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Microplastic distribution in monitoring well water in the final landfill area Putri Cempo Surakarta Indonesia

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ABSTRACT

The presence of microplastics in the environment is a serious problem, affecting water, soil, and air ecosystems. This study aimed to identify the presence and distribution of microplastics in monitoring well water around the Putri Cempo landfill, Surakarta, Indonesia. Groundwater is a vital source of domestic water in the region but is vulnerable to contamination from landfill leachate. Water samples from seven monitoring wells were treated using wet peroxide oxidation, then analyzed under a light microscope and confirmed with Fourier transform infrared spectroscopy (FTIR). The abundance of microplastics ranged from 320 to 1960 particles/L, with fragments as the dominant type, black as the most frequent color, and polystyrene (PS), polycarbonate (PC), and polypropylene (PP) as the main polymers. These results indicate that landfill-derived plastic waste contributes significantly to groundwater pollution. The findings underline the urgency of routine monitoring and integrated waste management to minimize microplastic exposure through community water supplies.

Keywords: microplastics, groundwater, landfill, monitoring wells, Surakarta.

INTRODUCTION

Plastic production is projected to continue increasing to 600 million tonnes by 2025, with Asia contributing almost half of global production in 2014 (1). Plastics are used in various sectors, such as packaging, construction, automotive, electronics, agriculture, and household appliances. The COVID-19 pandemic has led to an increase in the use of single-use plastics, including packaging, bags, containers, and medical devices in Southeast Asia. Plastic waste breaks down into microplastics (<5 mm), polluting water, soil, and air, and releasing hazardous chemicals that pose risks to human health (2) and the environment. Environmental factors such as weathering and ultraviolet radiation form these particles. Environmental pollution intensifies as a result. Microplastics (<5 mm) are now recognized as ubiquitous contaminants in aquatic, terrestrial, and atmospheric environments. Their persistence and potential to act as vectors for toxic chemicals raise concerns for both ecosystems and human health. While extensive research has documented microplastics in marine waters, rivers, sediments, and biota, information on their occurrence in groundwater systems remains scarce, while as much as 30% of daily water consumption for daily needs is obtained from groundwater (3). This knowledge gap is particularly critical in developing regions where groundwater serves as the primary source of domestic water. In Indonesia, recent studies have mainly focused on microplastics in surface waters, estuaries, sediments, and aquatic organisms, leaving groundwater largely unexplored. Given the country's heavy reliance on shallow wells, assessing groundwater contamination is essential for evaluating community exposure risks (4). The Putri Cempo landfill in Surakarta represents a potential hotspot for microplastic leakage due to the long-term accumulation and degradation of plastic waste. However, empirical data on microplastic pollution in groundwater near Indonesian landfills are lacking.

This study therefore investigates microplastic contamination in monitoring wells around the

Putri Cempo landfill. Specifically, it aims to quantify their abundance, characterize morphological and polymeric types, and discuss potential pathways and implications for groundwater quality. By addressing this gap, the study provides baseline evidence for groundwater microplastic pollution in Indonesia and contributes to the broader discourse on emerging contaminants in drinking water resources. Therefore, to date, research on microplastics in groundwater or well water in Indonesia remains relatively limited. Identifying microplastics in the groundwater at the Putri Cempo landfill will provide new information regarding the presence of microplastics in groundwater. Furthermore, this research can determine whether the monitored well water is contaminated by microplastics, the characteristics of the microplastics contained therein, and the quantity of microplastics.

METHODS

Research design

This study uses a descriptive quantitative approach to assess microplastic contamination in monitoring well water around the Putri Cempo Landfill in Surakarta. Samples were taken from seven monitoring wells using a targeted sampling method according to SNI 6989.58:2008 standards, using a water sampler. The samples were then stored in 350 ml glass bottles lined with aluminum foil to prevent plastic contamination. The samples were processed using the wet peroxide oxidation (WPO) method, which uses H_2O_2 and H_2SO_4 solutions to remove organic matter, followed by filtration using a glass microfiber filter. Microplastic identification was performed using a light microscope to determine quantity, shape, and color, and Fourier transform infrared spectroscopy (FTIR) to analyze polymer type. This FTIR instrument works by comparing the observed sample spectrum with known plastic polymer spectra. This analysis examines the interaction of electromagnetic radiation with wavelengths between 0.75–1000 μm, which is often used to detect and identify microplastics (5). Each type of plastic has a unique spectrum, allowing microplastics to be identified based on their spectral patterns. The spectral patterns produced by plastics make it possible to distinguish between different types of microplastics with high accuracy. Furthermore, these spectral patterns are compared to a reference database to determine the type of plastic present in the sample (6). The microscope used is a trinocular microscope that can view small objects such as body cells, animal and plant tissues, protozoa, bacteria, and viruses. The trinocular microscope magnifies the image of the object and allows for the viewing of small objects that cannot be seen with the naked eye using light (7). Abundance was calculated using the abundance analysis formula, and the results were then analyzed and presented in tables and graphs to illustrate the variation in microplastics between well points.

Study area

The research was conducted in the Putri Cempo Landfill area. The sampling point locations consisted of 7 points, namely at the monitoring wells in the Putri Cempo Landfill area, and recorded the sampling coordinates in Table 1 and Figure 1. This determination decision also took into account the requirements for site selection based on the SNI 6989:58:2008 standard regarding Groundwater Sampling Methods. The sampling process was carried out between April 2025 and May 2025 at each sampling point and then recorded at each sampling point. In this test, the location used was the Putri Cempo Landfill area.

The research location involved seven monitoring wells around the Putri Cempo Surakarta landfill with different characteristics according to their position relative to the landfill area. Monitoring wells 1, 2, 3, and 4 are located at the rear of the landfill, very close to the waste piles, and therefore have a high potential for direct infiltration of contaminants from the disposal zone. Monitoring well 5 is located within the landfill office area and is a deep well used for operational purposes, making it a reference point for groundwater conditions in the official management area. Meanwhile, monitoring wells 6 and 7 are located in the southern part of the landfill, relatively further away from the waste piles, but their location is close to the leachate flow path, so they still have a potential risk of contamination. The distribution of these well locations provides a comprehensive picture of the potential movement of microplastics in groundwater, both from the core zone of the landfill and from leachate migration to the surrounding area.

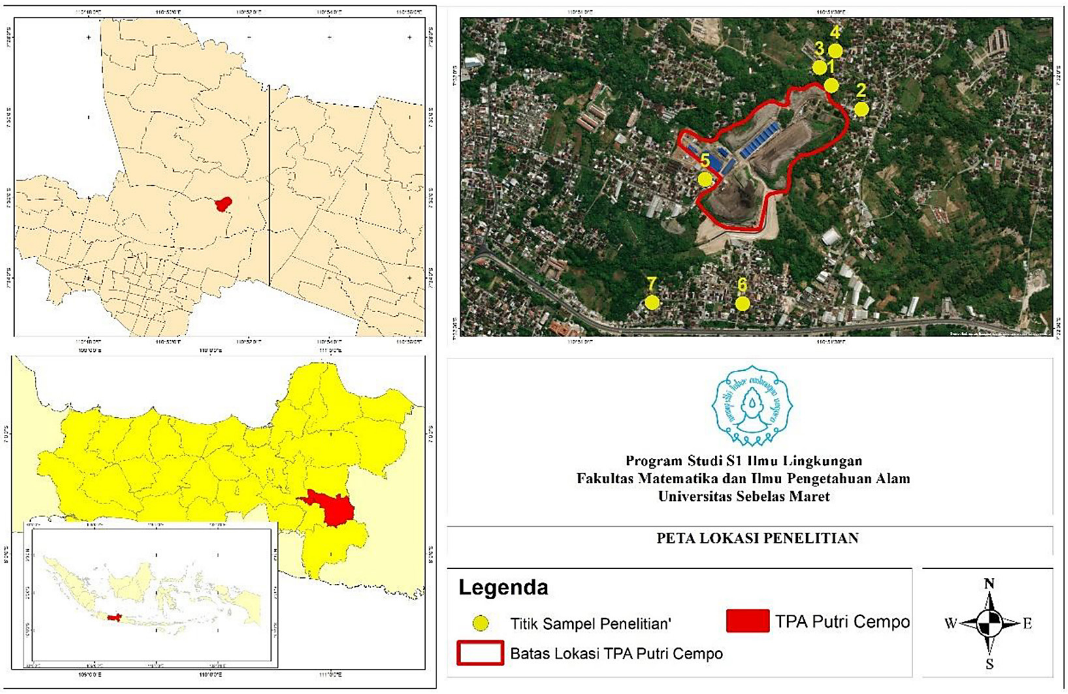


Figure 1. Sampling points in the Putri Cempo Surakarta Landfill area

Table 1. Coordinate points of sampling locations

Monitoring well	Coordinate points	
	x	y
1	110,8583321	-7,533644885
2	110,8593318	-7,534430222
3	110,8579491	-7,533056119
4	110,858474	-7,532511952
5	110,8541467	-7,536741154
6	110,8553876	-7,540829153
7	110,8523852	-7,540796023

Population and sample

The population in this study was all monitoring well water located in the Putri Cempo Final Disposal Site (TPA) area of Surakarta, which has the potential to be contaminated with microplastics due to waste disposal activities and the plastic degradation process in the TPA environment. From this population, the study took samples in the form of monitoring well water taken from seven monitoring well points (SP1–SP7). Each sample point was determined through geographic coordinates that reflect the distribution of locations in the Putri Cempo TPA area so that it can represent the condition of microplastic pollution in various parts of the study area. Thus, this study population is comprehensive in all monitoring wells in the TPA, while the samples analyzed are limited to the seven monitoring well points that are the locations for data collection.

Research instrument

Monitoring well water samples were taken at 7 sample points from the Putri Cempo landfill location as shown in Table 1. The sampling of monitoring well water was carried out in accordance with SNI 6989.58:2008 Groundwater Sampling Method, which involves several steps to ensure sample accuracy. First, prepare the equipment for water sampling and a glass bottle. Next, lower the water sample into the well to a depth of ±0–1 m. Let the sample fill with water until full, then lift it slowly to prevent contamination. The water was then transferred into a 350 ml glass bottle and tightly closed with aluminum foil. This procedure was done so that the plastic bottle cap would not be contaminated by the sample.

Sample testing

The National Oceanic and Atmospheric Administration (NOAA) method was used to test samples by varying the amount of H_2O_2 used. This method was used with certain adjustments to consider the characteristics of the sample. To identify microplastics, organic matter must be separated, the sample must be filtered, and then the microplastics must be identified. After testing, the sample will be examined under a microscope to provide a direct visual image of the microplastic morphology. Furthermore, the chemical characteristics of the sample will be analyzed through FT-IR spectrophotometry, which will be visualized in tables and graphs. In a prepared 100 ml glass bottle, the water sample is placed into a beaker and added with fifty milliliters of NaCl solution. This process is carried out for 24 hours, after which the wet peroxide oxidation (WPO) process is carried out using a hot plate until it is hot and does not boil. This process destroys the organic matter in the sample using a solution of hydrogen peroxide (30% H_2O_2) and sulfuric acid (30% H_2SO_4). Next, the sample is filtered using a glass microfiber, and it will be observed using a microscope and FTIR.

Data analysis

The analysis was conducted to identify microplastics, their quantity, and their shape characteristics. These characteristics include color (e.g., red, blue, green, white, yellow, gray, black, pink, transparent, and pigmented) and particle shape (e.g., fiber, film, fragment, and pellet). The aim of this study was to classify and quantify the amount of microplastics in each sample based on variations in particle shape. By comparing the number of particles found with the volume of filtered water, we compared the results of previous studies with measurements of microplastic abundance. We manually counted the separated microplastics once for each sample using a microscope trinoat 40–100x magnification to see the morphology of the microplastics. Next, the abundance of microplastics was calculated using the formula developed by Masura et al., 2015, as shown in the following equation:

$$C = \frac{n}{V} \tag{1}$$

where: C – Abundance of microplastics,
n – Number of microplastics (particles),
V – Volume of filtered water (L).

As part of the data analysis, microplastics in the samples were categorized based on their quantity, shape, color, and chemical characteristics. Both stages of the analysis included FTIR spectrophotometry on filtered paper to observe the chemical characteristics of the samples, which were then presented in tables and graphs.

RESULTS

Microplastic identification based on quantity

The results of the calculations for each monitoring well point were identified using a microscope connected directly to a laptop, as shown in Figure 2.

Microplastic identification based on abundance

The abundance of identified microplastics is in the range of 320–1960 particles/L. The highest

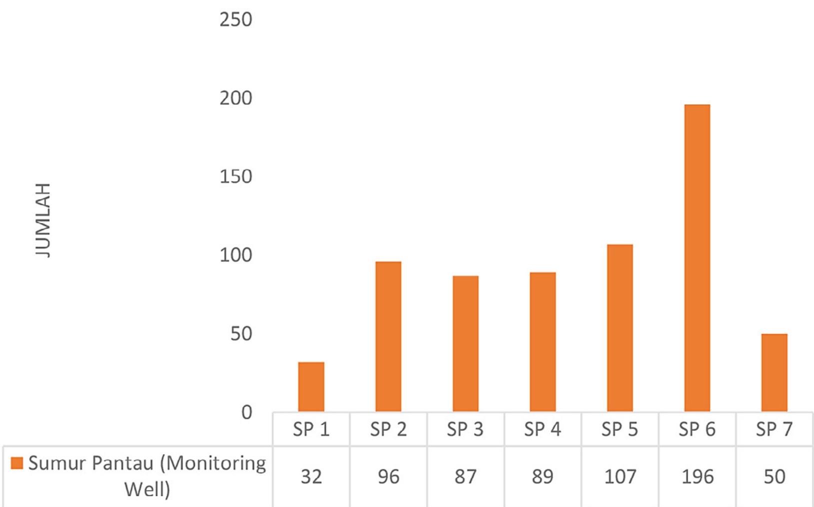


Figure 2. Graph of the number of microplastics in monitoring well water

abundance of microplastics is in monitoring well 6, which is 1960 particles/L, while the lowest abundance of microplastics is in monitoring well 1, which is 320 particles/L. We then calculate the abundance of microplastics in the monitoring well water at each point using the formula, resulting in the values shown in Table 2.

Identification of microplastics based on type

The characteristics of the types of microplastics found in the monitoring well water at the Putri Cempo Landfill in Surakarta are very diverse, including fibers, fragments, films, granules, and foam. Fragments are the most predominant type of microplastic due to their large numbers. Research on microplastics in the monitoring well water at the Putri Cempo Landfill in Surakarta found that fragments are the most dominant type (39%), originating from larger plastic fragments (Figure 3) (Table 3).

The graph in Figure 4 shows the variation in abundance and types of microplastics at seven monitoring wells (SP 1 to SP 7). Overall, fragments were the most dominant type of microplastic found, particularly at SP 6 with 1.270 particles/L. Granules also showed high abundance at several points, particularly at SP 3 with 710 particles/L and SP 2 with 550 particles/L. Fibers and films were also consistently found at most monitoring wells, although in varying amounts. Meanwhile, pellets and foam were found in much smaller quantities and only at a few locations. This pattern indicates that fragments are the most widespread form of microplastic contaminant, followed by granules and fibers, with SP 6 having the highest microplastic concentration.

Microplastic identification based on color

Based on the graph in Figure 6, black microplastics were the most dominant (228 particles), likely from the degradation of tires or black plastic. Transparent plastics (24 particles) were second. Other colors such as yellow, orange, brown, blue, and red were found in tiny amounts (4 to 10 particles). This indicates that black plastic is the primary source of microplastics in the study area, followed by transparent plastic, with other colors contributing less (Figure 5).

Identification of polymer compounds using FTIR spectrophotometry

After microplastic identification based on the number, type, and color using a microscope, it was carried out using FTIR with the aim of identifying the type of polymer in each sample or filter paper. This identification was carried out on seven samples. The results of the identification based on the shape of the microplastics indicated that a specific type of microplastic was most dominant in the well samples. The detected polymers are suspected to originate from these microplastics. FTIR spectrum readings were carried out in the wavelength range of 1000–4000 cm^{-1}. Figure 7 displays the results of the FTIR readings as follows:

FTIR analysis indicated that polystyrene (PS), polycarbonate (PC), and polypropylene (PP) were the most dominant microplastic polymers in most monitoring wells at Putri Cempo Landfill. PS (from packaging), PC (from reusable bottles/electronic components), and PP (from packaging/household products) were consistently detected. Other polymers such as nylon, PET, HDPE, ABS, and PTFE were found less frequently and in a site-specific manner. This diversity logically indicates a complex source of microplastic pollution from various types of plastic waste degradation in the landfill, with PS, PC, and PP as the main contributors.

The Table 4 shows representative absorption peaks used for polymer classification, with

Table 2. Total abundance of microplastics in well water monitoring

Sample	Filtered water volume (L)	Total particles	Particle abundance	Unit
SP 1	0.1	32	320	particles/L
SP 2	0.1	96	960	particles/L
SP 3	0.1	87	870	particles/L
SP 4	0.1	89	890	particles/L
SP 5	0.1	107	1070	particles/L
SP 6	0.1	196	1960	particles/L
SP 7	0.1	50	500	particles/L

Table 3. Number of microplastics by type

Sample	Filtered water volume (L)	Total particles	Particle abundance	Unit
SP 1	0.1	32	320	particles/L
SP 2	0.1	96	960	particles/L
SP 3	0.1	87	870	particles/L
SP 4	0.1	89	890	particles/L
SP 5	0.1	107	1070	particles/L
SP 6	0.1	196	1960	particles/L
SP 7	0.1	50	500	particles/L

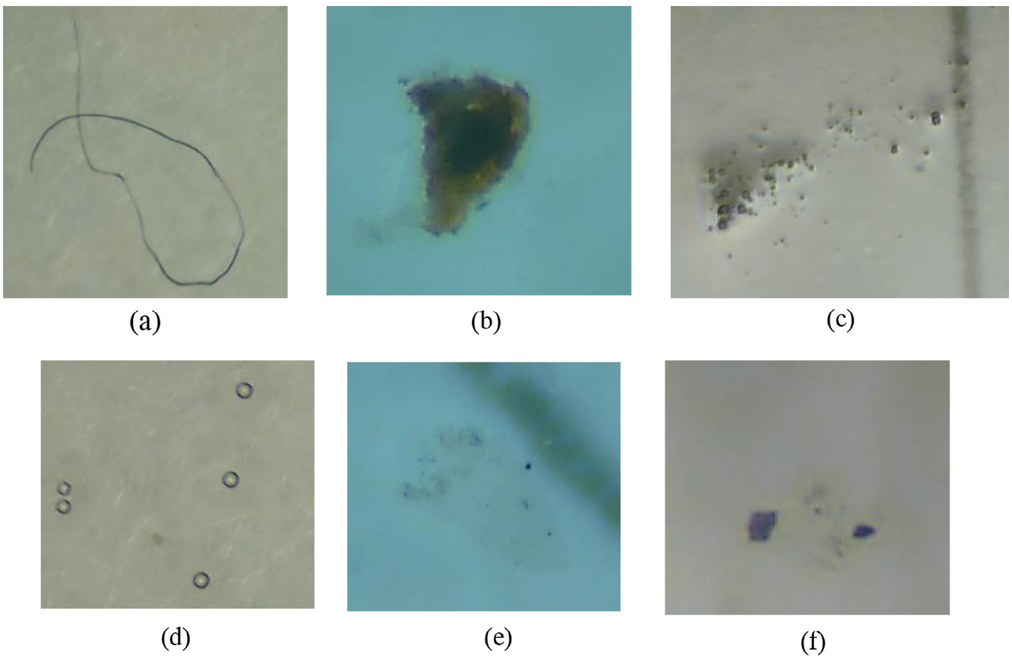
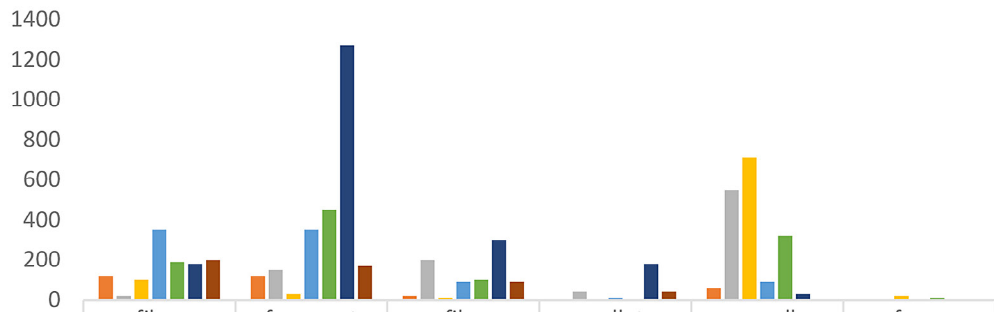


Figure 3. Microplastic forms: (a) fiber, (b) film, (c) foam, (d) granule, (e) fragment, (f) pellet



	fiber	fragment	film	pellet	granulle	foam
SP 1	120	120	20	0	60	0
SP 2	20	150	200	40	550	0
SP 3	100	30	10	0	710	20
SP 4	350	350	90	10	90	0
SP 5	190	450	100	0	320	10
SP 6	180	1270	300	180	30	0
SP 7	200	170	90	40	0	0

Figure 4. Abundance of microplastics (particles/L) by type in groundwater samples from 7 monitoring wells surrounding the Putri Cempo landfill, Surakarta

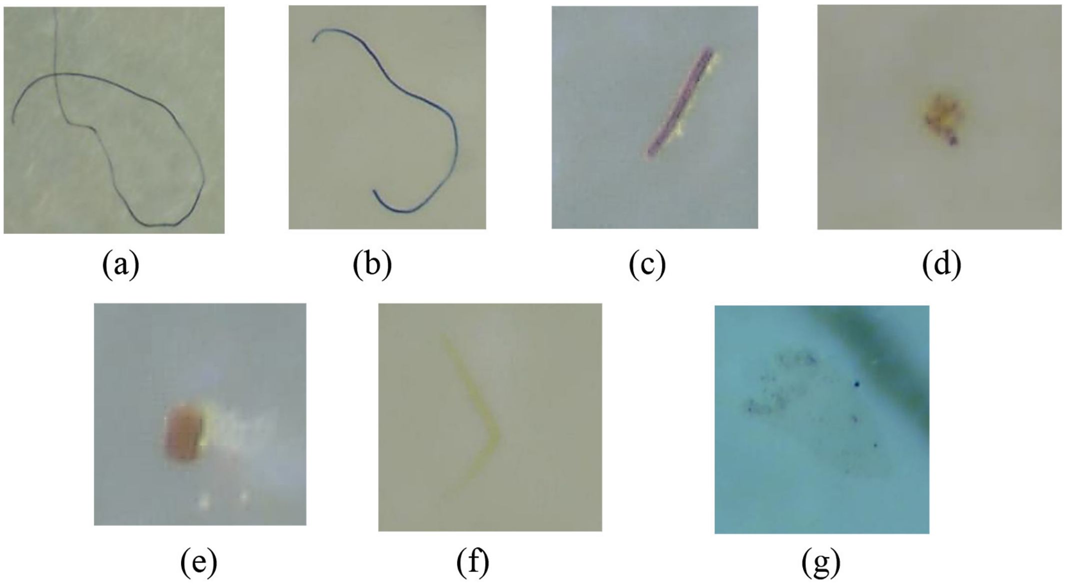


Figure 5. Microplastic colors: (a) black, (b) blue, (c) red, (d) brown, (e) orange, (f) transparent, (g) yellow

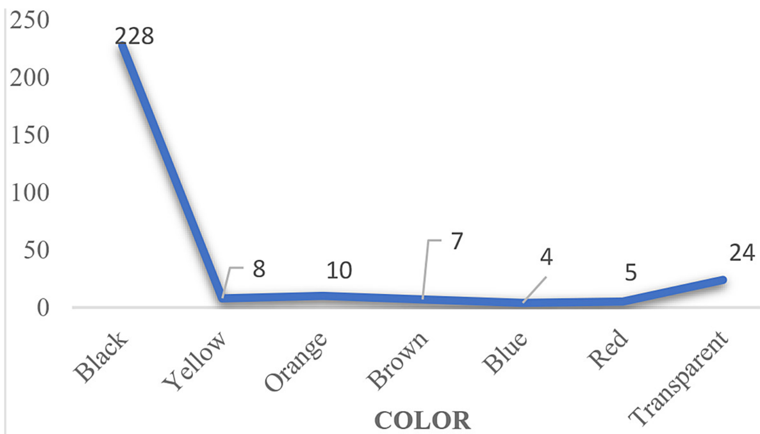


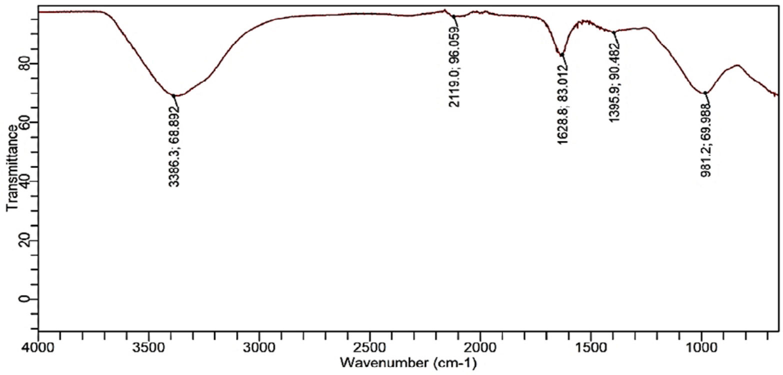
Figure 6. Microplastic chart by color

assignments based on reference spectra. PS, PC, and PP were identified as the dominant polymers, with minor detection of PET and PVC.

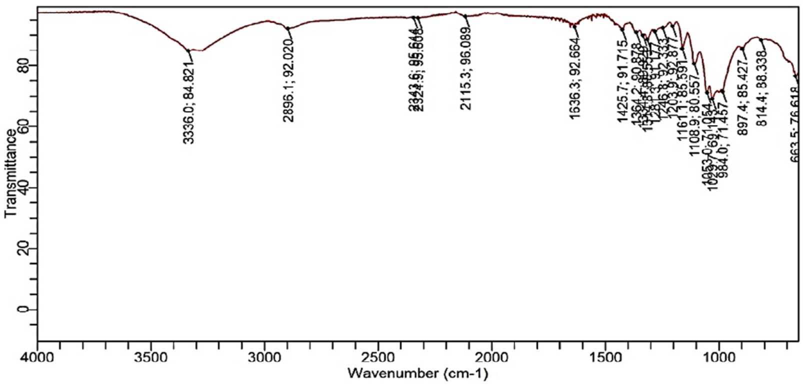
DISCUSSION

Identification of microplastics based on quantity

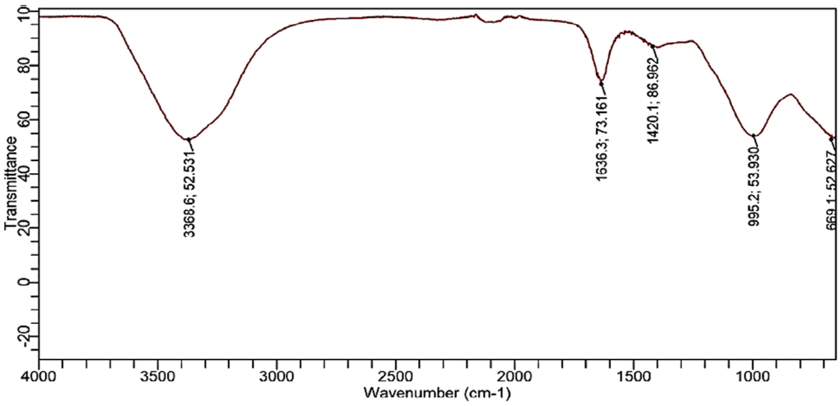
Monitoring well 6 had the highest number of microplastics with 196 particles, while monitoring well 1 had the lowest number with 32 particles. Differences in microplastic content and characteristics are due to environmental conditions, distance to the pollutant source, community behavior, and climate (6). The results of observations on monitoring wells that have microplastics are classified as high because the distance from the well and the landfill is relatively close and not far from the leachate area from the landfill, while the location of the well that is classified as low has slightly maintained water in the well because it is located behind the Putri Cempo landfill area. This serves as evidence that microplastics can originate from waste accumulation that has been present at the location for years. Microplastic pollution in groundwater comes from plastic waste that originates from plastic waste on the surface of the soil, which is then carried in through the pores of the soil where microplastics are driven by various human activities, run off from the surface of the landfill, floods, and atmospheric deposition (8). Landfills are one of the most common sources of microplastics in groundwater (9). Even groundwater wells can be a source of microplastic


Transmittance
Wavenumber (cm-1)
3386.3; 68.892
2119.0; 96.059
1628.8; 83.012
1395.9; 90.482
981.2; 69.988

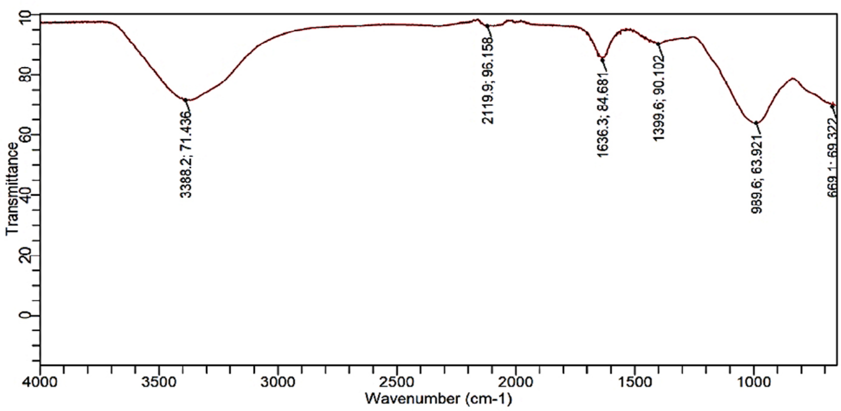
(a)


Transmittance
Wavenumber (cm-1)
3336.0; 84.821
2896.1; 92.020
2115.3; 96.089
1636.3; 92.664
1425.7; 91.715
1364.2; 90.878
897.4; 85.427
814.4; 88.338

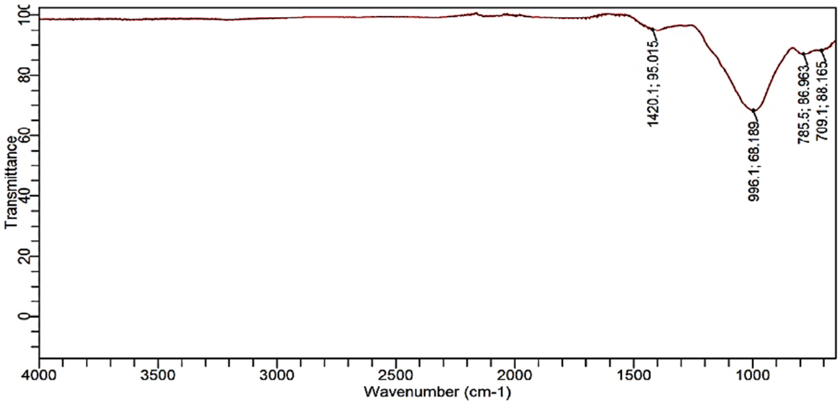
(b)


Transmittance
Wavenumber (cm-1)
3368.6; 52.531
1636.3; 73.161
1420.1; 86.962
995.2; 53.930

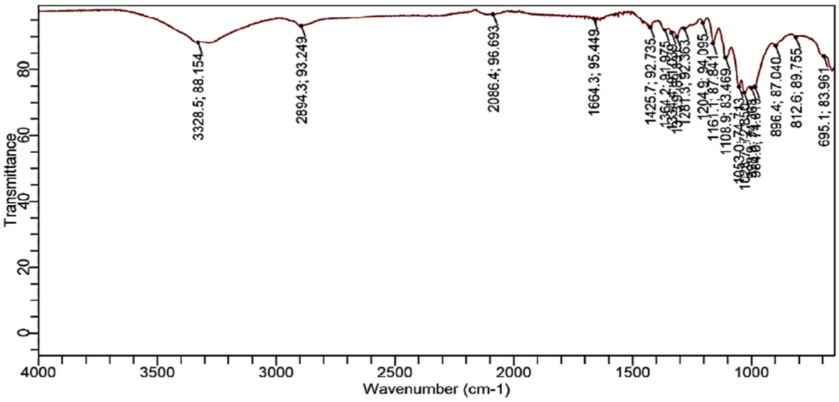
(c)


Transmittance
Wavenumber (cm-1)
3388.2; 71.436
2119.9; 96.158
1636.3; 84.681
1399.6; 90.102
989.6; 63.921

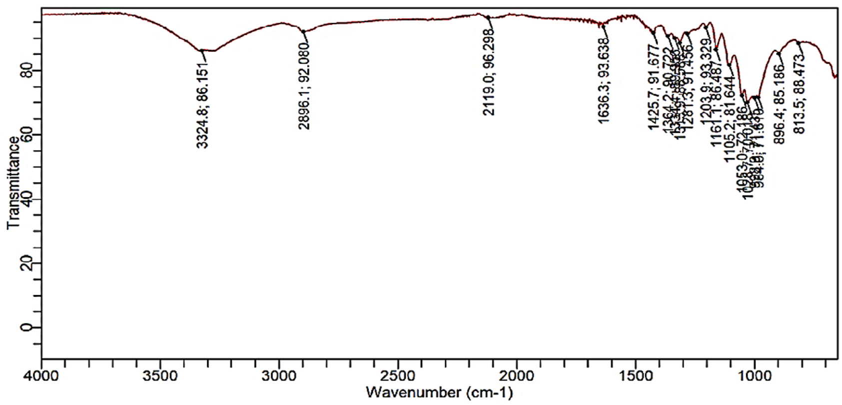
(d)



(e)



(f)



(g)

Figure 7. FT-IR test results: (a) Sample 1, (b) Sample 2, (c) Sample 3, (d) Sample 4, (e) Sample 5, (f) Sample 6, (g) Sample 7

contamination of groundwater because well casings, screens, and connecting pipes are often made of various types of plastic materials (10).

Identification of microplastics based on abundance

The abundance of microplastics in the water of monitoring wells around the Putri Cempo landfill ranges from 320 to 1.960 particles/L. The highest abundance of microplastics is in monitoring well 6 at 1.960 particles/L, and the lowest is in monitoring well 1 at 320 particles/L. Variations in abundance are influenced by differences in monitoring well locations, well construction design, surrounding environmental conditions, community behavior, and hydrodynamic factors such as

Table 4. Polymer composition of microplastics isolated from groundwater samples, identified through ATR-FTIR spectroscopy

Sample	Peaks (cm^{-1})	Characteristic peaks (cm^{-1})	Polymer
SP 1	1395	1409	PC
	1628	1601	PS
SP 2	1029	1027	PS
	1161	1166	PP
	1053	1094	PET
SP 3	1636	1634	*Nylon*
	669	687	*Nylon*
	995	997	PP
	1420	1409	PC
	3368	3298	*Nylon*
SP 4	1636	1601	PS
	989	972	PP
SP 5	996	997	PP
	785	759	ABS
	709	717	HDPE
SP 6	1028	1027	PS
	1161	1158	PC
	1204	1201	PTFE
	1364	1364	PC
SP 7	1028	1027	PS
	1105	1094	PET
	1161	1158	PC
	1425	1409	PC
	1364	1364	PC
	984	972	PP
	998	997	PP

ocean currents and wind speed (11). Differences in the composition and abundance of microplastics at each location station can be linked to variations in anthropogenic activities of the community in the region (12). Climate, particularly rainfall levels, can also influence the abundance of microplastics by increasing water discharge and current velocity, thus accelerating their movement. Once on the ground surface, microplastics can infiltrate into the soil pores along with rainwater flow (13). Microplastics with low density tend to be on the surface of the water, while microplastics with higher density will be distributed in the water column (14).

Identification of microplastics by type

As shown in Figure 4, fragments consistently dominated the microplastic composition across all wells, indicating the degradation of larger plastic debris as the main source. Fibers were the second most abundant type, suggesting contributions from textile-derived waste. Films, foams, and granules occurred in lower proportions. Spatially, SP4 exhibited the highest concentration of microplastics, which aligns with its proximity to the landfill's leachate pond. The dominant forms of microplastics identified were fragments with a total abundance of 254 particles, fibers with 116 particles, films with 82 particles, pellets with 27 particles, granules with 176 particles, and foam with 3 particles. Thin, flexible filaments were formed from larger plastic fragments that underwent photooxidative degradation due to exposure to ultraviolet light, resulting in fine fibers (15,16). Filaments can come from wastewater processing residues or from community activities that throw away disposable plastic and glasses, which then degrade into fine fibers. In addition, filaments can also come from textile fibers or fragments that are released from ropes, nets, and fishing equipment (17,18). Granular microplastics generally originate from microbeads found in cosmetic products and textile materials. The plastic fragmentation process is also influenced by various external factors, including ocean wave dynamics, wind speed intensity, biological interactions through organism bites, and anthropogenic activities that accelerate the breakdown of plastic materials into smaller particles. The environment around monitoring wells distributes plastic waste most widely, according to observations. Therefore, the most common type of microplastics consists of fragments, which include plastic bags, plastic bottles, food packaging, detergent packaging, beauty products, nets, and fishing lines. Foam microplastics have the lowest density compared to other forms, making them more abundant and easier to find (5). At the research location, numerous fibers were found in each sample due to its proximity to the Putri Cempo Final Disposal Site. Surface water is polluted, so microplastic particles have the potential to contaminate groundwater through infiltration into sediment pores, with a horizontal distribution pattern influenced by ocean current dynamics and hydrodynamic pressure due to wind gusts (19). Another anthropogenic factor that plays a role is the community's habit of throwing nets, fishing lines, and laundry wastewater directly into the soil. Microplastics that enter through soil pores, both vertically and horizontally, can contaminate groundwater (19), while the movement of microplastics is influenced by the speed of groundwater flow and depends on the type of soil and the distribution of microplastics in groundwater (20). Meanwhile, microplastic fragments generally have irregular morphology and originate from plastic materials with high-strength polymer characteristics that undergo a degradation or fragmentation process, breaking down into smaller particles (21). The differences in the size of the microplastics detected indicate a long-term degradation process in the marine environment, influenced by factors such as pH, temperature, depth, microorganism activity, salinity, and exposure to UV radiation (22)..

Microplastic identification based on color

Color variations in microplastics can serve as an important indicator in determining the source and type of polymer while increasing the accuracy of the morphological identification process and classifying microplastics more precisely (23). In this study, 7 different colors were found due to different lengths of exposure to sunlight (24), therefore microplastics will degrade, and the texture will be softer, so they will be easier to break down (25). The dominant color identified was black, with a total of 228 particles. The black color of the microplastics indicates the accumulation of contaminants associated with other organic particles, caused by the high absorption capacity of pollutants, which also reflects the condition of the environment that has been polluted (26). The high color intensity of microplastics indicates that the material has not undergone significant weathering or degradation, so the color change is not yet visible (27).

Identification of polymer compounds using FT-IR spectrophotometry

Identification of the types of microplastic polymers at 7 stations was carried out using FTIR, as shown in Figure 7. The results of the analysis showed the presence of several wavelength peaks that represent certain compound bonds Table 4. Based on the interpretation of the wavelength peak values, it can be identified that there are 8 types of microplastic polymers : PP (polypropylene), PC (polycarbonate), PS (polystyrene), PET (polyethylene terephthalate), HDPE (high-density polyethylene), ABS (acrylonitrile butadiene styrene), nylon, and PTFE (polytetrafluorethylene). The estimation of the types of PP, PC, and PET polymers with values ranging from 925 to 1250 cm^{-1} has a CH bending functional group bond, CH bonds are used as an indicator, considering that PE and PP are composed predominantly of CH groups (5). PP-type microplastics can originate from bottle caps, straws, and plastic toys. The PS polymer type is identified by the presence of a wavelength peak in the range of 1250–1700 cm^{-1}, indicating the presence of CH_2 bending bonds. Infrared spectrum analysis allows identification of the polymer type in the sample by matching the peak values with verified polymer characteristics. FTIR spectral analysis confirmed the polymer composition of microplastic particles. PS was identified by distinct aromatic C=C stretching at 1600 cm^{-1} and CH_2 bending near 1450 cm^{-1}. PP was characterized by absorption bands at 997 cm^{-1} (C–C stretching) and 841 cm^{-1} (CH_3 rocking), while PET exhibited strong absorption at 1710 cm^{-1} (C=O stretching) and 1094 cm^{-1} (C–O stretching). In addition, PC and polyvinyl chloride (PVC) were detected, with characteristic peaks consistent with published reference spectra. These assignments confirm that common consumer plastics such as packaging materials, beverage bottles, and disposable containers are major contributors to microplastic contamination in the groundwater surrounding the landfill.

Research conducted by Utami and Liani (2021) on the identification of microplastics in dug wells around the Piyungan landfill in Yogyakarta (28) found microplastics at these locations. Based on the results of the Kruskal-Wallis test, it was concluded that the distance of the wells from the Piyungan landfill affected the abundance of microplastics. The types of microplastic polymers identified at the three well locations were PS and PVC. In 2023, research was conducted on microplastics found in bottled drinking water (AMDK) circulating in Semarang, Central Java, and the results showed that all samples contained microplastics in the form of fragments and fibers. The microplastics found in AMDK were plastics with polyethylene terephthalate (PET) functional groups, estimated to originate from the AMDK packaging (29). Another study conducted by Cahyaningrum and Sari (2024) (30) identified the abundance of microplastics in groundwater and stated that microplastics were found in groundwater in the study.

CONCLUSIONS

The results showed that all monitoring wells in the Putri Cempo Surakarta landfill area were found to contain microplastics with varying abundances between 320–1960 particles/L. Monitoring well SP1 had the lowest number, namely 320 particles/L, followed by SP7 with 500 particles/L, SP3 with 870 particles/L, SP4 with 890 particles/L, SP2 with 960 particles/L, SP5 with 1070 particles/L, while the highest number was found at SP6 with 1960 particles/L. Fragments were the most dominant form of microplastics, followed by granules, fibers, and films, while pellets and foam were only found in small amounts. The most common color was black, presumably originating from the degradation of plastic packaging and tires, while FTIR analysis identified PS, PC, and PP as the main polymers. Overall, these results confirm that waste disposal activities at the Putri Cempo landfill significantly contribute to microplastic contamination in groundwater, with varying levels of contamination depending on the proximity of the wells to the landfill and leachate flow paths.

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