The Effect of Water Filters on the Removal of Microplastics

Gabriella Diaz

Introduction

Over the past decade, microplastics have become a major environmental and health concern. These plastics, less than 5 millimeters in length, have been linked to potential health risks in humans. Microplastics are found in places such as food, water, and even the air we breathe. On average, we consume 5 grams of microplastics a week[3].

Figure 1: Picture of microplastics on a human finger

Microplastics, first reported in 1970, are small fragments of plastic made from carbon and hydrogen atoms bound together in polymer chains. Other chemicals, such as phthalates, polybrominated diphenyl ethers (PBDEs), and tetrabromobisphenol A (TBBPA), are typically also present in microplastics, and many of these chemical additives leach out of the plastics after entering the environment[3]. Microplastics are commonly found in the breakdown of larger plastic pieces in resin pellets used for plastic manufacturing, or in the form of microbeads, which are small, manufactured plastic beads used in health and beauty products[1].

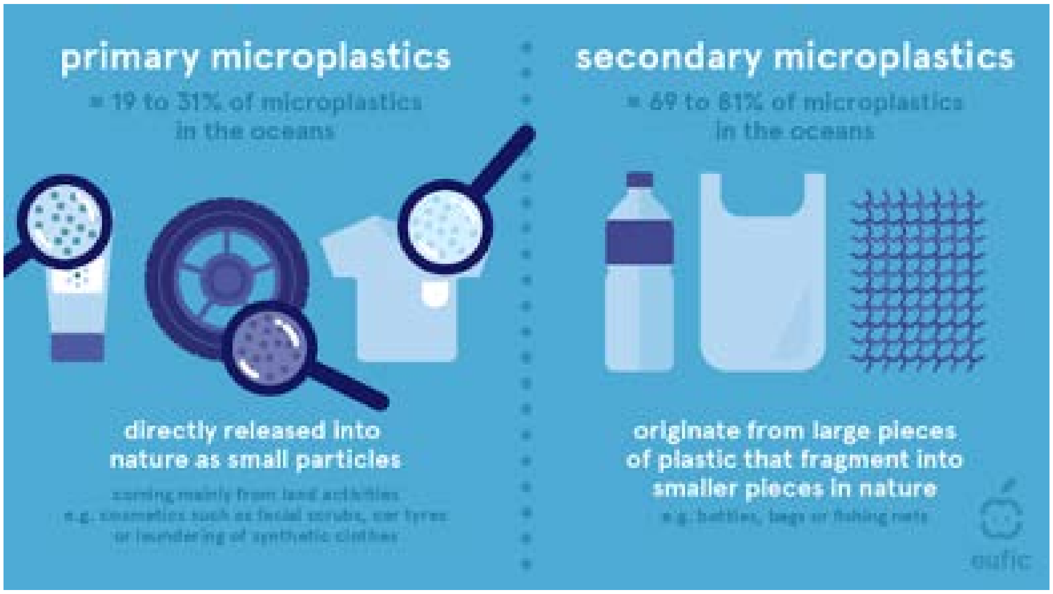

Figure 2: Examples and statistics of primary and secondary microplastics

Microplastics are divided into two categories: primary and secondary. Primary microplastics are plastics that are intentionally manufactured at a microscopic size and enter the environment directly. This happens through product use, such as personal care products being washed into wastewater systems from households, or abrasion during washing, like the release of plastic fibers from synthetic clothing. Examples include microbeads, plastic pellets (or nurdles), and synthetic fibers such as nylon.

Secondary microplastics, on the other hand, form when larger plastic items break down into smaller pieces. This process usually happens due to environmental factors such as UV radiation from sunlight, wave action, or wind abrasion[1].

Figure 3: Picture of detected microplastics in human lungs

In recent years, scientists have discovered traces of microplastics in the human lung, maternal and fetal placental tissues, human breast milk, and even human blood. The effect of microplastics on human health is still being studied, but known impacts include: oxidative stress, DNA damage, organ dysfunction, metabolic disorders, immune system disruption, neurotoxicity, reproductive and developmental toxicity, and relations to various chronic diseases[2].

		
Figure 4: Reverse Osmosis Filter	**Figure 5: Activated Carbon Filter**	**Figure 6: Ceramic Filter**

The reason why it is so difficult to get rid of microplastics is because the bonds that form between the polymer molecules are strong chemical attachments called covalent bonds, which are very difficult to break. Additionally, because of their small size, microplastics are extremely difficult to clean up.

In recent years, scientists have developed filters that help reduce the consumption of microplastics through drinking water. Reverse osmosis (RO) filters remove sediment and chlorine with a pre-filter, then force water through a semipermeable membrane to eliminate dissolved solids. After passing through the RO membrane, the water goes through a post-filter to polish it before reaching the faucet[4].

Activated carbon filters contain granular activated carbon (GAC), which is effective at removing certain chemicals, especially organic compounds, from water. GAC filters can also eliminate substances that cause bad odors or tastes, such as chlorine or hydrogen sulfide[5].

Ceramic filters use microscopic pores on a ceramic surface to remove bacteria and sediment from drinking water[6].

Figure 7: A photograph of plastic pollution in Africa

As previously mentioned, microplastics are difficult due to their small size and slow rate of decomposition. Because of this, once organisms, such as humans, come into contact with microplastics, it becomes impossible to remove them from the body. Individuals at highest risk are often in low-income or third-world countries. For example, low-income countries face a higher lifetime risk of cancers linked to indoor microplastic exposure, with 4.7 people per million affected[7]. Research like this highlights the importance of providing affordable water filters to these communities, which can help reduce microplastic exposure and contribute to aid human longevity.

At Princeton University, researchers have developed an innovative way to turn a common breakfast food into a low-cost material capable of removing salt and microplastics from seawater. Using egg whites, they created an aerogel: a lightweight, porous material with applications in water filtration, energy storage, and thermal and sound insulation. Egg whites, which are mostly protein, are freeze-dried and then heated to 900 degrees Celsius in an oxygen-free environment, forming interconnected strands of carbon fibers and sheets of graphene. Arnold and his co-authors demonstrated that this material can remove salt from seawater with 98% efficiency and microplastics with 99% efficiency[8].

Additionally, a team of researchers at New Mexico Tech is exploring the use of acoustic sound waves to separate microplastics from water. By using resonating chambers, acoustic waves move particles to specific regions or nodes. This process, called "acoustic focusing," allows plastics suspended in liquid to be sorted by size. Their prototype device, built with steel tubes and pulsing ultrasound waves, filtered one liter of water in 90 minutes and removed 80% of microplastics. The size of the tubes is important, and scaling up with larger or multiple tubes could enable practical, large-scale applications[9].

These experiments demonstrate how simple household items and materials can be transformed into powerful tools for water purification. Removing more than three-quarters of microplastics from contaminated water with accessible technology means that people without access to expensive inventions can still drink clean water. Just like the research mentioned above, these innovations aim to ensure everyone, regardless of income, has access to safe, clean water.

In this experiment, the effect of water filters on the removal of microplastics will be tested. The following independent variables will be tested as the types of water filters used: a strainer and coffee filter paper. The dependent variable is the quantity of microplastics detected in the water after filtration. The constants in this experiment include: the location (the chemistry lab), and the use of room-temperature bottled water, which will be mixed with microplastics for both the control and experimental groups.

The control group will consist of 50 mL of bottled water stored in a small bottle with a mass of 10.104 grams (excluding the cap). The experimental groups will each have 50 mL of bottled water stored in identical bottles (also 10.104 grams, excluding caps). Approximately 1.5 grams of glitter as the microplastics, which will be added and mixed into the water in all bottles.

The hypothesis being tested is: If various water filters are used, then the quantity of microplastics identified in the water will decrease because the filters will remove the microplastics.

Safety
A list of materials will be provided to follow safety concerns to ensure the well-being of everyone in the classroom. These personal protective equipment include: gloves, safety goggles, and a face mask.

Materials
- Coffee paper
- Strainer
- Cloth
- Bottled water (room temperature)
- 6 beakers
- 3 Containers
- 3 Plastic Cups
- Glitter
- Electric balance
- Gloves
- Safety Goggles
- Face Mask
- Weighing Boats

Procedure

1. Pre-measure the mass of an empty container using the electric balance. Record the mass.
2. Pre-measure the mass of the coffee filter using the electric balance. Record the mass.
3. Pre-measure the mass of the strainer filter using the electric balance. Record the mass.
4. Pre-measure the mass of a beaker using the electric balance. Record the mass.
5. Pre-measure the mass of a weighing boat using the electric balance. Record the mass.
6. Pre-measure the mass of a plastic cup. Record the mass.
7. Measure 50 mL of water in the beaker using the electric balance. Record the mass of the water.
8. Place a weighing boat on the electric balance and set the balance to zero.
9. Pour approximately 1.5 grams of glitter onto the weighing boat. Record the mass.
10. Repeat step 9 two more times so you have three portions of glitter measured.
11. Pour 50 mL of water into each of three plastic cups.
12. Record the mass of each plastic cup filled with water.
13. Add each of the 1.5 grams of glitter to each of the three plastic cups.
14. Record the mass of each plastic cup filled with water and glitter.

15. Take the first plastic cup and pour its contents into an empty container.

16. Record the mass of the container with the glitter-water mixture and make observations.

17. Take the second plastic cup. Place the coffee filter paper over an empty container.

18. Slowly pour the water-glitter mixture from the cup through the coffee filter paper into the container below.

19. Record the mass of the container with the filtered water and your observations.

20. Record the mass of the coffee filter paper after filtration and any observations.

21. Take the third plastic cup. Place the strainer over another empty container.

22. Slowly pour the water-glitter mixture through the strainer into the container below.

23. Record the mass of the container with the filtered water and your observations.

24. Record the mass of the strainer after filtration and any observations.

25. Review your research notebook to analyze which filtration method most effectively removed the microplastics from the water.

Experimental Setup

		
Figure 8: 50 mL of water in a 100 mL graduated cylinder	**Figure 9: 3 weighing boats filled with around 1.5 grams of glitter**	**Figure 10: a plastic cup filled with a mixture of around 1.5 g of glitter and 50 mL of water**

Results

		
Figure 11: The coffee paper filter containing the glitter particles that were filtered out of the water	**Figure 12: The container containing the water that was filtered through the coffee paper filter**	**Figure 13: The aftermath of the container and filter after glitter water was poured through the strainer**

In Figure 11, the coffee paper filter contains the filtered out glitter particles collected after filtering the water. In Figure 12, it shows the water after filtration through the coffee paper, with less visible glitter compared to before. In Figure 13, the strainer contains some glitter particles, but the filtered water still has visible glitter pieces.

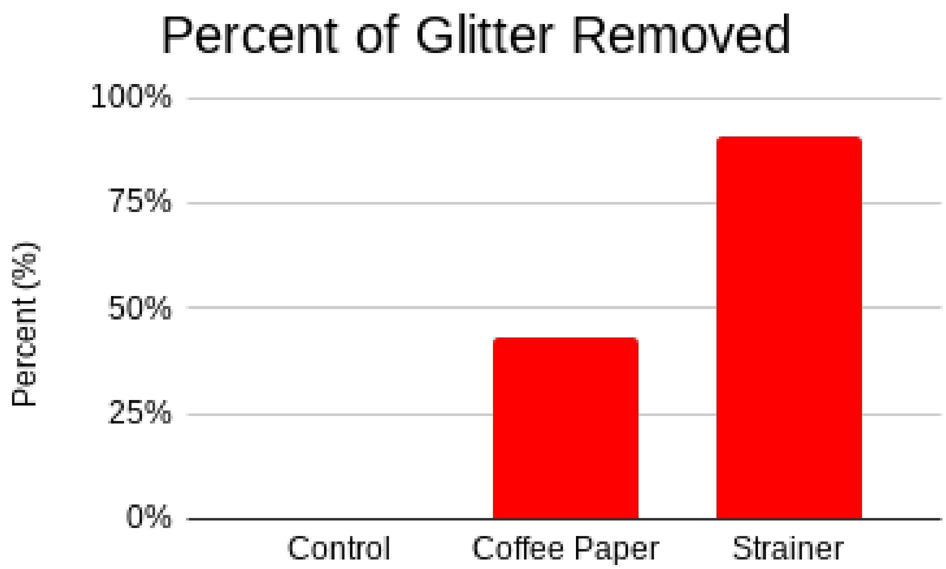

Figure 14: The percent of glitter removed by each of the filters in trial 1

According to Figure 14, the control group showed 0% glitter removal, while the coffee paper removed 43% and the strainer removed 91% of the glitter in trial 1.

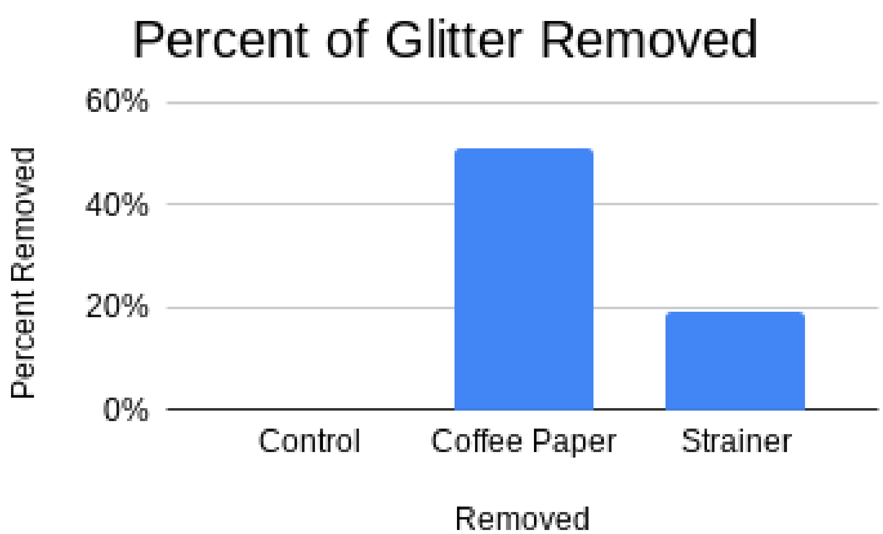

Figure 15: The percent of glitter removed by each of the filters in trial 2

In trial 2, shown in Figure 15, the control group again had 0% removal, the coffee paper removed 51%, and the strainer removed 19%.

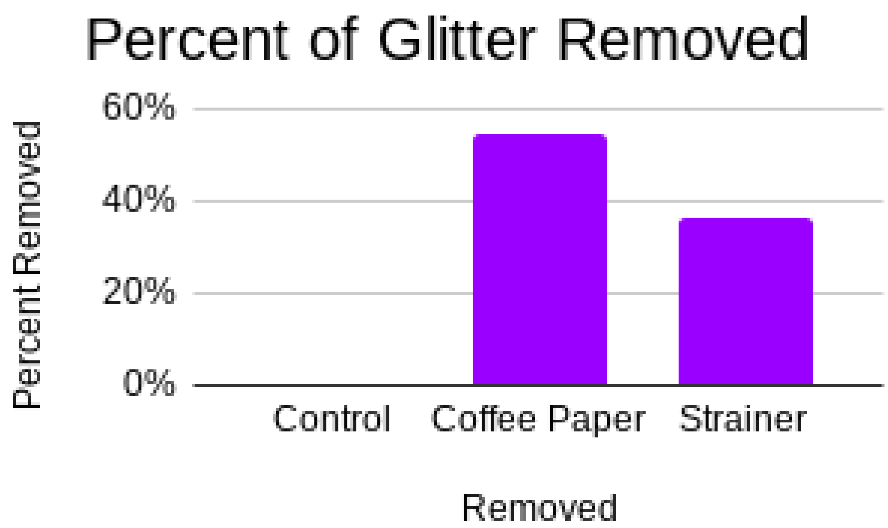

Figure 16: The percent of glitter removed by each of the filters in trial 3

In trial 3, illustrated in Figure 16, the control group remained at 0% removal, the coffee paper removed 54%, and the strainer removed 36% of the glitter.

Conclusion

In closing, the coffee paper filter was generally successful in removing glitter from the water, while the strainer's effectiveness varied across trials. Overall, coffee paper proved more consistently effective at filtering microplastics, supporting the hypothesis for one of the two filtration methods tested.

The high strainer removal in Figure 14 may be due to glitter producing static electricity, causing particles to clump together and get trapped more easily. This clumping likely affected the measurement and made the strainer appear more effective in that trial. In later trials, the pouring technique was adjusted to minimize this effect, resulting in more accurate results.

This experiment aligns with other research, such as the use of egg white aerogels and acoustic sound waves, showing that simple household materials can effectively remove microplastics. These accessible and inexpensive methods can help provide clean water to people worldwide, regardless of income.

In conclusion, inexpensive filtration methods like coffee paper and strainers can reduce microplastic consumption, making clean water accessible to more people.

Future Studies

For future experiments, microplastics extracted from face wash beads will be used instead of glitter. These beads more accurately represent real microplastics and will reduce issues caused by glitter's static properties. Glitter's metal coating and static charge caused particles to stick to container surfaces, altering results.

Microplastics vary widely in composition and size. Glitter is made of aluminum and plastic, microbeads in face washes are polyethylene terephthalate, and cosmetic beads are polyethylene. This diversity complicates efforts to detect and remove them.

Although we have not yet found a perfect method to eliminate microplastic consumption, innovations like reverse osmosis, activated carbon, and ceramic filters have improved removal rates significantly, approaching near-complete filtration.

As technology advances, ranging from simple filters like coffee paper to advanced materials and techniques, will continue to improve the removal of microplastics. With continued research and collaboration, a future with minimal to zero microplastic contamination in water is possible. Together, we can build a healthier and safer world.

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