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RESEARCH ARTICLE

A Correlation Analysis between Global Plastic Production and Floating Macro-and Micro-Plastic Waste in the Ocean

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ABSTRACT: Since their explosive development in the early 1900's, the use of plastics has deeply permeated not only our everyday lives but have also become an irreplaceable material for industrial purposes from manufacturing to research and development. Despite its usefulness, non-degradable plastic has become one of the major modern environmental concerns, as research has progressed since the late 1900's. Today, more than half of the total plastics produced around the world are discarded into the ocean – the part of our planet most remote from human populations but most impacted by plastic toxicity. In this study, the data from 35 years of global plastic production (GPP), proportion of different disposal methods, and distribution of macro- (> 4.75 mm) and micro-plastic (< 4.75 mm) waste found in the ocean were collected. Correlation analysis between GPP and macro- and micro-plastic wastes collected from the ocean were found to have R2 values of 0.9963 and 0.9969, respectively. With the acknowledgement of the possible damage that plastic wastes can cause, efforts have been made since the 1980's to reduce the amount of plastic wastes being discarded into the environment. As a result, there has been a significant increase in the proportion of recycled and incinerated plastic wastes. However, the total amount of ocean plastic waste indicates that the effect of new methods of waste treatment has not yet taken place. Efforts in further increasing the rate of plastic recycling and development of alternative materials to replace plastic use are needed in order to significantly reduce ocean plastic wastes.

KEYWORDS: Environment; Marine Plastics; Micro-plastics; Plastics Recycling; Waste Management.

Introduction

The massive increase in global plastic production (GPP) has contributed to the problem of plastic pollution in the world's oceans. Even though many scientific investigations have been done to address this problem, it has not been solved yet. The issue is complex, with many contributing factors, which means finding a solution is challenging. The sources of marine plastics are diverse, including land-based sources (packaging, plastic bags, and production waste), the fishing industry (ropes, nets, and fishing gear), and others. The variety of sources means that managing the pollution from these plastics is difficult, subsequently creating an abundance of plastic waste in marine environments. Current studies yield that plastic waste accounts for 60-80 % of the total waste in the ocean.[1]

Marine plastic waste can damage the environment in multiple ways. The most notable damage is caused by macroplastics such as fishing nets and plastic bags choking and starving marine species through ingestion or entanglement. The more serious problem, and more difficult one to solve, is the abundance of microplastics. Microplastics can be categorized as primary (direct release of particles from products such as cosmetics or household cleaning products) or secondary (small fragments of particles derived from larger plastic products).[2] These seemingly insignificant particles may take up to thousands of years to be completely degraded in ocean environment.[3] The hydrophobic nature of these microplastic particles allow them to bind toxic chemicals, which are then ingested by variety of different marine organisms.[4,5] Once released into the open water, these particles can freely travel throughout the ocean, which makes it nearly impossible to accurately track and control the flow of marine plastic waste. Some studies have even shown that plastic waste littered from China can travel all the way across the Pacific Ocean.[6]

This study focuses on the amount of GPP and plastic litter, including macro and microplastics found in the ocean. The correlation analysis was performed to find the best fit model based on the collected data. This study also focuses on the change of disposal methods and their impact on plastic waste found in the ocean from 1980-2015. Overall, this analysis provides the best fit model for predicting future marine plastic waste and the possible responses to solve the marine plastic waste problem.

Methods

Micro- and macroplastic data:

Micro- and macroplastic waste distribution data was acquired from the plastic pollution study by Erikson *et al*.[6] Estimates of total particle number and weight of plastic waste were derived from their 24 expeditions across the world's oceans at 1,571 different locations. Despite their hefty significance in the field of environmental science, the upper and lower boundaries of the terms micro- and macroplastic are poorly defined. In this case, due to the size of the mesh used, the upper boundary for microplastic was set at 4.75 mm. The study also includes an intermediate size class, mesoplastic, which accounts for all particles of size between 4.76 mm and 200 mm. For convenience, mesoplastic was combined with

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macroplastic in our study to compare just two different classes: micro- and macroplastics.

Global plastic production and waste management:

GPP data along with the statistics of their disposal methods were acquired from the statistical study by Geyer *et al.*[7] The original data was collected from global annual pure polymer (resin) production data published by the Plastics Europe Market Research Group and global annual fiber production data by The Fiber Year and Tecnon OrbiChem. The original data for different disposal methods of plastic waste was collected separately for four different regions: The United States (U.S. Environmental Protection Agency), Europe (collective report by PlasticsEurope), China (China Statistical Yearbook), and rest of the world (World Bank data).

Data analysis:

GPP and plastic waste collected from the ocean was analyzed by the power and exponential model regression using Microsoft Excel 365. The coefficient was analyzed as R squared, which is a statistical measure of how close the data are to the fitted regression model. The following equations were used to predict the GPP in year 2050. The GPP prediction equation is derived from the exponential regression, where x is the time (year):

$$y_{GPP} = 8\times10^{-42}\times e^{(0.0499x)} \quad (1)$$

Micro- and macro-plastic waste in ocean prediction equation is derived from the power regression model, where x is GPP in specific year. The following equation predicts the floating plastic in ocean:

$$y_{micro\text{-}plastic} = 20.731x_{GPP}^{1.6746} \quad (2)$$

$$y_{micro\text{-}plastic} = 486.49x_{GPP}^{12686} \quad (3)$$

After micro- and macro-plastic waste in ocean was calculated using the equations of (2) and (3), total plastic waste found in ocean can be predicted using the following equation:

Total plastic waste found in ocean= microplastic+macroplastic (4)

Results and Discussion

More than 8 million tons of plastic waste flows into the ocean every year. Most of the marine debris from surface waters consists of macroplastics and microplastics. According to their weight distribution (Figure 1, left), it may seem like the macroplastic wastes pose a greater threat to the environment. However, the microplastic particle count (Figure 1, right) by far outweighs that of the macroplastic count. These tiny microplastics can be consumed by many marine organisms such as corals, planktons, and marine invertebrates. Therefore, they are more easily transferred along the food chain to larger organisms such as fish and whales. Marine species often ingest these plastics, and they can cause severe injuries or death. For example, sharks, tuna, and shellfish are known to ingest plastic more frequently than other types of fish. The threat of

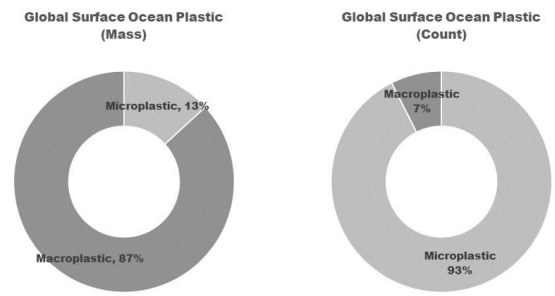

Figure 1: Global surface ocean plastic waste distribution by mass and count.

such as corals, planktons, and marine invertebrates. Therefore, they are more easily transferred along the food chain to larger organisms such as fish and whales. Marine species often ingest these plastics, and they can cause severe injuries or death. For example, sharks, tuna, and shellfish are known to ingest plastic more frequently than other types of fish. The threat of microplastic ingestion can pose detrimental health issues for humans as well, as these plastic particles can accumulate in the tissues of marine species that we consume. such as corals, planktons, and marine invertebrates. Therefore, they are more easily transferred along the food chain to larger organisms such as fish and whales. Marine species often ingest these plastics, and they can cause severe injuries or death. For example, sharks, tuna, and shellfish are known to ingest plastic more frequently than other types of fish. The threat of microplastic ingestion can pose detrimental health issues for humans as well, as these plastic particles can accumulate in the tissues of marine species that we consume.

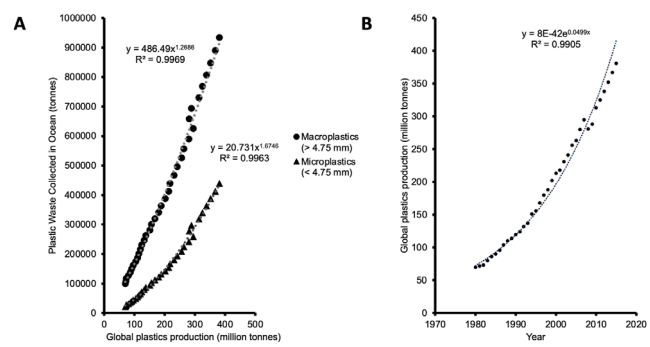

Figure 2: Regression fitting model with global plastic production (GPP) and plastic waste collected in ocean from 1980-2015 (A) Power law curve fitting to the GPP with micro- and macro-plastic waste (B) Exponential curve fitting to the GPP with year.

Combining the GPP from 1980-2015, total plastic production was measured each year. GPP massively increased from 1980 to 2015. This collected data was further fit into the power-law curve model. Correlation between micro- and macro-plastic waste collected and GPP closely follows a power law curve fit with R^2 values of 0.9963 and 0.9969, respectively (Figure 2A). According to the current trend in plastic production and use, GPP was predicted to reach over 2,134 million tons in year 2050 (derived from the curve model in figure 2B). In addition, this model predicts over 15.6 million tons of total plastic particles, which is equivalent to particle amounts of 7.5 million tons of micro-plastic and 8.1

million tons of macro-plastic particles, flow into the ocean each year after 2050. (derived from the curve model in Figure 2A).

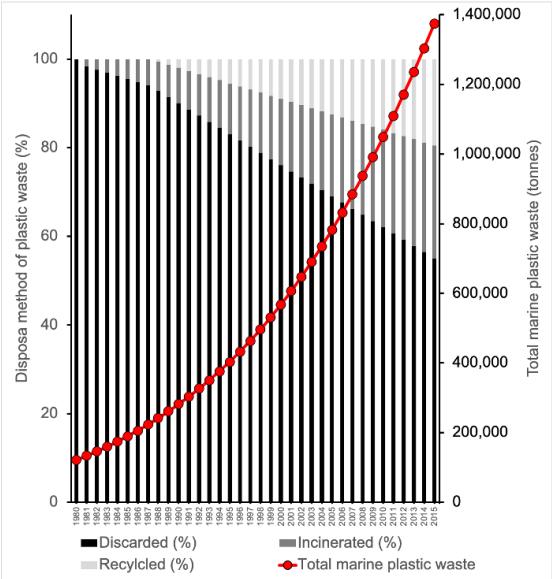

Figure 3: Change in plastic waste disposal method and total marine plastic waste from 1980 to 2015.

Unless searching for an alternative material that can completely replace plastic usage, current, practical solutions for mitigating the environmental impact of plastic waste include recycling and environmental-friendly disposal methods. The plastic waste management data from 1980 to 2015 was divided into three sections: discarded, incinerated, and recycled. Even though the percentage of incinerated and recycled plastic waste increased each year, both micro and macro plastic waste found in the ocean (total marine plastic waste) increased (Figure 3). This data suggests that either the current method of disposal management is not enough to reduce the amount of marine plastic pollution or that there is a delayed effect of disposal management on the marine plastic pollution and that we must wait to see its full effect.

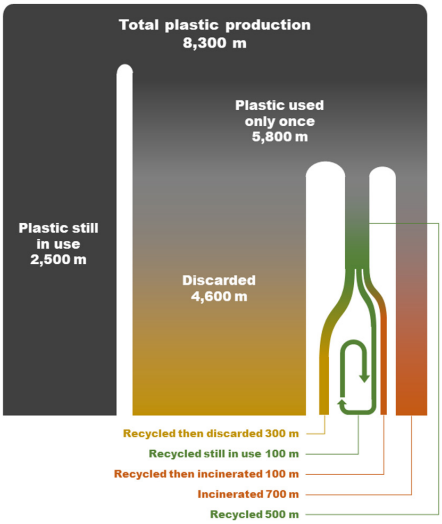

Figure 4: Total plastic production and their disposal method distribution by weight.

Discussion

There are two methods of plastic waste treatment that are relatively eco-friendly: recycling and incineration. By definition, incineration is a method which burns plastics or other wastes at a very high temperature. The advantage of this method is that it completely gets rid of waste material in a short period of time which would otherwise take thousands of years to degrade in natural environment. Due to the harmful chemicals released during the treatment process, incineration must be carried out in a tightly controlled environment. Since the late 1980s, rates of plastic recycling and incineration have been constantly increased. However, its impact on slowing the spread of ocean plastic waste has yet to be observed. To further analyze the effect of recycling plastic waste, the disposal method distribution by weight was analyzed. Despite the effort, over 50% of the plastics produced are still being discarded into the environment after they are used, and only about 1% of the total plastics produced are recycled and still being used. (Figure 4))

Conclusion

In this paper, the marine microplastic and macroplastic wastes found in the ocean from 1980 to 2015 were analyzed. With the GPP and marine plastic waste data, the correlation model was established by power-law curve fitting. If the current growth rate of plastic production persists, approximately 2,134 million tons of plastic will be produced by the year 2050. This means that more than 15.6 million tons of total plastic waste may flow into the global ocean each year after 2050.

The previous studies also demonstrated that the increase in plastic production may increase marine plastic pollution. For example, a study in 2018 indicates that a plastic production rate of 1,900 million tons would be produced in 2050, which was similar to our prediction.[8] This paper also estimates that 2 million tons of plastic pollution is delivered to the ocean by rivers each year. The statistics have forecasted that there will be more plastic waste found in the ocean than fish by mass.[9] Additionally, it shows that by 2050, there will be 12 billion tons of plastic waste in landfills or in the ocean.

One of the possible explanations for increased amounts of marine plastic waste is inefficient plastic waste management. In highly populated coastal regions, waste can flow directly into the open water without any intervention, creating a critical need for more efficient waste management systems. It is shown that a large portion of mismanaged plastic wastes are generated from these densely-populated coastal regions, like those of China, Indonesia and Philippines.[10] Previous studies indicate that improper solid waste management (SWM) infrastructure and services are still limited in the countries on the Indonesian coast.[11] One of the causes for this limited disposal management is the lack of community involvement. Laziness, lack of knowledge in solid waste recycling, and lack of time were identified as the main reasons. Therefore, providing formal education programs with training novel solid waste recycling technologies may increase the efficiency of SWM.

This paper has acknowledged some limitations. One of them is that this correlation model was not further analyzed by geographical location. Many studies indicate that the heaviest

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plastic polluters are in Asia: China, Indonesia, Philippines, Vietnam, and Sri Lanka. The statistical analysis from previous studies suggests that these countries contribute to more than 56 % of global plastic waste generated.[11] Therefore, further study is needed to analyze the plastic waste based on both geographical location and country.

In summary, it is clear that marine plastic wastes are delivered from the rivers and increasing drastically each year. The current waste management strategy is still very limited and fails to efficiently prevent marine plastic pollution, according to the statistics. Therefore, every country has to determine a manageable strategy for improving the efficiency of plastic waste management to save the world from marine plastic pollution.

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References

1. Andrady, A. L., Microplastics in the marine environment. *Marine pollution bulletin* 2011, 62 (8), 1596-1605.
2. Thompson, R. C., Microplastics in the Marine Environment: Sources, Consequences and Solutions. *In Marine Anthropogenic Litter*, Bergmann, M.; Gutow, L.; Klages, M., Eds. Springer International Publishing: Cham, 2015; pp 185-200.
3. Barnes, D. K. A.; Galgani, F.; Thompson, R. C.; Barlaz, M., Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society B: Biological Sciences* 2009, 364 (1526), 1985-1998.
4. Teuten, E. L.; Rowland, S. J.; Galloway, T. S.; Thompson, R. C., Potential for Plastics to Transport Hydrophobic Contaminants. *Environmental Science & Technology* 2007, 41 (22), 7759-7764.
5. Mato, Y.; Isobe, T.; Takada, H.; Kanehiro, H.; Ohtake, C.; Kaminuma, T., Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment. *Environmental Science & Technology* 2001, 35 (2), 318-324..
6. Eriksen, M.; Lebreton, L. C. M.; Carson, H. S.; Thiel, M.; Moore, C. J.; Borerro, J. C.; Galgani, F.; Ryan, P. G.; Reisser, J., Plastic Pollution in the World's Oceans: More than 5 Trillion Plastic Pieces Weighing over 250,000 Tons Afloat at Sea. *PLOS ONE* 2014, 9 (12), e111913.
7. Geyer, R.; Jambeck, J. R.; Law, K. L., Production, use, and fate of all plastics ever made. *Science Advances* 2017, 3 (7), e1700782..
8. Rhodes, C. J., Plastic Pollution and Potential Solutions. *Science Progress* 2018, 101 (3), 207-260.
9. Foundation, E. M. The new plastics economy: Rethinking the future of plastics & Catalysing action 2017. http://www.ellenmacarthurfoundation.org/publications..
10. Jambeck, J. R.; Geyer, R.; Wilcox, C.; Siegler, T. R.; Perryman, M.; Andrady, A.; Narayan, R.; Law, K. L., Plastic waste inputs from land into the ocean. *Science* 2015, 347 (6223), 768..
11. Lestari, P.; Trihadiningrum, Y., The impact of improper solid waste management to plastic pollution in Indonesian coast and marine environment. *Marine pollution bulletin* 2019, 149, 110505.

Author

Hyunwoo Zong is a Korean student from Korean Minjok Leadership Academy (KMLA) who takes a great interest in applied mathematics and engineering. When Hyunwoo was designing an ocean plastic collecting robot for another competition, he became interested in marine waste problems and decided to conduct this research.