RESEARCH ARTICLE

Microplastics—A Not So Micro Problem: Prevelence in a North Carolina Freshwater System

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ABSTRACT: While the plastics pollution crisis has remained on the wider global radar, a more recent and seemingly more pervasive type of pollution, known as microplastic pollution, has gained attention by environmentalists. However, there are large gaps in the research of microplastic pollution, especially in freshwater ecosystems. This study seeks to address this gap by investigating the prevalence of microplastics in the Catawba River Basin of North Carolina. The Catawba River Basin is an ideal study location due to its use for recreation, energy, and drinking water for the nearby metropolis of Charlotte, NC. Eighty water samples were collected from five different sites. These sites were characterized by recreated versus non-recreated areas and upstream versus downstream locations. Each sample was vacuum filtered through micron filter paper and then analyzed under a compound microscope for microplastics. Notably, the presence of microplastics in every water sample collected was found. The results showed a 45% increase in prevalence of microplastics in recreated areas compared with less recreated areas, and 25% increase in microplastics downstream of Wastewater Treatment Plants compared with upstream locations. More research is necessary to identify and understand the possible human health and ecological implications of microplastics in the North Carolina area.

KEYWORDS: Earth and Environmental Science; Water Sciences; Environmental Health; North Carolina Freshwater System; Microplastics.

Introduction

Microplastic contamination is recognized as a harmful global environmental problem.[1] Discovered in both aquatic and terrestrial environments, microplastics have been identified as synthetic polymer materials less than five millimeter and greater than one micrometer.[2] Though the highly ubiquitous extent of microplastic pollution can be narrowed down to two major sources categorized as primary versus secondary.[3] Primary sources are those directly manufactured into micro particle sizes, including: fertilizer capsules; fibers that shed from polyester, nylon and vinyl fabrics; unfiltered sewage and sludge from wastewater treatment plants; and industrial abrasives.[4-7] Secondary sources are considered macro particles from everyday plastic items like containers, beverages, packaging, etc., that break down in the environments due to photochemical processes, weathering, erosion, and ultra-violet (UV) radiation.[8] Through the combination of intentional and unintentional waste, these secondary sources are entering the environment on a daily basis, accounting for approximately 69-81% of the microplastic pollution found in the oceans.

Though the implications of microplastics are actively being researched, it is known that microplastics contain chemicals that are toxic and that these alter the development and behavior of organisms.[9-11] These microplastics can also embed themselves into the chemical and physiological makeup of these organisms and consequently become part of the food chain.[12,13] Thus, there is great concern surrounding the human consumption of microplastics especially as it has been estimated that humans consume a credit card's worth of plastic every week.[14] Studies have shown that microplastics exposure, particularly via consumption, in humans may be linked to cancer and liver disease.[15-17,11]

Even with the advanced treatments and filtration systems, freshwater sources can still be contaminated by microplastics. Further research indicates that the most advanced wastewater treatment plants, including activated carbon filtration, reverse osmosis, and membrane technology, can only filter out up to 60% of microfiber particles, and that from a single wash of synthetic clothing material, over 700,000 fibers can shed from garments.[18] Evidence reveals that freshwater organisms, specifically the amphipod species Gammarus duebeni, have the ability to ingest microfibers into their digestive tracts in less than four days.[19]

Biofouling has been seen to increase the risk of ingestion of these plastic particles by marine animals through mistaking them for food using visual and olfactory senses.[20] Additionally, biofouling increases the density of these particles and leads them to sink to the bottom of the ocean where they may remain for years on the deep, cold and less corrosive seafloor, and possibly ingested by benthic organisms.[21]

While much of the microplastic literature has focused on marine environments, there is a growing call to increase research on microplastics in freshwater systems as these are thought to be then entry points of plastic pollution.[22,23] In response to these calls, this study investigates the prevalence of microplastics in a North Carolina freshwater system.

Methods

Study Site :

This study was focused within the Catawba River Basin, located in North Carolina, United States (Figure 1). This river basin is 3,285 square miles and contains water bodies such as Lake James, Lake Hickory, Lake Norman, Mountain Island Lake, and Lake Wylie. Lake Norman is at the northern-most

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section of the Catawba River and feeds into the river, eventually draining into Mountain Island Lake to the south and eventually Lake Wylie. In particular, Lake Norman is the largest man-made body of water in North Carolina. Today Lake Norman acts as a recreation area, residential area, energy source, and water source for the nearby city of Charlotte. Aside from Charlotte, the Catawba River and Lake Norman provide the primary sources of drinking water to counties across North Carolina and some portions of South Carolina including, Lincoln County, Catawba County, Iredell County, Gaston County, and Mecklenburg County (where Charlotte is located). As of 2022, the population of Charlotte has increased by 26.51% since the most recent census and has obtained the status as the 14th largest city in the United States, as well as the second largest in the Southeastern region.[24] With the reputation as an industrial and highly evolving metropolis, through simultaneous population growth Charlotte is also a central worldwide hub for financial, technological and health care industries, thus stimulating an influx of laborers and white-collar workers from around the country.

Consequently, expanding population, pervasive urban-sprawl, and industrial development all serve to compromise and exasperate the environmental issues prevalent within and around the city. Concerns over air pollution levels, an increase in the frequency of urban heat islands, and sporadic weather patterns due to global warming contributing to stormwater runoff, extreme temperatures, and sedimentation have forced Charlotte city officials and citizens to grapple with the necessity of a healthy environment and the newfound pressures of a continuously growing population. Given these overarching factors, alongside input of thousands of tons of plastics into the environment from the necessary COVID-19 safety measures (masks, gloves, disinfectants, etc.), Charlotte's plastic and solid waste pollution is at the forefront of environmental stressors. Unlike the eight states across the US who have placed bans on single-use plastic bags or the six states who have a moratorium on Styrofoam materials, aside from general recycling measures and a transition towards replacing yard waste plastic bags with paper alternatives, there are not enough county-wide or state-wide measures to combat the threat of plastics pollution and subsequently microplastic pollution in Charlotte's freshwater systems. While wastewater treatment facilities for the Catawba River and Lake Norman are adequate to prevent chemical outbreaks and macroplastics, the growing population of North Carolina counties are proving to be a difficult task for our systems to handle. In addition, several wastewater treatment facilities, like the ones in Gaston County and surrounding Lake Norman, have already reached maximum capacity.[25] Even with the transition towards advanced membrane filtration methods, studies have proven that these systems may allow for the passage of micro and nano-particle plastics to enter into drinking water.[26]

With Charlotte being a sprawling metropolis, industrial power hub, and a sound attraction for financiers and industry workers, it is clear that the environmental risks associated with these conditions are intensifying the concerns related to increased pollution and environmental degradation.

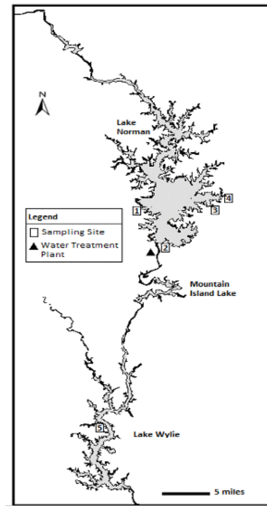

Figure 1: North Carolina Freshwater System Geographic Overview.

Sample Collection :

All samples were collected between June and November of 2021. The sampling sites were chosen based on their proximity to known physical and social characteristics that may influence microplastic contamination. For example, studies have shown that microplastic abundance is more prevalent around wastewater treatment plants and areas with high anthropogenic impact.[27,28] Similarly, sampling sites upstream and downstream of the Mount Holly Wastewater Treatment plant and in highly recreated and low recreated areas were chosen (Table 1). To distinguish recreated versus non-recreated areas, categories were based on proximity to commercial and public activities, including fishing, boating, recreational parks and industries like restaurants or factories for recreational areas, and private residential housing or remote locations without public access for non-recreated areas. An in-depth summary of sampling sites, surrounding characteristics and the number of samples taken from each site can be viewed in Table 1 below.

Table 1: Sample sites and characteristics.

Sampling Site Number	*Geographic Coordinates*	*Site Characteristics*	*Number of Samples Taken*
1	35.35, -80.97	Highly Recreated (Primary Highway NC-16 Intersects / Public Activities Including: restaurants, commercial ventures, boating, industrial factories, public parks)	11
2	35.50, -80.87	Highly Recreated (Public Marina / Commercial Fishing)	4
3	35.50, -80.86	Less Recreated (Private Residential Housing)	15
4	35.33, -80.98	Upstream from Wastewater Treatment Plant	28
5	35.11, -81.22	Downstream from Wastewater Treatment Plant	28

At each sampling site, surface water was collected in 1 liter glass mason jars with latex gloves. Each jar was filled to the halfway mark of the jar. The lid was sealed while submerged in the water to avoid contamination from the outside air. The water samples were all taken in 3-4 feet of water approximately 1.5 feet below the surface. This methodology follows that of grab sampling for microplastics used by

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Barrows.[29] Additionally, non-synthetic clothing was worn by the sample collector. Geographic coordinates were taken for each sample and the jar was immediately logged for data organization and management purposes.

Water Sample Analysis:

Each water sample was then evaluated for the presence and abundance of microplastics. After sterilizing all equipment with distilled water, the water sample was vacuumed and filtered through a 90 mm Buchner funnel using 11-micron filter paper. This aligned with the laboratory procedure used by Barrows.[29] Microplastics were identified based on their characteristics of durability under hot metal needle point pressure, and the relative unnatural coloration outlined in the Barrows method. To differentiate microfibers from fragments or Styrofoam the characteristics of slenderness, length (average microfibers are 1mm), and coloration were used. The majority of the fragments were transparent or yellowish in color, which was a clear divergence from the royal blue to red coloration of the fibers. Each filter paper contained eight, randomly placed, uniformly sized circles (113 mm^2) that were drawn by hand before conducting the filtration process. The filter paper was then placed in a glass petri dish and evaluated under a compound microscope. Microplastic identification and classification was conducted following characteristics outlined by Hidalgo-Ruz.[30] For each filter paper analyzed, the number of and type of microplastics were counted within the eight circles of the filter paper. Given that evaluating an entire filter paper would be time consuming, this allowed for a random subsample to be taken. The raw data found from these analyses can be seen in Appendix A and Appendix B.

Results

It was found that the downstream area had significantly (Student's T-test p=0.03) more microplastics than upstream (Figure 2). Additionally, it was found that highly recreated areas had significantly (Student's T-test p=1.37E-06) more microplastic abundance than low recreation areas (Figure 3). The results of these T-tests can be seen in Appendix C and Appendix D.

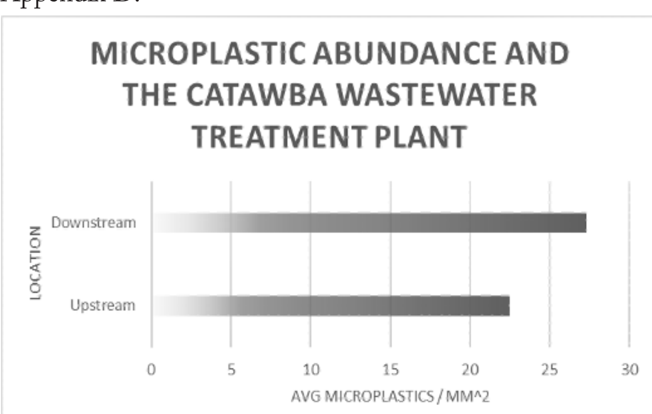

Figure 2: Microplastics prevalence in upstream versus downstream locations of the Catawba River Freshwater System.

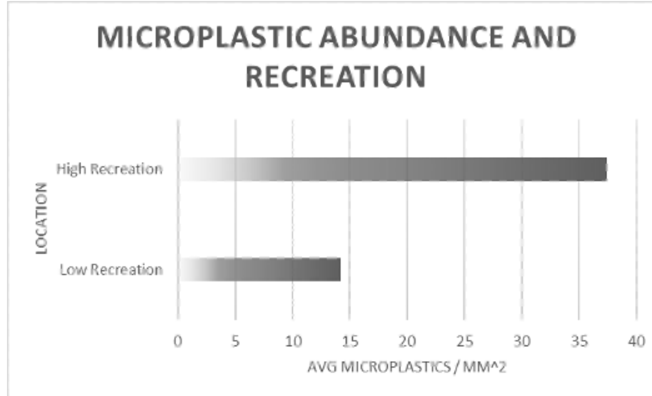

Figure 3: Microplastics prevalence in recreated versus less recreated locations of Lake Norman Freshwater System.

The most common type of microplastics we found were colored microfibers as shown in Figure 4.

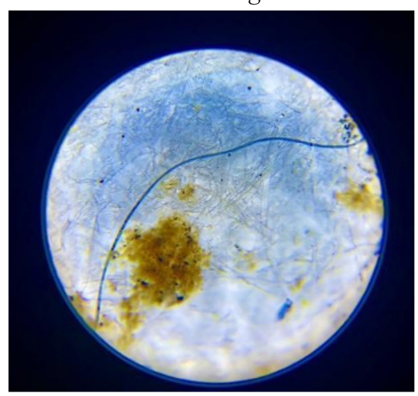

Figure 4: Blue microfiber particle extracted from our Lake Norman Recreated sample site.

However, though rare, over 20 microplastic fragments were identified in the freshwater samples like the one seen below in Figure 5.

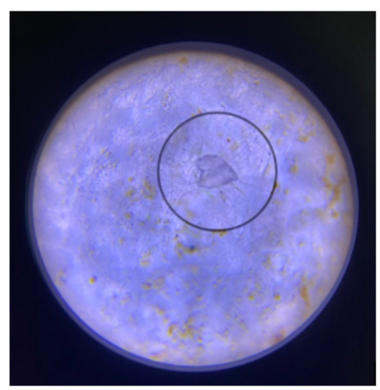

Figure 5: Blue microfiber particle extracted from our Lake Norman Recreated sample site.

In 100% of the samples taken which were identified the presence of microplastic pollution, with a high frequency in microfiber pollution. The average frequency and occurrence at each of the various sites with distinct characteristics can be seen below in Table 2.

Table 2: Sample sites and average number of microplastics.

Sampling Sites (Based on Primary Characteristic)	*Number of Samples from Each Site*	*Average Number of Microplastics per 113 mm²*
High Recreation	15	37.4
Low Recreation	15	14.2
Upstream From Wastewater Treatment Plant	28	22.5
Downstream From Wastewater Treatment Plant	28	27.3

In relation to the recreated versus less recreated data samples, there was a 45% difference in pervasiveness of the microplastic particles, with a major upswing in the amount of microplastics in recreated areas, as seen in Figure 3. This aligned with the assumptions of this study, as when collecting samples visible pollution and secondary macroplastic particles were strewn throughout the environment from restaurants, bars, and retail stores in proximity.

When assessing the differences in prevalence of microplastics between upstream and downstream, downstream samples demonstrated 25% more plastic particles than samples from upstream. This trend was predicted as the technology used during water and wastewater treatment processes in Mecklenburg County, though advanced, are not enough to prevent the flow of micro and nano plastic particles into the freshwater systems as effluent.

Discussion

In an effort to understand the pervasiveness of microplastic pollution in a local urban community, the results of this study compiled from freshwater sampling and analysis of this ubiquitous pollutant indicates that like many other areas, the community of Charlotte must take more decisive action to mitigate and reduce the consumption and waste of plastics pollution. Initially it was shocking that 100% of the samples identified contained some form of microplastic pollution, whether this be the more common microfibers or plastic fragments small enough to allow their absorption and ingestion in marine animals, these findings reinforced the need to comprehend the short- and long-term implications of these substances on the ecosystems and human health.[31] It has been clear for decades that plastics are a staple in consumer culture, yet only now society is starting to really understand the ramifications of this consumption and is now witnessing plastics become part of the human diet too. In the central European lowland river of southwest Poland, a study conducted on freshwater fish and their ingestion and accumulation of microplastics particles revealed that of the 389 sampled gudgeons and freshwater roaches, 54.5% ingested microplastics with the majority of particles being identified as microfibers. Some of these microplastics were entangled in the gills and dug into the mucus of the fins.[32] Though these freshwater animals may not be a common meal for most humans, the concern exists that other primary food sources like salmon, trout, or catfish, are most likely ingesting and accumulating these microplastics on a daily basis, thus demanding the question, what does this mean for humans? Furthermore, gudgeons and roaches are primary food sources for many freshwater and marine life including otters and kingfishers. While preliminary studies are still trying to comprehend the existence and effects of biomagnification of plastic particles up the food chain, it stands to reason that these otters, kingfishers and other marine life that intake plastic infested organisms may suffer negative consequences to their long-term health.

In analyzing high recreational versus less recreational areas, it was concluded that due to the frequency in activities such as commercial and public facilities, which contribute to the likelihood of direct and indirect litter or waste of plastics substances, the increase in plastics within recreated areas is an understandable finding. This mandates policy and action to mitigate future harm. Private areas also have greater access to advanced waste disposal and collection systems, and seem to have a more regular system of trash cleanup. The trends identified were specifically identified in the Lake Norman area, and further studies would need to be done to understand if these patterns align with rivers and streams as well. Similarly, there was a greater presence of biofouling of microplastics, especially fibers, in the Catawba River areas, with darker colored fibers observed having a higher amount of organic or inorganic material adhered to the outside. It is unclear if color or additives to plastics have any effect on whether a material has a greater likelihood of biofouling, but the implications of this are known. When observing samples that came from the middle of the water column, there seemed to be an increase in the amount of microplastics particles, since the density of freshwater is less than that of microplastics, due to the lesser salinity This therefore causing an increase along the bottom of lakes and rivers. Microplastic fragments identified seemed to be discolored, with a yellowish hue, and were irregular shapes. Zero evidence of Styrofoam particles were found, however, there were what seemed to be visible clear films. On cleanups along and near these areas, specifically in the upstream Catawba area, there was a significant presence of secondary Styrofoam macro particles. The general colors of the fibers identified were blue, red, black, and transparent. Although some were green, the validity of these were questioned as they may have been organic material such as algae.

With respect to the upstream versus downstream of wastewater treatment plants study sites, it was clear that although there was not as substantial a difference in the range of microplastics particles found between these locations, there is necessary concern over the contribution of wastewater treatment plants to the accumulation of plastic particles downstream and how this may affect freshwater organisms. The three major treatment facilities for Mecklenburg County include Lee S. Dukes, Vest, and Franklin. Although Charlotte Water Services has clarified in their 2020 Annual Drinking Water Quality Report that they have employed advanced treatment for wastewater treatment including aeration basins, secondary clarifiers, effluent filtration, and disinfection processes, studies have shown that these mitigation techniques still allow for up to 65 millions microplastic particles to be released into water daily, especially microfibers.[33,34] Furthermore, analyzing this study's

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results of the downstream samples, it is clear that when the wastewater after treatment is released into the surrounding water system of Lake Wylie, there was a significant increase in the prevalence of microplastics as these concentrated particles accumulated downstream. While there are few alternatives for more adequate and effective wastewater treatment solutions, it is necessary that Charlotte and surrounding counties fund and support research and development initiatives towards developing treatment facilities that may prevent and mitigate the dispersal of microplastic infested effluent into water systems.

While out of the scope of this study, it is necessary to note the diversity of factors that contribute to microplastic pollution especially in relation to marine pollution. In 2014 there was a worldwide call for the phasing out and banning of microbeads within cosmetic products as these substances, like microfibers, are understood to escape wastewater treatment and spread into freshwater and marine systems.[35] However, although many countries, including the US, have banned the incorporation of these products, the cosmetic industry is still under scrutiny for the widespread use of single use plastics in their packaging and products, and the dissemination of other microplastic particles within their home care products. Moreover, the cosmetic industry is not the only industrial sector that has some fault for microplastic pollution, but commercial industry and port facilities in general have been classified as major contributors to the prevalence of microplastic pollution near coasts and freshwater systems. In a study taken across Portuguese coasts, resin pellets (primary sources of microplastics) often used as industrial raw materials to be incorporated into goods or to create molds for products, made up 79% of the waste and plastic material collected.[36] The primary and secondary sources of microplastics around the world are boundless, cementing the idea that it may not be a simple feat in lessening the waste and consumption of these items. However, it is a necessary one for the future.

While this study identifies specific trends in the prevalence of microplastic pollution in recreated areas and in proximity to wastewater treatment facilities, future research is needed in understanding the prevalence of microplastics within freshwater organisms and drinking water as well. Though this study collected over 80 samples from various sites, it is necessary further research is conducted to support the trends identified and to have an accurate gauge of the magnitude of plastics pollution in the Catawba River Basin. This study did not get too involved in the intricacies of how and if microplastics act as vectors for harmful pollutants and possibly leach those chemicals into freshwater organisms, yet this is also a necessary step in comprehending the implications of ingesting plastics on human health.

Conclusion

There is clear evidence of microplastics in freshwater systems of the Catawba River Basin. Although the precise implications and extent of the threat may not be fully understood, it is known from prior and current research that microplastics can pose ecological and human health implications over time. It is necessary to gain a greater understanding of this problem. This is especially true given that a major metropolis, the city of Charlotte, uses the Catawba River Basin for drinking water. Although measures have been put into place to try to prevent the expansion of this problem such as Charlotte's initiative to phase out plastic bags for trash collection, there is still extensive contamination of the freshwater systems, as shown in this study. Policy recommendations for microplastic mitigation for the city of Charlotte are provided in Appendix E. Assessing the overall trends in recreated versus less recreated areas it is clear that humans have direct influence on the extent of microplastic pollution as there was approximately a 50% increase in microplastics in recreated than less recreated areas of Lake Norman. Furthermore, the prevalence of microplastics in greater varieties and prevalence downstream than upstream of the Catawba suggests that the wastewater treatment systems may not be having an equal distribution of adequate filtration in these hotspot areas, and that certain communities may be more influenced by this problem than others. Continued research and increased understanding is necessary regarding the toxicology of plastics and chronic health effects that may ensue from ingestion or inhalation of microplastics as this distressing problem continues.

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Contributions of authors

VF: Collection, data sampling, and evaluation of samples.

SF: Data organization and methodology development.

Conflict of Interest:

Authors report no conflicts of interest for this study. The authors alone are responsible for content and writing of this article.

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APPENDICES

Sample Number	Upstream Microplastics 113 mm2	Downstream Microplastics 113 mm2
1	10	24
2	20	17
3	18	24
4	15	21
5	10	33
6	10	36
7	15	44
8	11	21
9	21	33
10	28	17
11	30	36
12	29	16
13	20	21
14	21	30
15	26	42
16	27	30
17	40	21
18	23	33
19	24	21
20	49	28
21	37	20
22	12	31
23	22	28
24	15	32
25	29	24
26	25	17
27	26	28
28	18	36

Sample number	High recreation microplastics 113 mm2	Low recreation microplastics 113 mm2
1	22	17
2	30	21
3	23	19
4	42	11
5	41	14
6	32	16
7	36	11
8	45	16
9	31	7
10	37	13
11	64	16
12	53	14
13	28	12
14	34	9
15	43	17

Appendix B: Raw data for microplastics found in samples from high recreated areas and low recreated areas.

	High Recreation	*Low Recreation*
Mean	37.4	14.2
Variance	124.6857	14.31429
Observations	15	15
Pearson Correlation	-0.04092	
Hypothesized Mean Difference	0	
df	14	
t Stat	7.528206	
P(T<=t) one-tail	1.38E-06	
t Critical one-tail	1.76131	
P(T<=t) two-tail	2.76E-06	
t Critical two-tail	2.144787	

Appendix C: Results for the Student T-test between microplastics found in high recreation areas and low recreation areas.

	Upstream	Downstream
Mean	22.53571	27.28571429
Variance	88.18386	59.32275132
Observations	28	28
Pearson Correlation	-0.23775	
Hypothesized Mean Difference	0	
df	27	
t Stat	-1.86362	
P(T<=t) one-tail	0.036642	
t Critical one-tail	1.703288	
P(T<=t) two-tail	0.073285	
t Critical two-tail	2.051831	

Appendix D: · Results of Student's T-test for microplastics found in upstream and downstream locations.

Policy Recommendations:

To confront the issue of microplastic pollution in Charlotte, here we outline seven specific methods we may implement in our county to lower the risks of microplastic pollution.

1. Extended Producer Responsibility (EPR):

Extended Producer Responsibility policies have been adopted in a variety of ways nationally. States across the country have adopted these towards reducing our carbon footprint, making producers responsible for post-production hazardous wastes in wastewater treatment plants or nuclear energy facilities, and to minimize our plastic footprint. However, unlike states such as California, Maine and Maryland, North Carolina has been slow in adopting EPR policies. As the name suggests, policies like these are characterized by holding producers responsible for waste from pre-production materials, the manufacturing process, and post-consumer waste in the form of taxes, fees or government regulations. On July 13, 2021, Maine was the first state to implement an EPR policy towards paper and packaging waste. Producers are responsible for financing "stewardship organizations" who collect and recycle products on the producer's behalf. In this way Maine has cemented their stance on working collectively with producers, consumers and NGOs to foster an environmentally conscious community and reduce their plastic waste. North Carolina, specifically Charlotte, should follow their suit, as they have the means and resources to hold producers in North Carolina responsible for the production of plastic packaging, Styrofoam material in pre- and post- production, and paper cartons, boxes, or other resources. With the help of non-governmental organizations such as the Catawba Riverkeepers, the North Carolina Coastal Federation, and many others, producers across Charlotte should collaborate and help to finance these organizations in relation to waste collection and recycling. At this moment Charlotte and North Carolina as a whole has not implemented any EPR policies, but in order to reduce the risks of plastic pollution it is vital to mitigate plastic production at the source.

2. Taxes/Fees on Textile Companies:

As mentioned above in the description of microplastics as a source of pollution, microfibers are ubiquitous and make up 35% of the microplastic pollution in the world's ocean. Additionally, as only 60% of these microscopic fibers, which are approximately less than 10 micrometers, can be filtered out through wastewater treatment plants, a significant amount of these fibers are released into rivers, streams, and lakes eventually flowing into our ocean. The textile industries situated in North Carolina pose a major threat to the health of our environment, not only in regards to the levels of CO_2 emitted during the production process, but the use of synthetic materials such as nylon, polyester and rayon, in the production of textiles has vast implications on the microplastics matter. Trelleborg Engineered Coated Fabrics and Unifi, both located in North Carolina, are the two largest textile industries in the United States. Trelleborg, by their own reports, lists polyester, rayon and nylon as substantial materials which they incorporate into their products. However, Unifi states that their products are made from 100% recycled material and are intent on lowering their plastic byproducts and waste. We should incentivize the production of consumer and industrial goods, such as textiles, which use and produce non-synthetic or recycled material. There should be a cap on the amount of synthetic materials textile companies within and around Charlotte may use in their production, and they must start to transition to incorporating recycled and natural, biodegradable material in their products. If, as mentioned in Section 1, these producers help finance stewardship organizations to recycle and collect material, then there will be greater resources of recycled material for these companies to obtain. It is necessary that there be repercussions for the amount of synthetic material used in the pre-production and production process as well as how it is wasted in post-consumer use. This can take the form of government-initiated fees or taxes on textile companies for the amount of synthetic material used.

3. Banning Polystyrene:

Six states across the US have implemented local bans on polystyrene for the risks it poses towards the environment and human health. As mentioned in the description, polystyrene is persistent, lasting over 500 years in the environment, pervasive, and hazardous, especially if ingested by vulnerable populations like children and adolescents. Maine and California are two states which have led the ban on Styrofoam materials for containers, beverages, and packaging material, and have reaped the benefits of a Styrofoam free community. However, in North Carolina, specifically in Charlotte, which is the 15th largest city by population in the US, consumption and use of Styrofoam material in everyday living is ingrained in our society. This needs to change. Almost every fast-food restaurant, diner and take out options have some form of non-recyclable Styrofoam material within its contents. Antioxidants, UV stabilizers, lubricants, color pigments, nucleating agents, and flame retardants, are all harmful additives included in the production of Styrofoam. It is necessary to have an all-out ban of Styrofoam materials in restaurant facilities, packaging materials, beverage containers, and retail stores in Charlotte, to inspire other cities around North Carolina to act along similar lines. Hopefully, Charlotte's stance will encourage other cities to adopt more progressive environmental policies to lower the risk of endangering our ecosystems and population.

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4. Phase Out Single Use Bags:

This has been a controversial topic nationally, as states have had to make decisions on how they may phase out single use bags, which invade our environments and subsequently enter our ocean, and find alternatives that are less damaging. Charlotte has taken a step forward, with the initiative towards replacing plastic bags for yard waste with paper bags. However, paper bags use the same amount if not more fossil fuel expenditures than plastic bags. They are often not as durable and unsupported by the local population and additives included during production are just as harmful. Yet, there are solutions to this problem, and we can look at New York's policies towards banning plastic bags, as an example. Eight states so far have banned or phased out plastic bags, but North Carolina is not among this list. New York has banned the sale and dissemination of plastic bags in grocery and retail stores, in restaurants which collect their sales tax for "to-go" items, and for any carry home items that may have gone in a plastic bag previously. To supplement this ban, they have imposed a $0.10 fee on paper bags, and the New York City sanitation department supplies free reusable bags at their local events. Reusable and paper bags are accessible at most retail and grocery stores so that consumers have access to these options and are not left without means to carry their items. The exceptions to this ban include bags used to carry prescription drugs at pharmacies, laundry services and dry cleaners, packaging for raw meat, and newspaper wrapping. We believe Charlotte has the economic means and support from the local community to advance these policies and incorporate phasing out single-use plastic bags in our community. As New York has done, Charlotte should phase out the use of plastic bags for retail, grocery, take-out items from restaurants, and to-go bags, as well as adding fees on paper bag alternatives in these stores. To take this a step further, the proceeds from the fees on paper bags should be administered to local environmental organizations who focus their initiatives on reducing plastic pollution, preserving our natural ecosystems, and implementing recycling initiatives and collection services. We also believe that at local events such as river, stream and street cleanups, like the ones hosted by the Keep Charlotte Beautiful Movement and the City of Charlotte Stormwater Services department, should provide reusable bags to all those who come out and support the cleanups, as a way to foster both collection and environmentally conscious consumer decisions. This phase out transition should be completed by 2024. There should also be access to paper and reusable bags at retail and grocery stores, and the fee should amount to at least $0.10.

5. Circular Economy:

In a city-wide released document, in 2018, Charlotte made a statement regarding transitioning to a circular economy. In this document, the reasons behind the benefits of a circular economy versus a linear, were outlined, highlighting the idea of a zero-waste producing community in which all items are repurposed, reused, and included into the market without losing its value. Transitioning to a circular economy also promotes job growth in the recycling and reusing processes, focuses on preserving biodiversity and promotes equity within a community. Charlotte has clearly taken actions to forward this position, and has cemented their desire towards reducing environmental degradation, however, there are still areas for improvement and growth within this process. Transitioning our economy from linear to circular is not a new initiative, but for this to be effective, as it has been in the European Union, more effort must be put towards proactively reducing the harm and consumption of plastic material. For example, we should start thinking about expanding and advancing our recycling facilities, or advancing our waste collection systems and preventing plastics from entering our aquatic ecosystems. In the Netherlands, scientists and engineers innovated a bubble barricade which prevents plastic materials from entering aquatic ecosystems and can then be easily accessed for waste collection. It is technology like this which demonstrates the possibilities of a circular system. As with the Innovation Barn in Charlotte, we should be incentivizing and raising more community awareness of sustainable innovations, everyday practices, and how we can support local initiatives who foster the reduction of plastic waste and protection of our environment. This can be done through educational programs within schools, specifically lower levels such as elementary, middle and high school education, and should be brought up during council forums to discuss ways in which we can further our sustainability goals and increase our knowledge of the harms of plastics pollution.

6. Funding Research:

California is a leading state in confronting the microplastics crisis. In their Senate Bill 1422: "California Safe Drinking Water Act: microplastics," they proposed a series of investigations on drinking water quality in relations to the presence of microplastic pollution and required under the federal ordinance to regulate the contaminants in public and private water systems. This bill will implement the Safe Drinking Water Act more effectively, and by 2020 will have a concrete definition of microplastics. Although this act is ambitious, and may not fully come to fruition, it demonstrates California's seriousness on the issue of microplastics and will take an active role in reducing its implications. It is necessary that Charlotte acts in a similar manner. Speaking with several NGOs, including the Charlotte Catawba Riverkeeper, CMSWS, the Keep Charlotte Beautiful Movement, and a professor from UNC-Chapel Hill, it is clear that the trends and understanding of microplastics in North Carolina is not being researched thoroughly. With a pervasive issue such as this, it is necessary to have a firm commitment towards understanding and identifying the sources and implications of this issue, as we cannot take proactive steps towards reducing the harm of microplastics if we do not share a consensus that there is a significant problem. It is necessary to fund research and have outreach programs that target all citizens around Charlotte to inform them of the current information and understanding of microplastics around the Charlotte area. This can be done multiple ways. Either by local NGO and NFP organizations who help fundraise for research activities by universities around us, or grants given from state funds to university scholars and local organizations with the intent on researching the prevalence and effects of microplastic pollution in the North Carolina region. We believe we should be taking an active stance towards understanding and identi fying this problem, especially in our drinking water and food sources, which have a direct impact on our health, instead of neglecting its significance. Researching microplastic pollution is a complex process, especially in regard to understanding how humans are influenced, as there are many other factors that contribute to health risks. This is why it is necessary to have increased funding in universities and local organizations around North Carolina and Charlotte to finance advanced technology, a greater labor force, and gain credibility and support of other states and countries who are also researching microplastic pollution.

7. Cap and Trade:

Using the Cap-and-Trade model for carbon emissions as a guide, we believe implementing Cap and Trade market and government policies for plastic pollution can serve the same purpose and help with our goal towards zero waste. Acting as both an environmental and economic policy, cap and trade incentivizes companies and producers to stay below the carbon emission threshold when they are manufacturing, selling or transporting materials. As the government gives companies allowances for the specific amount of carbon emissions they can release on an annual basis. The allowances are through auctions or given freely depending on whether the company has stayed under their carbon emissions limit. The companies are then able to trade their allowances with other companies on their own terms for those who may have gone over their allowances and need some assistance. This works well under a free market system. We believe the same principle can be used with plastics production and post-consumer waste. There must be a maximum number of plastics that companies cannot go over for pre- production, the process of producing, and post-consumer waste, each set on different terms. For post-consumer waste, the policy should be set so that if their products are not recycled then they must use more of their allowances on the basis that this is entering our environment and causing harm. The limit should become stricter every year with the advancement of having a zero-waste community. The limits may be set differently depending on the type of company or manufacturing facility. For instance, the limits on textile companies for production of materials may be set lower than a plastic packaging company. We believe this can and should fit into the economic system of Charlotte, as this promotes free trade and environmental welfare.

Appendix E: Policy recommendations for the city of Charlotte regarding strategies to mitigate microplastics.

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