Microplastic Distribution Model in Ambient Air PM$_{2.5}$ Around the Medan Industrial Area, North Sumatra

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Abstract. This research aims to investigate and model the distribution of microplastics in PM$_{2.5}$-sized air particulates around the Medan industrial area, North Sumatra. Focusing on airborne particles less than 2.5 micrometers in diameter, this research seeks to understand the impact of exposure to microplastics on ambient air quality. The air sampling method was carried out systematically at various strategic points around the industrial area, and laboratory analysis was carried out to detect and identify microplastics. The research results showed that the number of microplastics in PM$_{2.5}$ in ambient air ranged from 41 – 92 particles with an abundance of 0.41 – 1.40 particles/m$^3$. The dominant form of microplastics around the Medan industrial area is fragments, amounting to 62%. The distribution of the number of microplastics and their abundance is marked in red, which is close to the source of pollution, namely industrial areas.
1 Introduction

Microplastics are plastic particles smaller than 5 nm, with this microparticle size it is very easy to enter and accumulate in the body of organisms. Thus, toxic chemicals contained in microplastics such as organic pollutants, heavy metals, and other chemical compounds have the potential to be exposed to organisms [1].

Microplastic pollution has become a global concern due to its negative impact on ecosystems and human health. Although much research has been conducted on microplastics in seawater and water bodies, studies on microplastics in ambient air are still limited and need to be further understood [2].

Microplastics are pieces of degraded plastic waste with a size of less than 5 mm, which can be found not only in water and soil but also in the air [3]. Research has shown that microplastics can enter the human body through inhalation because they can be dispersed in the air [4]. Although research on airborne microplastics is limited, there is concern that microplastics can be easily distributed to other locations [5]. In addition, research on microplastics in the air also shows that total water production can be increased by washing and water scouring, which can increase the rejection coefficient of microplastics [6]. Therefore, it is important to identify the presence of microplastics in the air and pay attention to their potential impact on human health and the environment.

Sources of microplastics in ambient air can come from various human and natural activities such as the degradation of plastic waste and industrial activities, synthetic fabric fibres, abrasion from the damaged car or motorbike tires, and ingredients used in cosmetic products [1]. Additionally, natural processes such as plastic weathering can also contribute to the increase in microplastics in the air.

Microplastics can be carried by the wind from one location to another. Due to this mobility potential, microplastics can be widely dispersed in the ambient air and carried far from their source of origin. Meteorological conditions such as wind, weather, and airflow patterns can also influence the distribution of microplastics in ambient air.

The presence and form of microplastics in the surrounding air have become a concern because of their potential impact on human health and the environment. Research efforts have been directed at identifying and quantifying microplastics in various environmental matrices, including air. Research has shown that microplastics are not only widespread in marine and freshwater environments, but also in the atmosphere [7]. Identification of microplastics in the ambient air is critical to understanding their source, transport, and potential health impacts. Additionally, the presence of microplastics in the air may be related to the processing of plastic waste, which causes the release of particles such as PM 2.5.

Research on microplastics in Indonesia mostly focuses on water bodies, especially on the island of Java, to overcome the problem of water pollution. Although there are several studies related to microplastics in ambient air in Indonesia, the dominant source of pollution is from transportation or vehicle traffic on roads such as in Makassar [8; 9; 10] and Surabaya [11,12,13].

This research aims to identify microplastics in PM2.5 in ambient air in terms of quantity, shape, and type. This research also aims to model the distribution of microplastics in the ambient air around the study area, namely in the Medan Industrial Area. The pollutant parameter observed in this study is PM2.5 because PM2.5 can freely enter the respiratory tract and settle in the alveoli of the lungs, so it has the potential to damage the function of human respiratory organs [14]. Based on research [15], PM2.5 has negative effects on human health after long-term exposure. The long-term impacts of PM2.5 exposure include cardiovascular disease, respiratory disease, and lung cancer. PM 2.5 also affects photosynthesis in plants. PM2.5 can clog leaf stomata and disrupt plant respiration [16].

2 Methodology

2.1 Data Collection

This research began with collecting secondary data in the form of wind direction and speed for the last 5 years to create a Windrose which was used to determine sampling points. Other secondary data include topographic maps, industrial area data, industrial layout maps, types of industry, and previous research data related to air quality around the Medan industrial area [17; 18; 19, and 20].

Meanwhile, the primary data collected are sampling coordinates taken using GPS, meteorological data (wind direction, wind speed, temperature, humidity, and pressure), PM2.5 concentration using HVAS (High Volume Air Sampler) according to SNI 7191.14:2016. Sampling PM2.5 was carried out at 6 sampling point locations with a sampling duration per point of 2 (two) hours. In addition, the primary data collected was an inventory of other emission sources such as the type and number of vehicles. The location of the sampling points in this study can be seen in Figure 1.

![Fig 1. PM2.5 sampling locations around the Medan Industrial Area](image)
2.2 Data Analysis

The data analysis method is carried out in several stages, namely sample preparation, and identification of the number and shape of microplastics using a microscope. After obtaining the amount of microplastics in PM2.5 in the ambient air, a microplastic distribution model was mapped using the Surfer program.

Sample preparation was carried out starting by conditioning the filter paper after taking the PM2.5 sample in a desiccator for 24 hours and then weighing it. The particulates stuck to the filter paper are rinsed with 50 ml of distilled water and the rinse water is collected in a glass beaker also called the filtrate. The filtrate is added with 35 ml of H2O2 and then left at room temperature for 8-10 days to destroy organic compounds in the filtrate. After that, the filtrate was filtered using Whatman paper and dried in the oven at 50°C for 24 hours [2].

Microscope observations were carried out after the samples were filtered on a Whatman GF/A quartz fibres filter (1.6 µm, 47 mm). The samples were observed visually under a binocular microscope to see the quantity and physical form of microplastics present in the samples. Particles suspected to be microplastics are sorted and observed. Microplastic particles were counted and categorized based on the size and shape of the microplastic. The forms of microplastics are divided into fragments, films, fibres, granular, etc.

After the number and shape of microplastics at each point were identified, mapping was carried out using the Surfer program. Surfer is a mapping and data analysis software used to create contour and isopleth maps, including concentration isopleth maps.

3 Results and Discussion

Ambient air PM2.5 sampling was carried out around the Medan Industrial Area with a total of 6 sampling locations spread across Medan Belawan and Subdistricts. Sampling PM2.5 in ambient air at this location aims to see the abundance of ambient air microplastics from industrial activity sources and transportation because the Medan Industrial Area is also traversed by vehicles to and from Belawan Port. Within Medan Industrial Area, there are more than 600 companies, ranging from MSMEs to multinational companies, which operate in the processing of palm oil, rubber, chocolate, coffee, tea, vegetables, and fruit. There are also companies engaged in marine and forest product processing, cold storage, steel molding, and food and beverage production.

The PM2.5 concentration was obtained by taking samples using an HVAS device. This tool has a filtration principle where dust will be sucked in through a vacuum pump that is installed on the tool and the particulates that are sucked in will be retained in the filter media in the form of glass fibre. Sampling at locations around Medan Industrial Area for PM2.5 was carried out for 2 hours. The results of PM2.5 concentrations in the ambient air around the Medan Industrial Area can be seen in Figure 2.

Based on Figure 2, PM2.5 concentrations around the study area already exceed the ambient air quality standards of PP No. 22 of 2021 where the threshold for PM2.5 (24-hour sampling time) is 55 µg/m³, namely TS3 and TS4. The sampling results show that the PM2.5 concentration ranges from 25.78 – 60.36 µg/m³, this figure when compared with the ambient air quality standard set by WHO [21] has exceeded the PM2.5 quality standard for ambient air is 15 µg/m³.

The high concentration of PM2.5 in TS3 and TS4 is because the location of TS3 is close to the Belawan PLTGU and TS4 is directly adjacent to Medan Industrial Area. Activities in power plants and industries that emit pollutants will become sources of pollution in TS3 and TS4. Apart from that, the influence of meteorological factors such as wind direction and wind speed, temperature, humidity, and pressure also influence the dispersion of pollutants.

Meteorological parameters have a significant effect on PM2.5 concentrations, where the contribution of each meteorological parameter to PM2.5 dispersion is more than 50%. This is in line with previous studies that show a positive correlation between temperature and PM2.5 and a negative correlation between humidity and PM2.5, such as in Thailand [22], Delhi, India [23], Jakarta [24], and China [25].

After sampling PM2.5 in the ambient air, sample preparation was carried out to count the number of microplastics using a binocular microscope. The results of identifying the number of microplastics around the Medan Industrial Area can be seen in Table 1.

<table>
<thead>
<tr>
<th>No</th>
<th>Sampling point</th>
<th>Number of Microplastic (Particle)</th>
<th>Abundance of microplastics in the air</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TS1</td>
<td>78</td>
<td>1.18</td>
</tr>
<tr>
<td>2</td>
<td>TS2</td>
<td>41</td>
<td>0.62</td>
</tr>
</tbody>
</table>

Fig 2. PM2.5 concentration around Medan Industrial Area compared to Indonesia Ambient Air Quality Standard and WHO standards.
Based on Table 1, the amount of microplastics in PM2.5 in the ambient air around Medan Industrial Area varies for all sampling points with the highest amounts at TS1 and TS6. TS1 is in Belawan II Village, precisely in front of Belawan Coffee, with the HVAS equipment positioned ± 5 m from the main road. At this point, the dominant source of pollution comes from vehicular traffic activities with the number of vehicles passing during sampling being ± 2,510. Meanwhile, TS6 is in Mabar Village, which is on a small road but busy with vehicles with a total of 566 vehicles.

The high number of microplastics in TS 1 and TS 6 is also related to sources of pollution around the sampling location, which can be the use of plastic in industry, such as for the production, processing, and disposal of plastic waste in industry, which can also contribute to the release of microplastics into the air. Apart from that, it can also come from vehicle tire dust; Vehicle tires that experience abrasion while driving can produce microplastic particles which are then spread into the air.

If we compare the results of this research with several studies in several regions in Indonesia and countries in the world with different pollutant sources and parameters, it can be seen in Table 2.

### Table 2. Number of microplastics in ambient air from several previous studies

<table>
<thead>
<tr>
<th>No</th>
<th>City</th>
<th>Year</th>
<th>Source of pollution</th>
<th>Air pollutant parameter</th>
<th>Abundance of microplastics in the air</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Makasar [8]</td>
<td>2021</td>
<td>Transportation</td>
<td>TSP</td>
<td>1.35 – 1.69</td>
</tr>
<tr>
<td>3</td>
<td>Makasar [9]</td>
<td>2021</td>
<td>Transportation</td>
<td>TSP</td>
<td>0.64 – 4.85</td>
</tr>
<tr>
<td>5</td>
<td>Iran [26]</td>
<td>2019</td>
<td>Urban</td>
<td>TSP</td>
<td>0.3 – 1.1</td>
</tr>
<tr>
<td>6</td>
<td>Shanghai [27]</td>
<td>2019</td>
<td>Urban</td>
<td>TSP</td>
<td>1.42 – 4.18</td>
</tr>
<tr>
<td>7</td>
<td>Paris [28]</td>
<td>2016</td>
<td>Urban</td>
<td>TSP</td>
<td>0.3 – 1.5</td>
</tr>
</tbody>
</table>

Most of the previous research related to microplastics in ambient air originates from transportation and activities in urban areas with the dominant pollutant parameter being TSP. In contrast to this research, the pollutant parameters analysed are particulates measuring 2.5 microns (PM2.5) and the main source is from industrial areas. Various activities in industrial areas ranging from the production and manufacturing process of goods, warehousing and logistics, power generation, product marketing, loading, and unloading of goods, and ports are the main sources of pollution in the study location.

Microplastics come in many types and vary greatly in size, shape, colour, composition, density, and other properties [29]. Existing microplastics usually come in the form of flakes, films, fibers, and pellets. The origin of microplastics can be determined based on their shape. For example, fibrous microplastics are mainly found in densely populated areas and areas where clothing and carpets are produced. Fibers are obtained from the production of synthetic fibers which are fragmented due to exposure to ultraviolet light, thus giving synthetic fibers elasticity and ease of spreading.

Because microplastics easily break down into small particles, they can accumulate in dust and soil at low density, making them more likely to enter the atmosphere and be inhaled [26]. Percentage distribution of microplastics in PM2.5 of ambient air around industrial areas. The terrain is visible in Figure 3.

**Fig 3. Distribution of microplastic forms in PM2.5 in ambient air around the Medan Industrial Area**

Figure 3 shows the distribution of microplastics in PM2.5 in the ambient air around Medan Industrial Area, dominated by fragments. Fragments are usually characterized as irregular shapes, crystals, plumes, powders, granules, pieces, and flakes. Apart from that, the fragments are hard, stiff, colored and have a high density [30]. Generally, 63-300 μm in diameter [31].

The shape of microplastics from the results of photography from a microscope can be seen in Figure 4.
In previous research [1; 8; 9; 10; 26; 27 and 28] the dominant form of microplastics from transportation and urban sources is fibre, while in this study the fragment form is more dominant for several reasons: (1) One way that microplastics are formed is through a greater plastic degradation process. This process can be caused by exposure to sunlight (ultraviolet radiation), heat, and other factors. The result of this degradation is smaller plastic fragments, (2) Abrasiveness and mechanical breaking, plastic can experience abrasion or mechanical breaking because of friction with various surfaces, such as the movement of water, wind, or interactions with other organisms. This process can cause smaller plastic fragments and fragments, (3) The influence of meteorological factors such as changes in temperature and atmospheric conditions, can affect the physical properties of plastic. Extreme weather can increase the possibility of microplastic fragments and released into the air (4) Certain industrial processes, such as plastic production and processing, can also produce microplastic fragments as waste or production residue and (5) The stable nature of plastic, must have relatively stable properties and does not decompose easily in nature. Because of this, plastic tends to maintain its existence in fragment form longer than changing into other forms.

Based on the results of identifying the number of MPs in PM2.5 in ambient air at several sampling points around the Medan Industrial Area, a model of the distribution of the number of MPs and the abundance of MPs can be created as shown in Figures 5a and 5b.

Based on Figures 5a and 5b, the same pattern can be seen for microplastics in PM2.5 around the Medan Industrial Area. The red colour shows the highest number when identifying MPs, where the highest points are at TS1 and TS6. It can be seen in the picture that the red colour is also closer to the source of pollution, namely the Medan Industrial Area Phase 1 and Phase 2. Apart from that, activities around the Medan Industrial Area are not only from the production process but also from the surrounding facilities and utilities such as power plants and ports. At TS1, the colour distribution of the number and abundance of MPs starts to turn yellow and approaches red, so this condition shows that the multiple activities around the Medan Industrial Area influence the presence of MPs in the ambient air.

Many factors influence the distribution of microplastics in the air, including sources of microplastics in the air that can come from land, human activities, and industry. The transport process of microplastics involves the movement of particles through the atmosphere. Wind and atmospheric turbulence can play an important role in carrying microplastics from one location to another. Microplastics can settle to the earth's surface through a deposition process. Factors such as particle size, specific gravity, and soil surface characteristics can influence deposition rates. Geographic factors, such as topography and land use, can influence the distribution of microplastics. Microplastics can interact with other particles and gases in the atmosphere, influencing their behaviour and distribution. The amount of microplastics is also influenced by population density, based on research [32], the abundance of microplastics increases significantly with higher population densities in the air.

4 Conclusion

This research specifically explores the microplastic content contained in air particulates with a diameter of less than 2.5 micrometres (PM2.5). Distribution of microplastics in the environment that may be exposed to industrial activities, which can be a source of microplastic pollution. This research not only identifies the presence of microplastics but also tries to model their distribution. The results of this research could have important implications for environmental policy and industrial practice in the region. If high levels of
microplastic concentrations are found, this could encourage changes in industrial practices to reduce microplastic emissions. This research can also provide important insights for monitoring air quality in industrial areas, by considering microplastics as a parameter that needs to be monitored more closely.

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