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Microplastic levels in the indoor air of buildings based on plastic waste recycling in Indonesia

Tri Marthy Mulyasari[1], Jojok Mukono[2,*], I Ketut Sudiana[3], Nur Hilal[4]

[1] Doctoral Program of Public Health, Airlangga University, Surabaya, Indonesia
[2] Faculty of Public Health, Airlangga University, Surabaya, Indonesia
[3] Faculty of Medicine, Airlangga University, Surabaya, Indonesia
[4] Department of Environmental Health, Politeknik Kesehatan Kemenkes Semarang, Semarang, Indonesia

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CORRESPONDING AUTHOR:

mukono_j@yahoo.com
Tel: (+31) 5956009
Fax: (+31) 5956027

ABSTRACT

Introduction: Microplastics are a new type of contamination in the environment caused by plastic fragmentation and degradation. The generation of plastic waste increases every year, therefore efforts are made to recycle it into building materials. It is unclear how building use resulting from recycling plastic waste affects the development of microplastics in the atmosphere. The purpose of this study is to determine the airborne concentrations of microplastics in buildings constructed from recycled plastic waste.

Materials and methods: The study measured microplastic levels in the air for 30 days in a miniature building made from plastic waste. Samples taken during the dry season in Indonesia in 2023. Air sampling is carried out by passive method. Visual observation of the shape, and amount of microplastics using a microscope.

Results: Microplastics are found in the air of building spaces made from recycled plastic waste with varying levels every day. The average level of microplasty in the air for 30 days was 30,8 particles/m^2/day. Maximum microplastic rate of 63 particles/m^2/day, and minimum rate of 18 particles/m^2/day. The average air temperature when sampling is 25,48 ºC, air humidity is 68,37 % and ultraviolet intensity is 860 mwatt/cm^2.

Conclusion: Microplastic levels in the air of building spaces made from recycled plastic waste that can not be identified can be identified whether they are still within safe limits or not. This is because there is no regulation in Indonesia even in the world that regulates the safe limit of microplastic levels in the environment.

Introduction

Microplastic pollution is a potential that can endanger living things both on land, sea, and air. This pollution occurs due to the disposal of plastic waste that is not properly managed. The usage of plastic for everyday necessities is what leads to the excessive production of plastic waste [1]. The world's plastic production is increasing every year. In 2013, the production of plastic

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reached 330 million tons, and it is anticipated to increase by up to 100 times by 2025. The majority of plastic waste that is disposed of into the environment is not correctly managed, resulting in its contamination of the ocean [2]. Meanwhile, the process of burning plastic waste will be a source of pollutants in the air [3].

The generation of plastic waste in Indonesia increased by 19% from 2018 to 2022 in line with the level of plastic consumption [4]. Plastic can cause environmental pollution due to its difficult nature to decompose. Various efforts are made to reduce the accumulation of plastic waste. The efforts made are also called 3R, namely reuse, reduce and recycle [5]. Recycling is carried out as an effort to process waste into other forms of goods so that it can be reused and has economic value [6].

Indonesia implements innovation in the transformation of plastic waste into economic products, specifically in the production of paving blocks [7], and room partitions [8]. Physical resistance tests on building material products made from plastic waste have been carried out, even claimed to have better strength than building materials in general [9]. Nevertheless, there has never been a study conducted to determine the presence of microplastics in the air as a result of the use of construction materials to recycle plastic waste. In fact, in the physical and mechanical process of making building materials, plastic recycling can accelerate the fragmentation of plastic into smaller particles, called microplastics(10).

Plastic particles having a diameter of 0.1 µto 5 mm are referred to as microplastics [11]. Microplastics are a new type of contaminant in the environment that has not been regulated about the safe limits of their existence. Microplastics have been discovered in a variety of environmental media, including food, soil, clean water, drinking water, and wastewater, according to the World Health Organization [11]. Plastics break down and fragment into tiny particles, which is how microplastics are created. Microplastics are formed as a result of a variety of physical, mechanical, chemical, and biological causes [12]. Physical and mechanical factors include ultraviolet light, climate, and mechanical stress [10]. Chemical factors include oxidation and hydrolysis, while biological factors are bacteria, fungi, predators, and other organisms that can change the size of plastic [12].

Secondary and primary microplastics are the two categories into which microplastics are classified according to their development process. Primary microplastics are deliberately made by humans for certain purposes, for example the use of microplastics to help exfoliate the skin. Therefore, primary microplastics generally have a regular surface shape compared to secondary microplastics. When plastics break down and fragment, secondary microplastics are created. The shape of the surface of secondary microplastics is generally uneven or asymmetrical [13]. Microplastics that have been identified in the environment in the form of fibers, fragments, films, pellets, granules, foams, filaments, beads, and granules [14]. There are many different hues of microplastics in the environment, such as red, orange, yellow, tan, brown, white, clear, gray, blue, black, and green [2].

Microplastics are present in the air due to emissions and dispersion from a variety of sources, including as indoor paint, toys, rubber, culinary utensils, construction materials, furniture, waste, and electrical wires [15]. Numerous nations have conducted studies on the airborne occurrence of microplastics. Microplastics were found in the air of apartments in the city of Paris, France as much as 1-60 fibers/ m^2 [16]. In Surabaya, Indonesia, the air quality of office buildings contains 3.84 particles/m^3 of microplastics. [17]. The level of microplastics in the air of Sydney Australia city houses is 22-6169 fibers/m^2/day [18], and in the Chinese city of Shanghai as much as 1.2-11.48 N/m^3 [19]. Polyethylene Terephthalate (PET), Polyethylene (PE), Polyester (PS), Polyacrylonitrile (PAN), and Poly N-methyl Acrylamide (PAA) are among the types of microplastics that have been detected in the air in different places [20]. Humans can be exposed to microplastics, especially from indoor air [15].

Because microplastics can cause oxidative stress, inflammation, and cancerous cells, they fall under the category of hazardous and toxic materials (B3). In addition, microplastics can also pollute the environment [2]. Microplastics present in the atmosphere have the ability to trigger both acute and chronic inflammation when they are inhaled by living creatures. Additionally, microplastics have the potential to release harmful compounds into the body, which can lead to a number of health issues such as cancer, reproductive issues, and developmental issues. Furthermore, it has been demonstrated that microplastics aid in the development of antibiotic resistance [21]. Microplastics are fine particles that are able to bypass the physical defense mechanism of the airways, resulting in accumulation in the alveoli [22]. Living in buildings made from plastic waste recycling is expected to increase the risk of residents being exposed to microplastics for a long time and adversely affect lung tissue. In order to assess the danger of health damage from the building's use, this study attempts to quantify the amount of microplastics in the air of structures formed of plastic waste.

Materials and methods

The miniature building measuring 1 m^3 consists of paving blocks and bricks made of a mixture of sand, cement and plastic waste flakes with a volume ratio of 1:2:3. The process of making a building starts from mixing plastic waste, cement, and sand. After mixing, it is then printed and pressed manually so that the material compaction occurs so that it is not easily destroyed. Bricks and paving blocks that have been solidified are then dried in the sun until dry. The arrangement of bricks and paving into miniature buildings coupled with cement and sand dough to glue together so that they do not collapse easily. The miniature building was made and located in Baturraden District, Banyumas Regency, Central Java Province, Indonesia. Fig. 1 depicts the construction method and design of tiny structures created from plastic trash.

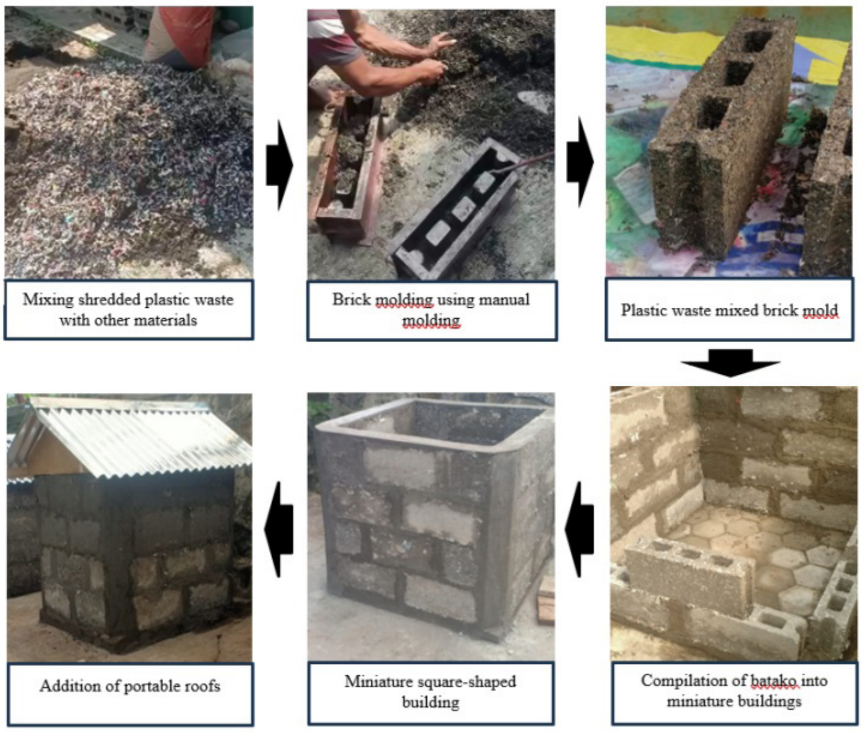

Fig. 1. The method of creating tiny structures out of plastic trash

Air sampling in miniature buildings made from plastic waste recycling was carried out during September 2023. Samples are taken for 30 days with a collection time every 1x24 h. The measured air parameters include microplastic levels, air temperature, air humidity, and ultraviolet intensity. The passive method of sampling dust is carried out using a vacuum cleaner to obtain microplastic dust. Vacuum cleaner using a 0.3 µm porous HEPA filter . The end of the vacuum is directed to the base of the miniature surface of the building, then it is moved in an orderly pattern from left to right until the entire surface of the building is passed by the vacuum funnel, and the dust on the entire surface base is taken. After the dust is taken, the HEPA filter is then rinsed using 1 L of aquadest. After the water has been cleaned, it is placed in a glass beaker and filtered using Whatman filter paper, which has a 90 mm diameter and 2.5 µm pores. Following filtration, the filter paper was examined under a microscope at a 40-fold magnification. Next, count the microplastics found in particle units/ m^2/day and identify their shapes.

Air temperature measurements are taken using a digital thermometer with ºC result units. Air humidity measurement with a digital hygrometer measurement result has a unit %. Ultraviolet intensity is measured using a UV meter with a unit of mwatt/cm^2. Following parameter measurement, the average, maximum value, minimum value, and standard deviation are computed for each parameter. The findings of the measurements are displayed using tables, graphs, and narratives.

Results and discussion

Results of measurement of temperature, air humidity, ultraviolet intensity, and microplastic levels

Measurements of air temperature, air humidity, ultraviolet intensity, and microplastic levels in buildings made from plastic waste recycling for 30 days are shown in Table 1

Table 1. Results of air temperature, air Humidity, ultraviolet intensity, and air microplastic levels

	Measurement results			
	Microplastics (particles/m^2/day)	Temperature (ºC)	Humidity (%)	UV (mwatt/cm^2)
Average	30,8	25,48	68,37	860
Minimum	16	24,1	58	133
Maximum	63	27,1	80	1.697
Standard deviation	11,68	0,63	6,85	377,76

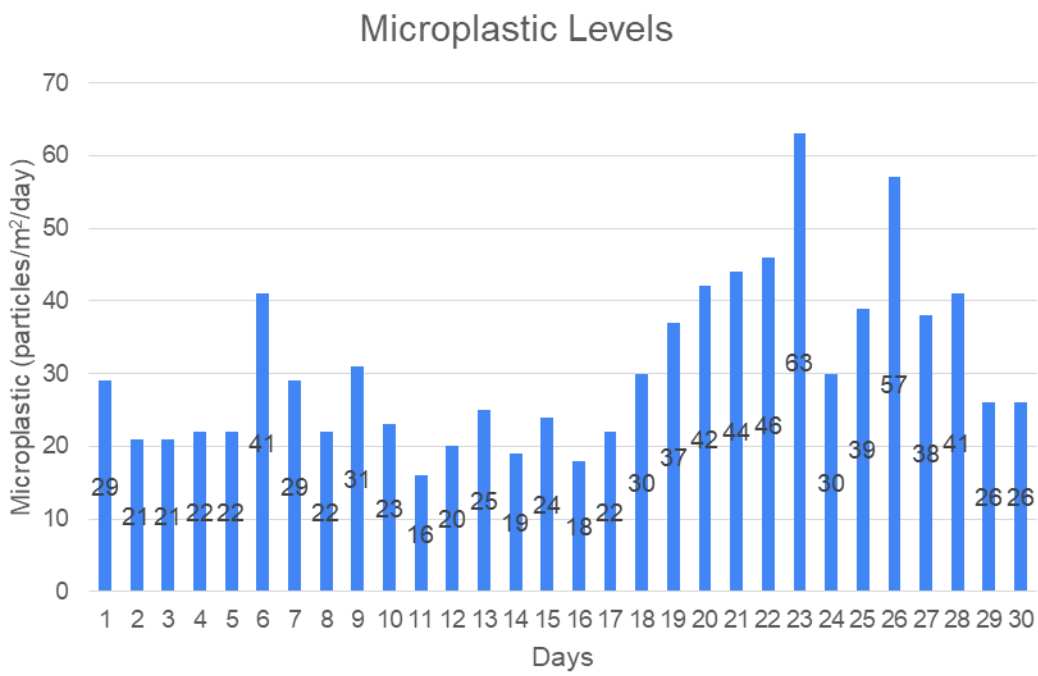

Fig. 2. Levels of microplastics in the air of buildings made from plastic waste recycling for 30 days

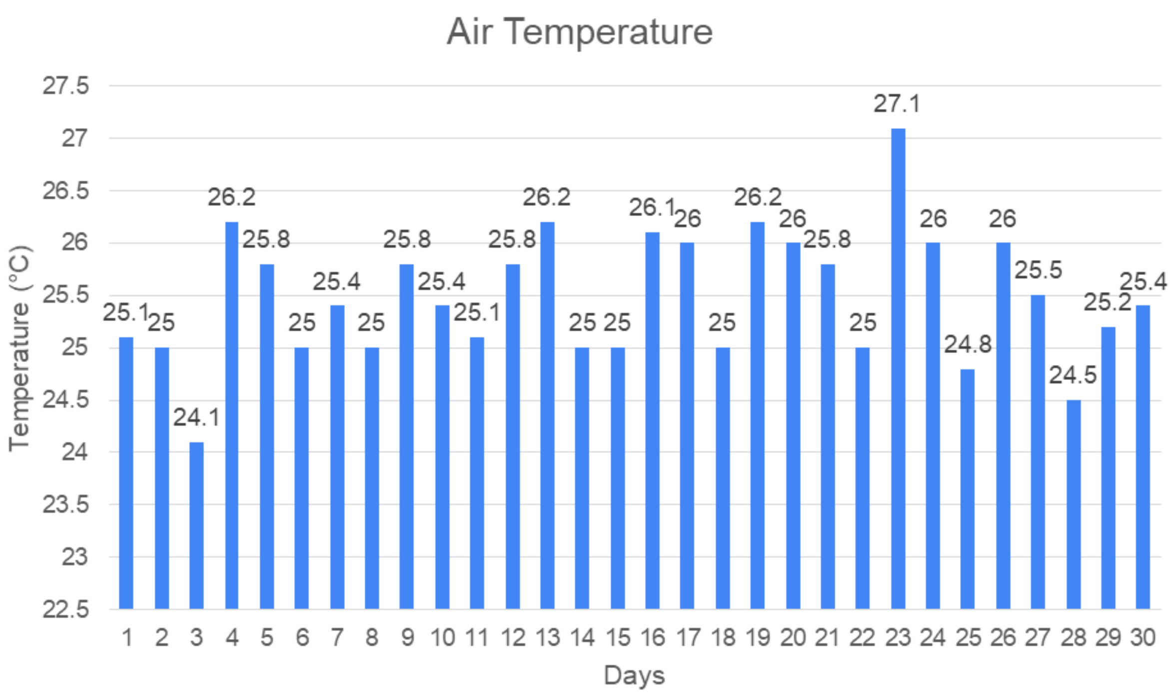

Fig. 3. Air temperature of buildings made from plastic waste recycling for 30 days

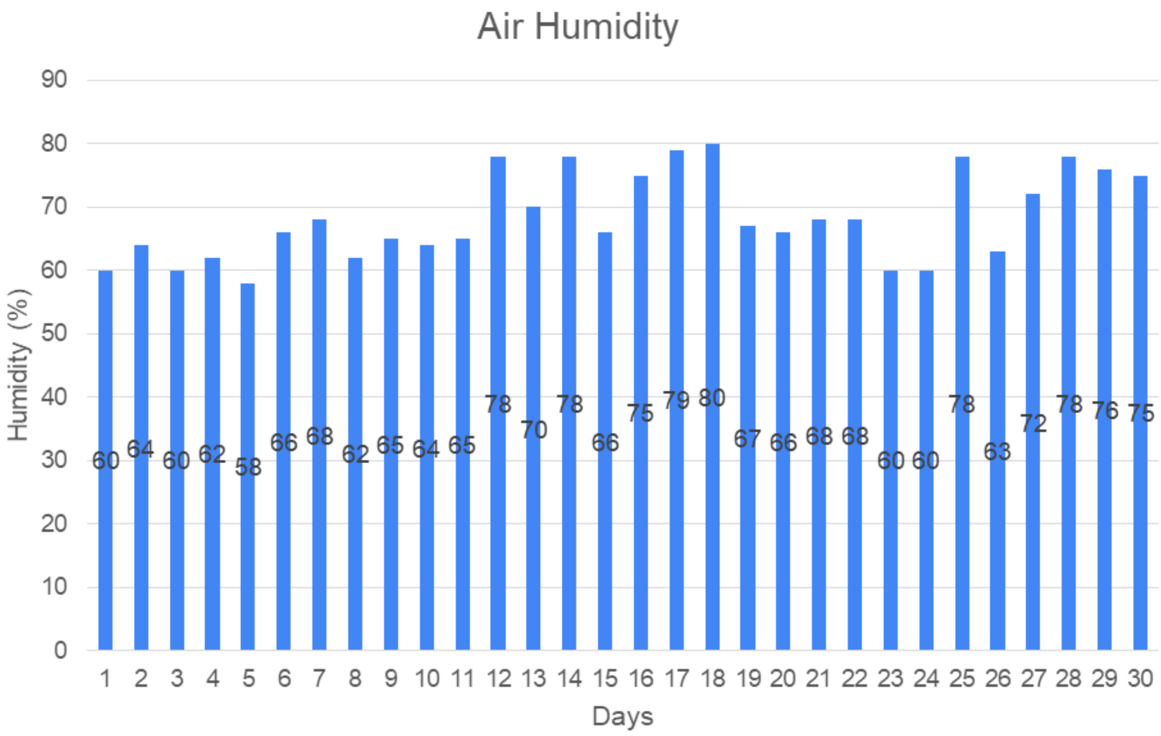

Fig. 4. Building air humidity based on plastic waste recycling for 30 days

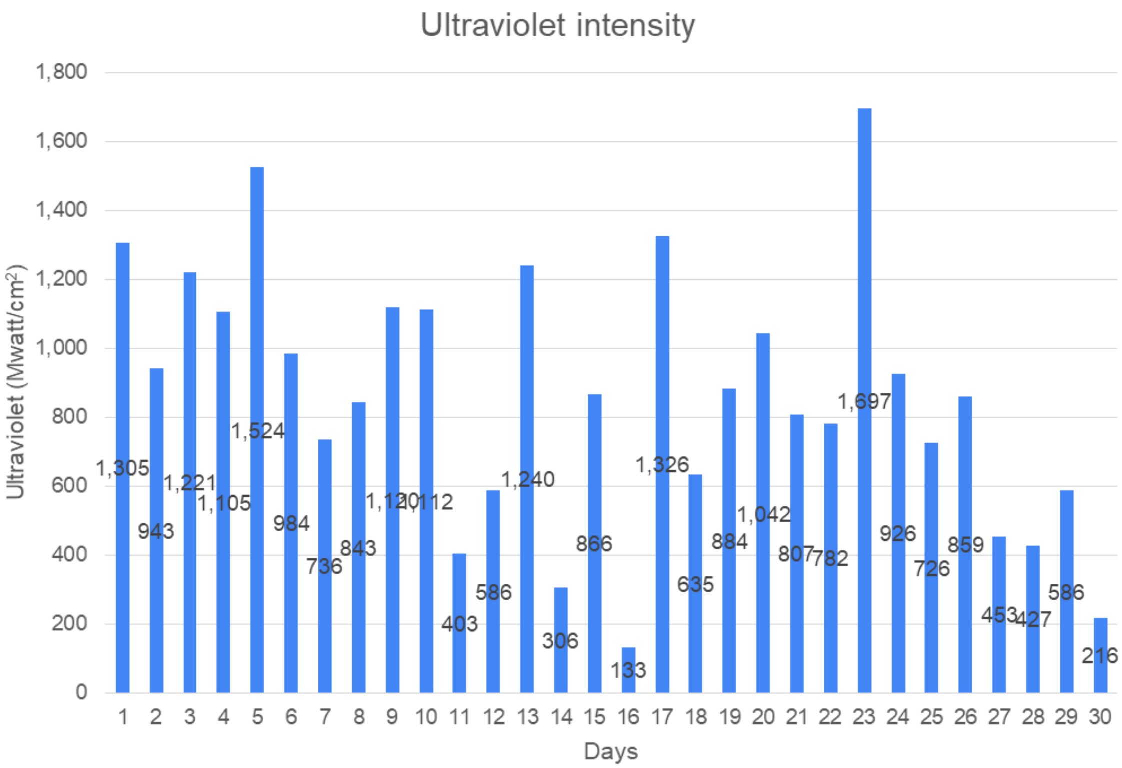

Fig. 5. Ultraviolet intensity in the building environment made from plastic waste recycling for 30 days

The maximum microplastic content rature was 27.1ºC, the air humidity was 60%, and the ultraviolet intensity was 1697 mwatt/m^2. This shows that microplastics are found in the most abundant way when air temperature of 63 particles/m^2/day was identified on the 23rd day of sampling, namely when the air tempeand ultraviolet intensity increase. In line with previous research, where microplastics are found in indoor air in various countries. Australia has been reported to have microplastics in space air, with an average of 22 to 6169 fibers/m^2/day in polyethylene, polyester, polyamide, polyacrylic, and polystyrene, each having a size of 200–400 μm [18]. In Shiraz, microplastics with an average of 195 MPs/g measuring 500-1000 μm were found in the form of polyethylene terephthalate and polypropylene [23]. In the United Kingdom, microplastics of 1414±1022 MP/m^2/day measuring 5-250 μm were found in PET, PA, and PP types [24].

Temperature, humidity and ultraviolet are environmental factors that are able to break down plastic particles into smaller sizes such as microplastics and nanoplastics [25]. Rainfall, wind direction and speed, resident density and activity, and other environmental conditions can also have an impact on the amount of microplastics in the air [26]. Geographical altitude can also affect the quantity of microplastics in the air [25]. Microplastics can be produced from the fragmentation of plastics caused by ultraviolet radiation resulting in oxidation in the polymer matrix causing the breakage of polymer bonds. Plastic that is exposed to ultraviolet for 1 month will result in physical changes in the form of cracks that appear on the surface of the plastic. The longer the exposure to ultraviolet, the cracks and microplastic debris will increase [10].

Plastic is resistant to deterioration in the environment. Plastics in water might take hundreds of years to degrade. Temperature, humidity, oxygen content, and sunshine all have an impact on the decomposition of plastic in water. Degradation is divided into two, namely photodegradation and biodegradation. Photodegradation is the process of changing compounds that are affected by radiation and photon absorption. Biodegradation is the process of breaking down the structure of organic compounds by microorganisms that are affected by temperature, humidity, pH, and nutrient availability [27]. Plastics undergo physical changes as a result of degradation, including discolouration, surface features, and the development of surface flaws. This will result in small pieces of plastic that lead to the formation of microplastics. Ultraviolet light is the most important factor in the plastic degradation process. Short-wavelength light absorption has the power to disrupt chemical bonds, leading to oxidation and other physical and chemical changes that split polymer materials. Degradation also leads to the dissolution of polymer compounds. Microorganisms can help the degradation process by metabolizing polymer compounds into CO_2, but the process is very slow [28].

Increased plastic pigment release is the result of the plastic's surface fractures and fragmentation, which let light and oxygen penetrate the interior surface and oxidize the microplastic. Waters exhibit varying degrees of breakdown for different polymers. Estrogen-releasing chemicals are released quickly in water by Polyvinyl Chloride (PVC). There is a slight surface alteration in Polyethylene Terephthalate (PET) but no discernible estrogenic activity. However, after weathering, Polybutylene Adipat-co-Terephthalate (PBAT) exhibits a heterogeneous surface with many voids. Shape, cracking, and fouling on the surface cause Acrylonitrile Butadiene Styrene (ABS) to become finer and change in color [29]. The molar mass falls during plastic particle weathering, signaling the breakdown of the polymer chain [30]. A study examining polymer weathering showed different degradation patterns in some polymers. High Density Polyethylene (HDPE) and nylon 6 break down into microfibers under ultraviolet light in seawater simulations, whereas High Impact Polystyrene (HIPS) and Polypropylene (PP) do not physically deteriorate [31]. It was discovered that pellets of PP, PE, and PS exposed to UV light in the atmosphere had more oxidized functional groups [32].

The form of microplastics in the air of building spaces made from plastic waste

Microplastics in the air of the room are identified by various shapes and colors by visual methods, namely observation with a microscope. The results of the identification of microplastic forms in samples for 30 days include fragments, fibers, and films.

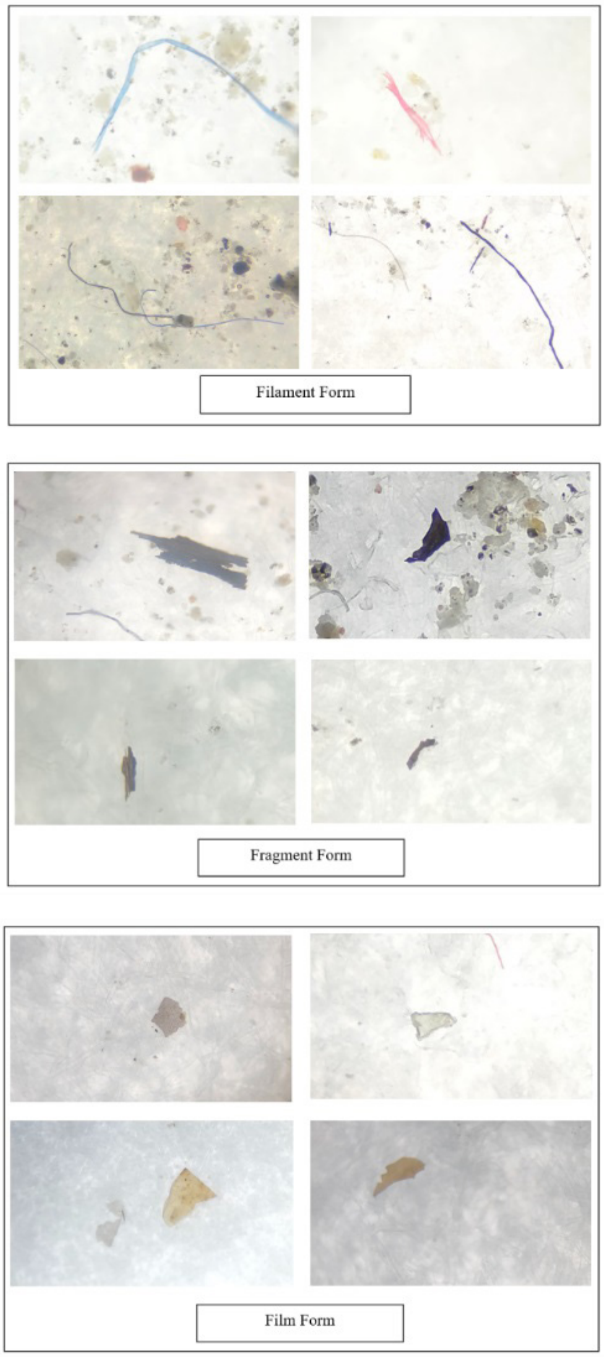

Fig. 6. Microplastic forms of filaments, fragments, and films with observation under a microscope

The form of microplastics in the form of filaments, fragments and films is the result of plastic fragmentation and degradation. The process by which microplastics are created affects their morphology. Microplastics are separated into two categories based on how they form primary and secondary. Primary microplastics, which are generally utilized in cosmetics and body care items, are purposefully created by dissolving plastic particles into tiny sizes. The form of primary microplastics is more regular, an example of which are microbeads. Meanwhile, secondary microplastics are formed due to the fragmment, degradation and weathering processes that are influenced by environmental factors. Secondary microplastics have irregular shapes. Secondary microplastics are frequently detected in the environment. Secondary microplastic forms such as filaments, fragments, and films [21]. The microplastics found in this study are secondary microplastics. This is due to the mechanical process of breaking down plastic particles to become smaller when recycled into building materials.

The impact of microplastics on health

Researchers are particularly concerned about the abundance of microplastics in the air since inhaling the tiny particles can have negative health effects [33]. Health risks may arise from breathing in microplastics through the respiratory system. The impact of airborne fine particles on the health of lung tissue has been highlighted by numerous research. Microplastic particles were also found in human sputum based on retrospective cases. Up to 78.36% of the microplastics found in phlegm were polyester, chlorinated polyethylene, and alkyd varnish. The size of the microplastic particles found in sputum was <500 μm, with a median of 75.43 μm, and a range of 44.67-210.64 μm. This indicates that a possible pathway for microplastics to reach the human body is through breathing [34]. The impact of exposure to microplastics depends on the size of the particles and their type.

Some studies show microplastics ≤20 μm in diameter have the potential to harm health. Particles ranging in size from 0.1 to 10 μm will gather within the respiratory system. The particle size <0.5 μm will be expelled again in the respiration process. Lung tissue may experience cytotoxic and inflammatory effects from microplastics [35]. The findings of Chan et al in 2020 study, which was based on a survey of 46 3-dimensional printing workers, revealed that 57% of those who worked more than 40 h a week had respiratory disorders like cough, dyspnea, increased production of respiratory mucus, decreased lung capacity, asthma, respiratory cancer, obesity, and cardiovascular disorders. The workers were made of polylactic acid (64%), acrylonitrile-butadiene-styrene plastic filaments (27%), and nylon (23%) [36].

Microplastics play a role as chemical contaminants as well as biological contaminants. Because microplastics can absorb a variety of chemical compounds, including 1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane, 1,1-dichloro-2,2-bis(chlorophenyl)ethylene, polychlorinated biphenyls (PCBs), and Polycyclic Aromatic Hydrocarbons (PAHs), they are considered chemical pollutants [37]. Polychlorinated Biphenyls (PCBs) are not easily soluble in water, but easily soluble in oil or fat. If PCBs compounds enter the body of living things, it will be difficult to excrete. This compound will bioaccumulate in the body's fat tissue, then toxic effects will occur in the form of abnormal skin growth, liver swelling, chronic diarrhea, gastrointestinal tract irritation, and lowering the body's immune system. Organic substances with hydrophobic qualities that are commonly found in the wild and are made up of different aromatic cyclic chains are known as polycyclic aromatic hydrocarbons, or PAHs. Bioaccumulation of high levels of PAHs is often found in marine life that lives and feeds on the bottom of the water such as shellfish. Microplastics are also a means of carrying various heavy metals and will be suspended for a long period of time. Microplastics as biological contaminants because plastics can be a substrate for the growth of potential pathogenic microorganisms [1].

Exposure to polyethylene and microplastic polystyrene will decrease superoxide dismutase and catalase and increase malondialdehyde as an indicator of free radical reactions in the blood of mice. In addition, there is a decrease in Acetylcholinesterase (AChE) in brain tissue as a neurotoxic response. Other pollutants like tris (2-chloroethy) Phosphate (TCEP) and Tris (1,3-Diclhoro-2-Propyl) Phosphate (TDCPP) become more harmful when microplastics are present. Microplastics with a diameter of 0.5-1 μm were also detected to accumulate in the extracellular liver and intestines of mice, triggering the appearance of oxidative stress [38]. In lung tissue, 14 days of exposure to Polystyrene (PS) microplastics can raise the expression of the inflammatory proteins TGF-β and TNF-α. If exposure to microplastics continues, there will be changes at the molecular level in the tissues and pose a risk to health [39]. In mice, inhaling polystyrene microplastics can also cause lung fibrosis by triggering the Wnt/β-catenin signaling pathway and oxidative stress [40]. Polystyrene Nanoplastics (PS-NPs) can cause inflammation, upset the redox balance, and cause apoptosis, which kills cells. Exposure to PS-NPs can reduce repair ability and result in lung tissue damage. Nanoplastic exposure causes epithelial cell barriers to be destroyed and causes cell death, which can result in tissue damage and chronic lung disease [41].

Conclusion

Microplastics found in the air of buildings made from plastic waste. The quantity of microplastics in the air is most abundant when the air temperature is high, the humidity is low and the ultraviolet intensity is high. The identified forms of microplastics are filaments, fragments and films that are secondary microplastics resulting from plastic fragmentation. The colors of microplastics found include black, red, orange, blue, green, and transparent white according to the color of recycled plastic waste.

Exposure to temperature, humidity, and ultraviolet can affect the process of fragmentation of plastic particles into microscopic sizes. The use of buildings made from plastic waste recycling should not be used in areas with high UV intensity and temperature to reduce the acceleration of the formation of microplastics in the air. Living in buildings made from plastic waste recycling cannot be ensured to be safe against potential exposure to microplastics. This is because there are no regulations that regulate the safe limit of microplastic pollution in the air. The use of buildings made from plastic waste recycling can be a potential exposure to microplastics for residents through inhalation. Inhaling microplastics will result in health problems such as lung tissue damage.

Additional investigation is required to explore the impact of the physical surroundings on the development of microplastics in the atmosphere and the resulting molecular health consequences.

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Competing interests

The writers say they have no known conflicts of interest.

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Ethical considerations

“Ethical issues (Including plagiarism, Informed Consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc) have been completely ob-served by the authors.”

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