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Research Article

CHARACTERISTICS OF AIRBORNE MICROPLASTIC POLYMERS USING PASSIVE SAMPLING AND THE INFLUENCE OF METEOROLOGICAL CONDITIONS

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Abstract

Tenayan Industrial Estate has various anthropogenic activities such as industrial and population activities. Many activities can affect the number of pollutants in the air, one of which is microplastics. Microplastics can be distributed through the air due to the influence of meteorological factors. This research sought to examine the abundance of microplastic particles in the ambient air around the Tenayan Industrial Estate based on the type and kind of microplastic polymer. The air sampling method employed was passive sampling, conducted at three locations: upwind, downwind, and center, carried out every 7 day for 28 days. Microscopical method to determine the amount of abundance, the classification of microplastic polymer types and types. Differential Scanning Calorimetry (DSC) tests were carried out to determine the type of plastic polymer. The research results are upwind point has an average of abundance of microplastics per week of 64,00 ± 39.53 particles/liter. The central point with the average abundance of 69,5 ± 31,38 particles/liter. The downwind point has the highest average microplastic abundance of 81 ± 60,86 particles/liter. The dominant form of microplastics is fiber with percentage of 60,7. The Microplastic polymer types identified are polyvinyl chloride, polycarbonate and polyamide. The results showed that the abundance of microplastics was influenced by meteorological factors, namely wind speed. Downwind location which is residential areas have highest microplastic abundance, it indicates accumulation rather directional transport.

Keywords: Abundance, Industrial Area, Microplastics, Passive Sampling

INTRODUCTION

Industrial areas are a factor that can support and encourage regional growth (Suyanto et al., 2024). Industrial areas typically don't consist of a single industry, but rather include various industries, ranging from home-based to large-scale (Bole, 2021). The growth of the industry will lead to increased sales of products, employment, and multiplier effects (Yuvanda et al., 2025). The Tenayan Raya Industrial Area in Pekanbaru City is located in the Tenayan Industrial Village. Based on 2024 data from the Statistics Indonesia for Tenayan Raya District, the Tenayan Industrial Village covers 19.42 km², with a population of 3,126 people and a population density of 161 people/km². The Tenayan Raya Industrial Area itself covers 1,550 hectares (Statistics Pekanbaru Municipality, 2024).

The growth of industry and infrastructure within this industrial area, coupled with the increasing activity of the community, can lead to increased air pollution from both community and industrial activities (Dehkordi et al., 2024). Industrial activities and the surrounding community, such as transportation can produce air pollution (Hernanda et al., 2025). Industrial processes produce byproduct such as emissions of sulfur dioxide (SO_2), nitrogen oxides (NOx), particulates, and volatile organic compounds, which are usually dispersed and mixed with dust (Nakhjiri & Kakroodi, 2024). Air pollutants in industrial areas are often mixed with other pollutants, such as microplastics (Amato-Lourenço et al., 2020).

The distribution of dust carrying these microplastic pollutants is not limited to point sources but can spread according to the direction of the wind (O'Brien et al., 2023). Microplastics contained in dust range in size from 1 micron to 5 mm, allowing these particles to be carried by the wind and mixed with the dust (Avilés Valera et al., 2025). Dustfall refers to particles suspended in the air and deposited in various areas over time due to the influence of gravity. Measuring dustfall typically involves chemical analysis to determine the source of the dust-causing particles and the content of substances within the dust that may be harmful to the surrounding environment (Zhou et al., 2024), and increase the risk of disease and other health problems for communities (Susbiyanto et al., 2024), even dental and oral health (Eshiev et al., 2025)

The dense activity in a region brings with it diverse sources of pollution (Kosova et al., 2024), particularly those carrying microplastic pollutants. The impacts of pollution of microplastic are initially invisible, but over time they become apparent and cause various problems and consequences (Singh et al., 2025). Microplastics that fall with dust are not only harmful to the environment but also have harmful impacts on human health (Ziani et al., 2023). Microplastic pollutants can cause oxidative stress toxicity, inflammation, and increased absorption or translocation. Several studies have shown that microplastics have the potential to cause disease, leading to metabolic disorders, neurotoxicity, and an increased risk of cancer in humans (Li et al., 2023). Microplastics have magnetic properties, which can bind to other pollutants. Therefore, when we inhale microplastics, we also inhale the harmful pollutants bound by them (Osman et al., 2023).

There has been quite a lot of research on microplastics in ambient air. In the research conducted by Purwiyanto et al., (2022) on the deposition of atmospheric microplastics in Jakarta, Wati et al., (2025) on characterization of airborne microplastics particles on urban roads. In the research of Samsukamal et al., (2025) on Airborne Microplastics in Indoor and Outdoor Environments in the Campus area, and research by Ding et al., (2026) on Airborne microplastics from the plastic manufacturing industry. In these studies, the microplastics found in the study location have been characterized, including the number, type, and shape. However, there has been no discussion regarding meteorological factors that can influence the presence of microplastics in ambient air. This study examines the influence of meteorological factors on microplastics at the research location using a correlation test.

The objective of this research was to analyze the abundance of microplastics, identify the types and kinds of microplastic polymers in the air found in dust samples in the Tenayan industrial area of Tenayan Raya District, Pekanbaru City, and analyze the comparison of microplastics based on meteorological factors.

RESEARCH METHOD

This research is a descriptive-analytical research with a quantitative approach.

Research Equipment and Materials

The equipment used in this study was a passive sampling dust collector with a 1-liter water volume. The passive dust collector specifications include a 4-mesh sieve, funnel, hose, and water gallon. Laboratory test equipment used in this study included Whattman No. 42 filter paper, a microscope, an oven, a desiccator, a measuring cylinder, a porcelain cup, an analytical balance, a stirring rod, a beaker, a dropper, and a vacuum pump. The materials used in this study were dust samples, $CuSO_4$ solution with a concentration of 1 ppm or 1 mg/L, 10 ml of 30% H2O2 solution, 400 ml of 30% NaCl solution, distilled water, and aluminum foil.

This study used a passive sampling method because it is more suitable for long-term monitoring, as it is able to provide average pollutant concentration values over a specific period relevant for exposure studies.

Figure 1. Passive sampler dust capture device

Research Location and Sampling Points

The sampling points in the Tenayan Industrial Village during the study were determined based on the following wind rose diagram. The wind rose diagram indicates that the dominant wind direction is southwest.

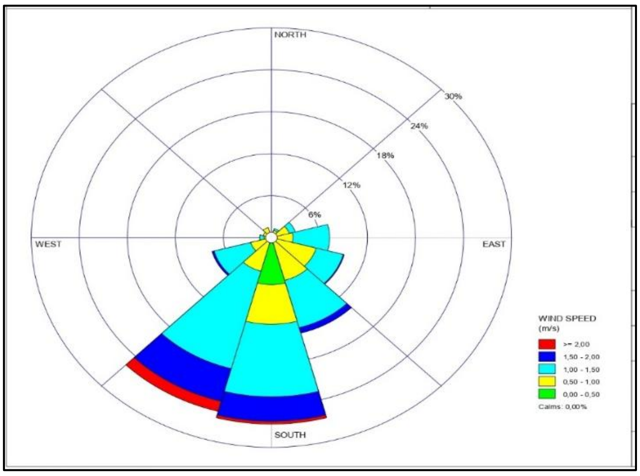

Figure 2. Windrose at the research site

Based on the windrose, the dominant wind direction is South-southwest. Therefore, the upwind, central, and downwind points determined as follows:

Figure 3. Sampling Point

Table 1. Sampling Point Coordinates

Sampling Point	N	E	Category
Upwind	0°33'43.70"	101°31'49.50"	Close to industrial activities
Central	0°32'40.47"	101°31'16.64"	Open areas and village centers
Downwind	0°31'17.15"	101°30'22.79"	Close to dense residential areas

Research implementation

Samples were observed under a microscope at 100-fold magnification to determine the type of microplastics present. Microplastic abundance was calculated using a counting chamber, and Differential Scanning Calorimetry (DSC) was performed to determine the type of plastic polymer.

Microplastic abundance calculated using the formula below (Rodrigues et al., 2020):

$$A = n/v$$

Description:
K : Microplastic abundance (particles/Liter)
n : Number of microplastics (particles)
v : Sample volume (liter)

Data Collection

Data collected from 3 sampling location which is upwind, central, and downwind of Industrial area. The sampling time conducted every 7th day for over four weeks (days 7, 14, 21, and 28). Meteorological data collection was also carried out on temperature, wind speed, humidity, and rainfall.

Data Analysis

Collected microplastic data processed to calculate the abundance of microplastics in the samples, the classification of microplastic polymer types and types This study processed data using statistical analysis methods with correlation tests. The study was performed with Statistical Product and Service Solutions (SPSS) software. The collected data first be processed to determine whether they are normally distributed. Normality testing will use the nonparametric One-Sample Kolmogorov-Smirnov method. Significance between variables X and Y will be tested using the Pearson Product-Moment correlation test. The Pearson Product-Moment correlation test is used to determine the closeness of the relationship between variables, expressed as a coefficient (r).

RESULTS AND DISCUSSION

Meteorological Data

The following is the meteorological data at the research location.

Table 2. Meteorological Data

Meteorological Conditions	Description
Temperature	28,3 - 26,96 °C
Wind Speed	2,24 – 1,04 m/s
Precipitation	9,58 – 0,13 mm/month
Humidity	20,67 – 18,75 g/kg

Based on the table above, the temperature in the Tenayan area is relatively warm every day. The Beaufort scale in Singleton (2008), indicates that wind speeds of 2.24 m/s – 1.04 m/s are included in the category of light gusts, while rainfall itself has a value of 9.58 mm/month – 0.13 mm/month with a low rainfall category, which coincides with the dry season in the area. The distribution of air pollutants is influenced by several factors, namely wind direction, wind speed, air temperature, humidity, and weather (Sangkham et al., 2021). The limitation of this research is the influence of the season when the research was conducted, because the research was conducted in the dry season, the research results might be different if it was conducted in the rainy season.

Microplastic Abundance

Microplastic abundance was calculated by counting the number of microplastics analyzed microscopically at 10x magnification. The following microplastic abundance data is presented in Table 3.

Table 3. Microplastic Abundance at Each Point Each Week

Point	Week	Microplastic Abundance (Particles/liter)	Avarage Microplastic Abundance (Particles/liter)	Standard Deviation (Particles/liter)
Upwind	1	108	64,00	± 38,93
	2	83		
	3	44		
	4	21		
Central	1	86	69,50	± 31,38
	2	64		
	3	100		
	4	28		
Downwind	1	164	81,00	± 60,86
	2	52		
	3	85		
	4	23		

The average microplastic abundance at the upwind point over four weeks reached 64,00 ± 39.53 particles/liter. The highest abundance occurred in the first week, with 108 particles/ml, and the lowest in the fourth week, with 21 particles/liter. The average microplastic abundance at the central point reached 69,50 ± 31.38 particles/liter. The central point had the highest abundance in the third week, at 100 particles/liter, and the lowest in the fourth week, at 28 particles/liter. The highest microplastic abundance was found at the downwind point was 81 ± 60,86 particles/liter. In the first week at 164 particles/liter, and the lowest in the fourth week at 23 particles/liter.

The number of microplastic varied each week. A decrease in microplastics occurred in the third and fourth weeks, consistent with changes in several significant meteorological factors, such as lower rainfall and higher wind speeds. These changes can indirectly affect the number of microplastic particles. The presence of microplastics is thought to be due to the activities of people living in the area, which, in turn, can cause the plastic to degrade, resulting in smaller particles (Anand et al., 2023). Microplastic abundance can vary, influenced by the area sampling conducted. A similar study conducted by Suryati et al., (2024) in an industrial area in Medan found microplastic counts of 0.41–1.40 particles/m^3. However, this study found lower microplastic counts, possibly due to the absence of a point source, or the microplastics formed from various industrial and anthropogenic activities being dispersed by natural factors, thus moving away from the point source.

Anthropogenic activities also produce small particles like microplastics, which can form through natural degradation such as UV radiation and weathering or deliberate degradation by human (Hu et al., 2024). Usually, the main source of these microplastic particles is the process of large plastic destruction from various activities in industry and anthropogenic activities, but it does not rule out the possibility that they can come from other sources outside the study area (Wu et al., 2023). This is evidenced by research by (Purwiyanto et al., 2022), who found that microplastics are transported atmospherically to other area by wind.

The downwind point is located in a residential area. The amount of microplastics in this area is greater than at other points, as the influence of significant anthropogenic activity allows the formation of microplastic particles (Priya et al., 2025). The large number of microplastics means that plastic will degrade more easily and quickly due to deliberate activities. Because microplastics readily break down into tiny particles, they can accumulate in dust and low-density soil, increasing their likelihood of entering the atmosphere. Additionally, microplastics in the air can be carried by the wind and travel to a variety of places, including areas far from the source (Jahandari, 2023). According to (Coccia, 2021) low air temperature causes the air density near the earth's surface to be almost the same as the air density above it, as a result the air convection flow moves slowly so that the concentration of pollutants becomes high because it accumulates on the surface, so that low wind speed causes the spread of air to be slow.

Microplastic Types

Microplastic identification was performed using microscope at 10x magnification by observing previously dried dust samples. This type analysis involved direct visual observation through the microscope and counting the number of microplastic types. According to (Fan et al., 2023) microplastics can be present in the form of fragment, films/filamen, and fibers. The following summarizes the number of microplastic types in the samples:

Table 4. Types of Microplastics in Samples

Point	Week	Types of Microplastics		
		Fragment	Filament	Fiber
UP	1	48	8	52
	2	25	12	46
	3	11	5	28
	4	4	2	15
CE	1	16	8	60
	2	20	4	40
	3	20	32	48
	4	8	4	16
DO	1	24	20	120
	2	8	4	40
	3	16	25	44
	4	8	4	11
Total		208	128	520
Percentage (%)		24,3	15,0	60,7

Based on the data above, the largest type of microplastic is dominated by the fiber type, especially at the downwind point with a total of 120 fiber particles. Besides fiber, the filament type is also found in the results of microscopic analysis with the largest number of 32 particles at the central point and for the last type that has been identified is fragments with the largest number of 48 particles at the Upwind point. The type of microplastic can be influenced by various activities around the sampling area, the average activity that occurs at each point is the daily activities of the community (Kye et al., 2023). The highest abundance value of 120 particles/L is greater than the results obtained by Wati et al., (2025) who found the largest microplastic content of 63 particles/L and Purwiyanto et al., (2022) of 40 particles, this is due to the longer sampling time in this study.

Fragments

Microplastic fragments accounted for 24.3% of the total number of microplastic particles. They were found in various shapes and colors. The following types of microplastic fragments are shown in Figure 4. The fragments appear to have imperfect angles and are green in color. Fragments are typically characterized by irregular shapes, crystals, lumps, powder, granules, pieces, and flakes (Andersen et al., 2024). Furthermore, fragments are hard, rigid, colored, and have a high density. They generally measure 60-300 μm in diameter (Zhang et al., 2020).

Fragments are the third most common type of microplastic derived from the fragmentation of macro waste (Yanuar et al., 2024) and generally come from pieces of jars, gallon jugs, hard plastic, small pieces of PVC pipe, and small pieces of beverage bottles from everyday activities (Arpia et al., 2021).

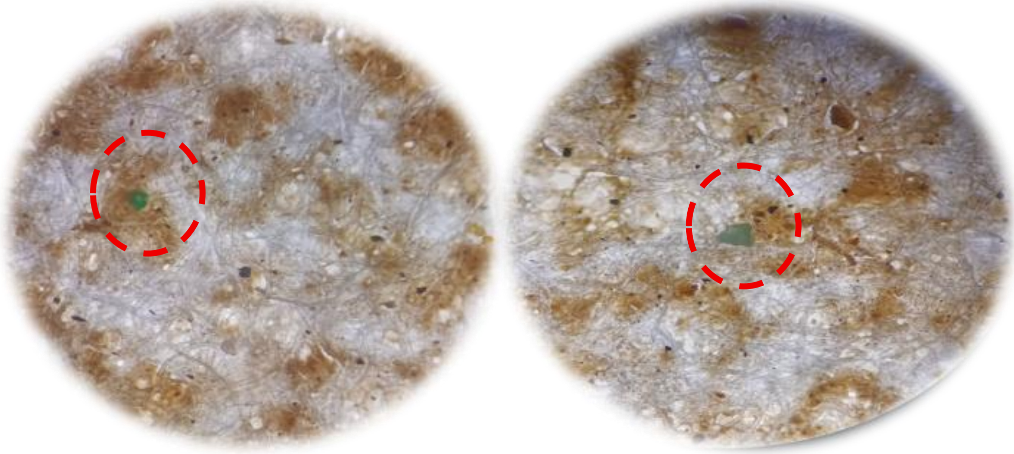

Figure 4. Fragment-Type Microplastics

Filaments

Filamentous microplastics accounted for 15% of the total microplastic types found in this study. The following filamentous microplastic types are presented in Figure 5**.**

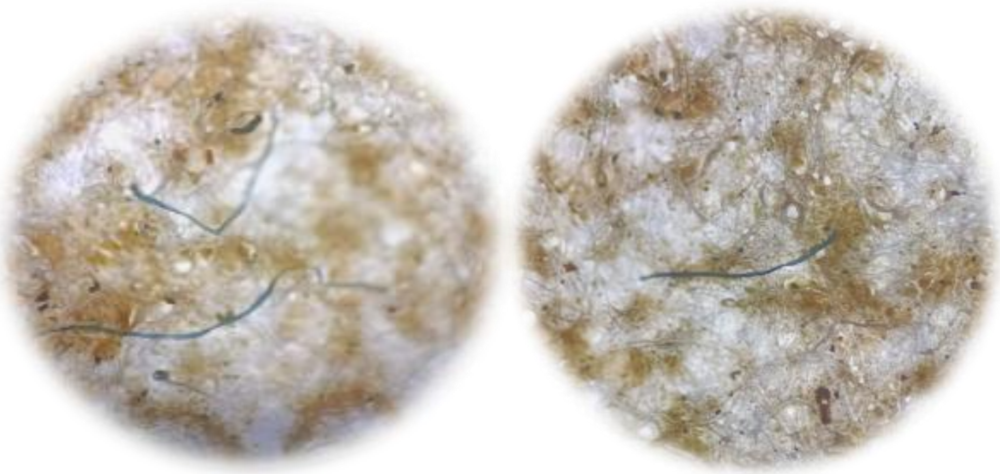

Figure 5. Filament Microplastic Type

Figure 5 shows filamentous microplastics, categorized as flat and blue in color. Food packaging and plastic bags are sources of film-type microplastics. Filaments or films are thin, flexible, sheet-like plastics, usually derived from plastic bags, paper, or other packaging materials (Briassoulis, 2023). It can sometimes be difficult to distinguish between thin, sheet-like fragments and plastic film.

Fiber

Fiber-type microplastics were the most abundant type of microplastic found in this study. The abundance of fiber-type microplastics reached 60.7%, representing more than half of the microplastic particles present. The following types of filamentous microplastics are presented in Figure 6.

Fiber is a plastic particle that has a thread-like shape with a length of around 5 mm which comes from polyester fibers which are usually found in fabric fibers (Periyasamy & Tehrani-Bagha, 2022). The image above shows fiber-shaped microplastics, characterized by their long, rope-like shape and being slimmer than film microplastics. Fiber type of microplastic can originate from clothing, discarded fibers, or plastic ropes (Priyadarshini et al., 2024). This type of microplastic has an irregular color and appears large and somewhat stiff, usually originates from the degradation of large plastics, such as plastic bags (Wang et al., 2022). Fibrous microplastics are primarily found in densely populated areas and areas where clothing and carpets are manufactured. The fibers are obtained from the production of synthetic fibers, which are fragmented by exposure to ultraviolet light, making them elastic and easily spread (Hossain et al., 2025).

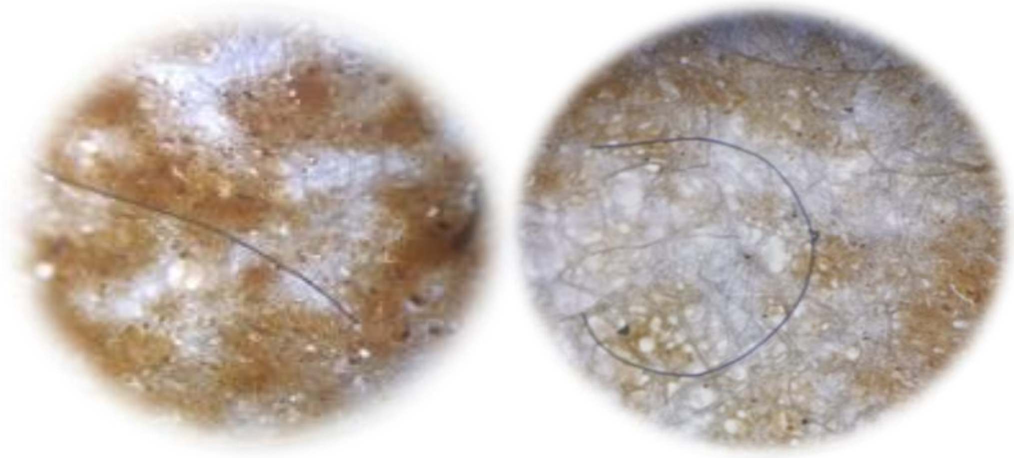

Figure 6. Types of Fiber Microplastics

Determination of Microplastic Types by Thermal Differential Scanning Calorimetry (DSC). In this study, DSC was used to determine the type of polymer that makes up the plastic in the dust samples. The following DSC curve is presented in the following image.

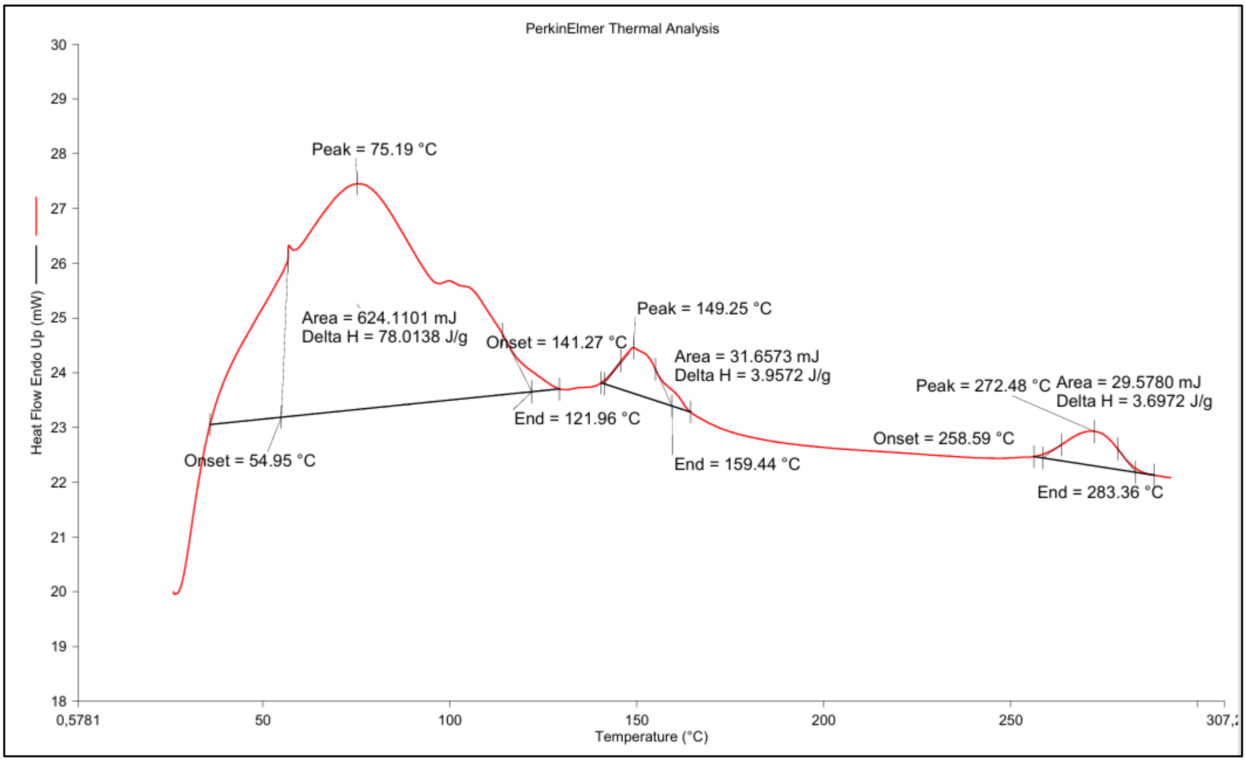

Figure 8. DSC Polymerization Test

Based on the image above, several polymer melting points were obtained. The melting points of plastic polymers were at 75.19°C, 149.25°C, and 272.48°C. According to Hidalgo-Ruz et al., (2012), the types of plastic polymers obtained were polyvinyl chloride (PVC) with a melting point of 75-110°C, polycarbonate (PC) with a melting point of 140-150°C, and polyamide (nylon) with a melting point of 160-275°C.

Polyvinyl chloride (PVC) is a type of thermoplastic polymer formed from the polymerization of vinyl chloride monomer. PVC has several characteristics that are preferred in the industrial world, such as: resistance to solvents, acids, bases, and long service life (Bharadwaaj et al., 2024). PVC is commonly used to produce door and window profiles, pipes (drinking water and waste), wire insulation, cables, raw materials for making paint, medical equipment and other (Lewandowski & Skórczewska, 2022).

Polycarbonate (PC) has a chemical structure of BPA (Bisphenol A) which is mass-produced in factories (Takeuchi, 2012) and is a common ingredient in polycarbonate plastic and epoxy resin (Hafad et al., 2021). Disposable or reusable food and beverage containers are often made from polycarbonate (Nilsson et al., 2024). High temperatures and prolonged exposure to sunlight can cause polycarbonate plastic hydrolysis, allowing it to spread into very small sizes (Ascione et al., 2019). Polyamide (nylon) is used in the manufacture of rope and clothing materials containing thread (Krishna et al., 2021). Other sources of contamination can come from combustion sources, packaging materials, or the process of converting plastic raw materials into packaging (Kóczán & Pásztory, 2024).

The effect of temperature, rainfall, wind speed, and humidity on the abundance of microplastics

Statistical testing was carried out using the T-test and the Pearson Product-Moment Correlation, as shown in the following figures.

Table 5. Statistical Tests Between Variables

Parameter	Normality (sig.> α 0,05)	Correlation (r) (r = 0,001-1,000)	Significance (α) (sig.< 0,05)	Conclusion
Temperature	0,200	0,567	0,433	H1 is rejected, H0 is not rejected
Wind speed	0,200	-0,960	0,040	H1 is accepted, H0 is rejected
Rainfall	0,200	0,935	0,065	H1 is rejected, H0 is not rejected
Humidity	0,200	0,756	0,244	H1 is rejected, H0 is not rejected

Relationship between Temperature and Microplastic Abundance, based on the results of statistical tests on table 5, the comparison of temperature and abundance data was normally distributed with a sig value of 0.200 (> α 0.05). The Pearson Product Moment correlation analysis revealed a correlation (r) between temperature and microplastic abundance of 0.849, with a significance value of 0.433 (> 0.05) and a positive relationship. The correlation value of 0.567 indicates a strong correlation between temperature and microplastic abundance in the Tenayan Industrial Village. However, the sig value was not found to be a relationship because the value obtained was > 0.05. Therefore, it can be concluded that there is no significant relationship between high and low temperatures and microplastic abundance.

Relationship between Rainfall and Microplastic Abundance, based on the results of the statistical tests on table 5, the comparison of rainfall and abundance data was normally distributed with a sig value (0.200 > α 0.05). A connection was revealed using the Pearson Product Moment correlation analysis findings, between temperature and microplastic abundance of 0.935, with a significance value (0.065 > 0.05) and a very strong positive relationship. A correlation value of 0.935 indicates a very strong correlation between rainfall and microplastic abundance in the Tenayan Industrial Village. However, the sig. value showed no correlation, as the value obtained was >0.05. Therefore, it can be concluded that there is no significant relationship between differences in rainfall and microplastic abundance.

Relationship between Wind Speed and Microplastic Abundance, based on the results of statistical tests on table 5, the ratio of wind speed and abundance was normally distributed with a sig. value (0.200 > α 0.05). The results of the Pearson Product Moment correlation analysis showed a correlation (r) between temperature and microplastic abundance of -0.960, with a significance value (0.040 < 0.05) and a negative correlation. The correlation value of -0.960 indicates a very strong negative correlation between wind speed and microplastic abundance in the Tenayan Industrial Village area, and a relationship exists because the value obtained is < 0.05. Therefore, it can be concluded that there is a significant relationship between wind speed and microplastic abundance, and there is a repulsive relationship. Higher wind speeds result in lower microplastic abundance, and lower wind speeds result in higher microplastic abundance.

Relationship Between Humidity and Microplastic Abundance, based on the results of statistical tests on table 5, the ratio of humidity and abundance is normally distributed with a sig value (0.200 > α 0.05). The results of the Pearson Product Moment correlation analysis obtained a correlation value (r) between temperature and microplastic abundance of 0.756, with a significance value (0.244 > 0.05) and a positive relationship. The correlation value of 0.756 indicates a strong positive correlation between humidity and microplastic abundance in the Tenayan Industrial Village area. However, the sig value does not indicate a relationship because the value obtained is > 0.05.

Wind speed is the only meteorological factor with a statistically significant effect Pearson correlation: $r = –0.960$, $p < 0.05$. Other factor, temperature, rainfall, and humidity showed no significant influence despite moderate–strong correlations. Becaouse downwind residential areas show the highest microplastic abundance, it indicates accumulation rather than simple directional transport. This result suggests that microplastics behave as semi-suspended particulates, not purely dispersive aerosols. Dominance of fiber-type microplastics Fibers (60.7%) have high surface area, low settling velocity, and strong aerodynamic drag. This makes them particularly sensitive to low wind regimes and prone to atmospheric stagnation. Together, these facts indicate that wind speed acts as a switch, not a scaler.

CONCLUSION

Based on the research conducted, it can be concluded that microplastic abundance ranges from 21 to 168 particles per liter. The highest microplastic abundance was found at the downwind point in the first week, with an abundance of 164 particles per liter, and the lowest at the downwind point in the fourth week, with an abundance of 23 particles per liter. The analysis of the microplastic types found consisted of three types: fragments, fibers, and filaments. The most abundant microplastic type was fibers, especially at the downwind point, with 60 fiber particles per liter. Besides fibers, filaments were also present with the highest number of particles which is 32 particles per liter at the central point, and fragments with the highest number 0f 48 particles per liter at the upwind point. The DSC test, to determine polymer types, found polyvinyl chloride (PVC), polycarbonate (PC), and polyamide (nylon) among the microplastics found in the Tenayan Industrial Area. The results of the correlation test stated that wind speed has a significant influence on meteorological factors on the abundance of microplastics. Downwind location which is residential areas have highest microplastic abundance, it indicates accumulation rather directional transport.

AUTHOR CONTRIBUTIONS

Conceptualization, A.S. and G.P.; Methodology, A.S. and G.P.; Validation, A.S., G.P. and A.I.; Formal Analysis, A.S.; Investigation, A.I.; Resources, A.S.; Data Curation, A.S. and A.I ; Writing – Original Draft Preparation, A.S. G.P. and A.I.; Writing – Review & Editing, A.S.; Visualization, A.I.; Supervision, A.I.; Project Administration, A.S.

CONFLICTS OF INTEREST

The authors declare no conflict of interest

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