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RECENT ENVIRONMENTAL GEOCHEMICAL TRENDS

Microplastic emissions from household washing machines: preliminary findings from Greater Kuala Lumpur (Malaysia)

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Abstract

Microplastics have been recognized as emerging pollutants with potential ecotoxicological impact. The contribution of washing machine use to microplastics emission at the household level is still not completely understood. This study aims to characterize microplastic emissions in laundry water from household washing machines from Greater Kuala Lumpur (Malaysia). Microplastics were found between 6.9E-3 and 0.183 g/m^3 in laundry water at household level. Microplastic shapes of fiber and fragment consist of polyester, nylon, and acrylic with average length of 2258.59 μm and were also identified in these laundry water samples. Questionnaire survey findings demonstrated fabric properties and washing parameters both likely contribute to microplastic emissions in laundry water and, ultimately, wastewater treatment plant influent. The impact of fabric properties and washing parameter factors on microplastic emission in laundry water at the household level merits further investigation. The findings of this study demonstrated the potential of laundry water as a microplastic source at the household level within a developing country.

Keywords Microplastics · Emission · Laundry water · Source

Introduction

Microplastic pollutants are of increasing interest to both researchers and the public (Novotna et al. 2019). Primary microplastics originate from clothing, personal care products, and cosmetics, while secondary microplastics are derived from the degradation of large plastics. Microplastics are synthetic particles less than 5 mm in size and are found in a variety of shapes, colors, and plastic polymer types found in both aquatic and terrestrial environments (Galvão et al. 2020). The presence of microplastics in aquatic and terrestrial environments is a serious concern with respect to toxicity effects on biota in multiple trophic levels and, ultimately, to humans (Anbumani and Kakkar 2018).

With the rapid turnover of the "fast fashion" sector, over 42 million tons of synthetic fibers and polyester are utilized annually (Kelly et al. 2019). Although multiple studies by Belzagui et al. (2019), Zambrano et al. (2019), and Napper and Thompson (2016) have investigated the influence of the number of washings, water temperature, detergents, and type of clothing and washing machine on microplastic release from clothes, there has been no detailed quantification and characterization of microplastics released by domestic washing machines at the household level. With daily usage of household washing machines, characterizing microplastics in laundry water is imperative as domestic laundry is seen as a major potential microplastic source to wastewater treatment plants (Sillanpää and Sainio 2017). With rapid urbanization and increasing purchasing power in developing countries, there has been an increase with 20% of appliance market of 31% in washing machine sales value and volume especially from Southeast Asia (Absolute Reports 2010). Specifically in Malaysia, 93.5% of urban area homes report having a washing machine and the percentage is expected to increase with socio-

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demographic changes affecting consumption behavior (Hansen and Nielsen 2016; Saim 2017). With the increase of washing machine usage, microplastics in laundry water will likely be one of remarkable route of microplastic sources from household with a continual flow to wastewater treatment plant. While in wastewater treatment plant, these microplastics are unable to be remotely effectively and enter river water as treated effluent which prompt toxicological risks to aquatic environment (Schöpel and Stamminger 2019).

The objective of this study was to evaluate microplastic emissions from household washing machines in Greater Kuala Lumpur (Malaysia). This study characterizes microplastics in laundry water with regard to their mass concentration, sizes, and shapes. To our knowledge, this is the first study of its kind to characterize microplastic emissions from washing machine water at the household level and provide quantitative information regarding one household microplastic pollution source entering wastewater treatment plants in Malaysia.

Materials and methods

This cross-sectional study was conducted from January to March 2020, with a total of 99 laundry water samples collected from houses from Greater Kuala Lumpur (Malaysia). Greater Kuala Lumpur is the most developed city with 7.2 million population and expected to rise up to 10 million in 2020. Furthermore, Greater Kuala Lumpur city is rated as the 2nd most liveable city in Southeast Asia with residential area hotspots (Alias et al. 2015).

In each residence, 1 L of laundry water released from the washing machine during washing mode was collected into a Schott glass bottle. The respondents were requested to complete a questionnaire on washing machine usage. The laundry water samples were transported to the laboratory, and microplastic analysis was performed based on a method adapted from Praveena et al. (2018). A total of 500 mL laundry water was filtered through a 0.45-μm Whatman filter paper via vacuum filtration. The filter paper was dried at 60 °C until a constant weight was achieved. The filter papers were weighed using analytical balance (Analytical Balance, GR-200 Series) before and after the filtration process. Next, the filter paper weight of microplastic mass was subtracted with mass of blank filter paper and divided by amount laundry water filtered to obtain the final amount of microplastic content in laundry water. The filter paper was divided into four quadrants, and each quadrant was photographed using a Nikon Eclipse E200LED MV RS microscope with a magnification of × 40 coupled with a BestScope International Limited camera to obtain particle shapes. Particle shapes in the samples were screened and classified into fiber, fragment, films, pellet, and foams based on microplastic shape classification by Lusher et al. (2017) and Vendel et al. (2017). Then, Image J 1.53 (http://imagej.nih.gov), an open-source particle analysis software, was used to measure the length of the particles. Fourier-transform infrared spectroscopy (FTIR) analysis was performed to confirm the presence of microplastics on the selected filter papers along with blank filter by identifying plastic polymers detected in the laundry samples. The spectra of each sample were scanned in the spectral wavelength range between 4000 and 400/cm at a resolution of 4/cm and compared with reference spectra using FTIR Thermo Nicolet 6700.

Quality control steps were taken through the analysis. All the laboratory surface used was cleaned before the analysis. All glasswares were acid-washed and rinsed with Milli-Q water before analyses and between sample analyses. Cotton lab coats and gloves were worn throughout the analysis to avoid airborne microplastic contamination. All the dried filters were stored in closed petri dish to avoid airborne particle with minimized movement in order to reduce particles straying away from the filter. The petri dish was only opened minimally during the analysis. All the blank and laundry water samples were analyzed in duplicates through the analysis. Lastly, the results were reported as a mean of duplicate samples.

Results and discussion

The microplastic content in laundry water released from household washing machines was between 6.9E-3 and 0.183 g/m^3 with an average of 0.068 g/m^3. The average microplastic length was 2258.59 μm, and microplastic fragments and fibers were detected in laundry water. Detailed information regarding mass, size, and color of each sample is summarized in Appendix A. Figure 1 shows the microplastic images and FTIR spectrum of plastics polymers in laundry water released from washing machine. The FTIR spectrums have indicated the presence of polyester, nylon, and acrylic (> 80% library match) in these laundry samples. These plastic polymers are the common materials utilized in fabric properties. In comparison with other studies, it is difficult and not possible to compare with current findings given the different methods, domestic washing machine settings, and clothes.

Table 1 summarizes the fabric properties and washing parameters associated with microplastics found in laundry water. There were substantial microplastic variations between each laundry sample, which can be due to specific fabric properties. Questionnaire results indicated that more than 50% of clothes washed in washing machines are made of nylon and polyesters. According to Carmichael (2015), polyester is the most dominant human-made plastic fiber, followed by nylon. Studies by Hernandez et al. (2017) and Åström (2016) have demonstrated that polyester showed diverse variations in microplastic fiber shedding and that shedding depends on

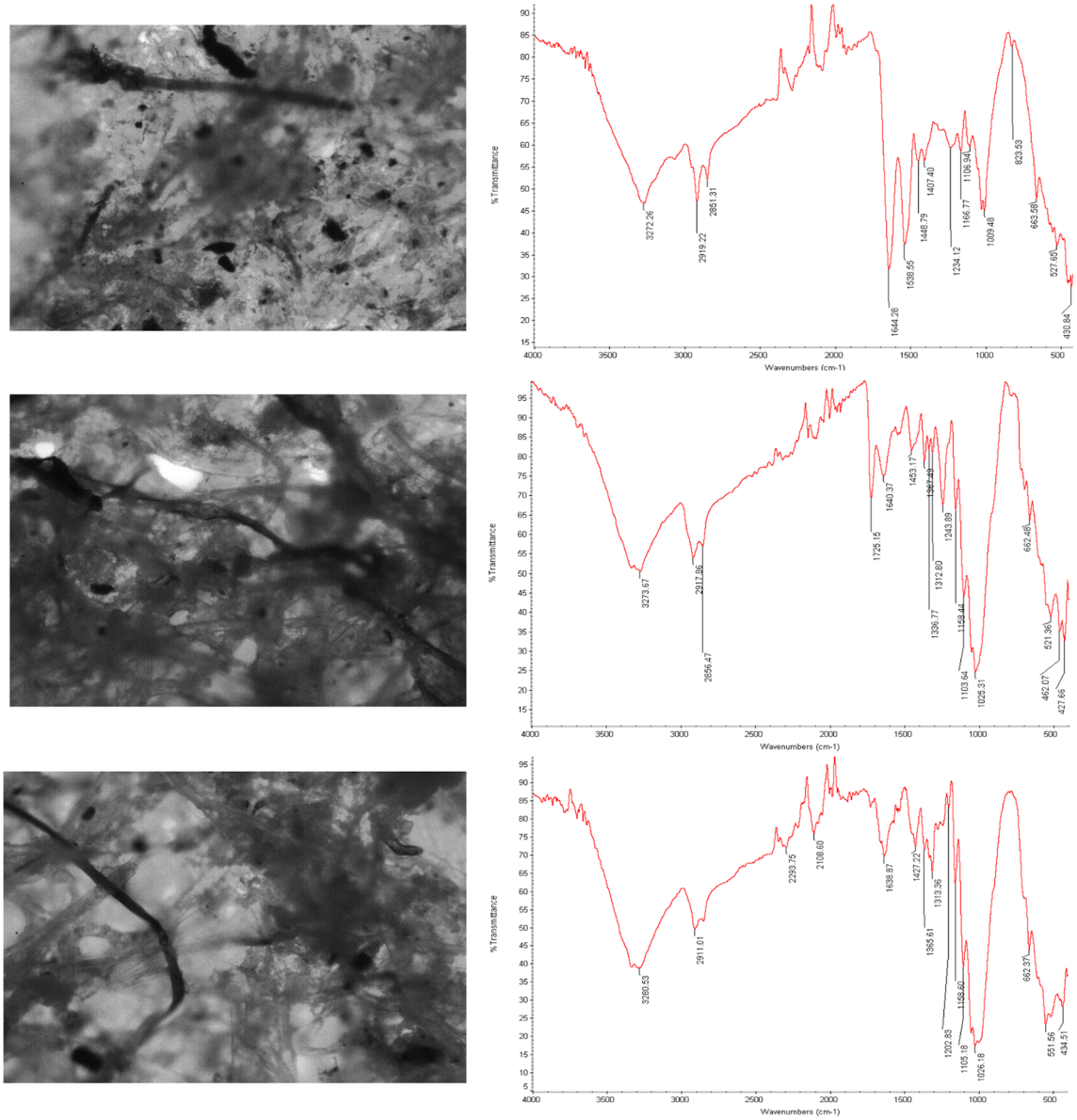

Fig. 1 Microplastic images along FTIR spectrums in selected laundry water samples

the fabric structure. Additionally, the majority of respondents washed a variety of clothes in a single wash without any clothes separation. This practice results in different fabric structures releasing different amounts and types of microplastics in laundry water (Salvador Cesa et al. 2017). A total of 91% of the respondents in this study used top-loading washing machines. According to Hartline et al. (2016), top-loading washing machines were found to contribute seven times more microplastics during washing than front-loading washing machines. The majority of the respondents washed their clothes using room temperature water between 41 and 60 min with washing frequency from every day to once per week. However, studies by Hernandez et al. (2017) and Kelly et al. (2019) have demonstrated that water temperature and washing duration were not the most important factors for microplastic release in laundry water. The majority of the respondents also reported using liquid detergent along with fabric softener during clothes washing. There are inconsistent findings reported on the effect of detergent on microplastics release into laundry water which needs further investigation, including detergent types and their interactions with different fabric structures (Carney Almroth et al. 2018; De Falco et al. 2018; Kelly et al. 2019; Mermaids Consortium 2017; Novotna et al. 2019).

Since microplastic emissions in laundry water still need further investigation on understanding multiple factors contribution, this study finding can be utilized as a way to raise awareness of consumer, textile industry, and policymakers. Furthermore, as policies to control microplastic release to wastewater are also lacking, a new policy for wastewater

Table 1 Type of clothes and washing information associated with microplastics found in laundry water among respondents from the Greater Kuala Lumpur (Malaysia) (n = 100)

No	Information	%
Fabric properties		
1	Type of clothes washed in washing machine	
	Cotton only	6
	Cotton and Synthetic cotton	29
	Nylon and Polyester	65
2	Clothes separation before washing in washing machine	
	Yes	31
	No	69
Washing parameters		
1	Washing machine type	
	Top-load	91
	Front-load	9
2	Water temperature	
	Hot	1
	Cold	8
	Room temperature	91
3	Washing frequency	
	Everyday	20
	Five times a week	3
	Four times a week	10
	Thrice a week	21
	Twice a week	27
	Once a week	19
4	Washing duration	
	10–20 min	3
	21–40 min	46
	41–60 min	51
5	Type of detergent	
	Liquid	61
	Powder	39
6	Fabric softener usage during washing	
	Yes	72
	No	28

treatment plants on microplastics needs to be a focus (Carney Almroth et al. 2018; Alpizar et al. 2020).

Conclusion

This study has provided preliminary quantification of microplastic emissions in laundry water from household washing machines in Malaysia. An average of 0.068 g/m^3 microplastics with mean length of 2258.59 μm with fragment and fiber shapes of polyester, nylon, and acrylic polymers were found in laundry water at household level. Questionnaire findings demonstrated that fabric properties and washing parameters are two factors contributing to microplastics emitted in laundry water. These findings provide the basis for a wide range of future studies that focus on the impact of fabric properties and washing parameters on microplastic emissions.

Authors contributions Sarva Mangala Praveena has contributed to the main conceptual idea, study design and full article writing. Sarva Mangala Praveena and Melati Syahira have performed the experiments and analysed the entire data. Josephine Liew Ying Chyi has conducted the Fourier-transform infrared spectroscopy (FTIR) analysis of the filter samples.

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Compliance with ethical standards

Competing interests The authors declare that they have no competing interests

Ethics approval and consent to participate This study has obtained approval from Ethics Committee for Research involving Human Subjects of University Putra Malaysia (UPM/TNCPI/RMC/ JKEUPM-2019-410). In this study, informed consent was used to introduce the participants about procedure and data handling in this survey.

Consent to publish Not applicable

Availability of data and materials All data generated or analysed during this study are included in this published article and its supplementary information files.

References

Absolute Reports (2010) Global residential washing machines market 2019 by manufacturers, regions, type and application, forecast to 2024. Maharashtra

Alias A, Rashid WAWA, Isa NKM (2015) Residential property hotspots forecasting in Greater Kuala Lumpur – economic characteristics and property attributes approach. Adv Environ Biol 9:8–10

Alpizar F, Carlsson F, Lanza G, Carney B, Daniels RC, Jaime M, Ho T, Nie Z, Salazar C, Tibesigwa B, Wahdera S (2020) A framework for selecting and designing policies to reduce marine plastic pollution in developing countries. Environ Sci Policy 109:25–35

Anbumani S, Kakkar P (2018) Ecotoxicological effects of microplastics on biota: a review. Environ Sci Pollut Res 25:14373–14396. https://doi.org/10.1007/s11356-018-1999-x

Åström L (2016) Shedding of synthetic microfibers from textiles. Institutionen för biologi och miljövetenskap Göteborgs universitet

Belzagui F, Crespi M, Álvarez A, Gutiérrez-Bouzán C, Vilaseca M (2019) Microplastics' emissions: microfibers' detachment from textile garments. Environ Pollut 248:1028–1035. https://doi.org/10.1016/j.envpol.2019.02.059

Carmichael A (2015) Man-made fibers continue to grow. Textileworld.com. http://www.textileworld.com/Issues/2015/_2014/Fiber_World/Man-Made_Fibers_Continue_To_Grow. Accessed on 29 Jun 2020

Carney Almroth BM, Åström L, Roslund S, Petersson H, Johansson M, Persson NK (2018) Quantifying shedding of synthetic fibers from textiles; a source of microplastics released into the environment. Environ Sci Pollut Res 25:1191–1199. https://doi.org/10.1007/s11356-017-0528-7

De Falco F, Gullo MP, Gentile G et al (2018) Evaluation of microplastic release caused by textile washing processes of synthetic fabrics. Environ Pollut 236:916–925. https://doi.org/10.1016/j.envpol.2017.10.057

Galvão A, Aleixo M, De Pablo H et al (2020) Microplastics in wastewater: microfiber emissions from common household laundry. Environ Sci Pollut Res 27:26643–26649. https://doi.org/10.1007/s11356-020-08765-6

Hansen A, Nielsen KB (2016) Cars, automobility and development in Asia: wheels of change. Routledge, New York. ISBN 1317396723

Hartline NL, Bruce NJ, Karba SN, Ruff EO, Sonar SU, Holden PA (2016) Microfiber masses recovered from conventional machine washing of new or aged garments. Environ Sci Technol 50:11532–11538. https://doi.org/10.1021/acs.est.6b03045

Hernandez E, Nowack B, Mitrano DM (2017) Polyester textiles as a source of microplastics from households: a mechanistic study to understand microfiber release during washing. Environ Sci Technol 51:7036–7046. https://doi.org/10.1021/acs.est.7b01750

Kelly MR, Lant NJ, Kurr M, Burgess JG (2019) Importance of water-volume on the release of microplastic fibers from laundry. Environ Sci Technol 53:11735–11744. https://doi.org/10.1021/acs.est.9b03022

Lusher A, Hollman P, Mandoza-Hill J (2017) Microplastics in fisheries and aquaculture

Mermaids Consortium (2017) Microfiber release from clothes after washing: hard facts, figures and promising solutions. Position Paper, (May), 1–9. Retrieved from https://www.plasticsoupfoundation.org/wp-content/uploads/2017/08/Position-Paper.Microfiber-release-from-clothes-after-wa. Accessed 12 July 2020

Napper IE, Thompson RC (2016) Release of synthetic microplastic plastic fibres from domestic washing machines: effects of fabric type and washing conditions. Mar Pollut Bull 112:39–45. https://doi.org/10.1016/j.marpolbul.2016.09.025

Novotna K, Cermakova L, Pivokonska L, Cajthaml T, Pivokonsky M (2019) Microplastics in drinking water treatment – current knowledge and research needs. Sci Total Environ 667:730–740. https://doi.org/10.1016/j.scitotenv.2019.02.431

Praveena SM, Shaifuddin SNM, Akizuki S (2018) Exploration of microplastics from personal care and cosmetic products and its estimated emissions to marine environment: an evidence from Malaysia. Mar Pollut Bull 136:135–140. https://doi.org/10.1016/j.marpolbul.2018.09.012

Saim Rashid (2017) Malaysia's demand structure with the influence of demographic factors. ARIBF Working Paper No. 2. Asian Research Institute of Banking and Finance. Kedah

Salvador Cesa F, Turra A, Baruque-Ramos J (2017) Synthetic fibers as microplastics in the marine environment: a review from textile perspective with a focus on domestic washings. Sci Total Environ 598:1116–1129. https://doi.org/10.1016/j.scitotenv.2017.04.172

Schöpel B, Stamminger R (2019) A comprehensive literature study on microfibres from washing machines. Tenside Surfactant Deterg 56:94–104

Sillanpää M, Sainio P (2017) Release of polyester and cotton fibers from textiles in machine washings. Environ Sci Pollut Res 24:19313–19321. https://doi.org/10.1007/s11356-017-9621-1

Vendel AL, Bessa F, Alves VEN, Amorim ALA, Patrício J, Palma ART (2017) Widespread microplastic ingestion by fish assemblages in tropical estuaries subjected to anthropogenic pressures. Mar Pollut Bull 117:448–455. https://doi.org/10.1016/j.marpolbul.2017.01.081

Zambrano MC, Pawlak JJ, Daystar J, Ankeny M, Cheng JJ, Venditti RA (2019) Microfibers generated from the laundering of cotton, rayon and polyester based fabrics and their aquatic biodegradation. Mar Pollut Bull 142:394–407. https://doi.org/10.1016/j.marpolbul.2019.02.062