Evaluation of PM$_{10}$ Concentrations in West Sumatra during Rainy Season

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Abstract. Pollutant concentrations in ambient air are fluctuating and influenced by the environment self-purification capability, such as by rainfall occasions. This research was done to evaluate ambient air particulate matter 10 (PM$_{10}$) concentrations in West Sumatra Province during rainy season. Data from four sampling locations were collected, in which two of them were collected by automatic data collection in air quality monitoring station (AQMS) located at a roadside in the front yard of West Sumatra Governor Office, and Global Atmosphere Watch (GAW) located at a background concentration area in Bukit Koto Tabang. Meanwhile, data in two other locations were collected by using a low volume air sampler. These two locations represent industrial area that is adjacent to a cement factory, and a campus area that is located nearby an agricultural area. The measurement results show that the highest PM$_{10}$ of 68.71±10.99 µg/Nm$^3$ was measured nearby the cement production plant, which exceeded World Health Organization (WHO) threshold for 24-hour measurement. However, it is still below the Indonesian National Ambient Air Quality Standard (NAAQS). On the other hand, the rest locations still met both standards, i.e. 13.20±3.11, 28.60±13.97, and 33.85±8.41 µg/Nm$^3$, at the background concentration area, Governor Office, and the campus area, respectively.

1. Introduction

PM$_{10}$ is a pollutant that is often discussed because of its effects to the environment. Various countries consider PM$_{10}$ as something that needs special attention. WHO sets PM$_{10}$ standard in ambient air at 50 µg/Nm$^3$ for 24 hours, and 30 µg/m$^3$ for one-year measurement [1]. Indonesia has set an ambient air quality standard based on the Indonesian Government Law No.41 year 1999 about Air Pollution Control, with a maximum PM$_{10}$ concentration of 150 µg/Nm$^3$ for 24-hour measurement. This regulation is still valid and has not been updated for 20 years.

PM$_{10}$ in ambient air can be originated from various activities. [2] revealed that the main contributors to PM$_{10}$ in a city are road dust, industries, and emissions from diesel or gasoline vehicles. In addition, the source of particulates can also come from agricultural activities. Burning residues from agricultural products is a common traditional way to get rid of crop residues, and eliminate pests. However, combustion of the remaining crops can emit pollutants such as CO$_2$, CO, particulates, and non-methane hydrocarbons [3 – 9]. PM$_{10}$ at certain concentrations can cause health issues such as
respiratory symptoms, exacerbations of respiratory, chronic cardiovascular disease, decreased lung function, even premature death [10]. Padang City is the capital of West Sumatra Province, with an area of 232.25 km$^2$. The measurement of PM$_{10}$ in the ambient air of the city of Padang has often been done before, both by educational and the Government institutions. The West Sumatra Government has an Air Quality Monitoring System (AQMS) to continuously measure air quality and to display the results in two different locations. The first display location, located nearby the AQMS unit, is at the front yard of West Sumatra Governor’s Office, and the second one is at the front yard of Padang City Mayor’s Office. The display of the measurement results is interpreted in the Air Pollution Standard Index, which categorizes air quality in 5 levels, namely good, moderate, unhealthy, very unhealthy, and dangerous [11].

This research was, therefore, conducted in order to compare different PM$_{10}$ ambient air concentrations from various sampling locations within West Sumatra Province during the rainy season. Evaluation of PM$_{10}$ concentrations is needed as an assessment of government policies on air quality management, particularly in West Sumatra Province.

2. Materials and Methods

2.1. Time and Location of Sampling

This research was conducted on 8-12 March 2018 by collecting PM$_{10}$ ambient air concentrations in four different locations, i.e. three within Padang City and one is located outside Padang City. The sampling locations have different activity characteristics, namely, one is nearby a main road with high transportation activities, while another one is located at Global Atmospheric Watch (GAW) Koto Tabang as a remote area that is located about 81 km from Padang City, to represent background concentrations of air pollutants. Meanwhile, two other sampling locations were located at a campus area, which surrounded by agricultural activities, and the last one is located nearby a cement industry. The research locations can be seen in Figure 1(a) and Figure 1(b).

![Figure 1](image-url)

**Figure 1.** Sampling locations: (a) outside Padang City; (b) within Padang City

2.2. PM$_{10}$ Sampling and Analysis

Sampling at two locations was conducted by using continuous air quality monitoring stations, while two others were done by using portable sampling equipment, i.e. low volume air sampler. 24-hour measurement data comprises of PM$_{10}$ ambient air concentrations and weather condition were collected from each sampling location.

Filters used for sampling by low volume air sampler were further analyzed by using gravimetric method. The filter weight difference before and after sampling was weighed by using an analytical
balance with 1 µg accuracy. On the other hand, PM$_{10}$ concentration data from AQMS were obtained automatically.

2.3. Public Health Analysis

Public health analysis was done at location where the highest PM$_{10}$ ambient concentration was observed. Questionnaires were distributed to respondents in residential areas that are estimated to be affected by PM$_{10}$, based on dominant wind direction in that area. Data obtained from questionnaires was in the form of general description of respondents including age and weight of respondents, duration of exposure to ambient air, active/passive smoker-respondent data, and ambient air influence on respondents' health.

The number of samples determined in this study was taken based on the minimum sample size formula:

$$n = \frac{Z^2 \cdot N \cdot p \cdot q}{d^2 (N-1) + Z \cdot p \cdot q}$$  \hspace{1cm} (1)

$n = $ Minimum sample size
$N = $ Total population
$d = $ Degree of accuracy used is 90% or 0.1
$p = $ Proportion of the target population is 0.5
$q = $ Proportion without attributes 1-p = 0.5
$Z = $ Normal std dev. for 1.96 with 95% CI

3. Results and Discussion

3.1. Results of PM$_{10}$ Measurements

PM$_{10}$ concentrations can be seen in Figure 2 that shows the highest concentration was detected nearby the cement plant location, with the average PM$_{10}$ concentration was 68.71 ± 10.94 µg/Nm$^3$. As for the minimum and maximum PM$_{10}$ concentrations in that sampling location were 58.72 and 85.35 µg/Nm$^3$, respectively. These values exceed the WHO standard which sets 50 µg/Nm$^3$ for a 24-hour average. The location of the cement industry has many residential areas around it, thus, this concentration that has exceeded the WHO standard will certainly have impacts on the health of communities around the cement plant, especially on children and the elderly.

Meanwhile, the average PM$_{10}$ concentration at the university campus was 33.85 ± 8.41 µg/Nm$^3$ with the highest measured concentration 43.48 µg/Nm$^3$. The location of the university campus is far from residential and traffic activities, however, it is near agricultural activity. Harvesting in the agricultural field is done 4 times a year, which one of them is conducted in March. During crop harvesting, the agricultural residue is burned by the farmers as a traditional practice to fertilize the land and to control pests. Therefore, the PM$_{10}$ ambient concentration in the campus area was most likely due to the agricultural activities.
The Governor’s office average PM$_{10}$ concentration was 28.6 ± 13.97 µg/Nm$^3$, which is relatively low concentration considering heavy traffic activities nearby the office location. The low concentration was most likely due to the dominant wind direction that blows from the southwestern direction during the day time and from the eastern direction during the night time. Since monitoring station is located at the western of the nearest road, thus, in the day time most pollutants emitted from the traffic will not be detected by the monitoring station. Windrose during the sampling at the Governor’s office can be seen in Figure 3.

Lastly, related to the background concentration that uses data obtained from GAW Koto Tabang, the PM$_{10}$ average concentration was 13.2 ± 3.11 µg/Nm$^3$. This background concentration is the condition of PM$_{10}$ in ambient air with only pollutants from natural sources.

![Figure 2. PM$_{10}$ concentration in rainy season](image)

![Figure 3. Windrose at governor’s office during: (a) day time; (b) night time](image)
3.2. Public Health Analysis

3.2.1. Existing Condition of Sampling Location. The distribution of questionnaires was carried out based on dominant wind direction information that occurs during the day time and the night time nearby the cement plant in Padang City. Wind direction data is shown by windrose in Figure 4. Based on the windrose, it can be seen that the dominant wind direction during the day time comes from the Northwestern direction with an average wind speed of 1.89 m/s. Meanwhile during the night time, the dominant wind direction came from eastern direction with dominant wind velocity of 0.4 m/s.

Dominant wind direction was plotted on the map of the area expected to be affected by the cement plant activities, namely Lubuk Kilangan District. Based on Figure 5, it can be seen that the area expected to be affected by the wind direction is Bandar Buat Village. The distance between the cement plant and Bandar Buat Village is around 5 km while the distance between the cement plant and Indarung Village is around 2 km. Determination of the number of samples is determined based on Formula (1) so that the number of respondents needed in distributing this questionnaire is 49 households for Bandar Buat Village.

![Windrose](image1.png)  
![Windrose](image2.png)

**Figure 4.** Windrose at cement plant vicinity during: (a) day time; (b) night time
3.2.2. Overview of Respondents. Data on general description of respondents were obtained by collecting data on age and weight. Figure 6 (a) explains that the respondents involved in this study were dominated by people who have ages above 50 years and Figure 6 (b) explains that the respondents involved in this study were dominated by people with body weights ranging from 50-60 kg.

![Figure 5. Lubuk Kilangan district map](image)

3.2.3. Exposure Duration. Exposure duration was obtained by collecting the duration of respondent activities within their residential environment. Respondents were dominated by housewives and household assistants. The duration of exposure was distinguished on a daily and weekly basis. Figure 7 (a) shows that the biggest daily exposure was 10-15 hours (55%) and followed by 15-20 hours of exposure (33%). Most respondents do activities outside their homes during working hours so that the rest of the time they do activities at home. The number of respondents who do activities outside home was 63%. Figure 7 (b) explains that the biggest weekly exposure is 7 days (84%). This is because respondents generally reside in the dwelling area. Meanwhile, Figure 8 shows respondent outdoor activities that shows more of them (63%) do outdoor activities.

![Figure 6. Respondent’s: (a) age; (b) weight](image)
Figure 7. Respondent’s exposure to PM$_{10}$ in researched area: (a) daily; (b) weekly

Figure 8. Outdoor activities

3.2.4. Cigarette Smoke Exposure. The possibility of bias on particulate exposure data due to the air quality due to nearby cement production plant needs to be anticipated by taking information on active and passive smokers in the environment around the respondents. Figure 9 shows that there are 65% of respondents who are active smokers. However, besides being an active smoker, the percentage of respondents who were in the cigarette-smoker’s environment were also sought out and the data showed that 76% of respondents were exposed by cigarette smoke in their environment.

Figure 9. Cigarette-smoking activity: (a) active smokers (b) passive smokers
3.2.5. Dust/Particulate Exposure

Data on respondent’s felt impacts from dust exposure was taken by asking several questions, i.e., how the dust effects on respondent’s health and house of the respondents. Figure 10 shows that as many as 69% of respondents felt the dust found in their environment is annoying, and when further asked about the effect of dust on respondent’s health, the answer was quite varied according to Figure 11 which shows that the biggest health complaints felt by respondents are coughing (84%), short breath (6%), eye irritation (6%), chest pain (2%) and the rest of respondents did not feel any complaints. As for the effects on the condition of the respondent’s houses exposed to the dust is shown in Figure 12, which shows that dust exposure causes the house roofs were covered by thick dust (92%) and the rest of the respondent's only complaints about their floors that are dusty.

![Figure 10. Respondents were disturbed by dust](image1)

![Figure 11. Health complaints](image2)

![Figure 12. Condition of House](image3)

4. Conclusions

During the rainy season, the highest PM$_{10}$ ambient air concentration in the researched area was measured nearby a cement production plant. PM$_{10}$ in the cement plants exceeded WHO air quality standards, but it was still below the air quality standard in Indonesian National Air Quality Standard based on Indonesian Government Regulation No. 41 year 1999. Agricultural activities also affected PM$_{10}$ in studied area, due to the post harvesting activities. The results of PM$_{10}$ roadside measurements conducted by an AQMS operated by the Local Government were not representative because the position of the equipment is not at the downwind area of the nearby road where traffic activities take place. The analysis of affected people nearby the cement plant shows that 98% of respondents felt
health complaints due to dust, but as many as 76% of respondents were in smokers environment so that this condition could also affect the health of the respondents. Further research needs to be done related to public health risk analysis to find out the causes of health complaints. Source apportionment is needed in particulates in the research location to connect it with the source of particulates and their influence on public health around the cement plant.

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