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Assessing the impact of microplastics on the environment

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Abstract. In this article, plastic pollution of the environment, including land and water, is one of the world's biggest problems, but little is known about the effects of synthetic polymers on soil populations. The main goal of the article is to analyze the presence of plastic in water and soil in Azerbaijan and around the world, as well as to propose methods of cleaning water and soil from plastic based on global and own experience. The methodology and materials used in this study were chosen to effectively investigate the distribution of microplastics in the environment. In the study, it was determined that the particles of microplastics are present in both soil and water, and the cleaning processes corresponding to them were indicated.

1 Introduction

Over the past decade, a sharp increase in the number of studies has allowed us to significantly expand our knowledge of microplastics in nature. However, fundamental questions and problems remain unresolved. Let us list two areas that are currently the most pressing. It is a material based on natural or synthetic polymers that can take a given shape when heated and, under pressure, stably retain it after cooling.

Plastic consists of structural repeating units called monomers. They are linked into long chains called polymers. Chemical ingredients with a plastic content of more than 50% are classified as hazardous [1].

In the soil, microplastics change the structure of the humus layer, disrupting natural processes such as water movement through the soil and the activity of soil microorganisms. The long-term presence of microplastics in the soil has a negative effect on the development of plants, productivity and agriculture. In addition, this pollution accelerates soil erosion and further pollutes water sources as a result of runoff.

About 80% of microplastics in wastewater are synthetic fibers that end up in drains after washing clothes. In 2013, about 55 million tons of clothing and textiles were produced from synthetic fibers. Some microplastic particles (probably nanoplastics, although no studies have been conducted) end up in rivers and oceans, bypassing treatment facilities. At the same time, particles that are 300 million tons of plastic [2-3].

Pollution of the environment with synthetic polymers is one of the largest environmental problems. Ubiquitous, plastic is found in all environments, impacting the planet's biota and human well-being. Plastic pollution can interact with other global processes and have remote

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and long-term consequences. The scale of plastic pollution is sufficient to use it as a stratigraphic indicator of the Anthropocene.

To reduce the production of microplastics at the global level, restrictions should be placed on the production and use of plastic products, especially single-use goods. Alternatively, the use of reusable and easily degradable materials in nature should be expanded. Microplastic pollution should be prevented by adopting laws and regulations at the global and local level.

The increasing plastic pollution of the World Ocean and freshwater bodies has been recognized for many years as a major threat in the environmental, economic and social spheres. According to their size, degradable polymers are classified as megaplastics with a characteristic size of more than 100 mm, macroplastics (20–100 mm), mesoplastics (5–20 mm) and microplastics (< 5 mm). Microplastics pose the greatest potential environmental hazard [4].

It is common to classify polymer waste not only by size but also by source. In this case, microplastics can be primary, which includes any plastic fragments 5.0 mm or smaller in size before they enter the environment. Sources include clothing microfibers, plastic granules, cleaning agents, etc [5].

Secondary microplastics are polymer wastes that form because of the destruction of large garbage. These are plastic particles that undergo fragmentation or photodegradation processes both at sea and on land.

Microplastics have the ability to accumulate in soils, water, and the bodies of living creatures, which leads to negative consequences for ecosystems:

Marine ecosystems: Research shows that microplastics in the oceans have a significant impact on marine fauna. Plastic particles are ingested by marine organisms, ranging from plankton to large mammals. This not only blocks the digestive systems of animals, but also contributes to the accumulation of toxins in their bodies.

Terrestrial ecosystems: Microplastics enter the soil with agricultural waste, rainwater, and even fertilizers. Their presence in the soil disrupts the structure of the soil, reduces its fertility, and affects plant growth.

Human impacts: Microplastics also enter the human food chain through the consumption of water, food (especially seafood), and inhalation of airborne particles. Although the full effects on human health are not yet fully understood, research shows that microplastics can promote inflammatory processes and carry toxic chemicals on their surface.

The sources of this type of microplastic are the decay products of plastic bags, disposable tableware, drinking bottles, etc [6].

Consumers also play an important role in this matter. Reducing the use of plastic products and opting for more environmentally friendly alternatives can significantly reduce the release of microplastics into the environment. It is important to educate people about the dangers of microplastics through education and awareness programs.

When all these measures are implemented, it will be possible to reduce the negative effects of microplastics on the environment and protect ecosystems in the future. Technological innovation, improved management strategies and public awareness will be key to preventing the spread of microplastics in the environment.

The consequences of plastic pollution of marine ecosystems have been studied in hundreds of studies. The degree of plastic pollution of terrestrial ecosystems, including soil, has also reached alarming proportions, but the associated environmental problems have attracted much less attention (Fig. 1) [7].

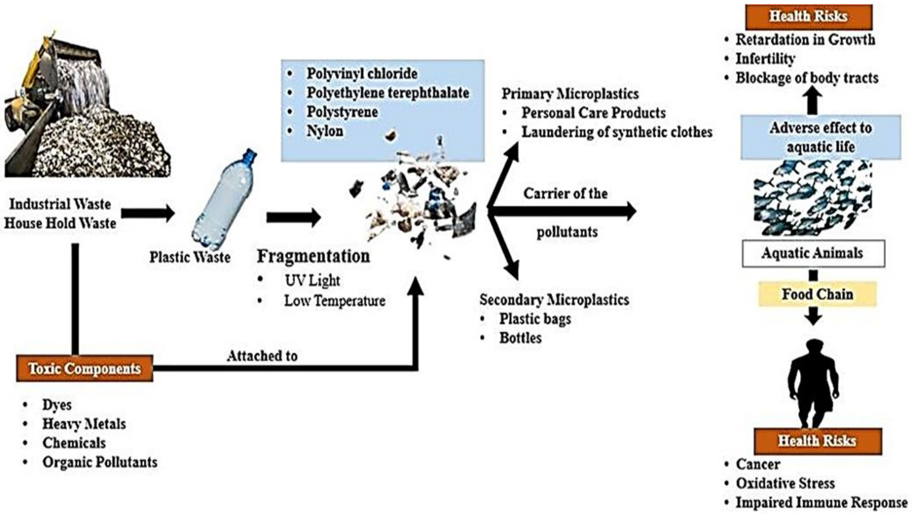

Fig. 1. The impact of microplastics on the environment and human health.

Plastic in terrestrial ecosystems usually enters the soil, and its further fate is determined by the self-purification capabilities of the soil environment Table 1 [8]**.**

Table 1. The main types of plastics.

Types of Plastic	Common abbreviation	Application
Polypropylene	PP	bottles, cups, garden furniture, food containers, packing
Polyethylene	PE	bands
Low Density Polyethylene	LDPE	bags, drinking bottles
High Density Polyethylene	HDPE	garbage bags, wrapping paper, agricultural
Polyethylene Terephthalate	PET	films, pipeline insulation materials
Polystyrene	PS	containers, containers,
High Impact Polystyrene	HIPS	pipeline production
Polyamide	PA	fibers, food films,
Polyester	PES	plastic bottles
Polyvinyl Chloride	PVC	disposable tableware,
Polycarbonate	PC	imitation crystal, plastic toys

In general, the diversity of plastic types and units of measurement used, including in relation to the particle sizes of microplastics, make it difficult to compare the data obtained. To date, particles of polyethylene (PE), polyethylene terephthalate (PET), polypropylene (PP), polystyrene (PS), polyvinyl chloride (PVC), acryl butadiene styrene (ABS), polyamide, polyester, etc. have been identified in the soil [9].

2 Methods and materials

The article presents the generalized and new methods and technologies available for cleaning plastic in water and soil, for example: filtration in various structures (mechanical methods), flotation, membrane and reverse osmosis systems, membrane bioreactors (physico-chemical and combined methods).

Mechanical methods are one of the primary methods widely used for cleaning microplastics. Mechanical methods include filtration, vibration cleaning, and mechanical separation. Filtration is used to separate microplastics from larger particles. Vibration technology, on the other hand, uses vibrating screens to remove very small particles from soil or water. The main advantage of mechanical cleaning methods is their high efficiency, but their application in large-scale areas and long-term processes is not very economical. Banning its production or creating biodegradable plastic has been proposed as an initial way to reduce the amount of microplastic in water and soil [10].

Mechanical methods are also used to clean microplastics in sewage treatment plants. Conventional wastewater treatment plants use strained nets with 16 mm gaps to capture microplastics. However, due to the smaller size of microplastics, filters with 10 mm or smaller gaps have begun to be used [11].

As a more effective method of wastewater treatment, multi-stage filtration is used. This technology captures large particles during the primary treatment of water, and then smaller microplastics are retained through second and third filters. Such a multi-stage system allows for a higher degree of capture and purification of microplastics.

To solve the problem - cleaning water and soil from plastic - there are many ways, but they mainly boil down to two:

- firstly, the creation of new types of plastic and materials that decompose in nature and are harmless to all living things.
- the second is the improvement of the existing ones and the creation of new effective methods and technologies for cleaning water from plastic.

To clean water and soil from microplastics, we offer mechanical and physico-chemical methods, as well as their combinations [12].

Physical distillation method is possible for small water streams. At sewage stations in Azerbaijan and other countries, tensioning is carried out on grids with gaps of no more than 16 mm (according to SNiP) with rectangular or other shaped rods. Such a gap in the bars does not allow holding plastic the size of a human hair, so we switched to a smaller gap size - 10 mm or less. Special granular materials or sand filters are also used in the mechanical cleaning process. These materials are applied as an additional treatment step for the retention and removal of microplastics from water and soil. This technology is highly effective in capturing small particles of microplastics. For example, microplastics of 5 microns and smaller can be effectively retained through specially designed granular material filters.

This method is used more often in the process of cleaning the soil. Cleaning with granular materials reduces environmental pollution by retaining microplastics in the soil and increases the suitability of the soil for reuse.

To capture fine particles of plastic, we suggest filtering on vibrating screens with slot-like sieves with opening sizes of 0.25-0.1 mm. Such screens are widely used for concentrate dewatering in processing plants in the mining and coal industries. Multi-stage filtration (2 or more stages) can be installed on the screens to increase the efficiency of plastic recovery. Capable of capturing plastic particles from 0.1 mm to 30 microns or less [13].

Filtration, however, as an additional cleaning, can be carried out through a layer of special granular material developed by us. It allows for the retention of pollutants in water and soil, including microplastics less than 5 microns in size.

Reverse osmosis is made possible by using semi-permeable membranes that allow water to pass freely and at the same time retain 90-99% of all dissolved inorganic compounds, 95-99% of organic substances and 100% of the smallest colloidal and plastic impurities [14].

Nanofiltration is a baromembrane process for the separation of substances with a molecular weight of up to 300–500 μm (working pressure 1–2 MPa). Nanofiltration membranes have holes with a nanometric diameter (1-3 nm). They retain electrolytes (NaCl 40-60%) and almost completely (98-99.9%) organic compounds (alcohol, sugar, pesticides, plastic, etc.). Microfiltration is a barometric process used to separate suspended and colloidal particles with a size of 0.1-10 μm, including plastic particles, from a solution (working pressure 0.01-0.05 MPa) [15].

Ultrafiltration is a process of baromembrane separation, as well as concentration and fractionation of solutions of high molecular weight compounds (working pressure 0.05-0.5 MPa). This process, unlike reverse osmosis, is used to separate systems where the molecular weight of the dissolved components is much greater than the molecular weight of the solution (water). In practice, ultrafiltration is used when the molecular weight of at least one of the components of the solution exceeds 500 μm (plastic, etc.) [16].

Flotation is based on different degrees of wetting of different substances with water. The essence of the process is that plastic particles adhere to air (gas) bubbles and carry them to the surface of the apparatus, where they form a foam. The optimal sizes of foam particles are 10^{-5}-10^{-3} m [17].

To reduce microplastic pollution, action is needed at both the global and local levels:

Reduce plastic use: Reduce the production of single-use plastic products and encourage the use of reusable alternatives.

Improve the efficiency of wastewater treatment systems: Current wastewater treatment systems are often unable to effectively capture microplastics, so new filtration technologies are needed.

Improve waste management: Moving to separate collection and recycling of plastic waste will help reduce its release into the environment.

International agreements: Global efforts and legislation are needed to reduce microplastic pollution, especially in developing countries where recycling rates remain low.

These proposed solutions are designed to reduce the environmental impact of microplastics globally and locally. First and foremost, it is important to reduce plastic production and encourage the transition to alternative reusable products. The production of single-use plastic products should be limited, because these products turn into microplastics and seriously pollute the environment [18].

Secondly, increasing the efficiency of wastewater treatment systems is an important step. Current sewage treatment systems struggle to capture microplastics effectively, so new technologies are needed. Filters and other modern technologies should be widely used in water purification processes.

Improving waste management is also important. Separation and recycling of plastic waste will help reduce the release of plastic waste into the environment. To achieve the best results, separate collection and treatment of different types of waste should be encouraged.

Finally, international agreements and legislative measures must consolidate global efforts to prevent microplastic pollution. Waste management systems in developing countries are still at a low level, so international cooperation and financial support are essential to improve recycling performance in these countries. When these measures are implemented together, it is possible to reduce the damage caused by microplastics to water and soil and make the environment safer.

In this way, both technological solutions and legislative measures are required to reduce the impact of microplastics on the environment. Solving these problems for the sustainability of ecological systems and human health should be one of the global priorities [19].

3 Conclusion

It mentioned that, there are both traditional and innovative methods for cleaning water and soil from plastic. Mechanical methods, flotation, membrane technologies (microfiltration, nanofiltration, ultrafiltration) and reverse osmosis systems offer effective solutions in this area. Also, combined technologies such as membrane bioreactors show high efficiency.

At this time, the presence of a large number of microplastic particles in the identified soil indicates the need to take environmental measures to prevent the dispersion of raw material granules. it is necessary to minimize the spread of polystyrene waste.

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