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The detrimental impact of microplastics on the Marine Environment and potential remediation strategies

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Abstract:

The current Marine environment is always polluted by microplastics, and this problem has been going on for a long time. Microplastics have seriously threatened marine life and marine ecosystems, interfering with their normal life and causing pollution in a great extent. In this paper, various hazards caused by microplastics to the ocean in the past are analyzed, and several typical treatment methods are listed and explained respectively. In this study, four methods are enumerated for treating the pollution, including coagulation method, photocatalysis method, biodegradation method and policy control. Different methods have different characteristics and advantages, but there are also some shortcomings that need to be improved and optimized in the future such as specific circumstances demand, limited governance, or high costs. Additionally, the study found that even though people have adopted many different ways to deal with microplastic pollution, the problem has not been completely solved. On top of the existing methods, more new, environmentally friendly, governance methods need to be developed. But the global pollution problem cannot be solved by a small number of people. This also means that in the future, the public needs to raise awareness of the problem and the monitoring of the Marine ecological environment.

Keywords: Microplastics; Marine Environment; Damage; Treatment; Degradation.

1. Introduction

Marine pollution is an increasingly serious problem worldwide. Many influential factors should be considered, among which the impact of microplastics cannot be neglected. With the continuous production of plastics and the maladministration, the pollution caused by plastic has become more and more serious. Microplastic has a diameter that is smaller than 5 millimeters [1]. This special feature makes it even harder to control, and indeed it is a grievous issue to combat. According to the foreknowledge, there will be 90 megatons of plastic liberated per year by 2030, and the amounts of plastic might surpass the number of fish in the marine environment [2]. Furthermore, nearly 65 million microplastics are discharged into the ocean from the wastewater treatment plant in one day [3]. However, although this treatment system has already been greatly improved, it is still not the only source of microplastic. Therefore, other essential factors like overproduction of these substances must be concerned as well, and several feasible treatments should be executed.

Due to their light weight and tiny size, these microplastics are able to diffuse in a large extent and even through the world, carrying by various sources such as wind, runoff, and waves. So far, it has been found in aquatic environments, atmospheres, and even polar regions. One thing different from the larger plastic is that microplastics are able to escape the layers of sewage treatment and be treated as sewage to the ocean. Microplastic includes mainly two types: primary microplastic and secondary plastic. Primary microplastic refers to the one that has already been tiny when it is initially generated, while secondary microplastic is large at first but then breakdowns by weathering processes. Whether what type it is, its own ability to absorb other pollutants can lead to more serious pollution, increasing the toxicity if heavy metals or toxic chemicals adhere to it. Once these small particles spread into the sea, a massive number of species may get threatened.

In fact, dissemination of the microplastics causes a lot of harm, including to microorganisms, animals, and even ecosystems. When microplastics deposit in the deep sea, numerous chemicals like some heavy metals release subsequently, and more seriously, these small pieces might be further decomposed into minute structures to affect the quality of the ocean. These small plastic pieces are easily swallowed by marine microorganisms; then the primary and secondary consumers might feed on these microorganisms, and these consumers can be preys of other predators at higher trophic levels, including humans. Ingredients in the microplastics then pass through even a whole food chain in a marine ecosystem, which could negatively affect the biological diversity in the ocean. In addition, microplastic can cause the problem of lipid peroxidation and loss of oxygen, and it can be a supporter of some invasive species or toxic microorganisms. Moreover, since the size of microplastic is tiny enough, it can be effortless to breathe into the lung, which could lead to a respiratory issue or reproductive problem.

This study discusses several feasible approaches to mitigate this problem. The first one is called Ocean Clean Up. It is a way to gather garbage by virtue of natural forces in the ocean, such as wind, waves, and currents, and also with a floating substance above the water surface and baffle underneath in order to prevent the fleeing of microplastics. Also, the Seabin project is a way to clean the microplastic by putting a bin moved vertically in the ocean, forced by the tide. This bin can skitter and collect the garbage. Cloud of Sea is a kind of device that can be added to any vessel and take in sewage water by creating friction with water around. Even on vessels, microplastics can be handled. Installing a special filter before the sewage gets into the treatment plant is a good way to increase filtration. There are several approaches to decrease the microplastic pollution at the source. Decreasing the production of microplastic, replacing microplastic with other materials that are more environmentally friendly, and government control are certainly pervasive. This study is looking forward to analyzing the current situation of microplastic pollution and proposing several approaches in order to mitigate this problem [3].

2. Common sources of microplastics

In view of the increasingly serious state of the problem, it is essential to analyse and identify its source. In this way, it will be more efficient to find the root cause of the problem and make a great contribution to solving microplastic pollution in the future. There are many sources of microplastics in everyday life, but the most common ones are divided into the following four types.

Industrial activities: These microplastics exist at the beginning of production in the form of tiny particles, such as plastic beads in industrial raw materials, and plastic particles added to skin care products (such as facial scrubs, facial scrubs, whitening toothpastes, etc.).

Everyday products: Some everyday products, such as facial cleansers, body washes, lipsticks, eyeshadow, etc., also contain microplastic components such as polyethylene and polypropylene.

Plastic waste decomposition: People’s discarded plastic waste, in the process of wind and rain, crushing, burying and incineration, will gradually decompose into a large number of microplastic particles or fragments of different particle size.

Daily activities: Microplastics are also produced by activities in daily life. For example, plastic particles are produced when car tires rub against the road, and these particles are dispersed into the environment by the wind.

In summary, the sources of microplastics are broad and diverse, including both direct emissions from industrial production, and the use of plastic products and the decomposition of plastic waste in daily life. These microplastics are widely distributed in the natural environment through air, water and other media, posing a potential threat to hu-

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man health and ecological environment.

3. Impacts of microplastics pollution

3.1 Effects on marine organisms

Microplastics can clog the airways of Marine life, making it impossible for them to breathe properly and eventually leading to death. Also, microplastics are able to cause an oxidative stress for these organisms, by demolishing structures of cells and dampening permeability of cell membranes. For example, Isocitrate dehydrogenase (IDH) is a kind of substance that is very crucial for the regulation of redox in cells. However, microplastics can stunt the normal function of IDH, causing a harm and oxidative stress on marine organisms. For the basis of the biologic chain, the photoautotrophic organism, algae also have a problem of oxidative stress. Microplastics hinder the photosynthesis of algae and cause it to produce more reactive oxygen species (ROS) which is detrimental for it. Finally, many algae can be damaged because of less photosynthesis and overproduce of ROS.

Acetylcholinesterase (AchE) is an essential chemical which cannot be ignored in the nervous system. It can ensure the transmission of neuronal information in brains, and it engage in growth and ripe of nerve cell. Occurrence of microplastics also cause an intervention in this substance, leading to brain damage of marine organisms.

Moreover, various chemicals in microplastics can lead to a devastation of endocrine system of these organisms. It can adversely affect the growth and reproduction of marine filter feeders. For example, one study found that years of accumulation of microplastics in marine filter-feeders can affect their growth and development and reduce their ability to reproduce. Substances like phthalates and bisphenol A are pernicious for animals like frogs, causing less eggs and offsprings. For the fish, their sense and perception can be harmed by phthalates, which would lead to a dangerous situation for their lives. Microplastics can also spoil immune system of organisms, making them more vulnerable to the danger. The more decrease of the size of microplastics, the bigger possibility to be consumed by organisms in low trophic levels, and thus deliver to the higher levels [4].

3.2 Effects on human

Microplastics can accumulate in tissues of organisms, and substances which remain in the bodies are able to deliver into next consumers which eat it. Human can also be affected by microplastics in mainly two avenues, food intake and inhalation. Sea food is a popular choice to be served as a meal for human's daily life, like fish and shellfish. Especially by eating fish, humans are able to get more protein, which could increase the possibility of swallow microplastics. According to the researches, there are 100,000 microplastics could be consumed by human each year in China [5]. Consuming sea food contained microplastics can lead to health problems to human. For example, microplastic particles in the daily diet may enter the body through digestive tract, causing damage to the gastrointestinal mucosa, causing inflammation, ulcers and so on. Long-term ingestion of microplastics may also affect nutrient absorption, leading to malnutrition. What is more, due to the property that microplastic is not easy to be fragmented and completely resolved, it can accumulate for a long period and threaten the health more seriously. According to the study which is assisted by human intestinal epithelial cell lines and goblet cells to illustrate situation inside human digestive system after consuming of microplastic, there is no big evidence of the fragmentation of these plastic particles. Therefore, it is dangerous for people who continue to eat sea food that has already be polluted by microplastics. Additionally, through inhalation process. Microplastics entering the lungs can damage lung function, and small plastic particles can stay in the liver, increasing the burden on the liver and leading to liver disease. Microplastics are easy to carry germs that may cause infection. Consequently, people should eat less sea food that contains microplastics and be careful to the inhalation of microplastics in air.

3.3 Effects on marine ecosystem

The marine ecological environment is the basic condition for the survival and development of marine organisms, and any change in the ecological environment may lead to changes in the ecosystem and biological changes. However, microplastics are like receiver, collecting other detrimental materials like toxic chemicals, transmitting them through a large distance, and finally harm marine lives in different ecosystems. Moreover, microplastic itself is a kind of pollutant to the marine ecosystems, killing a variety of organisms through processes like inhaling, poisoning, and entangling. A widely spread of microplastics can decrease biodiversity in a large extent, and they are difficult to degrade due to their chemical stability, enriching chemical poisons and various microorganisms and pathogens. They affect the global distribution of pollution, and causing great harm to the stability of marine ecosystems and marine environment. They not only directly impact the quality of seawater, but also indirectly interfere with the survival and growth of other organisms by affecting photosynthesis of primary consumers in the ocean like algae. Furthermore, microplastics also change normal functions of benthic organisms, and adsorb organic pollutants and heavy metals in the surrounding environment, resulting in combined toxic effects. Gradually, as the spread of microplastics pollution increase, more habitats and natural environments in the ocean could be destroyed. More seriously, if this dangerous situation continues to be maintained or even worsen, some species might encounter extinction. Loss of biodiversity can lead to degradation of ecosystem functions. Studies have shown that the loss of one species triggers compensatory behavior in others.

4. Approaches of alleviating microplastics pollution

Microplastics can be corroded by other environmental factors such as sunlight, water and wind, making them much more harmful. This means that effective methods are necessary. Some methods that people consider crude, such as incineration, bring another kind of environmental harm. Direct incineration of microplastic materials will release a large amount of greenhouse gases such as carbon dioxide, sulfur dioxide, etc., which will threaten air quality and the life and health of some organisms. Therefore, other more environmentally friendly approaches are required. However, even if it is possible to directly judge the pollution situation of the ocean through vision, it is not accurate enough to help predict the future trend of the situation, so that people can not really improve the problem in a more efficient and productive way. The severity of microplastic pollution needs to be more accurately predicted and measured through physical detection, mathematical analysis, and chemical experiments. Different from subjective judgments, scientific theories and objective facts are more convincing, so a solid reserve of subject knowledge and advanced experimental equipment are also crucial. Because of these scientific detection methods, it is even possible to predict the limit of the next release of microplastics and the extent of the harm. Also, with policies issued by governments, more people will be forced to join in this momentous activity of reducing microplastics pollution.

4.1 Coagulation method

Its basic working principle is to add coagulant to the water to be treated, so that the impurities in the water such as suspended matter and colloidal matter react with the coagulant to form floccule, and then use the sedimentation tank for solid-liquid separation. In actual operation, the water to be treated is usually introduced into the reactor of the coagulation precipitation experimental device, and then the coagulant is gradually added and fully stirred to mix, so that the coagulant can be evenly dispersed into the water. Then, the mixed liquid after the reaction is introduced into the sedimentation tank and left for a period of time to allow it to fully precipitate. After that, the supernatant is discharged and the water after preliminary treatment is obtained. In the whole process, the selection and dosage of coagulant, reaction time and temperature will affect the coagulation effect and precipitation efficiency. Therefore, in practical applications, these parameters need to be adjusted according to the water quality and treatment requirements to achieve the best treatment effect. Studies have shown that Fe-base salt is not a good coagulant in removing microplastics, and only 13% of them can be cleaned under a condition of pH 7.0 even at a relatively high concentration of 2 mmol L^{-1}. One possible expanation is that some microplastics do not settle effectively in this scenario, possibly due to the weak interaction between the coagulant and the original plastic surface. However, if 15 mg L^{-1} polyacrylamide (PAM) was added, the removal rate of microplastics reached around 90.91%. It is speculated that this is because of the static interaction between anion and cation, which forms a more stable and dense floc, thus effectively avoiding the escape of microplastics.

4.2 Photocatalysis method

Among several approaches around the world, photocatalysis is the most promising method to degrade microplastics. Photocatalysis is an environmentally friendly process that uses light energy to facilitate a chemical reaction that breaks microplastics down into carbon dioxide and water-soluble hydrocarbons under water-based conditions. In photocatalysis, the semiconductor acts as a photocatalyst by absorbing the energy of the light source, activating and producing reactive oxygen species (ROS). These ROS, including hydroxyl radicals (OH) and superoxide ions, play a crucial role in the degradation of microplastics. This extensive review explores in detail the mechanisms and processes of photocatalytic MP removal, highlighting its potential as an effective and environmentally friendly way to tackle plastic pollution. TiO_2 is a popular selection of catalyst adopted in this method. It has several attractive properties like low toxicity and low cost. Additionally, TiO2-TXT membrane has a great merit to support the process of decomposition, which is its high hydrophilicity. This property is conducive to the interaction between microplastics and the catalyst, which is able to drive the further process. This process is effective and productive under the ultraviolet light which has also been proved by experiments. However, there are still some shortcomings in photocatalytic degradation of microplastics, including

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strict requirements for light spectrum, solution concentration, catalyst and other factors, and narrow application range. Therefore, it is necessary to further explore and improve the application methods and effects of this technology, so that it can be more popular and efficient in microplastic pollution control [6].

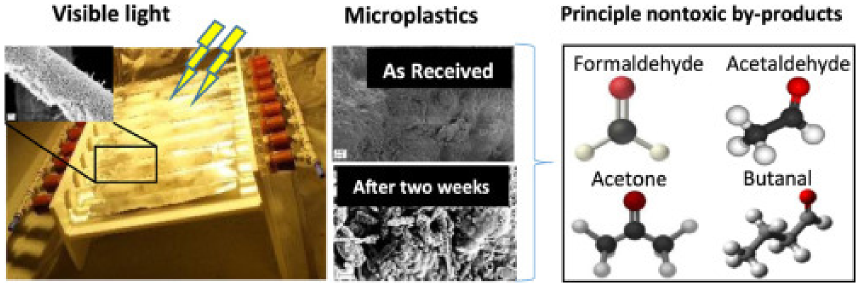

Fig. 1 Photocatalysts method of microplastics degradation [7]

4.3 Degradation method

This can be achieved by using microorganisms or plants that have the ability to degrade. Firstly, a promising way of degradation assisted by microbes. This is done by using microbes to help degrade microplastic materials so that they are continuously broken down and reduced in volume. Microbes multiply quickly and in great numbers. This is also a very important factor in why people are willing to adopt them.The method is mainly divided into four steps: Biodegradation, which refers to the combination of microbial communities and abiotic factors to cut the polymer into segments. The microorganisms then secrete enzymes and free radicals that convert the polymer into oligomers, dimers, or monomers. Then assimilation occurs, where the depolymerized molecules are recognized by receptors on the surface of the microbe and then cross the plasma membrane into the microbe cell. Finally, mineralization refers to the metabolic oxidation of depolymerized molecules into small molecular compounds such as CO_2, N_2, CH_4 and H_2O in microbial cells. Two typical microorganisms which have exhibited good result and impact on degradation process are Bacillus cereus and Bacillus gottheilii. It has been proved that they both create a huge positive impact on the degradation of microplastics, by increasingly decompose surface and inner structure of the original microplastics. Algae can use the carbon dioxide originally contained in microplastics as an energy source to build their communities, using this opportunity to continuously release a special enzyme to assist in the breakdown of the microplastic material. Since they are producers in the food chain, they can certainly be achieved in terms of environmental friendliness. Even though they may only achieve the desired effect within a certain range, they can indeed mitigate the harm caused by microplastics to a certain extent [8]. There is a figure below exhibiting main steps of biotic degradation of microplastics.

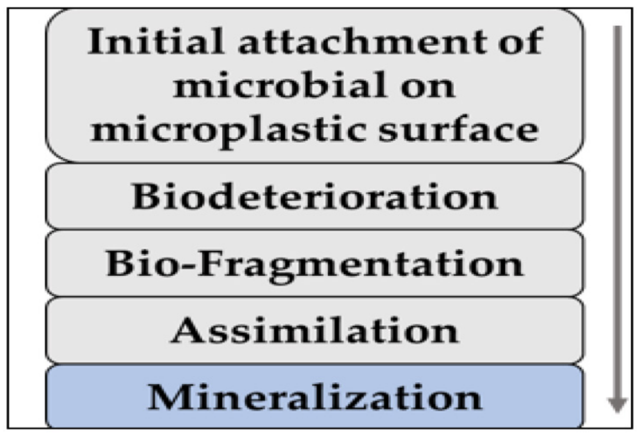

Fig. 2 Process of biotic degradation of microplastics [8]

4.4 Government management

In addition to the above two methods, government regulation is also a feasible solution. This approach is based on tackling microplastic pollution at its source. The sources of pollution from microplastics are so extensive that the difficulty of decentralized treatment is greatly increased. Therefore, it is more efficient to adopt a more centralized approach. Government regulations to reduce important sources of microplastics, such as plastic foam, have resulted in a certain reduction in the amount of microplastics produced. Several enactments and policies are also proposed around the world. The United Kingdom has suggested "Bead-Free Water Act", which banned even the adoption of biodegradable beads, asserting that although these beads are more likely to be decomposed, there is still a possibility that some of them remain to be harmful and not decompose completely. This policy was also supported by other countries like the United States, but only not included the prohibition of biodegradable beads. As for China, it has also issued relevant regulations, such as a ban on the production of cosmetics with microplastic foam, which has been in place for about two years now [9]. Since the government agencies have issued only written rules and regulations, but cannot really improve the behavior of the problem, the public needs to support the relevant work of the government agencies, especially the people living in the rural coast. It‘s a major source of microplastic pollution. It is not only necessary to oppose the production of products containing microplastics, but also to supervise the people around them to reduce the emission of microplastic products. The facts show that the problem of microplastic pollution has not greatly improved after the promulgation of various laws. This is due to a serious lack of local residents on the cause of this problem, the seriousness of the problem and the great harm caused by the problem has too much theoretical understanding and education. At the same time, because not all regions have completely banned the production, emission and use of a certain microplastic as in the UK and China, and the enacted laws do not clearly indicate the specific amount of microplastic production and reasonable emissions. These factors make the problem can not be completely solved, resulting in continued pollution and the continuous collapse of Marine ecosystems. Therefore, the law still needs to be revised more precisely to extend the practical implementation of the content to a wider area. For now, after more and more precise regulations on the production and emission of specific microplastics are issued, government agencies will still need to collaborate with the public and other relevant enterprises such as chemical plants, cosmetic manufacturers and sewage treatment plants to better monitor the Marine environment, especially for the developing countries.

5. Conclusion

Through the study, this paper found that even if people have taken some relevant measures, the current microplastics pollution of the ocean is still a huge problem. Therefore, people should maintain and strengthen the monitoring of the Marine ecological environment, continue to take existing measures and strive to develop new and more effective ways to reduce the harm caused by microplastics. Specifically, it should focus on the following aspects: First, reduce the production of microplastics, by improving the production and use of microplastics, reduce the use of single-use plastics, strengthen waste reuse and other ways. Second, improve the efficiency of microplastics processing and recycling, by developing new technologies and methods to accelerate the decomposition of microplastics in the environment using biodegradation techniques or efficient separation and collection techniques. Moreover, international cooperation should be strengthened. Microplastic pollution is a global problem that requires concerted efforts from all countries. The health of more ecosystems therefore depends on appropriate governance policies and effective implementation. However, some existing measures also have some shortcomings. For the coagulation method mentioned in this paper, the scope of its use is small. Because degradable plastics need to be degraded under specific conditions, their application scenarios are limited. Similarly, the disadvantages of photocatalytic methods include large catalyst band gap, easy recombination of photogenerated electrons and holes, and degradation under ultraviolet light. And biodegradation also requires specific conditions to decompose the fastest, otherwise too slow may cause pollution. Biodegradable plastics need to be separated from other waste and disposed of separately, a process that also adds to costs. Last but not the least, no matter how hard government agencies try to exert their power, they cannot have greater influence without popular support. The law will only restrict the large enterprises or companies that are in the public eye and in the market, but will not be able to fully monitor all corners of the world. Some unlisted companies or small unknown enterprises are difficult to control, which will be a difficult challenge and need to improve in the future. To sum up, although these methods are feasible, they still face some challenges and limitations in practical application, and further research and improvement are needed to overcome these shortcomings. This paper analyzes the main hazards of microplastics to Marine ecological environment, summarizes some common treatment methods, and points out the important defects of these methods, which provides some reference value for the improvement and improvement of microplastics treatment methods in the future. It is conducive to more innovative methods to get the ideological foundation.

References

[1] Yuan Z, Nag R, Cummins E. Human health concerns regarding microplastics in the aquatic environment-From marine to food systems[J]. Science of the Total Environment, 2022, 823: 153730.

[2] Fiore M, Fraterrigo Garofalo S, Migliavacca A, et al. Tackling marine microplastics pollution: an overview of existing solutions[J]. Water, Air, & Soil Pollution, 2022, 233(7): 276.

[3] Krishnan R Y, Manikandan S, Subbaiya R, et al. Recent approaches and advanced wastewater treatment technologies for mitigating emerging microplastics contamination–A critical review[J]. Science of the Total Environment, 2023, 858: 159681.

[4] Mao X, Xu Y, Cheng Z, et al. The impact of microplastic pollution on ecological environment: a review[J]. Frontiers in Bioscience-Landmark, 2022, 27(2): 46.

ISSN 2959-6157

[5] Freeman S, Booth A M, Sabbah I, et al. Between source and sea: The role of wastewater treatment in reducing marine microplastics[J]. Journal of Environmental Management, 2020, 266: 110642.
[6] Chen J, Wu J, Sherrell P C, et al. How to build a microplastics-free environment: strategies for microplastics degradation and plastics recycling[J]. Advanced Science, 2022, 9(6): 2103764.
[7] Uheida A, Mejía H G, Abdel-Rehim M, et al. Visible light photocatalytic degradation of polypropylene microplastics in a continuous water flow system[J]. Journal of hazardous materials, 2021, 406: 124299.
[8] Mahmud A, Wasif M M, Roy H, et al. Aquatic microplastic pollution control strategies: sustainable degradation techniques, resource recovery, and recommendations for Bangladesh[J]. Water, 2022, 14(23): 3968.
[9] Onyena A P, Aniche D C, Ogbolu B O, et al. Governance strategies for mitigating microplastic pollution in the marine environment: a review[J]. Microplastics, 2021, 1(1): 15-46.