EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2024, 25(11), 260–273
https://doi.org/10.12912/27197050/192678
ISSN 2299–8993, License CC-BY 4.0

Received: 2024.08.24
Accepted: 2024.09.15
Published: 2024.10.01

Characterization of Microplastics in Jakarta's Urban Downstream and Estuary Water Bodies

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ABSTRACT

Microplastic pollution in urban water bodies is a growing environmental challenge with significant implications for ecosystems and human health. This study aims to characterize microplastic contamination in Jakarta's Sunter River, Buaran River, and Marunda Estuary, which are crucial conduits for plastic waste into the marine environment. Using Raman spectroscopy, we conducted an extensive analysis of water, sediment, and biota samples from these sites to identify the types and sources of microplastic polymers present. Our findings reveal significant contamination, with polyethylene terephthalate (PET) and polypropylene (PP) being the most common polymers. The Sunter River had high levels of PET, primarily from discarded beverage bottles and food packaging, while the Buaran River was primarily contaminated with PP, commonly found in plastic containers, automotive parts, and textiles. In contrast, the Marunda Estuary showed a distinct pollution pattern, with a significant presence of foam particles likely originating from construction and packaging materials. This research demonstrates the effectiveness of Raman spectroscopy in precisely and consistently identifying microplastics, surpassing traditional visual inspection methods. By accurately determining the chemical composition of microplastics, Raman spectroscopy enhances our understanding of the origins and pathways of plastic pollution in urban environments. The study's conclusions underscore the need for targeted waste management strategies to address specific polymer types and reduce their environmental impact. For example, increasing recycling efforts for PET bottles and minimizing the use of single-use plastics made from PP could significantly decrease the presence of these microplastics in water bodies. Furthermore, by elucidating the polymer composition of microplastics, our work contributes to a better understanding of the associated health risks, as different polymers interact differently with environmental toxins. However, this study has limitations. It focuses only on selected urban water bodies in Jakarta, and the findings may not be applicable to other regions. Despite these limitations, our research has practical value, as it can inform policy-making and the development of interventions to mitigate microplastic pollution in urban aquatic environments.

Keywords: microplastic pollution, water quality, urban water bodies, Jakarta, polymer identification, plastic waste management, environmental health.

INTRODUCTION

Microplastics, defined as plastic particles smaller than 5 mm, have emerged as a pervasive environmental pollutant (Devi et al., 2023; Kurniawan et al., 2023; Matluba et al., 2023). Originating from various sources, including the fragmentation of larger plastic debris, the shedding of synthetic fibers from clothing, and the use of microbeads in personal care products (Jagatee et al., 2024; Tyagi, 2024), microplastics have been detected in virtually all environmental compartments. They pose significant ecological risks due to their small size, which allows them to be ingested by a wide range of organisms, from plankton to large marine mammals (Liu et al., 2024). Additionally, microplastics can act as vectors for chemical contaminants, potentially leading to bioaccumulation and biomagnification in food webs (Liaqat et al., 2024; Xu et al., 2024). Urban water bodies, such as rivers, estuaries, and canals (Kunz et al., 2023; Li et al., 2023), are particularly susceptible to microplastic pollution due to the high population density and industrial activities in surrounding areas.

Jakarta, the capital city of Indonesia, is no exception. With its rapid urbanization, inadequate waste management infrastructure (Suryawan and Lee, 2024a), and extensive use of plastic products, Jakarta faces significant challenges in managing plastic waste (Sari et al., 2022; Yang, 2024). The city's rivers and estuaries often serve as conduits for plastic debris, transporting it from urban areas to coastal and marine environments (Sianipar et al., 2022; Cordova et al., 2023; Sianipar and Lee, 2024; Suryawan et al., 2024). The Sunter River, Sunter River, and Marunda Estuary are key water bodies in Jakarta that are heavily impacted by urban runoff and waste discharge (Caljouw et al., 2009). These water bodies receive a continuous influx of pollutants, including microplastics (Saravanan et al., 2021; Lin et al., 2024), from various sources such as residential areas, industrial zones, and commercial establishments. The high levels of plastic pollution in these water bodies not only degrade water quality but also pose threats to aquatic life and human health (Sharma and Chatterjee, 2017; Bashir et al., 2020).

Previous studies have highlighted the widespread presence of microplastics in Jakarta's water bodies (Hastuti et al., 2019; Cordova et al., 2022; Henny et al., 2023). However, most of these studies have relied on visual identification methods, which can be subjective and limited in their ability to accurately characterize the types of microplastics present. Visual identification alone cannot provide detailed information about the chemical composition of microplastic particles, which is crucial for understanding their sources, behavior, and potential impacts. Visual identification alone cannot provide detailed information about the chemical composition of microplastic particles, which is crucial for understanding their sources, behavior, and potential impacts. Raman spectroscopy has emerged as a powerful analytical technique for the identification and characterization of microplastics (Ribeiro-Claro et al., 2017; Araujo et al., 2018; Tirkey and Upadhyay, 2021; Nava et al., 2021). This technique uses the scattering of monochromatic light to provide detailed information about the molecular composition of a sample. By comparing the Raman spectra of suspected microplastic particles with reference spectra of known polymers, this can accurately determine the types of plastics present in environmental samples (Lenz et al., 2015; Levermore et al., 2020). Raman spectroscopy is particularly valuable for distinguishing between different types of polymers that may look similar under a microscope but have different chemical properties and environmental behaviors. In this study, Raman spectroscopy was used to characterize the microplastic particles found in water samples. The objective was to provide a more detailed and accurate assessment of the types of microplastics present in these urban water bodies, thereby enhancing our understanding of the sources and pathways of plastic pollution in Jakarta. This study seeks to fill the gap in knowledge regarding the specific polymer composition of microplastics in Jakarta's water bodies, which has not been thoroughly investigated in previous research. By identifying the specific polymers that make up the microplastic particles, the aim was to trace their origins and suggest targeted strategies for mitigating plastic pollution. Our hypotheses focus on the identification of predominant polymer types, such as PET and PP, and their sources, which are hypothesized to differ across the studied water bodies due to varying local pollution sources. Findings from other studies have also underscored the critical role of advanced analytical techniques in microplastic research. For instance, the use of Fourier Transform Infrared (FTIR) spectroscopy has provided significant insights into the prevalence and types of microplastics in various environments (Kutralam-Muniasamy et al., 2020; Cowger et al., 2020; Teboul et al., 2021; Perumal and Muthuramalingam, 2022). Similarly, the combination of Raman spectroscopy and FTIR has been shown to enhance the accuracy of microplastic identification, particularly in complex environmental matrices (Käppler et al., 2016; Vinay Kumar et al., 2021).

The primary scientific objective of this research is to provide a comprehensive and detailed characterization of microplastic pollution in Jakarta's urban water bodies by identifying the specific polymer types present. Unlike previous studies, which primarily relied on visual identification methods

(Karlsson et al., 2020; Lusher et al., 2020; Lv et al., 2021), this study employs Raman spectroscopy to achieve a higher level of accuracy in detecting and categorizing microplastics. This approach seeks to uncover previously unknown patterns of microplastic distribution and composition across different water bodies, identify specific sources of polymer contamination, and determine the factors that influence the variability in microplastic pollution. By analyzing the spatial distribution of different polymer types, this study aims to establish correlations between local environmental conditions, human activities, and the prevalence of specific microplastics. We hypothesize that the predominant polymers, such as PET and PP, exhibit distinct variations across different water bodies due to the influence of localized pollution sources, such as industrial activities, waste management practices, and urban runoff. By uncovering these previously undocumented patterns and correlations, this research aims to fill a critical gap in the understanding of how microplastic pollution manifests and spreads in urban environments. The anticipated findings are expected to provide new insights into the pathways and origins of microplastic contaminants in Jakarta, ultimately informing the development of more effective and targeted waste management strategies and pollution mitigation efforts.

The analysis conducted in this study revealed significant levels of PET in Jakarta, primarily originating from beverage bottles and food packaging (Amin et al., 2022; Azizi et al., 2024). The implications of these findings are significant for environmental management and policymaking. By pinpointing the types of polymers prevalent in microplastic pollution, authorities can better tailor their waste management strategies. Microplastics can adsorb toxic chemicals from the environment, which may then be ingested by aquatic organisms and potentially enter the human food chain. Understanding the polymer composition of microplastics can help assess the risk of these health impacts, as different polymers have varying capacities to adsorb and release harmful substances. This detailed knowledge of the types of microplastics present is crucial for evaluating and mitigating health risks. Each water body can have different pollution sources and patterns, necessitating customized approaches to mitigation. The presence of foam particles in the Marunda Estuary suggests specific sources like construction sites or packaging industries, highlighting the need for targeted interventions in these sectors. This study's comprehensive approach to microplastic analysis, combining Raman spectroscopy with visual inspection and database comparison, sets a standard for future research. It demonstrates that accurate identification of microplastics and their polymer types is essential for understanding the full scope of plastic pollution and devising effective countermeasures. The combination of Raman spectroscopy, visual inspection, and database comparison provides a robust framework for future research on microplastic contamination.

METHOD

Sampling method

The study utilized purposive sampling, a method that involves selecting samples based on specific criteria to ensure their representation of the study area (Clausen et al., 2020; Buwono et al., 2021; Arredondo-Navarro and Flores-Cervantes, 2023). Samples were collected from three key water bodies in Jakarta: the Sunter River, Buaran River, and Marunda Estuary. These locations were chosen because they are known for illegal dumping activities, which are expected to impact the levels of microplastics in the water bodies. The sampling process was conducted systematically to obtain representative samples from the selected sites. Water samples were collected from three different points in each river: the right bank, center, and left bank. This approach ensured that the samples accurately reflected the water quality across different sections of the river. A total of 1000 ml of water was collected from each point, providing a comprehensive overview of microplastic contamination across the river's width. To prevent contamination, the collected water samples were stored in glass bottles, as glass is preferred over plastic to avoid introducing additional microplastic contamination. The study employed the composite sampling method, which involved combining multiple samples from different locations into a single composite sample. This approach provided a more representative assessment of overall water quality and microplastic contamination levels. In addition to water samples, sediment samples were also collected from the riverbeds at the same locations.

Sample storage

After collection, the water samples were carefully stored to maintain their integrity until they were analyzed in the laboratory. Proper storage was essential to prevent contamination and degradation, thus preserving the accuracy of the subsequent analysis. Each water sample was immediately transferred into tightly sealed glass bottles to avoid potential contamination from the container itself. Plastic containers were avoided to prevent the introduction of microplastics into the samples. The glass bottles were sealed tightly to maintain the purity of the samples, and they were stored in a cool, dark environment until they could be transported to the laboratory. This minimized temperature fluctuations and light exposure. Upon arrival at the laboratory, the water samples were promptly placed in a controlled storage area, usually a refrigerator or temperature-regulated storage unit, set at a consistent low temperature. This controlled environment was crucial for preserving the physical and chemical properties of the water samples. Maintaining a low, stable temperature helped slow down any potential biological or chemical processes that could alter the sample composition, thus preserving the original state of the water as closely as possible. Throughout the storage period, the samples were handled with care to prevent any disturbance to settled particles or introduction of new contaminants. All handling procedures followed strict protocols to ensure the integrity of the samples from collection through to analysis.

Sample analysis preparation

Before the analysis of the collected water samples could begin, a thorough preparation process was necessary to ensure that all equipment and procedures were set up to yield accurate and reliable results (Fig. 1). This preparation stage involved several critical steps to avoid contamination and

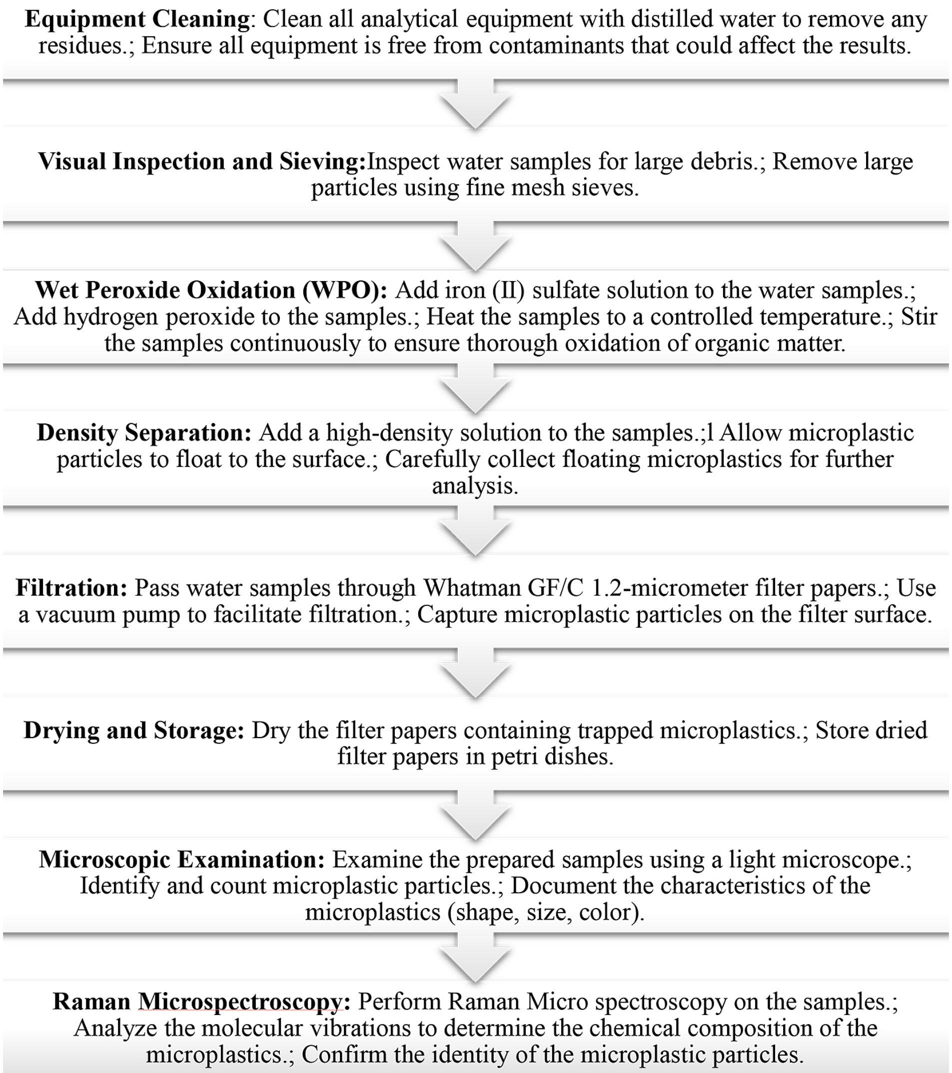

Figure 1. Analysis procedure

to properly process the samples for microplastic detection. The first step in sample analysis preparation was to ensure that all analytical equipment was meticulously cleaned. This involved washing the equipment with distilled water to remove any residues that could potentially contaminate the samples. The cleaning process was crucial because traces of contaminants could significantly affect the results of the microplastic analysis (Li et al., 2020; Mahmud et al., 2022).

Once the equipment was cleaned, the water samples underwent a pretreatment process designed to isolate microplastics from other materials present in the samples. This pretreatment stage was essential for ensuring that the analysis specifically targeted microplastics, eliminating interference from organic and inorganic matter. The pretreatment process began with a thorough visual inspection of the water samples to identify any large debris or foreign particles that could interfere with the analysis. These large particles were carefully removed using fine mesh sieves. The sieving process ensured that only particles within the microplastic size range remained in the samples.

Following sieving, the samples underwent a process known as wet peroxide oxidation (WPO). This procedure involved adding a solution of iron (II) sulfate and hydrogen peroxide to the water samples. The WPO process was designed to oxidize and break down organic matter, making it easier to isolate microplastic particles. The samples were heated to a controlled temperature and stirred continuously to ensure thorough oxidation. After the WPO process, the samples were subjected to density separation to further isolate microplastics. This technique involved adding a high-density solution to the samples, causing microplastic particles, which are typically less dense than most other materials, to float to the surface. The floating microplastics were then carefully collected for further analysis. The final step in the preparation process was filtration. The water samples, now containing isolated microplastics, were passed through fine-pore filter papers. The filter papers used were typically Whatman GF/C 1.2-micrometer filters, known for their ability to capture small particles (Kuo et al., 1997). The filtration process was facilitated by a vacuum pump to speed up the process and ensure efficient capture of microplastics on the filter surface. Once filtration was complete, the filter papers containing the trapped microplastics were carefully dried and stored in petri dishes. These prepared samples were then ready for microscopic examination and further chemical analysis. The microscopic examination involved using a light microscope to visually identify and count the microplastic particles. The characteristics of the microplastics, such as shape, size, and color, were documented. For a more detailed identification, Raman Microspectroscopy was employed. This advanced technique allowed for the determination of the chemical composition of the microplastic particles by analyzing the molecular vibrations of the materials. Raman Microspectroscopy provided precise information about the types of polymers present in the samples, confirming the identity of the microplastics (Lenz et al., 2015; Ribeiro-Claro et al., 2017; Araujo et al., 2018).

RESULT

Figure 2 illustrates the concentration of microplastic particles in water samples from three distinct water bodies in Jakarta. The Sunter River shows the highest concentration of microplastics,

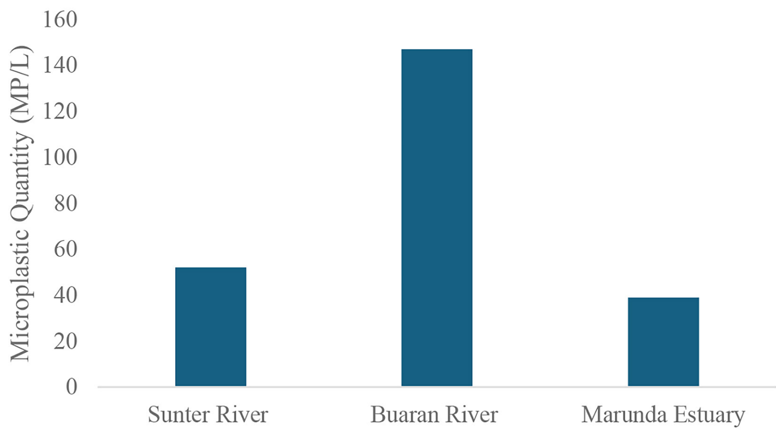

Figure 2. Number of microplastic particles in water samples by source

with a staggering 147 microplastic particles per liter (MP/L). This elevated level of contamination suggests significant pollution sources and possibly inadequate waste management practices in the surrounding areas. Such a high concentration is alarming and highlights the urgent need for intervention to mitigate pollution in this river. In contrast, the Sunter River displays a moderate level of microplastic pollution, with a concentration of 52 MP/L. Although this is considerably lower than the Sunter River, it still indicates a substantial presence of microplastics, necessitating continued monitoring and pollution control measures to prevent further degradation of water quality. The Marunda Estuary, on the other hand, has the lowest concentration of microplastics among the three sites, with 39 MP/L. This comparatively lower level of contamination may be attributed to better waste management practices or lesser industrial and residential waste inputs. However, despite being the least polluted among the studied sites, the presence of microplastics in the Marunda Estuary still warrants attention, as it can impact the marine ecosystem and potentially enter the food chain.

Figure 3a shows the distribution of microplastic particles found in water samples from the Sunter River, Sunter River, and Marunda Estuary. It is notable that fibers are highly prevalent in the Sunter River, making up a significant proportion of the microplastic pollution. The high presence of fibers in this river may be due to the discharge of textile waste, synthetic fibers from laundry, or remnants of fishing gear. In comparison, fibers are less common in the Sunter River and almost negligible in the Marunda Estuary. In the Buaran River, fragments dominate the microplastic profile. These are typically small, irregular pieces that result from larger plastic items breaking down due to environmental exposure and mechanical degradation. The high proportion of fragments in the Buaran River suggests significant plastic waste decomposition, possibly due to intense human activity and inadequate waste management practices in the surrounding area. In the Marunda Estuary, films are the most abundant type of microplastic. These thin, flexible plastics are often used in packaging materials such as plastic bags and wraps, indicating substantial plastic pollution from urban and industrial sources. The presence of films in this estuary highlights the impact of urban runoff and improper disposal of plastic packaging. Pellets, which are small, round pre-production plastic particles, are found in noticeable quantities in both the Buaran River and Marunda Estuary. This distribution likely indicates industrial activities where plastic pellets

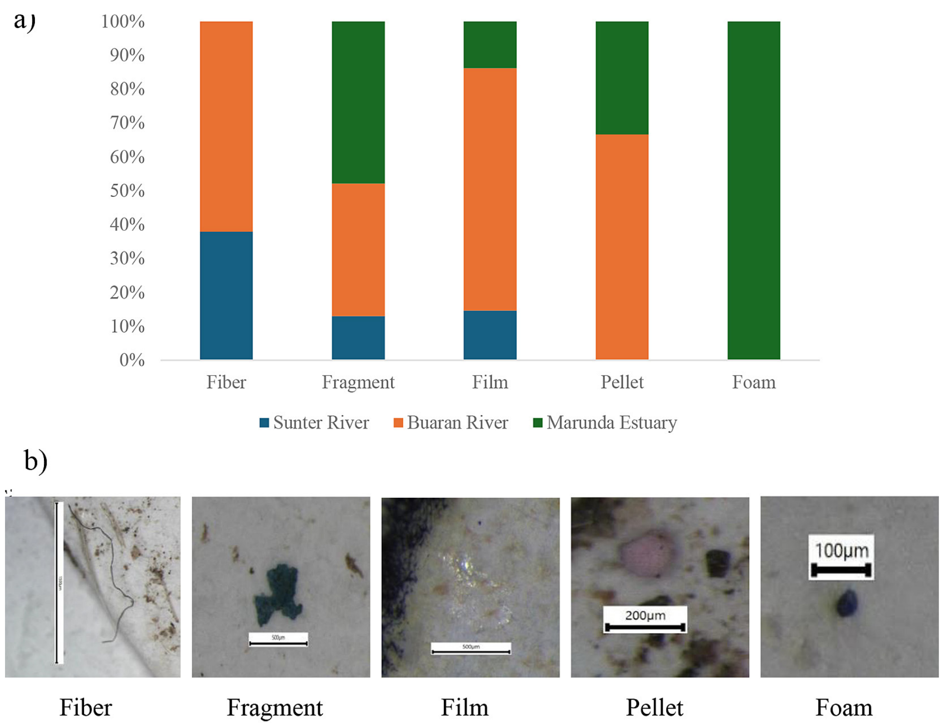

Figure 3. Distribution and visual identification of microplastic particles by type: (a) distribution of various types of microplastic particles found in the water samples from the Sunter River, Buaran River, and Marunda Estuary; (b) visual identification of microplastic types

are used as raw materials, leading to accidental spills or improper disposal. Foam particles are exclusively found in the Marunda Estuary. These lightweight, porous materials are commonly used in packaging and insulation. Their presence suggests pollution from packaging waste, construction debris, or discarded consumer products.

The varied distribution of these microplastic types across different water bodies emphasizes the diverse sources of plastic pollution. Each type of microplastic points to different pollution sources and pathways, underlining the need for targeted pollution control measures in each area.

Figure 3b provides a visual representation of the different types of microplastic particles observed under a microscope, enhancing understanding of their distinct characteristics. The fiber image reveals long, thread-like structures, typical of synthetic fibers from textiles or fishing lines. These fibers can be released into water bodies through laundry wastewater or discarded fishing gear. The fragment image shows irregularly shaped pieces, characteristic of the breakdown of larger plastic items. These fragments can originate from various sources, including consumer products, packaging materials, and industrial plastics that degrade into smaller pieces over time. The film image displays thin, flat pieces, resembling plastic bags or wraps. Such films are common in packaging and are often found in urban runoff and improperly managed waste. The pellet image presents small, round particles, known as nurdles, used as raw materials in plastic manufacturing. These pellets can enter water bodies through spills during transport or mishandling at industrial sites. The foam image depicts porous, lightweight particles, typically from packaging or insulation materials. Foam particles can break off from larger items used in packaging, or as disposable food containers (Kjeldsen and Scheutz 2003; Van Crevel 2016; Gao et al. 2023).

Table 1 provides a detailed breakdown of the number and abundance of microplastics in water samples, categorized by size classes. There are nine distinct size ranges, ranging from less than 20 micrometers (µm) to 5000 µm. This data illustrates the distribution of microplastics of different sizes in the sampled water bodies, showing which size classes are most prevalent. Notably, Class 3 (40–59 µm) and Class 6 (100–499 µm) have the highest abundance, indicating that microplastics in these size ranges are more common in the studied water samples. In contrast, some size classes, such as Class 1 (< 20 µm) and Class 5 (80–99 µm), show no detectable presence, underscoring the variability in microplastic size distribution. Understanding the size distribution of microplastics is crucial for assessing their potential impacts on aquatic ecosystems and human health (Gouin et al., 2022; Liu et al., 2022; Thornton Hampton et al., 2022), as different sizes can have varying environmental and biological effects. This detailed size analysis provides essential insights for developing targeted strategies to address microplastic pollution in water bodies.

Table 2 provides details on the number and abundance of microplastics in water samples, categorized by color. The microplastics are divided into six color groups: blue, red, transparent, black, green, and other colors. This data offers insights into the distribution of microplastics of different colors in the sampled water bodies, highlighting which colors are most prevalent. Transparent microplastics are the most abundant, accounting for 50% of the total microplastic count, followed by black microplastics at 34.45%. Other colors, including blue, red, green, and miscellaneous colors, are present in smaller

Table 1. Number and abundance of microplastics in water samples by size

No	Microplastic class	Abundance (MP/L)	Percentage (%)
1	Class 1 (< 20 µm)	0	0
2	Class 2 (20–39 µm)	3	1.26
3	Class 3 (40–59 µm)	95	39.92
4	Class 4 (60–79 µm)	24	10.08
5	Class 5 (80–99 µm)	0	0
6	Class 6 (100–499 µm)	70	29.42
7	Class 7 (500–999 µm)	26	10.92
8	Class 8 (1000–1999 µm)	17	7.14
9	Class 9 (2000–5000 µm)	3	1.26

Table 2. Number and abundance of microplastics in water samples by color

No	Microplastic color	Abundance (MP/L)	Percentage (%)
1	Blue	11	4.62
2	Red	16	6.72
3	Transparent	119	50
4	Black	82	34.45
5	Green	3	1.26
6	Other colors	7	2.95

quantities, indicating varying sources and types of plastic pollution. Understanding the color distribution of microplastics can help trace their origins (Merlino et al., 2020; Yaranal et al., 2021; Uoginté et al. 2022), as certain colors are associated with specific types of products or industrial processes. This detailed analysis of microplastic colors in water samples is essential for developing targeted strategies to address and mitigate plastic pollution in aquatic environments.

Figure 4 provides a comprehensive analysis of suspected microplastic particles in water samples collected from three distinct locations: the Sunter River, Sunter River, and Marunda Estuary. The Raman spectroscopy results for the Sunter River sample display a series of peaks at specific Raman shifts, indicating the presence of various chemical compounds typically found in microplastics. Notable peaks can be observed at several points along the spectrum, suggesting that the particles

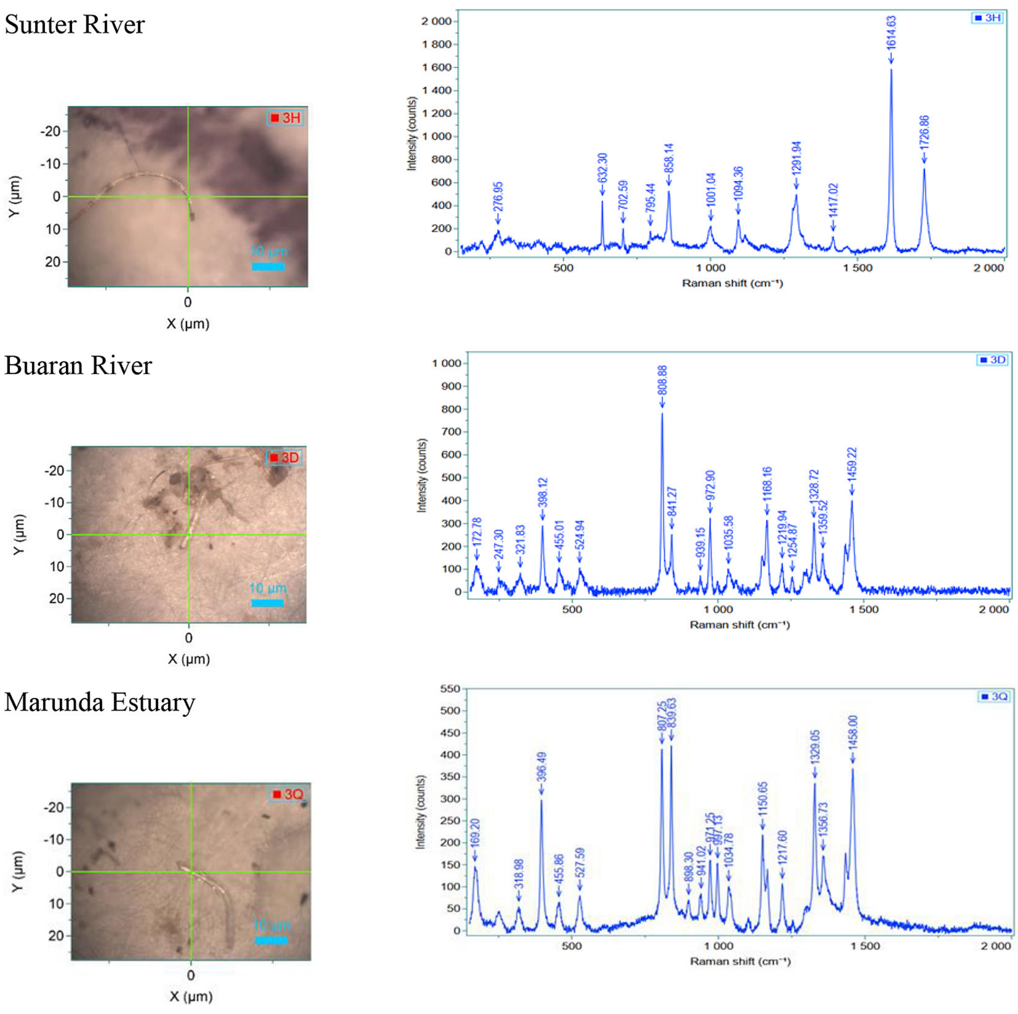

Figure 4. Raman spectroscopy results for suspected microplastic particles in water samples from Sunter River, Buaran River, and Marunda Estuary

are composed of common polymers such as polyethylene and polypropylene (Lenz et al., 2015; Araujo et al., 2018; Zada et al., 2018). The accompanying microscopic image reveals the particle's physical characteristics, including its size and shape (Cowger et al., 2020), which support the spectral data by providing visual confirmation of its synthetic nature. Similarly, the Sunter River sample's Raman spectrum exhibits distinctive peaks that closely resemble those seen in the Sunter River sample. This similarity suggests that the microplastic particles in both locations may have a comparable composition. The spectrum's intensity and peak positions are crucial for identifying the specific types of polymers present. The microscopic image of the Sunter River sample provides a clear view of the particle's morphology, showing details that align with the spectral analysis and further confirm its identity as a microplastic.

The Marunda Estuary sample's Raman spectrum also reveals characteristic peaks associated with synthetic polymers. These peaks are consistent with those found in known microplastic materials, confirming the presence of these pollutants in the estuary. The spectral analysis is corroborated by the microscopic image, which shows the particle's physical features, helping to identify it as a piece of plastic debris. The combination of visual inspection and Raman spectroscopy offers a robust method for identifying and quantifying microplastics in environmental samples. The microscopic images provide immediate visual evidence of the particles' presence, while the Raman spectra offer precise chemical characterization. This dual approach enhances the reliability of the identification process, ensuring that the detected particles are indeed microplastics. By comparing the Raman spectra and microscopic images across the three locations, it is possible to gain insights into the distribution and types of microplastics present in these water bodies. The results indicate that all three sites are contaminated with synthetic polymers, highlighting the pervasive nature of plastic pollution in aquatic environments. This detailed analysis underscores the importance of using advanced techniques like Raman spectroscopy for environmental monitoring and pollution assessment.

DISCUSSION

In Jakarta, Indonesia, the water samples from the Sunter River, Sunter River, and Marunda Estuary showed significant microplastic contamination. The concentrations were found to be 52 MP/L in the Sunter River, 147 MP/L in the Buaran River, and 39 MP/L in the Marunda Estuary. These findings highlight a high level of microplastic pollution in Jakarta's water bodies, particularly in the Buaran River, where the concentration was notably high. Comparatively, studies in other metropolitan cities have reported varying levels of microplastic contamination. In Paris, France, study found microplastic concentrations in the Seine river and Maine rivers ranging from 0.0221 and 0.1006 MP/L, with higher levels detected closer to the city center (Dalmau-Soler et al., 2021). The lower range of these concentrations compared to Jakarta suggests that urban management and waste treatment practices might differ significantly between these cities. A study conducted by Kapp and Yeatman in the Snake river reported concentrations ranging from 0 to 5.405 MP/L (Kapp and Yeatman, 2018). These values, while high, are still lower than the levels found in Jakarta's Buaran River but comparable to those in the Sunter River and Marunda Estuary. The variance within the Snake river could be attributed to the mix of urban runoff, industrial discharge, and varying waste management practices across the city. In Japan, study identified microplastic concentrations in highway runoff water samples contained high concentrations of 81–292 MP/L (Sugiura et al., 2021). Tokyo's relatively lower microplastic levels, compared to Jakarta's, might reflect Japan's stringent waste management policies and public awareness campaigns on plastic usage and disposal. Studies in European cities such as London, UK, reveal microplastic pollution levels in the Thames River ranging from 12.27 MP/L (Devereux et al., 2023).

For Jakarta, the high levels of PET and PP microplastics identified in this study indicate specific sources such as beverage bottles, food packaging, and plastic containers. Addressing these sources through enhanced recycling programs, stricter regulations on single-use plastics, and public education campaigns can significantly reduce the microplastic burden in Jakarta's water bodies (Johannes et al., 2021; Widagdo and Anggoro, 2022). Moreover, comparing Jakarta's microplastic levels to those in other cities underscores the need for comprehensive and localized approaches to pollution control. Policies successful in one metropolitan area might need adaptation to fit the local context of another. For

Jakarta, integrating advanced waste management technologies, improving urban planning to reduce runoff, and increasing community engagement in recycling initiatives are essential steps (Suryawan and Lee, 2024a, b).

The study of microplastics goes beyond visual identification under a microscope. Thorough analysis and testing of polymer types are necessary to accurately determine the nature of microplastic particles. Raman spectroscopy is one of the most effective methods for this purpose. By analyzing the chemical composition, Raman spectroscopy can identify whether a particle is a microplastic. In this study, Raman spectroscopy with a 785 nm spectrum was utilized (Li et al., 2016; Takahashi et al., 2020; Almaviva et al., 2022), which is particularly effective for reading wavelengths in water. The suspected microplastic particles were sampled from various sources, including water samples from Sunter River, Buaran River, and Marunda Estuary, as well as sediment and biota samples from these locations. Detailed results of the Raman shift analysis for the nine suspected microplastic samples found in Jakarta's waters are presented.

The Raman spectroscopy results revealed that the suspected microplastic particle in the Sunter River water sample exhibited characteristics of a fiber with a clear color. Spectral peaks for this particle were observed at shifts such as 276.95 cm^{-1}, 632.30 cm^{-1}, 702.59 cm^{-1}, 795.44 cm^{-1}, 858.14 cm^{-1}, 1001.04 cm^{-1}, 1094.36 cm^{-1}, 1291.94 cm^{-1}, 1614.63 cm^{-1}, dan 1726.86 cm^{-1}. Comparison of these spectral peaks with the database from the chromatography laboratory at the University of Indonesia revealed a 95.61% similarity to PET polymer. Previous research by Nava et al. (2021) supports this finding, showing similar Raman peaks for PET particles at 278 cm^{-1}, 626 cm^{-1}, 701 cm^{-1}, 800 cm^{-1}, 857 cm^{-1}, 1000 cm^{-1}, 1096 cm^{-1}, 1295 cm^{-1}, 1615 cm^{-1}, and 1730 cm^{-1}. Furthermore, other study conducted a study on marine microfibers and identified PET microplastic peaks at 1618 cm^{-1} and 1729 cm^{-1} (Absher et al., 2019), which align with the findings of this study. Similarly, the suspected microplastic particle from the Buaran River water sample appeared as a transparent fiber and exhibited spectral peaks at various shifts, including 172.78 cm^{-1}, 247.30 cm^{-1}, 321.83 cm^{-1}, 398.12 cm^{-1}, 455.01 cm^{-1}, 524.94 cm^{-1}, 808.88 cm^{-1}, 847.27 cm^{-1}, 939 cm^{-1}, 972.90 cm^{-1}, 1035.58 cm^{-1}, 1168.16 cm^{-1}, 1219.94 cm^{-1}, 1254.87 cm^{-1}, 1328.72 cm^{-1}, 1359.52 cm^{-1}, and 1459.22 cm^{-1}. Comparison of these spectral peaks with the chromatography laboratory database indicated a 95.13% similarity to PP polymer. Previous studies have shown that PP polymer has similar peaks at shifts, such as 252 cm^{-1}, 321 cm^{-1}, 398 cm^{-1}, 458 cm^{-1}, 530 cm^{-1}, 809 cm^{-1}, 841 cm^{-1}, 941 cm^{-1}, 973 cm^{-1}, 1040 cm^{-1}, 1167 cm^{-1}, 1219 cm^{-1}, 1257 cm^{-1}, 1330 cm^{-1}, 1360 cm^{-1}, and 1458 cm^{-1} (Nava et al., 2021). Study also noted that PP polymer exhibits a characteristic peak at 1458 cm^{-1} (Painter et al., 1977), which was likewise observed in the Buaran River sample.

The detailed Raman spectroscopy data collected and analyzed in this study provides a comprehensive understanding of microplastic contamination in Jakarta's water bodies. By integrating Raman spectroscopy with visual inspection and database comparison, this study offers a robust method to accurately identify microplastic particles and their polymer types. This approach not only confirms the presence of microplastics but also aids in tracing their origins and comprehending their environmental impact. The findings indicate significant microplastic pollution across all sampled locations, with varying types and concentrations. The Sunter River, Buaran River, and Marunda Estuary each exhibit distinct profiles of microplastic contamination, reflecting the diverse sources and pathways of plastic pollution in urban environments. The high similarity of spectral peaks to known polymers like PET and PP underscores the pervasive nature of plastic waste in these water bodies.

This detailed analysis emphasizes the importance of utilizing advanced techniques, such as Raman spectroscopy, in environmental studies. Visual identification alone is inadequate for accurately assessing microplastic pollution. By discerning the specific types of polymers present, researchers can better address the sources of pollution and develop targeted mitigation strategies. Furthermore, the consistent findings across different studies and databases reinforce the reliability of Raman spectroscopy as a tool for microplastic analysis. The ability to compare spectral peaks with established databases ensures that the identification of microplastics is both accurate and reproducible. This methodological rigor is crucial for developing a comprehensive understanding of microplastic pollution and its impacts. Raman spectroscopy has proven to be incredibly valuable in determining the specific types of polymers in microplastic particles found in Jakarta's waters. For example, the identification of

PET in the Sunter River highlights that beverage bottles and food packaging, which are commonly made from this polymer, are potential contributors. Similarly, the detection of PP in the Buaran River suggests pollution from plastic containers, automotive parts, and textiles, which frequently use this material. These findings have significant implications for environmental management and policymaking, as authorities can now tailor their waste management strategies to better address the prevalent polymer types in microplastic pollution. This can involve increasing recycling efforts for PET bottles and reducing the use of single-

CONCLUSIONS

This study presents a comprehensive analysis of microplastic pollution in various water bodies in Jakarta, specifically focusing on the Sunter River, Buaran River, and Marunda Estuary. By utilizing Raman spectroscopy in conjunction with visual inspection and database comparison, we were able to accurately identify and classify the polymer types of microplastic particles discovered in these environments. Key findings include the detection of polyethylene terephthalate (PET) in the Sunter River, primarily associated with beverage bottles and food packaging, and polypropylene (PP) in the Buaran River, commonly found in plastic containers, automotive parts, and textiles. The identification of these specific polymer types underscores the significant contribution of urban and industrial activities to microplastic pollution in these water bodies, revealing the extensive dispersal of plastic waste within Jakarta's aquatic environments. The study emphasizes the necessity of advanced analytical techniques such as Raman spectroscopy to accurately assess microplastic pollution. Relying solely on visual inspection is inadequate as it cannot provide detailed information on the chemical composition of the particles. Raman spectroscopy's ability to precisely match spectral peaks to known polymers provides a reliable and reproducible approach for microplastic identification, which is critical for developing effective mitigation strategies. The implications of these findings are crucial for environmental management and policymaking. By identifying the specific types of polymers that are prevalent in microplastic pollution, targeted waste management strategies can be developed. For example, initiatives aimed at enhancing recycling programs for PET bottles and reducing the production and consumption of single-use plastics made from PP could substantially decrease the presence of these microplastics in urban water bodies.

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