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Reduction of Microplastics in Washing Machine Effluent by Filtration Technique

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Abstract

Microplastic fibers are produced by washing clothes made of synthetic fibers. Such microplastic fibers are found in wastewater treatment systems and always flowing out into the rivers and seas resulting in environmental contamination. The purpose of this research was to study the efficiency of filters for reducing the amount of microplastic fibers in washing machine effluent by equipping a small cartridge filter at the end of the washing machine's drain hose. Five types of filters were used with the filter mesh size of 5-40 µm and a stainless-steel filter with the filter mesh size of 100-500 µm. Wastewater samples were collected from the washing machine before and after it was filtered to assess the efficiency of reducing microplastic fibers. The results showed that most of the types of microplastic fibers found were Polyethylene terephthalate (PET) and Nylons, which are plastics commonly used in the synthetic fibers. For one washing machine wash, an average of all microplastics can be released. 807.98±629.70 Items/L, with the majority of microplastics having fiber shapes, amounting to 806.86±628.99 Items/L, or 99.86% of all microplastics. From the study of the efficiency of filters, it was found that the most effective filter for reducing the amount of microplastic fibers was the smooth polypropylene filter 5 µm with an efficiency of 96.44%, but clogging easily. It is not suitable to use stainless steel filters modified to a sieve size in the range of 100-500 µm because the efficiency was 63.04%, which was not very high efficiency. Nonetheless, the flow rate was better than other types of filters. If using a suitable type of filter, it should be improved to increase efficiency.

Keywords : Microplastics; Microfibers; Filtration; Washing machine effluent

Introduction

Microfiber is the type of microplastic particle found in the first highest proportion in raw sewage and wastewater treatment processes in domestic [1]. The most common types of microfibers are Polyester, Polyamide, Elastane, including Rayon. For the source of the activity or the source of microfibers discharge from household wastewater to wastewater treatment processes, such as washing synthetic fabrics. Which is difficult to effectively treat by wastewater treatment systems. It would cause microfiber particles contaminated in the treated wastewater (effluent) discharging into the natural water sources ecosystems or may lead to further contamination and accumulation in the food chain.

Textile wastewater has been widely reported as a potential source of microplastics [2, 3]. Polyester garments are part of the microplastic problem. During cloth washing, plastic fibers with the size of 10 microns (µm) to 2-3 millimeters (mm) in diameter, collectively known as 'Microfibers', were released from the fabric materials [4]. Mixed in the washing water It always slips through the sewage system into rivers and floats out to the sea [4]. Will enter the food chain starting from small to large animals [5].

Although there are none of current studies confirming how microplastic parts affect human health, Microplastics tend to absorb various toxic chemicals into their bodies while floating in the water. When entering the body of food chain organisms such as fish, plants, etc.; the toxins that accumulate within these microplastics may further affect human health [1]. Acrylic laundry may release more than 700,000 microfibers per wash with an average load of 6 kg of laundry [6].

At present, there are many ways to remove microplastics such as sedimentation, microfiber trap devices in washing machines such as Cora Ball, including starting to invent proper microplastic filtration using various techniques.

The purpose of this study was to study the types of filters, which is suitable to reduce the number of microplastics in the washing machine effluent, that further to reduce the release of microplastics in the effluent from wastewater treatment systems into natural resources. This can reduce the impact occurred onto the environment.

Materials and Methods

Sampling methods

The HITACHI single-tank top-loading washing machine model SF-130XWV was used in this study. The water of 90 liters and the cloth with an average weight of 9 kg were added to the washing machine. A small cartridge filter (Cartridge Filter of Housing) was added at the end of the washing machine's drain pipe, and the effluent before entering the filter was collected as 10 water sample, 5 replicates. The collecting filtered water was brought to analyze the efficiency of the filter types.

Filter types study

To study the efficiency and suitability of microplastic filters, the ready-made filters bought in the market were used. The types of filters used including:

1. Yarn Filter Cartridge 5 µm
2. Polypropylene, Smooth Filter Cartridge 5 µm
3. Polypropylene, Pleated Filter Cartridge 5 µm
4. Stainless steel Filter Cartridge 40 µm
5. Polypropylene, Orange Peel Surface Filter Cartridge 50 µm

The one-stage and two-stage filtration were performed to determine which was the most efficient. When the filter is installed, sample water was collected before and after passing through the filter. To study the efficiency of microplastics filtration, The effluent that passed through the filter must flow evenly and do not clog until the washing machine stops working.

Figure 1 Installation of a two-stage filter system

Analysis of microplastics

Microplastics were analyzed by the density separation method modified by the Oceanic and Atmospheric Administration Nation (NOAA) [7]. In the first step, a 1,000 ml of water sample was filtered with a stainless-steel mesh sieve No. 50 (330 µm.) Then, it was collected on the sieve into a 600 ml beaker and baked at 105 Degree Celsius for 24 hours. The second step, the organic matter was decomposed by adding 20 ml of iron (II) sulfate ($FeSO_4$) and 20 ml of 30% hydrogen peroxide (30%: H_2O_2) into the annealed sample beaker. The chemical reaction causes the white foam to appear, and as the temperature decreases, the foam was disappeared. The third step, the sample was heated at 75 Degree Celsius for 30 minutes, NaCl 6 g was added and distilled water was sprayed around the beaker. The sample was stirred repeatedly for 5 minutes. The Fourth step, the sample was transferred from a beaker to a glass funnel and left for 24 hours. Then, the microplastics were floating on top of the surface.

Data analysis of microplastics

Microplastic images were analyzed using an Olympus SZ51 stereoscopic microscope to count the number of microplastics and differentiate the shape of the microplastics with the naked eye, and a Fourier Transform Infrared Spectroscopy (FTIR) was used to identify the types of Microplastics.

Results and Discussion

For the types and amount of microplastics from washing machine effluent, most microplastic fiber was found, and mixed with fragments and film forms slightly. This is consistent with the research study abroad [8] indicated that washing machine effluent were found to contain microplastics more fiber types than others, and washing accounts for 12% of microplastic discharging.

Counting and characterization of microplastics were analyzed to represent the number of microplastics found in washing machine effluent. Each form of microplastics found in washing machine effluent could be identified as shown in Table 1.

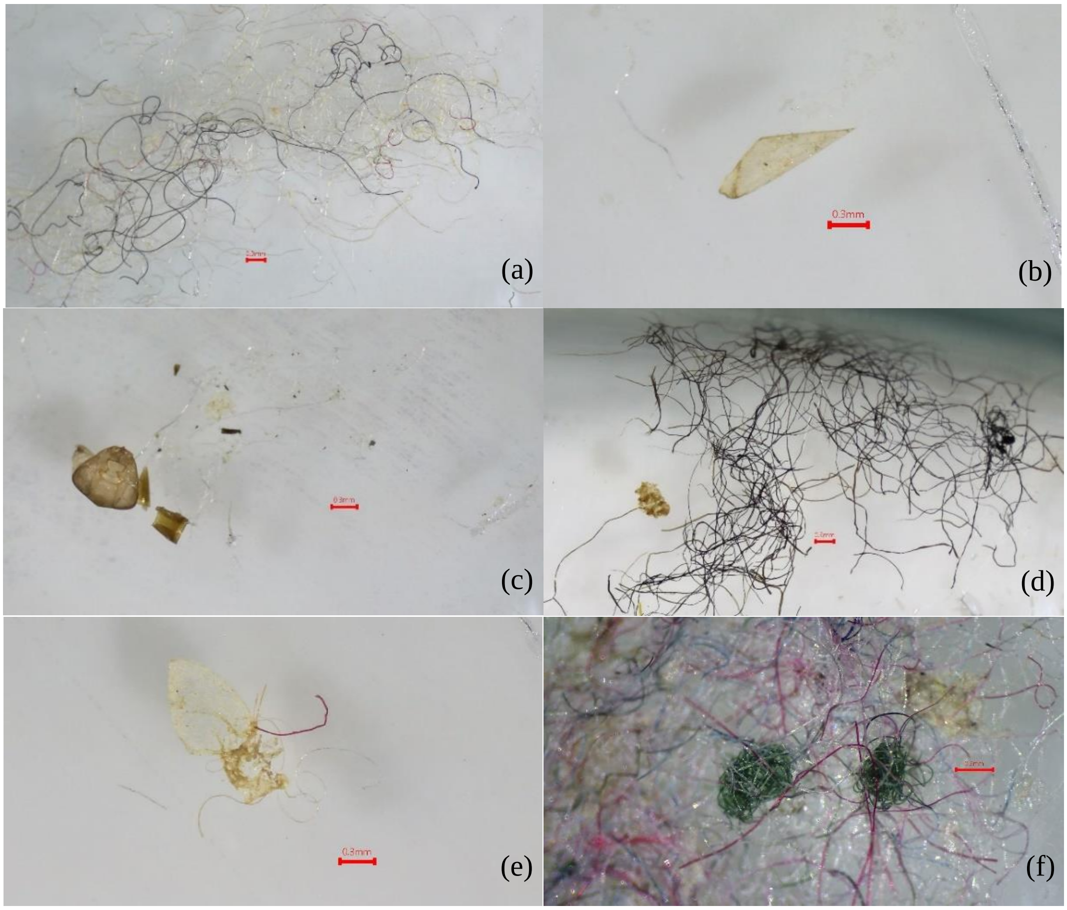

Figure 2 Shape of microplastics found in washing machine effluents
a : Fibers , b : Fragment , c : Films , d : Fibers , e : Fragment , f : Fibers

Table 1 Shape and amount of microplastics found in washing machine effluent for 10 samples, 5 replicates

Sample	Total amount of microplastics (Item/L)	Shape of microplastics			
		Fibers (Item/L)	Films (Item/L)	Spheres (Item/L)	Fragment (Item/L)
1	939.0±365.35	937.4±365.35	0.2±0.45	0.0±0.0	1.4±1.14
2	416.6±173.24	415.6±173.09	0.2±0.45	0.0±0.0	0.4±0.55
3	2,295.6±454.37	2,292.6±455.22	0.2±0.45	0.0±0.0	2.8±1.92
4	356.6±97.97	356.0±98.81	0.0±0.0	0.0±0.0	0.6±0.89
5	1,473.4±848.21	1472.4±849.05	0.0±0.0	0.0±0.0	1.0±1.22
6	319.8±86.01	319.6±86.09	0.0±0.0	0.0±0.0	0.2±0.45
7	773.4±206.60	771.4±207.40	0.2±0.45	0.0±0.0	1.8±1.30
8	552.8±319.79	552.2±319.19	0.0±0.0	0.0±0.0	0.6±0.89
9	560.4±210.71	559.6±210.90	0.2±0.45	0.0±0.0	0.6±0.89
10	392.2±243.01	391.8±242.95	0.0±0.0	0.0±0.0	0.4±0.55

Based on the results of the quantitative analysis of microplastics in the washing machine effluent, the average amount of microplastics is 807.98±629.70 Items/L, which includes microplastics with fiber shapes as follows; Fibers 806.86±628.99 Items/L, Films 0.10±0.11 Items/L, Spheres 0.00±0.00 Items/L and Fragment 0.98±0.81. Items/L. The results were calculated as the percentage of each shape of microplastics found in washing machine effluent of 10 samples: 99.86% Fibers, 0.01% Films, Spheres 0.00%, and fragment 0.12%, indicating that the majority of these microplastic fibers are obtained from wastewater through washing rather than splintering or from cleaning products [9, 10].

For the FTIR analysis, a total of 10 microplastic samples in washing machine effluent were mixed between PET and Nylons. They are commonly used as ingredients in the synthetic fiber production causing shedding during washing. This is consistent with the research study abroad [11] that measured the number of microfibers loosened from synthetic textiles from three materials (acrylic, nylon, and polyester) knitted using different gauges and techniques. All textiles were found to be shedding. It has been shown that loose fabric structures are more prone to shedding. For the additional study, [12] microplastics contained in water treated by three Australian wastewater treatment plants and particle characterization by FTIR analysis, PET microplastics (Polyethylene terephthalate) are the highest fibers or 80% of all microplastics, and irregular shape Polyethylene was 20% of all microplastics. This may be caused by the use of cosmetic and pharmaceutical products. Including cleaning washing clothes containing plastic fibers [12].

For the number of microplastics, it was found that the wastewater from the washing machine before passing through the filter contained about 319.8±86.01 - 2,295.6±454.37 Items/L, or the average number of microplastics which was 851.47±232.82 Items/L, which was a small number of microplastics more than in the research [6] finding that when washing clothes with an average load of 6 kg, more than 700,000 microfibers were released per wash, and [8] was found that washing containing the ingredient of synthetic fibers at one time can release up to 640,000 - 1,500,000 microfibers depending on the fabric types. It has the possibility that in each experiment, there will have different microplastic values. Because the type of fabric in each wash was not the same, this study did not specify the type of fabric and want to use common fabrics used in daily life to simulate and suit the daily life of people in general.

When installing one-stage and two-stage filtration systems found that the number of microplastics was reduced to 35.4 - 416.6 Items/L, or the average number was 103.18±52.34 Items/L, showing that the number of microplastics could be reduced. which can be thought of as efficiency in the removal of microplastics in the range of 55.63% - 96.44% as shown in Table 2.

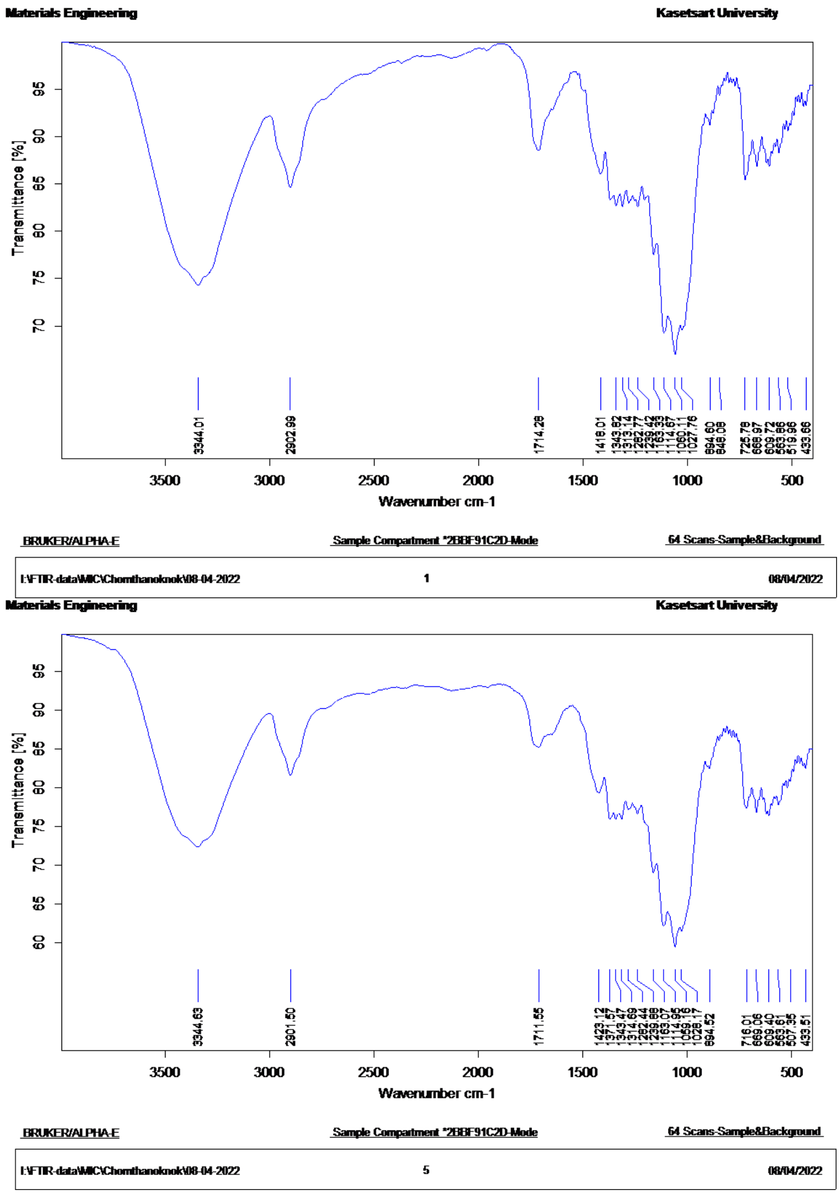

Figure 3 Example of FTIR curve of microplastics in washing machine effluent indicates the type of plastic

Table 2 presents that the Yarn Filter Cartridge 5 µm having the lowest efficiency of 55.63%. After filtration, there was still a large number of fiber microplastics. The most effective filter element was the Polypropylene, Smooth Filter Cartridge 5 µm with an efficiency of 96.44%, of which the efficiency was good, but it was necessary to take into account the practical use. Polypropylene, Smooth Filter Cartridge was easily clogged, caused washing machine stop working which was unable to continue, Therefore, it was not suitable for use with very high concentration wastewater. Next, the Pleated Filter Cartridge 5 µm had 90.07% with an efficient stable water flow rate. While Stainless steel Filter Cartridge 40 µm had 95.45% efficiency which was considered high efficiency and the washing machine could continue to operate normally, with a constant water flow rate.

Table 2 Filter efficiency study of One-stage and Two-stage filter system

Filter types	Average amount of microplastics before filter installation (Items/L)	Average amount of microplastics after filter installation (Items/L)	Efficiency (%)
One-stage filter system			
Yarn Filter Cartridge 5 µm	939.0	416.6	55.63%
Polypropylene, Smooth Filter Cartridge 5 µm	2,295.6	81.8	96.44%
Polypropylene, Pleated Filter Cartridge 5 µm	356.6	35.4	90.07%
Stainless-steel Filter Cartridge 40 µm	1,473.4	67.0	95.45%
Polypropylene, Orange Peel Filter Cartridge 50 µm	319.8	94.4	70.48%
Two-stage filter system			
Yarn Cartridge - Yarn Cartridge	773.4	73.4	90.51%
Yarn Cartridge - Pleated Cartridge	552.8	59.0	89.32%
Yarn Cartridge - Sieve	560.4	59.4	89.40%
PP Orange Peel - Pleated Cartridge	392.2	42.0	89.29%

The Orange Peel Filter Cartridge 50 µm had filtration efficiency of 70.48%. Due to the filter sieve size of 50 µm, the effluent can flow through more easily than other filters.

It was found that clogging is easy from the 1-stage filtration, because the size of the microplastic was larger than the filter sieve size and the filter used was more suitable for clean water. Therefore, the 2-stage filter was performed and found that the efficiency might not be much different from the one-stage filtering, but only causing better water flow.

Figure 4 shows the properties of the filter that filters out of the washing machine only once. The efficiency of filters of the same filter sieve size was different. This may be due to different filtering surface areas. The materials used to make the filters are different. The Yarn Filter Cartridge may release fibers during filtering due to its synthetic nature, just like the clothing used in the experiment.

From the research results obtained from the use of ready-made filters which is suitable for clean water for use in microplastic filtration, it was found that it was not suitable for practical use in microplastic filtration. The researcher modified the filter by using a stainless-steel mesh with a filter sieve size range of 100-500 µm, which is a suitable sieve size for filtering microplastics, of which the average length of microplastics is 360-660 µm [8] (Table 3).

Figure 4 Filters that have been used to filter microplastics in washing machine waste once
A: Yarn Filter Cartridge 5 µm, B: Polypropylene Smooth Filter Cartridge 5 µm,
C: Polypropylene Pleated Filter Cartridge 5 µm, D: Stainless steel Filter Cartridge 40 µm

Table 3 Study results on filtration efficiency of modified stainless-steel filters for 5 replicates

Filter types	Average microplastic weight before filter installation (g/L)	Average microplastic weight after installing the filter (g/L)	Efficiency (%)
One-stage filter system			
Stainless, Sieve (smooth) 100 µm	0.0059±0.001	0.0027±0.001	61.09%
Stainless, Sieve (smooth) 300 µm	0.0059±0.001	0.0028±0.000	48.55%
Two-stage filter system			
Stainless, Sieve (smooth) 300 µm - 100 µm	0.0065±0.001	0.0025±0.001	63.04%

The result of the efficiency on filtering with a self-modified stainless filter showed that the modified stainless filters were less effective than the ready-made filters, but the flow of effluent discharged from the washing machine was constant. Effluent water flows easily and does not stop the washing machine as it did when tested with a ready-made filter, which blocks the flow of water that the washing machine cuts off the operation due to the inability to drain water. Stainless steel filters are therefore more suitable for use in micro-plastic filters than general ready-made filters.

Conclusion

Reduction of Microplastics in washing machine effluent by filtration technique was studied. For washing characteristic by washing machine, for 1 time of washing uses water 90 liters for an average load of 9 kg of laundry, microplastics were released on the average of 807.98±629.70 Items/L of which the most component consisted of Fiber-shaped microplastics averaged 806.86±628.99 Items/L or 99.86% of all microplastics.

By FTIR analysis, it revealed that the main component was PET and Nylons microplastics, as today's garments use synthetic fibers based on PET and Nylons for better properties. Comparing all-ready-made filters used for microplastic filtration, the 5 µm smooth PP filter was the most efficient at 96.44%, which is a better filter for clean water. However, when used to filter water with microplastics, it could clog quickly, and there is a problem with the flow rate. As a result, the washing machine stops working. Therefore, it is not appropriate to filter microplastics.

For the application of the modified stainless-steel filters used in the 2-stage filtration test, the efficiency was 63.04%, which was not very high efficiency. But with the better flow rate than other types of filters, it was suitable to be further developed for better efficiency.

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