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Investigation of PM_{10} and $PM_{2.5}$ in Ambient Air: Spatial and Temporal Variations in the Western Area of a Cement Plant

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ABSTRACT

The objective of this study is to evaluate the horizontal distribution of particulate matter concentrations (PM_{10} and $PM_{2.5}$) in ambient air within the vicinity of the cement factory, with consideration for variations in spatial and temporal. The measurements were conducted using the EPAM 5000 instrument, with a total of six sampling points at distances of 0 km, 0.5 km, 1 km, 1.5 km, 2 km and 2.5 km, both during the day and at night, over a period of three days. Meteorological parameters such as air temperature, relative humidity, air pressure, and wind speed were measured to analyses their influence on particulate matter distribution. The findings revealed that the highest PM_{10} and $PM_{2,5}$ concentrations were measured at the location closest to the factory (B1) with values of 113.98 µg/m³ and 75.73 µg/m³ at night and 52.80 µg/m³ and 28.27 µg/m³ during the day. A clear pattern of decreasing concentrations of both types of particulates as the distance from the source increases is evident, with a significant decrease occurring at a distance of 0-0.5 km. The $PM_{2.5}/PM_{10}$ ratio at night (0.67) was higher than during the day (0.56), indicating a greater contribution of fine particulates at night. Meteorological conditions play an important role in the distribution of particulate matter, in particular changes in wind direction and wind speed at night contribute to differences in the concentration and distribution of particulate matter. The results of this study indicate an increased risk of exposure to particulate matter in areas near factories, especially at night, which can be a basis for consideration in the preparation of air pollution control policies and efforts to safeguard public health.

Keywords: *Spatial and Temporal Variations; Particulate Matter; Cement Plant*

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INTRODUCTION

Air pollution is the entry or inclusion of substances, energy, or other components into the ambient air by human activities, resulting in the quality of ambient air exceeding the predetermined quality standards [1]. The Committee for the Elimination of Leaded Gasoline has published data on the industrial sector, which is responsible for 22% of air pollution in Jakarta [2]. The cement industry is a significant contributor to air pollution. Cement production is associated with releasing air pollutants detrimental to the environment [3], [4]. The production activities of the cement plant will contribute to increased levels of air pollution in Padang City. A significant body of research has demonstrated that cement plants are a primary source of particulate matter that pollutes the environment. The production of cement, cementation materials, and asbestos-cement products is associated with dust and particulate emissions [5]–[7]. As asserted by [8], particulate matter (PM) is considered an ambient air pollutant that threatens human respiration.

Acknowledging the significance of particulate matter as an indicator of air quality and a potential health hazard is imperative. It is necessary to raise awareness regarding the health implications of particulate matter, particularly PM_{10} and $PM_{2.5}$, to facilitate the implementation of monitoring and control measures to mitigate particle pollution. Researchers have linked these particulates to various respiratory ailments, including acute respiratory infections (ARI), lung cancer, cardiovascular diseases, and premature death. A Study linked exposure to cement dust to various respiratory ailments, including coughing, severe respiratory noise, asthma, bronchitis, sinusitis, and narrowing of the respiratory tract [9]. $PM_{2.5}$ exposure is more harmful than PM_{10} exposure because $PM_{2.5}$ remains suspended in the atmosphere for a longer time, resulting in an increased chance of human inhalation. In addition, $PM_{2.5}$ reaches the deep areas of the human lungs and alveoli, which retain these particles, causing cytotoxic effects [10].

Author [11] asserts that the optimal distance from settlements to mitigate the risk of $PM_{2.5}$ exposure from the cement plant in Padang is more than 2.5 km. The study revealed that $PM_{2.5}$ exposure risk areas manifested at a radius of 0.5-1 km, 1.5-2 km, and 2-2.5 km. This research demonstrates the impact of distance on particulate matter concentrations. An Author [11] researched $PM_{2.5}$ concentrations and found three locations (Block D1 Complex, Block DII Complex, and Block DIII Complex, all at a distance of 1 km from the cement plant area) that did not meet the $PM_{2.5}$ quality standard. The standard for ambient air, set at 55 µg/m^3, was exceeded in all three locations, with average concentrations recorded at 60.88 µg/m^3, 55.75 µg/m^3 and 70.50 µg/m^3, respectively. Furthermore, research conducted by the author on PM_{10} in ambient air around the Padang city cement plant area [12] demonstrates that there is one location point as far as 0.5 km to the west of the cement plant area with a PM_{10} concentration value of 79 µg/m^3, which does not meet the national ambient air quality standards. The national standards, as outlined in Government Regulation No. 22 of 2021 concerning the Implementation of Environmental Protection and Management, stipulate a maximum concentration of 75 µg/m^3 for PM_{10}.

In light of the research findings outlined above, it is proposed that the study be conducted in the western part of the cement plant area, taking into account the prevailing wind direction, which has been determined to be east-west during daylight hours and east-west at nighttime, as indicated by the research data [13]. The selected location is characterized by high population density, which renders it susceptible to the direct impact of particulate emissions (PM_{10} and $PM_{2.5}$) on public health and the surrounding environment. Whilst prior research has examined particulate concentrations in the vicinity of cement plants, the present study boasts the advantage of conducting a simultaneous analysis of horizontal profiles for PM_{10} and $PM_{2.5}$, incorporating more intricate distance variations (up to 2.5 km) and taking into account the discrepancy in concentrations between day and night, a fact that has received scant attention in the local context of cement plants in Padang City.

METHOD

The study was conducted in the area surrounding the cement plant, which is located in the western part of the plant. A total of six sampling points were established, with varying distances from the emission source, designated as B1 (0 km), B2 (0.5 km), B3 (1 km), B4 (1.5 km), B5 (2 km), and B6 (2.5 km). The location of this study is illustrated in Figure 1.

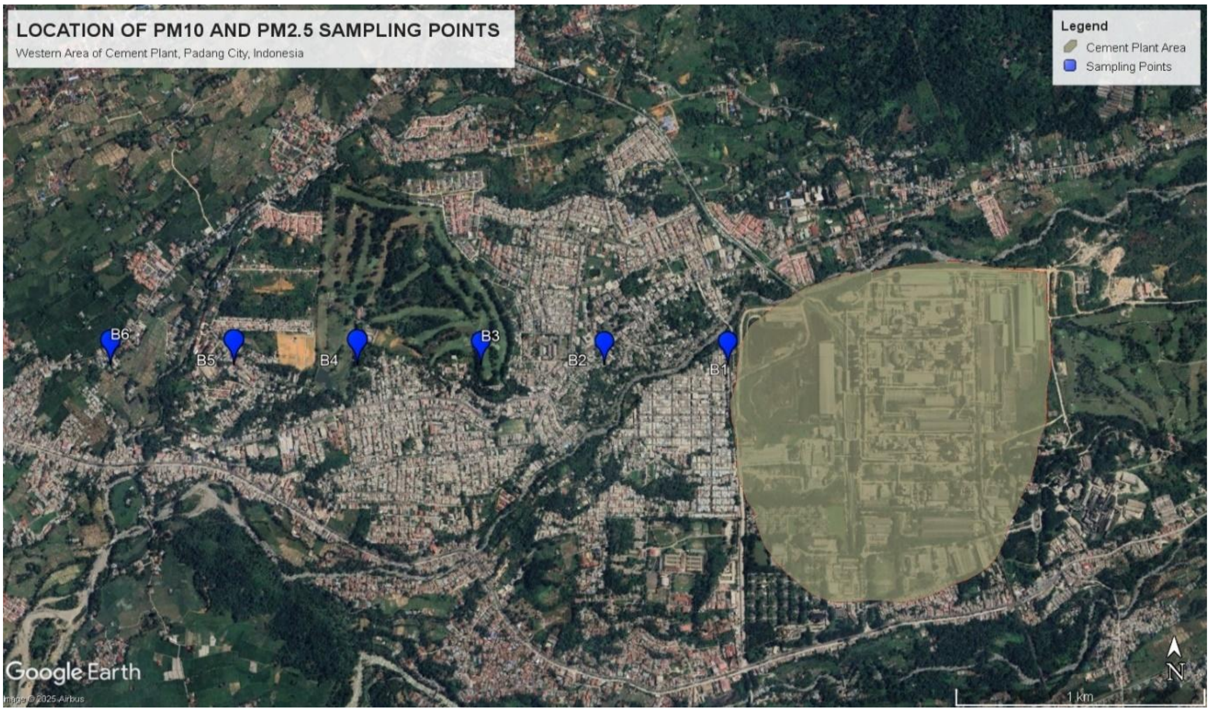

Figure 1. Description of sampling location

This study was conducted over 3 (three) days to obtain representative sampling measurement results. The measurement time was carried out during the day (09.00-13.00 WIB) and night (21.00-01.00 WIB). The selection of day and night data collection times in this study is relevant to variations in industrial activity, human activity, and meteorological conditions that affect the distribution and concentration of air pollution. Daytime data collection provides insight into the direct impact of factory activities and traffic pollution, while nighttime data collection reveals the impact of changing meteorological conditions. The combination of these two time periods is essential for generating a comprehensive understanding of the temporal variations in PM_{10} and $PM_{2.5}$ concentrations, which is crucial for identifying potential health impacts in the vicinity of cement plants. PM_{10} and $PM_{2.5}$ concentrations were measured using the EPAM 5000 Real Time Particulate Air Monitor tool. The tool's functionality entails directly measuring dust particle concentrations in ambient air, with the device positioned at an approximate height of 1.5 meters, which aligns with the human breathing zone. This configuration ensures that the PM concentrations measured reflect human exposure levels.

PM_{10} and $PM_{2.5}$ concentrations were measured for 10 minutes per parameter at each designated point. This method is based on research conducted by the author [13] with a modification of the measurement time to 10 minutes per parameter and the process takes 20 minutes to obtain PM_{10} and $PM_{2.5}$ concentration data at each sampling point.. The selection of a 10-minute measurement time interval in this study was predicated on the necessity to capture fluctuations in air pollution concentrations with a sufficient level of detail without producing data that is too voluminous and arduous to process. The validation of the method was achieved through tool calibration, precision testing, and comparison with reference methods, and consideration of environmental factors that affect air quality.

Meteorological conditions were measured at each sampling point using the Environment Meter type LT Lutron SP-9201. This instrument can measure and record data on indoor and outdoor meteorological conditions, including air temperature, air humidity, air pressure, and wind speed. Using the GPS tool, the researchers navigated the coordinates of the sampling location. It recorded meteorological data at 10-minute intervals for 30 minutes at each measurement point. Meteorological data measurement is carried out concurrently with the measurement of PM_{10} and $PM_{2.5}$ concentrations.

The data concerning PM_{10} and $PM_{2.5}$ concentrations were analyzed in order to establish horizontal profiles based on distance from the cement plant, as well as concentration variations based on measurement time (day and night). The $PM_{2.5}/PM_{10}$ ratio was calculated for each measurement point and time to indicate particulate characteristics. Graphical analyses were conducted to understand the differences in concentrations by distance and time, and to identify correlations between meteorological parameters and particulate concentrations.

RESULTS AND DISCUSSION

Meteorological Conditions around the Cement Plant Area

Meteorological conditions, including wind speed and direction, relative humidity, pressure, and temperature, have been demonstrated to influence the formation, diffusion, and chemical dispersion of particulates in the atmosphere up to the receptor [14], [15]. The meteorological condition data obtained were subjected to averaging, and the standard deviation was calculated. Figures 2 show the meteorological condition data processing results in the west of the cement plant area.

As demonstrated in Figures 2(a), 2(b) and 2(c) below, the temperature at the cement plant site in Padang City ranged from 22.57 to 32.15°C, the relative humidity ranged from 52.99 to 93.30%, and the air pressure ranged from 971.96 to 997.50 hPa. The data indicates that the temperature and relative humidity values fluctuate yet remain within the bounds of normalcy. Indonesia's geographical location is on the equator or within the tropics. Tropical regions, as defined by temperature measurements, are characterized by an average temperature of 20ºC. However, the Indonesian region typically experiences average temperatures of 35ºC, accompanied by high humidity levels reaching 85.0%, indicative of a tropical hot, humid climate. This phenomenon is attributable to Indonesia's geographical location at the intersection of two distinct climates, its position between two continents and two oceans, and its land-to-sea ratio [16].

As shown in Figure 2(d), the average wind speed at the study site ranged from 0.50 to 0.67 m/s, while the wind speed per sampling point ranged from 0.1 to 1.6 m/s. According to [17] in [18], the dispersion of particulates is influenced by wind speed. As the wind speed increases, the sand grains on the surface will roll and collide with others, and at a wind speed of 5 m/s, the crushed grains will float in the air and fall back to the surface, while if the wind is faster, then the fine particles will remain in the air.

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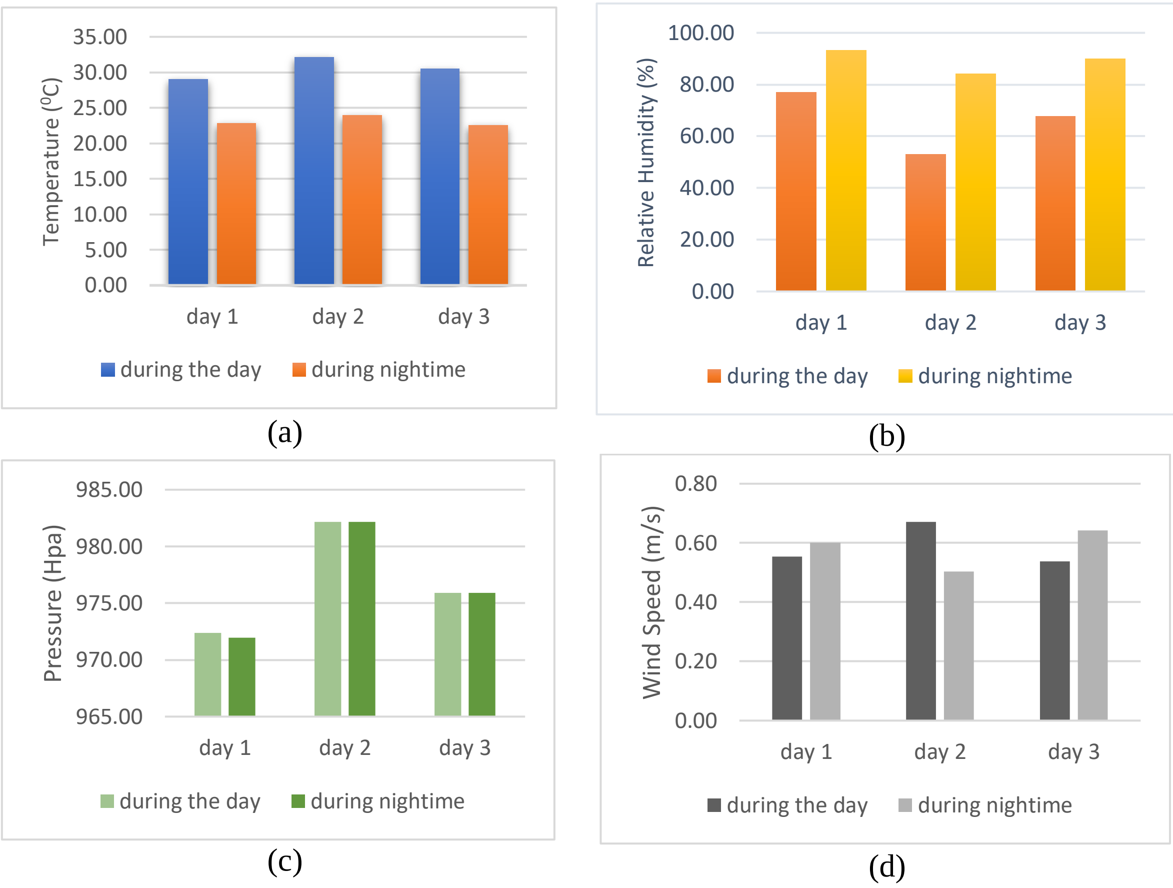

Figure 2. Air temperature of cement plant area (a), Relative humidity in the cement plant area (b), Air aressure in the cement plant area (c), and Wind speed of cement plant area (d)

A wind rose clearly indicates The dominant wind direction, a diagram that provides essential information on wind direction and speed. This tool is indispensable in analyzing wind data for meteorological purposes, particularly in the context of air pollution studies. The wind rose reveals the direction of the farthest spread of pollutants and the maximum range of these pollutants. The dominant wind direction at the sampling point location is depicted with a wind rose, as shown in Figure 3.

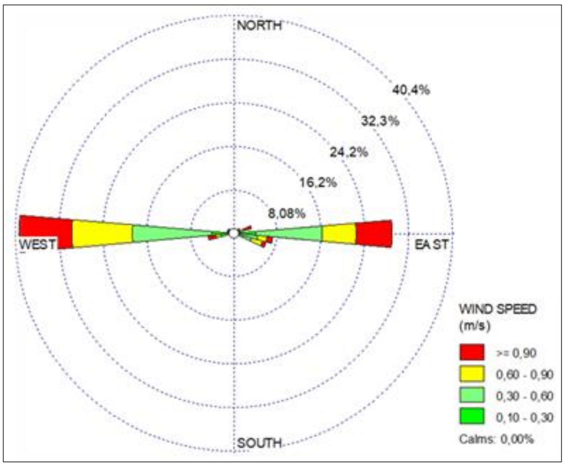

Figure 3. Wind rose plot for cement plant area of Padang

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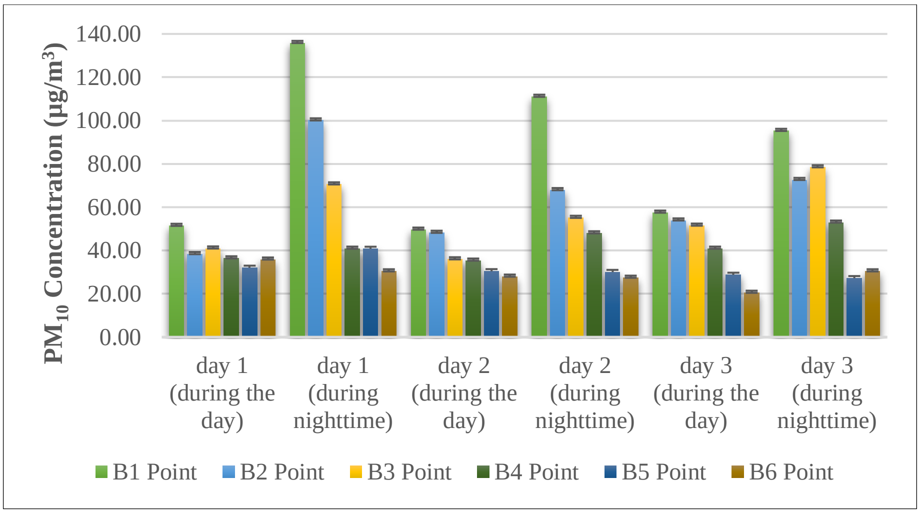
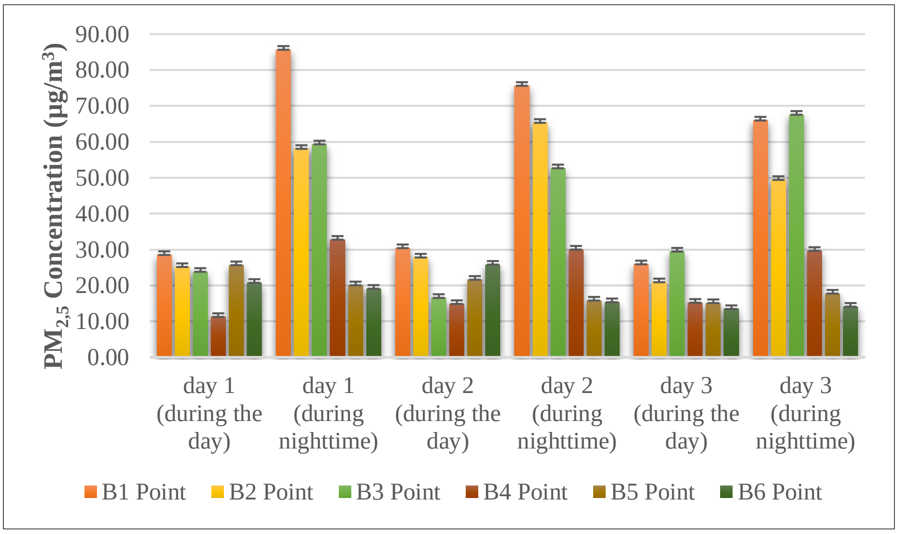
Figure 3 shows the wind speed of 0.10-0.30 m/s in dark green, 0.30-0.60 m/s in light green, 0.60-0.90 in yellow, and greater than or equal to 0.90 m/s in red. The wind speed in the morning at all sampling points comes from the east and west during the day and west to east at night, which follows this study [19], showing that the dominant wind direction moves from east to west and west to east.

PM_{10} and $PM_{2.5}$ Concentrations in the western of the Cement Plant Area

Figure 4(a) and 4(b) show the average PM_{10} and $PM_{2.5}$ concentration data and their standard deviations at each point during the measurements in the western part of the cement plant area.



(a)



(b)

Figure 4. The measurement results of PM concentration in the west of the cement plant area; (a) PM_{10} dan (b) $PM_{2.5}$

Figure 4 (a) and 4(b) clearly show the concentration data for PM_{10} and $PM_{2.5}$ in the west direction of the cement plant area. The highest average concentration of PM_{10} during the day is 52.80 μg/m^3. At night, the concentration soars to 113.98 μg/m^3. The lowest average concentration of PM_{10} during the day is 28.05 μg/m^3; at night, it's 29.37 μg/m^3. The highest

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average concentration of $PM_{2.5}$ during the day was 28.27 µg/m^{3,} and at night was 75.73 µg/m^3. The lowest average concentration of $PM_{2.5}$ during the day was 20 µg/m^3 and 16.18 µg/m^3 at night.

Spatial Profiles of PM_{10} and $PM_{2.5}$ Concentrations

The spatial profile study was conducted by averaging the PM_{10} and $PM_{2.5}$ concentrations each time over three days of measurement in the western cement plant area. This analysis determined changes in PM_{10} and $PM_{2.5}$ concentrations at 0 km, 0.5 km, 1 km, 1.5 km, 2 km, and 2.5 km. The spatial profiles of PM_{10} and $PM_{2.5}$ are illustrated in Figure 5.

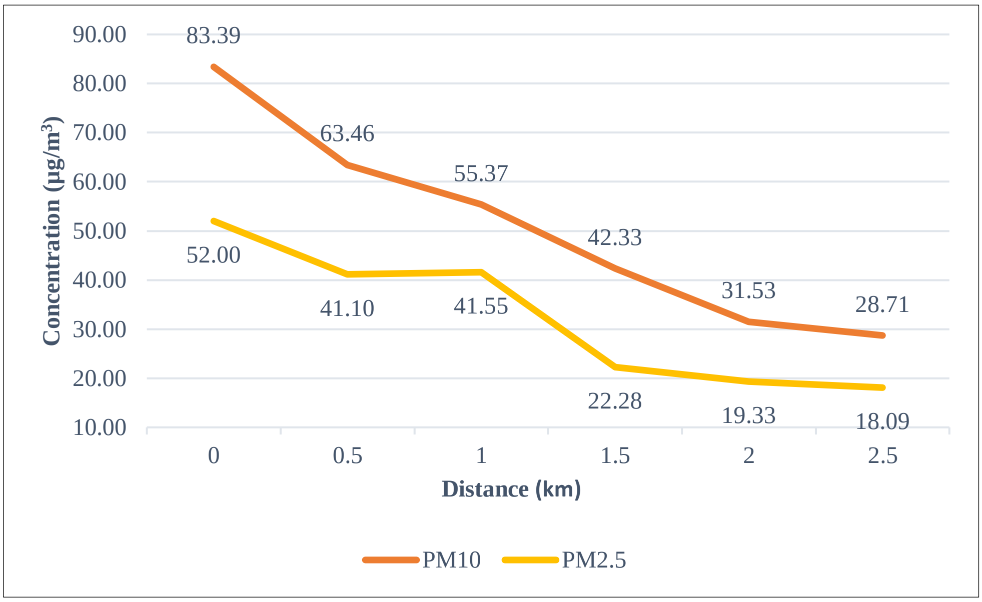

Figure 5. Spatial profiles of PM_{10} and $PM_{2.5}$ concentrations in the western area of the cement plant

The spatial profiles of PM_{10} and $PM_{2.5}$ concentrations from the cement plant are displayed in Figure 5. The results demonstrate a discernible pattern of decline as the distance from the plant increases. The PM_{10} concentration exhibited a decline from 83.39 µg/m³ at the nearest point (0 km) to 28.71 µg/m³ at the farthest point (2.5 km), while the $PM_{2.5}$ concentration demonstrated a decrease from 52.00 µg/m³ to 18.09 µg/m³. These high PM concentrations near the cement plant are influenced by lower wind direction fluctuations at night resulting in more limited horizontal dispersion, causing accumulation of pollutants around the emission source. This is consistent with the wind rose data in Figure 3, which shows the dominance of wind direction from the east and west. The profile demonstrates relative stability at distances exceeding 2 km. This decreasing trend in $PM_{2.5}$ concentrations as the distance from the cement plant increases is consistent with the findings of a study conducted by the present authors. [20].

The rate of decrease in PM_{10} and $PM_{2.5}$ concentrations as a function of distance exhibited notable variations. At the initial kilometre, the rate of decrease of PM_{10} was found to be more rapid than that of $PM_{2.5}$; however, at greater distances (>1 km), the rate of decrease of both particulate fractions became more analogous. This phenomenon can be interpreted as suggesting that coarse particles (PM_{10} component) tend to settle faster near emission sources, while fine particles ($PM_{2.5}$) can be transported further due to their longer residence time in the atmosphere.

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Temporal Profiles of PM_{10} and $PM_{2.5}$ Concentrations

It is essential to present the temporal profiles of PM_{10} and $PM_{2.5}$ particulates for each monitoring period during the day and night to see more studies on particulate concentrations with spatial and temporal variations in the western cement plant area. The pattern of the horizontal profile for each period will be known according to different wind directions and traffic conditions when the temporal profile of particulates is presented for each time. Figure 6 shows the temporal profiles of PM_{10} and $PM_{2.5}$ for each period.

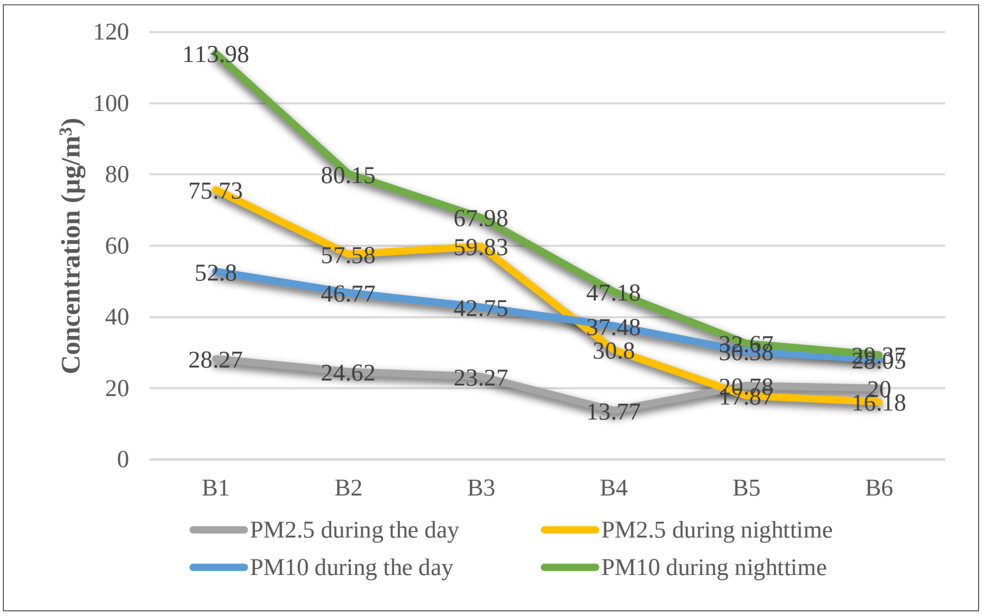

Figure 6. Temporal profiles of PM_{10} and $PM_{2.5}$ concentrations in the western area of the cement plant

Figure 6 compares the concentrations of PM_{10} and $PM_{2.5}$ during the day and at night. The results demonstrate that PM_{10} and $PM_{2.5}$ concentrations at night were consistently higher than during the day at all measurement points. At point B1 (the location nearest to the factory), the nighttime PM_{10} concentration reached 113.98 µg/m³, which is approximately 2.2 times the daytime concentration (52.80 µg/m³). A similar trend was observed at point B1, with the nighttime $PM_{2.5}$ concentration (75.73 µg/m³) being approximately 2.7 times the daytime concentration (28.27 µg/m³). The presence of elevated PM concentrations during the night is influenced by meteorological factors, particularly the predominant wind direction. At night, the dominant wind direction is oriented towards the west of the cement plant area, while during the day, it shifts towards the east of the plant. This phenomenon is analogous to the findings reported in the research conducted by [19] on PM_{10} and $PM_{2.5}$ concentrations, as well as those by [21] and [11]. It has been demonstrated that higher relative humidity at night (84-92%) favors secondary particle formation and hygroscopic growth of existing particles, resulting in increased PM concentrations at night. Significant diurnal temperature variations (7-10°C) promote night-time temperature inversions. The presence of night-time temperature inversions around the cement industry creates a 'pollution dome' with higher PM concentrations than during the day [22].

$PM_{2.5}/PM_{10}$ Ratio in Western Cement Plant Area

The average $PM_{2.5}/PM_{10}$ particulate concentration per measurement period was analyzed. The study of $PM_{2.5}/PM_{10}$ ratios was undertaken to determine the source of particulate emissions

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(that is, both natural and anthropogenic), so as to help evaluate their spatiotemporal distribution and effects on human health and the environment [23]. The $PM_{2.5}/PM_{10}$ ratio data in the cement plant's western area is shown in Table 1.

Table 1. $PM_{2.5}/PM_{10}$ values in the western area of cement plants in Padang City

Distance (km)	**Average PM during the Day**		**$PM_{2,5}/PM_{10}$**	**Average PM at Night**		**$PM_{2,5}/PM_{10}$**
	$PM_{2,5}$	**PM_{10}**		**$PM_{2,5}$**	**PM_{10}**	
B1	28,27	52,80	0,54	75,73	113,98	0,66
B2	24,62	46,77	0,53	57,58	80,15	0,72
B3	23,27	42,75	0,54	59,83	67,98	0,88
B4	13,77	37,48	0,37	30,80	47,18	0,65
B5	20,78	30,38	0,68	17,87	32,67	0,55
B6	20,00	28,05	0,71	16,18	29,37	0,55
Average ratio			0,56	Average ratio		0.67

As illustrated in Table 1, the data set encompasses the measurement of $PM_{2.5}/PM_{10}$ concentrations in the western area of the cement plant. During daylight hours, the $PM_{2.5}/PM_{10}$ concentration ranges from 0.37 to 0.71, while during nighttime hours, the range extends from 0.55 to 0.88, indicating that the dominance of fine particles is more significant than coarse particles. It is further supported by the fact that at almost all measurement points, the value of the $PM_{2.5}/PM_{10}$ ratio is >0.5. These results also indicate that particulates during this period will likely come from anthropogenic sources, such as combustion activities. In addition, the data presented in Table 1 indicates that the mean ratio of $PM_{2.5}/PM_{10}$ during daylight hours is 0.56, while at nighttime, this ratio increases to 0.67. This finding suggests that smaller-sized particulates influence the particulate concentration near the cement plant and that the ratio of $PM_{2.5}$ to PM_{10} at night is more than 0.60. It is generally attributable to the primary contribution of anthropogenic activities involving combustion processes [24]. Conversely, lower daytime ratios may indicate primary particle emissions, including mineral dust, local suspended topsoil, and road surface dust. These emissions are often caused by other mechanical activities that produce more significant amounts of coarse particles than fine particles. [25]. Moreover, the $PM_{2.5}/PM_{10}$ ratio obtained in this study in the western area of the cement plant is greater than the average $PM_{2.5}/PM_{10}$ ratio observed in Tabriz, Iran, which is 0.48. [26]. Meanwhile, in another study in Tehran, the ratio of $PM_{2.5}/PM_{10}$ was almost the same, namely 0.7 [27].

The $PM_{2.5}/PM_{10}$ ratio demonstrates a noteworthy pattern. During the day, the highest ratios are observed at points B6 (0.71) and B5 (0.68), while the lowest is recorded at point B4 (0.37). Conversely, at night, the ratio is observed to be highest at point B3 (0.88). This finding indicates that particulate characteristics may exhibit spatial variability, potentially influenced by local factors such as traffic activity, dust resuspension, and wind-dispersal patterns.

CONCLUSION

The findings of this study indicate a clear decreasing pattern in PM_{10} and $PM_{2.5}$ concentrations with increasing distance from the cement plant, suggesting that the plant is the primary source of particulate emissions in the study area. Furthermore, a consistent increase in PM_{10} and $PM_{2.5}$ concentrations was observed during night-time hours in comparison to daytime periods, with a range of 1.8-2.7-fold increase particularly in proximity to the plant. The variation in concentration between day and night is found to be closely related to changes in wind direction and variations in wind speed, changes in relative humidity and temperature inversion conditions. The average $PM_{2.5}/PM_{10}$ ratio is higher at night (0.67) than during the day (0.56), indicating a larger proportion of fine particles at night, which implies potentially more serious health impacts.

This study underscores the significance of incorporating spatial and temporal variations in the assessment of air quality and the formulation of pollution control strategies in the vicinity of industrial areas. It is recommended that the government conduct regular air quality monitoring around cement plants, especially during night time, and consider implementing more effective buffer zones. The cement industry should optimize particulate emission control systems, particularly for $PM_{2.5}$, and consider setting operational hours that can minimize the impact on air quality at night. Furthermore, there is a need for the dissemination of information regarding the potential risks of particulate exposure to the surrounding community, with the aim of raising awareness and encouraging the adoption of preventive measures, such as the wearing of masks and the reduction of outdoor activities during periods of high particulate concentration. This control strategy has the potential to be an effective approach to reducing particulate exposure for communities surrounding semen plant areas. The study recommends further research, namely the comparison of measurement results using EPAM 5000 with Low Volume Air Sampler (LVAS) and vertical profile studies, in order to ascertain the effect of PM10 and PM2.5 concentrations in the ambient air of cement factories.

REFERENCE

[1] Peraturan Pemerintah RI Nomor 22, "Peraturan Pemerintah Nomor 22 Tahun 2021 tentang Pedoman Perlindungan dan Pengelolaan Lingkungan Hidup," *Sekretariat Negara Republik Indonesia*, vol. 1, no. 078487A, p. 483, 2021, [Online]. Available: http://www.jdih.setjen.kemendagri.go.id/

[2] BBC Indonesia, "Jelang Asian Games 2018, Jakarta jadi kota berpolusi udara 'paling parah' di dunia," 2018. https://www.bbc.com/indonesia/trensosial-44882631

[3] S. Hua, H. Tian, K. Wang, C. Zhu, J. Gao, Y. Ma, Y. Xue, Y. Wang, S. Duan, and J. Zhou, "Atmospheric emission inventory of hazardous air pollutants from China's cement plants: Temporal trends, spatial variation characteristics and scenario projections," *Atmospheric Environment*, vol. 128, no. 2016, pp. 1–9, 2016, doi: 10.1016/j.atmosenv.2015.12.056.

[4] L. Zou, Y. Ni, Y. Gao, F. Tang, J. Jin, and J. Chen, "Spatial variation of PCDD/F and PCB emissions and their composition profiles in stack flue gas from the typical cement plants in China," *Chemosphere*, vol. 195, pp. 491–497, 2018, doi: 10.1016/j.chemosphere.2017.12.114.

[5] N. Mohamad, K. Muthusamy, R. Embong, A. Kusbiantoro, and M. H. Hashim, "Environmental impact of cement production and Solutions: A review," *Materialstoday Proceeding.*, vol. 48, pp. 741–746, 2021, doi: 10.1016/j.matpr.2021.02.212.

[6] A. K. M. Fell and K. C. Nordby, "Association between exposure in the cement production industry and non-malignant respiratory effects: A systematic review," *BMJ Open*, vol. 7, no. 4, 2017, doi: 10.1136/bmjopen-2016-012381.

[7] S. Mishra and N. A. Siddiqui, "A Review On Environmental and Health Impacts Of Cement Manufacturing Emissions," *International Journal of Geology, Agriculture and*

Environmental Sciences, vol. 2, no. 3 June 2014, p. 2, 2014, [Online]. Available: www.woarjournals.org/IJGAES

[8] WHO, "Ambient (outdoor) air pollution," 2021. https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

[9] WHO, "Environment, Climate Change and Health," 2022. https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/

[10] A. Valavanidis, K. Fiotakis, and T. Vlachogianni, "Airborne particulate matter and human health: Toxicological assessment and importance of size and composition of particles for oxidative damage and carcinogenic mechanisms,"*Journal of Environmental Science and Health, Part C Environmental Carcinogenesis and Ecotoxicology Reviews*, vol. 26, no. 4, pp. 339–362, 2008, doi: 10.1080/10590500802494538.

[11] I. L. Putri, "Analisis Konsentrasi Particulate Matter 2,5 ($PM_{2,5}$) Di Udara Ambien Dan Rekomendasi Tanaman Pereduksi $PM_{2,5}$ Di Perumahan Dosen UNAND Blok D, Ulu Gadut, Kota Padang," Univeritas Andalas-Padang, 2022.

[12] D. Wangsa, V.S. Bachtiar, and S. Raharjo, "Uji Model Aeromod Terhadap Sebaran Particulate Matter 10 µm (PM_{10}) di Sekitar Kawasan PT Semen Padang," *Jurnal Ilmu Lingkungan*, vol. 20, no. 2, pp. 291–301, 2022, doi: 10.14710/jil.20.2.291-301.

[13] T. Zheng, Z. R. Peng, H. Di He, S. Zhang, and Y. Wu, "Horizontal Profiles of Size-Segregated Particle Number Concentration and Black Carbon Beside a Major Roadway," *Atmospheric Environtment: X*, vol. 16, no. June, 2022, doi: 10.1016/j.aeaoa.2022.100187.

[14] L. Lagidze, "The Influence of Meteorological Conditions on Atmospheric Pollution in Georgia," *American Journal of Environmental Protection*, vol. 4, no. 3, p. 67, 2015, doi: 10.11648/j.ajep.s.2015040301.21.

[15] Kementerian Lingkungan Hidup dan Kehutanan, "Peraturan Menteri Negara Lingkungan Hidup Nomor 12 Tahun 2010 Tentang Pelaksanaan Pengendalian Pencemaran Udara Di Daerah," *Pelaksanaan Pengendalian Pencemaran Udara Di Daerah. Menteri Negara Lingkungan Hidup*, pp. 1–199, 2010.

[16] F. F. Syah and M. S. P. Nugroho, "Kenyamanan Termal Gedung Setda Kudus," *Sinektika Jurnal Arsitektur*, vol. 13, no. 2, pp. 105–113, 2015, doi: 10.23917/sinektika.v13i2.754.

[17] R. Geiger, R. H. Aron, and P. Todhunter, *The Climate Near the Ground Edition 5*, 5th ed. Germany: Vieweg Teubner Verlag Wiesbaden, 1995. doi: https://doi.org/10.1007/978-3-322-86582-3.

[18] A. Turyanti, "Analisis Ppengaruh Faktor Meteorologi Terhadap Konsentrasi PM_{10} Menggunakan Regresi Berganda (Studi kasus: Daerah Dago Pakar dan Cisaranten, Bandung)," *Jurnal Agromet*, vol. 25, no. 1, pp. 29–36, 2011, [Online]. Available: http://journal.ipb.ac.id/index.php/agromet

[19] D. Wangsa, *Pemodelan Sebaran Particulate Matter 10 µm (PM_{10}) Di Kawasan Industri PT. Semen Padang Menggunakan Software Aermod*. Tesis: Unversitas Andalas, 2021.

[20] R. Novirsa and U. F. Achmadi, "Analisis Risiko Pajanan $PM_{2,5}$ di Udara Ambien Siang

Hari terhadap Masyarakat di Kawasan Industri Semen," *Jurnal Kesehatan Masyarakat Nasional*, vol. 7, no. 4, p. 173, 2012, doi: 10.21109/kesmas.v7i4.52.

[21] I. Putra, "Analisis Konsentrasi Particulate Matter 2.5 ($PM_{2.5}$) Di Udara Ambien Dan Rekomendasi Tanaman Pereduksi $PM_{2.5}$ di Perumahan UNAND Blok B, Ulu Gadut, Kota Padang," Univeritas Andalas-Padang, 2022.

[22] T. Niedźwiedź, E. B. Łupikasza, Ł. Małarzewski, and T. Budzik, "Surface-based nocturnal air temperature inversions in southern Poland and their influence on PM_{10} and $PM_{2.5}$ concentrations in Upper Silesia," *Theoretical and Applied Climatology*, vol. 146, no. 3–4, pp. 897–919, 2021, doi: 10.1007/s00704-021-03752-4.

[23] F. Usman *et al.*, "Exploring the Mass Concentration of Particulate Matter and Its Relationship with Meteorological Parameters in the Hindu-Kush Range," *Atmosphere (Basel).*, vol. 13, no. 10, pp. 1–12, 2022, doi: 10.3390/atmos13101628.

[24] H. Zha, R. Wang, X. Feng, C. An, and J. Qian, "Spatial characteristics of the $PM_{2.5}/PM_{10}$ ratio and its indicative significance regarding air pollution in Hebei Province, China," *Environ. Monit. Assess.*, vol. 193, no. 8, 2021, doi: 10.1007/s10661-021-09258-w.

[25] C. K. Chan and X. Yao, "Air pollution in mega cities in China," *Atmospheric Environment*, vol. 42, no. 1, pp. 1–42, 2008, doi: 10.1016/j.atmosenv.2007.09.003.

[26] A. Gholampour, R. Nabizadeh, S. Naseri, M. Yunesian, H. Taghipour, and N. Rastkari, "Environmental Health Exposure and health impacts of outdoor particulate matter in two urban and industrialized area of Tabriz , Iran," *Journal of Environmental Health Science and Engineering*, pp. vol 12, no. 27, 2014. doi: 10.1186/2052-336X-12-2

[27] J. Jaafari, K. Naddafi, M. Yunesian, R. Nabizadeh, M.S. Hassanvand, M.G. Ghozikali, S. Nazmara, H.R. Shamsollahi and K. Yaghmaeian, "Study of PM_{10}, $PM_{2.5}$, and PM_1 levels in during dust storms and local air pollution events in urban and rural sites in Tehran," *Human and Ecological Risk Assessment*, vol. 24, no. 2, pp. 482–493, 2018, doi: 10.1080/10807039.2017.1389608.