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Factors influencing microplastic contamination in bottled drinking water in Indonesia: a systematic review

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Abstract

Purpose: This study aimed to determine the content of microplastics in Indonesia, the factors that influence them, and their impact on the human body. **Methods:** This study uses a qualitative method with a systematic literature review approach by reviewing eight journals screened using the prism method according to the inclusion criteria with a database derived from Science Direct, PubMed, Google Scholar, and the Invivo application. **Results:** The results showed that the concentration of microplastics in bottled water was 7,043 - 8,339 particles/L with sizes ranging from small to large (10-5000 μm). The dominant form of microplastics was fibers and fragments, primarily white, with the dominant composition being polypropylene (PP), polyethylene (PE), and polyethylene terephthalate (PET) polymers. Factors affecting microplastics in bottled drinking water include water sources, production processes, exposure to sunlight, and repeated use of bottles. Microplastics can cause hormonal imbalances, heart disease, infertility risk, digestive disorders, and growth inhibition. Ways to reduce MP particles in AMDK include traditional filtering of raw water, electrocoagulation, magnetic extraction, and membrane separation. **Conclusion:** This systematic literature review found that bottled drinking water in Indonesia contains 7,043 - 8,339 microplastic particles/L, primarily composed of PP, PE, and PET polymers. Factors influencing contamination include untreated waste disposal, high pollution levels, production processes, sunlight exposure, and repeated bottle use. These microplastics pose significant health risks, making it crucial to address these factors to reduce contamination and protect public health.

Keywords: bottled drinking water; influencing factors impact; microplastics

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INTRODUCTION

In the last decade, awareness of the environmental impact of plastic pollution, especially microplastics, has significantly increased. Despite a growing body of research on microplastics in ecosystems and bottled water, a considerable gap exists in studies focusing on Indonesia. Current research predominantly centers on identifying and quantifying microplastics, leaving a gap in understanding the specific factors contributing to microplastic contamination in bottled water in Indonesia and its health implications. This study aims to address this gap by investigating the sources and mechanisms of microplastic contamination in bottled water in Indonesia, providing novel insights into the local context and potential health risks.

This study aims to bridge this gap by investigating the factors influencing microplastic presence in bottled water in Indonesia and assessing their possible health impacts. This research seeks to enhance the understanding of microplastic contamination in Indonesian bottled water through a systematic literature review and provide insights into best mitigation and risk management practices.

By offering new perspectives and empirical data on microplastic contamination in Indonesia, this study is poised to contribute significantly to the academic literature. It aims to inform policymakers and industry stakeholders, promote effective mitigation strategies, and raise public awareness of the health risks associated with bottled water consumption.

With the development of the times and the increasing growth of society, the need for water also increases. With technological advances, many drinking water supply industries are contained in plastic containers. Aspadin data shows bottled drinking water consumption in 2018 was recorded at 29 billion liters annually. [1] The use of bottled water has also increased, causing many activities to search for clean water in water in the soil, rivers, and lakes, manage water in the sea, and restore polluted water [2]. In Indonesia, there was a significant increase in bottled water consumption. In 2005, the consumption of bottled water was only 4.1%, then rose sharply in 2017 to 42.8% and rose again by 10% in 2019 [3].

Microplastics are particles that are about 0.3 mm-> 5mm [4]. Microplastics are plastic particles that are difficult to decompose; this can be caused by improper disposal and handling of plastic waste [5]. Microplastics are not as easy to get rid of as the ocean, and plastic is a very persistent material [6].

In a study of 22 water bottles that were able to return and bottles that were only used once, three beverage packages and nine glasses taken from a grocery store in Germany found small (-50-500µm) and medium-sized (1-50 m) microplastics. Nearly 80% of all the items obtained had compound sizes ranging from 5 to 20 mm and were therefore not detected by the analytical techniques used in previous studies. For the amount received in the whole sample, there were 118 ± 88 particles in the disposable container, but only 14 ± 14 particles/l contained in the packaging container, which was used only once. What is included in the microplastic in the packaging of beverage storage containers is only 11 ± 8 particles. Still, the plastic element found was relatively high in several types of glass bottled water (range 0-253 particles/l, average 50 ± 52 particles/l). Statistically significant differences in the blank values (14 ± 13) with the type of packaging investigated can only be shown compared to the returnable bottles ($p < 0.05$). For some elements in the water in the plastic container bottle, it can be given back and re-identify what is there, such as polyester (PET primary polyethylene terephthalate, 84%) and polypropylene (PP, 7%). Statistically significant differences in the blank values (14 ± 13) with the type of packaging investigated can only be shown compared to the returnable bottles ($p < 0.05$). For some elements in the water in the plastic container bottle, it can be given back and re-identify what is there, such as polyester (PET primary polyethylene terephthalate, 84%) and polypropylene (PP, 7%) [7].

The microplastic research conducted by one of the leading universities in New York took 259 bottles of water, with the number of water brands being 11 bottles. In various countries, 93% of bottled drinking water is proven to contain microplastics, which is used for some countries, including Indonesia. The samples were about 30 aqua bottles, which included an average of 325 particles/L for each sample, with the highest content reaching 4.7143 particles/L. The size of the microplastics varies from 6.5 m to more than 100 m. The product from Nestle Pure Life is the water with the most microplastics globally, with a content of 10,390 particles/L. This is thought to be caused by bottling the water in the packaging and coming from the bottle itself. As is known from Wright's research, microplastics can cause a series of biological responses, including inflammation, oxidative stress, and necrosis, affecting the human immune system.[9].

Based on this explanation, many studies on microplastics in bottled water, but not too much is related to bottled drinking water in Indonesia. This study aims to research information about the content, factors that affect microplastics in bottled water in Indonesia, and the impact if they accumulate in water and the human body.

METHODS

Level of environmental vulnerability

Level of environmental vulnerability: Three parameters need to be considered in determining the feasibility of bottled drinking water: physical, biological, and chemical. The physical parameters include turbidity, taste, color, odor, temperature, dissolved solids, and microplastics, where microplastics can negatively affect the environment and cause human cancer,

Subjects

The population of this study was taken from the database Science Direct, Google Scholar, and Pubmed about 3090 journals on Google Scholar, 11453 journals on ScienceDirect, and 7324 on Pubmed according to keywords with samples being screened based on keywords that the author had previously set, based on the inclusion criteria of International and National Journals related to the content of microplastics in bottled water. In Indonesia, the influencing factors, the dangers of microplastics in bottled water, and how to overcome them, and the period of the journal is five years (2017-2021).

Research design

This study uses a qualitative design with a literature study approach. A systematic literature review is a scientific study that describes a predetermined topic; this SLR can allow researchers to review, analyze, and develop theories or methods of specific issues and review the gaps between one theory and another relevant to the field.

Data collection

The type of data used in this study has been obtained from the screening process by combining all data or sources related to the topic under study. This study examines journals and other scientific papers using the PRISMA method associated with the content of microplastics in bottled greeting water in Indonesia.

RESULTS

The following image is a word cloud generated from microplastic research publications. Word clouds are visual representations of text data, where the size of each word indicates its frequency or importance in the source material. This visualization technique helps quickly identify the most prominent terms and concepts within a body of literature, providing insights into the main focus areas and trends in the research field.

Figure 1. shows the word cloud in the image emphasizes the main focus and themes related to microplastic research, particularly highlighting how this issue is being studied in countries like Germany and Malaysia. Terms such as "university," "science," and "environmental" indicate that these sectors are actively involved in researching the nature, origins, and impacts of microplastics across various environmental systems. By featuring words like "wastewater treatment" and "removal," the image suggests that research efforts are directed toward un-

Figure 1. Form of Invivo Application Output

-derstanding the presence of microplastics and developing solutions for their mitigation and management. This image effectively reflects the urgency and diversity of approaches in microplastic research. It highlights international collaboration in addressing this global environmental issue in vivo is software that can be used to build and visualize bibliometric networks such as journals, titles, authors, publications, and so on. The results of a bibliometric analysis based on the title, keyword, and year of the journal that has been carried out using the systematic review and vosviewer method obtained several keywords related to and influencing the topic of microplastic research in bottled drinking water, which includes the elements present in microplastics found in bottled drinking water that affect it, the impact caused by microplastics on bottled drinking water, and efforts to deal with MP in bottled water.

The table above provides a comprehensive overview of research on microplastics' presence, impact, and mitigation in bottled drinking water. It includes various studies employing different research methods, from descriptive analysis to experimental approaches. The findings indicate that microplastics are found in multiple forms and sizes in bottled drinking water, with polymer fragments being the most common form. The studies also reveal that factors such as exposure to sunlight can influence the amount of microplastics in PET bottles. Furthermore, the research underscores the importance of adapting existing limits on microplastics in water to protect drinking water treatment processes. Lastly, studies on legal protection for consumers highlight the need for regulations to address microplastics in bottled drinking water.

Table 1. shows the results obtained on Google Scholar; there are 320 articles. Based on the title, 290 articles were selected. Then, after reading the abstract, 21 articles were selected, and finally, three

articles were selected, which would be reviewed by reading the entire article. For Science Direct, there were 1756 articles related to the topic; after entering the inclusion criteria, 1701 related articles were obtained. After reading the title and abstract, 20 journals remained, three of which are worth reviewing after reading them. Pubmed produced 41 journals; after entering the inclusion criteria, we got 12 journals; after reading the title and abstract, two journals are worthy of being studied with Systematic Review.

Table 1. Overview of research on microplastic presence, impact, and mitigation in bottled drinking water

Author	Title	Sample	Method	Result,
(Faujiah, Isma Nur Wahyuni , Ira Ryski, 2022)	Abundance and Characteristics of Microplastics in Drinking Water and Their Potential Impacts on Human Health	43 journals. With journals obtained based on the source, namely ResearchGate, Google Scholar, and ScienceDirect	Descriptive qualitative data analysis	Found in the form of microplastic fragments with the type of Polypropylene (PP) as many as 10.4 particles/L with a size >100 m, 335 particles/L with a length of 6.5-100 m; microplastic in the form of fiber and fragments with the types of Polystyrene (PS), Polyethylene-terephthalate (PET) and Polyethylene (PE) with sizes of 0.025-5,000 mm; microparticles of 12 to 58 particles/L with a size of 40 to 723 m; 118±88 particles/L of Polyethylene-terephthalate (PET) and Polypropylene (PP) microplastics and 14±14 particles/L of Polyethylene-terephthalate (PET) types.
(Faizah, Atyaf Umi. 2020)	a Comparative Study About the Amount of Microplastic in Polyethylene Terephthalate (Pet) Drinking Water That Was Exposed and Not Exposed By Sun At Environmental Health Laboratory of Poltekkes Kemenkes Semarang In the Year 2020	AMDK brand X, which is a PET bottle volume of 600 ml	Pre-Experimental	The amount of microplastics in PET-bottled water exposed to sunlight is different from that in water that is not exposed to sunlight. As a form of vigilance, the public is advised to keep PET-bottled water away from direct sunlight for both distribution and utilization of other types of PET bottles for different purposes, such as water disinfection using sunlight (SODIS).
(Mason et al., 2018)	Synthetic Polymer Contamination in Bottled Water	239 bottles of bottled water from various brands in China, USA, Brazil, India, Indonesia and Mexico	Experiment	Of the 259 total bottles processed, 93% showed signs of microplastic contamination. After considering the possibility of contamination, an average of 10.4 microplastic particles measuring > 100 m per liter of processed bottled water was found, with the predominance of Fragment form followed by fiber. Half of these FTIR spectroscopy confirmed that the particles were polymeric, with polypropylene being the most common polymer type (54%) used in the plastics manufacturing bottle caps.

(Shen, et al. 2020)	Removal of microplastics via drinking water treatment: Current knowledge and future directions	15 International Journals	Descriptive	The authors propose that existing pretreatments that limit the amount of microplastics in water should be adapted to protect drinking water treatment processes.
(Dyah Ayu, Mustikasari 2021)	*Legal Protection for Consumers of Packaged Drinking Water Products From Microplastic Content.*	legislation, official records or minutes in the making of laws and regulations, and judges' decisions	Descriptive	The author said that the form of legal protection for consumers related to the content of microplastics in bottled water is contained in Law No. 8 of 1999 concerning the safety and rights of consumers, which is meant by the existence of the law that can protect the rights of consumers on the bottled drinking water they consume.
(Ivana, Kezia 2021)	Microplastics in Drinking Water	Journal	Descriptive	The manufacturing, storing, and marketing process influences the presence of microplastics in the water when consumed. These activities also include allowing water to enter when water is put into a bottle and providing a cover. These activities can cause abrasion and remove microplastic elements. Other things, such as physical stress, can cause shaking of the packaging to release microplastic elements in the water.
(Handayani, Risa. 2020)	Literature Review of Microplastic Content in Bottled Drinking Water (Amdk)	Journal	Study of literature	The content of microplastics ranged from 7,043 to 8,339 particles/L. The dominant forms of microplastics encountered were fragments and fibers, with the colors being transparent, light blue, dark blue, reddish brown, dark brown, white, and red. The predominant size of microplastics in bottled water showed the size of tiny microplastics in the range of 1-10 m and the dominant size of large microplastics in the range of 10 - 5000 m. The dominant microplastic compositions found were polypropylene (PP), polyethylene (PE), and polyethylene terephthalate (PET) polymers.
(Schirinzi, *et a.* 2017)	Cytotoxic effects of commonly used nanomaterials and microplastics on cerebral and epithelial human cells	Cerebral and Epitel Human Cell	Experiment	The results confirmed that oxidative stress is one of the mechanisms of cytotoxicity at the cellular level, as observed for both cell lines, and that it is highly likely to cause tissue damage and chronic inflammation.

DISCUSSION

The content of microplastics in bottled drinking water

A review of studies related to microplastics, their characteristics, and their types then focused on the analysis of microplastics in drinking water and their consequences for human health [10]. With 43 journals obtained from Research Gate, Google Scholar, and ScienceDirect (Elsevier) with inclusion criteria, the journal must have a DOI and beform of at least one published in the last 5 years. From the review conducted, the authors conclude that microplastics in bottled drinking water are in the form of fragments with the type of Polypropylene (PP) as many as 10.4 particles/L with a size > 100 m and 6.5–100 335 particles/L with a length of 6.5–100 m; microplastics in the form of fiber and fragments with the type of Polystyrene (PS), Polyethylene-terephthalate (PET), and Polyethylene (PE) size 0.025-5, 000mm; microparticles of 12 to 58 particles/L with a size of 40 to 723µm; Microplastic as much as 118±88 particles/L type Polyethylene-terephthalate (PET) and also type Polypropylene (PP) and 14 Then supported by a researcher [2], The dominant forms of microplastics encountered were microplastics in the form of fragments and fibers, with the colors found being transparent, light blue, dark blue, reddish brown, dark brown, white and red [10].

Based on [8]. Most of the sample bottles were packaged in 500-600 ml, 750 ml, and 2L packages and then randomly selected with several 10 bottles, 6 bottles, and 4 bottles in sequence and injected with red nile solution. (prepared in acetone to 1 mg mL−1) and resealed. The vials are left to incubate with the injected dye for at least 30 minutes. The bottled water is then vacuum-filtered through a glass fiber filter. The filter is examined under an optical microscope using a blue crime light. All particles larger than100 m (large enough to be seen with the naked eye and manipulated with tweezers) are photographed, counted, and typed concerning morphology (Fragment, Fiber, Pellet, Film, or Foam). In addition, the first 3-5 particles were analyzed via FTIR. MPinto two volume fractions, called "NR"+"Particles larger than 100 m'' identified by FTIR and "NR marked particles" having a size of 6.5-100 m. For “NR + FTIR particles'' (>100 m), the mean density was found to be 4.15 MPP/L, with a range of 0–14 MPP/L, whereas in the smaller “NR marked particles” (6.5–100 um), the mean density is 23.5 MPP/L, with a range of 7–47 MPP/L. Of all samples from various countries studied, Indonesia, including 30 samples, showed an average of 325 particles/L with a maximum of 4.7143 particles/L for each sample. The size of microplastics ranges from 6.5 m to more significant than 100 m. Nestle Pure Life products have the highest microplastic content in the world, with 10,390 particles/L. With the number. The total concentration of MP in AMDK in Asia is 333.3, 272, and 119.8 particles/L, with a relatively large amount of consumption of 145.66 liters per capita [8].

For drinking water to be in proper packaging, it must meet specific criteria. In this case, microplastics in bottled drinking water for consumers are regulated in Law No. 8 of 1999 concerning the protection and rights of consumers. The SNI criteria to become SNI are following normative guidelines, understanding and explaining quality requirements, taking samples such as how to test, with the requirements of passing the test, hygiene, packaging of goods, and marking requirements [11].

The findings of our study on microplastic contamination in bottled drinking water have profound implications beyond the scientific community, impacting public awareness, policy-making, and consumer behavior. Microplastics in a daily consumed product like bottled water raises significant concerns for public health, necessitating urgent attention from health educators and policymakers.[12] The need for public education campaigns to raise awareness about the environmental and health risks associated with microplastics is evident. Such initiatives could encourage consumers to adopt more sustainable consumption practices, reducing reliance on single-use plastic bottles [13].

Moreover, our research underscores the necessity for stricter regulatory frameworks to mitigate microplastic pollution. It calls for policymakers to develop and enforce legislation to reduce plastic waste and ensure bottled water safety. The potential for this study to influence environmental policies and standards highlights the critical role of scientific research in shaping a sustainable future [14].

The industry's response to microplastic contamination is equally crucial. There is a growing need for innovation in packaging materials and filtration technologies to minimize microplastic presence in bottled water. The shift towards more sustainable packaging solutions aligns with environmental objectives and responds to increasing consumer demand for eco-friendly products [15].

Additionally, the social impact of microplastic contamination extends to consumer behavior. The awareness of microplastics' health risks may drive consumers towards alternatives such as home water filtration systems or reusable water containers, promoting a shift from single-use plastics [16].

Lastly, the global nature of microplastic pollution requires international collaboration among governments, research institutions, and environmental organizations. Joint efforts are essential to address the pervasive issue of plastic pollution and protect global water resources [17].

In conclusion, our study on microplastic contamination in bottled drinking water contributes to a broader understanding of its social implications, emphasizing the need for concerted public education, policy development, industrial innovation, and global cooperation to mitigate this pressing environmental challenge.

Inconsistent manufacturing standards across different brands can lead to varying levels of microplastic contamination in bottled water. Standardizing manufacturing processes can reduce this inconsistency.

Microplastics can contaminate bottled drinking water because it is influenced by several factors that determine some of them, namely water sources where microplastics can be contaminated from untreated waste disposal and high pollution in rivers and seas where filtration can only reduce about 78% of microplastic particles; this study in line with [2]. Then the next factor that is quite influential is the production process. According to [18], in the process of entering drinking water into the bottle, the hydrodynamic pressure on the plastic bottle, especially the process of giving the cap, became the source of the entry of microplastics into bottled drinking water.

The quality and thickness of plastic bottles can influence the release of microplastics. Higher-quality, thicker bottles are less likely to degrade and release particles. The packaging of bottled drinking water can also be a factor; there is a big difference between disposable and reusable bottled drinking water, with a ratio of 2,659 particles/L and 4. 889 particles/L according to research [17]. Stress on bottled drinking water also occurs during distribution, and consumption, and storage by opening the lid many times can cause abrasion of the cap and mouth of the bottle [12].

Poor handling and transportation practices, such as excessive shaking and exposure to harsh conditions, can increase microplastic contamination in bottled water

According to research conducted by [13], the sample of the Indonesian product AMDK is a PET bottle with a volume of 500 ml, then, with sample preparation, a sample of drinking water is taken in 500 ml packaging, and the sample will be filtered using Whatman filter paper, then proceed to the next step. analysis using a binocular microscope with 40x magnification after 2 different treatments; one bottled water was exposed to sunlight, and the other was not for 5 hours. The result is that sunlight contains UV rays that can cause mechanical effects on the cracked PET parts, so the number of MP particles in the affected AMDK increases. The average number of microplastics in bottled drinking water that is not exposed is 131.25 particles/liter [13].

The impact of microplastics on the body and efforts to eliminate microplastics from drinking water

Based on research conducted [14] through a journal review, microplastics can cause toxic effects on the human body. Microplastics can generate oxidative stress and induce tissue damage and chronic inflammation. A review by [9] investigated the potential impact of microplastic uptake on human health through gastrointestinal absorption. The absorption and translocation of microplastics depends on many factors, and smaller particles translocate more effectively for larger plastics (>2 mm) to stay in the intestinal tract. Although low concentrations of microplastics can enter the blood circulation, it is challenging to enter deep tissues through cell membranes due to their limited size and being cleared by the spleen [14]. This statement is the same as what has been researched, namely by [2], where it is explained that MP can cause an imbalance between hormones, can cause heart disease, and can make the body obese research and [13] states that the transformation of elements that are chemically plastic in body parts, interfere with intestinal microbes to affect the occurrence of blockage of the intestinal tract which results in a feeling of unseen fullness, physiological stress, changes in diet, and growth inhibition [13].

In research [15], Observations were made on brain cells and epithelial cells contaminated with microplastics using the test in vitro cytotoxicity by high content analysis. Brain and epithelial cells were stored on 96-well plates and then exposed to microplastic polymers at a size of 10 ng/mL to 10 g/mL for 24-48 hours. At the end of exposure, the tested solution was removed, and cells were stained with two fluorescent biomarkers for 30 minutes. at 37 °C in 5% CO2 atmosphere. Then, the labeling solution was aspirated, and cells were rinsed with PBS. Fluorescence measurements were determined at emission wavelengths of 485 nm (Hoechst) and 549 nm (DHE) using the Cell Insight NXT High Content Screening (HCS) Platform (Thermo Scientific) [15].

Several techniques and strategies were tried to remove microplastics from beverages [16]. Among them is traditional water filtration, which, in general, a conventional filtration process is a promising approach for removing microplastics. Traditional filtration strategies for small microplastic particles (up to 1mm in size) are more straightforward to remove microplastics from raw water. Circumstances Laboratory conditions must reflect conditions prevailing in drinking water treatment practices. In addition, the particle size distribution of microplastics in raw water and interactions between contaminants and other microplastics are needed to find a better scheme for removing microplastics. Electrocoagulation provides a cheaper tertiary treatment method that does not rely on the chemicals or microbes used in standard chemical coagulation processes and conventional activated sludge. Thus, making the coagulation process simple and robust, although this study has some limitations, given the microplastic removal efficiency and operating costs, this technique can be transferred and reproduced from the laboratory to industry. Then there is Magnetic Extraction, a separation technology that uses magnetic seeds and acids with an external magnetic field to increase the separation speed. The latter is a membrane separation often used for advanced drinking water treatment, which has the advantage of being stable. Depending on the size of the membrane, Membrane separation technology can be divided into ultrafiltration, nanofiltration, and reverse osmosis. The membrane has strong selectivity and separation can effectively remove organic pollutants, multivalent ions, and disinfection by-products while reducing water hardness [14].

CONCLUSION

This study identifies key factors influencing microplastic contamination in bottled drinking water in Indonesia. Significant sources of contamination include untreated waste disposal and high pollution levels in rivers and seas, with filtration processes reducing only about 78% of microplastic particles. During the production process, hydrodynamic pressure, particularly during capping, introduces microplastics into the water. Environmental exposure, such as sunlight, degrades plastic bottles, increasing microplastic contamination. Additionally, repeated use and handling of bottles cause abrasion, releasing more microplastic particles.

Microplastics pose significant health risks, including hormonal imbalances, heart disease, infertility, digestive disorders, and growth inhibition. Their presence can lead to oxidative stress, tissue damage, and chronic inflammation in the human body. Therefore, addressing these factors is crucial for reducing microplastic contamination and protecting public health.

Governments should implement stricter regulations on bottled water production to minimize microplastic contamination, including higher standards for filtration and packaging and tighter oversight of waste disposal. The industry must invest in eco-friendly packaging technologies to reduce plastic degradation. Public education campaigns are essential to raise awareness about the health risks of microplastics and promote sustainable practices. Improved plastic waste management and international collaboration are crucial to developing practical solutions. Ongoing research into microplastic health impacts and removal methods is necessary to provide comprehensive data and solutions.

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