nl/en/project/standardised-and-scalable-methods-quantify-and-characterise-mnp-environmental-compartments
[19] https://projecten.zonmw.nl/en/project/development-and-harmonization-pyrolysis-gc-ms-methods-identification-and-quantification
[20] https://projecten.zonmw.nl/en/project/harnessing-machine-learning-improve-identification-and-quantification-micro-and

Recommendations

Determine the presence of MNPs in the air.

- Analyse the composition of the mixture.
- Focus on standardising methods (national and international).
- Set up systematic sampling points in existing monitoring networks.
- Make a distinction between microplastics and nanoplastics in particulate matter due to the expected difference in absorption and dispersion in the body and the level of toxicity per mass unit.
- Focus on both measuring and modelling for the purpose of estimating exposure in humans.
- Focus on monitoring the entire life cycle of MNPs and not just the polymers that make up a microplastic.

Presence of MNPs in the body

- Analyse internal exposure of the lungs and the extent to which MNPs can accumulate in the lungs and other tissue.
- Identify differences in exposure between groups: gender, age, high sensitivity, professional groups.
- Invest in research into the correlation between external and internal exposure, to determine whether external concentrations can be used to estimate internal exposure.

Assess the toxicity of MNPs

- Produce well-characterised and representative MNPs (relevant to human exposure).
- Focus on standardising and validating test methods, formulating guidelines and harmonising study designs.
- Draw up guidelines for extrapolating studies in animals and cells to human health risks.
- Verify whether methods used for particulate matter and nanomaterial research are suitable for MNPs.

Risks

- Risk assessment of MNPs must focus on both the risks associated with the polymer and the contribution of chemical substances bound to MNPs, degradation products and contamination with micro-organisms.

Abbreviations

Abbr.	Written out	Examples
ABS	acrylonitrile butadiene styrene	Lego
BR	butadiene rubber	Tyres, shoe soles
CR	chloroprene	Raw material for rubber
CPE	chlorinated polyethylene	Cable insulation
EPDM	ethylene propylene diene monomer	Roof covering, sealant
EVA	ethylene vinyl acetate	Toys, shoes, sports gum shields
HDPE	high-density polyethylene	Outdoors (highly weather resistant)
HR	halobutyl rubber	Bicycle tyres (airtight seal)
NBR	nitrile butadiene rubber	o-rings
PA	polyamide	Nylon
PAN	polyacrylonitrile	Fibres suitable for fabrics
PBS	polybutylene succinate	Agricultural film (biodegradable)
PC	polycarbonate	'Safety glass'
PE	polyethylene	Artificial grass, nappies, sanitary towels
PET	polyethylene terephthalate (polyester)	Drinking bottles
PMMA	polymethyl methacrylate	Plexiglass
PP	polypropylene	Furniture, jerry cans, baby bottles
PS	polystyrene	Polystyrene
PTFE	Polytetrafluoroethylene	Teflon, non-stick coating
PUR	polyurethane	Mattresses, insulation material
PVC	polyvinyl chloride	Construction material, rain gear
SAN	styrene acrylonitrile	Transparent tableware
SB(R)	styrene-butadiene rubber	Tyres

MNPs micro and nanoplastics
MPI microplastic index
PM particulate matter

Literature

WHO 2022: Dietary and inhalation exposure to nano- and microplastic particles and potential implications for human health ISBN 978-92-4-005460-8
GEA 2020: Plastics in the environment (ISSN 2363-832X);
Health Canada 2020: Science assessment of plastic pollution: Environment and Climate Change Canada (ISBN 978-0-660-35897-0);
COT 2021: Overarching statement on the potential risks from exposure to microplastics (Report TOX/2019/62);
VKM Report 2019: Microplastics; occurrence, levels and implications for environment and human health related to food: Opinion of the steering committee of the Norwegian Scientific Commitee for Food and Environment (ISBN: 978-82-8259-332-8)
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