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Experimental Investigation on PM10 and PM2.5 Concentrations in North Bandung

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ABSTRACT

North Bandung is an area where there are several tourist attractions, including the Dago Dream Park. The main road to several locations in North Bandung is via the road in front of Terminal Dago. For this reason, the purpose of this study was to collect data on PM2.5 and PM10 concentrations at both locations, namely in front of Terminal Dago and Dago Dream Park. Data collection was carried out for seven days, from Monday to Sunday, from 08.00 to 16.00 local time. To evaluate air quality in these two places, the national standard, namely PPRI No. 22 of 2021 and international standards from WHO were applied. The measurement results show that the concentrations of PM2.5 and PM10 in these two locations are still within the national standard. Meanwhile, when evaluated with WHO standards, PM10 concentrations in both locations are still within standard, but for PM2.5, there are several days where the air quality is out of the standard. The average concentrations of PM2.5 and PM10 during the 7 days of measurement at Terminal Dago are 19.9 μg/m^3 and 21.6 μg/m^3, respectively. While the average concentration of PM2.5 and PM10 during 1 week of data collection were 18.9 μg/m^3 and 19.9 μg/m^3, respectively. This means that the concentration of PM2.5 and PM10 at Terminal Dago is slightly higher than that of at Dago Dream Park. In addition, based on an evaluation using national standards, Dago Dream Park tourist attractions still have good air quality and are safe for local residents and tourists. From the data recorded at the health Centre (Puskesmas), the number of ARI cases in the two locations in 2020 and 2021 is relatively not much different.

KEYWORDS

North Bandung
Air pollution
PM10 and PM2.5
Tourist attractions
Dago Dream Park

INTRODUCTION

One of the goals of people traveling to cool places in the mountains is not only to seek a physical and mental peace, but also to a breath healthy and fresh air. Naturally, the air in the mountains

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is fresher and free from pollution, because apart from relatively not many vehicles passing by, there are also many trees in the mountains that are able to absorb pollutants in the air. Two of the main components of air pollutants are PM2.5 and PM10 [1–3]. Air is categorized as healthy if the concentrations of PM2.5 and PM10 are below national or international quality standards. The currently applicable national PM2.5 and PM10 quality standards are PPRI No. 22 of 2021 [4] and Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.14/MENLHK/SETJEN/KUM.1/7/2020, respectively [5]. Meanwhile, international standards that are commonly used are from the World Health Organization (WHO) of 2021 [6].

Bandung has always been known to have many tourist attractions, both in southern Bandung and northern Bandung. Nowadays, apart from being a tourist spot, northern Bandung is also occupied as a luxury residential area. Consequently, North Bandung is currently experiencing an increase in population density. The area that used to be green as a buffer for water sources has now turned into a residential area. This condition of course will reduce the air quality in North Bandung. Decreasing air quality in an area is indicated by increasing concentrations of PM2.4 and PM10 [7–10]. According to Lestari [11], air quality in Bandung has reached to an unhealthy stage, because in several places PM10 concentrations have been recorded above the WHO annual standard [6].

One of the early indicators on the impact of PM2.5 and PM10 pollutants in an area is the increasing cases of acute respiratory infections (ARI) [12–15]. In addition, due to higher absorption percentage in the lungs of PM2.5 as compared to PM10 [16,17], PM2.5 is more dangerous than PM10 to human health. Therefore, national and international standards [4, 6] for PM2.5 are lower than that of PM10.

Wellid et al. [14]reported that cases of ARI in the limestone industry were much higher than areas where there was no limestone industry. For example, 3,480 and 4,567 cases of ARI in the Padalarang limestone industry were recorded in 2020 and 2021 respectively, as compared to only 1,409 (2020) and 1,517 (2021) cases for the areas far from the limestone industry. Apart from causing ARI, PM2.5 and PM10 pollutions can also cause other diseases, depending on the substances or materials contained in these particulates [9, 18–21]. As in other big cities, the city of Bandung also has a big potential to face quite severe air pollution, as faced by several cities in China and India [22–24].

Therefore, the objective of this study is to measure PM2.5 and PM10 concentrations and to justify the latest pollutant level in two locations in North Bandung; Terminal Dago as the entrance to tourist areas, and Dago Green Park as a tourist spot. In addition, the number of ARI cases recorded at the health center (Puskesmas) adjacent to these two locations will be analyzed. The focus here is to see the correlation between PM2.5 and PM10 concentrations with ARI cases in these two places.

MATERIALS AND METHOD

Data collection for measurements of PM2.5 and PM10 concentrations was carried out from 08.00 to 16.00 at two locations, namely in front of Terminal Dago and Dago Green Park, from January to May 2023. Terminal Dago represents the main road that must be passed by when heading to the tourist area which is located in North Bandung. While Dago Green Park is one of the tourist attractions located in North Bandung.

PM2.5 and PM10 concentrations were measured using the HT-9600 particle counter. The air quality in both places will be evaluated using two national standards [4,5] and one international standard [6]. The two national standards are Republic of Indonesia Government Regulation Number 22 of 2021 (PPRI Number 22, 2021) [4] and Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.14/MENLHK/SETJEN/KUM.1/7/2020 [5]. International standard is from the World Health Organization (WHO) [6]. The summary of standards according to PPRI Number 22 of 2021 [4] and WHO 2021 [6] are shown in Table 1. Meanwhile, the standard for Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.14/MENLHK/SETJEN/KUM.1/7/2020 [5] is presented in the pollutant standard index (PSI) level, as shown in Table 2. The PSI level can be determined by using equation (1).

Table 1. Standards of PM2.5 and PM10 according to PPRI No. 22 & WHO [4,6]

Pollutant	**Averaging Time**	**PPRI No. 22, 2021**	**WHO (2021)**
PM2.5	24-hour	55	15
	Annual	15	5
PM10	24-hour	75	45
	Annual	40	15

Table 2. PSI levels and categories

Category	**Color**	**PSI Level**
Good	Green	1 – 50
Moderate	Blue	51 -100
Unhealthy	Yellow	101 – 200
Very Unhealthy	Red	201 – 300
Hazardous	Black	≥ 301

$$PSI = \frac{(I_a - I_b)}{(X_a - X_b)} (X_x - X_b) \tag{1}$$

where,

PSI = PSI level
I_a = PSI level top limit
I_b = PSI level bottom limit
X_a = Ambient concentration top limit (μg/m^3)
X_b = Ambient concentration bottom limit (μg/m^3)
X_x = Measured concentration (μg/m^3)

The PM2.5 and PM10 measurement locations are shown in Figure 1. The figure shows that the test locations still have relatively many trees marked in green on the map. The existence of these trees will create a positive impact to the surrounding air where besides being able to produce oxygen, it can also absorb pollutants in the air [25]. The location of Dago Green Park is located at the north of Terminal Dago with a distance of about 2 km.

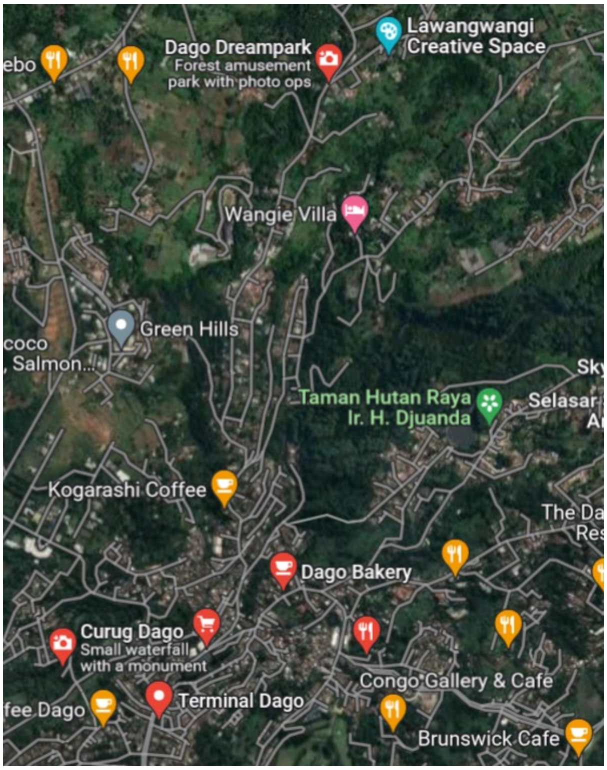

Figure 1. Location of data collection, Terminal Dago and Dago Dream Park

RESULT AND DISCUSSION

Air Quality in Terminal Dago and Dago Dream Park

Figure 2 demonstrates the concentrations of PM2.5 and PM10 in Terminal Dago. It can be seen that the concentration of PM2.5 is not much different as compared to concentration of PM10. The average PM2.5 and PM10 during the seven days of measurement were 19.9 $\mu g/m^3$ and 21.6 $\mu g/m^3$, respectively. This means that 92.1% of the particulate matter in the air at Terminal Dago contains particulate matter with a diameter of less than 2.5 µm (PM2.5), and the remaining 7.9% is particulate matter with a diameter above 2.5 µm and less than 10 µm. In terms of absorption percentage in the lungs and health risks, PM2.5 is more dangerous than PM10 [16,17]. For this reason, pollution from PM2.5 must be considered more seriously by the government, because in general the PM10 content in particulate pollutants is generally more than 85% with a diameter of less than 2.5 µm.

It can be seen in Figure 2 that the concentrations of PM2.5 and PM10 when evaluated using the national standard PPRI No. 22 [4] is still far below standard. In other words, the level of air pollutant in the Terminal Dago area is still in good condition and comfortable for people living in that area, as well as for tourist's activities.

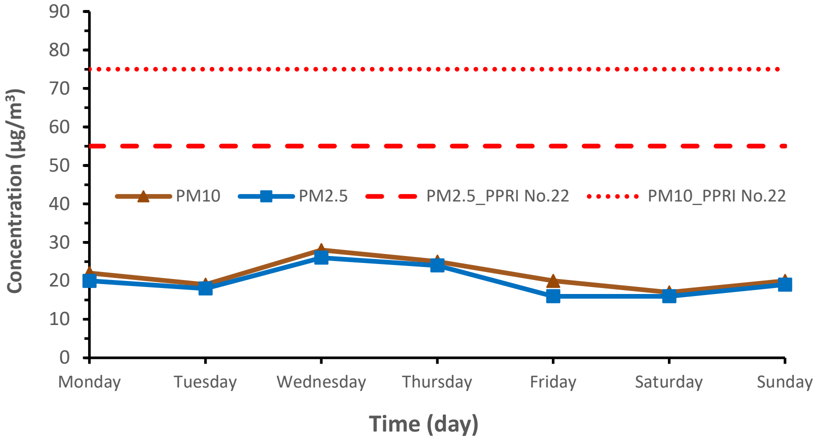

Figure 2. Concentrations of PM2.5 and PM10 in Terminal Dago

Figure 3 illustrates the concentration of PM2.5 and PM10 in Dago Dream Park for 7 days of data measurement. In seven days, the averages of PM2.5 and PM10 are 18.9 μg/m^3 and 19.9 μg/m^3, respectively. Similar to Terminal Dago, the concentration of PM2.5 and PM10 in Dago Dream Park also indicates a lower concentration as compared to national standard PPRI No. 22 [4]. However, this data shows that the percentage of PM2.5 content in particulate pollutants at Dago Dream Park is higher than at Terminal Dago. Apart from that, the particulate matter contains 95.3% of PM2.5, while the rest, which is 4.7%, is particulate matter with diameters above 2.5 μm and less than 10 μm. From the percentage data of PM2.5 and PM10 contained in the particulate matter, the sources of pollution can be further analyzed. However, in this study the types and sources of PM2.5 and PM10 pollutants are not carried out.

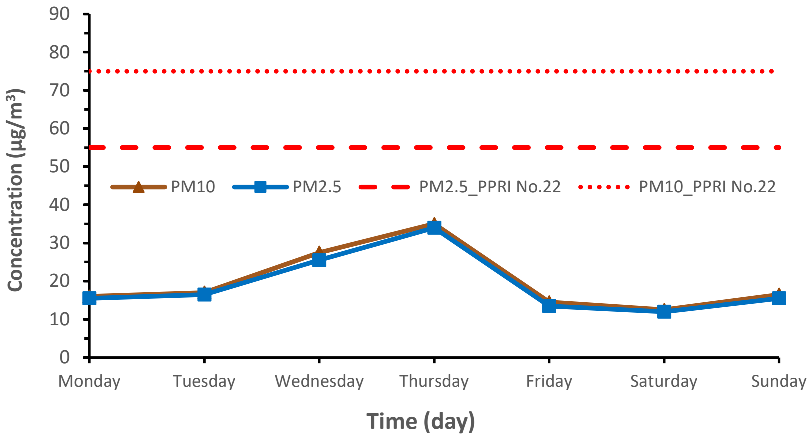

Figure 3. Concentrations of PM2.5 and PM10 in Dago Dream Park

It has been mentioned previously that the average PM10 concentrations for one week at Terminal Dago and at Dago Dream Park were 21.6 μg/m^3 and 19.9 μg/m^3, respectively. In other words, the concentration of PM10 at Terminal Dago is slightly higher than that of at Dago Dream Park. Meanwhile, the comparison of daily PM10 concentrations at both locations for a week is shown in Figure 4. In the figure, it can be seen that during the 7 days of data collection, there are 6 days where the concentration in Terminal Dago is higher than that in Dago Dream Park. There is only one day (Thursday), where the concentration of PM10 at Dago Dream Park is higher than that at Terminal Dago. It is observed that road construction in front of Dago Dream Park on Thursday led to this finding.

In Figure 4, it can be seen that the concentrations of PM10 in both locations were still below national [4] and international standards [6]. As a result, the air qualities in these two locations are considered safe for residents in the area and for tourists visiting to Dago Dream Park.

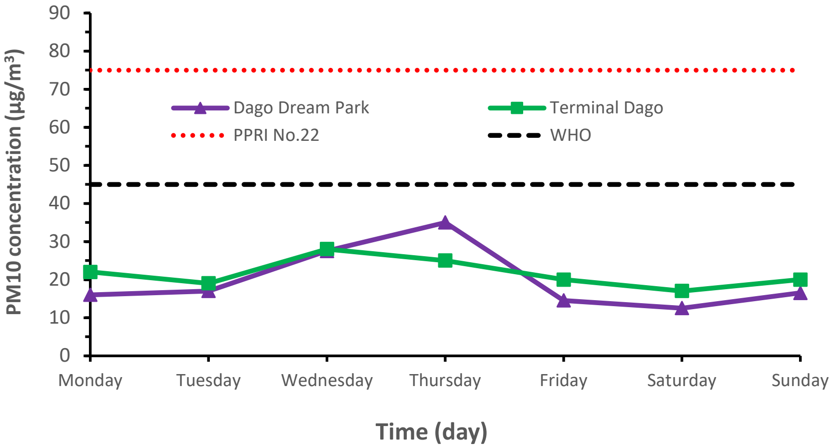

Figure 4. Concentrations of PM10 in Terminal Dago and Dago Dream Park

Figure 5 depicts PM2.5 concentrations at Terminal Dago and Dago Dream Park during the seven days of data measurement. Evaluation with national standards [4] shows that the concentrations at both locations are still within standard of less than 55 $\mu g/m^3$. However, evaluation with WHO international standards [6], indicates that air quality at Dago Terminal is out of standard for all days, while air quality at Dago Dream Park is out of standard from Sunday to Thursday. This means that the air quality at Dago Dream Park is only good for family tours on Friday and Saturday. However, air quality on Sunday at Dago Dream Park can be considered as relatively safe by considering the concentration of PM2.5 at Dago Dream Park on Sunday (15.5 $\mu g/m^3$) is only 0.5 $\mu g/m^3$ or 3.33% above the WHO standard of 15 $\mu g/m^3$.

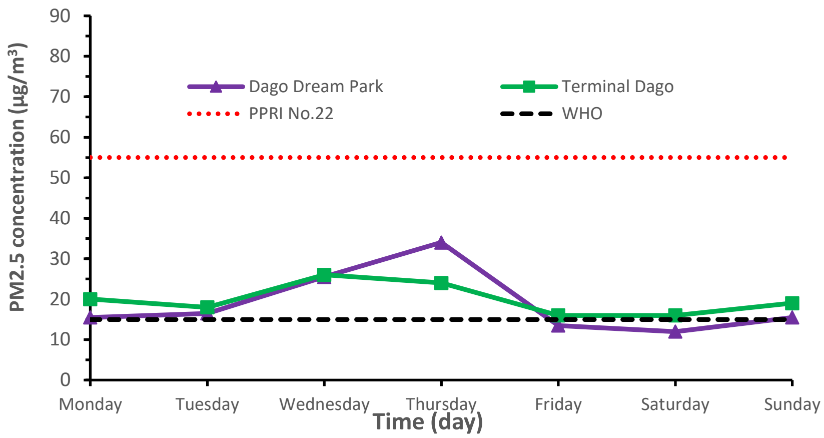

Figure 5. Concentrations of PM2.5 in Terminal Dago and Dago Dream Park

Pollutant Standard Index of Terminal Dago & Dago Dream Park

Another national regulation that regulates air pollution is the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.14/MENLHK/SETJEN/KUM.1/7/2020 [5]. This regulation issues air quality categories based on the numbers calculated using equation (1). Meanwhile, the Pollutant Standard Index (PSI) category is shown in Table 2. Based on this table, PM10 concentrations for 7 days of measurement at both locations fall under the "Good" category, as shown in Figure 6. This means that the two areas have good quality and are safe for human respiration.

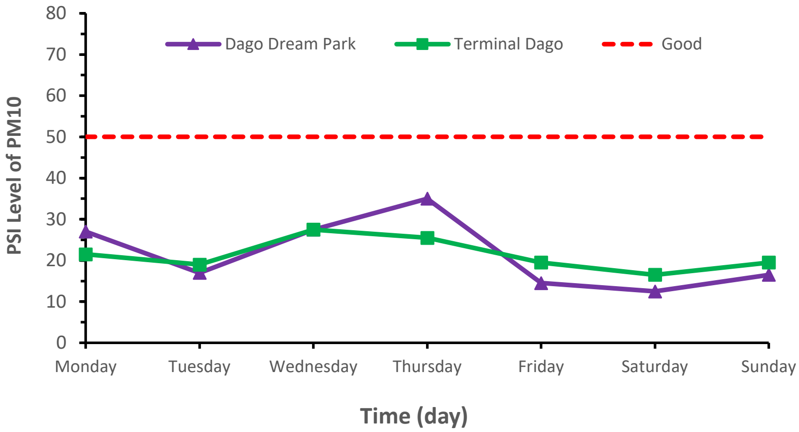

Figure 6. Pollutant Standard Index of PM10 in Terminal Dago and Dago Dream Park

Different conditions for PM2.5, as shown in Figure 7, where the concentration of PM2.5 at the Terminal Dago, during the 7 days of measurement was in the "Medium" category. As for Dago Dream Park, there are only four days (Monday, Friday, Saturday and Sunday) where the air quality can be categorized as "Good", while the rest of the days are in the "Medium" category. With the "Good" category, the air quality in the Dago Dream Park area is safe for residents in the vicinity and visiting tourists. To achieve the "Good" category for seven days, the regional government needs to make efforts to reduce the presence of PM2.5 in the area, for example by planting trees which can absorb more air pollutants.

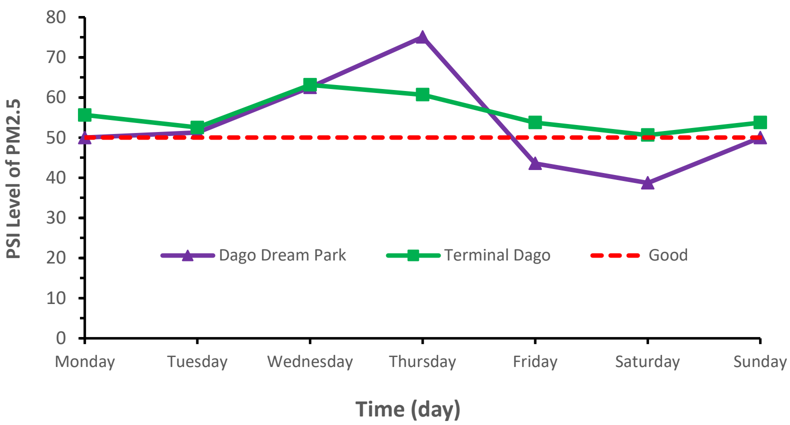

Figure 7. Pollutant Standard Index of PM2.5 in Terminal Dago and Dago Dream Park

Cases of Acute Respiratory Infection in Terminal Dago & Dago Dream Park

As previously mentioned, one indicator of air exposure in an area is the number of ARI cases reported in that area. Figure 8 shows the number of ARI cases recorded at the Dago Health Center and Lembang Health Center. The Dago Health Center (Puskesmas) is near the Terminal Dago, while the Lembang Health Center is close to Dago Green Park. Figure 8 shows the ARI data for 2020 and 2021 at Puskesmas in both locations. From the figure it can be seen that in 2020, a higher number of ARI cases occurred at Dago Dream Park. Whereas in 2021, more cases were recorded at the Dago Terminal. From the measurement data, it shows that PM2.5 and PM10 concentrations in Dago Terminal are slightly higher than in Dago Dream Park. Therefore, it should be expected that the number of ARI cases in Dago Terminal is slightly higher than that in Dago Dream Park. However, the data shows different in 2020. This is likely due to the social and economic differences of the people living in these two regions.

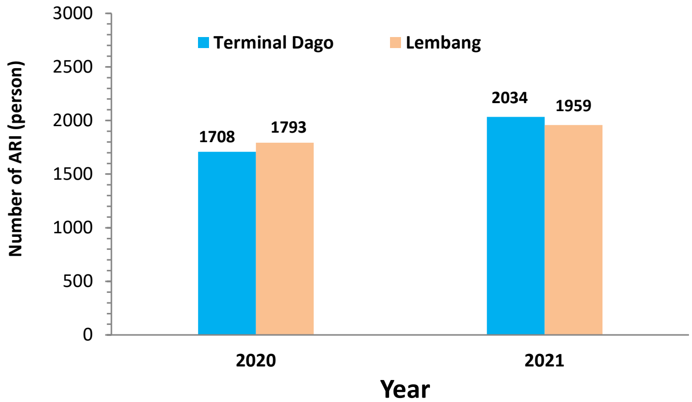

Figure 8. Number of Acute Respiratory Infection in Health Center at Terminal Dago and Dago Dream Park

In the previous section it was mentioned that Wellid et al. [14] reported the number of ARI cases in the limestone industry in Padalarang in 2020 and 2021 were 3480 and 4567, respectively while the neighboring sub-districts where there was no limestone industry were only 1409 and 1517 cases. This means that the number of ARI cases in Terminal Dago and in Dago Dream Park is lower than ARI cases in Padalarang but more than in sub-districts which are adjacent to the limestone industry. The relationship between PM2.5 and PM10 concentrations with the number of ARI cases in an area needs further investigation. The number of ARI cases is not only caused by air pollution from PM2.5 and PM10, but also due to cigarette smoke pollution, both active and passive smokers.

CONCLUSION

Measurements of PM2.5 and PM10 concentrations have been carried out in two places, namely at Dago Terminal as the main road to tourism sites in North Bandung, and Dago Dream Park as one of the tourist attractions in North Bandung. In addition, data on the number of ARI cases recorded in the health center adjacent to the test site have also been reported. Based on test data, PM10 concentrations at both locations are still below the national standard PPRI no. 222 of 2021 and international standard by WHO. In the case of PM2.5, even though it is still below the national standard, at Terminal Dago, for 7 days the measurement has been above the WHO standard, and for Dago Dream Park, there are several days above the WHO standard.

Evaluation using the PSI (Pollutant Standard Index) for PM10, in both locations indicates the air quality is in “Good” category. However, evaluation of PM2.5 shows all data in Dago Terminal is in the “Moderate” status, while at Dago Dream Park, there are days with the category of "Good" and "Moderate". This means that at Dago Terminal, the government needs to pay more attention to PM2.5 concentrations so that it can be lowered below WHO standards, for example by increasing the number of trees around Terminal Dago.

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REFERENCES

[1] N. R. Martins and G. Carrilho da Graça, “Effects of airborne fine particle pollution on the usability of natural ventilation in office buildings in three megacities in Asia,” *Renew. Energy*, vol. 117, pp. 357–373, Mar. 2018, doi: 10.1016/J.RENENE.2017.10.089.

[2] D. Sierra-Porta, Y. T. Solano-Correa, M. Tarazona-Alvarado, and L. A. N. de Villavicencio, “Linking PM10 and PM2.5 Pollution Concentration through Tree Coverage in Urban Areas,” *CLEAN – Soil, Air, Water*, vol. 51, no. 5, p. 2200222, 2023, doi: https://doi.org/10.1002/clen.202200222.

[3] N. R. Martins and G. Carrilho da Graça, “Impact of outdoor PM2.5 on natural ventilation usability in California’s nondomestic buildings,” *Appl. Energy*, vol. 189, pp. 711–724, Mar. 2017, doi: 10.1016/J.APENERGY.2016.12.103.

[4] “PP No. 22 Tahun 2021 tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup [JDIH BPK RI].”

[5] “Permen LHK No. 14 Tahun 2020 tentang Indeks Standar Pencemar Udara [JDIH BPK RI].”

[6] “WHO Global Air Quality Guidelines.”

[7] A. B. Vicente, P. Juan, S. Meseguer, C. Díaz-Avalos, and L. Serra, “Variability of PM10 in industrialized-urban areas. New coefficients to establish significant differences between sampling points,” *Environ. Pollut.*, vol. 234, pp. 969–978, Mar. 2018, doi: 10.1016/J.ENVPOL.2017.12.026.

[8] M. F. Ibrahim, R. Hod, A. M. Nawi, and M. Sahani, “Association between ambient air pollution and childhood respiratory diseases in low- and middle-income Asian countries: A systematic review,” *Atmos. Environ.*, vol. 256, p. 118422, Jul. 2021, doi: 10.1016/J.ATMOSENV.2021.118422.

[9] S. L. Lewis, L. M. Russell, J. A. McKinsey, and W. J. Harris, “Small contributions of dust to PM2.5 and PM10 concentrations measured downwind of Oceano Dunes,” *Atmos. Environ.*, vol. 294, p. 119515, Feb. 2023, doi: 10.1016/J.ATMOSENV.2022.119515.

[10] N. T. T. Nhung, C. Schindler, T. M. Dien, N. Probst-Hensch, and N. Künzli,

"Association of ambient air pollution with lengths of hospital stay for hanoi children with acute lower-respiratory infection, 2007–2016," *Environ. Pollut.*, vol. 247, pp. 752–762, Apr. 2019, doi: 10.1016/J.ENVPOL.2019.01.115.

[11] L. Puji, "Tantangan pengelolaan kualitas udara di Indonesia: Karakteristik, dampak, sumber dan pengendaliannya," Orasi Ilmiah Guru Besar Institut Teknologi Bandung, 2016.

[12] B. D. Horne *et al.*, "Short-Term Elevation of Fine Particulate Matter Air Pollution and Acute Lower Respiratory Infection," *Am. J. Respir. Crit. Care Med.*, vol. 198, no. 6, pp. 759–766, Apr. 2018, doi: 10.1164/rccm.201709-1883OC.

[13] J. Cheng, H. Su, and Z. Xu, "Intraday effects of outdoor air pollution on acute upper and lower respiratory infections in Australian children," *Environ. Pollut.*, vol. 268, p. 115698, Jan. 2021, doi: 10.1016/J.ENVPOL.2020.115698.

[14] I. Wellid and N. Yuningsih, "Kaji eksperimental konsentrasi pm10 di kawasan industri batu gamping padalarang dan sekitarnya 1-5," *J. Ilmu Lingkung.*, vol. 17, no. 1, pp. 11–20, 2023, doi: 10.31258/jil.17.1.p.11-20.

[15] N. Ab Manan, A. Noor Aizuddin, and R. Hod, "Effect of Air Pollution and Hospital Admission: A Systematic Review," *Ann. Glob. Heal.*, 2018, doi: 10.29024/aogh.2376.

[16] W. C. Hinds, *Aerosol technology: Properties, behaviour and measurement of airborne particles*. John Wiley and Sons, New York, 1999.

[17] I. Salma, I. Balásházy, W. Hofmann, and G. Záray, "Effect of physical exertion on the deposition of urban aerosols in the human respiratory system," *J. Aerosol Sci.*, vol. 33, no. 7, pp. 983–997, Jul. 2002, doi: 10.1016/S0021-8502(02)00051-4.

[18] V. T. Vu, B. K. Lee, J. T. Kim, C. H. Lee, and I. H. Kim, "Assessment of carcinogenic risk due to inhalation of polycyclic aromatic hydrocarbons in PM10 from an industrial city: A Korean case-study," *J. Hazard. Mater.*, vol. 189, no. 1–2, pp. 349–356, May 2011, doi: 10.1016/J.JHAZMAT.2011.02.043.

[19] L. M. Russell, L. N. Hawkins, A. A. Frossard, P. K. Quinn, and T. S. Bates, "Carbohydrate-like composition of submicron atmospheric particles and their production from ocean bubble bursting," *Proc. Natl. Acad. Sci.*, vol. 107, no. 15, pp. 6652–6657, 2010, doi: 10.1073/pnas.0908905107.

[20] J. S. Apte, M. Brauer, A. J. Cohen, M. Ezzati, and C. A. Pope, "Ambient PM2.5 Reduces Global and Regional Life Expectancy," *Environ. Sci. Technol. Lett.*, vol. 5, no. 9, pp. 546–551, 2018, doi: 10.1021/acs.estlett.8b00360.

[21] N. Zhang *et al.*, "Chemical characteristic of PM2.5 emission and inhalational carcinogenic risk of domestic Chinese cooking," *Environ. Pollut.*, vol. 227, pp. 24–30, Aug. 2017, doi: 10.1016/J.ENVPOL.2017.04.033.

[22] X. Yang, L. Jiang, W. Zhao, Q. Xiong, W. Zhao, and X. Yan, "Comparison of Ground-Based PM2.5 and PM10 Concentrations in China, India, and the U.S.," *International Journal of Environmental Research and Public Health*, vol. 15, no. 7. 2018. doi: 10.3390/ijerph15071382.

[23] L. Ping, Y. Wang, Y. Lu, L.-C. Lee, and C. Liang, "Tracing the sources of PM2.5-related health burden in China," *Environ. Pollut.*, vol. 327, p. 121544, 2023, doi: https://doi.org/10.1016/j.envpol.2023.121544.

[24] G. Sharma, S. Annadate, and B. Sinha, "Will open waste burning become India's

largest air pollution source?," *Environ. Pollut.*, vol. 292, p. 118310, 2022, doi: https://doi.org/10.1016/j.envpol.2021.118310.

[25] A. E. Putri, M. Humairo, and U. Agustina, "Reduction Effort of Pm 10 and Co With Phytoremediation Method Using Trees and Decorative Plants in Surabaya, Indonesia," in *International Conference on Natural Science and Environment (ICNSE)*, Sidney, Australia, 2016, pp. 10–13.