Concentration of Microplastics in the Chesapeake Bay

Introduction

Over the past fifty years, plastics have increasingly become more popular with consumers and manufacturers. In the year 1950, there were an estimated 1.7 Mt (million metric tons) of plastic produced in the world. While only sixty-five years later, there were approximately 380 Mt of produced a year. Unfortunately, the major increase in plastic production has resulted in a skyrocket in pollution levels.

Nearly half of all plastics produced today are intended for packaging or shipping purposes. Manufacturers believe that plastics are an ideal material for packaging because they are cheap, durable, flexible and most importantly, they can be thrown away after a single use. This ideal is destroying the planet because approximately 60% of all plastic ever made have accumulated in landfills or the natural environment (Horton, 2018). Many commonly used polymers for plastics are extremely resistant to biodegradation, like polyethylene and polystyrene. Some of the characteristics that cause the polymers to resist biodegradation are high molecular weight, hydrophobicity, and cross-linked chemical structures. There is evidence that some organisms can aid in the process of biodegradation, for example, bacteria, fungi, and mealworms. However, these organisms are not always present in the environment and, therefore, the plastics are not always able to be broken down. It is these characteristics that make plastics such a demanding force when it comes to pollution in the environment (Horton, 2017).

Plastics are now manufactured in all physicochemical properties. The most pressing property to the marine environment is their size. Microplastics are pieces of plastic with a diameter of less than 5mm and are steadily becoming the most invasive (Paul, 2018). Plastics that are specifically manufactured to be that small are called “primary microplastics” and are produced as “nurdles.” Nurdles are small pellets that are used as raw materials to make plastic products, glitter, and microbeads, which are then used to produce personal care products and cosmetics (Horton, 2018). In the industrial setting, they are found in abrasives that are used for sandblasting or cleaning. Primary microplastics are likely to be washed down industrial and even domestic drainage systems and into wastewater treatment streams where they are sometimes just allowed past all of the filtration devices and flow directly into rivers and streams (Horton, 2017). Physical impacts on small organisms like internal abrasions and blockages have been reported. Moreover, the damage caused by microplastics has been found to lead to cellular necrosis, inflammation, and lacerations of tissues in gastrointestinal tracts (Hermsen, 2018). Plastics that are broken down while in the environment are called “secondary microplastics” (Horton, 2018). Secondary microplastics first enter the environment as macroplastics which are large pieces of plastics. Examples of secondary microplastics include plastic water bottles, car tires, fishing gear, and grocery bags. These are the plastic items that are commonly seen in the environment but they are not the most abundant. They only seem to be the most abundant because of their large size. This large size in comparison to microplastics allows macroplastics to be noticed more often and more easily by the human eye.

There are many ways for a piece of plastic to find its way into the environment. Plastics have been found in many forms including primary microplastics and macroplastics which are then broken down into secondary microplastics. Microplastics, like microbeads, are commonly present in wastewater which is discharged into rivers while nurdles can be lost to freshwaters during production processes. Some examples of secondary microplastics include illegal dumping, mismanaged waste, and unintentional losses (Horton, 2018).

Many microplastics are less dense than seawater which causes them to float. Therefore, there are higher concentrations in the sea surface microlayer than in deeper waters. This would not be the expected scenario since the sea surface microlayer is only the upper 1-1000 µm of the ocean. However, the sea surface microlayer is home to diverse marine organisms such as microscopic algae and bacteria (Anderson, 2018).

There are two main ways for an organism to be affected by microplastics: ingestion and adherence. Ingestion is the most common and occurs when an animal swallows the plastic. It can also occur if the plastic enters the organism during its filtration process. Adherence occurs when the plastic attaches to the outside of the animal. This could be harmless but in the case of a fish, it could be a life or death matter. If the plastic was to adhere to a fish’s gill it could become lodged in its lung. This is an obvious problem and could cause the fish to die of asphyxiation. Another way absorption can harm an animal is that the plastic can be distributed through the circulatory system and enter into different tissues and cells which could potentially result in several types of adverse effects (Barboza, 2018). In a much milder case, microplastics could adhere to the fur of a dog which would not harm it.

Microplastics have toxic effects on many organisms. One of which is that when an organism ingests a microplastic it also ingests the pollutants that it was carrying or was coated in (Paul, 2018). In a recent study, scientists found the specific toxic effects that microplastics have on mussels. These included a decrease in phagocytosis and strong lysosomal destabilization, in addition to a reduction in filtering activity. **Phagocytosis** is a process by which certain living [cells](https://www.britannica.com/science/cell-biology) called phagocytes ingest or engulf other cells or particles. In many animals, phagocytosis is mainly a defensive reaction against infection and invasion of the body by foreign substances. The study found that mussels were more likely to absorb microbeads than any other form of microplastics. They also found that mussels tend to only absorb small particles which leaves the larger particles in the water (Qu, 2018).

Freshwater ecosystems provide very important services to humans. For example, the ecosystems provide fresh drinking water, food sources, and climate regulation. When it comes to human food sources, scientists are have become increasingly more concerned with what the organisms are ingesting. They are concerned because if a mussel ingests plastic particles and these particles remain inside of the mussel until they are harvested and eaten, then the human who is consuming the mussel is also consuming the plastic. This may not cause a large effect if the mussel consumed one tiny particle of plastic but recent studies have shown that there is a widespread epidemic of microplastic invasions in freshwater ecosystems. They found that levels of microplastics are diverse but are have high concentrations in polluted areas like the 1,146,418.36 particles m−3 in the Los Angeles River and the average concentrations of 1.56 ± 1.64 and 5.51 ± 9.09 mg/l in lakes and [wetlands](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/wetland), respectively, of Texas (Martins, 2018). From this information, one can infer that mussels are not ingesting a few particles of plastic but they are, in fact, ingesting many particles. Additionally, when humans eat mussels they typically eat more than one, so they are consequently ingesting what could be millions of plastic particles in one sitting.

In the Chesapeake Bay, concentrations of microplastics demonstrated statistically significant positive correlations with population density and the proportion of urban and suburban development within watersheds. The concentrations in four estuarine rivers in the bay’s system reached a mean of 246 g km-2 corresponding to 260,000 particles km-2. These concentrations increased after major rain events (Dris, 2015). This means that runoff plays an important part in the microplastic pollution in the Chesapeake Bay.

In this experiment, the number of microplastics that is in the water along more populated areas of land will be observed and compared to the number of microplastics in deeper waters. It was hypothesized that due to more human activity along the coast of the Chesapeake Bay, there will be more microplastics on the inner coastal waters. This is because of the pollution stemming from mismanaged waste, litter, and runoff along the coast.

Methods and Materials

The water samples were thawed. The mass of a clean, dry 500 ml beaker was determined. The solid material that was left after the samples were thawed were collected onto a 60 µm sieve and rinsed with DI water. Next, the solids were transferred from the sieve to the beaker with a DI rinse. The solids were left to dry at 50°C for at least 48 hours.

Once the solids were dry, the mass of the beaker and the solids was taken which allowed for the mass of the solids to be determined. 20 ml of aqueous 0.05 M Fe(II) solution was added to the beaker and swirled gently to loosen the dried solid. Next, 20 ml of 30% hydrogen peroxide was added to the solution. The mixture sat for 5 minutes at room temperature. The beaker was set on a hot plate, covered with a watch glass and heated to 75°C while being monitored with a thermometer. As soon as the bubbles occurred at the liquid surface, the beaker was removed from the heat and placed into the hood until the boiling stopped.

Once the boiling stopped, the beaker was returned to the hotplate and heated to 75°C for 30 minutes and swirled regularly to remain mixed. No organic matter appeared to still be present in the sample, so it was not necessary to repeat the experiment. The mixture was allowed to cool and the un-oxidized solids were collected on to the 60 µm sieve and then rinsed into a 20 ml glass scintillation vial with DI water. Each sample was diluted to exactly 20 ml and a subsample of a known volume of the mixture in the vial was transferred on to a counting wheel and the microplastic particles were counted. The number of subsamples that needed to be counted was based on the concentration of microplastic particles in the sample.

Results

Figure 1. The amount of microplastics found in each location. Aimes Creek had the lowest concentration of microplastics and the Coan River had the highest concentration. While the Potomac River had a concentration just below that of the Coan River.

Figure 1 shows that Aimes Creek contained the least amount of microplastics with an average of 140 microplastics per sample. The device used to collect the sample was dragged for 503 meters. This sample, sample one, contained 100 microplastics. In sample two, the device was dragged for 506 meters and there were 180 microplastics found. The diameter of the device used to collect the sample was not recorded. However, all of the samples in this experiment were collected using the same device.

The Coan River contained an average of 215 microplastics per sample as shown in Figure 1. In sample one from the Coan River, the device was dragged for 253 meters and was found to have 300 microplastics while sample two from the Coan River was dragged for the same distance and only contained 130 microplastics.

Figure 1 also showed that the Potomac River contained an average of 209 microplastics per sample. In sample one from the Potomac River, the device used to collect the sample was dragged for 515 meters. This sample showed that there were 120 microplastics. The device in sample two was dragged for 505 meters. This sample contained 180 microplastics.

Discussion

At the beginning of the experiment, it was hypothesized that due to more human activity along the coast of the Chesapeake Bay, there will be more microplastics on the inner coastal waters. The results proved the hypothesis to be inconclusive. They showed that the Coan River contained the most microplastics and not Aimes Creek as hypothesized. Since the Potomac River did not have the highest concentration of microplastics the hypothesis was completely disproved.

In a study of the Seine watershed in France, similar results were found. The study stated that the per capita tire and road waste pollution mass release estimated to be 1.8 kg inhabitant (-1) yr(-1). From that figure, the scientists were able to find that 18% of that release was transported to freshwater while only 2% made it to the estuary (Unice, 2018). This information reaffirms the results of this experiment because more microplastics were found in the freshwater system or the Coan River than the Potomac River which is closer to the estuary, the part of the water system that meets the tide or the ocean. However, the results from Aimes Creek are inconsistent and must be ruled out in order for the study to be deemed similar to this experiment.

Crabbing in the Chesapeake Bay is extremely common. It has been a popular source of food and jobs for many years and has greatly increased throughout the past 50 years. In 1948 there were 60,000 crab pots in the Chesapeake Bay, but that number grew to one million by 2008 (Grymes, 2017). Crab pots are mostly made of metal but the holes that allow crabs that are too small to keep are lined with a plastic ring. As these pots begin to age so does the plastic that is attached. The plastic will start to disintegrate and particles fall off. This may seem insignificant but as the number of crab pots increase throughout the years so do the number of crab pots that are left in the water or go missing. Allowing the whole plastic ring to contribute to the problem of microplastics littering our waterways.

The Coan River is in a high-density area for adult crabs while Aimes Creek and the Potomac River are low density areas for adult crabs (Grymes, 2017). This information explains why there were more crab pots found in the Coan River while the samples were being taken than in the Potomac or Aimes Creek. As previously stated, the more crab pots there are the more likely there will be a higher pollution of microplastics in the area. This explains why the Coan River had the highest concentration of microplastics.

Wastewater treatment plants must follow effluent guidelines that are nationally regulatory standards how much wastewater can be discharged into surface waters. It has been estimated that wastewater effluent, on average, releases four million microparticles per facility per day. When multiple Wastewater Treatment Plants are discharging wastewater effluent in the Chesapeake Bay’s streams and rivers, this is a significant concern for the ecosystem (Murphy, 2018). The Potomac river is home to quite a few wastewater treatments which are all upstream of the location of where the samples were taken for this experiment. With these facts in mind, it is easy to understand why there were such a high concentration of microplastics found in the Potomac River as compared to the microplastics found in Aimes Creek, a secluded part of the Potomac.

Figure 1 showed that Aimes Creek had the least amount of microplastics. It was deemed to be inconsistent with the results found in the study in the Seine water system in France. One reason as to why there were a smaller amount of microplastics found in the Aimes Creek is because it was very secluded. It is located off of one of the smaller branches of the Lower Machodoc Creek. This makes it hard for the pollution in the Potomac River to find its way into Aimes Creek.

A study of wetlands of Machodoc Creek showed that the salinity is decreasing (Moore, 1975). While male crabs prefer water with a low salinity, female crabs need a salinity of at least 26 parts per 1,000. This helps to explain why crabbing does not occur in the Aimes Creek. Therefore, there are little to no microplastics from crab pots in the Aimes Creek.

Another reason as to why the results show that there are more microplastics in the Coan River than in the Potomac is because freshwater and terrestrial environments are recognized as origins and transport pathways of plastics to the oceans. While each body of water may have significant amounts of microplastics present in the samples taken, it is more likely for small rivers and creeks to have higher concentrations since they are used to carry the plastics towards the ocean (Horton, 2017).

One reason as to why the results vary so much within the same water source is because the trowel may have been taken at different depths. It has been proved that there are higher concentrations of microplastics in the sea surface microlayer or the upper 1-100mµ meters of the ocean water than at deeper parts of the water. Microplastics tend to be highly concentrated at the upper lever of the water because most plastics are very buoyant (Anderson, 2018).

The samples collected in this experiment were taken in August of 2018. They were then put in the freezer and were frozen until the experiment was able to be conducted. All of the samples were taken from about the same amount of water to prevent errors. They were not, however, taken by the same scientist and this is only because the samples were taken as a part of an educational program and it was beneficial to allow multiple scientist perform multiple sample collections.

Works Cited

Anderson, Zachary; et al. “A Rapid Method for Assessing the Accumulation of Microplastics in the Sea Surface Microlayer (SML) of Estuarine Systems.” *Scientific Reports*, 21 June 2018.

Barboza, Luis; et al. “Marine Microplastic Debris: An Emerging Issue for Food Security, Food Safety and Human Health.” *Marine Pollution Bulletin*, August 2018.

Dris, Rachid; et al. “Beyond the ocean: contamination of freshwater ecosystems with (micro-)plastic particles.” *Environmental Chemistry,* 2015.

Grymes, Charles A. “Crabs in Virginia.” Virginia Places, 2017.

Hermsen, Enya; et al. “Quality Criteria for the Analysis of Microplastics in Biota Samples: A Critical Review.” *Environmental Science and Technology*, 2018.

Horton, Alice A.; et al. “Microplastics in Freshwater and Terrestrial Environments: Evaluating the Current Understanding to Identify the Knowledge Gaps and Future Research Priorities.” *Science of the Total Environment*, 2017.

Horton, Alice, and Simon Dixon. “Microplastics: An Introduction to Environmental Transport Processes.” *Wiley Interdisciplinary Reviews-water*, 2018.

Kay, Paul, et al. “Wastewater Treatment Plants as a Source of Microplastics in River Catchments.” *Environmental Science and Pollution Research*, July 2018.

Martins, Alexandra; Guilhermino, Lucia. “Transgenerational Effects and Recovery of Microplastics Exposure in Model Populations of the Freshwater Cladoceran *Daphnia Magna* Stratus.” *Science of the Total Environment*, August 2018.

Moore, Kenneth; Silberhorn, Gene. “King George County Tidal Marsh Inventory.” College of William and Mary W&M Scholar Works, 1975.

Murphy, Bob; et al. “Microplastics in the Chesapeake Bay and its Watershed: State of the Knowledge, Data Gaps, and Relationship to Management Goals. Proposal for a STAC ‘Responsive Workshop.” CBP’s SAV Workgroup, 2018.

Qu, Xiaoyun, and Lei Su. “Assessing the Relationship between the Abundance and Properties of Microplastics in Water and in Mussels.” *Science of the Total Environment*, 15 Apr. 2018.

Unice, KM; et al. “Characterizing export of land-based microplastics to the estuary – Part I: Application of integrated geospatial microplastic transport models to assess tire and road wear particles in the Seine watershed.” Science of the Total Environment, 2018.