Environmental processes and ecological effects of microplastics in the ocean

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Abstract. There are no doubts that plastics problem in the ocean environment has become an increasingly worldwide focus in past several decades. A number of experts regard the plastic wastes as one of the hardest anthropogenic threats. The degraded items of large individual plastics lead to millions of microplastics (MPs) ultimately. As a result, the new pollution has appeared in the ocean. The ever-growing MPs have been detected in subtotal sea products, such as sea food and table salts. The MPs can bring potential health risk to people by enrichment in sea products. Furthermore, the economic development of offshore fishery and the marine tourism have been inhibited badly. This article will make a brief review on present studies about MPs in the ocean.

1. Introduction
People use large quantities of plastic products will make the human living regions be deposited with plastic waste, especially the urbanized areas. Rainfall runoffs bring the deposited plastic wastes to the water. Consequently, the marine environment is the eventual gathering place of plastic waste. As reports go, global annual production of plastics are about 300 million tons, and they flow into the ocean is growing by a rate of 20 million tons yearly[1]. Actually, every plastic product will flow into the ocean ultimately. These plastic products have the characteristics of low biochemical degradation and they will stay in the ocean environment for hundreds of and thousands of years. The plastics will be broken down into micro-debris by ultraviolet, external forces and hydrolysis. Hence, the plastics will still exist in the ocean with the smaller form-that we call the microplastics(MPs) (particle size less than 5 mm plastic but some investigators hold the size is less than 1mm which is a more intuitive value)[2, 3]. Floating MPs can not only provide the habitats of reproduction for microorganisms, but also enrich the chemical toxicity.

Based on the analysis of domestic and foreign literatures in recent years, this paper reviews the sources, influences, distribution, features, analysis methods, bioaccumulation and ecological risk of MPs in marine environment, looking forward to the future research trends and priorities.

2. Plastic waste in ocean environment
Plastic production is continually increasing, and experts have estimated that the production of plastic will reach 33 billion tons by 2050[4]. Plastic wastes play a predominant role in ocean wastes. On the coastal zones and the surface of sea water, you can see them clearly. Ocean currents had great impact on distribution of MPs. Researchers sampled seawater from the surface of the Mediterranean Sea of
France, northern Italy and Spain. The results showed that Mediterranean Sea covers 2.5 million of km$^2$, suggesting that the Sea can be considered as an additional great accumulation zone of floating plastic debris at global scale[5].

Plastics will become brittle and break easily, they are not only protected by the sea water cooling, but also sea water and seaweed will prevent them from exposing to sunlight. As a result, their chemical properties will be stable for ages in the ocean. The researcher’s data showed that the problem of plastic pollution cannot be overlooked.

2.1. Plastics affect the marine environment
(1) Destroying the beauty of the beach and affecting the tourism industry; (2) Disturbing the safety of sailing.

2.2. Do harm to marine life
(1) Eating plastics by mistake may lead to animal esophageal puncture, indigestion, malnutrition; (2) Marine animals and sea birds are entangled with plastics, especially fish nets and big sharp plastic fragments, they may contribute to increasing the mortalities of large marine mammals[6]; (3) Toxic substances in plastics will enrich in marine organisms; (4) Floating marine plastics can bring alien species that they can disrupt the status of the original marine ecosystem.

3. MPs waste in ocean environment
MPs are plastic chips with a particle size of less than 5 mm. Through the physical factors (ultraviolet radiation, external force, hydrolysis), the large plastics can form the miniature plastic debris. They suspended in the sea or settle in the coastline and seabed.

3.1. The sources of MPs in ocean environment
The known MPs sources include land-based input, river emission, coastal tourism, ship transport and marine fishery. Terrestrial input plastic wastes are the major sources. An article mentioned that the plastic wastes amount was 6300 metric tons, only a very small percentage of plastic wastes were recycled, approximately 80% were accumulated in landfills or natural environment[7]. Some common detergents, cosmetics and industrial raw materials contain a large number of MPs components. Due to the MPs particle’s small size, the present sewage treatment processes are not able to remove them. Rainfall runoff played a role of carrier that brought the plastic wastes into the ocean. The scientists created a model that calculated 4.8 to 12.7 million metric tons of plastic wastes entering the ocean in 2010, and they predicted the cumulative amount of plastic wastes would increase by an order of magnitude by 2025[8]. Furthermore, river plastic emissions were one of the MPs source in the ocean. China accounts for 30% of the top 20 polluting rivers in the world, the river which contains the highest contaminant is Yangtze River[9]. Scientists estimated that 1.15 to 2.41 million metric tons plastic wastes flow into the ocean[9]. Pearl River located in west Hong Kong, a survey indicated that West coast’ MPs abundance was higher than east coast notably, it was regarded as potential plastic debris source[10]. During summer, the phenomenon will be existed that the use of beaches increases markedly. It should not be overlooked for coasts that the amount of plastic wastes by tourism activities. For example, the average abundance of plastic debris was 25 n / m$^2$ and 3.2 g / m$^2$ in Punta del Este[11]. The deposition of plastic materials was controlled by physical processes (wind, current, wave and tide action), flushed into the ocean[12, 13].

Passing ships littered plastic wastes into the sea which is another source[6]. In recent years, the rapid development of aquaculture industry led to the extensive use of foam polystyrene flotation devices. The aquaculture floating devices would get aged or corrupted, so the debris will flow into the marine environment. The replacements between new and old fishing nets have also become one of the sources. In addition, the sudden maritime shipping accidents could cause a lot of plastic products into the ocean. After photolysis or broken, plastics formed various different shapes of minute fragments that aggravated environmental pollution.
3.2. Influence on ocean environment
Due to the special physical and chemical properties of MPs, its impacts are much worse than the plastics on the marine environment.

(1) Impede the spread of sunlight in seawater. Floating or suspending MPs in the sea water prevented sunlight from transmitting, so the creatures’ life activities couldn’t be normal. (2) Impacts on marine organisms. MPs were ingested by low trophic fauna, with unknown consequences for healthy[3]. MPs lead to direct toxicity on marine organisms’ different parts of their bodies, reduce energy reserves, affect physiological functions [14, 15]. These toxicities will be transmitted along the food chain that enter into the human bodies, endanger human healthy ultimately. (3) Polluting sea food, salt, which are indispensable to human life[16]. (4) The impacts on community economy. A conservative estimation showed that the MPs pollution caused economic losses of up to 13 billion to marine ecology annually[17]. In addition, the economic benefits of fisheries were greatly affected. For example, long-term exposure to polystyrene MPs can inhibit fish hatching, reduced fish’s birth rate, and changed the feeding habits and habits of juveniles, destroy juvenile fish sense of smell, increase the mortality by predators as well[18].

4. Wide distribution of MPs

4.1. MPs in coastal areas and estuaries are relatively concentrated
The investigators found that MPs pollution has been quite prevalent in the coastal regions. And the one of the scientific teams found that Yangtze River estuary had the higher MPs content than other rivers in China, only second to Canada's Charlotte Queen's Bay[19]. The contents of less than 5 mm plastic particles in the Yangtze River estuary, Jiaojiang, Oujiang and Minjiang reach about 4137 / m$^3$, 956 / m$^3$, 680 / m$^3$ and 1246 / m$^3$ respectively [19, 20]. The mean abundance for Pearl River estuary was 5595 / m$^2$ [10]. The conducted areas of Solent estuarine complex has 2759 MPs particles in total [21]. MPs concentrations ranged three orders of magnitude (< 1.0 g / km$^2$ to 563 g / km$^2$)in four estuarine tributaries within the Chesapeake Bay[22], According to the human activities frequency, bathing beaches MPs concentrations exhibited higher than non-bathing beaches[23]. There also had spatial and temporal distribution for sediments, the most likely reasons were tidal beach geographical positions and seasonal differences. For example, the MPs content in the sediments of the coastal tidal flat was much higher than the intertidal sediments in Hong Kong, and the MPs content of the sediments in Incheon-Kyeonggi coastal sea after the rainy season is higher than before the rainy season(from June to October)[10, 24].

4.2. MPs in the remote environment
Giant larvaceans have special physical structures-‘mucus houses’, which can transport MPs particles from sea surface to deep sea[25]. In deep sea sediments, the MPs abundance was more up to four of magnitude than in sea surface, MPs in sediments ranged from 1.4 to 40 pieces per 50mL[26]. Polar environments have been also polluted by MPs. Arctic Sea ice contains concentrations of MPs are several orders of magnitude greater than those in Pacific Gyre[27]. After analyzing nine sediment samples (2340-5570m in depth in the Arctic Sea), the researchers concluded that the abundance was 42-6595 MPs / kg[28]. The reason why MPs appear on north polar region was the Thermohaline Circulation[28].

5. Separations and identifications

5.1. Separations
The scientists can filter the water directly or use the trawls to segregate the MPs from the water samples. It is complicated for segregating the MPs from the sediments samples. The widely used methods include that sediments are soaked by saturated sodium chloride solution, sodium polyoxalate solution or seawater designed a elutriation tube device for MPs in sediments separation, the device
was mainly composed of three parts, a PVC column, a sieve and with a mesh screen[12, 29, 30]. An investigator optimized the device, but it also needs to be improvements to allow separation of MPs from sediment particles [31]. The practical samples have complicated components, so the researchers can use the hydrogen peroxide (H₂O₂) to preprocess the sediments with the purpose of eliminating the interferences[30].

5.2. Identifications
Due to the complex external forces, particles cannot be regarded as MPs through their appearances simply. So, researchers used pyrolysis gas chromatography / mass spectrometry to simultaneously identify the types of MPs and their additives [32,33]. This method has the advantages of direct injection, qualitative and quantitative, but it required high experimental conditions. The thermal analysis, such as differential scanning calorimetry, thermal desorption gas chromatography, thermal desorption gas chromatography mass spectrometry, were also used for MPs identification, which had superiority on mixture identification, but they had the disadvantage of damaging the sample [34-36]. In situ non-destructive methods are another type of identifications, include Fourier transform infra-red spectroscopy (FTIR), Raman spectroscopy [37-41]. In addition, researchers have utilized lipophilic dyes to identify MPs[42].

6. Problems and suggestions

6.1. Problems
(1) Study on nanoplastics
Just like large plastics can break down into small plastics, millimeter or micrometer plastics can form nanometer plastics under external force. However, there are few studies on nanomaterials. The single and collaborative mechanisms of nanometer level should be studied deeply.

(2) Standard separation methods for different size
It is necessary to establish rapid separation methods and standardization for different media, different sizes of MPs.

(3) Unified units
Researchers should use the uniform concentration units to describe the MPs so that improve the comparability among the different areas.

(4) The influence on dynamic environment
Through the ocean surface circulation and ocean vortex, MPs can transport into the deep ocean. Currently, the deep sea is the final collection of MPs. The studies of marine MPs need to combine with the marine dynamic environment, in order to monitor MPs environmental behavior better.

6.2. Suggestion
In the future, the governments should also strengthen the formulation and supervision of policies and regulations. As the marine MPs mainly come from the land source, just like plasma processing technology, a new harmless disposal treatment should be promoted in depth. Furthermore, plastics were replaced by reducing the use of refractory plastics, encouraging and supporting the production of degradable materials, or using other environmentally friendly substances. Every coastal zone should establish a monitoring group of MPs. The function of this group is that share methods and experiences in order to provide data baseline for MPs’ researchers.

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