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The presence and danger of microplastics in the oceans

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ABSTRACT

Since the environmental pollution by microplastics is a relatively new area of research, the main problem is the lack of appropriate rules, regulations and parameters globally. Therefore, the sources of primary and secondary microplastics particles vary from source to source, and due to this the difference in the division of microplastic particles by size arises too. Moreover, various techniques and technologies are used when testing seawater and sediment as well. Ultimately, with different qualities of the obtained results, it leads to difficult and/or inadequate comparison. Furthermore, the research has been mainly conducted on smaller marine organisms, which needs to be extended to other larger organisms as well as to the human population to create a complete image of the negative effects of contamination of the marine food chain and the marine environment with microplastic particles in general.

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1 Introduction

Plastic has many advantages. From price, durability, and weight to the so-called "malleability", the possibility of forming various shapes, that provides the possibility of using it on an unlimited scale. Although it has only been produced for about 80 years, its disadvantages and negative effects are notably visible each day. Over the years, we have started to produce high quality and more durable plastic material that, therefore, takes longer for its decomposition. That said, increased production from 1.5 million tons in 1950 [6] to 368 million tons in 2019 [28] results in greater environmental contamination.

Furthermore, microplastics are, by number of pieces, the most common form of plastic in the oceans, however that makes only 8% of the plastic in the oceans, if it is viewed by weight, while the remaining 92% are in the form of large plastic objects [33]. The accumulation of microplastic particles in the marine environment poses a global threat to the marine organism food chain. The exposure of marine organisms to this type of pollution has undeniable detrimental effects not only on their quality of life, but also on their lifespan. Yet, the possibility of absorption and retention of plastic components and / or toxic compounds within organisms as well as the possibility of a trophic transmission within the food chain, with the seriousness of the consequences arising therefrom, poses a risk to human consumption.

Plastic is ubiquitous in various shapes, sizes, materials, and densities in ocean areas, both in surface areas and in the area of pelagic and benthos. Ocean pollution by microplastics has triggered attention primarily because of the potential danger to human health. So, when it comes to microplastics, in the last decade, there has been a greater interest of scientists and researchers in it and, therefore, the incidence of studies on this topic is growing rapidly.

2 Description of the research process

The carried out study presents an overview of relevant research today and is divided into five interrelated units. The first part refers to the sources of pathways of microplastic particles in the marine environment, the second shows different definitions of microplastic particle sizes, the third reviews the presence of microplastics in the world's seas and oceans, the fourth part describes the hazards arising from the contamination of the marine ecosystem with microplastic particles, while the fifth deals with the potential negative effects on humans due to the presence of microplastics in the marine food chain.

2.1 Sources of microplastics

According to the International Union for the Conservation of Nature [6], microplastics is divided into the primary and secondary ones. Primary microplastics are microplastics that are released directly into the environment, while secondary microplastics contaminate the marine environment arising from some plastic material that is already in the environment, regardless of whether it was originally micro or macro in sized.

However, It is difficult to determine the amount of secondary microplastics, due to the unknown degree of fragmentation, and these data are based on assumptions and are therefore not reliable. Numerous environmental factors, such as: photooxidation, mechanical, thermal and/or chemical processes play a role in the process of decomposition of macroplastics into secondary microplastics.

Furthermore, the research is mostly based on primary microplastics, considering the relevance and availability of the data. The relevance of these data stems from the fact that we know its main sources, as well as the size of the world population that produces it and the technology used in order to reduce its emissions. According to the following pattern, approximately accurate data on the amount of primary microplastics discharge have been obtained [6]:

$$\text{Impact} = \text{Population} \times \text{Affluence} \times \text{Technology Efficiency} \quad (1)$$

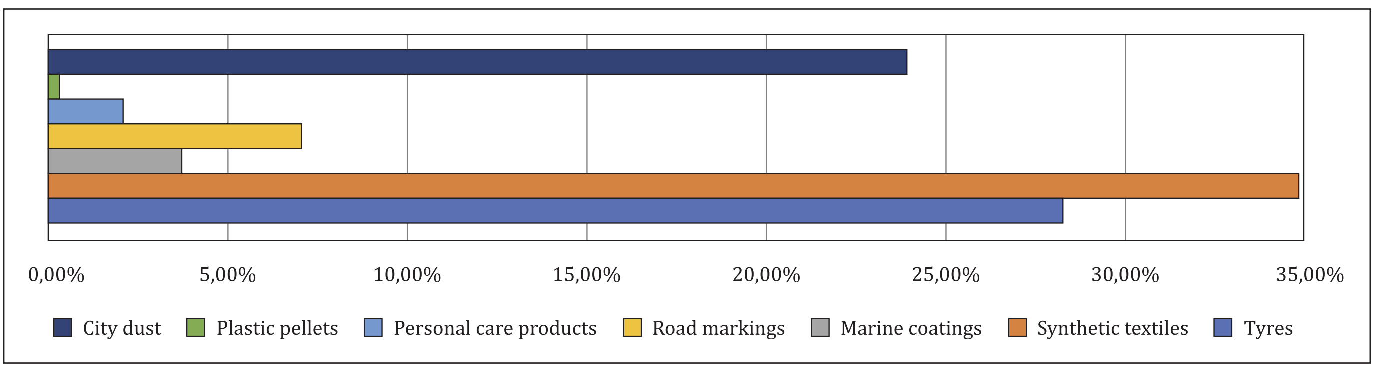

Chart 1 Shares of seven main sources of primary microplastics

Source: Authors according to IUCN data for 2017 [6]

Table 1 Primary sources of microplastics according to the Norwegian environment agency

Microplastics intentionally created	Personal care consumer products
	Industrial or commercial products
Unintentional spill in production and transport	Pellets loss from plastic factories and transport
Microplastic as a by-product / dust emission	Maritime coatings: shipyards, marinas and boatyards
	Building surface maintenance
	Commercial cleaning of synthetic fibers: textiles
Emissions from wear and tear of plastic products during normal use	Households, dust and laundry
	City dust and road wear
	Indoor dust at public and commercial buildings
	Wear and tear of products in aquaculture, fishery and agriculture
Microplastic particles created by waste handling and recycling	Landfills
	Organic waste treatment
	Paper recycling
	Metal shredding
	Food waste shredders
	Decommissioning of ships and oil rigs
	Plastic recycling facilities

Source: Authors according to [31]

Nevertheless, discharge flows can be represented by population size, inflows or activities that generate losses and the ability of the treatment system to extract microplastics.

According to [6], primary microplastic is one of the main global sources of plastics in the oceans, originating from a number of sources (see Chart 1) among which the most common ones are car tires (28.3%), synthetic textiles (34.8%), marine coatings (3.7%), road markings (7%), personal care products (2%), plastic pellets (0.3%) and city dust (24%).

While according to [31], primary sources are those added as new plastic material of micro size to the environment. Major microplastic sources are the ones where microplastics are:

1. Intentionally produced and used as such,
2. An inherent by-product of other products or activities,
3. Emitted as such by accidents or unintentional spill,

All the above mentioned sources are presented in Table 1.

Therefore, the sources or the processes of the formation of secondary microplastics can be divided into the following three parts:

1. Fragmentation of macroplastic particles due to environmental exposure,
2. Fragmentation of macro particles into micro particles by direct action of marine organisms/animals,
3. Re-suspension of old microplastic particles accumulated in the soil or sediment [31].

This example of different definitions and divisions of primary and secondary sources of microplastic particles has resulted in a confusion and difficulty in comparing the results of the conducted studies. Furthermore, primary MP, as well as secondary MP, can also be resuspended after accumulating in the marine sediment. However, resuspension with primary and secondary sources could be considered the third branch of the main division of microplastic sources, while on the other hand, it does not have to be considered as source at all, since these are particles already in the shape and size of microplastic particles in the marine environment and do not represent newly entered quantities.

2.2 Division of micro (plastic) by size

Ranges as well as units of measurement are defined differently by different sources, which is also an obstacle when comparing the results of different surveys.

According to [18], its sizes are defined in the following ranges:

- Nanoplastics (0.001 μm – 0.1 μm),
- Microplastics (0.1 μm – 5000 μm = 5 mm),
- Macroplastics (> 5 mm),

while according to [33], plastic size classes are categorized as:

- Microplastics (0.05 cm – 0.5 cm),
- Mesoplastics (0.5 cm – 5 cm),
- Macroplastics (5 cm – 50 cm),
- Megaplastics (anything above 50 cm).

The research [12] has presented the follwing size classes:

- Small microplastic (< 1 mm)
- Large microplastic particle (1 mm – 5 mm)
- Mesoplastic (5 mm – 25 mm)
- Macroplastic (> 25 mm)

It is imperative to adopt a global classification of quantities and other basic parameters related to this topic, to make the results of future research easier to compare.

2.3 The presence of microplastics in the oceans

It is estimated that from the annual amount of plastic production, sooner or later, 10% of plastic by its weight ends up in the world's seas and oceans [12]. That means that, for instance, out of 368 million tons of plastic produced in 2019, 36.8 million tons of plastic will be found in the ocean at some point and in some form. If that amount is divided by the world population of 7.7 billion people, which is amounted for the same year, approximately 4.8 kilograms of plastic ends up in the marine environment per person per year.

In the marine environment, microplastics accumulate on the surface, in the water column, in sediment, on the shoreline, and, potentially, in marine organisms. The concentration of microplastics is highest along the seabed, as well as in sediment, where it makes up almost 3% of the dry weight of the substance, which also represents the highest concentration of microplastics found in the marine environment [17]. Article [22] states that different techniques/protocols have been used in testing microplastic concentrations in sediments and therefore the results are often not comparable.

Moreover, according to [3], various processes such as bioturbation, that is the process of sediment processing by organisms living below its surface, affect the distribution, and thus the concentration and distribution of microplastic particles in a particular area.

Examination of sediment samples serve as reference values in the assessment of current seabed microplastics pollution. Too many factors affect the values obtained and they change too often. However, sediment samples taken repeatedly over a period of time show notably different values of microplastic concentration. Namely, there is often an exponential increase or decrease in concentration. Therefore, the samples cannot be a visual representation of sediment contamination by microplastics on a global scale, but only indicate the current condition of the examined area.

2.4 Danger and impact of microplastics on the marine food chain

Man has invented, produced, used, and ultimately released microplastic particles into the marine environment, thus endangering not only the marine biota, but also himself as well. This chapter presents the impact of microplastic particles on the marine food chain and the numerous negative consequences that arise from this problem.

Although microplastic is not easily visible to the human eye and even under a microscope it is difficult to distinguish it from other particles such as sediment, tissue, etc., depending on what is being sampled, its appearance in the food chain creates a certain dose of concern for the health and survival of organisms.

Previous researches have pointed out various results, but, according to [17], on average of 30 – 60% of the sampled fish have found a share of primary or secondary microplastics. Nevertheless, microplastics affect not only fish but also other organisms such as plankton, marine reptiles, worms, shellfish, sea cucumbers, lobsters, crabs, etc. Of particular concern is the fact that a large proportion of contaminated plant and animal organisms has also endangered protected species.

There are numerous proven negative effects as well as health consequences on marine organisms, both demersal ones, which take up microplastics from the sediment they are surrounded by, and pelagic ones, which take up microplastics from the water column in which they are located. However, except directly from the marine environment, marine organisms adopt microplastics through the food chain as well. That is achieved by the so-called trophic transmission, apropos by eating organisms smaller than themselves, which have been contaminated with some type and form of microplastics.

The first problem related to the contamination of the marine environment with microplastics relates to their bioaccumulation by marine organisms. According to [19], the main potential of accumulation is the ratio of the size of microplastic particles and the size of marine organisms. Moreover, according to [18], that is especially reflected in large predators, marine mammals that are at the top of the marine food chain. Although it is easier for larger organisms to eject microplastic particles from the intestinal

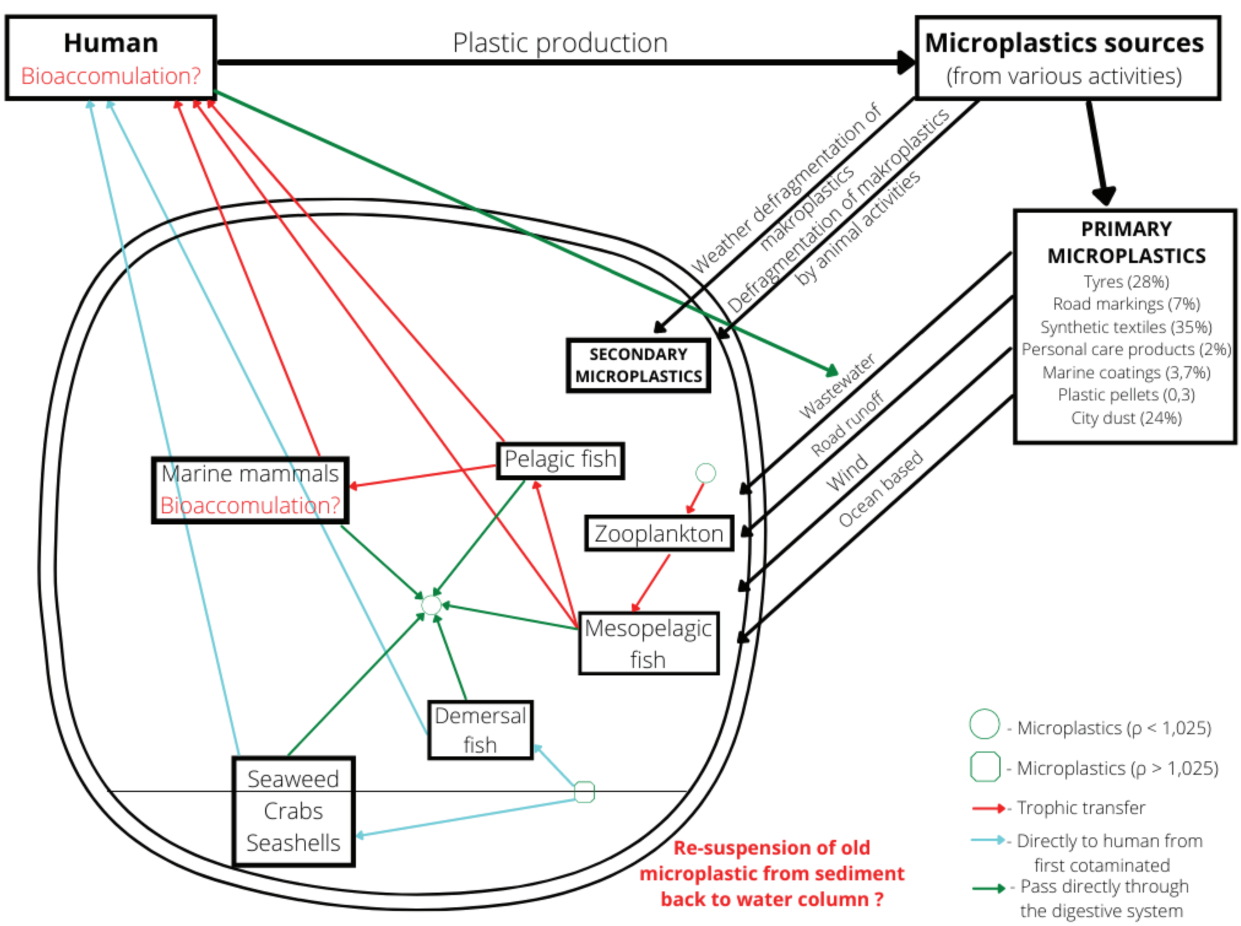

Figure 1 Marine food chain contaminated with microplastics

Source: Authors prepared by Canva online tool; https://www.canva.com/

system, in addition to their longer life span, thus a greater accumulation of microplastics in the body is possible. But not enough attention has yet been paid to this factor. Laboratory tests are mainly performed on smaller organisms while tests on marine mammals that have the greatest bioaccumulation potential are still not conducted in sufficient numbers to be able to create a broader picture of the actual impact of microplastics on such organisms.

Another problem associated with bioaccumulation is the contamination of the marine environment with microplastics. Namely, according to [29], plastic consists of various additives, chemical and toxic substances which, when released, can also notably harm the body and cause numerous disorders, where the toxicity of individual particles depends mainly on their size, and in a lesser extent on the composition. While [26] expires that juvenile fish, as well as larvae of other marine organisms, represent one of the most important links in the sustainability of populations for which the toxic effect of microplastic additives could be fatal.

The third type of problem is the shape and size of the microplastic particle itself. Namely, [20] states that thin, and oblong particles are more easily absorbed into the body than short and spherical ones. While size is a key factor which affects the amount of particles ingested in marine organisms, it is also the range of negative effects.

It is estimated that by 2025, the ratio of plastic to fish in the world's seas and oceans will be 1 to 3 tons, which is equivalent to 600 plastic bags for every 10 kilograms of fish [13]. That is not surprising, despite the fact that approximately 100 million tons of seafood are consumed annually, and the plastic produced is close to 400 million tons per year [19]. Overfishing of fish and other marine organisms, along with an enormous plastic production, results in the previously listed facts.

2.5 Impact of the marine food chain contamination on humans

It is known that the consumption of fish products has many advantages. They are rich in nutrients, but it is questionable what effect they have on the human body if they are rich in PBT (Persistent bioaccumulative and toxic compounds). It is therefore necessary to define the relationships of positive and negative effects from the consumption of fish and other seafood, that is, to make a risk-benefit assessment.

According to [35], microplastic particles can affect the body in the following ways: physically, chemically, and microbiologically. Although the impact of microplastic particles on the human body is a relatively young area of research, previous research [8, 30, 34] has shown that small microplastic particles found in human stool, cancer samples and in amniotic fluid and placenta in pregnant women pose a risk to pregnancy, embryo, development, and health in general. Furthermore, [34] has shown that microplastic particles do not degrade in the body resulting in a number of adverse effects including oxidative stress, granuloma formation, etc. Moreover, in addition to the microplastic particles themselves, there is a danger of the harmful effects of bacterial pathogens, which are found in the biofilm with which the microplastic particles are coated [10]. Given the identified MP particle sizes [1] < 10 μm (which is less than bacteria) and <0.3 μm (which is less even than viruses), it has been found that they can enter the bloodstream, brain and other tissues and organs, which can be the base for many chronic diseases, but also for numerous inflammations, cell damage, and DNA damage.

Except by swallowing, microplastic can come into contact with fish and other marine biota by adhering to their external parts such as gills and fins. These parts, as well as the intestines, are most often removed when consumed by humans. Therefore, in this way, the risk of ingestion microplastics from the marine food chain is significantly reduced. However, the impact and presence of microplastics in humans has not yet been sufficiently investigated. There are still unknowns regarding the absorption, distribution, metabolism, and excretion of microplastics in humans. To obtain relevant effect values, the research is needed to be based on toxicological, epidemiological, and model studies and not just based on estimates. However, the stated results of previous researches, i.e. the identified microplastic particles in humans, do not arise entirely from the marine food chain, but are the cumulative result of all food chains at the top of which man is or may be.

3 Research results and discussions

The basic data/parameters related to MP, on which most researches have been based, are not clearly defined at the global level. Various "input data" are used from study to study, leading to an inadequate comparison of the final research results. It is also necessary to define the methods/protocols and technologies used in individual sampling or testing of seawater or sediment.

Although various technologies have been designed to remove microplastic particles from the ocean, the question is how effective this really is, based on the spread of microplastic particles from the polar regions, across the deepest parts of the ocean to sediment and coast, and, of course, the ratio of ocean sizes and removal technologies.

Particle removal also does not matter if we do not stop bringing new plastic into the oceans. Of course, the accumulated concentration of microplastic particles in the oceans would then decrease or remain at the same level without further contamination. However, removal and reintroduction are not really the solution. On the other hand, such a process may result in by-catches of marine organisms, implying that, depending on the technology, it may remove microorganisms from the water column or those connected by the biofilm to the MP particles themselves.

Therefore, biodecomposition, along with the prevention of further ingestion, is the only complete way to remediate marine pollution with plastic.

4 Conclusion

The presence of microplastics has been recorded in most of the sampled oceanographic habitats around the world, which means that the plastic revolution is coming to charge. Addressing this problem is imperative but there is still no global regime to coordinate this environmental challenge. The essence of solving each problem, including this one, lies in the prevention, that is, in finding a solution for closing the source of plastics or in reducing the production and use of it, but also in increasing recycling (the percentage of which is increasing, but still lags far behind other products like paper, iron, etc.) and / or reuse, or combustion for energy production and in the production of biodegradable plastics. Prevention is a key factor in improving each action. Corrective actions for the "plastic ocean" are long-lasting, economically unprofitable, require enormous amounts of energy and, most importantly, are insufficiently effective.

Above all, further researches should focus on developing protocols to prevent further contamination of the marine environment with microplastic particles.

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