Can microplastics pose a threat to ocean carbon sequestration?

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Abstract

Global climate change has attracted worldwide attention. The ocean is the largest active carbon pool on the planet and plays an important role in global climate change. However, marine plastic pollution is getting increasingly serious due to the large consumption and mismanagement of global plastics. The impact of marine plastics on ecosystem responsible for the gas exchange and circulation of marine CO_2 may cause more greenhouse gas emissions. Consequently, in this paper, threats of marine microplastics to ocean carbon sequestration are discussed. Marine microplastics can 1) affect phytoplankton photosynthesis and growth; 2) have toxic effects on zooplankton and affect their development and reproduction; 3) affect marine biological pump; and 4) affect ocean carbon stock. Phytoplankton and zooplankton are the most important producer and consumer of the ocean. As such, clearly, further research should be needed to explore the potential scale and scope of this impact, and its underlying mechanisms.

Keywords: microplastics; marine plastic pollution; marine biological pump; ocean carbon sequestration

The invention of plastics accelerates the operation of this era. However, because of mass production, large-scale consumption and distempered plastic waste management system, plastics are increasingly released into the environment and eventually enter oceans. Ocean plastics can be broken into smaller pieces to form microplastics or even nanoplastics, and the harm of ocean plastic pollution has been scientifically focused on (Shen et al., 2019b). Global oceans are the largest natural sink for CO_2, and play an important role in mitigating level rise of atmospheric CO_2 and global warming. Once the ability of oceans for CO_2 sequestration is disturbed, the global carbon cycle pattern will dramatically change, thus threatening the basic conditions for human survival. The specific issue is whether ocean (micro)plastic pollution will interfere with the carbon sequestration of oceans. Herein, there are four scientific evidences to prove the potential interference of microplastics on ocean carbon sequestration (OCS).

Firstly, microplastics can affect phytoplankton photosynthesis and growth. Although phytoplankton may be small, these creatures play a huge role in marine ecosystems. Phytoplankton is the primary producer of ocean, and it can utilize CO_2 adsorbed from the atmosphere or ocean to produce organic matters and O_2 by photosynthesis (**Fig.1**). Marine primary production approximately accounts for 80% of the total oxygen production of the earth. Consequently, researchers are interested in exploring more about phytoplankton because they play an important role in OCS (Witman and Writer, 2017). However, the widespread presence of microplastics in the ocean has a negative impact on the growth of phytoplankton, causing the change of phytoplankton community, thus destroying the stability of the marine ecosystem. A large amount of (micro)plastics floating on oceans can affect the light transmission, thereby influencing the efficiency of phytoplankton photosynthesis. The feeding, metabolism, development and reproduction of phytoplankton can be affected by microplastic pollution, and this toxicity will significantly increase with the size decrease of microplastic particle (Sjollema et al., 2016). When microplastics exist in water, phytoplankton can easily combine with them and aggregates, the co-existing of microplastics is likely to inspire combination with phytoplankton as well as phytoplankton aggregation, thereby reducing the chance of phytoplankton contacting with light and reducing marine primary productivity. A research showed that the photosynthetic rate of phytoplankton (*Dunaliella tertiolecta*) reduced by 45% after exposed to microplastics (250 mg/L) (Sjollema et al., 2016). The decomposition and fragment of microplastics are one of the main sources of nanoplastic particles in the ocean (Shen et al., 2019a). Bhattacharya et al. (2010) showed that the exposure of polystyrene nanoplastics (1.6 – 40 mg/mL) to *Chlorella* and *Scenedesmus* can reduce the content of chlorophyll a in algae cells and increase the production of active oxygen in algae cells. Besseling et al. (2014) reported that the growth and development of *Scenedesmus obliquus* were inhibited after exposed to polystyrene nanoplastics and the content of chlorophyll synthesis decrease significantly. Additionally, when the growth conditions are limited, *Chaetoceros sp.* and *Rhodopsis salina* can secrete mucilaginous substances such as polysaccharides to form algae mass and polymerize with the surrounding microplastics (Underwood et al., 2004). This behavior can not only change the density of algae mass and affect its distribution in the sea water (Long et al., 2017), but also promote the transfer of low-density microplastics to sea floor (Ward and Kach, 2009). Although these data come from laboratory research, they still have practical significance. The widespread presence of microplastics in oceans has been confirmed, which may affect the development and reproduction of primary producers in the marine food chain/web, thus disturbing the process of air-sea gas exchange and OCS.

Secondly, microplastics have toxic effects on zooplankton and affect their development and reproduction. Zooplankton is the first and most important consumers of phytoplankton (**Fig. 1**). They play an important role in the regeneration of marine nutrients, the cycling of biogenic elements, the flow of mass, energy and genetic information through food chain/web, and the degradation of environmental pollutants. Zooplankton can affect the degradation of marine particulate organic carbon (POC) through respiration, thus affecting the depths of marine POC re-mineralization, and the role of oceans in regulating atmospheric CO_2 concentration and global climate change. If no zooplankton is involved in the OCS processes, the sequestrated carbon will soon reenter into water and atmosphere. However, the widespread presence of microplastics in oceans might change this situation. A research performed by Cole et al. (2015) reported that the presence of microplastics can not only bring harmful effects to zooplankton (copepods), but also reduce the uptake and consumption of carbon due to the ingestion of microplastics causing satiety. Copepods reduced their food intake by 40% after plastic ingestion, and with time, copepod eggs became smaller and less likely to hatch, and increased the total mortality of contaminated copepods. Additionally, an increase in the amount of exposure to microplastics over time could lead to a significant reduction in carbon biomass intake by zooplankton (Cole et al., 2016). Zooplankton may consume less carbon sequestrated by phytoplankton, not only because the consumption capacity of zooplankton declines, but because the carbon sequestration capacity of phytoplankton declines owing to the threat of microplastics. Microplastic ingestion by zooplankton is a global phenomenon. A research performed by Setälä et al. (2014) reported that microplastic can be ingested by various taxa of zooplankton, mainly including mysid shrimp, rotiferans, polychaete worm larvae and copepods in the Baltic Sea. Moreover, microplastic ingestion by zooplankton was also recorded in the Indian Ocean off the coast of Kenya (Kosore et al., 2018) and the Yellow Sea off the coast of China (Sun et al., 2018a; Sun et al., 2018b). Evidence also showed microplastics can be transferred from smaller to larger zooplankton when predation occurs (Shen et al., 2019b). Therefore, if this global phenomenon changes irreversibly, the ability of OCS will be seriously affected, and the global carbon cycle pattern will change dramatically, thus threatening the basic conditions on which human beings depend for their survival.

Thirdly, microplastics may affect marine biological pump. Biological pump and microbial carbon pump are the main ways for ocean to sequestrate CO_2 (**Fig.1**). The former is the process by which phytoplankton transforms inorganic carbon into POC through photosynthesis, self-deposition and zooplankton feeding, and POC ultimately is transmitted to the deep oceans. The latter converts active dissolved organic carbon into recalcitrant dissolve organic carbon through the action of microbes, thus increasing the residence time in oceans. When phytoplankton is ingested by zooplankton, the carbon can be transported to the deep oceans by fecal pellets. These fecal pellets descend to deep water, deposit on the ocean floor and are finally buried in the mud. The carbon sink efficiency of zooplankton fecal pellets is determined by factors such as the production rate, organic composition, sedimentation rate, zooplankton community composition and degradation rate of fecal pellets. Nevertheless, a recent research showed that when fecal pellets are contaminated with microplastics, their equivalent spherical diameters significantly decrease, and sink rate decrease by 1.35-fold. Besides, the fecal pellets under these conditions are more likely to be fragmented than uncontaminated pellets(Wieczorek et al., 2019). Fecal pellets contaminated by microplastics reduces the downward flow of sequestrated carbon to the ocean floor, thereby reducing the proportion of sequestrated carbon, and this phenomenon will significantly increase as the amount of ocean plastic input increases. Moreover, carbon storage by microbial carbon pump is the over effect of series of micro biological activities in marine ecosystem. According to the microbial carbon pump theory, microorganisms (autotrophic, heterotrophic, prokaryotic, eukaryotic unicellular organisms and viruses) in the ocean are the main contributor of recalcitrant dissolved organic carbon turned from dissolved organic carbon (Jiao et al., 2010). Nevertheless, there are few studies on the effect of microplastics on marine microbial carbon pump. Obviously, the potential effect of microplastics on the transport of fecal pellets to the deep ocean and on microbial carbon pump need to be further studied, which is a cause of very significant concern.

Finally, the presence of microplastics on ocean floor may also affect ocean carbon stock. Ocean surface is not the end station of ocean plastics. Plastics on ocean surface only accounts for 1% of the plastic wastes produced on land (Kaiser et al., 2017). The sinking ability of plastics is related to its density and biofouling. Biofilms coating on microplastics can change the buoyancy and viscosity of microplastics in seawater, thus weakening the floatation kinetics and hydrophobicity of microplastics and causing the microplastics to settle into the depths of ocean. It may affect the circulation of organic matter and nutrients in deep water, thereby affecting the carbon stock of ocean. Certainly, the behaviors and the potential impact of microplastics in deep-ocean environment are largely unclear (**Fig.1**).

Overall, the above four interconnected scientific evidences show that the presence of microplastics is of great influence for affecting ocean carbon sequestration. As global plastic production continues to increase, ocean will suffer from more white pollution as a vast open environment. Research on impact of marine microplastics on OCS is a new research topic. Many conclusions are still in the speculative stage, and there is not enough data to support it. Consequently, marine carbon sinks are critical to the global climate, and the potential impact of microplastic pollution on phytoplankton sequestrated CO_2 with the transportation via zooplankton to the deep-ocean should be of a great concern. Obviously, further research is needed to understand its underlying mechanisms and scale and scope of this impact.

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Declaration of interest

The authors have no conflict of interest to declare regarding this article.

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