Impact of Microplastics on Ecosystems and Humans

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Introduction and Motivation to Microplastics

Microplastics are defined as small pieces of plastics that are 5 millimeters in length or smaller (National Oceanic and Atmospheric Administration (n.d.)). Microplastics are the result of many different plastic products. Some sources include plastic debris breaking off larger plastic particles, manufacturer pellets for production and microbeads. Due to their small size, microplastics make their way into the environment as well as life. Microplastics are a concern for environmental and human health because the foreign particles may have adverse effects. It is imperative to study microplastics because such a wide variety of products today are created using plastics. The high rates of pollution of the plastic product also means that large amounts of microplastics could already be harming the environment.

Microplastics are a relatively novel issue that environmental scientists have been researching. Plastics were invented in 1907 by chemist Leo Baekeland as he was the first man to successfully synthesize polymers in chains. However, plastics only became widespread after the post World World Two boom in industry in America and other western countries. Plastics became used for a wide range of products because of their desirable properties. Some of the characteristics are that they tend to be good insulators, extremely durable yet low density, and chemical resistant. Plastics are found everywhere in the modern world. From medical equipment, to single use products, and packaging, plastic’s properties means that it is used in favor of most other materials. One issue is that the potential harm for plastics was never truly assessed. The immediate positive of plastic products outweighed any sort of notion that they could be harmful to the environment or to humans. Today, scientists are realizing the impacts of plastics, especially microplastics, are having on the environment. The fact that plastics are so widely used yet the consequences could be large. Studying microplastics is imperative for the continuation of human society who so heavily relies on plastics.

Background, Findings, and Discussion:

Distribution and Accumulation in Aquatic Environments

Understanding how microplastics move throughout the ecosystem is imperative to understanding their implications on the environment. Microplastics make their way around the environment through various phases of the water cycle. Plastics are made from human industry and are often disposed of after limited uses. Considering the linear economy of the western world, plastics are mostly discarded in trash and often end up in sewage.

Sewage is one of the leading causes for microplastics to spread to the coasts and oceans (Browne et al.). Debris can also come from rivers, runoff, and tides. Microplastics come by fragmenting off of larger objects. Because of the nature of plastics, when they break off, they are the same material, just not part of the long chain of polymers. This means they still maintain all of the chemical properties. Microplastics also have been estimated to come from fishing equipment and lost cargo (Law, K. L., & Thompson). Due to the small nature of microplastics, they are difficult to clean up. The use of trash nets is ineffective against microplastics. Researchers from Browne et al. found trash nets and various meshes were not able to successfully defend against microplastics because they are too small, going below 5mm. Other wastewater treatment methods like vortex separation systems are also not very effective at removing microplastics. Some of the smallest microplastics that have been found are as small as 20 micrometers (Law, K. L., & Thompson). The poor performance of catching microplastics means they distribute themselves further through the water cycle. As microplastics are transported into the ocean through rivers and wastewater, they accumulate on the coasts. This is a concerning finding because coasts are one of the most biodiverse habits for life in all aquatic environments. Microplastics can also be transported around through ocean currents. Microplastic counts have been found universally in oceans with averages ranging from 2-30 microplastics per .25 liter of sediment (Law, K. L., & Thompson). Microplastics have even been found in the waters of the Arctic. Microplastics have been found to be extremely pervasive and ubiquitous in aquatic environments. Analyzing the various stages of the water cycle will help increase the understanding of the movement of microplastics throughout the environment.

Pathways of Microplastics into the Food Chain

The permeation of microplastics into the food chain allows for the potential negative health effects to be felt in humans and in other species in the environment. Understanding the mechanisms in which microplastics are distributed through the food chain gives a deeper understanding in the fight against microplastic harm. Microplastic consumption can be found at all trophic levels of the food web (Smith et al.,2018). Due to their small size, microplastics were found in species of planktonic organisms and larvae (Toussaint et al, 2019). These species are at the bottom of the food chain, meaning that all trophic levels above them have the capacity to consume microplastics by feeding on them. Two major factors play a part in microplastics moving from the bottom to the top of the food chain. Bioaccumulation and biomagnification increase the amount of microplastics found in species higher up the food chain. Bioaccumulation is the process in which contaminants build up in an individual overtime. For example, if a fish lives longer, it will gradually increase the amount of microplastics in its body over time. Humans tend to feed on the higher trophic levels of species in aquatic life which usually accumulate more microplastics since they live longer compacted to the producers like plankton. The other major effect contributing to microplastics moving in the food chain is biomagnification. Biomagnification is defined as the effect as concentrations of toxins or pollutants increase at higher levels of the food chain (Smith et al., 2018). For example, fish in the oceans feed on many plankton. The plankton themselves contain little microplastics themselves but since the fish need to consume many of the plankton, the concentration in the fish increases. This effect moves all the way up the food chain and affects humans. Understanding how microplastics accumulate in the food chain and affect species at all trophic levels, all the way to humans, is a key feature in helping reverse dome of the negative effects.

Microplastics can also enter the food chain through various other methods. One proposed method of microplastics entering the food chain is through the air. Microplastics used in textiles are able to become airborne and are found both inside and outside. The inhalation of the plastics could allow for the accumulation of plastics in the lungs and potential absorption into the body. It was found that 87% of human lungs studied contained some sort of plastic fibers inside, causing concern with the increased attention on microplastics (Toussaint et al. 2019). Another major source for microplastics coming into the food chain is through drinking water. Municipal drinking water comes mostly from the treatment of ground and surface water and some coming from wastewater. A study aimed to determine the amount of microplastics in groundwater in a small region in Germany and found a low concentration of .7 pieces of microplastic of per m^3 (Toussaint et al 2019). This study would seem to disprove that sources for drinking water would be a major source of microplastics in the food chain. However, this is only one study of a small area and only considering groundwater and not surface water. Considering the large amounts of microplastic found in coastal areas indicates that microplastic concentrations would be much higher, especially in more developed places. Considering the high amounts of plastic pollution in surface waters, microplastics should be expected to be higher in drinking water. It is important to note that many water treatment methods have been shown to be ineffective at removing microplastics from water. Microplastics make their way into the food chain, especially into humans, not only through sources in food but potentially through water and air as well.

Human Health Implications of Microplastic Ingestion

The pervasive nature of microplastics in the environment and the food chain ultimately means that humans will deal with the consequences of these foreign particles in their systems. A study conducted by Cox et al. (2019) proposes that the average person could consume from anywhere to 74,000 to 121,000 particles of microplastics per year. The numbers estimated are concerning to say the least. Even though the particles could be very small, there is no known mechanism in which they are readily removed from the body. Meaning that the accumulation of microplastic over time could be detrimental to one's health. The study also further estimated that frequent use of disposable plastic water bottles could increase the amount of microplastic particles by up to 90,000 (Cox et. al 2019). The frequent use of plastic products increases the likelihood of microplastic caused health issues. The health risks of ingesting microplastics are varied. One mechanism in which it could harm humans by transporting harmful chemicals. Microplastics could be carriers into the bodies for chemicals like HOCs, including PCBs, DDT's and PAH (Wright & Kelly, 2017). All of these chemicals are toxic to humans. Another mechanism for which microplastics could be harmful is increasing stress by causing an immune response in the body. The immune system can detect the microplastic particles and try to eliminate them (Wright & Kelly, 2017). This can cause increased inflammation and stress on the body. Adding extra stress and inflammation are detrimental to human health, leading to a wide variety of illnesses and conditions. Microplastics accumulation in tissues could lead to further health complications down the line. One last proposed mechanism for harmful effects to humans is to the digestive system. Microplastics have been observed to disrupt the microbiome (Cox et al. 2019). The delicate balance in the microbiome is crucial for human digestive and overall health. A final health consequence was revealed by MacMahon, K & Howard in regards to male reproductive health. The study revealed that the presence of microplastics reduced male sperm count by around 10%. This number is concerning because the presence of microplastics could affect the reproductive health of the population. This is already on top of the fact that lots of men already deal with illnesses and stresses that reduce their sperm count in the first place. The declining sperm count in men is just one of the many potential negative health effects on humans from the accumulation of microplastics.

Ecological Impact of Microplastics on Marine Life

As microplastics enter the environment, ecological impacts will occur. The small nature of these particles means that they will evade filtration and removal and make their way into various species. The strong presence of microplastics in aquatic environments has negative impacts on fish populations. One effect is the blockage of the digestive tracts. Plastic taking up spaces in the bodies of fish leads to a reduction in the amount of nutrients absorbed for the fish (Barboza et al., 2018). The accumulation of microplastics also allows for increased concentrations of toxins within the body. Another major area of interest of the harm of microplastic in aquatic life is the neurological effects on fish. Barboza et al

(2018) reveals that the microplastics found in fish are neurotoxic. Neurotoxins can damage the brain and other features of an organism's nervous system. The manifestation of neurotoxins can be seen as behavior and neurological changes. The idea being that microplastics can be detrimental to the neurological processes in fish that help in survival and reproduction. Another major effect seen on aquatic organisms from microplastics is the inhibition of growth. In Galloway and Lewis (2016), the presence of microplastics in young marine thomas leads to stunted growth. The leading cause of this phenomenon is the reduced energy and nutrient consumption derived from microplastic accumulation in the body. Another major acute effect of microplastics on the aquatic environment is the harm to reproductive health. The accumulation of microplastics and hence more toxic substances can disrupt the endocrine systems of marine life (Galloway and Lewis, 2016). The effects of this issue are reduced fertility and the reduced viability for offspring. Many long term effects could arise from the many problems posed by microplastics. One such problem is threatening biodiversity. The reduced survivability and reproduction success of marine life could lower the diversity of species in marine ecosystems. Certain niches could be removed and a cascade of issues foul arise. One example of this in the food web is the removal of important predator prey dynamics. Many species could be without food sources or no natural predators leading to extremes in populations. The decreased survivability in a certain species population could lead it towards extinction. The less individuals who survive, the less genetic diversity will exist. A decrease in population size and the start of genetic drift moves the species closer to the extinction vortex. Marine life is threatened by microplastics because it makes it harder for them to survive and reproduce. The more microplastics damaged aquatic life, biodiversity is threatened.

Gaps in Microplastic Research

Identifying gaps in the research pertaining to microplastics will help decide future directions to help solve the issue. One of the main qualms surrounding microplastics is that it is a relatively new issue to be studied and discussed. Even though plastics have been around for decades, it is only recently that the negative consequences, especially long term, of microplastics are being realized. In the connection of marine and human health, the short term effects of microplastics are well understood, the long term effects of chronic exposure and generational effects are not very well researched. In Wright & Kelly (2017), it is noted that the effects of low dose exposure of microplastics over larger timescales are not studied very much. This means that researchers must contribute more of their efforts to the long term effects of microplastics to get a more holistic understanding of the dangers they pose. It also does not help that biases are present to study the acute effects of hazards because they take less time to research and tend to be favored. Another issue in research of microplastics is the variability in toxicology. Many plastics could contain differ polymers and or additives that could drastically change the toxicology effects of their microplastics (Andrady, A. L., 2017). While difficult, the topic needs to be addressed in future studies. One last issue is the lack of standardized research methods for microplastics. Toussaint et al 2019 points that there is no universal approach to study the ecological and health impacts of microplastics and that this can lead to inconsistencies and limits the ability to compare results across other studies. In the future of microplastics, various new ideas and methods must be used to fill gaps in the research. Standardization of research will help scientists compare results from different studies. Long term studies evaluating the chronic effects of microplastics will also reveal greater insights into the dangers of microplastics. More comprehensive and widespread research will be crucial in understanding microplastics and what actions to take next on them.

Conclusions and Future Directions

Microplastics are a complex challenge for scientists and the world due to their small size, widespread presence and potential negative effects to human and marine health. The spread of microplastics throughout the water cycle plays a large factor in their distribution. The entrance of microplastics are the bottom of the food chain for marine life through producers and also into humans plays a large role in determining the amount of microplastics found in organisms at every level in the food chain. Even though there are many gaps in the research on microplastics, they point scientists and researchers towards helping combat the issue of microplastics. Various proposed methods for dealing with microplastics could help protect the environment and humans. Advanced filtration systems that can remove the extreme small particles could protect water supplies and prevent microplastics from entering at the bottom of the food chain. The exploration and expansion of more biodegradable materials in lieu of plastic products could help reduce the amount of plastic waste in the environment that is causing lots of harm. The future of microplastics relies on the increased effort to study and mitigate their effects.

References

Barboza, L. G. A., Vieira, L. R., Guilhermino, L. (2018). Microplastics in wild fish from the North East Atlantic Ocean and their potential for causing neurotoxicity. *Environmental Health Perspectives, 126*(6), 064001. https://doi.org/10.1289/EHP.2151

This article studies the impact that microplastics are having on the neurological health of fish in the North East Atlantic Ocean. This can be used to study the food web and bioaccumulation.

Browne, M. A., Crump, P., Niven, S. J., Teuten, E., Tonkin, A., Galloway, T., & Thompson, R. C. (2011). Accumulation of microplastic on shorelines worldwide: Sources and sinks. *Environmental Science & Technology, 45*(21), 9175-9179. https://doi.org/10.1021/es201811s

The article shows how shorelines are the primary locations where microplastics end up. The article can be used to talk about the effects of pollution and the water cycle.

Cox, K. D., Covernton, G. A., Davies, H. L., Dower, J. F., Juanes, F., & Dudas, S. E. (2019). Human consumption of microplastics. *Environmental Science & Technology, 53*(12), 7068-7074. https://doi.org/10.1021/acs.est.9b01517

The article estimates how much microplastics a person may be consuming though food and water to estimate the potential health effects.

MacMahon, K & Howard, (2024). Microplastics and sperm quality: Is there a connection? *Environmental Health News.* Retrieved from https://www.ehn.org/microplastics-sperm-quality-2669440104.html

This article examines the role that microplastics are having in decreasing the reproductive health of males. It can be used to talk about the negative health consequences and further repercussions of microplastics.

Galloway, T. S., & Lewis, C. N. (2016). Marine microplastics spell big problems for future generations. *Proceedings of the National Academy of Sciences, 113*(9), 2331-2333. https://doi.org/10.1073/pnas.1600715113

The article focuses on the bioaccumulation of microplastics in marine life and how that effect can increase over time and threaten marine species in the future.

Law, K. L., & Thompson, R. C. (2014). Microplastics in the seas. *Science, 345*(6193), 144-145. https://doi.org/10.1126/science.1254065

This article is a general overview of microplastics in the marine ecosystem and can help convey some lower level information.

National Oceanic and Atmospheric Administration. (n.d.). What are microplastics? *NOAA National Ocean Service.* Retrieved from https://oceanservice.noaa.gov/facts/microplastics.html

The article also provides a lower level and definitions of water microplastics are in general and how they relate to aquatic ecosystems.

Smith, M., Love, D. C., Rochman, C. M., & Neff, R. A. (2018). Microplastics in seafood and the implications for human health. *Current Environmental Health Reports, 5*(3), 375-386. https://doi.org/10.1007/s40572-018-0206-z

The article gives the reader a better sense of what effects microplastics might have on seafoods. It provides estimates on toxic levels of microplastics.

Toussaint, B., Raffael, B., Angers-Loustau, A., Gilliland, D., Kestens, V., Petrillo, M., … & Elia, M. (2019). Review of micro- and nanoplastic contamination in the food chain, and implications for human health. *Environmental Health, 18*(1), 57. https://doi.org/10.1186/s12940-019-0506-9

The article can be used to discuss bioaccumulation and biomagnification and how it relates to threatening human health.

Wright, S. L., & Kelly, F. J. (2017). Plastic and human health: A micro issue? *Environmental Science & Technology, 51*(12), 6634-6647. https://doi.org/10.1021/acs.est.7b00423

The article talks about some of the risks made by microplastics, specifically cellular and immune response. It also points out gaps in the research about microplastics.

Andrady, A. L. (2017). The plastic in microplastics: A review of sources, composition, and toxicology. *Environmental Science & Technology, 51*(12), 6820-6835. https://doi.org/10.1021/acs.est.7b0101

This article examines the toxicology of microplastics and can be used to gain a deeper understanding of the potential hazards they provide for human health.