Tropical Environment, Biology, and Technology

Review
Volume 1(1), 2023, 14-24
https://doi.org/10.53623/tebt.v1i1.221

Occurrence of Microplastics in Drinking Water in South East Asia: A Short Review

Wei Xuen New[1], Risky Ayu Kristanti[2]*, Helena Manik[2], Yureana Wijayanti[3,4], Daniel A. Adeyemi[5]

[1]Environmental Engineering Program, Curtin University Malaysia, CDT 250, Miri 98009, Malaysia
[2]Research Center for Oceanography, National Research and Innovation Agency, Jakarta, 14430, Indonesia
[3]Civil Engineering Department, Faculty of Engineering, Bina Nusantara University, Jakarta, Indonesia, 11480
[4]Environmental Engineering, School of Engineering and Energy, Murdoch University, Western Australia, Australia
[5]School of Science and Technology, Babcock University, Ilishan-Remo, Ogun State, Nigeria, Nigeria

*Correspondence: risky.ayu.kristanti@brin.go.id.

SUBMITTED: 12 March 2023; REVISED: 29 April 2023; ACCEPTED: 3 May 2023

ABSTRACT: This study reviews the levels and sources of microplastics in drinking water in Southeast Asia, assessing potential risks to human health and the environment, evaluating water treatment processes, and identifying remediation strategies to reduce microplastic pollution. Southeast Asia is home to nine of the ten most plastic-polluted rivers in the world, discharging vast amounts of plastic waste into the sea, causing adverse effects on marine biodiversity and ecosystems. Microplastics have become a global environmental issue and are found in various sources of drinking water, including tap water, plastic and glass bottled drinking water, treated water, and both single-use and returnable plastic bottled drinking water. Ingesting microplastics can cause physical damage and chemical toxicity, leading to health problems such as inflammation, DNA damage, and cancer. The study discusses physical, chemical, and biological methods for remediation, which have benefits and drawbacks and may not be effective in all situations. More research is needed to understand the extent of microplastic pollution in Southeast Asia and develop effective remediation strategies. Eliminating microplastics from the environment is necessary to protect ecosystems, wildlife, and human health.

KEYWORDS: Microplastics; drinking water; abundance; health; remediation method

1. Introduction

Microplastics (MPs), tiny bits of plastic with a diameter no more than 5 millimetres, are abundant in both underground and surface water bodies. Onshore activities, such as littering, industrial leaks, unprocessed or inadequately treated municipal effluent, and ship coating, contribute to deliberate and inadvertent plastic losses. Sea-based activities include unlawfully discarding fishing gear into the ocean [1, 2]. The chemical characteristics of MPs are crucial for detection. Fourier transform infrared spectroscopy (FTIR) and Raman spectroscopy are the two most common methods for identifying MPs based on chemical characterisation. FTIR spectroscopy uses knowledge of the molecular vibration of MPs particles to reliably detect MPs. Raman spectroscopy is one of the popular and straightforward methods for surface characterization, which can be used with Raman spectra imaging (microscopy) to create spatial chemical images based on the sample's Raman spectra and detect MPs [3, 4]. MPs may have a detrimental effect on nature due to their bio-accumulative properties, causing gastrointestinal blockages and damage, reducing the amount of energy produced by animals, and even leading to death [1, 5]. Therefore, it is essential to detect and mitigate MPs' presence in water bodies to prevent their harmful impact on wildlife and the environment.

Southeast Asia is home to 9 of the 10 most plastic-polluted rivers in the world, making it a region with a high level of microplastic contamination. The Mekong, Chao Phraya, and Irrawaddy rivers, among others, discharge a significant amount of plastic waste into the sea, causing adverse effects on marine biodiversity and ecosystems. In addition, Indonesia, the Philippines, and Thailand have been identified as some of the largest contributors to the ocean plastic pollution crisis. Microplastic pollution is also prevalent in the region's freshwater ecosystems, which are essential for providing clean water for drinking and irrigation [6, 7]. Several studies have found significant levels of MPs in freshwater sources across Southeast Asia, such as the Citarum River in Indonesia and the Saigon River in Vietnam [8, 9].

However, efforts to tackle plastic pollution in Southeast Asia have been hampered by weak waste management systems, inadequate infrastructure, and limited resources. A lack of awareness and education on plastic pollution also contributes to the issue. Nonetheless, there are initiatives being implemented to reduce plastic waste and promote sustainable practices in the region. Thailand has implemented a plastic bag ban, and Indonesia has pledged to reduce marine plastic debris by 70% by 2025. The Association of Southeast Asian Nations (ASEAN) has launched a framework for action on marine debris, highlighting the importance of reducing plastic waste and promoting sustainable waste management practices in the region [7-9].

The prevalence of microplastic pollution in Southeast Asia is a cause for concern and requires urgent action to address the issue. Effective waste management practices, improved infrastructure, and education on sustainable practices are necessary to reduce the amount of plastic waste entering the environment and ultimately reduce the negative impact of MPs on human health and the ecosystem. This research aims to review the levels and sources of microplastics in drinking water in Southeast Asian countries, assess the potential risks to human health and the environment, evaluate existing water treatment processes, and identify remediation strategies to reduce microplastic pollution.

2. Occurrence and Source.

2.1. Drinking water and wastewater treatment plant.

MPs have been detected in Southeast Asia, including in drinking water. Previous studies have tested tap and bottled water, as well as raw water and water treatment plants. In Surabaya, Indonesia, the water supply system was found to be contaminated with microplastics, leading residents to rely on bottled water or water refilling stations for their drinking water. Two popular bottled water brands and three frequently used water refilling stations were tested, with one bottled water brand found to contain polyethylene terephthalate (PET) microplastics at an average concentration of 7.585 µg/g and one water refilling station found to have high concentrations of LDPE microplastics (30.21 µg/g) [10].

In Bangkok, four drinking water treatment plants (DWTPs) were analyzed, and microplastic contamination was found in riverine water designated for drinking water production, with an average concentration ranging from 0.43 to 1.52 particles per liter [11]. This raises concerns about the potential health risks associated with consuming microplastic-contaminated water. In Malaysia, eight major bottled water brands were analyzed to determine the presence of microplastics and potential human exposure. The researchers used a membrane filtration method followed by visual and polymer identification to detect microplastic particles. The samples of bottled water contained microplastic concentrations ranging from 8 to 22 particles per liter, with an average of 11.7 ± 4.6 particles per liter. The most common types of microplastics found were fragments, and transparent-colored microplastics were the most prevalent. Particles ranging between 100 and 300 µm in size were the most dominant, accounting for approximately 31% of microplastics in these bottled water brands [12]. These findings underscore the need for further investigation into the potential health risks associated with the ingestion of microplastics through bottled water consumption.

Polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), and polyethylene succinate (PEST) are the most commonly found types of plastic in drinking water. Characterization of microplastics (MPs) is often conducted using FTIR and Raman spectroscopy. Schymanski et al. found that PEST contributed to 84% and 59% of reusable and single-use plastic bottled water samples, respectively [13]. Previous studies have shown that the concentration of MPs in treated water from water treatment plants is very low (0.0007 and 0.003 particles/L), which is attributed to the high removal rate of MPs in these facilities. Surface water, groundwater, ocean water, and grey water are all influents of drinking water treatment plants. Some innocuous compounds present in raw water may not be removed during the treatment process, and MPs can subsequently enter the treated water and ultimately our drinking water through these water sources [14, 15].

Another research examined the presence and distribution of microplastics (MPs) in influent and effluent from three typical industrial wastewater treatment plants (WWTPs) in Danang, Vietnam. The study found that the average abundance of MPs in the influent and effluent was 183-443 particles per liter and 138-340 particles per liter, respectively. The MPs removal efficiency was ranged from to be 21.8% - 25.5%, respectively. Consequently, the average loading capacity of MPs released to the environment was estimated to be 1.5×10^7 to 8.3×10^7 particles per day, respectively. The results of this study suggest that measures should be taken to reduce microplastic pollution in industrial wastewater and prevent its discharge into the environment [16].

2.2. Household.

Microplastics (MPs) can be found in households in Southeast Asian countries due to several reasons. One of the main factors is plastic packaging. Household items, including food and beverage containers, are frequently made of plastic, which can break down into smaller particles and end up in the environment. Synthetic fabrics, such as polyester and nylon, are also commonly used in clothing and textiles. These fabrics shed microfibers when washed, which can enter wastewater treatment plants and ultimately end up in waterways and oceans.

Additionally, personal care products like exfoliating scrubs and toothpaste contain microbeads made of plastic that can enter the water system when washed off. Some cleaning products, such as liquid detergents and fabric softeners, also contain microplastics that can end up in wastewater. The study discovered high levels of PP in rice and tempeh, both of which are widely consumed in Indonesia as staple foods. Rice is the primary carbohydrate source, while tempeh, a fermented soybean cake, is a major protein source. The investigation also looked into the presence of microplastics in table salts and toothpaste commonly used by participants to determine the extent of contamination in human consumables. The analysis showed that all tested samples of salt and toothpaste contained microplastics. Table salts had high levels of PP (8.69 µg/g) and LLDPE (26.27 µg/g), while toothpaste had high levels of PP (23.47 µg/g) and HDPE (14.79 µg/g) [10].

2.3. Industry discharge.

The production and disposal of plastic materials by industries are one of the primary sources of MPs in the environment. As plastic products break down, either through natural weathering or improper disposal, they release microplastics into the air, water, and soil [17]. Additionally, industries involved in textile manufacturing, food and beverage processing, and pharmaceutical production can contribute to the discharge of microplastics into the environment through the release of wastewater containing microplastics. Rubber is a major industrial commodity in Southeast Asian countries, particularly in Indonesia, Thailand, and Malaysia [18]. These countries are among the largest natural rubber producers in the world, with Indonesia being the largest producer, followed by Thailand and Malaysia. The rubber industry is a significant source of microplastic (MPs) pollution due to several factors. Firstly, the process of producing rubber involves the use of various chemicals and synthetic materials, including plasticizers, stabilizers, and antioxidants, which can release MPs into the environment during production and disposal. Secondly, rubber waste generated from the manufacturing process can also contribute to MPs pollution when not properly disposed of. Finally, the use of rubber products, such as tires and rubber gloves, can release MPs into the environment through wear and tear [19, 20]. Improper disposal of tires can also exacerbate the plastic pollution problem. Dumping tires in landfills can cause them to break down into smaller pieces, releasing microplastics into the environment. Additionally, leaving tires in open areas or throwing them into water bodies can cause even more harm. Over time, they can break down into tiny particles that can be ingested by marine animals and ultimately enter the food chain, leading to further environmental degradation [21].

3. Impact to human health

There is still ongoing research about the potential impacts of microplastics on human health, but studies have shown that microplastics can enter our bodies through ingestion, inhalation, and dermal exposure. Once inside our bodies, they can potentially cause harm in several ways. In Southeast Asia, where plastic waste management systems are often inadequate, microplastics are likely to continue to pose a significant threat to human health unless appropriate measures are taken to reduce plastic pollution. Therefore, it is crucial for governments and communities in the region to work together to improve waste management infrastructure and to raise public awareness about the importance of reducing plastic use to protect both human health and the environment [22]. It is suggested that the smaller the size of the microplastic, the easier it is for humans to ingest or inhale, potentially allowing it to enter the bloodstream or accumulate in organs such as the lungs, liver, or kidneys. Research has shown that microplastics can cause tissue damage, inflammation, and other negative health effects in animals. While the impacts of microplastics on human health are not yet fully understood, it is suspected that similar effects could occur in humans [23]. In addition to size, the type of polymer used to make the microplastic can also affect its potential health impacts. Certain polymers, like polyvinyl chloride (PVC) and polyethylene terephthalate (PET), which are commonly used in food packaging, can break down into harmful chemicals when exposed to heat or sunlight. These chemicals can then leach into food and potentially cause harm to human health. Other polymers, such as polypropylene (PP) and polyethylene (PE), are generally considered safer and less likely to break down into harmful chemicals [24, 25]. A recent study first observed the presence of MPs in the human placenta with a size range from 0.005 to 0.01 mm [31, 32]. MPs in the circulation system may cause inflammation, oxidative stress, increased coagulability, pulmonary hypertension, and cytotoxicity. Other recent studies indicated that the exposure of humans to MPs leads to the interruption of the immune system. As a result, children aged 5 to 11 have a higher possibility, approximately 70%, of being diagnosed with asthma. MP is also considered particulate matter, which may provoke chronic inflammation or other immune system diseases that increase the possibility of diagnosed cancer [26, 27].

Remediation

3.1.Physical methods.

The advantages and disadvantages of different remediation methods is shown in Table 1. The sponge made of chitin has the ability to adsorb MPs effectively. The efficiency of the sponge is increased by adding oxygen-doped carbon nitride ($O\text{-}C_3N_4$) and graphene oxide (GO) into it. GO and $O\text{-}C_3N_4$ conquer the porous structure of the sponge, thereby amplifying water and MPs adsorption efficiency. Functionalised MPs with different charges are adsorbed on the sponge by hydrogen bonds, π–π interactions, and electrostatics. The reinforced sponge can remove aminated polystyrene with higher efficiency than an ordinary sponge, with removal efficiency elevated from 70.4% to 83.2%. The sponge is reusable and can be used for a maximum of three cycles due to its outstanding compressibility, achieving 40 and 50 MPa at wet and dry conditions, respectively. The reinforced sponge is biodegradable in a natural environment, and it shows no discrimination against microorganisms. However, the sponge exhibits different affinity to different charged MPs, and its adsorptive efficiency for negatively charged MPs is lower. Carboxylated polystyrene exhibits much lower removal efficiency by the reinforced sponge, attributed to its negatively charged nature [28, 29].

Ultrafiltration is a method of separating MPs that requires less energy and cost and achieves higher removal efficiency. The primary mechanism of ultrafiltration is the rejection or blocking of MPs larger than the pore size on the influent side, while the MPs are adsorbed into or on the pores and surfaces of the membrane, eliminating MPs from the water. Lapoinate et al. suggested that ultrafiltration membrane is the most capable technique for MPs removal, with over 90% of remediation efficiency compared to other conventional processes such as adsorption and air flotation [30]. The ultrafiltration membrane achieved 100% removal of polyethylene due to its larger dimension compared to the pores (30 nm). However, membrane fouling is always a problem. Membrane fouling is triggered when concentration polarisation happens near the membrane wall when water passes through the membrane. The size of MPs is particularly significant to the membrane fouling. Previous studies indicated that the membrane flux reduced to 83% of the initial flux after a period of time. The tinier the particle size, the more consequential the membrane fouling [31, 32]. The schematic of ultrafiltration technology in microplastics removal is shown in Figure 1.

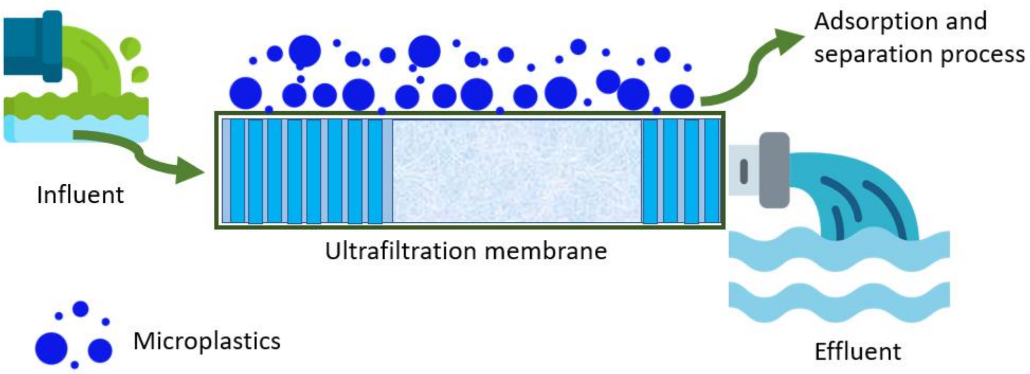

Figure 1. The schematic of ultrafiltration technology in microplastics removal.

3.2.Biological Method.

In the activated sludge process, microorganisms such as protozoa, metazoan, plankton, and mussels help in the removal of MPs through degradation, adsorption, or aggregation. The removal rate of MPs in the activated sludge process from a WWTP was reported to reach up to 16.6% [33]. Additionally, flocculants such as ferric sulphate ($Fe_2(SO_4)_3$) have been shown to increase the efficiency of MPs removal from the activated sludge process [33, 24]. This method is effective for removing MPs of various sizes and shapes, with the highest removal rate reported for MPs ranging from 1 to 5 mm [33]. The membrane bioreactor is another widely accepted method for the removal of MPs from wastewater due to its high-quality output and small footprint. This method combines filtration with suspended growth biological reactors to remove MPs. The membrane bioreactor has been reported to remove MPs up to 80% in urban WWTPs and 99% in municipal WWTPs [33, 35]. This technique is effective in removing MPs of various sizes and types, including microfibers, microbeads, and nanoplastics [33].

One of the advantages of the activated sludge process and membrane bioreactor is that they are cost-effective and require less energy compared to other conventional methods of MPs removal, such as adsorption and air flotation. Moreover, these methods can remove a wide range of MPs with varying sizes and shapes. Another advantage of the membrane bioreactor is that it produces high-quality treated wastewater that can be reused for non-potable purposes such as irrigation, reducing the demand for freshwater resources. However, it should be noted that both the activated sludge process and membrane bioreactor have limitations in removing MPs smaller than 1 µm in size. Moreover, both methods may contribute to the accumulation of MPs in the sludge, which can pose a risk of secondary pollution if not disposed of properly.

Therefore, it is crucial to combine these methods with other advanced techniques to achieve a more comprehensive and efficient MPs removal [34].

3.3.Chemical method.

Photocatalysis and Fenton process are two effective methods for the removal of MPs from water sources. The Fenton Process utilizes hydroxyl radicals ($OH^{\cdot}$), which are highly reactive and are produced when Fe^{2+} reacts with H_2O_2, to oxidize organic impurities and pollutants. This results in the degradation of the pollutants into mineral products, carbon dioxide, and water. The Fenton Process has shown to achieve a high rate of MPs weight loss, reaching up to 96%, and a mineralization efficacy of 76% due to the active hydroxyl radicals, proton-rich environment, and synergy of hydrothermal hydrolysis [33, 34]. Another method for the remediation of MPs is photocatalysis, which is cheap and energy-effective. In this method, MPs are degraded under visible light, such as sunlight, with the assistance of a photocatalyst such as N-TiO_2, ZnO, ZnS, ZrO_3, and BiOCl. When the photons from the light provide enough energy, the photocatalyst produces excited electrons (e^-) and holes (h^+). These holes (h^+) then interact with water molecules or hydroxyl groups (OH-) to generate hydroxyl radicals ($OH^{\cdot}$), which are capable of degrading organic contaminants due to their strong oxidizing property. Ariza-Tarazona et al. have reported up to 6.40% of mass loss of high-density polyethylene (HDPE) in the aqueous medium during the photocatalytic degradation using photocatalyst N-TiO_2 [35, 36]. However, temperature and pH values play a crucial role in this method, as low pH values (pH 3) and temperature (273.15 K) achieved the highest mass loss, which was 71.77 ± 1.88%. Although this method is considered new in MPs remediation, as other parameters have not been investigated yet, further research is required [37].

Table 1. Advantages and disadvantages of different remediation methods

Type	Method	Advantages	Disadvantage	Reference
Physical	Adsorption	-Reusability -Biodegradable	-Selective affinity to different charged of MPs	[28, 29]
	Filtration	-Cost- and energy efficient -High removal efficiency	-MPs smaller than the mesh size can be missed -Decreased efficiency induced by membrane fouling	[30, 31]
Chemical	Photocatalyst Degradation	-High energy efficient -Cheap	-Better performance only in specific condition	[35, 36]
	Fenton Process	-High Efficiency -Sustainable	-Narrow working pH range -High cost and risks for transportation of H_2O_2 and Fe^{2+}	[33, 34]
Biological	Activated Sludge Process	-Relatively low initial cost -Hygienic, safe, and convenient	-Required stable of volume and type sludge being processed -May not be suitable for all type of wastewater	[33-35]
	Membrane Bioreactor	-High quality, disinfected product -Decreased sludge waste	-Complexity -Costly compared to Activated Sludge Process	[34]

4. Conclusions

In conclusion, the occurrence of microplastics (MPs) in drinking water has become a global concern, and South East Asia is not an exception. The high population density, rapid urbanization, and inadequate waste management practices in the region have led to the widespread distribution of MPs in the environment, including in drinking water sources. This issue poses a significant threat to human health and the environment. Studies conducted in South East Asia have reported the presence of MPs in various wastewater treatment plant and drinking water sources, including tap water, bottled water, and groundwater. The studies have revealed that the concentration of MPs varies depending on the source and location. The most commonly found MPs include fibers, fragments, and films, which are known to have adverse health effects on humans. Several methods have been proposed for the removal of MPs in drinking water, including the use of activated carbon, membrane filtration, Fenton process, and photocatalysis. These methods have shown promising results in removing MPs from drinking water. However, further research is needed to determine the most effective and cost-efficient method for large-scale removal of MPs from drinking water. The presence of MPs in drinking water is a growing concern that requires urgent attention from governments, policymakers, and the public. The implementation of effective waste management practices and the adoption of sustainable production and consumption patterns can reduce the release of MPs into the environment. Additionally, regular monitoring of drinking water sources and treatment plants can help identify the sources of MPs and ensure the provision of safe drinking water to the public.

Acknowledgments

The authors thank Curtin Universiti Malaysia and National Research and Innovation Agency (BRIN) Indonesia for facilitating this work. Collaboration from Bina Nusantara University Indonesia, Murdoch University Australia, and Babcock University Nigeria is highly appreciated.

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Riani, E.; Cordova, M. R. (2022). Microplastic ingestion by the sandfish Holothuria scabra in Lampung and Sumbawa, Indonesia. *Marine Pollution Bulletin*, *175*, 113134. https://doi.org/10.1016/j.marpolbul.2021.113134.

[2] Prata, J.C. (2018). Airborne microplastics: Consequences to human health? *Environmental Pollution, 234*, 115–126. https://doi.org/10.1016/j.envpol.2017.11.043.

[3] Primpke, S.; Wirth, M.; Lorenz, C.; Gerdts, G. (2018). Reference database design for the automated analysis of microplastic samples based on Fourier transform infrared (FTIR) spectroscopy. *Analytical and Bioanalytical Chemistry*, *410*, 5131–5141. https://doi.org/10.1007/s00216-018-1156-x.

[4] Lv, L.; He, L.; Jiang, S.; Chen, J.; Zhou, C.; Qu, J.; Lu, Y.; Hong, P.; Sun, S.; Li, C. (2020). In situ surface-enhanced Raman spectroscopy for detecting microplastics and nanoplastics in aquatic

environments. *Science of the Total Environment*, *728*, 138449. https://doi.org/10.1016/j.scitotenv.2020.138449.

[5] Ivleva, N.P.; Wiesheu, A.C.; Niessner, R. (2017). Microplastic in Aquatic Ecosystems. *Angewandte Chemie - International Edition*, *56*, 1720–1739. https://doi.org/10.1002/anie.201606957.

[6] Lebreton, L.C.; Van der Zwet, J.; Damsteeg, J.W.; Slat, B.; Andrady, A.; Reisser, J. (2017). River plastic emissions to the world's oceans. *Nature Communications*, *8*, 1-10. https://doi.org/10.1038/ncomms15611.

[7] Ricciardi, M.; Pironti, C.; Motta, O.; Miele, Y.; Proto, A.; Montano, L. (2021). Microplastics in the Aquatic Environment: Occurrence, Persistence, Analysis, and Human Exposure. *Water*, *13*, 973. https://doi.org/10.3390/w13070973.

[8] Nguyen, N.T.; Nhon, N.T.T.; Hai, H.T.N.; Chi, N.D.T.; Hien, T.T. (2022). Characteristics of Microplastics and Their Affiliated PAHs in Surface Water in Ho Chi Minh City, Vietnam. *Polymers*, *14*, 2450. https://doi.org/10.3390/polym14122450.

[9] Sembiring, E., Fareza, A.A., Suendo, V. *et al.* (2020). The Presence of Microplastics in Water, Sediment, and Milkfish (*Chanos chanos*) at the Downstream Area of Citarum River, Indonesia. *Water Air Soil Pollut*, *231*, 355. https://doi.org/10.1007/s11270-020-04710-y.

[10] Luqman, A.; Nugrahapraja, H.; Wahyuono, R.A.; Islami, I.; Haekal, M.H.; Fardiansyah, Y.; Putri, B.Q.; Amalludin, F.I.; Rofiqa, E.A.; Götz, F.; Wibowo, A.T. (2021). Microplastic Contamination in Human Stools, Foods, and Drinking Water Associated with Indonesian Coastal Population. *Environments*, *8*, 138. https://doi.org/10.3390/environments8120138.

[11] Chanpiwat, P.; Damrongsiri, S. (2021). Abundance and characteristics of microplastics in freshwater and treated tap water in Bangkok, Thailand. *Environmental Monitoring and Assessment*, *193*, 258. https://doi.org/10.1007/s10661-021-09012-2.

[12] Praveena, S.M.: Ariffin, N.I.I.; Nafisyah, A.L. (2022). Microplastics in Malaysian bottled water brands: Occurrence and potential human exposure. *Environmental Pollution*, *315*, 120494, https://doi.org/10.1016/j.envpol.2022.120494.

[13] Mintenig, S.M.; Löder, M.G.J.; Primpke, S.; Gerdts, G. (2019). Low numbers of microplastics detected in drinking water from ground water sources. *Science of The Total Environment*, *648*, 631–635. https://doi.org/10.1016/J.SCITOTENV.2018.08.178.

[14] Johnson, A.C.; Ball, H.; Cross, R.; Horton, A.A.; Jürgens, M.D.; Read, D.S.; Vollertsen, J.; Svendsen, C. (2020). Identification and Quantification of Microplastics in Potable Water and Their Sources within Water Treatment Works in England and Wales. *Environmental Science and Technology*, *54*(19), 12326–12334.

[15] Pivokonsky, M.; Cermakova, L.; Novotna, K.; Peer, P.; Cajthaml, T.; Janda, V. (2018). Occurrence of microplastics in raw and treated drinking water. Science of The Total Environment, 643, 1644–1651. https://doi.org/10.1016/J.SCITOTENV.2018.08.102

[16] Do, M.V.; Le, T.X.T.; Vu, N.D.; Dang, T.T. (2022). Distribution and occurrence of microplastics in wastewater treatment plants. *Environmental Technology & Innovation*, *26*, 102286. https://doi.org/10.1016/j.eti.2022.102286.

[17] Kumari, A.; Rajput, V.D.; Mandzhieva, S.S.; Rajput, S.; Minkina, T.; Kaur, R.; Sushkova, S.; Kumari, P.; Ranjan, A.; Kalinitchenko, V.P.; Glinushkin, A.P. (2022). Microplastic Pollution: An Emerging Threat to Terrestrial Plants and Insights into Its Remediation Strategies. *Plants*, *11*, 340. https://doi.org/10.3390/plants11030340.

[18] Hytönen, J.; Nurmi, J.; Kaakkurivaara, N.; Kaakkurivaara, T. Rubber Tree (*Hevea brasiliensis*) Biomass, Nutrient Content, and Heating Values in Southern Thailand. *Forests* **2019**, *10*, 638. https://doi.org/10.3390/f10080638.

[19] Carrasco-Navarro, V.; Nuutinen, A.; Sorvari, J.; Kukkonen, J.V. (2022). Toxicity of Tire Rubber Microplastics to Freshwater Sediment Organisms. *Archieves of Environmental Contamiantion and Toxicology*, *82*, 180–190. https://doi.org/10.1007/s00244-021-00905-4.

[20] Poma, A.; Aloisi, M.; Bonfigli, A.; Colafarina, S.; Zarivi, O.; Aimola, P.; Vecchiotti, G.; Arrizza, L.; Di Cola, A.; Cesare, P. (2023). Particle Debris Generated from Passenger Tires Induces Morphological and Gene Expression Alterations in the Macrophages Cell Line RAW 264.7. *Nanomaterials*, *13*, 756. https://doi.org/10.3390/nano13040756.

[21] Mihai, F.-C.; Gündoğdu, S.; Markley, L.A.; Olivelli, A.; Khan, F.R.; Gwinnett, C.; Gutberlet, J.; Reyna-Bensusan, N.; Llanquileo-Melgarejo, P.; Meidiana, C.; Elagroudy, S.; Ishchenko, V.; Penney, S.; Lenkiewicz, Z.; Molinos-Senante, M. (2022). Plastic Pollution, Waste Management Issues, and Circular Economy Opportunities in Rural Communities. *Sustainability*, *14*, 20. https://doi.org/10.3390/su14010020.

[22] Ng, C.H.; Mistoh, M.A.; Teo, S.H.; Galassi, A.; Ibrahim, A.; Sipaut, CS.; Foo, J.; Seay, J.; Taufiq-Yap, YH.; Janaun, J. (2023) Plastic waste and microplastic issues in Southeast Asia. *Frontier in Environmental Science*, *11*, 1142071. https://doi.org/10.3389/fenvs.2023.1142071.

[23] Yee, M.S.; Hii, L.W.; Looi, C.K.; Lim, W.M.; Wong, S.F.; Kok, Y.Y.; Tan, B.K.; Wong, C.Y.; Leong, C.O. (2021), Impact of Microplastics and Nanoplastics on Human Health. *Nanomaterials* *11*, 496. https://doi.org/10.3390/nano11020496.

[24] Yuan, Z.; Nag, R.; Cummins, E. (2022). Ranking of potential hazards from microplastics polymers in the marine environment. *Journal of Hazardous Materials*, *429*, 128399, https://doi.org/10.1016/j.jhazmat.2022.128399.

[25] Kefer, S.; Miesbauer, O.; Langowski, H.-C. (2021). Environmental Microplastic Particles vs. Engineered Plastic Microparticles—A Comparative Review. *Polymers*, *13*, 2881. https://doi.org/10.3390/polym13172881.

[26] Farhat, S.C.L.; Silva, C.A.; Orione, M.A.M.; Campos, L.M.A.; Sallum, A.M.E.; Braga, A.L.F. (2011). Air pollution in autoimmune rheumatic diseases: A review. *Autoimmunity Reviews*, *11*, 14–21. https://doi.org/10.1016/J.AUTREV.2011.06.008.

[27] Prata, J. (2018). Controlling land-based sources as a measure to reduce (micro)plastic contamination in coastal environments. *Frontiers in Marine Science Conference Abstract: IMMR'18*, *5*. https://doi.org/10.3389/conf.fmars.2018.06.00094.

[28] Goh, P.S.; Kang, H.S.; Ismail, A.F.; Khor, W.H.; Quen, L.K.; Higgins, D. (2022). Nanomaterials for microplastic remediation from aquatic environment: Why nano matters? *Chemosphere*, *299*, 134418. https://doi.org/10.1016/J.CHEMOSPHERE.2022.134418.

[29] Wang, Z.; Sun, C.; Li, F.; Chen, L. (2021). Fatigue resistance, re-usable and biodegradable sponge materials from plant protein with rapid water adsorption capacity for microplastics removal. *Chemical Engineering Journal*, *415*, 129006. https://doi.org/10.1016/J.CEJ.2021.129006.

[30] Lapointe, M.; Farner, J.M.; Hernandez, L.M.; Tufenkji, N. (2020). Understanding and Improving Microplastic Removal during Water Treatment: Impact of Coagulation and Flocculation. *Environmental Science and Technology*, *54*, 8719–8727. https://doi.org/10.1021/ACS.EST.0C00712/SUPPL_FILE/ES0C00712_SI_001.PDF.

[31] Ma, B.; Xue, W.; Hu, C.; Liu, H.; Qu, J.; Li, L. (2019). Characteristics of microplastic removal via coagulation and ultrafiltration during drinking water treatment. *Chemical Engineering Journal*, *359*, 159–167. https://doi.org/10.1016/j.cej.2018.11.155.

[32] Liu, X.; Yuan, W.; Di, M.; Li, Z.; Wang, J. (2019). Transfer and fate of microplastics during the conventional activated sludge process in one wastewater treatment plant of China. *Chemical Engineering Journal*, *362*, 176–182. https://doi.org/10.1016/J.CEJ.2019.01.033.

[33] Iyare, P.U.; Ouki, S.K.; Bond, T. (2020). Microplastics removal in wastewater treatment plants: a critical review. *Environmental Science Water Research & Technology*, *6*, 2664.

http://doi.org/10.1039/d0ew00397b.
[34] Lares, M.; Ncibi, M.C.; Sillanpää, M.; Sillanpää, M. (2018). Occurrence, identification and removal of microplastic particles and fibers in conventional activated sludge process and advanced MBR technology. *Water Research*, *133*, 236–246. http://doi.org/10.1016/j.watres.2018.01.049.
[35] Ariza-Tarazona, M.C.; Villarreal-Chiu, J.F.; Barbieri, V.; Siligardi, C.; Cedillo-González, E.I. (2019). New strategy for microplastic degradation: Green photocatalysis using a protein-based porous N-TiO2 semiconductor. *Ceramics International*, *45*, 9618–9624. https://doi.org/10.1016/J.CERAMINT.2018.10.208.
[36] Ahmed, M.B.; Rahman, M.S.; Alom, J.; Hasan, M.S.; Johir, M.A.H.; Mondal, M.I.H.; Lee, D.Y.; Park, J.; Zhou, J.L.; Yoon, M.H. (2021). Microplastic particles in the aquatic environment: A systematic review. *Science of the Total Environment*, *775*, 145793. https://doi.org/10.1016/j.scitotenv.2021.145793.
[37] Zhang, M.; Li, J.; Ding, H.; Ding, J.; Jiang, F.; Ding, N.X.; Sun, C. (2019). Distribution Characteristics and Influencing Factors of Microplastics in Urban Tap Water and Water Sources in Qingdao, China. *Water, Air, & Soil Pollution*, *230*, 1312–1327. https://doi.org/10.1080/00032719.2019.1705476.