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*Review Article*

# PRESENCE OF MNPs IN WATER ENVIRONMENT-PATHWAYS OF DEGRADATION AND IMPACT ON ORGANISMS

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Abstract

In recent years, micro- and nanoplastics (MNPs) in the natural environment have become a severe issue. Therefore, it seems significant to be knowledgeable on the topic. The purpose of the literature review presented here is to describe the general characteristics of plastic particles, their main sources, degradation mechanisms, and the impact of plastic particles on individual systems of the human body. The usefulness and scale of distribution of plastics worldwide is shown, considering the increase in their production in recent years. Up-to-date literature indicates that they may influence the development of cancer, e.g. stomach, liver, or colon cancer. Scientists associate microplastics with the development of cardiovascular and immunological diseases. They also draw attention to the temporal correlation between the increased incidence of the above-civilization diseases and the increased environmental contamination with microplastics in recent decades.

Keywords: microplastic, nanoplastic, degradation, polymers, human health

## 1. INTRODUCTION

The concept of microplastics (MPs) first appeared in 1972 [1]. Microplastics are small plastic particles (synthetic polymers) with dimensions of less than 5 mm [2]. Some particles decay to even smaller sizes, being impossible to see with the naked eye (less than 1 μm). Such particles are referred to as nanoplastics (NPs). Polymer micro- and nanoparticles are created as a result of the breakdown of plastic garbage (e.g. tires, food packaging, bottles, or synthetic fabrics), but they can also be waste from factories or small fragments of cosmetics, such as peelings or cosmetic thickeners.

Micro-nanoplastics (MNPs) can be found in any ecosystem element, polluting sea bottoms, lake surfaces, and even uninhabited islands [3–5]. MNPs enter the environment mainly through sewage systems when they are washed out with cosmetic residues [6]. MNPs are extremely light and can move

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with wind and rain. The particles reach water and food via these routes, from where they enter organisms.

The presence and accumulation of MNP in the environment are the subject of ongoing evaluation and growing scientific interest. The toxicity of MNPs is not yet fully understood. Nevertheless, it is known that these particles can easily penetrate the tissues of organisms such as fish, turtles, birds and even humans [7–9].

The production of plastics has expanded in recent years, and it is difficult to imagine one's life without them. Research into the potential dangers of micro- and nanoplastics to the human body gained prominence after 2019, when food packaging made of plastics began to be used on a large scale in the wake of the COVID-19 pandemic [10–13]. Studies from researchers around the world suggest that plastic particles may result in, for example, increased inflammation or an increased chance of developing neurodegradative diseases [14, 15]. Given that this problem potentially concerns each of us, it is important to raise human awareness of this issue. Therefore, we intended to review the literature on micro- and nanoplastics; the main sources in the environment, methods of degradation, and potential routes of absorption of micro- and nanoparticles into the body.

## 2. SOURCES OF MICRO AND NANOPLASTICS AND PRESENCE IN THE ORGANISMS

Plastic microbeads are used in the production of cosmetics, synthetic clothing, and plastic products [16, 17]. These particles are also standard in toothpaste, hair styling sprays, and marine dyes. Mass production of plastic-containing goods began in the 1940s. Nevertheless, at that time nobody thought about the effect plastics might have on the environment and therefore on humans as well.

Microplastics appear in the environment due to the breakdown of larger plastic fragments or from the origins as small particles. The main sources of microplastic particle release are:

- washing clothes and synthetic textiles,
- abrasion of car tires while driving,
- dust in urban agglomerations,
- marine paints (on ships, ferries, etc.),
- cosmetics and other personal use products,
- plastic pellets,
- plastic bottles,
- plastic bags,
- disintegration of fishing nets due to UV radiation and exposure to seawater (salt and constant waves).

Plastic microparticles are released from both primary sources, such as everyday plastic products and artificial processes, and secondary sources, such as natural fragmentation due to weathering effects [18, 19]. The decomposition of plastics into smaller particles is shown in Figure 1.

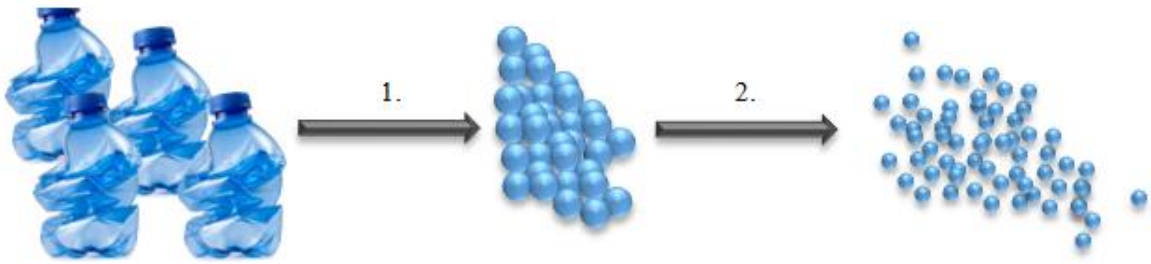

Fig. 1. Decomposition of plastic materials to microplastics (1) and subsequently to nanoplastics (2) [own graphics]

MNPs are composed mainly of polypropylene, polyethylene, and polystyrene. To a lesser extent, they can also consist of nylon fibers, polyesters, and polyurethanes [20, 21]. MNPs mainly appear in the environment through water transport. When collected from households, such as from washing clothes, they pass through the sewage system and then reach wastewater treatment plants [22]. These plants are not equipped with filters capable of capturing such small polymer particles, so most of the MNP ends up in rivers and further into the seas and oceans [23, 24].

Many MNPs float in water (mainly polyethylene and polypropylene plastics); scientists estimate between 93,000 and 268,000 tons. Polymer waste containing polyvinyl chloride and polyethylene terephthalate is heavier than water and settles to the bottom of water bodies [25]. Wind, capable of carrying small particles over long distances, is another source of transport of MNPs easily entering the human respiratory system [26]. MNPs from plastic bags and packaging are also found in soil.

MNPs are a problem closely associated with the marine environment, which mainly receives plastic waste of anthropogenic origin. The waste processed in this way is fragmented into smaller and smaller sizes (micro and nano). MNP can be found throughout the volume of a water body, depending on the density of the polymer particles (polyethylene (PE) and polypropylene (PP) float on the water surface, polystyrene (PS) in the water column, and polyvinyl chloride (PVC) and polyethylene terephthalate (PET) settle to the bottom of the tank). Fish, sea turtles, and even birds treat plastic particles as food, so they get into their bodies [27].

MNPs in the seas and oceans come mainly from landfills and sewage and are removed from ships and drilling platforms [28]. In recent years, scientists have been observing the increased concentration of plastics in sea waters, resulting in the Great Garbage Patches forming on the surface of the oceans, with an area of up to many thousands of square kilometers. The most famous GGP is the Great Pacific Garbage Patch (GPGP),which was discovered in 1998 in the Pacific Ocean (between Hawaii and California) [29]. The surface area of the GPGP is comparable to the Iberian Peninsula, and its weight is estimated to be 3.5 million tons. In 2014, British scientists published the results of a study in which they showed that MNPs accumulate not only in GGPs floating on the surface but also under the water surface. MNPs in the water column easily penetrate organisms that treat these particles as food. The European Commission presented a report on the number of species of marine organisms in which MNPs were detected (Table 1).

Table 1. Effect of MNPs on marine organisms [30]

| Organism | Number of species | Number of species infected with MNPs |
|---|---|---|
| sea turtles | 7 | 6 (86%) |
| sea birds | 312 | 51 (16%) |
| albatrosses, petrels, shearwater | 99 | 10 (10%) |
| pelicans, cormorants | 51 | 11 (22%) |
| marine mammals | 115 | 32 (28%) |
| seals and sea lions | 14 | 11 (79%) |
| whalebones (e.g. blue whale) | 10 | 6 (60%) |
| fishes | - | 34 |
| shellfish | - | 8 |

Today, MNPs in rivers are common, mainly in the form of plastic manufacturing waste. In addition, plastic particles in rivers are formed by the fragmentation of polymer waste floating on rivers. Most of these are observed in estuaries, deposited there mainly in the form of pellets, fibers, and film fragments [31–33]. MNPs have also been found in standing water. Researchers from China and the United States have found plastic particles in Taihu and Ontario lakes; in these cases, plastic pellets of 100-1000 μm were mainly observed near urban and industrial areas [34].

Water and sewage management should play an extremely important role to combat the presence of micro- and nanoplastics in the environment [35–37]. MNPs present in sewage are mainly particles from cosmetics and fabric fibers that enter the sewage during washing [38, 39]. As research shows, MNPs can enter sewage treatment plants through two main routes: domestic sewage, i.e. from residential buildings, and rainwater [40, 41]. In the second case, research shows that MNPs may enter sewage through runoff from roads, which it enters from car tires. Table 3 shows the concentrations of MNPs in raw sewage.

Table 2. Concentration of MNPs in raw sewage

| Concentration [particles/m$^3$] | Type of particles | Literature |
|---|---|---|
| 15100 | Fibers – 71%<br>Fragments – 18%<br>Foil – 11% | [42] |
| 380000-90000 | Fibers - 68%<br>Scraps – 9%<br>Flakes – 14%<br>Foil – 7%<br>Granules – 2% | [43] |
| 631-100000 | Fibers – 33–80%<br>Flakes – 5–20%<br>Foil – 5–50% | [44] |
| 200000 | No data | [45] |

Given the above information, the process of MNP removal in wastewater treatment plants is extremely important. Conventional wastewater treatment methods usually involve three steps: 1) mechanical removal of contaminants such as grease or sand; 2) biological treatment of organic contaminants; 3) additional filtration [46, 47]. The removal of MNP depends on the size and biodegradability of the particles. In the first step, gravity sedimentation and flotation processes using grids or primary settling tanks are used. At this stage, MNPs with sizes between 20 and 500 μm are removed [48]. Between 50 and 99.96% of microplastics are removed during wastewater treatment in wastewater treatment plants [48]. Literature data indicate that during wastewater treatment, up to 90% of microplastics are removed during sedimentation in primary settling tanks. However, it is important to note that MNPs, due to their different shapes and sizes, may behave individually.

A study by researchers in the United States showed the presence of MNPs in the atmosphere, showing that the largest source of air pollution is plastic particles from road dust - 84% [49]. MNPs are released into the atmosphere by moving cars, which provide the mechanical energy to carry the particles. Other sources of MNP in the airspace are the oceans (11%) and agricultural dust - 5%. In both cases, pollutants enter the atmosphere through strong winds. The presence of MNP in the atmosphere is a global problem, as plastic particles can remain in the air for up to a week. This time enables MNP to spread for thousands of kilometers; the upper limit of particle migration even suggests the possibility of intercontinental transport [50, 51]. This means that even places where plastics are not produced are also vulnerable to contamination by MNPs.

The literature has thoroughly analyzed the sources of MNP in the atmosphere. Air pollution by MNP not only depends on the nature and intensity of emissions. Weather conditions, such as snowfall or rainfall, as well as the topography of the area, are of great significance. It seems that the distribution of different materials (PE, PS, PP, PVC, and PET) depends on the climate, so during periods of lower rainfall more PS accumulates in the atmosphere, and in months when rainfall increases, more PS accumulates in the atmosphere are particles from PE [52]. In regards to topography, MNP deposition in the air is influenced by the complex landscape and density of the study area [20].

## 3. POLYMERS USED IN THE PRODUCTION OF PLASTICS

Plastics are materials composed of natural or synthetic polymers, most often obtained from pure polymers (e.g., polymethyl methacrylate (PMMA), polystyrene (PS), polyethylene (PE), polypropylene (PP), polyethylene terephthalate (PET), copolymers or polymer blends). In addition, a distinction is made between plastics obtained from pure polymers as a result of their chemical (e.g., by hydrolysis) or physicochemical (e.g., by degradation) modification or by the addition of substances such as: plasticizers, fillers, stabilizers, dyes and pigments [53].

The polymers can all be classified by several criteria and one of them is their thermal behavior. A division is made between thermoplastics and thermo- and chemically-cured plastics, known as duroplastics [54].

The division that is often used in classifying polymers is according to the main component. For example, a distinction is made between materials in which the basic components are polyalkenes (PE, PP, PS, vinyl resins, polyvinyl acetate (PVA), polyvinyl alcohol (PVOH), polyvinyl chloride (PVC), polyvinylidene chloride (PVDC), fluoropolymers, acrylic resins, phenoplasts, aminoplasts, polyamides, polyurethanes, polyformaldehyde, polycarbonates, cellulose derivatives (e.g. cellulose acetate).

Plastics are widely used in various industries, including packaging, machine parts, instruments, and household goods (Table 3) [55, 56].

Table 3. The use of polymers in industry [55, 56]

| Type of polymer | Density [g/cm$^3$] | Products |
|---|---|---|
| polyethylene (PE) | 0.93 – 0.98 | packaging, bottles, bottle caps, sacks, bags, skis, sails, housings for apparatus and machines |
| polypropylene (PP) | 0.89 – 0.91 | packaging, laboratory and medical equipment, cable insulation, car parts, toys, furniture |
| polyvinyl chloride (PVC) | 1.20 – 1.45 | tubes, catheters, packaging |
| polymethyl methacrylate (PMMA) | 1.18 – 1.19 | glazed, partition walls, advertising panels, reflectors, noise barriers, door fillings |
| polystyrene (PS) | 1.20 – 1.45 | electrotechnical components, insulators, household items, car parts, toys, packaging |
| polyethylene terephthalate (PET) | 1.38 – 1.39 | bottles, fabrics, housings for electronic devices |

## 4. DEGRADATION OF MICRO- AND NANOPLASTICS

Polymers, the main components of plastics, undergo many changes that alter their properties. Such modifications are due to chemical, physical, or biological reactions that result in the breaking of bonds and subsequent chemical changes in the structure of the polymers. The described transformations are characterized by polymer degradation.

Micro- and nanoparticles often undergo degradation when exposed to light (photodegradation) [57]. This kind of degradation is recognized as a significant source of environmental damage to polymers. Most polymers are subject to photodegradation initiated by UV radiation and visible light. UV radiation defines the lifetime of polymers used in outdoor applications. Given that it has sufficient energy to break the C-C bond, the damaging wavelength of UV radiation depends on the number and structure of the C-C bonds in the compound. Therefore, degradation occurs at different wavelengths for different molecules, e.g. at 280 nm for PS, 300 nm for PE/PET, and 370 nm for PP [58, 59]

The photodegradation of plastics alters their physical and optical properties. The most harmful effects are visual effects (yellowing), weakening of mechanical properties, and weight loss. Additionally, PE and PP, under the influence of UV radiation, are more fragile and lose their plasticity.

Thermal degradation of polymers under normal conditions is similar to photodegradation [58]. The main difference is that thermal degradation occurs throughout the plastic, while light-initiated degradation takes place only at the sample's surface. Thermal degradation of polymers appears through random and chain degradation initiated by heat and UV light.

Atmospheric ozone degrades polymers under normal conditions [58]. The presence of ozone in the air, even in minimal amounts, causes the aging of polymeric materials. The degradation process leads to a change in the polymer mass and a worsening of its mechanical and elastic properties. Additionally, the presence of ozone leads to the formation of by-products containing oxygen in their structure. Mechanochemical degradation takes place under the influence of mechanical stresses and intense ultrasonic irradiation [58]. A chemical reaction often supports the decomposition of the polymer by mechanical force. Biodegradation is the transformation of compounds caused by microorganisms [60–62]. The mineralization of organic compounds such as polymers produces carbon dioxide and water (under aerobic conditions) or methane and carbon dioxide (under anaerobic conditions). Regarding plastics, biodegradation leads to changes in the material's surface and the loss of its mechanical properties. The process takes place with the participation of microorganisms, and the degradation causes the backbone chain of the polymer to break, and then, with the assistance of enzymes, the loss of the molecular weight of the polymer. Biodegradation is chemical, although the source of harmful substances is microorganisms. The susceptibility of the polymers to this process depends mainly on the availability of both the enzyme and the site in the polymers for enzyme attack, the enzymatic specificity of the polymer, and, if required, the presence of a coenzyme [58]. Biodegradation can occur at various structural levels, i.e., molecular, macromolecular, microscopic, and macroscopic, depending on the mechanism.

The last method of polymer degradation, extremely popular on an industrial scale, is catalytic degradation [63]. PE, PP and PS wasted composes into gases and oils [58]. Adding a catalyst improves the quality of the obtained products, reduces their decomposition temperature, and allows for selectively getting a specific product.

## 5. ROUTES OF MICRO- AND NANOPLASTICS INTO ORGANISMS

Three main pathways for the penetration of MNPs into organisms are known (Figure 2). The first is the gastrointestinal tract (digestive system); MNPs can enter by direct ingestion of particles deposited on food or everyday products. Another way is the indirect route - with the consumption of products of animal origin, such as aquatic organisms. This is how MNPs enter the human gastrointestinal tract through the consumption of, for example, fish containing them [14]. Another route of MNP entry into organisms is through the air (respiratory system) [64]. A third route for micro- and nano-scale polymeric waste to enter organisms is through direct skin contact with the polymer (dermal system), which occurs, for example, when people crush polymeric objects [65].

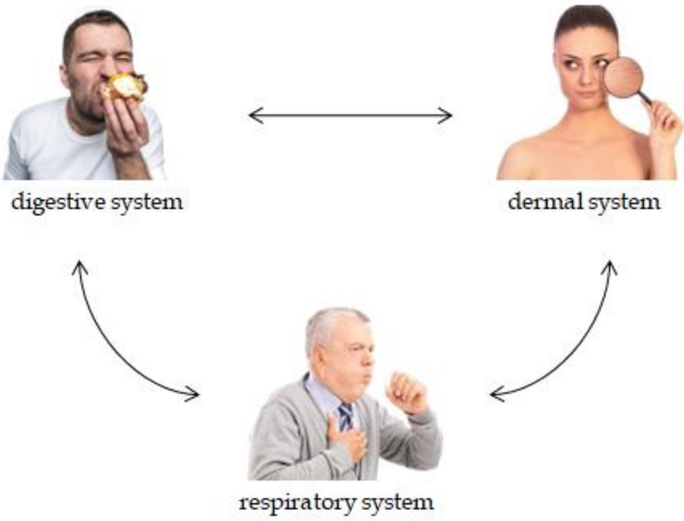


Fig. 2. Main routes of absorption of MNPs into organisms [own graphics]

### 5.1. ABSORPTION THROUGH THE DIGESTIVE SYSTEM

Human exposure to MNP is mainly through the digestive system. This is mainly due to the ubiquitous plastic in households, such as food containers. These types of materials are usually made of polyethylene terephthalate (PET) and polystyrene (PS ) [66]. Literature data indicate that approximately 40% of global plastic production is applied to the packaging industry [67]. An example of how packaging materials increase human exposure to contaminants is the presence of MNPs in mineral water from PET bottles. It was found that in disposable PET bottles, their concentrations ranged from 0.1 to 1.8 μg/dm$^3$, while in reusable bottles, the levels increased several times and reached values from 0.6 to 7.3 μg/dm$^3$ [68, 69]. Figure 3 shows the global production of polymer bottles depending on the type of material they are made of and the polymer particle size distribution. Moreover, it has been proven that MNPs are released from plastic tea bags at a rate of approximately 11.6 billion MNPs per cup of beverage [70].

The digestive system plays the most important role in the mechanism of MNP absorption into the human body [71]. The absorption of MNPs by the body may take place through the small intestine. It depends on the ability of particles to penetrate the intestinal mucus, which is influenced by, among others, the passage of MNPs into organic matter or intestinal content and particle sizes [72, 73]. Subsequently, after MNPs penetration through the intestinal mucus, the particles are internalized by the intestinal epithelium. It can occur via several mechanisms, including: transcytosis (uptake and transport of smaller particles by enthrocytes), or paracellular transport across gaps between cells, depending on the concentration and size of MNPs [71].

Apart from the penetration of MNPs through the small intestine, another interesting path of MNPs entry into the human body is the uptake of particles by macrophages present in the gastric epithelium, followed by their translocation through the intercellular spaces of the epithelium, ultimately reaching the lymphatic vessels [74].

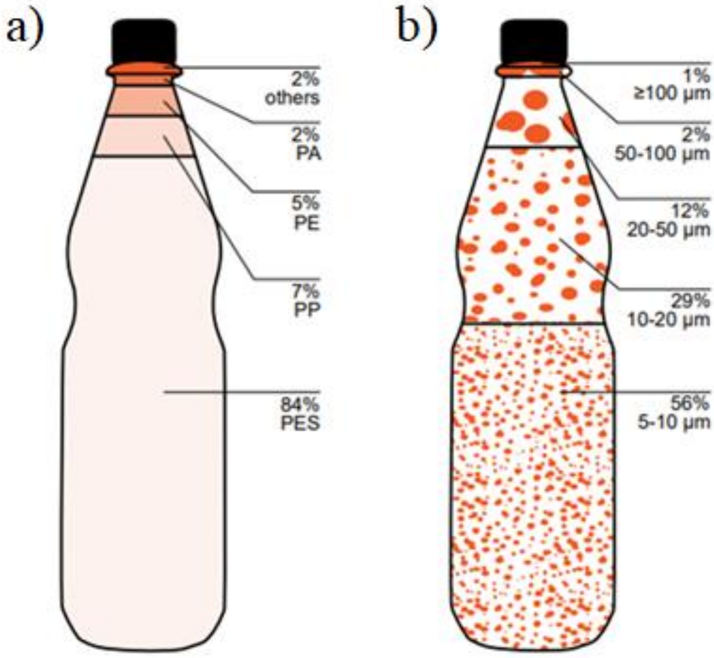


**Fig. 3.** Distribution of plastic bottle production depending on: a) polymer type b) polymer size. PA - polyamide; PE - polyethylene; PP – polypropylene; PES – polyethersulfone [69]

The source of MNPs for humans may be beverages and food, e.g., mineral water or animal products. Plastic particles may also accumulate in the intestines of aquatic organisms that have treated MNPs as food during their lives. Seafood such as mussels may collect MNPs through water filtration. It has been shown that mussels directly transfer MP to higher trophic levels [75]. MNPs are also found in soil environments [76]. It has been found that this type of contaminant can be transferred from soil to plants and then from plant food to humans. Scientists from China found that the roots are most susceptible to MNPs, followed by the leaves and, finally, the stem [73]. Plastic particles can also damage the photosynthesis mechanism [77]. As the root systems in trees and older plants develop, the levels of MNPs in them also increase [78]. MNPs can move from roots to stems and leaves via the vascular systems inside plants. Interestingly, biodegradable plastics pose a more significant threat to seed and plant development than synthetic polymers [79]. The accumulation of MNPs and the accompanying damage may also have consequences for crops ‘quality and thus threaten human health. For example, PS has been shown to enter rice roots and translocate to aerial parts [80]. MNPs can affect plant biomass, tissue composition, and root function. The accumulation of polyethylene (PE) particles in broccoli, and radish sprouts was analyzed and their presence was found in both cases [81]. The impact of polymethyl methacrylate (PMMA) on rapeseed was also assessed [82]. It was found that the rapeseed germination index was inhibited under the influence of MP. Plastic particles are detected in both bottled and tap water.

MNPs can affect human health directly and indirectly. The first type of MNP exposure depends on the location of the particles in the body. The presence of MNPs in human blood has been confirmed, which is particularly important because plastic granules can travel to further human organs [83]. Moreover, plastic particles and polymers contain chemicals deliberately added during production, such as antioxidants, stabilizers, and flame retardants that can penetrate the intestinal barrier [84].

The second indirect exposure of MNP to human health is because the MNP surface is an ideal environment for the grown of pathogens [85]. MNPs can be a carrier on which pathogens and pollutants develop and move. Pathogens that form specific layers on the surface of MNPs may be fungi, bacteria, and protozoa. Plastic particles as a carrier can affect the transport and deposition of chemical pollutants such as additives, heavy metals, organic pollutants, antibiotics, pesticides, or fungicides [86].

MNPs significantly influence the functioning of the digestive system. The impact of plastic particles on the digestive tract depends mainly on where they accumulate. A study on mice confirmed that MNPs can accumulate in various organs [87]. PS of 5 μm and 20 μm were administered to the animals with water. After 28 days of exposure, plastic of both sizes was recorded in the liver, kidneys and intestines. All changes related to MNPs described in the current literature may cause chronic inflammation in the gastrointestinal tract, particularly Crohn's disease [88].

PS and other types of plastic, such as PE, may have adverse effects on the digestive tract. Changes in mice exposed to PE were observed in the small intestine and colon. The adverse effects of MNPs have also been described concerning mouse liver. The changes were less extensive than in the intestines but still observable. The swelling was noticed in some cells of this organ, as well as a strong pro-oxidant effect. Liver metabolism and the hepatic-intestinal axis were disturbed. The observed changes resulted in an increased risk of insulin resistance [89].

Studies in organisms suggest that MNPs can cross the blood-brain barrier (figure 4) [90]. They can increase inflammation and potentially increase the risk of neurodegenerative diseases. It has been proven that PS particles can be detected just two hours after ingestion. Moreover, experiments on laboratory mice provided information that PS crosses the blood-brain barrier in addition to being present in the blood. This barrier protects the brain from harmful toxins [91].

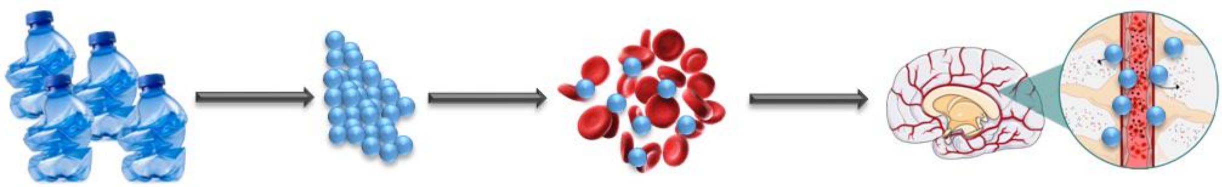

Fig. 4. Scheme of degradation of plastics into micro- and nanoparticles and then penetration into the human body [own graphics]

## 5.2. ABSORPTION THROUGH THE RESPIRATORY SYSTEM

The respiratory system is one of the three main routes of absorption of MNPs into the human body [92]. MNPs enter the respiratory system along with dust suspended in the air. Scientific research shows that both short-term and long-term exposure are harmful; in both cases morbidity, symptom severity and mortality risk increases. Particles of suspended MNPs reach different areas of the respiratory system, depending on their size. In the case of larger particles, MNPs are retained in the upper respiratory tract. Smaller particles, e.g., those with a size of up to 100 nm, can reach the bronchial regions. In comparison, even smaller particles with a size of approximately 25 nm can penetrate much more profoundly, e.g., into the lungs [93].

In the nasal cavity, the flow velocity of MNPs is lower than in further sections of the respiratory system, but after passing through the trachea, the flow becomes even. The geometry of this organ influences the absorption rate of MNPs in the lungs [94].

Air pollution MNPs pose a significant threat already at the stage of prenatal life [95]. MNPs suspended in the air may penetrate the fetus through the placental-vascular barrier, which may result in deterioration of the functioning of the respiratory system in growing children and an increased incidence of respiratory infections, including recurrent pneumonia or bronchitis.

The mechanism of absorption of MNPs in the respiratory tract is based on the capture of particles from the air by the respiratory system and then through their sedimentation in this system [71]. However, the deposition of MNPs in the alveoli occurs mainly in the case of micro-scale particles (approx. 5 µm and smaller). The respiratory system, unlike the digestive system, is much better at expelling unwanted particles. MNPs are largely removed from the system through mucociliary transport (the movement of mucus towards the throat, driven by the beating of the cilia). Particles larger than 5 µm rarely reach the alveoli, which is confirmed by studies of human lung biopsies, where only microplastics with a size <5.5 µm were found [96]. Similar studies were conducted in dogs that were exposed to the uptake of MNPs of various sizes, however, microplastics >8 µm in size were unable to pass through the lung capillaries [97]. In the case of internalization of MNPs particles in the lung alveoli, the mechanism may be, among others, through cross-linking in intercellular spaces or alveolar migration in type I pnaumocytes or capillary endothelium [98].

## 5.3. ABSORPTION THROUGH THE DERMAL SYSTEM

The last system discussed through which MNPs can enter the human body is the skin - the dermal system. The mechanism of particle penetration is simple because it is based on direct physical contact of humans with MNPs, present e.g., on everyday items or cosmetics. Human skin is divided into four layers: the stratum corneum, the active dermis, the dermis, and the subcutaneous connective tissue [99]. During contact with MNPs, the upper layer of the skin, i.e., the epidermis, acts as a protective shield and its task is to defend the body against harmful substances and factors, including polymer particles [100]. Therefore, it is essential to maintain the healthy condition of the stratum corneum to ensure it is adequately protected.

Particles ranging in size from 4 to 20 nm can partially penetrate healthy and damaged skin, while particles above 20 nm only enter the body in damaged skin [101]. Larger MNPs with sizes above 45 nm do not penetrate the skin but can settle on it and then enter the human body, e.g., through the digestive tract.

## 6. CONCLUSIONS

Currently, there is a rapid increase in plastic production around the world. This material is released into the environment in the form of micro- and nanoparticles and is found in both industrialized and natural areas. MNPs can be found in any element of the ecosystem that pollutes the seabed or lake surface. Since plastics can enter the environment mainly through sewage, modernization of existing wastewater treatment systems is undoubtedly one of the priority tasks in water and wastewater management. Plastic pollution is and will be a problem for decades to come, and spreading awareness about it can help generate new ideas that will ultimately help eliminate it. Therefore, this article summarizes the latest scientific reports on plastics; their sources, degradation mechanisms, absorption by the human body, and water and sewage management.

The small size of microplastics facilitates their uptake by organisms, causing the accumulation of harmful waste, thus disturbing their physiological functions. MNPs are widely available and integrated into the ecosystem, disrupting biogenic flora and fauna. Polymer molecules also directly affect human health. This is primarily related to their size, because smaller particles (nanoplastics) can penetrate human organs to a greater extent, entering them with the blood, entering the bloodstream, and some particles that will not be absorbed into the circulatory system, the body, can cause local inflammation even on the skin. Despite the lack of literature on the environmental occurrence of nanoplastics, it is reasonable to expect that they will be present in the environment in larger quantities than larger microplastics. Therefore, nanoplastics are considered more toxic than microplastics due to their ability to penetrate cell membranes and disrupt cell function.

It should be emphasized that the interactions between all plastic particles and the environment cannot be explained by a single model of micro- and nanoplastics. Many variables influence how MNPs interact with and enter cells. Given the diversity of nanoparticle applications and even greater potential in the future, understanding and predicting their behavior and impact on biological systems becomes extremely important.

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