MICROPLASTICS IN NATURAL WATER: SOURCES AND DETERMINATION

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The paper is devoted for origin of microplastics in aquatic environment and possible methods of characterization and analysis. According to US National Oceanic and Atmospheric Administration, microplastics are synthetic organic polymer particles with a size less than 5 mm. Microplastics pollution is a significant ecological problem in the world. A lot of surface waters are significantly polluted by various types of microplastics. These pollutants were found in rivers, lakes, oceans, sediments, wastewater, drinking water and bottled water. But in Ukraine microplastic problem of surface water do not meet the interest of scientists and ecological organizations. Disintegration of plastic waste is one of the main sources of microplastics in water. But there are a lot of other sources of primary and secondary microplastics, including components personal care products, industrial abrasives, abrasion from car tires, paint failure, industrial processes, textile washing, at-sea losses, etc. Microplastics can harm ecosystems and cause many health problems for different organisms, including problems with feeding and digestion, endocrine disruptions and changes in cellular functions. In general, health effects and environmental impacts are dependent on the size of the microplastic particles and chemical structure of these polymers. Thus, it is very important to understand chemical composition, physical forms, transport in environment and fragmentation of microplastics due to the need to predict possible exposure effects. There are a lot of methods for characterization and analysis of microplastics, but all of them have some disadvantages. Microplastics determination is often especially difficult for water with low microplastics content due to very large volumes of water samples and very small mass of separated plastics.

Keywords: *aquatic environment, microplastic particles, microplastic pollution, plastic waste, water pollution*

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1. Introduction

According to US National Oceanic and Atmospheric Administration, microplastics are synthetic organic polymer particles with a size less than 5 mm (Duis & Coors, 2016).

Microplastics have been investigated for over 50 years especially in the marine environment, but only in recent years research has also started to focus on freshwater environments (Scherer et al., 2020).

In general microplastics presence in aquatic environment is one of the significant water quality problems in XXI century, because now these particles are present in different rivers, lakes, oceans, sediments, soils, wastewater, drinking water and even bottled water. For example in the surface layer of River Danube between Vienna (Austria) and Bratislava (Czech Republic) mean concentration of small plastic items was 0.938 items/m^3 in 2010 (Duis & Coors, 2016).

Microplastics are ubiquitous contaminants and can harm different ecosystems (Prata, 2018).

Microplastics occupy different areas of the water column and benthic sediments due to the varying density of different plastic materials (Bergmann, 2015). Plankton-consuming organisms are at risk of accidentally or selectively ingesting of microplastics with plankton due to mixing and interruption of these suspended particles and plankton.

Evaluating the harmful impacts of microplastics on the ecosystem is a difficult task as they come in a range of physical characteristics such as size, shape, color, etc., as well as chemical compounds like polymer, adhesives, and other chemicals. These factors determine the fate, transport, and bioaccumulation of microplastics in various ecosystems (Kumar et al., 2022). In general, health effects are dependent on the size and type of the microplastic particles.

Microplastics with the size about 1–5 mm may compromise feeding and digestion. Microplastics can become trapped in an organism and cause toxic effects by obstructing bodily pathways (Katare et al., 2022). Very small microplastic particles may permeate into the lipid membranes of organisms, altering the membrane structure, membrane protein activity, and therefore cellular function (Bergmann, 2015).

Depending on their density, microplastics can either float and come into contact with pelagic organisms on the surface of the water (low-density microplastics) or sink to the bottom of the water and interact with benthic organisms (high-density microplastics) (Kumar et al., 2022). Low-density microplastics can also impede photosynthesis of algae, mix with food sources, and create additional toxicity in bodily systems (Katare et al., 2022).

Polythene and propylene, for instance, can cause an accumulation of polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) within an organism (Katare et al., 2022).

According to the some experiments (Duis & Coors, 2016), consumption of microplastics may provoke endocrine disruption for freshwater fish.

So, nowadays microplastics pollution is very important problem due to significant and insufficiently explored environment and health effects of these pollutants.

2. Microplastics Origin and Presence in Aquatic Environment

Every year rivers carry 1.25–2.41 million tons of plastic material into the seas and oceans (Kurtela & Antolović, 2019). Urbanization and industry are among the most significant causes of microplastics pollution in rivers (Scherer et al., 2020). In the water residue inside the USA there are $3.5 \cdot 10^{3}$ microplastic units per 1 L, but in Mongolia microplastic content in water is only $2.0 \cdot 10^{-4}$ units/L (Katare et al., 2022).

Ukraine is the country with significant urbanization, large consumption of different synthetic polymers and not enough effective waste sorting, so problem of microplastics presence in surface water may become more and more acute.

The problem of plastic waste first appeared in the 1950s due to beginning of massive production of plastic. Now plastic production reached 300 million tons per year and about 50 % of these plastic products are single used (Kurtela & Antolović, 2019).

About 15–50 % of plastic waste is dumped into oceans. This typically occurs

after plastic waste ends up on land or when plastic materials are carried by wind or flowing water and discarded into water bodies like oceans, rivers, lakes, etc. (Katare et al., 2022). The freshwater ecosystem receives microplastics from the terrestrial environment and transport the polluted water to the seas and oceans (Katare et al., 2022). Moreover, polluted rivers and lakes are freshwater sources, which are used for drinking water production.

Nowadays in the environment there are a lot of various microplastics with differing in size, shape, chemical composition and specific density that originate from a variety of different sources (Duis & Coors, 2016). But in general scientists can divide microplastics into two sections. There are primary (produced in a micro-size range) and secondary (produced by the fragmentation of macroplastics) microplastics (Figure 1).

Disintegration of plastic waste is one of the main sources of microplastics in water. But there are a lot of other sources of primary and secondary microplastics, including discharge after wastewater treatment, tire wear, paint failure, industrial processes, textile washing, at-sea losses, etc. (Duis & Coors, 2016; Hale et al., 2020).

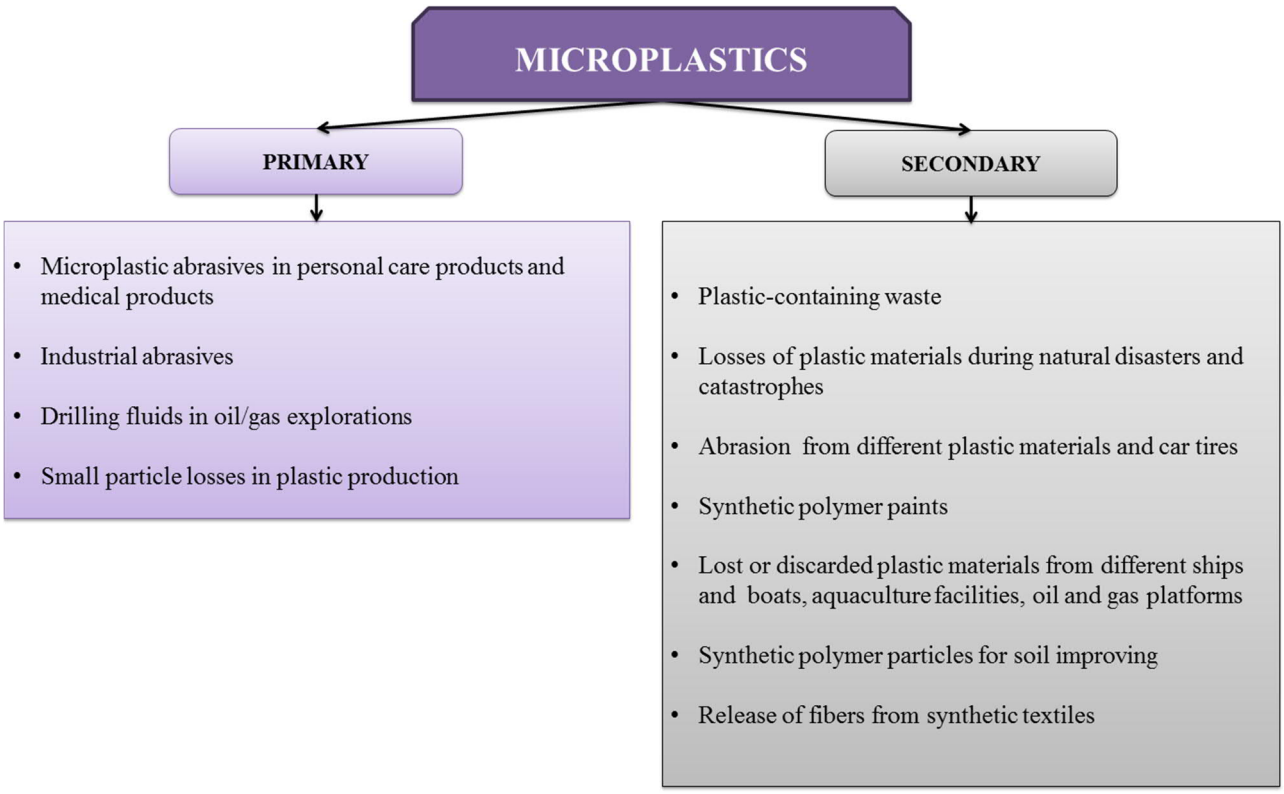

Fig 1. *Microplastics classification*

Microplastics are commonly found in freshwater, with the number concentrations ranging widely - from 10^{-2} to 10^{8} units/m^3 (Koelmans et al., 2019).

PE and PP microplastics are the main types of microplastics in freshwater systems (Zhao et al., 2022). The order of the most commonly detected polymers globally is PE ≈ PP > PS > PVC > PET, which likely reflects global plastic demand and a greater tendency for PVC and PET to settle due to their higher densities (Koelmans et al., 2019).

Fibers, fragments, film, foam, and pellets are the most frequently shapes of microplastics (Koelmans et al., 2019; Li et al., 2018; Yu et al., 2018). Fibers were found in 95 % water samples, fragments and films were found in 86 % and 74 % of samples, respectively (Kumar et al., 2022).

3. Methods of Microplastics Characterization and Analysis

Understanding of chemical composition, shapes and fragmentation of microplastics is very important for risk assessment and prediction of environmental impact.

There are two stages to analyze microplastics: purification and extraction as the first step, followed by quantification and identification as the second step. Initially, microplastics need to be separated from the primary medium to enhance or modify subsequent quantification and/or identification (Katare et al., 2022).

There are a lot of methods for characterization and analysis of microplastics, but all of them have some disadvantages (Table 1) (Hale et al., 2020; Litynska et al., 2022). But some problems occur when using any method of characterization and analysis of microplastics.

All methods usually have one common preparation stage, namely filtration of water sample throw membrane filter. Surface waters often contain a lot of natural organic matter, which causes fouling of membrane filter during filtration of large volumes of water samples. Thus, sometimes separation of microplastics from natural water is difficult and very prolonged process.

Table 1. *Microplastics classification (Litynska et al., 2022)*

Methods	Disadvantages
Light microscopy	Method cannot provide chemical composition; cannot differentiate synthetic polymers from sample interferences
Fourier transform infrared spectroscopy (FTIR)	Conventional FTIR is typically limited to targets >10 μm due to diffraction limit considerations
Raman microspectroscopy	Very expensive equipment
Atomic force microscopy	Very expensive equipment
Optical photothermal infrared spectroscopy	Very expensive equipment
Fluorescence microscopy with usage of a lipophilic fluorescent dye (Nile red)	A lot of biogenic materials, including chitin, also are fluorescent Method cannot differentiate synthetic polymers from these biogenic materials
Pyrolysis gas chromatography/mass spectrometry (GC/MS)	Very expensive equipment; method cannot determine size and shape; destruction of samples
Nuclear magnetic resonance	Very expensive equipment; method cannot determine size and shape; destruction of samples

Also microplastics determination is especially difficult for water with low microplastics content due to very large volumes of water samples and very small mass of separated microplastics (Chaudhari & Samnani, 2023; Terzi et al., 2022). This problem may be typical for many Ukrainian natural waters due to the insignificant use of plastic packaging materials in the USSR. Plastic waste takes a long time to break down into microplastics. Therefore, the plastic waste that has accumulated over the past decades can yet incompletely destructed into microplastics and can be in the state of macroplastics.

But, despite all difficulties, from an environmental point of view, the definition of microplastics in natural waters is very important and necessary.

4. Conclusions

Microplastic pollution is a major ecological issue worldwide. According to the US National Oceanic and Atmospheric Administration, microplastics are synthetic polymer particles with a size of less than 5 mm. The problem of plastic waste first emerged in the 1950s with the start of plastic production on a massive scale. Currently, plastic production has reached 300 million tons per year, and approximately 50% of these plastic products are single-use items. The disintegration of plastic waste is a significant source of microplastics in water, but there are many other sources, including the release of wastewater after treatment, tire wear, paint failure, industrial processes, textile washing, at-sea losses, etc.

Numerous methods exist for characterizing and analyzing microplastics, though each method has its disadvantages. However, challenges often arise when applying any method for the characterization and analysis of microplastics.

Typically, all methods include a common preparation stage, which involves filtering a water sample through a membrane filter.

Light microscopy is the most popular and the least expensive method of microplastic determination, but this method cannot provide chemical composition and cannot differentiate synthetic polymers from sample interferences.

Raman microspectroscopy, atomic force microscopy, optical photothermal infrared spectroscopy are the most precise methods, but all of them require very expensive equipment.

Regardless of the challenges that come with it, defining the presence of microplastics in natural waters is vital and essential from an environmental standpoint.

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МІКРОПЛАСТИК У ПРИРОДНИХ ВОДАХ: ДЖЕРЕЛА ТА ВИЗНАЧЕННЯ

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Стаття присвячена джералам потрапляння мікропластику до водойм та можливим методам характеризації та аналізу цих полютантів. Згідно Національного управління океанічних і атмосферних досліджень США, мікропластик – це частинки синтетичного органічного полімеру розміром менше 5 мм. Забруднення мікропластиком є серйозною світовою екологічною проблемою. Багато поверхневих вод є в значній мірі забрудненими різними видами мікропластику. Ці полютанти були знайдені в річках, озерах, океанах, осадових відкладеннях, стічних водах, питній воді та бутильованій воді. Але в Україні проблема присутності мікропластику у поверхневих водах не викликає значного інтересу науковців та екологічних організацій. Розкладання пластикових відходів є одним із основних джерел мікропластику у воді. Але існує багато інших джерел первинного та вторинного мікропластику, наприклад, компоненти засобів особистої гігієни, промислові абразиви, частинки від стирання автомобільних шин, частинки фарб, промислові процеси, прання текстилю тощо. Мікропластик може завдавати шкоди екосистемам і викликати багато проблем зі здоров'ям у різних організмів, включаючи проблеми з живленням і травленням, ендокринні розлади та зміни клітинних функцій. Загалом вплив на здоров'я та навколишнє середовище залежить від розміру частинок мікропластику та хімічної структури цих полімерів. Таким чином, дуже важливо знати хімічний склад, форму та особливості міграції мікропластику в навколишньому середовищі, оскільки ця інформація є потрібною для прогнозування можливих ефектів впливу. Існує багато методів характеризації та аналізу мікропластику, але всі вони мають деякі недоліки. Визначення мікропластику часто є особливо складним для вод з низьким вмістом мікропластику внаслідок необхідності дуже великих об'ємів проб води та дуже малої маси відокремленого пластику.

Ключові слова: *водне середовище, забруднення води, забруднення мікропластиком, пластикові відходи, частинки мікропластику*