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by Vera Surtia Bachtiar

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Research Article
Mapping of PM_{10} Concentrations and Metal Source Identifications in Air Ambient at Surrounding Area of Padang Cement Factory

Vera Surtia Bachtiar, Yenni Ruslinda, Dharma Wangsa and Ekho Kurniawan

Department of Environmental Engineering, Faculty of Engineering, Andalas University, Kampus Limau Manis, 25163 Unand Padang, Indonesia

Abstract

Objective: This study aims to map the ambient air quality in the region of Semen Padang factory due to presence PM_{10} and metals of Ca, Al, Fe, Si and Na. **Methodology:** Measurements using a low volume sampler and analysis of PM_{10} concentration using a gravimetric method. Analysis of metal concentrations of Ca, Al, Fe, Si and Na by using spectophotometric atomic absorption method. The PM_{10} concentration during the day which ranged from 33.61-118.13 μg N m^{-3}, higher than the night that ranged between 22.48- 43.41 μg N m^{-3}. Concentration of PM_{10} during 24 h on the calculation ranges between 28.05-130.77 μg N m^{-3} and do not exceed the ambient air quality standard that is 150 μg N m^{-3}. **Results:** Metal concentrations of Na and Si is greater than the metals of Ca, Al and Fe both during the day, while at night the metal of Na is greater than the metal of Si, Ca, Fe and Al. Mapping the concentration of PM_{10} and metals Ca, Al, Fe, Si and Na with 10 surfers obtained radial spread of concentration during the day where the dominant direction of the spread is to the East, while at night the dominant towards the West and Northwest. **Conclusion:** The location that has the highest concentration of PM_{10} and metals both day and night there is at Block D Gadut area within ±1.5 km West of Semen Padang factory.

Key words: Mapping, PM_{10}, metal, ambient, Semen Padang factory

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Corresponding Author: Vera Surtia Bachtiar, Department of Environmental Engineering, Faculty of Engineering, Andalas University, Kampus Limau Manis, 25163 Unand Padang, Indonesia

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Air pollution is now show increasingly in very poor condition[1,2]. Sources of air pollution comes from a variety of activities such as industry, transport, offices and housing. The impact of air pollution is a decrease in air quality so that negative impact on human health[3-5]. Semen Padang factory is a cement company in West Sumatra which could potentially contribute to air pollution to the surrounding area. Source of air pollution in the cement industry is derived from mining operations, milling raw materials, combustion, coal mill, cement mill, cement packing and transportation of cement. There are five chemical composition contained in the cement, the limestone (CaO) 60-65%, silica sand (SiO_2) 17-25%, alumina (Al_2O_3) 3-8%, hematite (Fe_2O_3) 0.5-6%, magnesia (MgO) 0.5-4% and soda/potash (Na_2O+K_2O) 0.5-1%.

Air emissions resulting from the processing of raw materials of cement can cause adverse effects, such as respiratory disorders[6]. A study of PM_{10} in cement factory[7] shows that PM_{10} effected accute health in areas with annual concentrations that is lower than 40 μg m^{-3} (EU limit standard). The area around Semen Padang factory is a densely populated area, commercial area and there are several important institutions in Padang. It required intensive research and monitoring related to particulate matter 10 μm especially Particulate Matter (PM_{10}) in ambient air resulting from the activity of the Semen Padang factory in ambient air. This study aims to map the ambient air quality in the region of Semen Padang factory due to presence PM_{10} and metals of Ca, Al, Fe, Si and Na. The results of this study can be used as an evaluation not only for Semen Padang factory but also other stakeholders in an effort to increase awareness of the company and the public on the environment, particularly in the control of air pollution.

MATERIALS AND METHODS

Indonesian National Standard[8] section 6 explains that in the dominant wind direction, ambient air quality monitoring sites a minimum of two locations with emphasis on residential location or specific places, while in others the wind direction at least one point. Based on windrose obtained for the region of Semen Padang factory, on the day the dominant winds moving towards the East and the other half toward the Northeast, South and Southeast. At night the dominant winds moving towards the West. Based on the ISO 19-7119.6-2005, then set at 20 sites representing the region of Semen Padang factory that is Ulu Gadut, Baristand, Atap Genteng, Padayo, Building Water Treatment Semen Padang (BPAM SP), Tambang Karang Putih, SMAN 14 Padang, Tambang Silika, Komplek Igasar, Pondok Bambu, SMK N 8 Cengkeh, Rear PLN Bandar Buat, Bandar Buat, PGSD UNP Gadut, Block B Gadut, Block D Gadut, Kampung Jawa Gadut Limau Manih, Taratak Permai, Baringin Village and Padang Besi.

Month sampling time from January-March, 2013, each sampling point taken one time during the day and once at night with long measurement is 6-12 h at 06:00 to 18:00 pm during the day and at 18:00 to 06:00 pm at night day. Sampling was discontinued if the condition does not allow, which is when it rains. This is because the rainfall occurs during the rinsing process in the air so that the ambient air conditions after rain relatively clean or free from particulate contaminants. Measurements were carried out in this study of PM_{10} and metal concentrations of Ca, Al, Fe, Si and Na contained in PM_{10}.

The PM_{10} sampling is done by means of Low Volume Sampler (LVS). Data retrieval conditions meteorological parameters obtained from the sampling locations using tools that can measure the weather link meteorological parameters such as temperature, relative air humidity, air pressure and wind speed and direction. Analysis of the concentration of particulate matter carried by the gravimetric method.

Metals that measured in this study is Ca, Al, Fe, Si and Na. This 5 metal has a different type of wavelength and absorption ranges. The tools that used in the measurement of the concentration of these metals is Atomic Absorption Spectrophotometer (AAS). The principle of this tool is as energy absorption of radiation by free atoms that excited in the system that stating the metal concentrations. This tool requires the reading of the particulate samples are in liquid form. In this case to dilute particulate that has accumulated on the filter is done by the method of filter destruction. Destruction process is done in a fume hood because of using HNO_3 solution. Calculations that used to obtain the metal concentrations in the ambient air after absorption with SSA measured.

Concentration maps created by using the software Surfer 10. The data that needed is a data sampling point coordinates (x and y) that obtained from the measurement location coordinates by using Global Position System (GPS). While, the value of z is the value of the concentration of particulates in the sampling point (μg N m^{-3}). From the processing of this data will be obtained concentartion maps of PM_{10} in the region of Semen Padang factory and surrounding areas.

RESULTS AND DISCUSSION

Meteorological parameters: Temperature which is obtained in the area of Semen Padang factory and surrounding area ranges 22.46-35.61°C. The highest temperature occur in the day and the lowest temperatures occur in the early evening. The average temperature during the day is 29.49°C and the average temperature at night is 24.24°C. The temperature difference between day and night due to differences in the absorption of sunlight by the earth's surface, therefore in the evening, air temperature is lower due to the absence of sunlight received by the earth[9,10]. Relative humidity ranged between 57.68-100%. In contrast to the air temperature, relative humidity during the day lower than night. The average relative humidity during the day was 70.76 and 87.01% in the evening.

The average air pressure ranged from 616.86-772.96 mmHg. The average air pressure measured during the measurement during the day was 759.19 mmHg and mean at night is 752.09 mmHg. The difference between the air pressure that occur during the day is not far different from the night.

The difference in temperature and air pressure resulting in wind speed and direction in the area of Semen Padang factory is also varied. This is due to the wind will move from places with high air pressure to places with low air pressure. Wind speed ranged from 0.0-1.25 m sec^{-1}. The average wind speed during the day is 0.66 m sec^{-1}, while at night is 0.30 m sec^{-1}. The dominant wind direction during the day is from the West, Southwest and Northwest, while at night the dominant wind blows from the East and Southeast. Topography sampling sites located in the foothills allow for deflection of the wind when the wind blows against the hills. But in general the sampling locations are still influenced by the cycle of onshore wind and sea breeze due to Padang is located on the seashore.

Analysis and mapping of PM_{10} concentration: The PM_{10} concentration during the day ranged from 32.64 μg N m^{-3} up to 118.13 μg N m^{-3}, while the concentration of PM_{10} at night ranged from 22.48 μg N m^{-3} up to 143.41 μg N m^{-3}. Locations that have the highest PM_{10} concentrations at day and night is Block D Gadut. The location that has the lowest PM_{10} concentration during the day is Komplek Igasar, Tambang Karang Putih and Baringin village, while evenings in a row is komplek Igasar, Padayo (Lubuk Paraku) and Tambang Karang Putih. Average of PM_{10} concentration at day and night is 69.80 and 68.59 μg N m^{-3}. Comparison of PM_{10} concentration in the day and night in the area of Semen Padang factory can be seen in Fig. 1. About 24 h PM_{10} concentration obtained

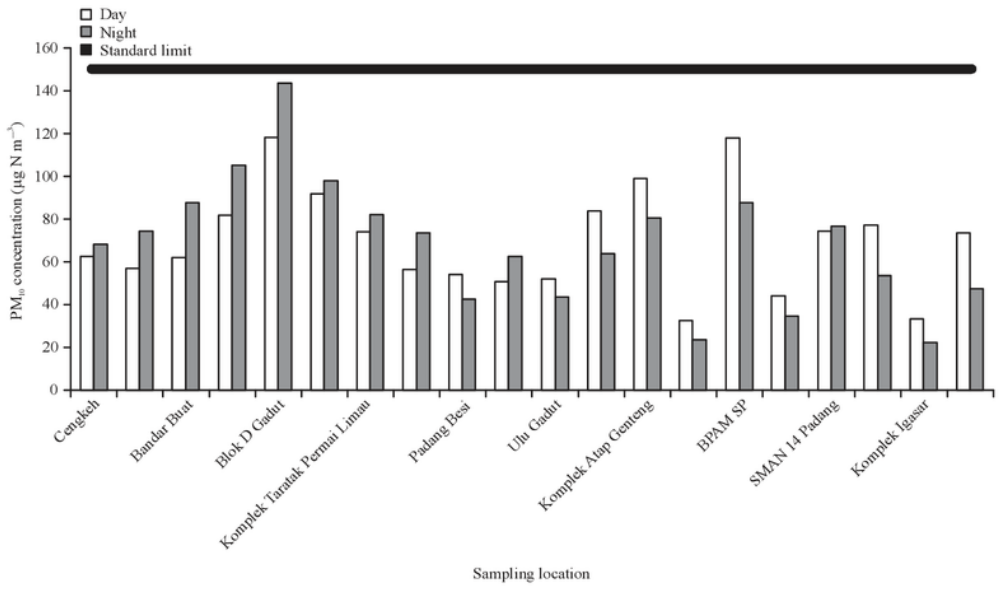

Fig. 1: PM_{10} concentration at sampling locations at day and night and ambient air quality standards

from the approach of the calculation that is to average values of PM_{10} concentration at day and night. Based on these calculations obtained a 24 h PM_{10} concentration value is 28.05 μg N m^{-3} up to 130.77 μg N m^{-3}. About 24 h PM_{10} concentration average is 69.17 μg N m^{-3}. Ambient air quality standard set out in the Government Regulation[11] No. 41 of 1999 on air pollution control, set the value of the maximum levels of PM_{10} concentration is 150 μg N m^{-3}. This means the air quality parameters of PM_{10} in ambient air Semen Padang factory area is still quite good.

PM_{10} concentration mapping and identifications: The PM_{10} concentration mapping aims to facilitate informed the spread of particulate pattern. Mapping that form isoconcentration image will show the level of PM_{10} in ambient air concentrations of Semen Padang factory region. Mapping will also facilitate the identification of ambient areas that exposed by an industry particularly particulate emissions[12]. Mapping the concentration is displayed with a color variation of a certain concentration range. In addition, the particulate concentration contour lines will bring up the value of a certain concentration. The spread of PM_{10} concentration in ambient air generally radial which is generally the highest PM_{10} concentrations are marked with red color while the lowest PM_{10} concentration is marked with purple.

Based on the mapping image of PM_{10} concentration in the region of Semen Padang factory both at day, night and in the span of 24 h (day-night) concentrated on the location of Block D Gadut. This location is right next to the Western Semen Padang factory with a distance of ±1.5 km. In the daytime PM_{10} concentration range from 30-120 μg N m^{-3}, in the evening hours of the range of concentrations ranging from 20-145 μg N m^{-3} and 24 h concentration range is 25-135 μg N m^{-3}. For detail, mapping of PM_{10} concentration in the day, night and during 24 h are shown in Fig. 2-4.

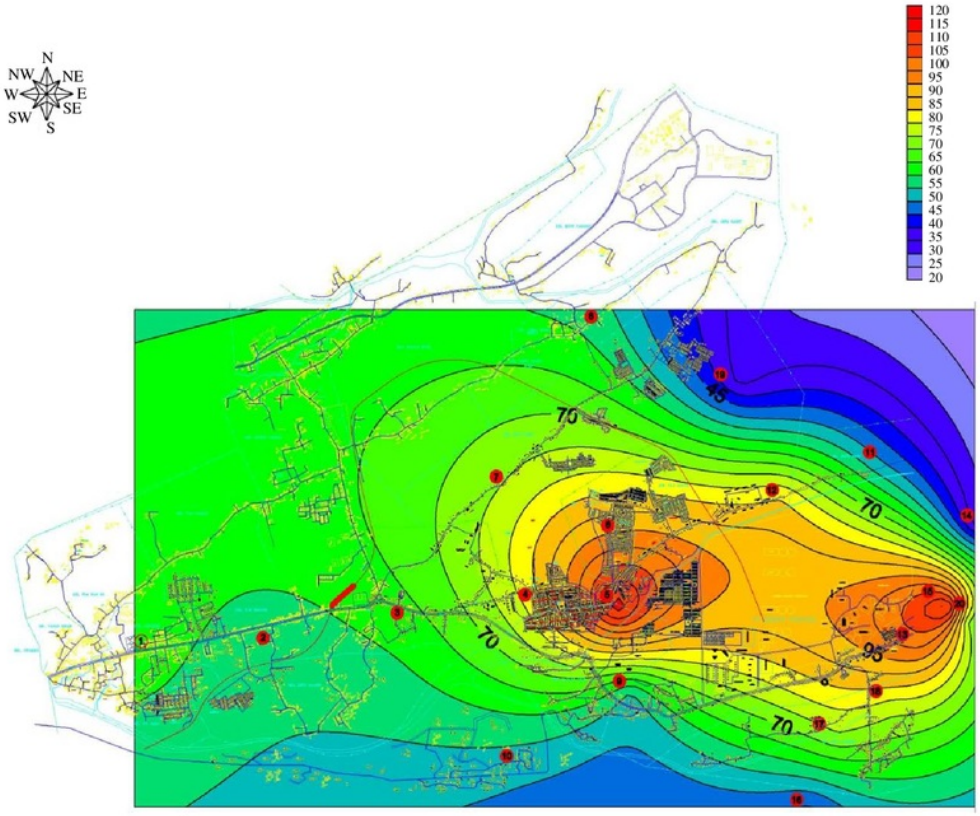

Fig. 2: Mapping the PM_{10} concentration at the day

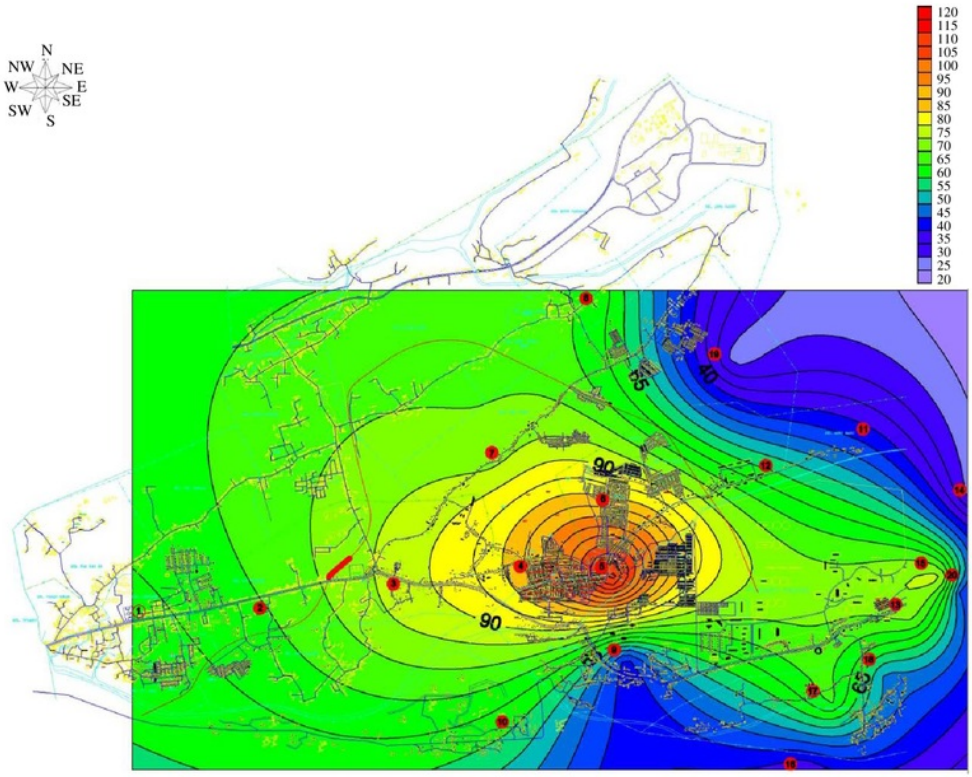

Fig. 3: Mapping the PM_{10} concentration at the night

Concentrations of PM_{10} which is attached to the air comes from various sources. These sources are generally derived from mechanical activity (destruction/grinding and abrasion ground level), evaporation and the suspension of dust. The PM_{10} can last a few minutes to a few hours in the air. Besides PM_{10} can be brought from a distance of[13] <1-10 km. The concentration and distribution of PM_{10} is also influenced by the physical and chemical conditions of the atmosphere at the time of sampling[14,15]. The concentration of PM_{10} is formed by anthropogenic activities, road dust due to transportation and construction activities, farmland, natural dust and the burning of land[16]. The presence of cement factory, mines, farms, vacant lots and roads in the area of Semen Padang factory is possible formation of PM_{10} concentrations[15]. One source who was instrumental in the formation of PM_{10} concentrations at the sampling location is the activity of production and factory stack emissions of Semen Padang factory. Based on the results of monitoring in the field, there is a change in the color of vegetation and roof of the building that grayish at ±1.5 km radius, especially leading up to the West and the East of the Semen Padang factory. This condition is different from the situation in the background is Komplek Igasar area, where there is relatively no change in the color of vegetation and roofs of houses around the site.

The PM_{10} concentration that obtained during the day is greater than the night for the East region of Semen Padang factory. It is due at noon dominant wind blows from the West, Southwest and Northwest that carries particulate matter from Semen Padang factory and other sources to the dominant direction of the East and Southeast. The concentration of PM_{10} night higher than day time contained in the Western region of Semen Padang factory as the dominant wind from the East Semen Padang factory.

Metal concentrations analysis of Ca, Al, Fe, Si and Na in PM_{10}: The results of the analysis of metals in PM_{10} concentrations obtained each metal concentrations vary between day, night and each sampling location. The

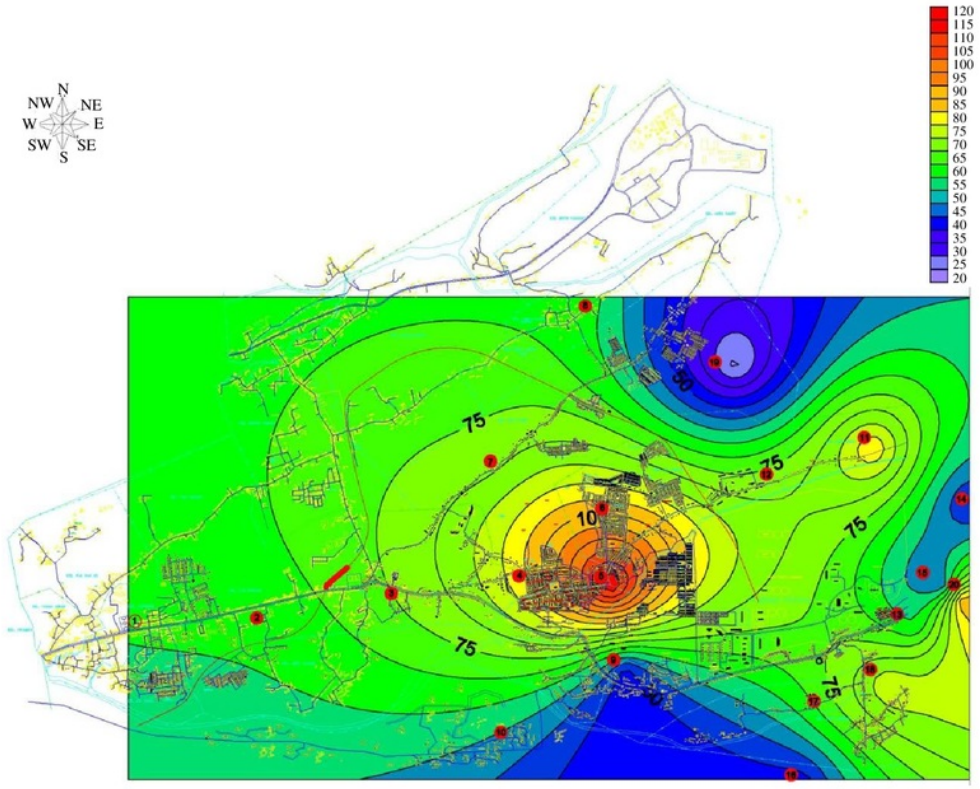

Fig. 4: Mapping the PM_{10} concentration at 24 h

difference in the concentration of each metal in all sampling sites thought to result from other sources in each sampling location other than the dominant source comes from factory stack cement industry in Semen Padang factory.

Metal concentrations in the day and night in PM_{10} in the area of Semen Padang factory is dominated by Na metal. The Na metal concentrations are generally higher due Semen Padang factory stack are using raw materials containing Na clay in the form of Na_2O in addition to the supply of raw materials clay originating from Kuranji sub district are transported by using a truck to Semen Padang factory will add high Na metal in ambient air. Comparison of the concentration of each metal in the day and night can be seen in Fig. 5 and 6, while the average composition of the metal concentrations of Ca, Al, Fe, Si and Na and other components in PM_{10} can be seen in Fig. 7 and 8.

Cement production that using raw materials limestone as much as ±81%, silica sand as much as ±9%, ±9% clay and iron sand ±1% will result in air emissions of metals Ca, Al, Fe, Si and Na. Average concentration of metals Ca, Al, Fe, Si and Na in the day in a row are 2.25, 1.69, 1.26, 3.40 and 4.36 μg N m^{-3}. Average concentration of metals Ca, Al, Fe, Si and Na at night in a row is 2.77, 1.29, 1.21, 2.79 and 4.02 μg N m^{-3}. The order of the concentration of this 5 metals from highest of the day is Na, Si, Ca, Al and Fe, while the order of the concentration of this 5 metal from highest of the night is Na, Si, Ca, Al and Fe.

Identification of metal source of Ca, Al, Fe, Si and Na: Metal Ca derived from the activities of Semen Padang factory emissions that uses the raw materials limestone, clay and iron sand containing metallic Ca in the form of CaO. Addition of Semen Padang, a source of limestone, at the Mount Karang Putih within about 2 miles of Semen Padang and clay taken from the Kuranji Padang sub-district is possible to add the metal concentrations in ambient air Ca Semen Padang region and surrounding areas since displacement due to the movement of the wind. Metal Al

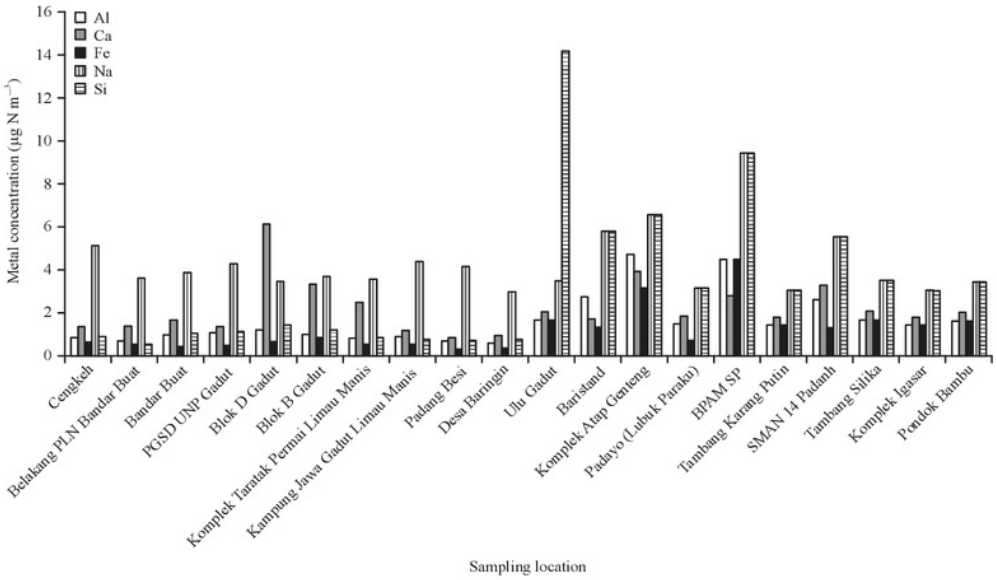

Fig. 5: Comparison chart of metal concentrations of Ca, Al, Fe, Si and Na during the day in PM_{10} at sampling location

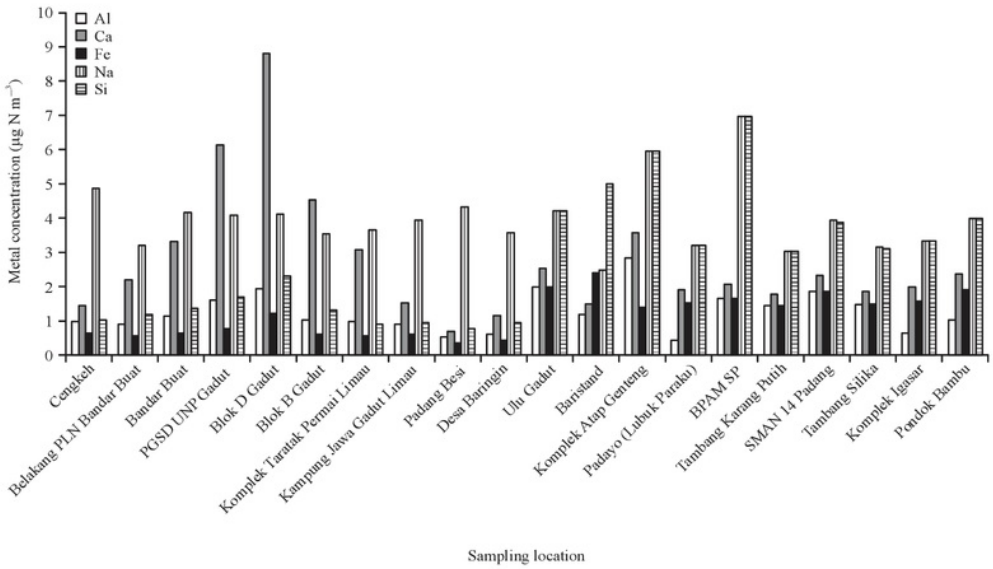

Fig. 6: Comparison chart of metal concentrations of Ca, Al, Fe, Si and Na during the night in PM_{10} at sampling location

derived from stack emissions of Semen Padang as Semen Padang using clay, sand and limestone iron-containing metal Al in the form of Al_2O_3. Clay taken from the district Kuranji Padang using mobilization, resulting in increased levels of dust in the ambient air. Iron sand or iron metal comes from the emission of Semen Padang for using clay in the form of Fe_2O_3+FeO and also contained in the iron ore in the form of Fe. Metal Si comes from the emission of Semen Padang from using clay, iron sand and limestone and silica containing metal Si in the form of SiO_2. Na metal derived from Semen Padang emissions because it uses raw materials clay in the form of Na_2O.

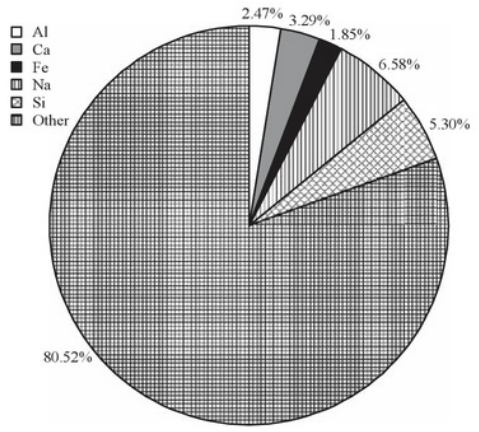

Fig. 7: Composition of average concentration of metals Ca, Al, Fe, Si and Na and other components at Semen Padang factory zone area during the day

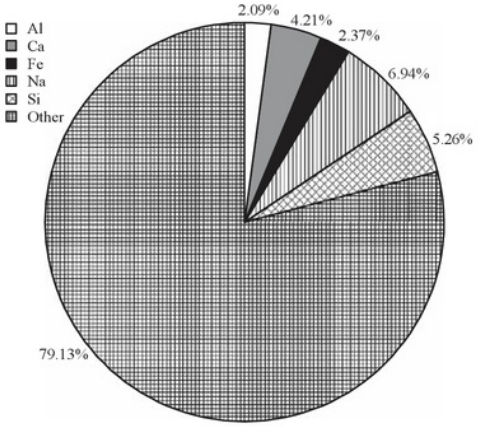

Fig. 8: Composition of the average concentration of metals Ca, Al, Fe, Si and Na and other components at Semen Padang area and surrounding areas at night

CONCLUSION

The concentration of PM_{10} during the day is higher for the East region of Semen Padang and during the night is higher for the Western region of Semen Padang. About 24 h PM_{10} concentrations obtained from calculations ranged from 28.05-130.77 μg N m^{-3}. About 24 h PM_{10} concentration does not pass through the ambient air quality standard PP 41, 1999 which has been set at 150 μg N m^{-3}. Metal concentrations were measured starting from the highest to smallest at the day is natrium (Na), silica (Si), calcium (Ca), aluminum (Al) and iron (Fe), whereas in the night of the highest metal concentration to smallest is natrium (Na), silica (Si), calcium (Ca), aluminum (Al) and iron (Fe). The spread of PM_{10} concentration and metals of Al, Ca, Fe, Na and Si generally radial direction during the day where the dominant deployment to the East, while at night the dominant towards the West and Northwest of Semen Padang. The location with the highest concentration of PM_{10} in the day and night is Block D Gadut within ±1.5 km West of Semen Padang. From the identification of sources of PM_{10} and metals of Ca, Al, Fe, Si and Na showed that several locations in the area of Semen Padang factory could potentially be affected by emissions from Semen Padang factory, in addition to other sources around the sampling location.

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