Filtering microplastics using semipermeable membrane filters

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Literature Review

Introduction

With the variety and usefulness of plastics, it is not a surprise that many products in the market are made from plastic. However, with the popularity of this material, came the abundance of litter that now invades the environment. Plastics serve various purposes and are cheap to manufacture, so within the 100 years that it has been created, it has become a staple material in many commercial products. In fact, during the past 75 years, plastic production has increased from 1.5 million tons to 322 million tons a year (Coppock, Cole, Lindeque, Queiros, & Galloway, 2017). Consequently, the ubiquity and mass production of the product means that many plastics are improperly disposed of which allow them to pollute nearby bodies of water and other habitats. An estimated 4 to 12 million tons of plastics is estimated to escape into marine environments from 2010 alone which plastics to collect in the ocean and other bodies of water (Coppock et al, 2017). Those plastics can then be broken down into smaller microplastics from the ocean currents which makes it hard to remove from the environment.

Microplastics in the Environment

Improper disposal of plastics has led to its collection in the Pacific Ocean, known as the Great Pacific Garbage Patch. Due to ocean currents, plastic particles from all over the world are gathered in the Pacific Ocean to create a mass of plastic that weighs an estimated 1.15 to 2.41 million tons (The Great Pacific Garbage Patch, n.d). However, the Great Pacific Garbage Patch isn't the only collection of plastic; other smaller patches exist too where ocean currents gather them. Plastic particles also accounted for 65% of the collected debris along the shoreline of the Tamar Estuary in the United

Kingdom in 2010 (Brown, Galloway, Thompson, 2010). The presence of plastics is growing, and its effects are seen in the ocean. The pieces of plastic break down in to smaller pieces creating an abundance of microplastics too.

Microplastics have also been found further down in the water than just on the surface. Deep sea sediments have also been found to contain microplastics. The defined size of microplastics change from study to study, but they are typically defined as plastic particles or fibers that are 5 millimeters or. The issue with plastics in the wild is their resilience to breaking down. When plastic wears down, such as from erosion, it typically only breaks down physically and becomes much smaller pieces. Plastic is a tough material, so its molecular structure stays the same while it physically gets smaller. A study done by Lisbeth Van Cauwenberghe (2013) showed that even at a depth of 4000 meters microplastics could be found. Microplastics contamination is not limited to the surface of the ocean and can be found below the surface of the water and even in the sediments. The variety of plastics means that their different densities also allow some to sink to deeper depths in the ocean. The sinking inevitably makes them mix in with the sediment at the sea floor. Plastic

Dangers of Microplastics

Plastic pollution contaminates the ocean life and many of the foods people consume. Microplastic can act as a medium that absorbs other pollutants which may cause even more damage to wildlife and humans. Microplastics allow other contaminates to become even hundreds of times more concentrated which makes the toxicity even more potent. Studies have shown that microplastics are carriers of triclosan and polyvinyl chloride which are some common pollutants that may act similarly to other pollutants. With a certain pH and a higher salinity, microplastics adsorption capacities increase too (Ma, Zhao, Zhu, Li, & Yu, 2019). This means that when microplastics reach the ocean, they can exacerbate the toxicity of other present pollutants because of the saltiness of the ocean. Due to the higher absorption of toxins, when those pollutants concentrate in the microplastics, organisms higher in the trophic level suffer from higher levels of toxins in their systems.

Because of the small particle sizes, small fish are likely able to eat them. Most plastics can pass through the digestive system, but some pieces can be absorbed and imbedded into the tissue of the fish. This also applies to humans and the extent to the damage is largely unknown. However, if there are toxins in the microplastic, organisms consume a more concentrated dose than otherwise without the microplastic. The plastics themselves can also bioaccumulate in organisms themselves. Species higher in the food chain may eat other organisms with plastics particles already in their tissue. Over time larger organisms can build up more and more plastic in their internal organs. The tissue of organisms could become inflamed from the sharp plastic fragments, and marine feeders could suffer malnutrition and even reproductive issues (Sun, Dai, Wang, Loosdrecht & Ni, 2018). The plastic can also potentially clog the digestive track of the animal it invades which may eventually lead to the death of the animal.

Microplastics may also act as a medium for invasive species, such as pathogenic organisms. In a study done by Inga V. Kirstein (2016), there was a high diversity of organisms living in the microplastic and many produced bacteria containing pathogens. Prior studies showed that there were even harmful algae species found on plastic debris. The algae were found in the biofilm that provided protection and collected nutrition for the bacteria growing in them. Other potentially dangerous bacteria were also found in the biofilm which can cause harm in other species in the ocean. They also can spread human pathogens from previous contact with humans. Because of the ease that plastics can enter the environment, many marine species are subjected to the consequences of human pollution.

<u>Microplastics in Sewage</u>

Cosmetic products such as toothpaste and facial cleaners with added microbeads, directly add microplastics into the wastewater. Along with synthetic clothing made up of polyester and nylon, the washing process results in thousands of shed microplastic fibers that accumulate in the sewage water. The water then enters wastewater treatment plants where they are filtered. Most water that comes through to the sewage system this way are from households and other municipal services such as laundry and textile services. Other similar products like ropes can also shed plastic fibers into local sewage. There are also road paint particles that can be introduced into sewage as run off (Coppock, et al, 2017).

Although 99.9% of the microplastics can be filtered from wastewater, the microplastics extracted can end up in sludge which is used for other purposes (Lares, Nicbi, & Sillanpaa, 2018). Sewage sludge has been found to be one of the main ways microplastics have enter the ocean and other bodies of water. Sludge can be used as fertilizer and in green construction. Since the sludge is introduced back into the environment, so are the microplastic (Lares, et al, 2018). They are washed away after use and pollute the marine habitats.

Within the collected microplastics found in the sewage system, it was found that microplastics fibers were much more common than microplastics particles were. One study found that polyester fibers made up 79.1% of all the microplastics they had collected in their sample of multiple water plants (Sun, et al, 2018). They were described to be equally thick and bent. Out of the microplastic polymers found in the sewage plants, the most abundant were polyethylene which constituted 63.9%

of the microplastic polymers as. The next most common type of plastic is polypropylene. They make up a majority of the plastic particle found (figure 1). They were the most present in sewage wastewater and comes in different fragment shapes. Although the overall concentration of microplastic particles is relatively low, the overall discharge of microplastics builds overtime.

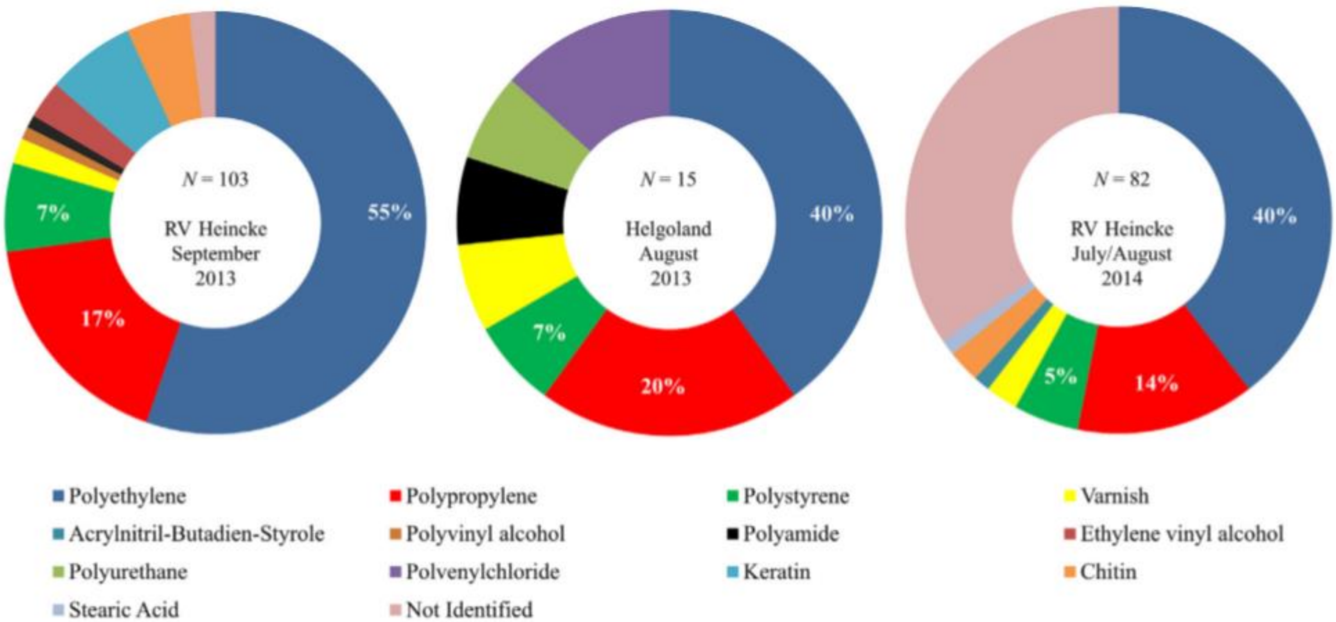

Figure 1. The distribution of polymers found in a study done by Kirstein (2016). Across the months of September to August with N being the total number of particles. Samples were taken from the drift line of Helgoland and the North and Baltic Sea.

<u>Methods of Filtration</u>

One method currently being used to filter microplastics is to separate based on densities. By using density and floatation, the denser particles sink to the bottom of the sample and the lighter particles will float to the top. Most plastics, such as polypropylene and polyethylene, are lighter than sea water (Mai, Bao, Shi, Wong, & Zheng, 2018). Common chemicals used in this type of separation are zinc chloride, sodium chloride, and sodium iodine due to their inexpensiveness (Coppock, et al, 2017).

Any sediments found in a sample can sink to while other plastic particles float in the remaining water. This method helps isolate the microplastic by removing the denser sediments.

Other methods implement mesh filters to screen out microplastics. However, there are problems with catching the smaller microplastics. Any mesh filter that is greater than 250 micrometers risked losing some of the microplastics and lets them pass through the filter (Lares, et al, 2018). Another issue with the mesh filters is clogging. Due to the small size of the pores, filters are easily blocked by larger particles that may be in the water sample along with the microplastics. It is difficult to balance the ability to filter all the plastics with cleaning the filter to be able to use it again.

Identification of Microplastics

There are 2 common ways that microplastic can be viewed. Both methods are visual and use microscopes to view the plastic. The first method is Raman spectroscopy. This technique is based off inelastic light scattering. It provides a vibrational spectrum that allows one to find the components of a sample (Sun, et al, 2018). This method has better spatial resolution compared to the next method of identification, but it is prone to fluorescence interference from other items in a sample. It is possible to get false reads of microplastic with Raman spectroscopy. Florescent dyes, such as Nile Red, Fluorescein isophosphate, and Safranine T, have also been used in conjunction with this method to make reading easier and more accurate (Lv, Qu, Yu, Chen, Hong, Sun, & Li, 2019). With the use of thermal expansion and contraction characteristics of the different types of plastics, the dyes can stain the microplastics and make reading them easier when using Raman spectroscopy. The accuracy of this method can be improved because of the increased fluorescent intensity of the microplastics, but it takes longer to detect microplastics.

The other method that is commonly used the Fourier Transform Infrared microscopy (FTIR). This method is the more commonly reported method in microplastic identification in wastewater treatment plants. This technique exposes microplastics to infrared radiation for a spectrum to be obtained. Peaks in the spectrum represent specific chemical bonds between atoms. From the spectrum, the composition of the molecules present can be compared to a library to identify the specific microplastic present (Sun, et al, 2018). This method is commonly used but is labor intensive because each particle must be placed under light microscopy for each particle to be analyzed separately.

They are both used for microplastic identification and are based on visual observation. However, it becomes to view microplastics that are smaller than 1 micrometer due to the limitations of the equipment. Even viewing anything smaller than 10 micrometers becomes difficult because of the small size of the particles. Some particles may be counted multiple times while others are not counted at all. The small size of the particles also makes samples prone to contamination. Airborne fallout from nearby sources can contaminate the samples. There is also a potential loss of microplastic during extraction. Sometimes some of the sample microplastic is lost during the identification of the sample. Samples are also prone to contamination. Other plastics sources can shed more particles into a filtered sample which would increase the count microplastics measured.

Conclusion

It is difficult to filter microplastics in large scale due to the amount small size of the particles. The volume of microplastics in the environment and the inefficiencies of current technologies make it difficult to clean marine environments. Another problem with filtering microplastics is the risk of filtering out other marine life. Microplastics can be as small or smaller than many plankton and other microorganisms that live at the surface of the ocean. Due to the size similarities, filtering the microplastics out of the water would also result in the extraction of the microorganisms which are vital to the native ecosystems. The presence of other particles beyond the microplastics makes filtering on a large scale difficult, and the microplastics found deeper in bodies of water and sediments make it even more difficult to filter them out.

It is important to filter out microplastics for the sake of the environment and ultimately humans. Before the plastic can get the chance to leave the sewage plant, it can should removed from the sludge. Another method that some treatment plants already use to is burning the sludge. In that case, the microplastics are removed along with the rest of the sludge. However, this is not a practice done by all wastewater treatment plants, so then the best method to decrease the microplastic pollution is to filter out the microplastics before it is used for other purposes. To prevent the increased release of microplastics into the environment, microplastics can be filtered out of sewage plants and other pipe before the water and sludge are used for other purposes.

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