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Satbayev University

ХАБАРЛАРЫ

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НАЦИОНАЛЬНОЙ АКАДЕМИИ
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NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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MICROPLASTICS IN THE AQUATIC ENVIRONMENT: OVERVIEW OF THE PROBLEM AND CURRENT RESEARCH AREAS

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Abstract. In the article there is a review of world experience in the study of pollution of water bodies, including plastic particles. To date, the problem of plastic pollution has become global. Plastic pollution is a relevant and relatively new direction. The term "plastic" is a generalized name for the family of synthetic polymers. Plastic is a highly demanded material, which is used in all sectors of the economy for various reasons such as low cost, durability, etc. At the same time, it has a negative impact on the environment and impacts humans and living organisms by entering the food chain. Scientists classify plastic into micro- and macro-plastic according to particle size. Analysis of the study of plastic pollution leads to the conclusion that the smaller the size of the particles, the greater their impact on the pollution of water bodies. The difficulty of assessing plastic pollution is the lack of a unified recommended methodology. The study of MP problems in continental water bodies, including its possible concentrations, interaction with hazardous chemical compounds and impact on biota, is just beginning to be investigated. In this situation, it is reasonable to recommend the inclusion of micro- and macroplastics as one of the components of the program for monitoring the qualitative condition of surface waters.

Keywords: Pollution, aquatic ecosystem, microplastics, polyethylene
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Аннотация. Мақалада су нысандарының, пластикалық қалдықтармен ластануы бойынша зерттеулерддің әлемдік тәжірибелереріне шолу жасалды. Бүгінгі таңда пластикпен ластану мәселесі жаһандық сипатқа ие болды. Пластикпен ластану өзекті мәселе және салыстырмалы түре жаңа бағыт болып есептеледі. «Пластик» термині синтетикалық полимерлер класының жалпыланған атауы. Пластик экономиканың әр түрлі салаларында арзан, берік және т.б болғаны үшін сұранысқа ие материал болып табылады. Сонымен бірге ол қоршаған ортаға және тамақ арқылы адамдар мен тірі организмдерге теріс әсер етеді. Бөлшектердің мөлшері бойынша ғалымдар пластикті микро және макро пластикке жіктейді. Пластикалық ластануды зерттеуді талдау бөлшектердің мөлшері аз болса, соншалықы су нысандарына әсер етеді деген қорытындыға әкеледі. Пластикпен ластануды бағалаудың қиындығы біркелкі ұсынылған әдістемелердің жоқтығында. Континентті су айдындарында МП мәселелерін ,мүмкін болатын концентрациясын және қауіпті химиялық қосылыстармен өзара әрекеттесуін зерттеу енді қолға алына бастады.Бұл жағдайда жер үсті суларының сапалық жағдайын бақылау бағдарламасына микро және макро пластикті қосуды ұсыну орынды.

Түйін сөздер: Ластану, су экожүйесі, микропластик, полиэтилен

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МИКРОПЛАСТИК В ВОДНОЙ СРЕДЕ: ОБЗОР ПРОБЛЕМЫ И АКТУАЛЬНЫЕ ОБЛАСТИ ИССЛЕДОВАНИЙ

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Аннотация. В статье выполнен обзор мирового опыта по исследованию загрязнений водных объектов, в том числе и пластиковыми частицами. На сегодняшний день проблема загрязнения пластиком стала глобальной. Загрязнение пластиком является актуальным и относительно новым направлением. Термин «пластик» — обобщенное название семейства синтетических полимеров. Пластик является высоковостребованным материалом, который используется во всех отраслях экономики по различным причинам как низкая себестоимость, долговечность и т.д. В то же время он оказывает негативное влияние на окружающую среду и воздействия на человека и живые организмы путем попадания в пищевую цепочку. По размеру частиц учёные классифицируют пластик на микро- и макропластик. Анализ изученности загрязнения пластиком приводит к выводу, что чем меньше размер частиц, тем больше они оказывают влияние на загрязнение водоемов. Сложность оценки загрязнения пластиком заключается в отсутствии единой рекомендованной методики. Изучение проблем МП в континентальных водоемах, включая его возможные концентрации, взаимодействие с опасными химическими соединениями и воздействия на биоту, только начинает исследоваться. В этой ситуации резонно рекомендовать включение микро- и макропластика одной из составляющих программы мониторинга за качественным состоянием поверхностных вод.

Ключевые слова: загрязнение, водная экосистема, микропластик, полиэтилен

Introduction. In 2011, the United Nations Environment Program identified plastics, including micro- and macroplastics, as an emerging environmental problem (UNEP. Year Book, 2011). Research is still relatively new, and the problems associated with plastics are not yet fully understood, with current research showing that despite their small size, micro- and macroplastics pose a more serious problem. Recently, a lot of efforts of scientists have been devoted to the study of micro- and macroplastic pollution specifically in the aquatic environment. At the same time, most of the publications are aimed at studying the problems of plastic pollution in the marine environment, while they are still limited for freshwater systems. Considered in studies (Sighicelli et al., 2018) semi-enclosed systems with changing hydrographic conditions, freshwater lakes may be affected by the presence of micro- and macroplastics even more than oceanic and coastal regions. Thus, microplastics found in freshwater ecosystems can contaminate aquatic biota, cause physical damage, and enter the food chain while their toxic effects may be considered low. Since the advent of systematic studies, micro- and macroplastic pollution has been identified in lakes of various sizes in North America, South America, Europe Asia and Africa. At present, there are virtually no data on plastic pollution in remote lakes whose watersheds do not have a permanent population. Under these conditions, micro- and macroplastics can arrive with atmospheric precipitation even in remote protected areas (Brahney et al., 2020).

Results and discussion

One of the main environmental problems today is the pollution of the environment and the world's oceans by micro- and macroplastics (MP). The term "plastic" or plastic" refers to a family of synthetic polymers created since the 1940s, although the term "plastic" itself has been used since the late 19th century (Kazmiruk et al., 2020).

Plastic itself is nowadays one of the necessary materials and is used in absolutely all areas of industry. The physical and chemical properties of plastic, providing strength, weightlessness and durability combined with low cost, are indispensable, in the manufacture of household products, in construction and manufacturing. But, in addition to the practical qualities, there are also negative consequences, because the impressive amount of plastic waste threatens the environment through the discharge of sewage water, littering of the coastal strip during industrial and domestic activities, in shipping and fishing, coastal protection activities, operation of landfills. The massive use of plastic products in industrial production, also in the household influenced the origin of the difficulty of accumulation, i.e. storage of plastic waste for their subsequent implementation (processing, recycling, disposal). It takes up to a thousand years for this material to decompose completely, with the threat of highly toxic substances entering the soil and water, which eventually through the food chain enters the human body and accumulates in it.

One of the key factors of the current use of plastics in the manufacture and in human life appears to be the low cost of polymers, their reliability and durability, as well as bio inertness. The following variants of plastics are used for the production of plastic materials (Kozin et al., 2005):

– polyethylene (PE);
– polypropylene (PP);
– polystyrene (PS);
– polyethylene terphthalate (PET);
– polyvinyl chloride (PVC).

Different researchers define the concept of "microplastic" differently. So, for example, scientists from the USA M. Gregory and A. Andradi consider that microplastic is barely visible particles which freely pass through a mesh filter with a cell diameter of 500 microns, but which can be retained by a mesh filter with a cell diameter of 67 microns, thus larger particles are called by them as "mesomusor". The authors (Rumyantsev et al., 2019) note that in some research works concerning aqueous media, plastic particles are divided by size into nanoplastic (< 1 μm) and small microplastic (< 1 mm), large microplastic (1-5 mm), microplastic (< 5 mm), mesoplastic (< 25 mm), macroplastic (> 25 mm) and megaplastic (> 1 m). In this regard, it seems appropriate to consider the transformation in the aquatic environment of the water body under study of only micro- and macroplastics with the above mentioned particle sizes in accordance with the following information on plastic particles.

As in the marine environment, existing studies of freshwater systems on a global scale show that MP is a common feature in these systems. For example, MP has been found on the shores of beaches, in the surface waters of lakes, rivers, estuaries, and the biotic communities that inhabit them. Thus, one of the most significant aspects in solving geoecological problems related to the problems of pollution of water bodies is the study of pollutants transported on the surface of solid particles. The smaller the particle size of suspended sediments, the greater their influence on the processes of water body pollution (Pozdnyakov et al., 2012). As of today, methods for their quantitative and qualitative analysis have not been practically developed, as indicated by the work of renowned scientists (Zobkov et al., 2017). Nevertheless, two main processes that lead to the formation of microplastics in water bodies should be identified:

1. direct ingress into the aquatic environment of microplastic particles used in various consumer goods;
2. degradation of larger plastic wastes entering water bodies from land. Plastic wastes are found almost everywhere in recreational areas, in surface waters and in the deep-water environment, but the weathering/destruction rates in each of them differ significantly (Fendall et al., 2010). On this basis, two types of micro- and macroplastics entering water bodies are distinguished:

– Primary micro- and macroplastics are particles of plastic (pellets, fibers) that are intentionally produced in small sizes and added to consumer products (e.g., cosmetics) to give them certain properties;

– Secondary micro- and macroplastics are plastic products that have disintegrated into particles during the weathering process (e.g., a decomposing plastic bag). Regardless of whether it is primary or secondary plastic, the defining feature of micro- and macroplastic is its size, which is less than 5.0 mm (Arthur et al., 2009). Larger plastics break down into microparticles under the influence of photo-oxidative, thermal, microbial and mechanical influences, but the actual degradation of plastics is a slow process, which determines their durability and attractiveness for material use (Barnes et al., 2009).

At the same time, sources of micro- and macroplastic pollution in aquatic systems are discarded or lost plastic fishing gear, garbage dumping on the shore, littering by people working on the water, weathering of various types of paint used on boats, and land-based plastic wastes such as tire wear on roads and waste packaging materials (plastic bags), while there is also atmospheric transport of plastic trash particles from densely populated or industrialized areas. At the same time, the deposition rate of plastic debris particles in some freshwater systems is in the range of 1,000–890,000 particles per square kilometer.

As noted, in addition to meso- and macro-plastics in the form of disposable items: plastic bottles, nappies, packing bags, etc., waste from creams, gels, lotions, scrubs, peelings, sunscreens and detergents, etc., containing micro-plastics enter the continental water bodies.

It is important to note that most MPs contain hydrophobic radicals in their molecular structure and are able to form with other hydrophobic substances in natural waters, in particular, with such persistent organic pollutants, polychlorinated biphenyls, pyrethroids, etc. In this case the sorption- desorption reaction is reversible and depends on thermal conditions and peculiarities of the structure of the interacting substances themselves. Other micro- and macroplastics like polyacrylamides, polymers of lactic and glycolic acids, etc., contain hydrophilic groups in their molecular structure besides hydrophobic radicals. These MPs can react not only with various POPs, but also with heavy metals. Direct and complete attachment of molecules in this case results in the formation of adducts - stable products of indefinite structure. As some studies have shown, due to these properties, the concentration of

persistent organic compounds collected on microplastics in seawater can be several orders of magnitude higher than their natural background. This may even give the impression that MP plays some kind of positive role in seawater purification. However, it must be remembered that at the same time aquatic fauna together with microplastics may receive lethal doses of POPs and die. Serious consequences can also be expected for people using fish, marine animals and waterfowl for food purposes. It has been noted above that the MP used in various economic activities is, in most cases, environmentally neutral in itself. Entering continental freshwater reservoirs, MP becomes a threat to the ecosystem due to its hydrophobic and hydrophilic properties, which contribute to accumulation of various pollutants on it (Rumyantsev et al., 2014).

It is accepted that plastics are a reasonably cheap, easily processed material whose properties can be changed relatively easily, and there is no reason to believe that their mass production and consumption will decrease in the near future or in the distant future, or that they will be replaced by some other material. This means that the number of items made of plastic will only increase, which will inevitably generate an increasing mass of plastic microparticles in the environment, and given their resistance to degradation, and accumulation even if plastic waste is properly managed through recycling and reuse. Already more than 90 % of microplastics detected in various environments and biological objects are microfibres of less than 10 μm in size. It has been experimentally established that micro - particles continue to degrade and disintegrate into nanoparticles. These particles are easily transported by water currents and air masses, reaching the remotest corners of the planet (Kazmiruk et al., 2020; Amirgaliyev et al., 2020).

The study of MP problems in inland water bodies, including its possible concentrations, interaction with hazardous chemical compounds and impacts on biota, is only beginning to be investigated. In this situation, it is reasonable to recommend the inclusion of micro- and macroplastics as one of the components of a surface water quality monitoring programme.

Study of environmental pollution by plastics in non-CIS countries

A study of the world literature and scientometric databases has identified the problems of environmental pollution by plastics, including the micro- and macroplastics we study, which have caused a public and global resonance as a global problem of the 21st century. Plastic pollution of inland waters itself is considered in the context of the ways plastic debris enters marine waters, but pollution of inland water bodies, aquatic and coastal ecosystems is a separate problem, if only because surface waters are the main source of water supply for the Earth's population and plastic pollution of inland waters is part of global plastic pollution. The state of research into micro- and macro-plastic pollution of inland water bodies and watercourses is about the same as research into plastic pollution of terrestrial ecosystems — it is either non-existent or only just beginning, although the Environment Programme (UNEP) considers plastic pollution at the level of global climate change. The potential damage caused by micro- and macroplastics to a wide range of freshwater fauna has not yet been established, although the adverse effects are well described for similar marine species (entanglement in nets, use as nesting material, etc.). (Bletter et al., 2018).

Contaminated areas are a major source of plastic debris entering water bodies and streams. End- of-life plastic products or fragments can remain on the ground for months or sometimes years before they are transported to water bodies. The pathways by which plastic waste enters water bodies and streams can be concentrated or diffuse. Concentrated pathways may include the discharge of untreated wastewater through sewer outlets, open sections of sewage ditches and collection pathways for storm water and wastewater from urbanised areas, as well as temporary watercourses. Depending on the hydraulic characteristics of the watercourse (length, width, bottom slope), degree of clogging and volume of waste, it may not immediately reach water bodies, but remain for some time on the bed of the channel or be semi-filled with sediment (mineral particles) or other debris. The buoyancy of the fractions may vary over time, depending on their shape, the degree of abrasion against the ground and other debris, and external conditions. Distributed pathways of plastic waste are typical for coastal areas, slopes, beaches, recreational areas, where direct washout during rainfall and snowmelt is possible. As water bodies are located in depressions in the terrain, plastic debris is easily rolled over by the wind, often reaching the aquatic environment. Lighter plastic bags, with their high floatation, can be carried in the air. Many people have repeatedly seen bags flying in the sky and, in strong winds, being lifted by rising air currents and carried for many kilometres (Kazmiruk et al., 2020). The most dangerous for aquatic and riparian ecosystems are spontaneous and organized dumps located in the catchment area (Bletter et al., 2018).

Japan has a long history of studying micro- and macroplastics. In-depth research has been carried out since 2009 by Tokyo University of Science and Technology and Kyushu University. The active cooperation between

Admiral Nevelskoy Moscow State University and these educational institutions has enabled them to study their experience in detail. Thus, as a result of joint research on the floating laboratory of the University of Tokyo in the summer season of 2016, a series of microplastics samples were collected in the western waters of the Japanese archipelago. These collaborative studies provided a more holistic picture of the distribution of microplastics in the near-surface strata. Chemical analysis of the obtained particles allowed particles to be recognized, and their size and quality composition to be determined. Micro- and macroplastics were found to be dominated by polypropylene and polystyrene, but the quantitative composition of the particles was significantly lower (Yakimenko et al., 2016).

Unfortunately, there are only sporadic, fragmentary and short-term studies of macro- and meso- plastic pollution in aquatic ecosystems, which is not comparable to the total amount of pollution occurring that is visible to the naked eye. The 2016 "European Conference on Plastics in Inland Water" fully reflects the current level of research. Only 13 % of studies on plastic pollution have focused on freshwater ecosystems, mainly on microparticle pollution, with almost no studies on submerged plastic. This state of affairs is due to the lack of a monitoring system for plastic pollution, its spatial and temporal heterogeneity, its mobility and the difficulty of detection in flooding. Two approaches are possible in monitoring plastic pollution: observation and material collection. The first approach mainly focuses on qualitative analysis, the second on quantitative analysis. Surveillance methods (visual or surface imaging) can be used from the banks of rivers and lakes or from the water surface. Observation from the banks of water bodies is useful for determining the mobility of plastic waste and its transport by water currents. Regarding the physical collection of plastic debris from the water surface or from the water column, these can also be done from the shore or from watercraft. Collection of material from the shore can provide information on the abundance and composition of the waste and can be used in studies on waste accumulation or mobility. When plastic fragments are collected directly from the waterbody, the size composition of all plastics floating on the water surface or in a semi-suspended state in the water column can be determined. Nets or cages are mainly used, but surface booms may be used to retain floating plastics. Bottom trap nets, box traps or grab dredgers, commonly used in zoobenthos surveys, may be used to examine pieces of plastic deposited on the bottom. The mesh size of the nets is determined by the size of the fractions to be surveyed. The hydrological regime of the water body/stream and hydrometeorological conditions, especially wind speed and direction, must be taken into account, since in high winds plastic debris may concentrate repeatedly near certain banks or in stagnant areas. Research on plastic pollution in freshwater systems was carried out in only 23 of 197 countries. Most of the studies were conducted in Western and Central Europe, the USA and Canada (67 % of the studies). Much less research has been carried out in Asia (16 %), mostly in China, although the majority of freshwater capture fisheries are in rivers in Asia, and 7 of the 20 most plastic-polluted rivers in the world pass through the major cities of China. Several studies are devoted to water bodies of Latin America (11,8 %) located in Brazil, Argentina, Columbia and Chile, Africa (4 %) (South Africa and Tanzania) and Australia (2 %). Although the main problems of plastic pollution are located in low- and middle-income countries and where the main freshwater fisheries are located, the vast majority of studies (69 %) are confined to water bodies in industrialized countries. Roughly equal numbers of studies focus on rivers, lakes and estuaries. There are almost no studies on reservoirs, and those that do exist focus exclusively on reservoirs in China. The vast majority of the research is confined to water surfaces and shoreline substrates. However, studies carried out on the Thames River (London, UK) show that a significant proportion of plastic debris moves near the bottom (Bletter et al., 2018).

An example of a detailed comprehensive study reflecting the overall picture of plastic pollution in freshwater ecosystems can be found in the coastal strip of Lake Setubal, located in the floodplain of one of the largest rivers in the world, Paraná (Argentina) (Bletter et al., 2017). The city of Santa Fe, which has 653,000 residents and whose rubbish dumps and storm drainage systems allow plastic waste to flow directly into the lake, is located on the western bank of the lake. All macro-plastic fragments were collected on two 5 m wide and 50 m long transects located in the most and least polluted areas of the beach and identified by a reconnaissance visual survey. The mesoplastic particles were collected from areas of 1 m^2 located on the transects. In order to obtain representative data, triplicate plots were duplicated and a 3 cm layer of sand was removed. The sand was then sieved through 5 mm sieves. As in most other studies, plastic litter in the Lake Setubal area was dominated by food packaging, bags (sacks, film) and disposable food containers (mainly bivalve containers, trays and cups). On average, 1.15 plastic macro particles were found in each 1 m^2 of the surveyed area, 42 % of which were food packaging. The average density of plastic debris was 4.9 g/m^2. Plastic bottles had the highest weight, which was more than 3 times the total weight of the bags. It is important to note that while films clearly dominate the number

of items at the macro level, foam particles dominate at the meso level, and solids and fibres dominate among microparticles.

The authors of the following work (Tang et al., 2022), performing studies of microplastic content in water and bottom sediments of Songshan Lake in Donggang, indicate that this pollutant is widespread, so the average amount of microplastic in surface water and bottom sediments of the lake was 2.29 ± 0.98 pcs/m3 and 244 ± 121 pcs/kg. The compositions of the common polymers found in microplastics included PE, PP, PP copolymers, PS and PVC, with PE (47 %) and PP (36 %) being the most common. The appearance of the plastic fragments suggests that this contamination is mainly from secondary sources.

In (Scott et al., 2021), in order to fill in the gaps about the environmental impact of MP, interesting experiments were carried out, in which the authors concluded that the duration of the environmental impact is related to the degree of adsorption. As a result, it was found that the adsorption properties of microplastics in the field were much higher than in the laboratory. This indicates that adsorption by microplastics is greatly enhanced by the presence of inorganic and/or organic substances associated with these materials and may pose an environmental hazard to aquatic biota in general.

In a review article (Cai et al., 2022), the authors point out that MP transformation processes in inland aquatic systems are poorly studied. Based on their review, they came to the following conclusions: migration and transformation processes may form a closed and complex circle along the food chain; microplastics migration and transformation processes may be influenced not only by water flow, but also by the vertical state, i.e., the depth of a water body. The authors agree that future research on MP in the aquatic environment should focus not only on determining the amount of microplastics, but also on confirming the factors of influence inherent to natural conditions, i. e. take into account natural, geological features. Thus, a review of current global research shows that micro- and macro-plastic pollution is a rather current environmental problem with great potential to become global. At present, sufficiently accurate data on the harmful effects of plastic particles on human health do not yet exist and attention needs to be paid to this aspect. At the same time, there is a great need to improve and disseminate knowledge and experience, to apply best environmental practices and technologies. All this will enable effective measures to be taken to identify problems and find possible solutions to prevent plastic from entering the aquatic ecosystem in the future.

Study of environmental plastic pollution in Central Asian and CIS countries

Problems related to the pollution of the aquatic environment by polymer particles have attracted the interest of the general scientific community relatively recently (Moore et al., 2002; Thompson et al., 2004). The main attention is focused on MP pollution of seas and the World Ocean, while the study of land waters is in its infancy despite the fact that they may be one of the main sources of this pollution of the World Ocean. At present, pilot studies of MP in surface water and sediments have been conducted on only a few lakes (Great American Lakes Superior, Guron, Erie; Lake Geneva and Garda in Europe; Hubsugul in Mongolia) and major rivers (Danube, Elbe, Moselle, Neckar, Rhine in Europe; San Lawrence and Los Angeles in the USA) (Eerkes–Medrano et al., 2015). The lack of information on this new type of pollution in terrestrial surface waters makes it difficult to assess risks to the environment and requires both monitoring studies to establish the amount of MP present in surface waters and exploratory studies to discover its sources and pathways. To summarize this important study of freshwater systems in terms of their MP pollution, the currently unresolved challenges are: developing an effective methodology for monitoring MP in terrestrial surface waters; identifying the main factors responsible for the presence, quantity and spatial distribution of MP in surface waters; understanding the process of plastic waste degradation and MP formation; assessing the role of rivers in carrying plastic particles into the ocean; assessing and understanding the interaction of living organisms with plastic particles and the formation of MP in surface water; and developing an effective methodology for monitoring MP in surface waters. The authors agree that progress in this direction can only be achieved using a sound scientific basis and as a result of joint efforts of legislative and regulatory authorities at international, national and regional levels.

Legislative initiatives to ban microplastics are already in place or under consideration in many countries. In Central Asia (CA) and CIS countries, the fight against micro- and macroplastics is just gaining momentum. The solution to any problem requires public participation. There are no legislative acts to prohibit the use of MP yet. At the moment, there are few major scientific studies on the spread and increase/decrease of microplastics in CA and CIS, so it is difficult to talk about any statistics. But considering the fact that even modern sewage treatment plants cannot filter out all microparticles of plastic we can say that it is present in water bodies (Blinovskaya et al., 2015; Ismukhanova et al., 2022). Here it should be noted about the results of studies of the content of microplastics

in the water and in the surface layer of bottom sediments of Lake Ladoga carried out by the Institute of Lake Science of the Russian Academy of Sciences (Pozdnyakov et al., 2018), in which the authors state that when solving geoecological problems associated with the pollution of water bodies one of the most significant aspects is the study of pollutants transported on the surface of solid particles. The authors, note that the smaller the size of suspended sediments, the greater their influence on the processes of pollution of water bodies. The particles themselves may be chemically neutral. Accordingly, it is the high sorption capacity of MPs that requires increased attention to investigation of the presence of these particles in water bodies. It should be noted that during the works carried out by the authors microplastic particles were registered in all investigated samples, irrespective of the sampling locations along the water area and on tributaries, and it is also convinced that the number of microplastic particles will only increase.

A significant paper (Zobkov et al., 2021) summarizes information on the patterns of microplastics transport and accumulation in land surface waters in comparison with continental seas. It also analyses information published in foreign and Russian literature. A comparative analysis of original materials obtained by the authors during studies in the Baltic Sea and Lake Onega using identical methods of microplastics determination is presented and the results are compared. It was revealed that statistically higher amount of microplastics in bottom sediments of Onega Lake compared to sediments of the Baltic Sea. The authors agree that the lakes act as filters, purifying surface waters of the land as they flow into the continental seas, becoming their primary accumulator.

A number of scientists dealing with microplastics pollution in 12 high-mountain lakes located in the Tibetan Plateau, have concluded that the source of microplastics in high-mountain ecosystems is human activity and atmospheric conditions with seasonal variability. The main factors of microplastics deposition are primarily atmospheric transport from urban point sources, precipitation (rain and snow). In addition, as noted by the authors, MP is able to easily reach isolated ecosystems and be deposited in terrestrial and aquatic ecosystems via atmospheric transport. For example, MP has been detected in such remote locations as the Arctic, deep-water environments sea surfaces and glaciers (Ambrosini et al., 2019; Cabrera et al., 2020).

Thus, based on the analysis of scientific publications on micro- and macroparticles of synthetic polymers in aquatic ecosystems, it is shown that microplastics research in freshwater ecosystems is becoming a relevant research area. A significant proportion of publications are devoted to microplastics in marine ecosystems, with few publications directly related to freshwater systems research. Only solitary studies of microplastics levels in water and bottom sediments, in the waters of Lake Ladoga, Lake Onega, the Neva, the Don, the Yangtze rivers, lakes located in the Altai Mountains, in Mongolia and China can be noted. Microplastics are classified according to a number of criteria, the main sources of their introduction into the aquatic environment, the impact of microplastics on biotic components of aquatic ecosystems and the level of microplastic particles in various freshwater matrices are described. Taking into account inevitable growth of global production of synthetic organic polymers, detection of plastic waste degradation products in aquatic environment and poorly studied mechanisms of microplastics toxicity and hazard for living organisms, the most important tasks in the field of water safety are to intensify research in this area, to include microplastics among chemical and biological indicators of the current program of freshwater ecosystem monitoring, to create a systematic approach to its implementation on a single.

Study of environmental plastic pollution in Kazakhstan

The Republic of Kazakhstan is no exception in terms of plastic waste accumulation, according to a paper (Silpa et al., 63) published in 2018. The World Bank estimates that 2.01 billion tonnes of municipal solid waste are generated worldwide every year, and it is expected to rise to 3.4 billion tonnes by 2050. Each person produces an average of 0.74 kg of waste per day (this value varies from 0.11 kg to 4.54 kg in different countries), in Kazakhstan it is 0.78 kg per day. High-income countries produce around 34 per cent of the world's waste, or 683 million tonnes, even though they only account for 16 per cent of the world's population. According to those figures, each person generates an average of 720kg of waste per year, compared to 285kg in Kazakhstan. According to the Office for National Statistics, the population of Kazakhstan, for example, is nearly 19.2m as of 1 May 2022, so it can be calculated that Kazakhstan produces about 600,000 tonnes of plastic waste annually (19.2m x 285kg x 11 %). If we trust the figures of Kazakhstani experts, then, according to some of their data, the volume of plastic waste generated annually is already 844.8 thousand tons.

At the same time, MP pollution itself is a growing, but at the same time understudied problem, in particular for our country. Despite this fact, we managed to find a number of publications relevant to our scientific interests. For example, the authors (D'Hont et al., 2021) have attempted to assess the relationship between microplastics concentrations and the distance to rivers, coastlines, cities, sediment particle size or water depth in closed basins

such as the Black Sea and the Caspian Sea. The results of this study show that microplastics concentrations in the bottom sediments of the Black Sea were approximately twice as high as in the Caspian Sea. However, it is interesting to note that fragment concentrations decreased with depth, while fibre concentrations were independent of depth and no relationship was observed between distance to shores, rivers and towns and the size of the grains themselves. To summarize, the authors note that both basins show higher MP concentrations compared to earlier studies.

It should be noted that the main focus of microplastics research in our region has been in the Caspian Sea, as a number of researchers (Javad et al., 2020) evaluated the presence of MP in coastal and surface sediments and water samples taken in the coastal area of the southern Caspian Sea, near Mazandaran Province, Iran. They examined a total of 32 sediment samples and 10 water samples, with an average MP concentration of 15 units per kg in sediment and 710 units per m3 in coastal water. The results of this study showed that fibres accounted for the predominant proportion of MP in both media, comprising 97 % of the microplastics in both sediment and water samples. The authors, suggest that the main sources of MP particles may be from local releases of large amounts of domestic wastewater and urban surface runoff due to high population densities, as well as industrial and fishing activities in the area.

The presence of MPs in the flora and fauna of the aquatic ecosystem is of interest, as (Mohammad Zakeri et al., 2020) in a study in the southern Caspian Sea found MPs in the digestive system of two fish species, with 68 % of the 111 individuals analysed having MPs present. This baseline data has become particularly relevant as the population of the region has been consuming fish in their entirety. This fact is clearly of particular concern and the need to strengthen the search for solutions to this problem.

Lakes in southern Siberia provide a wide range of ecosystem services and are the most important elements of annual and interannual flow distribution of Siberian rivers, but the extent of their MP pollution remains unknown. In this connection, representatives of the Institute of Water and Ecological Problems of the Siberian Branch of the Russian Academy of Sciences N. Malygina and others, for the first time for Siberian lakes located in the Altai Mountains and the West Siberian Plain, which is similar in principle to the object of our study, estimated the MP content in the aquatic environment (Malygina et al., 2021). The authors focused their attention on six lakes, (Talmen, Dzhulukul, Teletskoye, Zluduri, Degtyarka and Kuchukskoye). All mountain lakes are fully or partially part of the specially protected natural areas (Katunsky and Altaisky nature reserves), where they tried to analyze the concentration, composition and spatial distribution of MP. Despite the fact that some of these lakes are unaffected by human activities, and others are located in protected areas without permanent population, MP were found in all of the studied lakes. MP concentrations ranged from 4 to 26 MP per litre. Compared to other inland lakes in southern Siberia, moderate MP concentrations were observed. Fragments and films with sizes from 31 to 60 nm dominated among the recorded forms of MP. The sources of MP depend on local human activities (fishery, transport, waste disposal). Therefore, sufficiently high concentrations were observed even in remote lakes. The results of the study established a baseline that underlines the need for increased attention to waste management and water use in freshwater environments.

The main problems associated with the accumulation of microplastics in the aquatic environment are reflected in (Bragina et al., 2022). The authors, based on literature sources, describe methods of reducing plastic waste in aquatic ecosystems, citing, in particular, the lack of research, except for data from the Institute of Hydrobiology and Ecology of Kazakhstan, in which, Baimukanov M., et al. point out the need for further research for qualitative and quantitative assessment of plastic pollution volumes and clarifying the impacts on living organisms and aquatic ecosystem (Baimukanov et al., 2017). Their research has shown that all surveyed areas of the Seal Islands were contaminated with microparticles of various lengths and shapes of plastic. Large synthetic fibres attributed to macroplastics were also found. In addition, other non-plastic artefacts were present in the samples. Microplastics were also found in the gastrointestinal tracts of Dolginsky herring, Caspian roach, round goby and tsutsik goby, which are potential food items for the Caspian seal. Thus, only as a result of the autumn expedition in 2020, the institute staff collected 3,790 kg of abandoned fishing nets, most of which are monofilament nets, the most destructive to seals. This work has demonstrated that there is a new type of pollution in Kazakhstan, in particular in the Caspian Sea - micro- plastics and other micro-, macro-artefacts, including plastic particles. The micro- and macroplastics detected are of secondary origin. Fishing nets made of synthetic polymeric materials, plastic bags, plastic bottles, etc. are the source of this type of pollution. Thus, per 1 km^2 of the coastline of Cape Tupkaragan, according to the fall 2019 data, 785.5 kg of abandoned fishing nets, 1786.0 kg of various plastic and other rubbish - municipal solid waste.

According to the performed analytical review the most recent knowledge about the problem of micro- and macroplastics in the aquatic environment is summarized, it is established that they cause significant harm to all species of living organisms, without exception. To obtain a more accurate assessment of MP exposure and its potential effects on human health, further research is required, which includes systematic monitoring of aquatic ecosystems, studying the sources and distribution of MP in freshwater. Thus, in order to identify the main factors for the spread and occurrence of MPs in water bodies, comprehensive scientific research is needed to fill the existing significant gaps in this area.

Conclusions

A review of the world experience in research of pollution of the environment, water bodies by micro- and macroplastic particles, both foreign and CA, CIS countries and Kazakhstan, has been conducted. The main directions of research among scientists of the EU, the USA and Japan concerned mainly the accumulating capacity of MP in marine ecosystems. Studies of toxic impact of MPs on inland freshwater ecosystems started almost recently. Unfortunately, this problem, actively discussed abroad, is not studied in our country. Hence, the project AP14870595 "Monitoring of the condition and assessment of the level of contamination of the aquatic environment of Lake Markakol with micro- and macroplastics", in fact, this work is one of the first in our country and is aimed at attracting public attention to the problem of micro- and macroplastics in the aquatic environment.

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