Occurrence and characteristic of microplastics in suspended particulate, a case study in street of Yogyakarta

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Abstract. Microplastics (MPs) are increasingly recognized as emerging pollutants affecting the hydrosphere, geosphere, and atmosphere. One of the primary suspected sources of MPs is road dust in urban areas, with the majority originating from transportation, such as vehicle tires and road marking paint. MPs with a size of less than 5 mm can be ingested by humans from the air, and their potential effects remain largely undiscovered. There is still limited research on MPs in the air, particularly in Yogyakarta, one of the major cities in Indonesia. This study approach MPs as suspended particulates and, as such, employed a High Volume Air Sampler (HVAS) to collect air samples for Total Suspended Particulates TSP, $PM_{2,5}$ and PM_{10} in four locations with high human activity and traffic volumes in Yogyakarta. A digital microscope was used to identify the number, shapes, and colors of the MPs. The results revealed 4576 particles of MPs in all the samples, with East Ringroad having twice the number of MPs compared to West Ringroad. The order of occurrence in terms of shapes was as follows: fragments (39%), films (37%), and fibers (25%). In terms of color, black was the dominant color of MPs, followed by brown and transparent. These results suggest a significant presence of black, fragmented-shaped MPs, which could indicate that most MPs in the ambient air near Yogyakarta's roads originate from vehicle activity, consistent with previous findings. Furthermore, the high number of colored fibers and films may indicate packaging and fabric degradation in the surrounding area.

1 Introduction

Microplastics (MPs) are one of the main micropollutants that are present in the air and the water [1]. The term "microplastics" describe plastic materials that were smaller than 5 mm [2–4]. MPs pollution is an emerging issue in environmental [3]. Intentionally made MPs were called primary microplastics meanwhile plastic waste that breaks down in the environment through both chemical and physical processes (degraded/exfoliated/ fragmented), including wave action and ultraviolet (UV) light were called secondary

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microplastics [5]. Microplastics include particles with different morphologies, including shape (fibers, fragments, granular/spheres, films, and foam), color and variability in surface porosity [6].

Microplastic pollutants in the environment have risen steadily in recent decades, equivalent to expanding global plastic production, and are predicted to climb more in the future [7]. MPs can be found in soil, air, and water [6,8–10]. As an emerging contaminant, it has sparked significant concern in society due to their extensive distribution and associated impacts on the environment [11–13]. MPs primarily enter ecosystems through human activity. Microplastics can be carried in the environment via atmospheric or aquatic currents, depending on their weight and density [11]. While lighter microplastics can be relocated across the pedosphere by wind, denser microplastics might accumulate or be buried in the soil [11,14]. MPs can be carried by the wind as airborne microplastics and consequently be transported to remote areas such as glacier zones, high mountains and even cloud [15].

MPs have the potential to travel and physically transport nutrients across the environment [12]. Microplastics are an increasing concern in aquatic environments with many research suggest that MPs pose great physical and physiological threats to aquatic organisms and capable of entering the food web [14,16]. MPs in the environment affect soil processes and plant production, change the composition of microbial communities, are absorbed by biota, resulting in impaired health and mortality, move up the food chain, and act as vectors for pollutants [17].

Microplastics are now in our air, and we may have breath it's in as evidence that MPs already found in human lung tissue [18]. Suspended MP particles have been isolated from many atmospheric locations. Airborne microplastics (AMPs) should be regarded as a major concern in human health because they are a component of atmospheric particulate matter [13]. Particulate matter (PM), with aerodynamic diameters (D) ≤100 µm, represents an inhalable fraction, but greatest respiratory and cardiovascular hazard were for particulate that have an aerodynamic diameter < 10 µm called PM_{10} and ≤ 2.5 µm called $PM_{2.5}$ [19].

Aspherical microplastics like microplastic fibers (MPFs), account for a major fraction of discharged, airborne, and deposited microplastics observed in both natural and build environments. Several studies have revealed large amounts of fiber in the atmosphere. Plastic polymer fragments are estimated to be present in 29% of these threads [20,21]. Rubber as the material of tire also included in class of plastic [22,23]. Tire wear particles (TWP) that often mention as major microplastic, when the particles have been generated at the road surface through interaction between tire and pavement, the TWP can either sediment at the road edge or enter the environment through road runoff or via air. Suspended particle happened when the mechanical processes of vehicle tire movement, braking, and vehicle turbulence allow these roadside MPs to obtain enough mechanical energy to overcome inertial or cohesive forces and be resuspended into the atmosphere. Recent theoretical estimates suggest that TWP is one of the dominating sources of MPs pollution globally [24].

In the past decades, a significant amount of research has been done on MPs pollution in the environment, with the majority of research concentrating on their occurrence, fate, and impact in the marine and aquatic environment [6,9]. There is less information about MPs at the urban, industrial and domestic settings where significant environmental MPs are generated by a variety of processes and practices [25]. Study about MPs at the air in Indonesia are only based on Surabaya City about MPs in ambient air [20] and on Jakarta City about atmospheric disposition of MPs [26], there are little known studies about MPs in Yogyakarta City as one of larger city in Indonesia and its increasing population and steady stream of students and tourist. Yogyakarta's increased traffic activity has resulted in a decline in air quality in roadside areas, significantly in the main street and intersection of the city where there are lot of human and vehicles activity [27]. Therefore, a study on occurrence and characteristic of microplastic pollution in suspended air near the street is necessary to further understand the quality of ambient air in Yogyakarta City.

2 Material and methods

1.1 Study area

This research was carried out in 4 sampling location on intersection of Yogyakarta arterial road called Ringroad (**Fig 1**). This location was used since it's have high number of vehicles activities like braking and speeding [21,28] and also human activity near the intersection [27,29]. The 4 site define as: Site 1, located on West Ringroad (WR) street (7°47'59.3"S 110°19'48.1"E) sampled at March 2023, it's a main road to the new airport, the area also consisted of university, school, home industry and restaurant; Site 2, located in South Ringroad (SR) street (7°49'40.5"S 110°21'14.6"E) sampled at April 2023, the area around consisted of home industry and residential area; Site 3, located in East Ringroad (ER) (7°47'00.1"S 110°25'46.3"E) sampled at June 2023, a main road that connecting Yogyakarta City and Solo City, the area also near airport for air force, home industry and lot of retail; lastly Site 4, located in North Ringroad (NR) street (7°45'29.9"S 110°23'43.8"E) sampled at June 2023, it's near bus station and also the road that connecting Sleman Regency and Yogyakarta City. Based on research of Ramadan and Susilo [27] on Yogyakarta Road traffic, all four sites have steady amount of medium to high vehicle volume throughout the day.

Fig 1. (**A**) Map of Yogyakarta Ringroad and location of sampling site, (**B**) sampling device at (1) East Ringroad, (2) North Ringroad.

2.2 Sampling and pre treatment

Ambien filter sampler were the common methods for sample collection of suspended MPs in outdoor [9]. In each location of this study uses total suspended particulate (TSP), PM_{10} and $PM_{2,5}$ as the base parameter for air sampling similar to other studies [13,20,25]. The sampling method use following Indonesia Standard Metode refers as SNI, which is SNI 7119-3: 2017 for TSP, SNI 7119.15 : 2016 for PM_{10}, and SNI 7119.14 : 2016 for $PM_{2,5}$. MPs were collected by the active sampling method using High Volume Air Sampler (HVAS) with the Gravimetric Method. Air samples were collected on microfiber filter paper size 60 x 60 cm (*Staplex Type* TFAGF810) and a sampling time of 24 hours. The HVAS were placed in roadside of each intersection at a height of 1.2 m to mimic breathing height of an adult. The device with flow rate of 1.2 m^3/second, work like a vacuum pump draws air through the filter media so particles collected on the filter surface. Each HVAS was place around 100 – 200 meters from heavy traffic road (**Fig 1)**. The environmental parameter such as wind speed, temperature, humidity and pressure also recorded 24 times with a time span of 1 hour each in 24 hours.

2.2 Identification and measurement of MPs

A total of 12 sample (4 TSP, 4 PM_{10} and 4 $PM_{2,5}$) in form of filter paper was collected in 4 sampling location. TSP, PM_{10} and $PM_{2,5}$ concentration was counted using weighed analysis based on each parameter. Microplastic analysis on filter paper was using method first suggested by Abbasi [25] and then modified by Akhbarizadeh [30]. Filter paper was cut into 4 parts and placed in a glass beaker with 80 mL of deionized water. It was then placed in an ultrasonic bath for 40 minutes. The filters were then rinsed with deionized water and removed from the beakers. The washed airborne particles were put in the oven at 60°C for 24 hours to dried it. To eliminate any organic debris from the samples, the dried particles were treated with 80 mL of 30% H_2O_2 for 6 days. The samples were then immersed in 30 mL of potassium iodide solution with a density of 1.6 g/cm^3, shaken for 10 minutes at 350 rpm, and allowed to settle for 1 hour then it gets filtered. The solution then centrifuged for 3 minutes at 4000 rpm, after that get filtered through Whatman 0.45 μm filter paper with a vacuum pump that connected to magnetic filter funnel. The filter paper containing MPs objects were air dried for 24 hours. Next, the Whatman filter paper then divided into 4 quadrants, each quadrant was analysed using Olympus microscope UTV0.5XC-3 with 4x/0.1 magnification that connected to a computer. The Microscope used to observe the amount, color, and physical form of microplastics. Microplastic particles are counted for each parameter and location, and all MPs were grouped based on color and shape.

2.4 Definition of MPs Shapes

The MPs obtained from the samples were classified into four types based on their shape: fiber, fragment, film, and granule [31]. Fibrous MPs are linear MPs that are three times longer in one plane than in the other two, looking like strands or thread. Fragment MPs are brittle and flaky. Film MPs are thin and typically transparent or have a surface gloss. Granular MPs are spherical MPs with nearly equal lengths in three-dimensional. The color of MPs also observed as form of identification of possible MPs source [9,32–34], also important for future (eco) toxicological studies as color may alter some of MPs effects on organism [33].

3 Result and discussion

The concern of MPs inhalation (D ≤100 μm) [35] to human was one of the main reasons this research focused on suspended air around the street area. TSP, PM_{10} and $PM_{2,5}$ as parameter of air quality could contain MPs, referring to MPs characteristic as a light particle that could suspended in the air. Based on the microplastic observation (**Fig 2**), the abundance of plastic particulate counted from highest to lowest are ER (0.86 particles/Nm^3)> NR (0.82 particles/Nm^3)> SR (0.59 particles/Nm^3)> WR (0.42 particles/Nm^3). The highest number of MPs in East Ringroad as the street are connecting Yogyakarta City, eastern part of Sleman regency and Solo City as the main road. Based on research by Ramadan [16] this intersection in ER are one of the area with high vehicles volume on roads, as in the morning, majority of vehicles are heading to Yogyakarta city to go to work or school. This is also influenced by the existence of schools, universities, government centers, business centers and other economical centers in the area of Yogyakarta city keeping the road busy all day long. The area around ER sampling point is commercial area, airport area and rail station, the same situation also could apply to NR point as the area have huge and varied number of activities, that directly impact the amount of traffic in both ER and NR site. Similar study in Surabaya city [20], MPs analysis in ambient air yield similar result where road with more traffic have higher number of MPs than street with lower traffic.

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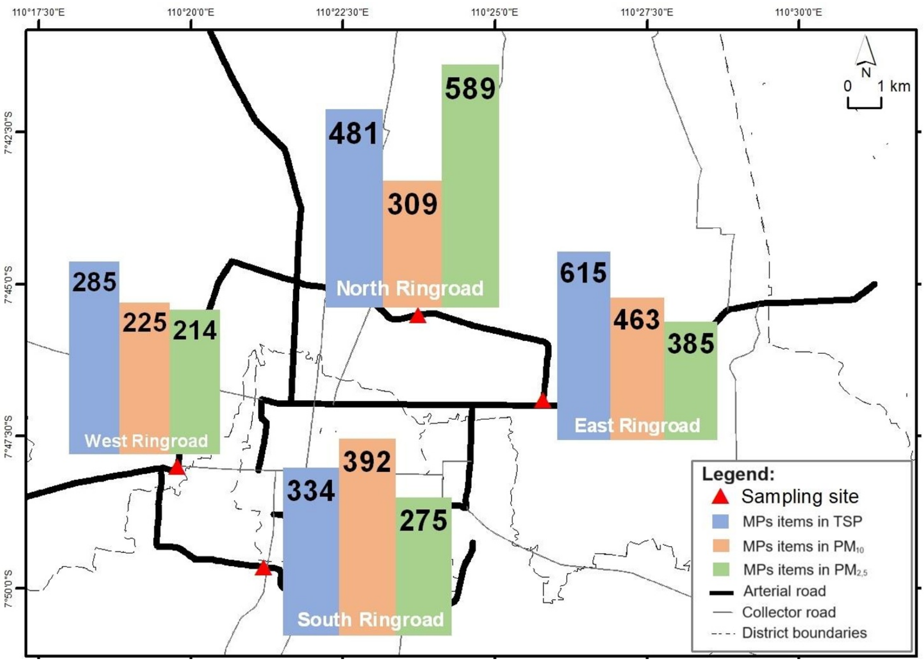

Fig 2. Sampling site and the number of MPs counted in each location.

Generally, the number of MPs items in all sampling site were highest in TSP sample, except in SR and NR which is just below the highest parameter. The amount of particle in TSP was 38% of total MPs, followed by $PM_{2,5}$ (32%) and then PM_{10} (30%), this percentage could give potential size distribution of MPs in Yogyakarta as other study compiled [2,9] that distribution of MPs size were wide from 2 µm to 5000 µm.

The majority of MPs study in the air categorized MPs as fragments, film, fiber and granule [9,32]. In this study, identified MPs are fragments, film, and fiber (**Fig 3**). No granule MPs were found in this study which quite reasonable as majority of granule MPs come from primary MPs and were found in water [20]. The shapes of microplastic found at the 4 locations, consisted of fragments, fiber and film (**Fig 4**). NR MPs consisted of film (40%) followed by fragment (38%) and fiber (22%), meanwhile the highest number of MPs in West Ringroad are fragment (46%), followed by film and fiber around the same percentage. have the lowest number of all accounted MPs. The findings are consistent with earlier research like Yukioka [5] and Abbasi [25] that MPs were dominated by fragment and film. A study by Liu [14] about suspended MPs in Sanghai where the majority of MPs found were fiber have the same shapes with this study. Fiber MPs comes from textile, as Asian production accounted for the vast majority of polyester production. Textiles manufactured from synthetic fibers often have great durability and abrasion resistance.

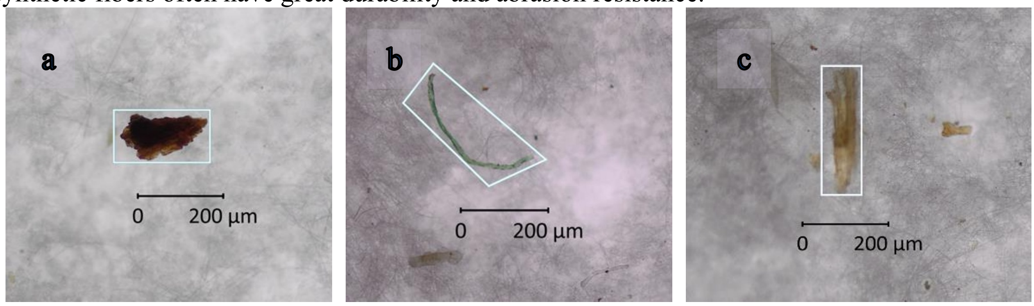

Fig. 3. Noticeable MP found in the filter at ER in PM_{10} parameter. a. fragment, b. fiber, c. film.

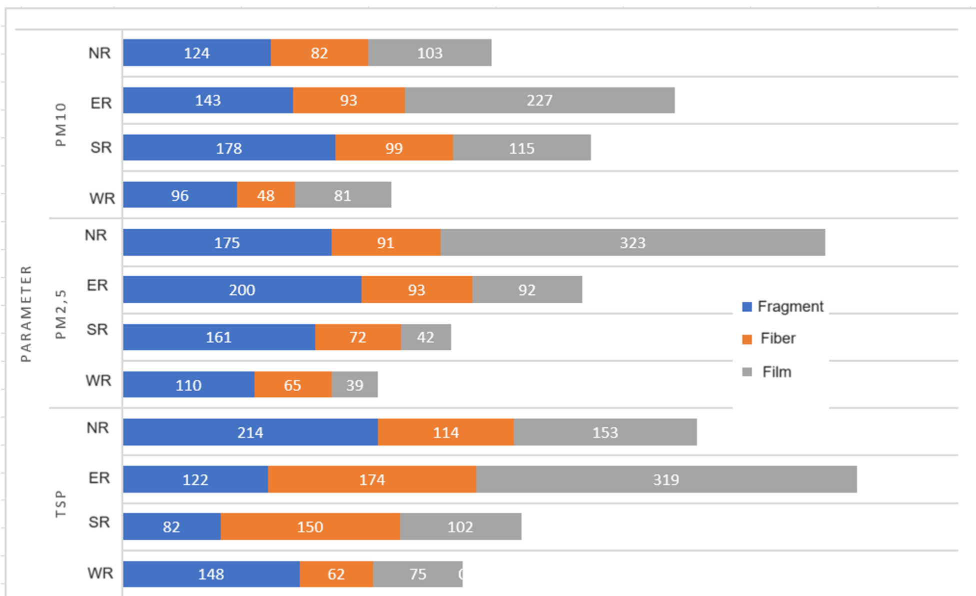

Fig. 4. MPs found based on shapes

Color can be utilized to identify potential sources of plastic waste [34] but also could reveals the degradation stage of plastics, the source of MPs [9,32]. A process called photoaging, induce changes in plastic color (particularly brightness), which could help identify how long plastic particles have been exposed to in the environment. Plastics' colors gradually shift to light colors with prolonged solar exposure (discoloration or whitening), and subsequently to yellow or amber (yellowing and tanning, respectively) due to weathering [32].

In this study, MPs are group as black, blue, brown, clear/transparent, green, orange, purple, red, and yellow (**Fig 5**). The majority of MPs found was black (47%), followed by brown (20%), clear/transparent (16%), yellow and red (each 6%), blue (2%), purple and green (each 1%) and the last is orange (<1%). The result are similar for street dust research for MPs, specifically by Abbasi [25] and Kang [8], stated that black MPs as the majority color of MPs, most likely come from tire, shoes sole and electrical insulation. This study was done in intersection and roadside where majority of vehicles push brakes to stop, this indicated that MPs in this study based on the color percentage come from the street area.

The color found in all location and parameter varies greatly. ER have the highest number of Ms in both TSP and PM10 parameter, that both have great number of yellow MPs. As for PM2,5 parameter, NR site have the highest amount of yellow and red MPs. Transparent and other colored MPs were commonly found in urban area [9,25]. ER are one of the most number of economy activity in all intersection due to their location, many buses and souvenir shop are around the area that could contributed to high number of MPs. Indonesia as country also generated lot plastic pollution, created through consumption and incorrect disposal of waste on land [36] which make MPs from packaging or container come in many color in Indonesia.

Regarding the color classification of MPs on term of shapes, fragment MPs in black was most dominant overall, with film and fiber roughly even split among the second and third most major color. The large number of brown MPs were found at the sample, also similar to study by Hiwari [37] that might indicates MPs contains Polystyrene (PS) and Polypropylene (PP) polymers.

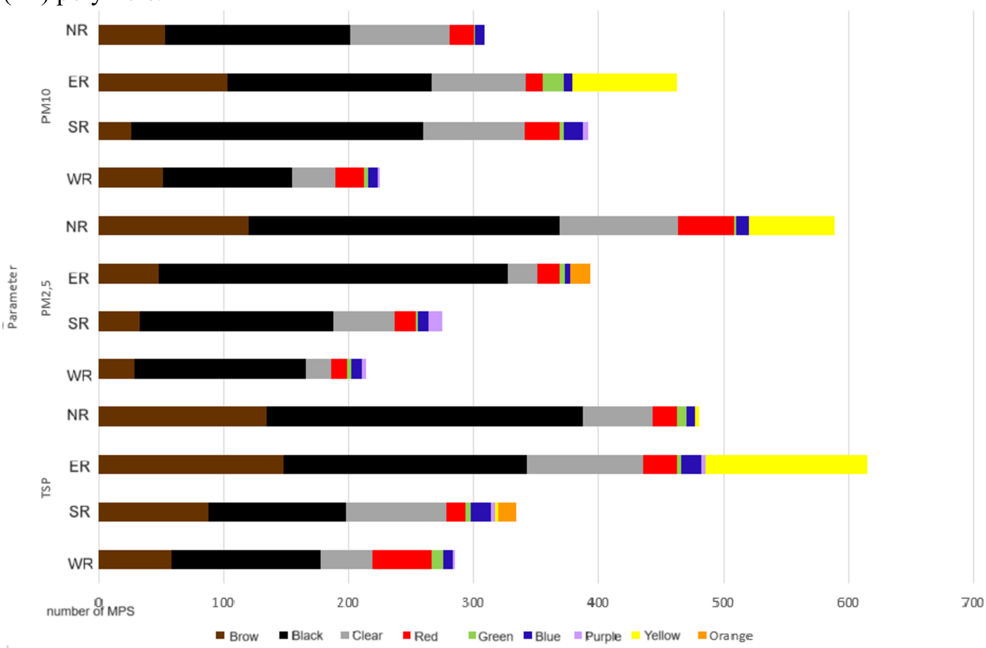

Fig. 5. MPs found based on color

Because of their small size, microplastics can be consumed by a wide range of creatures, and multiple studies have confirmed their bioavailability in the environment [8]. The number of MPs swallowed per day based on average dust intake values for adults and children, respectively quite high. The estimated intake of MPs during acute exposure is 5 or 3.3 times higher for adults and children [25]. The probability of inhaling airborne MPs is determined by their size, which also influences whether they will reach the respiratory system. As a result, particles may be inhalable (able to deposit in upper airways after entering by the nostrils or mouth) as well as respirable (able to reach and deposit in the deep lung) [9]. These MPs may also be capable of transporting microorganisms, posing an extra risk to exposed organisms once they enter the host respiratory system. Recent research have used a variety of methodologies to assess the ecological harm posed by microplastics [14].

4 Conclusion

The microplastic quantity was found in all area of study. The number of plastic particulate in three sampling, South Ringroad, East Ringroad, and North Ringroad all above 1000 items, while West Ringroad around 724 items. The most dominant shapes of MPs found were fragment (39%), followed by film (37%) and then fiber (25%). The majority of MPs found was black (47%), followed by brown (20%), clear/transparent (16%), yellow and red (each 6%), blue (2%), purple and green (each 1%) and orange (<1%). The result finds in this study presenting alike data with lot of study regarding MPs in the air.

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