RESERCH ARTICLE Open Access

Gema Lingkungan Kesehatan
Vol. 22, No. 2 (2024), pp 103-107
e-ISSN 2407-8948 p-ISSN 16933761
Doi: https://doi.org/10.36568/gelinkes.v22i2.130 Journal Hompage: https://gelinkes.poltekkesdepkes-sby.ac.id/

The Effect of Ultraviolet Exposure on the Quantity of Microplastics in the Air of Buildings Made from Plastic Waste

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ABSTRACT

Microplastics are new environmental contaminants that result from plastic degradation and fragmentation. Ultraviolet is one of the physical factors that can affect plastic fragmentation. The study aimed to analyze the effect of ultraviolet exposure on microplastic levels in the air of buildings made from plastic waste materials and methods of true experiment research with posttest-only control group design. Air sampling was conducted 60 days in buildings made from plastic waste with treatment and control samples. Sampling of airborne microplastics by passive method. Visual observation of microplastics using a 10-fold magnification binocular microscope. Analysis of the effect of UV exposure on microplastic levels by simple linear regression. The results showed that the average level of microplastics in the air of buildings made from plastic waste in the treatment sample was 38.78 particles/m^2/day, and in the control sample, 22 particles/m^2/day. There are 3 forms of microplastics found in the air of buildings made from garbage, namely fragments, fibers, and films. Analysis of the effect of ultraviolet exposure on the quantity of microplastics in the air of buildings made from plastic waste obtained a p-value of 0.000<0.05. The study concludes that ultraviolet exposure affects microplastic levels in the air of buildings made from plastic waste.

Keywords: Ultraviolet, Microplastics, Air, Recycling

INTRODUCTION

The generation of plastic waste tends to increase each year. In Indonesia, plastic waste occupies the second position among the types of waste produced from 2018 to 2022, after food waste, with an average percentage of 19% (Kementerian, 2021). The increase in plastic waste is due to population growth, plastic consumption, and littering habits. The most produced plastics are 36% polyethylene (PE), 21% polypropylene (PP), 12% polyvinyl chloride (PVC), and the remaining types are polyethylene terephthalate (PET), polyurethane (PUR), and polystyrene (PS) (GESAMP, 2019).

Plastic's non-biodegradable nature leads to plastic waste accumulation, resulting in environmental pollution. Waste management can be conducted through reuse, reduce, and recycle, known as the 3R concept (Undang-Undang RI, 2008). Recycling is a method of processing inorganic waste by converting it into other usable items (Arico & Jayanthi, 2018). Innovations have been made to process plastic waste into economically valuable items such as paving blocks and walls (Burhanuddin et al., 2018; Winnerdy & Laoda, 2020). The physical and mechanical processes of making building materials from recycled plastic waste can accelerate plastic fragmentation. Larger plastics fragment into microplastics due to physical factors like heat radiation and mechanical factors like friction and pressure (Susanto & Trihadiningrum, 2021).

Microplastics are plastic particles smaller than 5 mm (Marsden et al., 2019). They result from plastic fragmentation. Factors influencing plastic fragmentation include biological, chemical, and physical or mechanical factors. Physical factors influencing fragmentation are ultraviolet rays, washing processes, climate, and mechanical pressure (Ummah, 2013). Microplastics are classified based on their shapes into five categories: hard and coarse particles, small pellets, filaments, films, and foams (Jain et al., 2021). Ultraviolet radiation exposure plays a crucial role in causing brittleness on plastic surfaces, thus increasing the likelihood of particle size reduction to micro (Susanto & Trihadiningrum, 2021).

Microplastics have been found in various environments, including air, food, soil, clean water, drinking water, and wastewater (Marsden et al., 2019). The presence of indoor air microplastics has been studied in several countries. Microplastics were found in the air of office buildings in Surabaya, Indonesia (Bahrina, 2021), in residential air in Sydney, Australia (Soltani et al., 2021), in residential air in Shanghai, China (Xie et al., 2022), and in apartment air in Paris, France (Dris et al., 2017).

Making building materials from recycled plastic waste involves physical and mechanical processes, such as shredding plastic waste into smaller sizes. In addition to shredding, manufacturing building materials from plastic waste involves pressing and compaction (Burhanuddin et al., 2018). These physical factors increase the risk of microplastic formation (Ummah, 2013).

Using building materials made from recycled plastic waste can lead to microplastic pollution in the air (Alabi et al., 2019; Wright & Kelly, 2017). However, the impact of indoor air microplastic pollution on the health of building occupants is not yet clear.

Physical quality tests of buildings made from plastic waste have been conducted, but their impact on microplastic pollution in the air has not been studied. If microplastic air pollution is not addressed, it is feared that it could affect the health of building occupants, particularly harming the respiratory system. This study aims to analyze the effect of ultraviolet exposure on microplastic levels in the air of buildings made from plastic waste.

METHODS

This study is a true experiment with a posttest-only control group design. The experimental unit consists of the air within a miniature building made from plastic waste, measuring 1 cubic meter. There are control and treatment samples, each comprising one miniature building made from recycled plastic waste serving as the experimental unit. The treatment sample involves a building made from recycled plastic waste exposed to UVA and UVB radiation for 60 days. The control sample is a building made from recycled plastic waste that has not been exposed to UVA and UVB radiation. The study's independent variable is the intensity of UV light, while the dependent variable is the quantity of microplastics in the air. The control variables are the plastic waste's weight and the building's volume.

The experimental units made from plastic waste are miniature buildings constructed from bricks and paving blocks made from plastic waste, cement, and sand. The bricks are made with a volume ratio 1:2:3 for cement, sand, and plastic. For the paving blocks, the volume ratio of cement, sand, and plastic is 1:2:3, with an additional layer of cement and sand on the top. The buildings serving as treatment units are fitted with UVA and UVB lamps, while the control units are not fitted with UV lamps.

The research was conducted over 60 days, from September to October 2023, in Banyumas Regency, Central Java. Ultraviolet measurements were taken using a UV meter with units of mw/cm². Air samples from the buildings made from plastic waste were collected using a passive gravity method, performed every 24 hours. Dust that settled on the surface of the building was collected using a vacuum with a HEPA filter of 0.3 µm pore size. The microplastic content in the air was examined using a visual method. The first step in examining the microplastics involved three times rinsing the HEPA filter with 1 liter of distilled water. The rinse water was then filtered using Whatman filter paper with a diameter of 90 mm and a pore size of 2.5 µm. The filter paper was then observed under a microscope, and the number of microplastics was counted in units of particles/m². The influence of UV intensity on the quantity of microplastics in the air was analyzed using linear regression. Data normality was tested using the Kolmogorov-Smirnov test. The analysis results are presented in tables and narratives, including the quantity of microplastics in the air and the effect of ultraviolet exposure on microplastic quantity. The identified forms of microplastics are presented in images and narratives.

RESULTS AND DISCUSSION

Buildings Made from Plastic Waste

The construction of miniature buildings made from plastic waste consists of bricks and paving blocks, as shown in Figure 1.

Figure 1. Miniature Building Made from Plastic Waste

Description:

1	:	This results from shredding plastic waste, which is mixed with cement and sand.
2	:	The process of molding the mixture into bricks and paving blocks using compaction techniques.
3	:	Assembly of materials into a miniature building made from plastic waste.
4	:	Building made from plastic waste.

Plastic waste of various types is mixed in, producing building materials such as bricks and paving blocks. The initial step in creating these building materials is shredding the plastic waste into smaller particles to facilitate mixing with other materials. The volume ratio of cement, sand, and plastic is 1:2:3. For paving blocks, the top layer is supplemented with a mixture of cement and sand.

Creating building materials from plastic waste is an innovation aimed at reducing the volume of plastic waste. There are two methods for producing building materials from recycled plastic waste. The first method involves melting plastic waste at high temperatures until it becomes liquid, followed by molding and pressing (Burhanuddin et al., 2018). The second method involves shredding the plastic waste and mixing it with other materials, such as sand, cement, water, paint, oil, and lime, followed by molding and pressing (Mahardika, 2021). The physical and mechanical processes involved in producing building materials from recycled plastic waste can accelerate the fragmentation of plastic into microplastics.

The control sample is a miniature building made from recycled plastic waste without exposure to UV A and UV B. The treatment sample is a miniature building made from recycled plastic waste continuously exposed to UV A and UV B light.

Examination of Microplastic Levels in the Air of Buildings Made from Plastic Waste

The results of the microplastic level calculations in the air of buildings made from plastic waste over 60 days, measured every 24 hours, are presented in Table 1.

Table 1. Average Quantity of Microplastics in the Air of Buildings Made from Plastic Waste

Sample	N	Microplastic Quantity (particles/m²/day)			STD
		Min	Max	Mean	
Control	60	11	28	22	3,99
Treatment	60	26	72	38,78	9,78

In this study, microplastics were found in the air of buildings made from plastic waste in quantities ranging from 11 to 72 particles/m²/day, with particle sizes ≥2.5 µm. This is consistent with previous studies where microplastics were found in the indoor air of apartments in Paris, France, ranging from 1 to 60 particles/m², linked to the use of plastic furniture and occupancy density (Dris et al., 2017). Other similar studies found microplastics in the air of homes in Sydney, Australia, ranging from 22 to 6169 particles/m²/day (Soltani et al., 2021). The levels and deposition of microplastics are influenced by factors such as rainfall, wind speed and direction, occupant density and activity, and other environmental factors. Microplastic levels in the air tend to increase during the rainy season (Allen et al., 2019). Local environmental factors such as altitude and geography also affect the abundance of airborne microplastics (Liu et al., 2019). In this study, air sampling was only conducted during the dry season, which might increase microplastic levels during the rainy season. Future research should examine the differences in microplastic levels in the air between these two seasons.

In this study, air samples were collected using the passive method, which involves collecting settled dust every 24 hours using a vacuum with a HEPA filter. Air sampling for microplastic examination can be performed using passive and active methods. The passive method involves collecting settled dust on surfaces to obtain airborne microplastics, using gravity as a principle. The active method involves drawing or suctioning air using a pump-like device to measure the volume of air sampled. Microplastic identification can be done using visual methods and Fourier Transform Infrared (FTIR). The visual method employs a microscope to identify and count microplastics (Zhang et al., 2020).

Identification of Microplastic Forms in the Air of Buildings Made from Plastic Waste

The observed forms of microplastics in the air of buildings made from plastic waste found on the filter paper were filaments, fragments, and films.

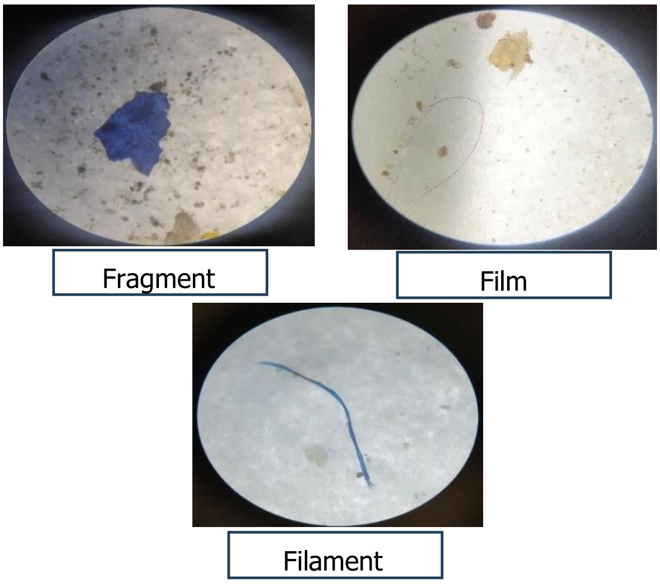

Figure 2. Forms of Microplastics in the Air of Buildings Made from Plastic Waste

The forms of microplastics found in the air of buildings made from plastic waste include fragments, filaments, and films. Previous research has identified microplastic forms using visual methods such as fibers, fragments, films, pellets, foams, granules, filaments, and beads. Based on their formation process, microplastics are divided into primary and secondary microplastics. Primary microplastics originate from human activities and are intentionally manufactured to meet human needs. Primary microplastic forms include spheres, pellets, granules, and foams. Secondary microplastics result from the fragmentation of plastic into smaller particles caused by various factors. Secondary microplastics have irregular shapes, including fibers, filaments, fragments, microfibers, sheets, and threads (Jain et al., 2021). The microplastics found in the air samples of buildings made from plastic waste are secondary microplastics derived from the fragmentation of plastic waste used as a mixture in building materials.

Analysis of the Effect of Ultraviolet Exposure on Microplastic Quantity in the Air of Buildings Made from Plastic Waste

The normality test results using the Kolmogorov-Smirnov test showed a significance value of 0.200, indicating that the data is normally distributed. Subsequently, a simple linear regression analysis was conducted. The results of the analysis of the effect of ultraviolet exposure on the microplastic levels in the air of buildings made from plastic waste are presented in Table 2.

Table 2. Analysis of the Effect of Ultraviolet Exposure on Microplastic Quantity in the Air of Buildings Made from Plastic Waste

Variable	Plastic Waste Base	
	Kuantity Microplastic	
	b	p
UV Exposure	0,450	0,000*

*p < 0,05 (significant)

Data analysis shows that ultraviolet exposure affects the quantity of microplastics in the air of buildings made from plastic waste, with a p-value of 0.000 and a beta coefficient of 0.450. The beta coefficient indicates a positive relationship, meaning that increased ultraviolet exposure will increase the quantity of microplastics in the air of buildings made from plastic waste. Ultraviolet exposure increases the quantity of microplastics in the air by 45%.

Several factors, including ultraviolet light, influence microplastic fragmentation. Ultraviolet exposure can accelerate the fragmentation of plastic into micro-sized particles (Song et al., 2017). According to previous research, microplastics can be produced from the fragmentation of plastic caused by ultraviolet radiation and the mechanical degradation of plastic by water flow velocity. Ultraviolet radiation causes oxidation in the polymer matrix, resulting in the cleavage of polymer bonds. Ultraviolet exposure for one month will cause physical changes in the form of cracks on the plastic surface. As the duration of ultraviolet exposure increases, the cracks and resulting microplastic fragments will also increase (Susanto & Trihadiningrum, 2021). Ultraviolet exposure results in the fragmentation of polymers into smaller particle sizes.

Microplastics in the air can have adverse health effects, particularly on the respiratory system. Inhalation exposure to microplastics can result in accumulation in the respiratory tract if their size is between 0.1 to 10 microns. Microplastic particles with a size of ≥5 microns will settle in the nose, nasopharynx, trachea, and bronchial branches. Particles smaller than 0.5 microns will be expelled during the respiratory process. Microplastics in lung tissue can cause cytotoxic and inflammatory effects (Dong et al., 2020). Microplastic exposure increases the risk of chronic obstructive pulmonary disease (COPD). Chronic obstructive pulmonary disease occurs when lung tissue experiences inflammation, narrowing, or damage characterized by persistent and progressive airflow limitation. Chronic obstructive pulmonary disease is associated with an excessive chronic inflammatory response in the airways and lung parenchyma. This occurs due to the interaction between host factors and environmental exposures, including air pollution, workplace exposure to substances, cigarette smoke, respiratory disease history, and socioeconomic status (Yudhawati & Prasetiyo, 2019).

CONCLUSION

The study results indicate that the average concentration of microplastics in the air of buildings made from plastic waste is 16.78 particles/m²/day higher in the treatment sample compared to the control sample. The identified forms of microplastics include three types: fragments, filaments, and films. Ultraviolet exposure significantly affects the quantity of microplastics in the air of buildings made from plastic waste, with a p-value of 0.000. This suggests that using buildings made from plastic waste in areas with high ultraviolet intensity is not recommended. Ultraviolet exposure influences the fragmentation of plastic into microplastics, with a significance value of 0.000, indicating that buildings made from plastic waste should ideally not be used in regions with high ultraviolet intensity due to the potential adverse health effects from inhalation exposure to microplastics.

SUGGESTION

This study has a limitation in the pore size of the filter paper used, which is 2.5 microns, meaning that airborne microplastics smaller than 2.5 microns could not be detected. Future research should use filter paper with a pore size of 0.1 microns to optimize the identification of airborne microplastics down to the smallest sizes.

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