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# Detection of Microplastics in Bottled Water

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**Abstract.** Mismanagement of plastic waste has caused plastic leaking into nature and entering our food chain as microplastics, which may have negative impacts on wildlife and our health. However, data on microplastics in bottled water are still limited, especially in Sarawak, Malaysia. This study aims at investigating the presence of microplastics in the bottled water that manufactured locally. So that the F&B manufacturers and other key stakeholders can take necessary actions to prevent or minimize microplastics pollution in our drinking water. A total of 40 bottled MW and DW samples from 4 local products in Sarawak and Malaysia was investigated. A filtration and observation processes using the membrane filters (0.45 µm pore size) and digital microscope (Nikon Eclipse LV150N) were developed to identify and quantify the presence of microplastics based on their types, shapes, and sizes as criteria. A library database was also developed to ensure the consistency of this identification process. A total of 2022 microplastics with an average of 50.6 particles per bottle (500-mL packing) was detected in the samples. Bead, fibre, fragment and film were detected in all the samples, but fibre (48%) and fragment (36%) made up the majority (84%) of microplastics in the samples. However, microplastics in the MW samples were found 13% higher than the DW samples. This was also true across the products investigated in this study except between X (MW) and Z (DW). On the other hand, the results also indicated that the majority (66.7%) of microplastics smaller than 20 µm were consistently detected in all the samples. Nevertheless, other detection methods such as Raman, Fourier Transform Infrared (FTIR) Spectroscopy, etc. should be considered for a more thorough investigation. Lastly, it is important to revisit the sampling and testing procedures for similar studies like this to prevent or minimize any cross-contamination to the samples.

## Introduction

The world has rapidly produced plastic due to it is a highly demanded industrial material for its cost-effectiveness. However, the rapid consumption of single-use plastics and waste mismanagement has currently caused 37% of world plastic waste being poorly managed [1]. Waste mismanagement refers to inadequate waste collection, treatment, disposal and management system. Mismanaged plastic waste has caused plastic leaking into nature and entering our food chain as microplastics. Microplastics exist in different types of sizes, shapes and colours with some spherical, fibrous or random appearance. According to Crawford & Quinn [2], microplastic is generally defined as any piece of plastic in size along its longest dimensions, which its standardized size can be categorized into macroplastic (≥25 mm), mesoplastic (<25 mm to 5 mm), plasticle (<5 mm), microplastic plus mini-microplastic (<5 mm to 1 µm), and finally nanoplastic (<1 µm).

On the other hand, microplastics can be further classified as pellet, microbead, fragment, fibre, film, and foam, as shown in Table 1. However, four main categories, i.e., bead, fibre, fragment and film, are commonly found in microplastic studies [3, 4, 5]. Fragments are rigid particles with angular and irregular shaped, and some fragments particles are thick with sharp crooked edges. It is believed that fragments primarily come from hard plastics through fragmentation. Fibres are long thin or thread-like with a slender shaped piece particle. It comes from fabrics, nets, fishing lines, and ropes. Beads are spherical, or an aggregate of spheres shaped piece particle which came from the cosmetic products. Films are thin sheet or membrane-like piece particle which generally derived from plastic bags and packaging material. It appears as irregular shapes, but in comparison with fragments, they are thin, soft, flexible, and usually transparent. The shape of microplastics can affect floating, sinking and transportation behaviour of microplastic through densities. Studies have suggested that such characteristics may affect the fate and removal rate at drinking water treatment plants [3] and wastewater treatment plants [6].

Table 1 Classification of microplastics (Crawford & Quinn, 2017).

| **Types** | **Size** | **Shape/ Appearance** |
|---|---|---|
| Pellet | <5 mm–1 mm | A small spherical piece |
| Microbead | <1 mm–1 μm | A small spherical piece |
| Fragment | <5 mm–1 mm | An irregular shaped piece |
| Microfragment | <1 mm–1 μm | An irregular shaped piece |
| Fibre | <5 mm–1 mm | A strand or filament of plastic |
| Microfibre | <1 mm–1 μm | A strand or filament of plastic |
| Film | <5 mm–1 mm | A thin sheet or membrane-like piece of plastic |
| Microfilm | <1 mm–1 μm | A thin sheet or membrane-like piece of plastic |
| Foam | <5 mm–1 mm | A piece of sponge, foam, or foam-like plastic material |
| Microfoam | <1 mm–1 μm | A piece of sponge, foam, or foam-like plastic material |

Humans and animals are found ingesting more microplastics each year from food and drinking water. Several studies have recently detected significant amounts of microplastics not only in our surface water but also in tap and bottled water [7, 3, 8, 9, 10, 5, 11, 12, 13, 14, 15, 4]. There are a few types of bottled water products, i.e., mineral water, drinking water and distilled water. Most of the bottled mineral water is sourced from the underground water, wells or mountain lakes and rivers. Bottled mineral water contains naturally dissolved minerals that meet the water quality standards with minimal water treatment processes. Meanwhile, bottled drinking and distilled water are obtained from municipal tap water delivered by the domestic water distribution system. Tap water is further treated with the filtration, reverse osmosis or distillation processes to produce bottled drinking and distilled water. Other water treatment processes may include the electrodialysis, ion exchange, ultraviolet sterilization, chlorination disinfection, etc.

A few studies have suggested some of the current water treatment plants are unable to completely remove microplastics [16, 17, 18, 19]. Moreover, Mason et al. [7] have suggested that microplastics in the bottled water could be partially coming from the packaging and/or bottling process. In Malaysia, the sales of plastic bottled water had reached nearly MYR700 million in 2019 [20]. Hence, microplastics may also be present in our bottled water that can pose a potential risk to our health. However, data on microplastics in bottled water are still limited especially for Sarawak State in Malaysia. This study aims at investigating the presence of microplastics in the bottled mineral water (MW) and drinking water (DW), which manufactured in Kuching and other cities in Sarawak and Malaysia. So that the key stakeholders from the F&B industry may take necessary actions to prevent microplastics contaminating our bottled water.

## Methodology

To order to meet the aim and objectives of this study, two main experimental works, as described below, were conducted for investigating the presence of microplastics for the local bottled water samples.

**Experimental Design and Setup.** A library database was prepared as a guideline to identify the types of microplastic particles that would be used as a standard reference for this study. The database has two main parts, i.e., the standard reference part that adopted from Mandy Sartain et al. [21] and the control sample part that generated from the experiments. As shown in Table 2, a garment (synthetic towel), plastic bottle, plastic bag and facial product were used to produce four different types of microplastic particle, i.e., fibre, fragment, film and bead, respectively. The garment, plastic bag and facial product were cut into smaller pieces in the range of 0.1 mm to 5 mm using a normal pair of scissors. Meanwhile, a kitchen grinder was used to grind the plastic bottle into smaller pieces. The produced microplastic particles were mixed with distilled water using a glass rod in a 500-mL beaker and prepared as the control samples. The control samples were then analyzed with filtration and observation processes.

The filtration process was conducted in Swinburne Chemical Engineering Laboratory. As shown in Figure 1, a 1000-mL filtering flask, 500-mL filter funnel, sample holder with a base and clamp were required for the filtration process. The filtration system was assembled by connecting to a vacuum pump with tubing. A microporous membrane filter (Ø47 mm, 0.45 µm pore size) was clamped in between the holder and funnel. Then, each control sample was poured from the filter funnel and filtered through the membrane filter. The filter with possible microplastic particles retained on it was transferred to a petri dish. Lastly, the Petri dishes were covered and dried at room temperature, as shown in Figure 2 before the subsequent observation process. To minimize any cross-contamination to the experiments, a clean cotton lab coat and nitrile powder-free gloves were used throughout the sample analysis. All the glassware and tools were cleaned by repeated rinsing with distilled water before processing each sample.

Meanwhile, the observation process for the filtered samples was conducted Swinburne Civil Engineering Material Laboratory. Each filter sample was prepared with glass slides in this lab also for the observation process. As shown in Figure 3, a digital microscope (Nikon Eclipse LV150N) with 5x objectives lens was used throughout this process. Other more common methods, such as Raman and FTIR Spectroscopy [21], were not considered for this study due time and other resources constraints. Nevertheless, the microscope that employed for this study, which has Nikon NIS-Elements D Imaging software, was adequate to measure microplastic particles and produce digital images ranging from 1 to 300 µm. Hence, any microplastic smaller than 5 µm were not considered for this study. Lastly, the digital images generated from the control samples were tabulated to match the standard reference [21] for the library database, as shown in Table 2.

**Sampling and Testing.** The selection criteria for the bottled water samples, as shown in Table 3, were considered for the experimental works. Due to different volume packing and products available for each brand, the sampling procedure had decided to adopt the Type 2 method. Therefore, Brand X from Kuching with both bottled MW and DW, Brand Y from Perak with bottled MW only, and Brand Z from Sibu with only bottled DW were chosen for this study. As a result, a total of 40 bottled water samples with 10 samples from each product, as shown in Table 4 were obtained for the lab testing. The same lab testing procedures, as described above, i.e., filtration and observation processes, were applied for each of the acquired samples. Lastly, the obtained results were recorded and analyzed for the particle count, distribution and comparison between bottled MW and DW samples.

Table 2 A library database generated based on the standard reference (Mandy Sartain *et al.*, 2018) and control samples.

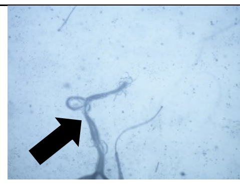
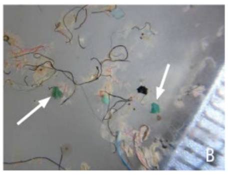
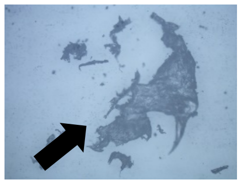
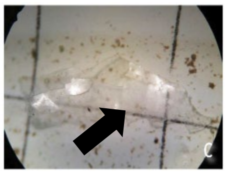
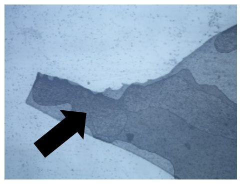
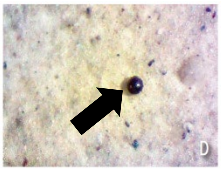
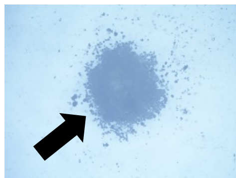
| Type of Microplastic Particle (Source) | Standard Reference | Control Sample[1] |
|---|---|---|
| Fibre<br>(garment-synthetic towel) |  |  |
| Fragment<br>(plastic bottle) |  |  |
| Film<br>(plastic bag) |  |  |
| Bead<br>(facial product) |  |  |

Figure 2 Vacuum filtration setup for the bottled water samples.

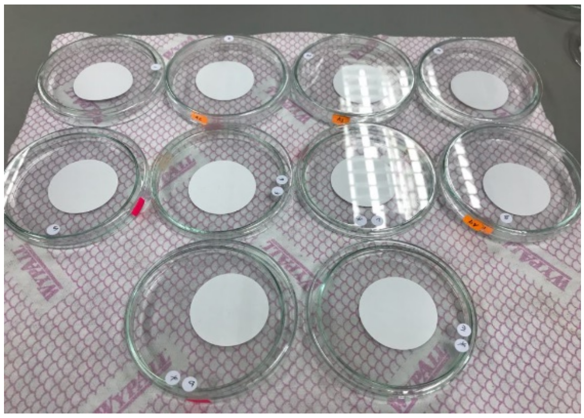


Figure 1 Filtered samples for the observation process.

[1] 5x objectives lens (magnification) was used throughout this experiment to generate the images

Figure 3 A digital microscope, Nikon Eclipse LV150N, for observing the microplastics.

Table 3 Selection criteria for bottled water samples.

| Method | Selection Criteria |
|---|---|
| Type 1 | A different brand with 2 x MW + Different brand with 2 x DW (min. 4 brands of bottled water samples) |
| Type 2 | One brand with both MW & DW + Different brand with both MW & DW (min. 3 brands of bottled water samples) |
| Type 3 | Two brands with both MW & DW (min. 2 brands of bottled water samples) |

Table 4 Description of the obtained bottled water samples.

| Brand | Bottled MW | Bottled DW | No. of Bottled Water Samples |
|---|---|---|---|
| X | Underground water | Tap water + Filtration treatment | 10 + 10 = 20 samples |
| Y | Underground water | N/A[2] | 10 samples |
| Z | N/A | Tap water + Reverse osmosis treatment | 10 samples |

## Results and Discussion

A total of 2022 particle count of microplastics in the 40 bottled water samples was detected. As shown in Figure 4, Product Y (MW) has the highest total of 660 microplastics detected and with an average of 33 particles per litre. For the remaining Products X (MW), X (DW) and Z (DW), their averages are 24.2, 19.5 and 24.5 particles per litre, respectively. On the other hand, fibre has the highest 48.0% of microplastics detected as shown in Figure 5 and then followed by fragment (36.2%), film (15.2%) and bead (0.6%), respectively. In other words, fibre and fragment made up the majority (84.2%) types of microplastics found in the 40 samples. This is also true for each product (see Figure 4).

In Figure 6, a total of 1143 and 879 particle count of microplastics was detected in the bottled MW and DW samples, respectively. The bottled MW samples have shown higher particle count, i.e., 13%, than the bottled DW samples. It appears that a similar trend is also exhibited for each type of microplastic in the samples except for products between X (MW) and Z (DW). This is also true for products within the same brand, i.e., between X (MW) and X (DW) (see Figure 4). Furthermore, Figure 7 shows that the majority (66.7%) of detected microplastics was smaller than 20 μm. Such persistent of microplastic at drinking water treatment plants, treated water and bottled water have also been reported in several studies [16, 17, 18, 22, 19].

[2] Non-applicable due to the product unavailability for the bottled water samples

## Conclusion and Recommendations

This study investigated 40 bottled MW and DW samples from 4 local products in Kuching and other cities in Sarawak and Malaysia. A filtration and observation processes using the membrane filters and digital microscope were developed to identify and quantify the presence of microplastics. A library database was developed to ensure the consistency of this identification process. A total of 2022 microplastics with an average of 50.6 particles per bottle (500-mL packing) was detected in the samples. Bead, fibre, fragment and film were detected in all the samples, but fibre (48%) and fragment (36%) made up the majority (84%) of microplastics in the samples. However, microplastics in the MW samples were found 13% higher than the DW samples. This was also true across the products investigated in this study except between X (MW) and Z (DW). On the other hand, the results also indicated that a majority (66.7%) of microplastics smaller than 20 μm were consistently detected in all the samples. Although significant amounts of microplastics were detected in this study, there were some challenges and limitations during the experiments, e.g., possible cross-contamination from the membrane filters and long duration of the observation process, etc. Hence, other methodology such as Raman and Fourier Transform Infrared (FTIR) Spectroscopy should be considered for more accurate investigation. Unless more understanding of the health impact of ingesting microplastics has been adequately investigated, it is strongly suggested for water treatment operators and F&B manufacturers to take necessary actions preventing or minimizing microplastic pollution in our drinking water.

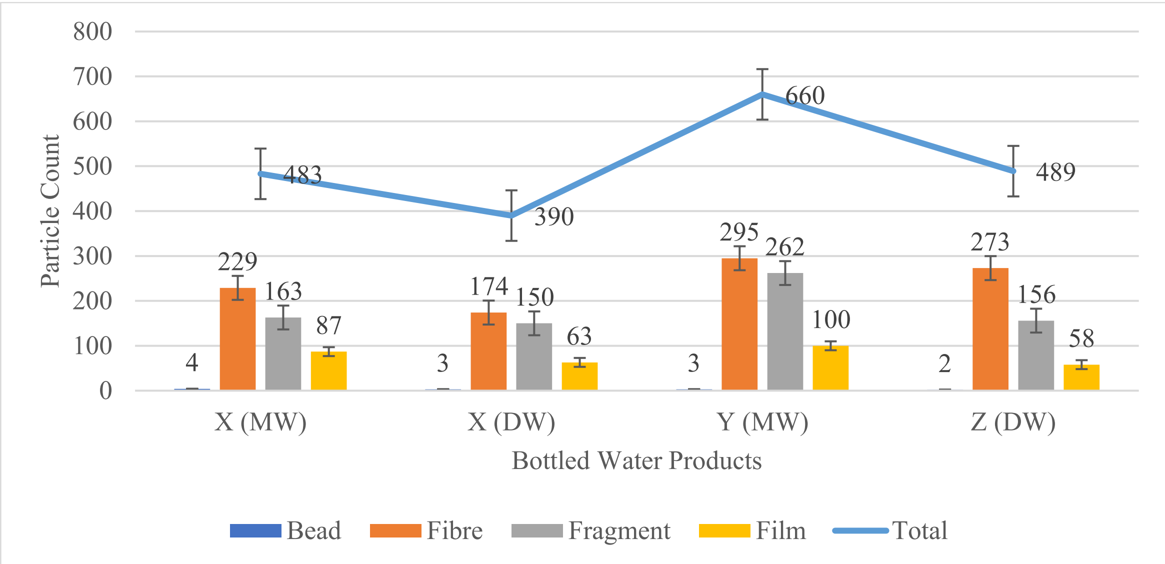



Figure 4 Particle count of microplastics from the 40 bottled water samples.

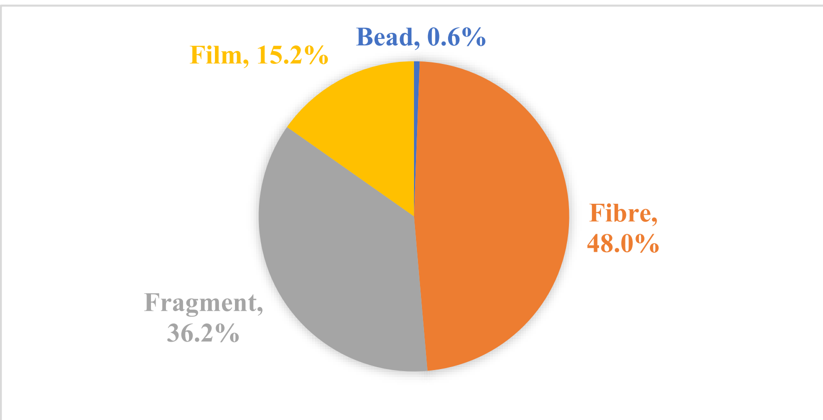



Figure 5 Percentage of microplastic particles detected for the 40 bottled water samples.

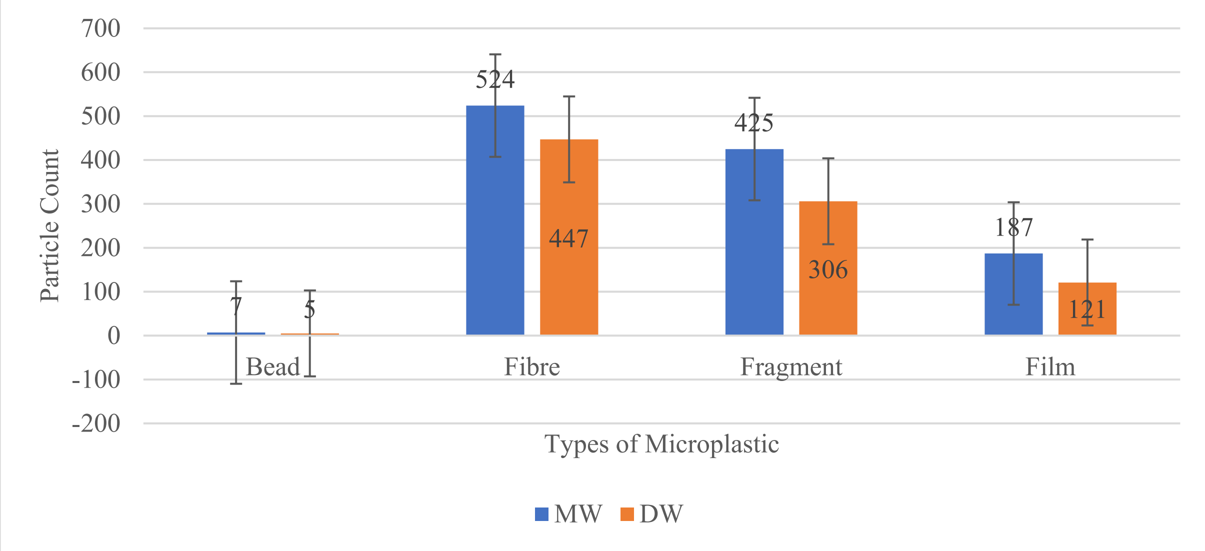



Figure 6 Comparison of microplastic particle count between bottled MW and DW samples.

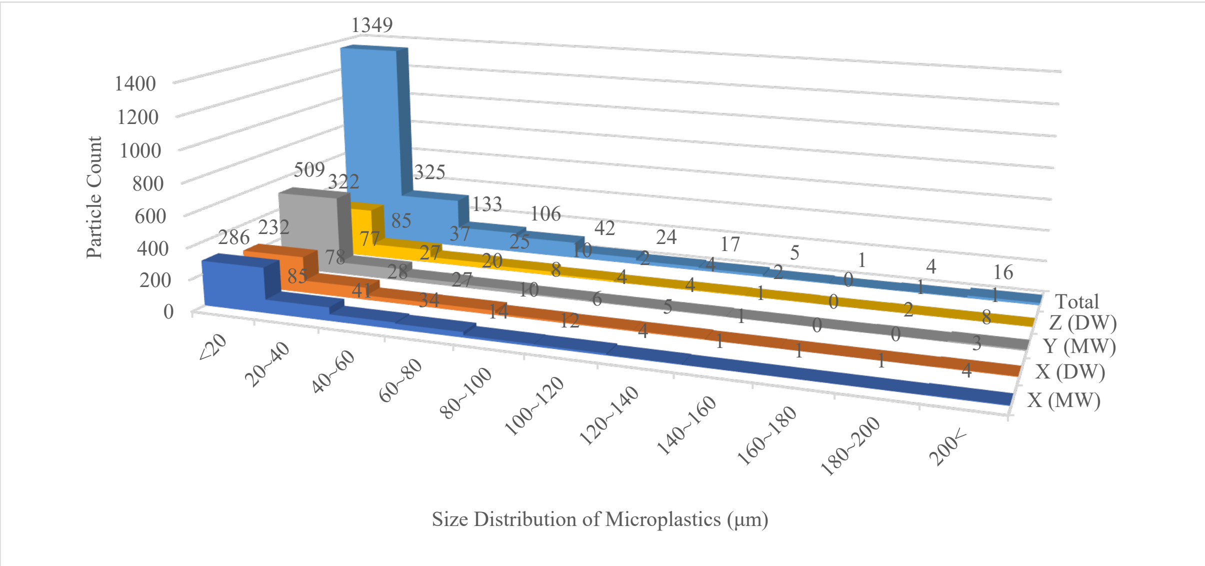



Figure 7 Size distribution of the detected microplastics in the 40 bottled water samples.

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