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Analysis of environmental health risks from exposure to polyethylene terephthalate microplastics in refilled drinking

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ABSTRACT

BACKGROUND AND OBJECTIVES: Microplastic pollution has a far and wide presence in the surroundings. It can be encountered in the sea, wastewater, freshwater, food, air, and water sources. It is even present in refilled drinking water. This study aims to analyze environmental health dangers of the exposure to polyethylene terephthalate microplastics in refilled water sources in Tamangapa, Makassar City, Indonesia.
METHODS: This research is an observational study with an environmental health risk analysis. Sampling was conducted in Tamangapa, Makassar City, Indonesia. A total of 100 respondents were involved. Additionally, 20 samples of refilled drinking water were examined in the laboratory using the Fourier Transform Infrared test. Data analysis was carried out by calculating the intake and risk quotient values. If risk quotient > 1, it is considered necessary to carry out risk management.
FINDINGS: An average polyethylene terephthalate microplastic concentration of 0.0052 milligram per kilogram per day, an average intake rate of 210 milligrams per kilogram per day, an average exposure frequency of 350 days, an average exposure duration of 30 years, average intake exposure to polyethylene terephthalate microplastics above 0.0004, and an average risk quotient value above 1 were obtained. If they build up in the body, microplastics may have harmful consequences, including organ inflammation, internal or external damage, and chemical alteration of plastics that have already entered the body.
CONCLUSION: Some measures of risk management that can be performed are to reduce the concentration of risk agents if the pattern and timing of consumption cannot be changed, reduce the consumption pattern (intake rate) if the concentration of risk agents and the time of consumption cannot be changed, and reduce the contact time if the risk agent concentration and consumption pattern cannot be changed.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
60	7	5

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INTRODUCTION

Plastic is a collection of synthetic or man-made organic compounds that can be transformed into various shapes, sizes, colors, and densities (Hesselink *et al.*, 2019). The world's plastic products have reached 360 million tons. Asia is the region with the most significant growth in plastic waste production in the world, reaching a level of 51 percent (%) (Plastic Europe, 2019). Particularly, Indonesia is the world's second-largest producer of marine plastic debris, after China, reaching 262.9 MT of plastic annually (Monteleone *et al.*, 2019). Every year, Indonesia dumps as much as 0.48–1.29 million metric plastic waste into the sea, which is also the second highest in the world (Jambeck *et al.*, 2015). This number increases yearly in line with the increasing demand for plastic by the public (Hoegh *et al.*, 2015). Microplastic pollution has a far and wide presence in the environment (Manatura and Samaksaman, 2021; Takarina *et al.*, 2022). It can be encountered in the sea, sewage, clean water, food, air, water sources, and even in drinking water, including refiled drinking water (Wagner and Lambert, 2017). Microplastics come from plastic waste that is improperly handled and thrown away into the environment (Ayuningtyas, 2019; De Sliva *et al.*, 2021). One of the factors that increase the possibility of microplastic contamination in drinking water is weak control over the quality of drinking water during the production process, both for water in single-use bottles and for water in multiple-use bottles (Handayani, 2020). Based on research results by Kasmini and Batubara (2023), of 500 oyster samples collected, 139 were contaminated with microplastics. The most dominant type of microplastic contamination in oysters is fiber contamination, with up to 170 particles found, followed by contamination in the form of films and fragments, each with 28 particles and 19 particles. The results of this study revealed that oysters consumed by people have been contaminated with microplastics. The study hypothesized that microplastics are present in refiled drinking water and cause contamination in it. Microplastics can enter the freshwater environment in various ways. They originate from, among other sources, degraded plastic waste (Isma and Danira, 2022). Microplastics were found in refiled drinking water depots with an abundance of 0.8 (particles/L) in line shapes, red and blue in color, and 1.02–1.491 millimeters (mm) in size

(Machrany *et al.*, 2021). In bottled drinking water, microplastics were found in the form of fragments of the polypropylene type at 10.4 particles/L in sizes > 100 micrometers (µm), and at 335 particles/L in sizes between 6.5 µm and 100 µm (Isma and Danira, 2022). Polyethylene terepthalate is a linear thermoplastic polymer consisting of repeating units of terephthalic acid and ethylene glycol monomers (Yoshida *et al.*, 2016). PET, polyurethane, polystyrene (< 10% each), polyethylene (36%), polypropylene (21%), and polyvinyl chloride (12%) are involved in the production of non-fiber plastics. The production of non-fiber products requires polyesters, including 70% PET (Geyer *et al.*, 2017). Water supplies or groundwater are contaminated by PET plastic or the substances it has leached. Numerous studies have shown the migration of microplastics from PET plastic into the water. The pH levels and scent strength of the military water that was packed in PET were examined and recorded. After long-term water storage, it was discovered that these were higher than the US Food and Drug Administration's (USFDA) and US Environmental Protection Agency's (USEPA) recommended limits (Greifenstein *et al.*, 2013). Microplastic particles of this type that measure 50 µm can translocate to the liver or spleen through the lymph, posing a risk of inflammation and changes in immune processes (Nirmala *et al.*, 2023). Currently, there are only a few studies focused on microplastic contamination in drinking water. Weak supervision opens up opportunities for drinking water to be easily contaminated with microplastics as it goes through production stages, for example, during the processes of sterilizing, washing, rinsing, and sealing drinking water packaging (Handayani, 2020). Therefore, this study offers a reference for researchers to conduct research on the health risks of exposure to polyethylene terephtalate microplastics in refiled drinking water in Tamangapa, Makassar City. The purpose of this study is to analyze the average level, intake rate, frequency of exposure, duration of exposure, daily intake level (intake), level of risk (risk quotient), health risks, and risk management of the exposure to polyethylene terephthalate microplastics in refiled drinking water in Tamangapa, Makassar City, Indonesia in 2023.

Fig. 1 shows the refiled drinking water sampling location in the Tamangapa, Manggala District, Makassar City, Indonesia. The location covers a total
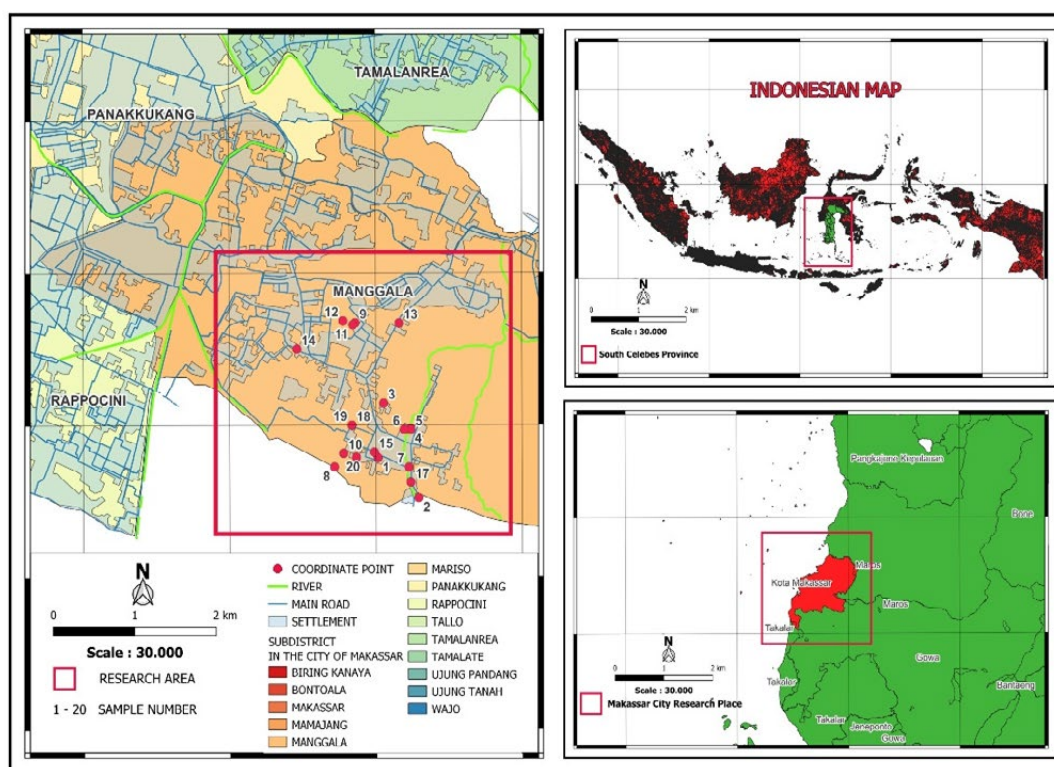
Fig. 1: Geographic location of the refilled drinking water sampling location in the Tamangapa, Manggala District, Makassar City, Indonesia

area of 662 square kilometers (km^2), equal to 66,200 hectares (ha). Previous study was carried out by machines in Tamangapa village, Makassar city. The location covers a total area of 662 square kilometers (km2), equal to 66,200 hectares (ha) by taking six air samples, of which three samples came from residents' homes and three air samples from depots).

Fig. 2 shows that the highest rainfall of 765 mm was in January, and the lowest rainfall of 8 mm was in July. Indonesia is classified as a tropical country. The average temperatures of warm waters in the Indonesian territory are 28 °C, 26 °C, and 23 °C in coastal areas, inland and highland areas, and mountainous areas, respectively.

MATERIALS AND METHODS

Sample collection

Samples of refilled drinking water in this study were taken at the research location, Tamangapa, Makassar City. A total of 20 refilled drinking water samples were taken directly from depots or residents' homes.

The non-probability convenience sampling method, which is commonly used to overcome unwanted limitations in small- to medium-scale research, was employed in this study (Taherdoost, 2016).

Sample preparation

Before use, all pieces of equipment were washed with 10% nitric acid and rinsed with aquabidest to avoid contamination from the equipment. Refilled drinking water samples were prepared at 1,000 ml and given 2 drops of 0.1% Nile Red dye solution, then they were incubated for about 30 minutes. Nile Red dye solution will be adsorbed on the surface of microplastics, but not on most natural materials, making microplastics visible under a microscope with a magnification of 100× to 400×. For characterization with FTIR (Fourier Transform Infrared) test materials were filtered first using a cellulose nitrate filter with a specified weight and a pore size of 0.45 μm. The residual weight can be calculated to determine the microplastic content quantitatively with aquabidest
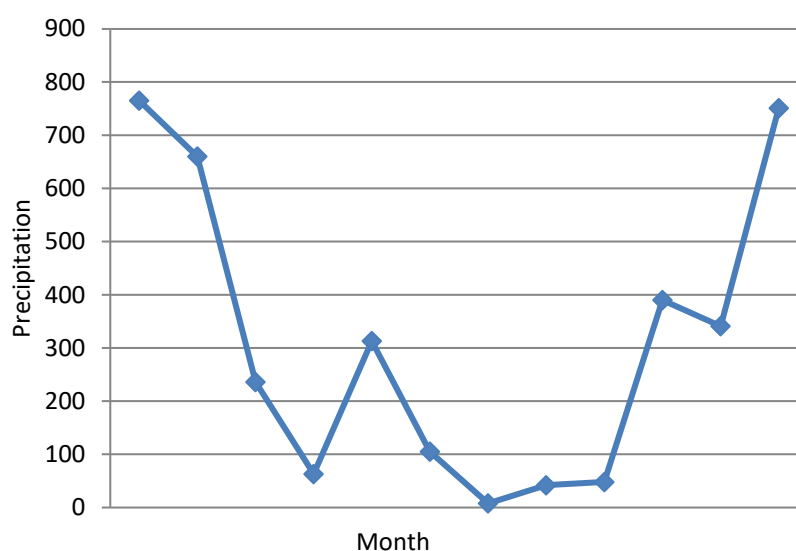
Fig. 2: The rainfall from January to December.

as a standard blank (Taherdoost, 2016).

Determination of the mass and concentration of microplastics

Initially, filter paper with a pore size of 0.45 μm was used to filter aquabidest as a blank. Then, it was dried in a desiccator for 24 hours. After drying, the filter paper was weighed, and the mass was recorded. The water samples were then filtered with the filter paper. The filter paper was once again dried in a desiccator for 24 hours after filtering was finished. After drying, the filter paper was weighed again, and the mass was recorded. The difference between the volume of filter paper after filtering and the initial mass was the mass of the microplastics accommodated on the filter paper. This microplastic mass represents the concentration of microplastics in each liter of water that went through the filtration process (Taherdoost, 2016).

Characterization of the number of microplastic particles

For morphological analysis (fragments, fibers, pellets, films, etc.), the residue on the filter was examined under an optical microscope (Leica ICC50 HD) with 100× and 400× magnification. In addition to morphological analysis, an examination under an optical microscope using the modified Neubeuer

Improved Counting Chamber method was also carried out to count the number of particles per sample volume. This method is an accurate method that is commonly used to measure the number of cells/particles in biological fluids. In this method, observations with a microscope are carried out on samples positioned in a given space (0.1 mm). Then, the quantity of particles observed in the sample volume is counted. In this study, the results of this calculation were converted into units of the amount of debris per liter of the sample, with the assumption that the samples were homogeneous, i.e., the drinking water samples were homogeneous solutions. Furthermore, the microplastic residue filtered on the cellulose nitrate filter with 0.45-micrometer pores was measured by Fourier Transform Infrared (FTIR) with a pure polymer standard. FTIR characterization is a chemical examination method used to establish the identity of a compound in a sample (Samimi and Mansouri, 2023). The identity of a compound can be recognized from its functional groups, namely, the types of bonds between different atoms, which are the part that distinguishes one compound from another (Samimi and Shahriari-Moghadam, 2021; Samimi and Safari, 2022). This FTIR characterization can identify functional groups in compounds by reading the infrared light signals transmitted by the compounds in samples, which occur in the FTIR

instrument used (Dutta, 2017; Ehzari *et al.*, 2022; Samimi and Shahriari-Moghadam, 2023).

FTIR microscopy

The molecular make-up of plastic particles may be determined by combining vibrational spectroscopy with optical microscopy and/or SEM. To prevent the development of unsettling peaks in the spectrum, it is often crucial to remove the suspected microplastic particles from the sample matrix since the signal intensity acquired relies on the size of the particles investigated (Nguyen *et al.*, 2019). FTIR micro-spectroscopy is an efficient and popular technique for locating microplastics. The signal is reliant on changes to the molecule dipole moment brought on by molecular vibrations. The molecule is brought to a higher vibrational state by absorbing IR light, and this state is precisely correlated with the kind of bonds that are present in the molecule under investigation. Contrary to scanning electron microscope-energy dispersive X-Ray, infrared spectroscopy is a very effective technique for obtaining fingerprint data on the sample's molecular composition and the particular bonds that are present (Gurumurthy *et al.*, 2017). An FTIR microscope's spatial resolution is only 10–20 m, despite being wavelength-specific and subject to established diffraction restrictions. For FTIR to function correctly, ideally, samples should be stored on a substrate that is transparent to IR and has a thickness of at least 150 nm. This limitation makes FTIR most effective for particles bigger than 20 m in size. It is still possible to analyze aggregations or films of smaller particles (Chen *et al.*, 2020). Because it is better than other technologies at detecting microplastic particles as tiny as 20 m, micro-FTIR spectroscopy (micro-FTIR) is an ideal tool for identifying microplastics in the air. IR is a region belonging to the electromagnetic spectrum between the microwave and visible light regions. FTIR spectroscopy, which takes the form of molecular fingerprinting, is typically applied in the constrained frequency range between 4,000 and 400 cm^{-1} (wavenumber), as it is this "fingerprint" region that offers practical value for identifying bonds, even though the IR region spans in wavelength from about 700 nm to 1 mm. It is possible to observe the existence of distinctive atoms or atomic groupings and, as a result, ascertain the composition by comparing the infrared spectra of diverse materials.

Time and place

Sampling was conducted in Tamangapa Village, Makassar City. The populations in this study were people who consumed refilled drinking water and all refilled drinking water depots located in Tamangapa Village, Makassar City. This study involved 100 respondents, who were sampled using a purposive sampling technique, and 20 water samples taken directly from depots.

Data analysis

In this study, the environmental health risk analysis (ARKL) was implemented in the following stages:

a. Hazard identification

In this stage, the type of polyethylene terepthalate microplastic polymer contained in refilled drinking water was determined.

b. Dose-response analysis

A dose-response analysis was carried out based on the standardization issued by the US-EPA Agency for the reference dose (RfD) value of polyethylene terepthalate microplastics, which is 0.0004 milligram per kilogram per day (mg/kg/d). Calculation was performed using Eq. 1 (USEPA, 2020).

c. Exposure analysis

$$I = \frac{C \text{ x } R \text{ x } fE \text{ x } Dt}{Wb \text{ x } t \text{ avg}} \qquad (1)$$

Where;

I (Intake)	The total concentration of risk agents that enter the human body with a certain body weight (kg) every day (mg/kg/day)
C (Concentration)	The concentration of the risk agents of polyethylene terephthalate microplastics in refilled drinking water (mg/l)
R (Rate)	The rate of consumption or the volume of water that enters the human body every day (mg/l)

fE (Frequency of Exposure)	The length or number of days (days/year) of exposure to microplastics each year (350 days/year for residential default value)
Dt (Duration)	The duration or number of years of exposure
Wb (Weight of Body)	Human body weight/ population/group
t avg (Time Average)	Average time period (30 years × 365 days/year for non-carcinogenic effects and 70 years × 365 days/year for carcinogenic effects)

d. Risk characterization

Risk characterization for non-carcinogenic effects was carried out by dividing intake by the dose or concentration of risk agents using Eq. 2 (USEPA, 2015).

$$RQ = \frac{I}{RfD} \tag{2}$$

Where;
RQ: Risk characterization
RfD: Response concentration analysis
I: Intake (exposure)

Microplastics: Origins and routes toward drinking water

Drinking water sources are mostly contaminated by microplastics (both primary and secondary) due to surface runoff and wastewater/wastewater treatment plant waste discharge. There are a large number of industries using microplastics (primers) for various applications, including pharmaceuticals, make-up, etc. These principal microplastics are flushed away after usage and end up in home wastewater (Surya et al., 2021). Some of the microplastics in bottled drinking water come from the packaging and or

Table 1: Comparison of microplastic analysis techniques

Methods	Advantages	Limits
Scanning electron microscopy (SEM)		
An intense electron beam is used to scan the sample's surface. Images may be produced thanks to the sample's electron beam scattering.	This technique provides high-resolution (0.5 nm resolution) images of the sample.	Samples must be prepared for observation; the type of polymer cannot be identified; instrument acquisition is expensive; it is an old-fashioned analysis.
Raman spectroscopy		
Inelastic scattering takes place when laser energy strikes the object. The frequency shift between two beams may be used to assess the chemical makeup of a sample.	It is a reliable method for identifying microplastics; it can detect microplastics down to 1 µm in size; it causes no damage; it can analyze solutions and tolerate the presence of water.	Samples must be properly prepared to isolate important microplastics; It can be affected by additives, dyes, impurities, and the background fluorescence of the sample; data acquisition can take time; It takes costly equipment, and without standards, understanding data could be challenging.
Fourier transform infrared spectroscopy		
The sample is exposed to infrared light, and the spectrums of its transmission or absorbance then contrasted with those of samples that are known.	It is reliable; it causes no damage; micro-FTIR can study particles down to 20 µm in size; it can determine the MP composition; it is able to map the surface of large samples.	The accuracy will suffer when the target particle is smaller than 20 µm, expensive equipment is needed; the sample must be processed or purified to remove matrix interferences; the spatial resolution of detection is limited by the radiation's wavelength, and the best resolution is down to tens of microns; water is also impossible to detect.
Optical microscopy		
The preparation and identification of samples is done under an optical microscope.	Quick screening is feasible; it is the cheapest of all techniques; it is able to detect the size, shape, and color of MPs; it is easy to identify non-plastic particles when recognized.	It lacks qualitative chemical identification; it bears polymer error potential for inorganic materials; optical microscopes may miss small particles.

Table 2: Worldwide reported contamination of microplastics in drinking water (Surya *et al.*, 2021)

Water type	Identification methods	Size range (Mm)	Concentration (Particles/L)	Shape	Composition	Sources
Source of drinking water (groundwater)	FTIR spectroscopy	50 – 150	0 – 7	Fragment	Polyethylene, polyamide, polyester, polyvinyl chloride	Mintening *et al.*, 2019
	Pyrolysis–GCMS	-	6.4	Fiber	Polyethylene	Panno *et al.*, 2019
Water treatment from a water treatment plant	FTIR spectroscopy & micro Raman imaging microscopy	1–10	338±76 to 628±28	Fragment, Fiber	Polyethylene terephthalate, Polypropylene, Polyethylene	Martin *et al.*, 2018
Tap Water	FTIR spectroscopy	100 – 5.000	0 – 61	Fiber	-	Kosuth *et al.*, 2018
Plastic water bottle						
	FTIR spectroscopy	6.5 - >100	0 to 10.000	Fragment	Polypropylene	Mason *et al.*, 2018
	-	-	3.57	Fiber	-	Kosuth *et al.*, 2018
	Micro FTIR spectroscopy	5 – 20	118±88 (returned bottle 14±14 (single use bottle)	Fragment	Polyethylene terephthalate, Polypropylene	Darena *et al.*, 2018
	Micro Raman spectroscopy	< 5	4,890±5,430 (returned bottle 2,649±2,857 (single use bottle)	-	Polyethylene	Oßmann *et al.*, 2018
Glass water bottle	FTIR spectroscopy	6.5 – 1.410	14.8(.100µm)	Fragment, fiber	-	Mason *et al.*, 2018
		>100	1,396(6.5–100µm)	Pellet, film, foam	-	
	Micro FTIR spectroscopy	> 100	50±52	-	Polyamide, Polyethylene, Polypropylene	Darena *et al.*, 2018
	Micro Raman spectroscopy	< 5	6.292±10.521	-	Polyethylene, Styrene–butadiene–copolymer	Oßmann *et al.*, 2018
Carton bottled water	Micro FTIR spectroscopy	> 100	11±8	Fiber	Cellulose, Polyethylene, Polypropylene	Darena *et al.*, 2018

bottling process itself. Otherwise, contamination can also come from raw water sources, packaging materials, washing machines, or the circuit in the process of filling water into packaging. Microplastics contamination in refilled drinking water can come from the management process which uses equipment or pipes made of plastic such as polyvinyl chloride, polypropylene, and polyethylene (Mason *et al.*, 2018). The effluent produced from wastewater treatment facilities includes considerable levels of contamination as these facilities lack the tools required to completely remove microplastics (Amrutha *et al.*, 2020). Once this waste is mixed with freshwater sources, microplastics are introduced into the clean/ drinking water supply chain (Elvis *et al.*, 2019). A case in point is that the increased concentrations of microplastics in the Chicago River were reportedly caused by effluents from local sewage treatment facilities (Amanda *et al.*, 2014). It is also crucial to remember that a lot of the parts of water purification and distribution systems often comprise plastics like high-density polyethylene, polyvinyl chloride,

Table 3: Distribution of Respondent Characteristics in Tamangapa, Manggala District, Makassar City 2023

Variable	Frequency (n)	Percentage (%)
Gender		
Male	58	58
Female	42	42
Age		
< 12 years	40	40
12–40 years	3	3
41–60 years	55	55
> 61 years	2	2
Level of education		
Elementary school	43	43
Junior high school	15	15
Senior high school	20	20
College	22	22
Type of work		
Not yet working	43	43
Housewife	15	15
Government employees	20	20
Self-employed	22	22
Weight		
< 30 kg	27	27
31–60 kg	31	31
> 60 kg	42	42

and polypropylene (Mintening *et al.*, 2019), which can also aid in the development of microplastics in the water they transport. Environmental elements, each with unique environmental properties, such as sunshine, temperature, and air/oxygen, among others, have a big effect on how microplastics break down into (secondary) microplastics (Weinstein *et al.*, 2016).

RESULTS AND DISCUSSION

According to Table 3, the male respondents outnumbered their female counterparts (58 males or 58% of all respondents), the most vulnerable respondents were in the 40–60 years age group (56 people or 55% of all respondents), and the education level of the majority of respondents was elementary school (43 people or 43% of all respondents). Forty-two percent of all respondents weighed above 60 kg, and 27% weighed under 30 kg.

Body weight reflects nutrients in the human body; people with an ideal body weight are sufficiently nourished (Sartika, 2008). Low body height or weight can be influenced by nutritional intake into the body and physical activity. In a study, it was found that the toxic substance in the body is inversely proportional to body weight because the greater the body weight, the wider the toxic substance distribution in the body

(Girikallo *et al.*, 2022). An individual with a great body weight has more fat contained in the body (Zhang *et al.*, 2020).

Fig. 3 depicts the results of observing and identifying microplastics in refilled drinking water from depots in Tamangapa, Manggala District, Makassar City, under a microscope with a 45× magnification. The correlation between the type and size of detected PET microplastics is directly proportional to the specific source of refilled drinking water. Microplastics were found in refilled drinking water depots at 0.8 particles/L in the line shape, red and blue in color, and 1.02–1.491 mm in size (Machrany *et al.*, 2021).

Fig. 4 displays the levels of microplastics in the 20 samples of refilled drinking water examined at the Ecotoxicology Laboratory of the Faculty of Fisheries and Marine Sciences, showing a maximum concentration of PET microplastic contamination of 0.030 mg/kg and a minimum of 0.001 mg/kg. Based on the results of laboratory tests, different microplastic concentrations were obtained because the levels of microplastic particles differed for each sample. The path that PET microplastics in refilled drinking water take into the body can impact on human health. PET microplastics may go into the body through the ingestion route, that is, when they are ingested and enter the body through the gastrointestinal tract.
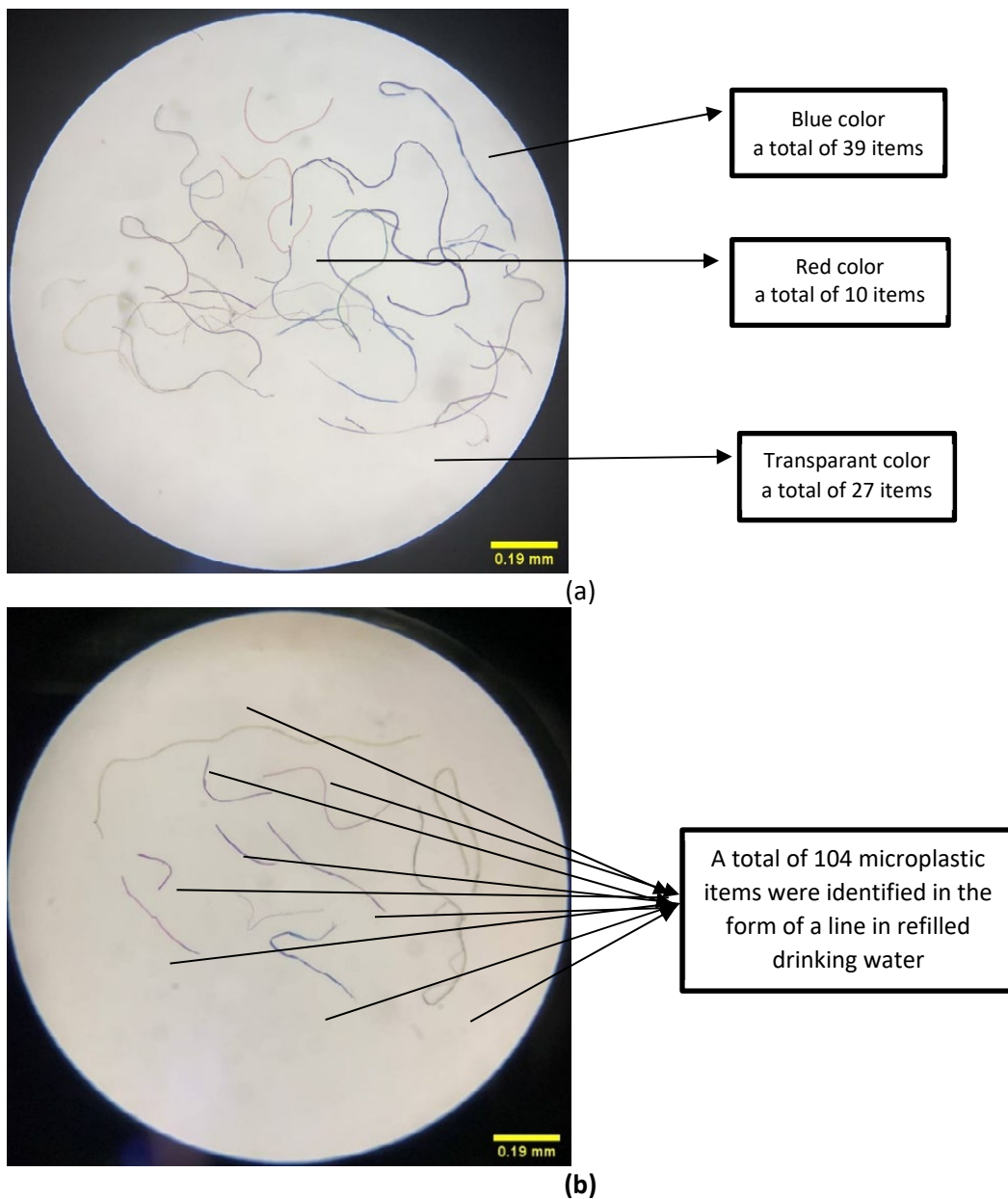
Fig. 3(a) and (b) Color and total number of microplastic particles in refilled drinking water

Foods and drinks contaminated with microplastics are considered one of the primary forms of human exposure to microplastics. Microplastics are defined as particles that are less than 5 mm in diameter and consist of polymers (Storck *et al.*, 2015). By source, primary and secondary microplastics are the two categories into which microplastics fall (Zhang *et al.*, 2020). The microplastics contained in bottled drinking water partially come from the packaging and/or the bottling process itself (Mason *et al.*, 2018). In refilled drinking water, microplastic contamination can come from the management process that uses equipment or pipes of plastic such as polyvynyl chloride (PVC), polypropylene (PP), and polyethylene (PE). Based on
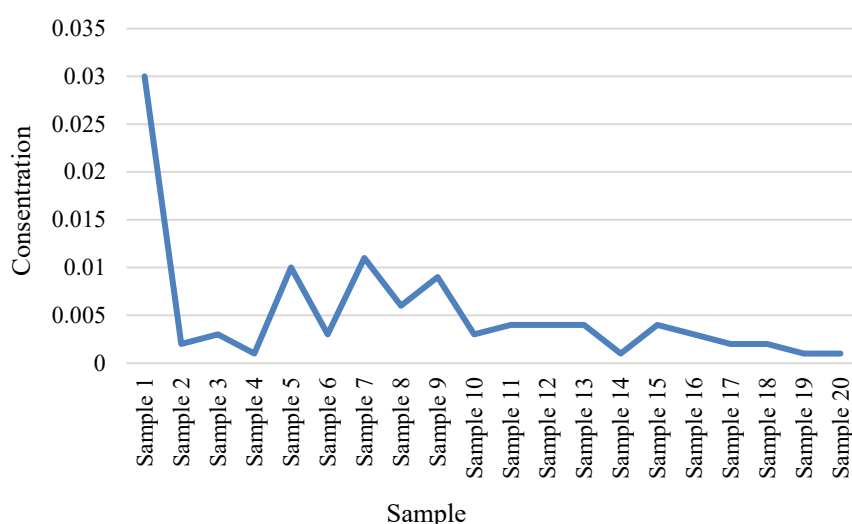
Fig. 4: Concentration of microplastics in refilled drinking water

test results and the reading of the type of polymer from the FTIR analysis, microplastics were found to be in the line form. A student at the University of North Dakota (UND) measured the concentrations of microplastics in water containers, bottled water, and locally produced soft beverages on campus. The results showed that microplastics were present in the bottled water samples at an average of 101 particles/liter (Abdulmalik and Mansurat, 2019). This quantity is smaller than the microplastics content of the samples from the cask and soft drink. The most prevalent form of microplastics was that of a fragment (Savitri, 2015).

The use of FTIR analysis allowed for the detection of microplastics. PVC, PP, PET, PS, HDPE, and LDPE were discovered in the samples after comparison of the FTIR spectrum data with electronic spectrum libraries. FTIR spectroscopy (Thermo Fisher Scientific-US) is often used for the chemical identification of suspected microplastic particles, even when they may be visually detected by optical microscopy. Table 4 shows that the ages (years) of the respondents ranged from 7 years to 68 years, with a median value of 50 years. The respondents' body weights ranged from 21 kg to 73 kg, with a median value of 57 kg. The respondents' intake rates ranged from 126 mg/kg/day to 269 mg/kg/day, with a median value of 210 mg/kg/day. The frequency of exposure refers to how much the respondent consumed refilled drinking water. Interview results revealed that all respondents

consumed refilled drinking water. Study results by Abdulloh (2020) showed that by type, of all the refilled drinking water samples investigated, 25 samples contained HDPE microplastics, 13 samples contained PVC microplastics, and 11 samples contained PE microplastics. By shape and color, 159 blue fiber particles, 130 red fiber particles, 67 transparent fiber particles, and 35 yellow fiber particles were found.

The greater the frequency of exposure, the greater the level of risk due to microplastic exposure. If one has an exposure frequency of 350 days, then he/she will most probably have a high intake (I) value. The more often and the longer an individual is in a polluted environment, the greater the number of agents likely to enter the body and the greater the risk of health problems occurring (Juwitriani *et al.*, 2016; Samimi *et al.*, 2023). The average value increases beyond the consumption of refilled drinking water because the level of human need for drinking water varies. Every human being requires drinking water in the amount of at least 8 L/day. Prolonged exposure to polyethylene terephathalate microplastics contained in refilled drinking water will cause an accumulation of microplastics in the body. The longer an individual is exposed to a hazardous substance, the greater his/her likelihood of being exposed to a health risk. Although in a low concentration, the accumulation resulted will cause health effects in the long term (Rochman *et al.*, 2016). As shown in Fig. 6, the mean
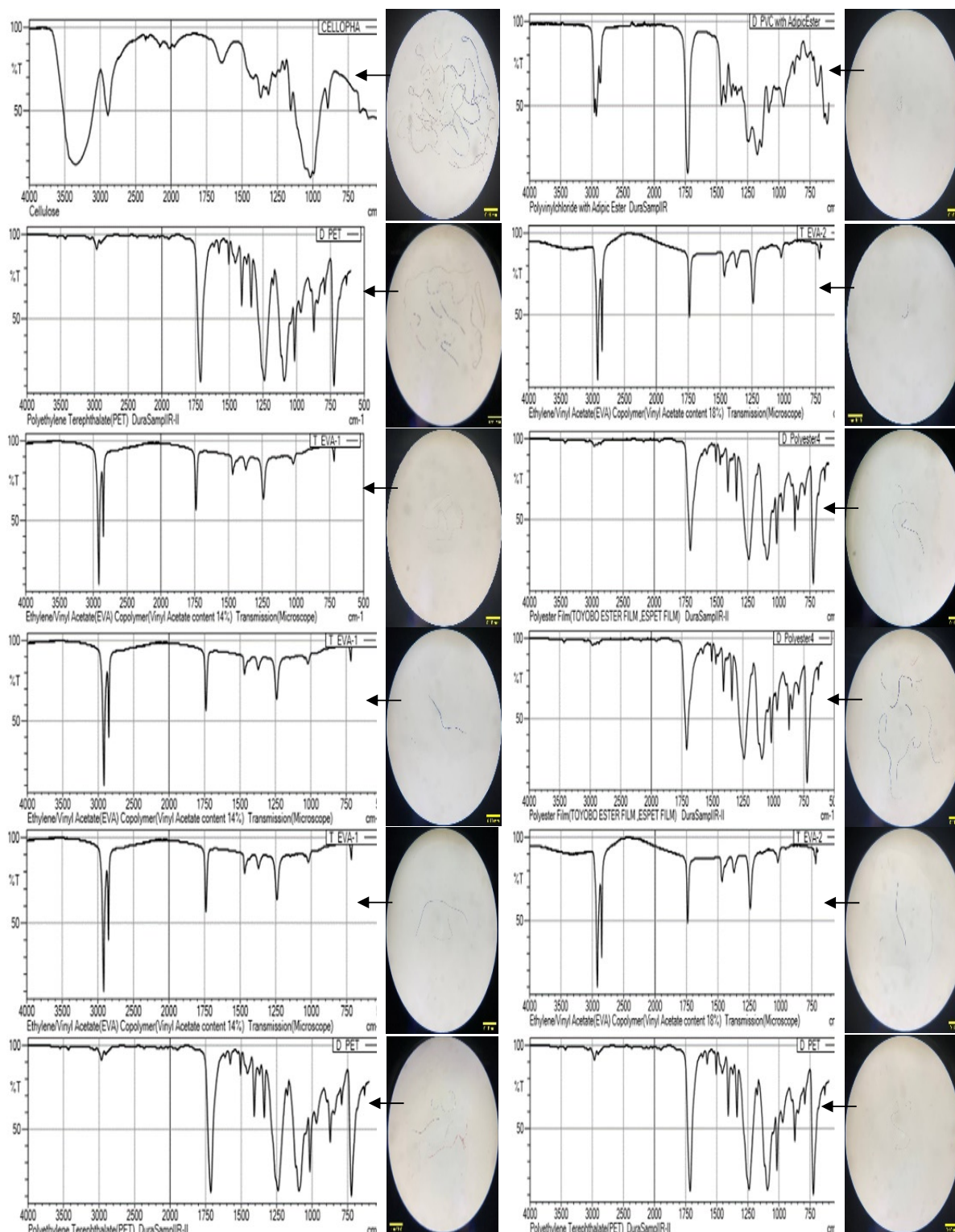
Fig. 5: Results of the FTIR analysis of the microplastics in refilled drinking water

Table 4: Characteristics of respondents based on risk analysis and community activity patterns in Tamangapa, Manggala District, Makassar City

Indicator	Min	Max	Median	Information
Age	7	68	50	Years
Weight	21	73	57.50	kg
Intake Rate	126	269	210	mg/kg/day
Frequency of Exposure	350	350	350	day/years
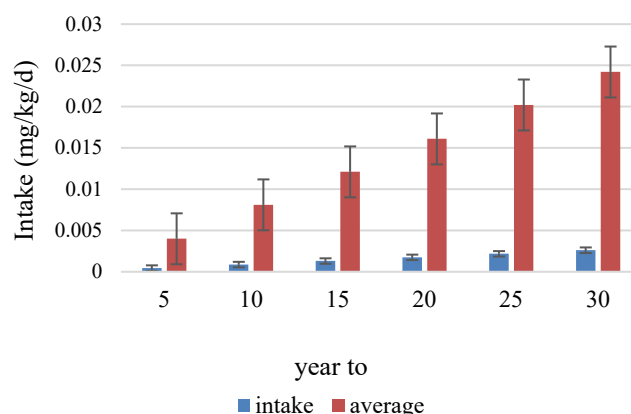
Fig. 6: Projected mean intake of polyethylene terephalate microplastics during 30 years of exposure time

intake of PET microplastics in Tamangapa, Makassar City, is projected to continuously increase from the 5th to the 30th year, with microplastic intake values between 0.000434 and 0.002607. Smaller fractions of ingested microplastics (1–10 μm) can be absorbed in the intestinal area and trapped in the human body throughout life. In cases where excretion of bile is limited, the trapped particles will reach a higher concentration in all body tissues than in the intestine despite the small particle size.

Estimates were made of the MP intake levels in salt, the water, and the air. The median and maximum microplastic consumption recorded for salt and the air were close to the 90th percentile. The readings recorded for tap water, however, were below the 50th percentile of the distribution range (Siswati and Khuliyah, 2017). The relationship between intake and risk agent concentration, exposure frequency, and exposure duration is linear. In other words, the greater the values of these variables, the greater the individual's intake. The longer the individual drinks contaminated refiled drinking water, the greater the intake value and the greater the risk for adverse health effects (DGDCEHMH, 2012).

Fig. 7 shows the projected risk quotient for the exposure duration of 5–30 years on microplastics (polyethylene terephalate) in Tamangapa, Makassar City, which always increases, exceeding the reference dose in the next 5–30 years. RQ > 1 indicates that the level of risk is unacceptable or unsafe, which necessitates controlling risk in order to drive the RQ down below 1. The average non-carcinogenic risk quotient calculation was higher due to differences in body weight. Toxicity will affect those with low body weights more easily than an individual with a high body weight. In other words, the greater the body weight, the lower the risk of suffering from non-carcinogenic diseases. The level of risk will increase with the increasing duration of exposure or estimated time. Table 5 shows that the risk management that must be carried out against PET microplastic exposure is projected to span 5–30 years in duration of exposure, with a minimum value of 2.52E+08, a maximum value (Max) of 2.47E+10, and an average value of 6.48E+09. For the intake rate, the minimum value (Min) is 4.29E+07, the maximum value is 3.27E+09, and the average value (Mean) is 2.52E+08. As for reference doses, the minimum value (Min) is
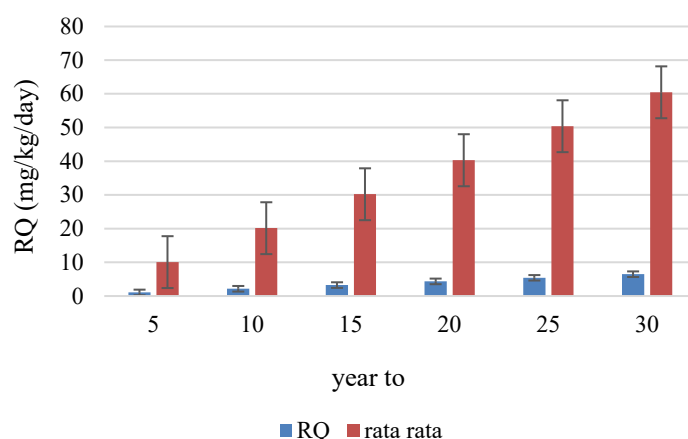
Fig. 7: Projected mean risk quotient of polyethylene terephalate microplastics during 30 years of exposure time

Table 5: Minimum, maximum and mean risk management values in Tamangapa, Manggala District, Makassar City

Variable	Risk Management (mg/kg/day)		
	Min	Max	Mean
Duration time	2.52E+08	2.47E+10	6.48E+09
Intake rate	4.29E+07	3.27E+09	2.52E+08
Reference dose	3.13E+05	2.90E+07	2.90E+06

3.13E+05, the maximum value (Max) is 2.90E+07, and the average value (Mean) is 2.90E+06.

The degree of risk is stated in numbers without units as a result of computing the ratio of intake to reference dose/concentration of a non-carcinogenic risk agent, which may also be regarded as either a safe or an unsafe risk agent for organisms, systems, or populations (Darena, 2018). When microplastics are ingested, the addictive substances and absorbed chemicals can be released in digestive juices and potentially transfer to edible tissues (Campanale *et al.*, 2020). Particles smaller than 150 µm can enter through the gastrointestinal epithelium of mammals and cause systemic exposure. However, scientists hope that only 0.3% of these particles be absorbed (A'yun, 2019). If microplastics accumulate in the body, they can have negative impacts such as inflammation of the organs, internal and/or external injuries, transformation of plastic chemical contents into the body, intestinal microbial disturbances that cause blockage of the intestinal tract resulting in a sensation of pseudo-fullness, physiological stress,

changes in diet, growth inhibition, and decreased fertility (Isma and Danira, 2022). Microplastics may also serve as conduits for the introduction of bacteria into the water. Lower trophic levels are thought to acquire microplastics that have polluted the biota at higher trophic levels. The entry of microplastics into the bodies of biota can damage the digestive tract, reduce growth rate, inhibit enzyme production, reduce steroid hormone levels, and affect reproduction. Biota consume organisms at lower trophic levels and then experience biomagnification, in which case the biota also has the potential to be consumed by organisms at higher trophic levels, including humans, and affect the organisms' health (Wright and Kelly, 2017). Several emerging technologies can be employed as a means to deal with microplastics. One of such technologies is biorefinery, which can be implemented at or near a landfill, on the condition that plastic waste is separated from other kinds of waste. It will help reduce plastic waste on site and indirectly reduce waste as a whole (Madadian *et al.*, 2020).

Risk management

Risk management aims to control factors and risks that can cause health problems due to consuming refilled drinking water containing polyethylene terephthalate microplastics. In the risk analysis with an agent-oriented approach, several variables are measured to determine the magnitude of the risk, namely, the concentration of polyethylene terephthalate microplastics in the environment, duration of exposure, rate of intake, and frequency of exposure.

a. Risk control through the reduction of microplastics in drinking water can be performed by calculating the concentration at which polyethylene terephthalate microplastics in drinking water are safe for everyday consumption or use for a certain period of time.

b. Intake control can be performed by reducing the amount of consumption of refilled drinking water while maintaining other factors such as body weight, concentration of microplastics (polyethylene terephthalate), and frequency of exposure. Various efforts have also been made to degrade hazardous synthetic plastic polymers, which are currently the biggest contributor to plastic waste burden to the environment. Enzymes from actinomycetes, bacteria, fungi, insects, and other microbes have been researched for their possible involvement in the biodeterioration, biofragmentation, absorption, and mineralization of these petrochemical-based polymers and their minute components (Amobonye et al., 2020). Other mitigation strategies focus on lowering plastic trash output and keeping it out of as many different habitats as feasible. It can be achieved using various procedures. Among those procedures are government initiatives to progressively or outright prohibit the widespread sale and usage of plastic bags as well as the commercial usage of microplastics in beauty products. Single-use plastic bag bans or/and restrictions are examples of such a strategy (Ogunola et al., 2018).

Limitations

This study was limited to microplastics of the polyethylene terephalate polymer type. In addition, this study did not examine the stool of the respondents, so at what concentration polyethylene terephthalate microplastics are excreted from the human body stool is not known. Future researchers are suggested to develop other research regarding microplastics in drinking water. Monte Carlo simulations may also be implemented to determine the variables or values that have the most effect on exposure to microplastics in refilled drinking water.

CONCLUSION

Microplastic pollution has a far and wide presence in the environment. It can be encountered in the sea, sewage, clean water, food, air, water sources, and even in drinking water, including refilled drinking water. Microplastics of the polyethylene terepthalate type are mostly used for food and beverage packaging purposes. Microplastic particles of this type can translocate to the liver or spleen through the lymph, posing a risk of inflammation and changes in immune processes. Polyethylene terephthalate microplastic exposure in refilled drinking water in Tamangapa, Makassar City poses a health risk. Some measures of risk management that can be taken are to reduce the concentration of risk agents if the pattern and timing of consumption cannot be changed, reduce the consumption pattern (intake rate) if the concentration of risk agents and the time of consumption cannot be changed, and reduce contact time if the risk agent concentration and consumption pattern cannot be changed. Other mitigation strategies focus on lowering plastic trash output and keeping it out of as many different habitats as feasible. It can be achieved using various procedures. Among those procedures are government initiatives to progressively or outright prohibit the widespread sale and usage of plastic bags as well as the commercial usage of microplastics in beauty products. Single-use plastic bag bans or/and restrictions are examples of such a strategy. The limitation of this study lies in the use of only microplastics of the polyethylene terephalate type. The study also only discusses the effects on the human body through feces and without tracing deeper other health problems or health symptoms caused by exposure to microplastics (polyethylene terephthalate). Drinking water is safe for health if it meets the physical, microbiological, chemical, and radioactive requirements as mandatory parameters and additional parameters based on the Regulation of the Minister of Health regarding drinking water requirements.

AUTHOR CONTRIBUTIONS

S. Kasim dealt with the literature review, experimental design, methodology, analysis and interpretation of results, and preparation of the manuscript text and manuscript edition. A. Daud carried out the experiments, literature review, simulation modeling, data collection, and article writing. A.B. Birawida provided assistance with the literature review, data collection, and manuscript writing. Some of the final tests were carried out by A. Mallongi, who also oversaw data curation and validation. A.I. Arundhana read the manuscript and explained the model simulation's findings. A. Rasul compiled data and reviewed the presentation draft. M. Hatta assisted in the development of the manuscript and literature review.

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CONFLICT OF INTEREST

The authors declare that there are no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, were observed by the authors.

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ABBREVIATIONS	DEFINITION
%	Percent
μm	Micrometer
ARKL	Environmental health risk analysis
C	Concentration
Cm	Centimeter
Dt	Duration exposure
fE	Frequency exposure
FTIR	Fourier transform Infra-red
Fig.	Figure
GCMS	Cromatografi gas spectrometri massa
HDPE	High density polyethylene
I	Intake
IR	Infrared
Km^2	Square kilometer
L	Liter
LPDE	Low density polyethylene
m	Meters
Max	Maximal value
Mg/kg/d	Milligram per kilogram per day
Min	Minimal value
MT	Million ton
nm	Nanometer
mm	Millimeter
PE	Polyethylene
PET	Polyethylene terephthalate
PP	Polypropylene

PS	Polystirene
PVC	Polyvinyl chloride
R	Rate
RfD	References doses
SEM	Scanning electron microscopy
Tavg	Average time period
USDFA	Us food and drug administration's
Wb	Weight of body

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