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Understanding Microplastics in Freshwater: From Little Stream to Big River

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Abstract

The purpose of this study is to better understand how microplastics move through rivers. Microplastics can come from various sources, but the main characteristic of them is their size. These plastics have diameters between 10 nanometers and 5mm. Because these particles are easily confused with food sources, ingestion and bioaccumulation of microplastics in many aquatic organisms has been a hot topic for concern (Besseling et al, 2017; Liedermann et. al, 2018; Nel et. al, 2018; Siegfried et. al, 2017; Windsor et. al, 2019). Ingestion of these microplastics can be detrimental to both human and ecological health due to pathogen accumulation on plastic surfaces. Consumption of these plastics can lead to sickness, harm to bodily functions, and even death. Plastic debris has been documented in the intestines of many marine animals such as fish, turtles, shrimp, and shore birds. In addition to the marine environment, plastics have been documented in freshwater fish, insects, and invertebrates. (Bordós et. al, 2018; Nel et. al, 2018; Peng et. al, 2017; Rodrigues et. al, 2018; Windsor et. al, 2019). As evidence of these contaminants becomes more persistent in our environment, it is important to document and understand the way these microplastics are transported in waterways. This research explores the questions, “How do microplastic distributions differ upstream and downstream of wastewater treatment plants?” and, “How do microplastic concentrations vary amongst different sized streams?” In order to answer these questions, a research team collected one sample upstream and one sample downstream of seven different wastewater treatment discharge sites. These seven sites were on six different streams including Hickory Creek, Orion Creek, Crow Creek, Geneseo Creek, the Rock River and the Mississippi River.

Chapter 1: Introduction

Today we use plastic materials that are designed to be used for a few minutes, but have properties that can last forever. For half a century, people have been producing plastics and living in a “throw away culture”. In other words, people are producing plastics that have very short lifespans, which ultimately end up in our environment or a landfill. In addition to the fact that plastics are being produced on such a large scale and are being thrown away at increasingly fast rates, plastics are also extremely prevalent in our environment because they take hundreds-thousands of years to break down (Whiteley, 1987; Peng et. al, 2017; Liedermann et. al, 2018).

Plastics are made out of hydrocarbons, which are not able to decompose naturally. The durability of plastics leads to large accumulations of plastics in both terrestrial lands and aquatic environments. This durability also makes plastic a desirable construction material for manufacturers. Over the years, more and more plastics have been produced to meet consumer needs, which means that more and more plastics are exposed to living organisms. Specifically, plastic production has increased by 29% in the last ten years, equaling around 322 million tons of plastic a year, or 40 kg per person per year (Liedermann et. al, 2018; Rodrigues et. al, 2018). These plastics can accumulate in animals and make their way up the food chain through ingestion. This accumulation reaches animals at higher trophic levels including predatory fish, birds, and even humans. Consuming plastics can harm animals’ digestion systems and threaten their ability to survive. In addition to the obstructions in their digestive systems, plastics can also poison organisms by leaching toxic chemicals as they degrade but also serve as a magnet for other biohazards in the environment (Windsor et. al, 2019; Bordós et. al, 2018; Nel et. al, 2018; Rodrigues et. al, 2018; Peng et. al, 2017).

Microplastics have diameters between 10 nanometers and 5mm and can come from various sources. Because these particles are easily confused with food, ingestion and bioaccumulation of microplastics in many aquatic organisms has been a hot topic for concern (Windsor et al. 2019; Liedermann et. al, 2018; Nel et. al, 2018; Besseling et. al, 2017; Siegfried et. al, 2017). Microplastic pollution can reach waterways in many ways, but two main sources of microplastics come from manufactured plastic beads used as exfoliates in personal care products and the fragmenting of larger degraded plastics and synthetic fibers (Windsor et al. 2019; Peng et al. 2017; Estahbanati and Fahrenfeld 2016). The problem with these plastics is that a majority of them will eventually be carried into freshwater environments either directly through effluent discharge from sewer systems or runoff from terrestrial rains.

Although studies of microplastics in freshwater environments are more limited than marine studies, plastics have been documented in freshwater fish, insects, and invertebrates as well (Bordós et al. 2018; Nel et al. 2018; Peng et al. 2017; Rodrigues et al. 2018; Windsor et al. 2019). Ingesting microplastics is detrimental to both human and ecological health because biotic and abiotic pathogens accumulate on plastic surfaces due to their hydrophobic properties. Plastic consumption can lead to sickness, harm to bodily functions, and even death (Peng et.al, 2017). This is a troubling fact considering that plastic debris has been documented in the intestines of many organisms (Windsor et. al, 2019; Peng et. al, 2017; Rochman et. al, 2013). Many believe that the amount of microplastics thought to be in freshwater environments is more than originally expected. While microplastic pollution in oceans is already a major concern for marine environments, microplastics in freshwater environments may also be a major concern that is less understood, less documented, and more crucial than previously considered (Bletter et. al, 2018). Freshwater resources supply protein via fish and other aquatic organisms to a large majority of the human population and supply humans and other organisms with freshwater. These valuable resources may be at risk of contamination from microplastic pollution (Bordós et. al, 2019). Therefor it is crucial to investigate where these plastics are occurring, where they may be coming from, and how they are moving through freshwater systems.

The purpose of this study is to better understand how microplastics move through different sized streams and to investigate wastewater treatment plants as point sources of microplastic pollution. It is important to understand where these potentially hazardous particles may be concentrating, how they move through riverine environments, and what role point sources of wastewater may be influencing concentration rates. To understand which human activities may be influencing microplastic pollution more than others is to also understand management strategies and actions to be taken. It is crucial to target potential point sources of pollution in order to take preventative measures to protect the health of organisms such as fish, reptiles, mussels, insects, and humans. Better assessment of microplastics in freshwater resources is needed to develop better remediation and filtration methods for filtering out these plastics.

As evidence of these contaminants become more persistent in our environment, it is important to document and understand the way plastics move through different watershed scales and the way people may be personally contributing to the microplastic issue. By understanding how these particles are distributed throughout different sized waterways and what roles treatment plants play, one may be more equipped to take action to mitigate microplastic pollution to prevent organisms from ingesting these contaminants that may harm their bodily functions.

Study Area

This study documents the spatial distribution of microplastics concentrations at different sized streams above stream and downstream of wastewater treatment facilities. Seven different wastewater treatment discharge sites were investigated: Hickory Creek, Orion Creek (A.K.A. Mosquito Creek), Crow Creek, Geneseo Creek, the Rock River and the Mississippi River (Figure 1). This study area has a wide range of stream sizes from a few feet wide to just under a mile wide. These sites are a good representation of both urban and rural areas which discharge wastewater into waterways.

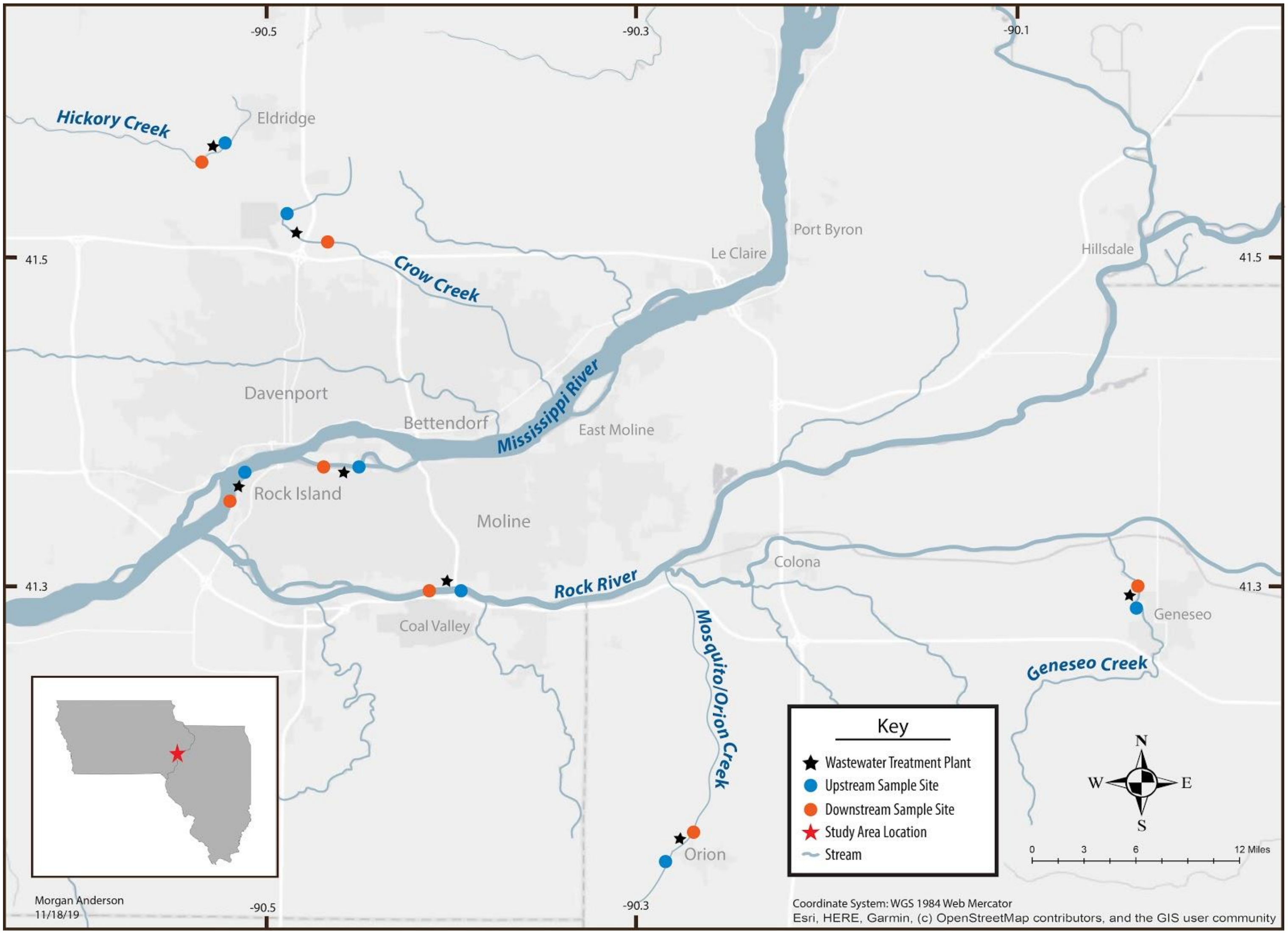


Figure 1: Map of study area showing sample points above and below stream of wastewater treatment plants.

Chapter 2: Literature Review

Anthropocene/Plasticine

The Anthropocene has been referred to as the geologic period that we are currently living in. Geologists describe this geologic period as being characterized by large amounts of anthropogenic alterations to the landscape. Geologists theorize that in millions of years, traces of mankind will be detectable in these rock layers and easily identified for unique characteristics such as conglomerations of displaced sediment, human artifacts, and layers of conglomerate trash and plastic. Because plastic traces will be such a prevalent characteristic of the geology in the Anthropocene, many experts even refer to this time period as the Plasticine (Zalasiewicz et. al, 2016).

The reason that experts believe that plastics will be so prevalent in the Plasticine is due to the legacy of our plastic waste. For half a century, people have been producing plastics and living in a “throw away culture”. In other words, people are producing plastics that have very short lifespans, which ultimately end up in our environment or a landfill. In addition to the fact that plastics are being produced on such a large scale and are being thrown away at faster rates, plastics are also extremely prevalent in our environment because they take hundreds-thousands of years to break down. Plastics are made out of hydrocarbons, which are not able to decompose naturally in nature. The durability of plastics in the environment leads to large accumulations of plastics in both terrestrial lands and aquatic environments. While this durability leads to high occurrences of accumulation in the environment, it also makes it a desirable construction material for manufacturers due to its longevity, lightness, and cheapness. Over the years, more and more plastics have been produced to meet consumer needs, which means that more and more plastic is accumulating in the environment (Liedermann et. al, 2018; Rodrigues et.al, 2018).

Plastics are found virtually everywhere as a result of human activity. Usually, plastics are disposed of as garbage with the idea that they will end up in a landfill where it will be out of harm's way. However, the efficiency of these disposal methods can vary. While landfills are the destination for a lot of plastic waste, many pieces of plastic debris can fall out of trash cans, sanitation vehicles, and landfills themselves. These plastics are then carried by wind and water and end up in places where they were not meant to be. To make matters worse, people will also litter the ground with plastics intentionally, out of disregard for the environment or laziness. While this seems like a less common scenario for plastic pollution in the environment, it does happen. This high occurrence of plastics in the environment can be a threat to both human and ecological health (Nel et. al, 2018; Bletter et.al, 2018). The fate of the plastic that is not properly disposed of or recycled will be in waterways, and ultimately the world's oceans. Many plastics will accumulate in circular currents in the ocean, called gyres. These gyres become giant floating islands of trash, which is mostly plastic. Plastic debris has been documented in the intestines of many marine animals such as fish, turtles, shrimp, and shore birds. In addition to the marine environment, plastics have been documented in freshwater fish, insects and invertebrates (Nel et. al, 2018). Accumulation of plastics in these animals can make their way up the food chain and effect animals at higher trophic levels such as humans. Not only can the consumption of plastics harm animal digestion and survival, but they can also poison organisms since plastics can leach toxic chemicals in addition to serving as a magnet for other biohazards in the environment. The hydrophobic properties of plastics cause other biotic and abiotic pathogens to accumulate on their surfaces. Consumption of these plastics can lead to sickness, harm to bodily functions, and even death (Bordós et. al, 2018; Nel et. al, 2018; Peng et. al, 2017; Rodrigues et. al, 2018; Windsor et. al, 2019).

While plastics do not decompose in the natural environment, they do break down into smaller pieces and fragments. For this reason, plastics are often categorized into groups based on their size and source. Plastics that have been manufactured and have not undergone fragmentation with degradation are considered primary plastics while those that have been fragmented from other sources of plastic are considered secondary plastics (Peng et. al, 2017; Estahbanati and Fahrenfeld, 2016; Windsor et. al, 2019). Within these two categories, plastics can be broken down into smaller classes based on their size. Primary and secondary plastics can be classified from largest to smallest as macroplastics, mesoplastics, microplastics, and nanoplastic. Macro, meso, and microplastics can be seen with the naked eye while nanoplastics may be more difficult to see. We can find all types of plastics in both terrestrial and aquatic environments, and all types can pose different risks to the environment and human health. One type of plastic that has recently gained more attention as a concern would be primary and secondary microplastics (Bletter et. al, 2018). These plastics are less than 5mm in diameter, but greater than 10 nanometers. Many of these microplastics are visible to the naked eye and can be sorted out with a plankton net. Because these particles are easily confused with a main food source for many lower trophic level organisms, plankton, ingestion and bioaccumulation of microplastics in many aquatic organisms has been a hot topic for concern (Besseling et al, 2017; Liedermann et. al, 2018; Nel et. al, 2018; Siegfried et. al, 2017; Windsor et. al, 2019).

Microplastics

Microplastics are characterized as plastic particles with a diameter between 10 nanometers and 5 millimeters (Besseling et al, 2017; Liedermann et. al, 2018; Nel et. al, 2018; Siegfried et. al, 2017; Windsor et. al, 2019). Microplastics can be either primary or secondary, meaning that microplastics are manufactured to be in this small category and are also the result of the breaking down of larger plastic specimens as the plastic degrades from heat and UV radiation. Many primary microplastics are manufactured for cosmetics and exfoliate shower scrubs. These primary microplastics often enter waterways through wastewater treatment plants when they are flushed down drains in municipal plumbing systems. Secondary microplastics, on the other hand, can come from a wide array of sources. These fractured plastics can be sourced from tire wear, synthetic fabrics, storm runoff, and larger plastics (Estahbanati and Fahrenfeld, 2016). It is much harder to designate point sources of secondary microplastic pollution compared to primary ones considering the wide range of potential sources. Some common characteristics of microplastics include that they can adsorb organic and inorganic pollutants, they can leach toxic chemicals, and they are often mistaken for food sources in the lower trophic levels (Bordós et. al, 2019; Peng et. al, 2017, Windsor et. al, 2019). While these microplastics are all similar in size, one thing that most microplastics do not have in common is their densities. Fifty percent of microplastics are less dense than water, so they will float on surface waters and transport to the world's oceans (Besseling et. al, 2017; Liedermann et. al, 2018; Rodrigues et. al, 2018).

The other fifty percent, however, is not as likely to end up in the ocean. These denser plastics will float throughout different parts of the water column and may be retained in freshwater sediments because they are more dense and will settle out and deposit in the environment. When considering the properties of microplastics, however, they are able to accumulate organic matter that comes into contact with them, which can make these aggregates containing plastics much more dense than their original property (Besseling et. al, 2017; Liedermann et. al, 2018; Rodrigues et. al, 2018). This suggests that the microplastics, which normally float on surface waters of freshwater environments, will become heavier and sink to the bottom of rivers for sedimentation and retention of more microplastics than what was previously considered.

Water

To understand how our freshwater resources may be at risk of microplastic pollution, one has to understand the hydrological conditions of rivers and waterways. We know that microplastic are transported through rivers, but to better understand how these resources may be at risk, it is crucial to understand how and where microplastics move through these systems. We know that microplastic can and will accumulate organic matter and other mineral colloids, changing the dynamics of these plastics as they move through the water column (Besseling et. al, 2017; Peng et. al, 2017; Rodrigues et. al, 2018). Denser particles are more likely to settle out of the suspended sediment load and be retained by rivers. In addition to the density of the microplastic, another important factor to consider when thinking about transport has to do with how fast the water is moving, or discharge of the river. Faster currents and higher discharges will result in more transport of particles whereas lower flow conditions may lead to more retention and sedimentations of particles. What this means to researchers is that microplastics are not constrained to specific regions of the water column. Dense particles can be picked up by currents in higher flow conditions and may be exposed to many different elevations within the water column. Likewise, less dense particles are not subject to be constantly transported. During periods of low flow, particles that may normally move in the suspended sediment loads of rivers may settle out and be retained until being picked up again during periods of more intense discharge. Particles may also aggregate more organic and inorganic substances as they are subjected to longer periods of transport. With these factors being stated, it is crucial to better understand how microplastics are normally distributed throughout the water column (Nel et. al, 2018; Liedermann et. al, 2018).

Since microplastics are likely to be exposed at different elevations in the water column, different organisms and ecosystems will be at risk. Microplastics at surface waters may be more accessible to water fowl and organisms that feed near the surface. Likewise, bottom feeding organisms and macroinvertebrates will be more susceptible to ingesting microplastics that are retained in sediments and are floating near the bottom of river channels (Nel et. al, 2018). Better understanding how these particles flow through rivers may help policy makers and scientists assess which organisms are most at risk for microplastic contamination. Knowing the routes that the most microplastics take could also help people design remediation techniques to filter microplastics efficiently. This better understanding could also help future researchers collect freshwater microplastic data more efficiently. Currently, the majority of microplastic studies are on marine environments (87% marine, 13% freshwater), this research could help scientists develop more solid strategies for getting accurate representations of microplastics in riverine environments (Bletter et. al, 2018).

Managing Pollution in Rivers

To protect our natural resources from microplastic pollution, there are two solutions: stop producing plastic products and improve methods for filtering out plastic pollution before it reaches our waterways. While it is unlikely for plastic production to cease to exist with the existence of petroleum, more realistic approaches to dealing with plastic pollution in water systems come down to the filtering aspects, reducing consumption of plastics, and developing biodegradable plastics. Filtering can be one potential management strategy for microplastics. Briefly mentioned earlier, wastewater treatment plants have been linked to higher concentrations of microplastic pollution in rivers receiving treated water (Besseling et. al, 2017; Bletter et. al, 2018; Bordós et. al, 2019; Estahbanati and Fahrenfeld, 2016; Peng et. al, 2017; Siegfried et. al, 2017; Windsor et. al, 2019). Many cosmetics and personal cleaners contain microbeads for exfoliating properties, which go down the drain and ultimately are received in wastewater at sewer plants. These treatment plants often times are not equipped to filter out microplastics, or if they are, they are not 100% effective at doing so.Currently, there is no minimum filtering standards for microplastics in the United Sates. Many studies have been done in Europe to assess the amount of microplastic contamination coming from wastewater effluent, and studies show that the better the filtration systems, the less primary microplastic pollution was discharged (Bordós et. al, 2019).

Several efforts have been taken to reduce the amount of primary microplastics going down the drain and reaching waterways including several bans on the production of microbeads and distribution of products with microbeads. The United States government has banned the sale of products containing microbeads through the Microbead Free Waters Act passed in 2015 (Peng et. al, 201; Lam et. al, 2018; McDevitt et. al, 2017**;** Fu et. al, 2019). While this is a significant step in the right direction to try and reduce microplastics entering waterways, it is not the solution. This act does not put any restrictions on secondary microplastics coming from synthetic fibers in clothing, fragments from larger plastics, and particles from tire wear. It is important, thus, to look toward policy for managing secondary microplastic through means of storm water and wastewater treatment management.

Of these secondary microplastics, a significant source of this pollution takes the form in microplastic fibers. A study in California on wastewater treatment found that fibers were being discharged into the Pacific Ocean at a rate of one microfiber per liter (Browne et al. 2011). For comparison, even the greatest amount of plastics found in this study were still less than one particle per liter. The primary source of these fibers is from degraded synthetic fibers found in clothing. During the wash cycle, abrasion and weathering of the fibers breaks them down, which ultimately go to wastewater treatment facilities and ultimately the aquatic environment. One study showed that worldwide 78% of polyester fibers and 22% of acrylic fibers come from domestic washing machine discharges (Lam et. al, 2018). Yet another study in China (Fu et. al, 2019) suggests that microfibers may be one of the most significant sources of microplastics due to their abundance in the ecosystem and role in aquatic biology. Fu et al. (2019) concluded that a 5kg wash of polyester fabrics can produce a total of 6,000,000 microfibers, which are easily transferred to waterways through sewage systems. The study proceeds to explain how microplastic fibers were observed in sediment samples and were also dominant microplastic types sampled from biota. One way to personally combat the degradation of microfibers in wash loads is to use fabric softener and to buy more durable clothes instead of cheap disposable ones. The usage of softener alone can reduce up to 35% of the microfibers released in the laundry (Lam et. al, 2018; De Falco et al. 2018). Because of the important role microfibers play in plastic pollution, and their significant tie to wastewater treatment plants, policy implications should be developed around filtration and better capture before these contaminants reach aquatic ecosystems.

Although measures towards better filtration and capture of microplastics could decrease the amount of plastics, especially microplastic fibers that reach aquatic ecosystems, these steps alone cannot solve the problem to microplastic pollution. Even if filtration is 99 percent effective at retaining microplastics, that one percent will still be released, and this release will only increase over time if plastic consumption is not limited. In order to make a real difference, filtration strategies need to pair with minimizing plastic pollution at its source by reducing the consumption of it. Some tactics for accomplishing this task include establishing legislation, bans, and taxation policies on plastic goods. (Lam et. al, 2018; McDevitt et. al, 2017, Fu et. al, 2019) Some of these tactics are being put into place around the world, although in limited amounts. In addition to bans in the U.S, other countries that have taken similar actions including Canada, the Netherlands and New Zealand (Wang et. al, 2018). These case studies are good first steps, but laws banning microbeads are easy first steps that do not address the full extent of all types of microplastic pollution. Microbeads are easily replaced with other materials, have low societal value, are assured to end up in the environment, and do not have much opposition to banning, which makes policy implenentation easy to do compared to other sources of microplastic pollution such as secondary microplastics (McDevitt et. al, 2017).

In addition to bans on microbeads, many governing bodies have made efforts to place bans or impose fees on single use plastics, plastic bags, and fishing equipment (Fossi et. al, 2019, McDevitt et. al, 2017). These fees can deter users from plastic goods and steer them towards more sustainable materials. Although these acts have raised awareness about microplastic contamination, they are not very effective, and further steps need to be taken.

One can see that there is a massive amount that needs to be done in terms of legislature and management of general plastic and microplastic materials. One significant step that governing bodies need to make is defining plastic materials as a priority pollutant, as defined under the US Clean Water Act. Priority pollutants are used to determine water quality standards and discharge limitations (Rochman et al. 2013; Worm et al.2017; Lam et. al, 2018). By deeming microplastics as a priority pollutant, implementation of monitoring programs, determination of discharge limits, and reports and legal actions would follow. Prior to this action, managers thinking about legislative actions would need to prioritize raising awareness through education and outreach (Fossi et. al, 2019). These actions would aid in effective decision making and support for legislative action. Another step that should be taken is toward research and development into bioplastics that are deemed “ecocyclable”. Material is ecocyclable when, “material could be naturally and safely recycled into the carbon cycle without any human intervention,” can do so in 18 months, and is nontoxic (McDevitt et. al, 2017, p. 6614). These plastics could be incentivized by governments, making them more cost effective than traditional plastics. These types of plastics would have to be monitored and certified to meet these standards. Bioplastics could serve as a temporary substitution to plastics until humans can get a handle on their plastic addiction. While these steps may not be a silver bullet to microplastic management, they may be the stepping stones that are needed to make a significant reduction to our plastic legacy.

Chapter 3: Methods

Field Methods

This research was completed using field and lab methods. Samples were collected upstream and downstream of seven different wastewater treatment discharge sites: Hickory Creek, Orion Creek, Crow Creek, Geneseo Creek, the Rock River and the Mississippi River (Figure 1). To collect samples, a plankton net was used, which was provided by the Augustana College Biology department. At the small and medium sized streams, sampling was done just below the surface by wading (Figure 2). Collection on large and extra-large streams were done by boat with a suspended reel with the help of Augustana professor Dr. Heine (Figure 3). The time the nets were deployed depended on the velocity of the water and sediment load in the streams. Velocity was determined with a flow meter provided by the Augustana Upper Mississippi Center (Figure 4) and bed load was estimated qualitatively and with deployment test runs. The deployment times varied from 15 second to 180 seconds (Table 1a and 1b). Inspiration for this field sampling protocol came from Liedermann et. al (2018).

Table 1a: Site deployment conditions

Site Name	Upstream/Downstream	Depth at deployment (m)	Area of the opening (m^2)	Diameter of Net (m)	Time Deployed (sec)
Hickory Creek	Upstream	0.4	0.073	0.3048	180
Hickory Creek	Downstream	0.41	0.073	0.3048	180
Orion Creek	Upstream	0.19	0.073	0.3048	180
Orion Creek	Downstream	0.38	0.073	0.3048	180
Geneseo Creek	Upstream	0.78	0.073	0.3048	120
Geneseo Creek	Downstream	0.67	0.073	0.3048	120
Crow Creek	Upstream	0.235	0.073	0.3048	120
Crow Creek	Downstream	0.27	0.073	0.3048	120
Mississippi River	Upstream	3.048	0.073	0.3048	30
Mississippi River	Downstream	3.048	0.073	0.3048	60
Mississippi River	Upstream	4.572	0.073	0.3048	60
Mississippi River	Downstream	3.2004	0.073	0.3048	75
Rock River	Upstream	3.048	0.073	0.3048	15
Rock River	Downstream	3.048	0.073	0.3048	15

Table 1b: Site deployment conditions cont.

Site Name	Upstream/Downstream	Velocity (m/s)	Discharge (m^3/S)	Volume of Water Sampled (m^3)	Volume of Water (L)	Width of stream (m)	Approx. Stream Size (S/M/L/XL)
Hickory Creek	Upstream	0.221088147	0.016139435	2.905098257	2905.098257	2.5	Small
Hickory Creek	Downstream	0.404934279	0.029560202	5.320836427	5320.836427	3.4	Small
Orion Creek	Upstream	0.2	0.0146	2.628	2628	3.04	Small
Orion Creek	Downstream	0.2	0.0146	2.628	2628	3	Small
Geneseo Creek	Upstream	0.4	0.0292	3.504	3504	6.3	Medium
Geneseo Creek	Downstream	0.2	0.0146	1.752	1752	13.6	Medium
Crow Creek	Upstream	0.2	0.0146	1.752	1752	3.7	Small
Crow Creek	Downstream	0.4	0.0292	3.504	3504	7.37	Small
Mississippi River	Upstream	1.072	0.078256	2.34768	2347.68	795.0159	XL
Mississippi River	Downstream	0.585	0.042705	2.5623	2562.3	669.4871	XL
Mississippi River	Upstream	0.503	0.036719	2.20314	2203.14	68.8848	XL
Mississippi River	Downstream	0.4	0.0292	2.19	2190	80.4672	XL
Rock River	Upstream	0.66	0.04818	0.7227	722.7	205.435	L
Rock River	Downstream	0.6	0.0438	0.657	657	197.815	L

Figure 2: Researchers Justin Pope (left) and Morgan Anderson (right) collecting a sample in Geneseo Creek by wading into the stream and holding plankton net in place (Photo Taken by Eden Shriver).

Figure 3: Researcher Morgan Anderson aboard Augustana's research boat The Stewardship with sampling net attached to a weight and flow meter by a suspended wire reel (Photo taken by Alex Disabato).

Figure 4: Researcher Morgan Anderson using flow meter to record the average velocity of Crow Creek.

Each sample site was documented with velocity, discharge, depth, date, and geographic location. This study documented the spatial distribution of microplastics in different sized streams above stream and downstream of wastewater treatment plants. Wastewater treatment plants have been linked to higher concentrations of microplastic pollution in rivers receiving treated water (Bordós et al. 2019; Windsor et al. 2019; Bletter et al. 2018; Besseling et al. 2017; Peng et al. 2017; Siegfried et al. 2017; Estahbanati and Fahrenfeld, 2016). Because of this factor, sampling sites were chosen at road acess points above and below wastewater treatment discharge sites going into the Mississippi River, Rock River, Hickory Creek, Crow Creek, Geneseo Creek, and

Mosquito Creek, which is referenced as Orion Creek in this research study. At the small and medium sized streams, which were qualitatively determined to be Hickory Creek, Orion Creek, Crow Creek, and Geneseo Creek, sampling was done just below the surface by wading. Collection on large and extra-large streams, which were the Rock River and Mississippi River sites, were done by boat with the same plankton net and a suspended reel. After deployment, the contents of the plankton net were emptied into a glass jar aided by a pressurized sprayer.

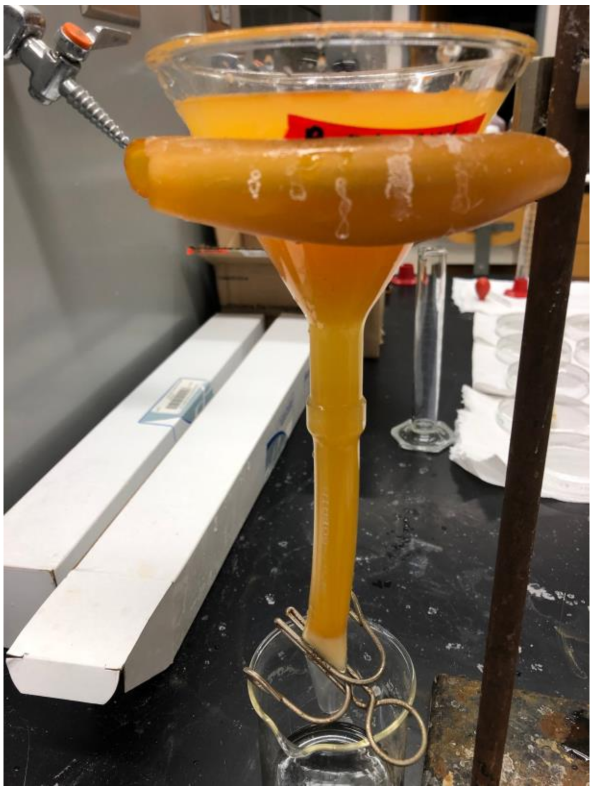
Lab Methods

After collecting samples from the sites, they underwent extensive preparation processes, which included sieving, organic matter digestion, density separation, and filtration. First, samples were sieved with a 5mm sieve and then a .125mm sieve. This allowed for a range of plastic sizes in the microplastic range that could also be easily identified under a dissecting microscope. After sieving, the samples underwent organic matter digestion in order to get rid of any bio solids and organisms that may have been captured during sampling. Digestion took place with 30% hydrogen peroxide and a .05 M iron (II) solution for 1-2 hours (Figure 5). Digesting the organic contents this way decreases the likelihood of misidentifying an organic particle as a plastic particle (Rodrigues et al. 2018).

Figure 5: Hydrogen peroxide (30%) and iron (II) sulfate added to sieved sample in order to digest organic compounds.

After sieving and digestion, Plastic particles were then separated from the other materials with a density sorting liquid. This liquid was a sodium chloride (NaCl) solution. For every 20 ml of liquid sample, 6 g of salt were added to the solution. The solution increased the density of the water, which allowed plastic particles to suspend in the liquid while the sand and sediment settled out on the bottom. This solution was added to the sample after undergoing organic matter digestion and was placed into a glass funnel (Figures 6a and 6b).

A.



B.

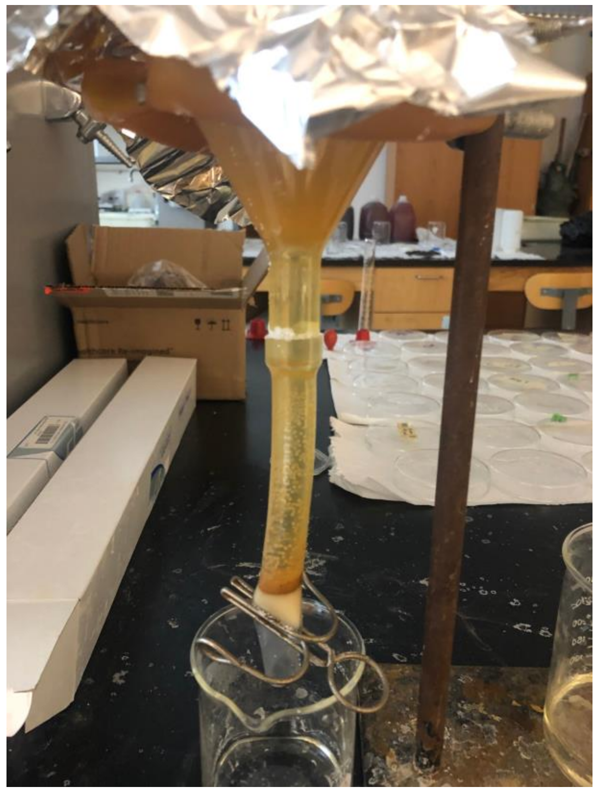


Figure 6: Image A on the left depicts a sample that has undergone digestion and has been mixed with NaCl to facilitate density separation of particles. The image B on the left is the same sample after 24 hours. This time allowed the heavier sediment and particle

Adding salt to the solution is similar to how an egg will sink in fresh water but will float in saltwater. Once the less dense particles were able to float to the surface, the sediment left on the bottom was drained, and the remaining solution was filtered onto glass microfiber filters. The samples were then dried for at least 24 hours before being counted for plastics. Samples were hand sorted through, and plastic specimens were counted as one particle if they met the criteria for plastic specimens. Each sample was and sorted through using a dissecting microscope and an Ultraviolet Light (UV) (Figure 7). The UV light would make the plastic particles glow, which made them easier to identify. The general criteria for counting a particle as a microplastic was based color, texture, thickness, and fluorescence under UV light (Figure 8). This criterion was developed from studies by Prata et.al (2019) and also by tactical knowledge attained through various test runs and training videos. These videos were by Berg (2018) and Beri (2015), which were accessed on YouTube. These videos served as guidelines that followed similar steps in academic journals by Rodrigues et al. (2018) and Liedermann et al. (2018). Due to limited criteria for counting plastics, deciding what to and what not to count as a microplastic was very subjective. The samples were then analyzed as particle of plastic/Liter. The methods used for calculating these values were dividing the total number of particles counted by the volume of water sampled in the stream site. Calculations were done through Microsoft Excel formulas. Each sample was assessed in plastic particles/liter to ensure an equal comparison among sites. To decrease the subjectivity of counting, there was only one counter who took frequent breaks between each sample to avoid exhaustion. Due to the objective nature of counting, there may be some source of error with the results of this study. Other sources of error may be cross contamination of plastic from clothing fibers, plastic squeeze bottles, and plastic particulates in the air.

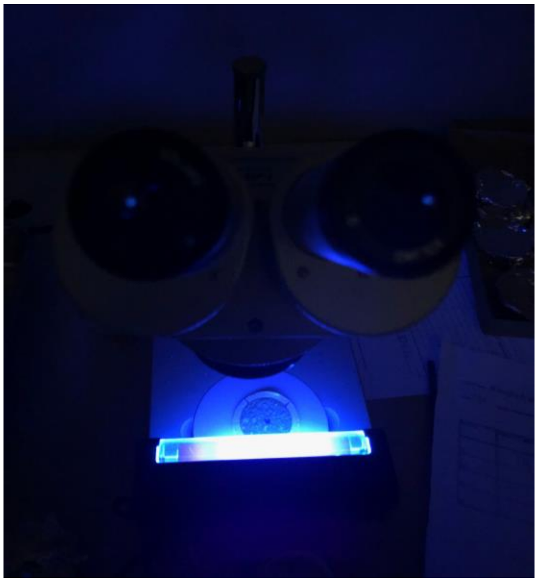


Figure 7: Dissecting microscope, filtered sample, and UV light used to identify plastic particles.

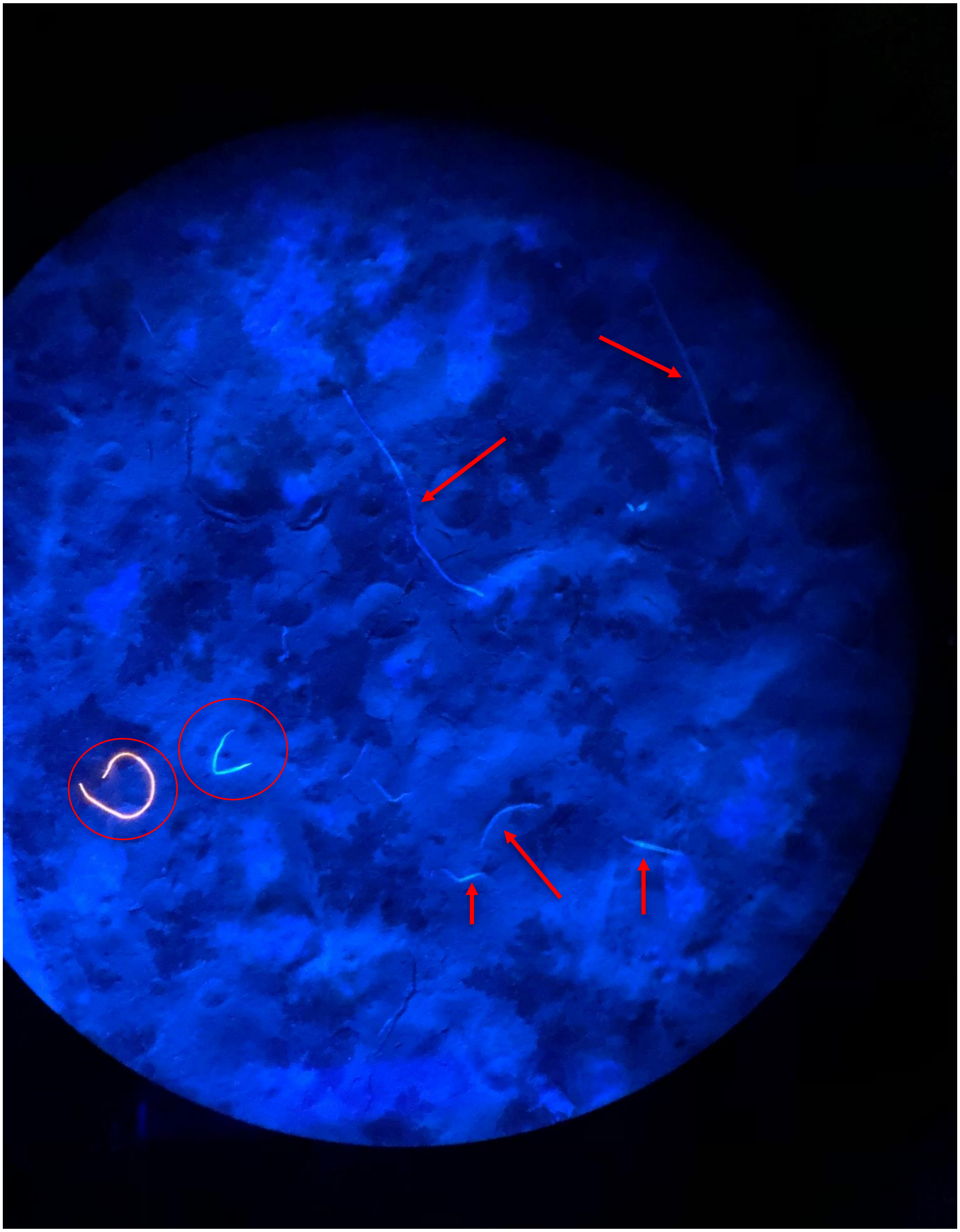


Figure 8: Microscopic view of sample under UV light at 40x magnification. Fluorescent fibers in the lower left corner, which are circled in red, are certainly plastics. Lightly fluorescent fibers, pointed out by red arrows, are also probably plastic and would have been counted as so in this study.

Chapter 4: Results

Based on the particles/liter concentrations, the results showed that four of the seven sites had more particles/liter downstream compared to upstream sites. These sites of increase were Orion Creek, Geneseo Creek, Mississippi River at Moline North plant, and the Rock River at Moline South plant. The other three plants that had decreases in plastic particle concentrations downstream were Hickory Creek in Eldridge, Mississippi River at Rock Island, and Crow Creek in Eldrige. Of these sites, the site with the most change downstream was Geneseo Creek with a 389.47% increase. See Figure 9 for percent change of particles/Liter concentrations downstream of wastewater treatment plants of all sites.

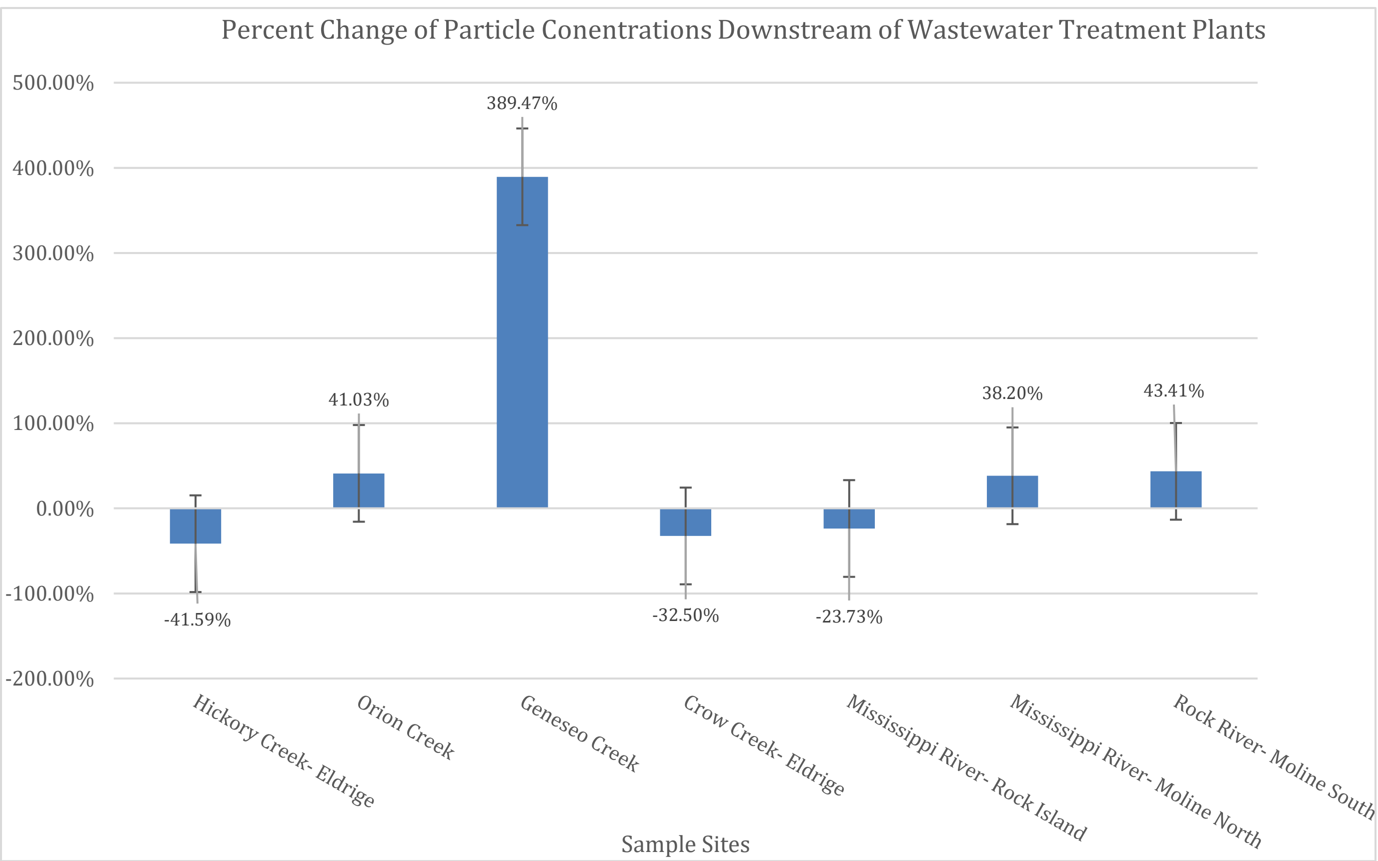


Figure 9: Percent change of plastic particle concentrations downstream of wastewater treatment plants. A statistical T- test was done on upstream vs. downstream samples, which produced a P-Value of .29. This statistical analysis suggests that wastewater treatment plants are not statistically significant in variables to determine microplastic concentrations.

Although increases were variable between stream sizes and between upstream and downstream sites, plastic particles were found at each site. A general trend is that the large and extra-large streams have more plastics than the small and medium streams. The most plastic particles/liter were found at the downstream site at the Rock River Moline South Slope at .27 particles/liter. The least amount of plastic concentrations were at .0108 particles/liter at Geneseo Creek. See Figure 10 for relative particles/liter concentrations upstream and downstream at each site and see Table 2 for a summary of all results.

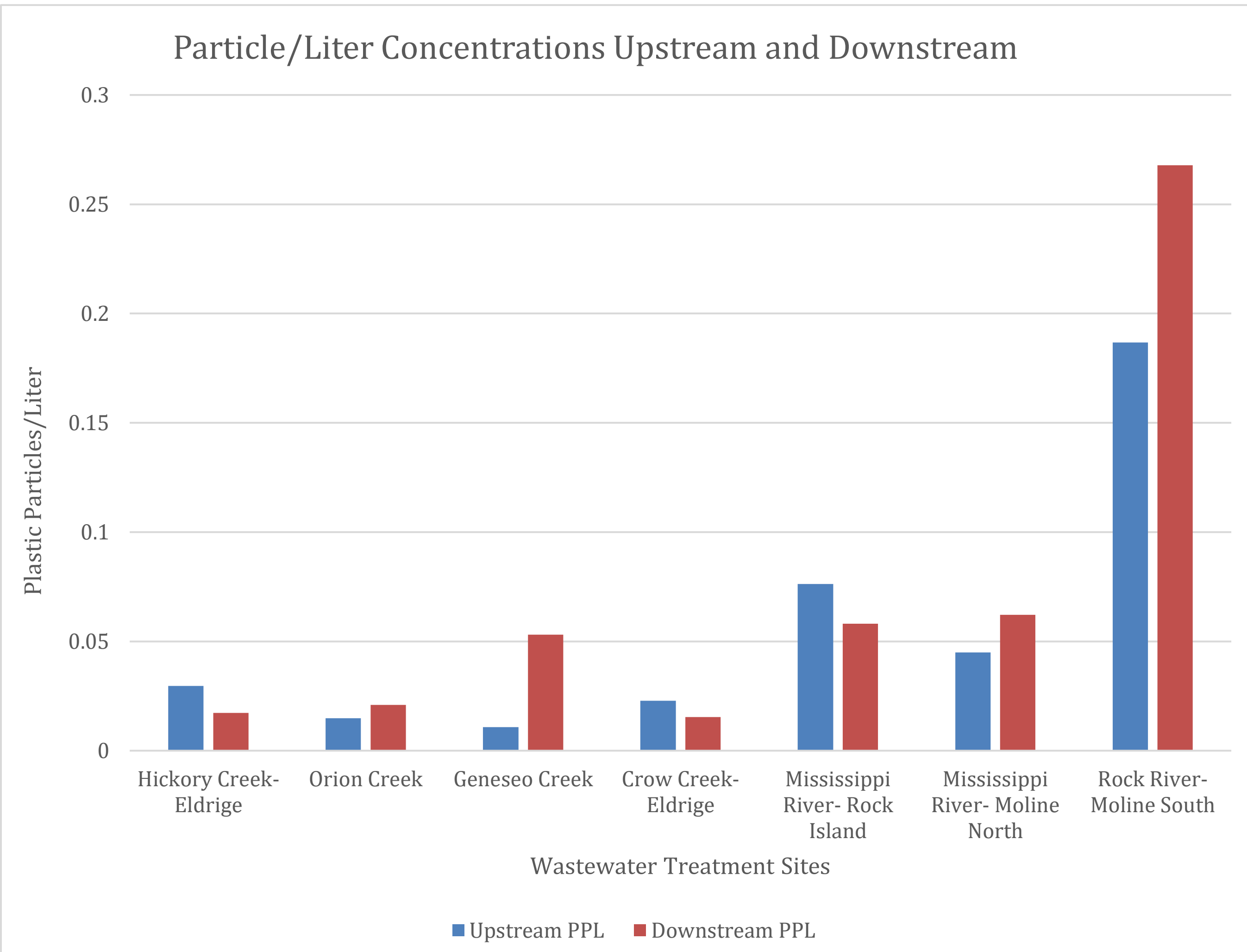


Figure 10: Particle/liter concentrations upstream and downstream across all stream sizes. A statistical T- test was done on small/medium stream sizes vs. large/extra-large sizes, which produced a P-Value of .0549. This statistical analysis suggests stream size is a statistically significant in variables to determine microplastic concentrations with an almost 95% confidence.

Table 2: Results showing total plastic concentrations and percent change downstream of wastewater treatment plants

Treatment Plant	Plant Location	Approx. Stream Size	Upstream PPL	Downstream PPL	Percent Increase Downstream
Hickory Creek- Eldrige	41.64845, -90.60031	Small	0.02960313	0.017290515	-0.415922746
Orion Creek	41.35717, -90.38201	Small	0.014840183	0.020928463	0.41025641
Geneseo Creek	41.45771, -90.16783	Medium	0.010844749	0.053082192	3.894736842
Crow Creek- Eldrige	41.61958, -90.57251	Small	0.02283105	0.015410959	-0.325
Mississippi River- Rock Island	41.5007, -90.59968	Extra-Large	0.076245485	0.05815088	-0.237320346
Mississippi River- Moline North	41.51055, -90.53785	Extra-Large	0.044935864	0.062100457	0.381979798
Rock River- Moline South	41.46231, -90.49725	Large	0.186799502	0.267884323	0.434074074

Stream size proved to be a statistically significant variable with a P-value of .054887, which means that the size of the stream effects the concentrations of microplastics with an almost 95% confidence. On the other hand, the variable of wastewater treatment plants was not found to be statistically significant with a P-value of .290172, which is not low enough to be accepted by most scientific standards as a significant variable. Correlation graphs were created with excel to show the relationship between different stream size variables and microplastic Concentrations (Figures 11-14).

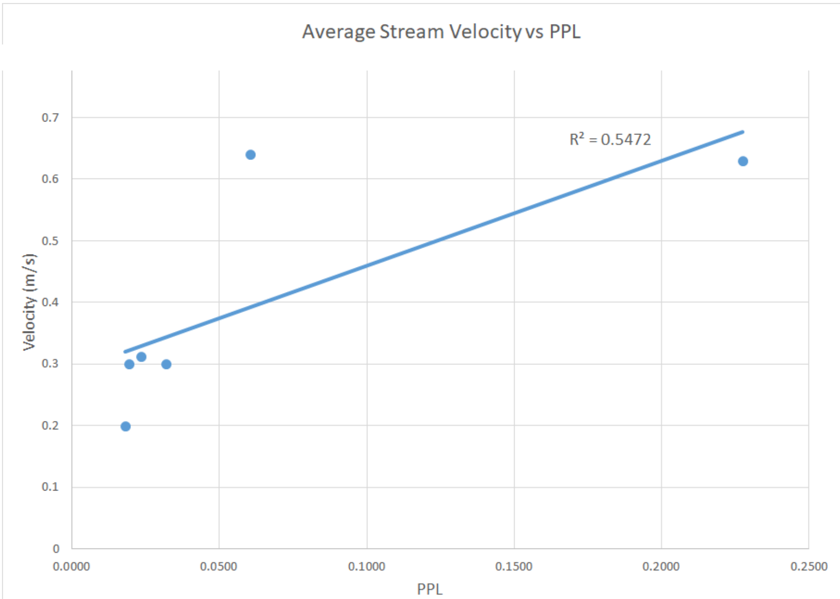


Figure 11: Correlation graph showing a positive relationship between stream velocity and plastic particles/liter concentrations

Figure 12: Correlation graph showing a positive relationship between average stream width and plastic particles/liter concentrations

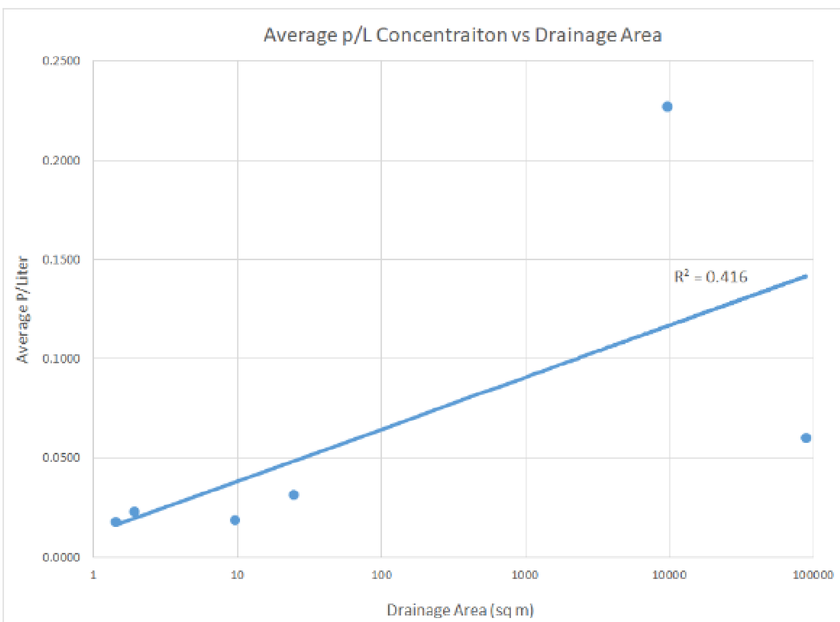


Figure 13: Correlation graph showing a positive relationship between drainage area and plastic particles/liter concentrations

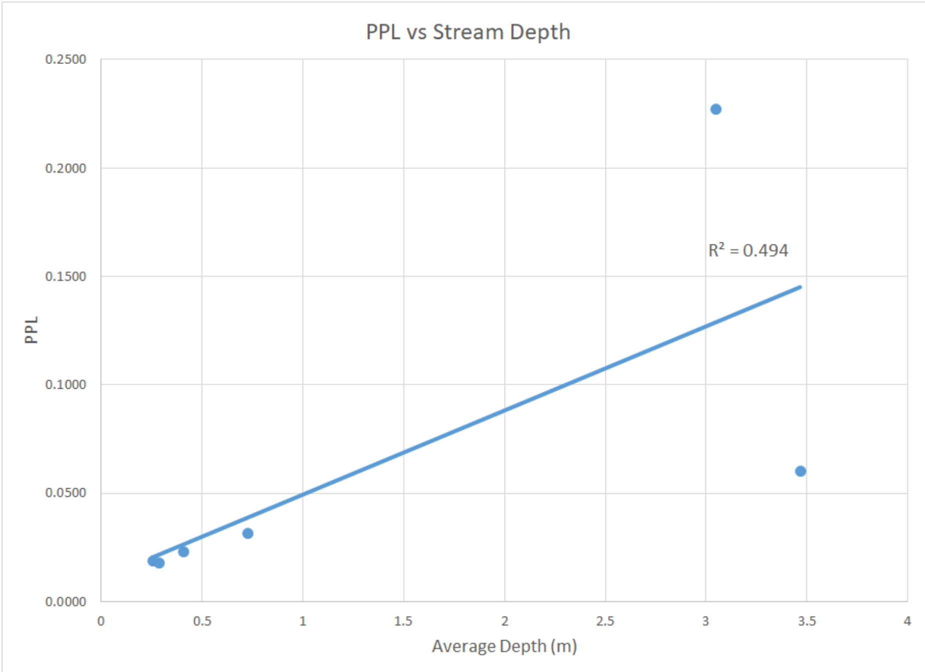


Figure 14: Correlation graph showing a positive relationship between stream depth and plastic particles/liter concentrations

Chapter 5: Discussion

The results in this study suggests that freshwater microplastic pollution is an issue due to their presence in every stream that was sampled. In addition to finding microplastics present, the results also show that microplastics are moving through freshwater systems in complex ways. Freshwater systems are often thought primarily as transport routes for microplastics from land to sea, but this study shows that they may be retained in freshwater environments. In three of the seven sites, there were decreases downstream of waste water treatment plants, which suggests that these plastics are either being retained in the sediment of are being diluted by incoming tributaries or treated wastewater effluent. It is hard to understand what exactly is happening to these plastics without further research, but this study shows that freshwater microplastics are not simply moving plastics from terrestrial lands to the marine environment.

In addition to showing the complexities of microplastic transport in rivers, the results from this study also shows that plastics are more concentrated in large streams compared to small and medium streams. This may be since large rivers have a larger drainage area, thus have more people in their drainage areas, but reasons for this trend in my research are not fully understood. The large rivers in this study were also located in areas of higher urbanization, which may also be a factor in the higher concentrations, but further research is needed to determine if this is a credible variable.

Yet another result from this study shows that wastewater treatment plants are more variable when considering their role in microplastic concentrations. While they may be potential point sources of pollution, they were not a significant factor across all of the sample sites. This contrasts to some of the literature, which linked wastewater treatment plants directly to microplastic concentrations (Siegfried et al., 2017; Estahbanati and Fahrenfeld, 2016). However, the results from this study showed that waste water treatment plants can be potential significant contributors in microplastic concentrations, but the role they play may be more site specific than previously understood. For example, Geneseo creek had an almost four-fold increase in microplastic concentrations downstream of the city’s wastewater treatment plant, which suggests that this treatment plant may play a significant role in microplastic concentrations.

The results of this research will add to the understanding of microplastic transport and pollution in riverine environments. As mentioned earlier, studies on microplastic pollution have been heavily focused on marine environments while freshwater environments are extremely under represented. Research has shown that rivers, while transport mechanisms to marine environments, can be sinks for microplastic pollution. In a modeling study by Bessiling (2017) their results showed that millimeter sized plastics are highly likely to be retained in rivers, emphasizing that freshwater bodies of water are not just means of transport for microplastics, but also sinks for microplastics. Additionally, in a study by Bordos (2019), researchers found microplastics in 92% of their water samples and 69% of sediment samples from freshwater collected from fish ponds in Europe. Another study on large and medium rivers by Liedermann (2018) further shows how microplastics are prevalent is freshwater by finding microplastics throughout the entirety of the water column in rivers, not just the surface. There have also been several studies that have shown microplastic ingestion in freshwater organisms, making the results of this study crucial for representing microplastic pollution affecting freshwater environments (Nel 2018, Windsor 2019). Hopefully the research in this study will open up more discussion about how microplastics may have a larger impact on freshwater environments than previously perceived. In addition to conversation, the results of this study will generate answers as to how microplastics are being transported through rivers. While there are many studies done on microplastics in large bodies of water, there are very few studies done on small terrestrial streams. This information may prove to be helpful for conservationists, policy makers, wastewater treatment directors, and other researchers.

In the case of finding more particles of plastic downstream of each wastewater treatment site in comparison to upstream, the literature suggests that wastewater treatment plants are linked to higher concentrations of microplastic pollution in rivers receiving treated water (Besseling et. al, 2017; Bletter et. al, 2018; Bordós et. al, 2019; Estahbanati and Fahrenfeld, 2016; Peng et. al, 2017; Siegfried et. al, 2017; Windsor et. al, 2019). Another study shows that the better the filtration systems, the less primary microplastic pollution discharged (Bordós et. al, 2019). In order to explain why some samples had a higher amount of microplastics upstream, the literature suggests that the hydrology of the rivers may play a role. Large discharge and high velocity could cause more plastic particles to suspend that normally would sink in low flow conditions. (Nel et. al, 2018; Liedermann et. al, 2018).

Chapter 6: Conclusions and Future Work

The results of this study show that microplastics are present in small, medium, and large stream environments. Overall, there were higher concentrations of plastics in large and extra-large streams compared to medium and small streams. When looking at the percent change of plastic concentrations downstream, four out of the seven sample sites increased in concentration, suggesting that wastewater treatment facilities may be contributing to the microplastic pollution issue, but are site specific due to the variability in concentrations found downstream. One site of particular interest is Geneseo Creek, which had a dramatic increase in microplastic concentration almost four-fold downstream of the city's wastewater treatment facility. This dramatic increase suggests that the treatment plant plays a significant role in microplastic pollution, but one cannot be entirely certain. There are too many unknown variables to conclude this theory. The percent change downstream did vary among different sized streams in both rural and urban centers, which suggests that there are other variables at play determining the concentrations of microplastics in freshwater. Further research needs to be done on this topic to investigate other potential sources of microplastics. Not only should research be done on potential sources of microplastics, but also hydrology, plastic properties, methodology for collecting and isolating microplastics, and other freshwater environments.

Because there is such a lack of knowledge about microplastics in freshwater, there are many different projects that could and should be done on this topic. As of 2018, only 13% of all microplastic studies were done on freshwater environments (Bletter et. al, 2018), which makes freshwater studies crucial for fully understanding potential microplastic pollution impacts. One first basic step to better understand microplastics in freshwater is to definitively show that they are there. With so many terrestrial streams, wetlands, lakes, and rivers, there are many opportunities to study where plastics may concentrate. Another potential project could be a human geographic study about perceptions of plastic in our environment. Additional research could also be done to replicate this project to see if the results change or if the results are consistent with findings. Many aspects of this project, such as river size, sampling method, location, plastic size, and flood conditions, could be changed to make for many other interesting research topics. Methodology is another important area of research when it comes to microplastic research in freshwater. More studies should be done to add to sampling, isolation, and identification methods. The implementation of Fourier Transform Infrared Spectrometry could be utilized for a more concrete identification. This technology could also tell future researchers the exact type of plastic found in a sample. This could help researchers make interpret where specific microplastics may be sourced from. It is important to continue researching plastics in the environment to provide information to conservationists, policy makers, wastewater treatment directors, and other researchers. The full implications of microplastics in the environment are not fully known yet, but as mentioned earlier, research shows that organisms are consuming these particles and can harm them by physical and chemical means. Better understanding microplastics means better understanding how to protect not only aquatic organisms, but all beings that may be exposed to microplastics, including humans.

Summarized list of potential future work:

- Duplicate study
- Study on one or two sites over time- variability
- Study with more focus on stream size
- Looking at sediment samples
- Same sites, different methods
- Using my methods and comparing them to FTIR spectroscopy
- Water column distribution
- Looking at direct effluent at different WWTP
- Looking at a places without WWTP
- Social perception of microplastics

References

Berg, E. 2018. *Microplastic Processing Protocol*. YouTube. https://www.youtube.com/watch?v=esFTU-9RcaA&t=2s (last accessed 11 Nov. 2019).

Beri, D. 2015. How to Sample Microplastics. YouTube. https://www.youtube.com/watch?v=FJ36Gt6Rn0k&t=1s (last accessed 11 Nov. 2019).

Besseling, E., J. T. K. Quik, M. Sun, and A. A. Koelmans. 2017. Fate of nano- and microplastic in freshwater systems: A modeling study. *Environmental Pollution* 220:540-548.

Blettler, M. C. M., E. Abrial, F. R. Khan, N. Sivri, and L. A. Espinola. 2018. Freshwater plastic pollution: Recognizing research biases and identifying knowledge gaps. *Water Research* 143:416-424.

Bordós, G., B. Urbányi, A. Micsinai, B. Kriszt, Z. Palotai, I. Szabó, Z. Hantosi, and S. Szoboszlay. 2019. Identification of microplastics in fish ponds and natural freshwater environments of the Carpathian basin, Europe. *Chemosphere* 216:110-116.

Browne, M. A., P. Crump, S. J. Niven, E. Teuten, A. Tonkin, T. Galloway, and R. Thompson. 2011. Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks. *Environmental Science & Technology* 45:9175-9179.

De Falco, F., M. P. Gullo, G. Gentile, E. Di Pace, M. Cocca, L. Gelabert, M. Brouta-Agnésa, A. Rovira, R. Escudero, R. Villalba, R. Mossotti, A. Montarsolo, S. Gavignano, C. Tonin, and M. Avella. 2018. Evaluation of microplastic release caused by textile washing processes of synthetic fabrics. *Environmental Pollution* 236:916-925.

Estahbanati, S., and N. L. Fahrenfeld. 2016. Influence of wastewater treatment plant discharges on microplastic concentrations in surface water. *Chemosphere* 162:277-284.

Fossi, M. C., T. Vlachogianni, F. Galgani, F. D. Innocenti, G. Zampetti, and G. Leone. 2019. Assessing and mitigating the harmful effects of plastic pollution: the collective multi-stakeholder driven Euro-Mediterranean response. Ocean &

Coastal Management105005. *Chemosphere* 162:277-284.

Fu, Z., and J. Wang. 2019. Current practices and future perspectives of microplastic pollution in freshwater ecosystems in China. *Science of the Total Environment* 691:697-712.

Lam, C., S. Ramanathan, M. Carbery, K. Gray, K. S. Vanka, C. Maurin, R. Bush, and T. Palanisami. 2018. A Comprehensive Analysis of Plastics and Microplastic Legislation Worldwide. *Water, Air, & Soil Pollution* 229:345.

Liedermann, M., P. Gmeiner, S. Pessenlehner, M. Haimann, P. Hohenblum, and H. Habersack. 2018. A Methodology for Measuring Microplastic Transport in Large or Medium Rivers. *Water (20734441)* 10:N.PAG.

McDevitt, J. P., C. S. Criddle, M. Morse, R. C. Hale, C. B. Bott, and C. M. Rochman. 2017. Addressing the Issue of Microplastics in the Wake of the Microbead-Free Waters Act? A New Standard Can Facilitate Improved Policy. *Environmental Science & Technology* 51:6611-6617.

Nel, H. A., T. Dalu, and R. J. Wasserman. 2018. Sinks and sources: Assessing microplastic abundance in river sediment and deposit feeders in an Austral temperate urban river system. *Science of The Total Environment* 612:950-956.

Peng, J., J. Wang, and L. Cai. 2017. Current understanding of microplastics in the environment: Occurrence, fate, risks, and what we should do. *Integrated Environmental Assessment & Management* 13:476-482.

Prata, J. C., J. P. da Costa, A. C. Duarte, and T. Rocha-Santos. 2019. Methods for sampling and detection of microplastics in water and sediment: A critical review. *TrAC Trends in Analytical Chemistry* 110:150-159.

Rochman, C., E. Hoh, T. Kurobe, and S. Teh. 2013. Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress. *Scientific Reports* 3:3263.

Rodrigues, M. O., A. M. M. Gonçalves, F. J. M. Gonçalves, H. Nogueira, J. C. Marques, and N. Abrantes. 2018. Effectiveness of a methodology of microplastics isolation for environmental monitoring in freshwater systems. *Ecological Indicators* 89:488-495.

Siegfried, M., A. A. Koelmans, E. Besseling, and C. Kroeze. 2017. Export of microplastics from land to sea. A modelling approach. *Water Research* 127:249-257.

Wang,J.,Zheng,L.,Li,J.,2018 .A critical review on the sources and instruments of marine microplastics and prospects on the relevant management in China. *Waste Manage.* Res. 36, 898–911.

Windsor, F. M., R. M. Tilley, C. R. Tyler, and S. J. Ormerod. 2019. Microplastic ingestion by riverine macroinvertebrates. *Science of the Total Environment* 646:68-74.

Wellner, B., and T. Geyer. 2012.Mississippi, Rock Rivers among Worst for Pollution. *The Quad-City Times.*

Worm, B., H. K. Lotze, I. Jubinville, C. Wilcox, and J. Jambeck. 2017. Plastic as a Persistent Marine Pollutant. *Annual Review of Environment and Resources* 42:1-26.