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Mapping of ozone gas (O_3) concentrations in Padang city

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Abstract

This study aims to analyze and map the concentration of ozone gas in ambient air in Padang City. The study was conducted by taking samples of ozone gas at 52 points in Padang City for one hour of measurement. Ozone concentration was analyzed by NBKI method using a spectrophotometer. From the results obtained, the concentration of ozone gas at Padang City varied between 6.32 and 87.06 μg/Nm^3 at an average concentration of 25.67 μg/Nm^3. This condition is still below the quality standards set by Goverment Regulation of Indonesian Republic Number 41-1999 amounted to 235 μg/Nm^3. Factors affecting the amount of ozone gas concentration are transportation factors and meteorological factors. The most influential Meteorological factor is the air temperature. Mapping the concentration of ozone gas in Padang City by using Surfer 10 illustrates that an area with the highest ozone gas concentration range is in the North, Northwest and Southern area of Padang City. The highest ozone gas concentration range of 65-90 μg/Nm^3 is in the southern which is in Kecamatan Lubuk Begalung and the lowest ozone gas concentration was located in the East and Northeast which is in Kecamatan Lubuk Kilangan and Kecamatan Pauh with a concentration range of 5-20 μg/Nm^3.

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Keywords: Mapping of Gas Ozone Concentration; Ambient Air; Padang City

1. Introduction

Padang City is the capital of West Sumatra Province which is not free from air pollution. Physical development of the city, the establishment of industrial centers along with the increasing use of motor vehicles resulted in the

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increase of air pollution source, which became a cause of ozone pollution in the city of Padang. Measurements of ozone gas in Padang City was made by [1] in Pasar Raya which indicates that the average concentration of ozone gas in Padang City in the afternoon (76.6μg/Nm^3) is higher than in the morning (44.3 μg/Nm^3), the average concentration dropped from noon to afternoon (68.1 μg/Nm^3) and rised from afternoon to evening (68.8 μg/Nm^3). In the study of ozone gas, measurement was only taken in one area, so does not represent the actual concentration of ozone gas in the area of Padang.

Mapping the distribution of ozone gas concentration at Padang City based on geostatistical analysis by [2] showed that the highest concentrations of ozone gas were found in the North, West, South of Padang City, where the concentration were greater than 10.5 ppb (parts per billion). The concentration of ozone gas were lower on the East with a concentration range between 8 and 10.5 ppb, but the highest concentration of ozone gas were still far below the standards set by Goverment Regulation of Indonesian Republic Number 41-1999. Measurement of the ozone gas concentration in mapping the surface ozone gas at Padang City was done by using a regression equation between the concentration of ozone gas and air temperatures, which theoretically demonstrated a high correlation figures.

Determining the level of photochemical oxidants (ozone gas dominant) is influenced by the presence of NO_2 (nitrogen dioxide), VOCs (Volatile Organic Compounds), light intensity, temperature, wind speed and high inversion contained in the air [3]. According to [4], the effects of fluctuations in meteorological factors, namely; solar radiation, air temperature, and wind speed to fluctuations in the concentration of ozone gas in the air are quite large. The existence of many factors that affect the concentration of ozone gas in the air showed that the concentration of ozone gas at Padang City in particular can not only be measured from the value of the regression between ozone concentration and air temperature, so in this study measurements of ozone gas concentration were taken directly in ambient air at Padang City. The results of measurements of the ozone concentration is then mapped to the administrative area of the city of Padang.

2. Literature review

Ozone gas (O_3) is a pale blue gas composed of three oxygen molecules. First discovered by Christian Friedrich Schoenbein in 1840, this compound is derived from the word "ozein" (Greek) meaning smell, because the strange scent inflicted on lightning storm. The molecular formula of ozone, O_3, was given by Jacques-Louis Soret and later confirmed by Schoenbein in 1867 [5]. The formation of ozone gas depends on the amount of natural and anthropogenic factors. High concentration of ozone gas, is not only limited to the urban environment, but can also have an impact towards a relatively clean area in a remote area. Atmospheric conditions and the effect of exchange-tropospheric ozone stratosphere are several factors that affect the rate of ozone gas concentration in an area [6].

A study on variations of surface ozone concentration at three different areas in Delhi, India was conducted by [7]. This study aimed to compare the variation of concentrations in three areas, where each area differs in vegetation and traffic levels. This study also conducted the monitoring of meteorological conditions. The results of this study showed that the highest ozone concentrations are mainly located in highly populated areas with dense vegetation and traffic with the influence of meteorological conditions was almost the same in every area. Therefore it can be concluded that the place which is very dense with vegetation and has an impact emissions from transport showed high levels of ozone concentrations compared to areas with vegetation and transportation that are not so dense.

Khiem et al [8] conducted an analysis of the relationship between the changes that occur in meteorological condition and the variation of ozone concentration levels in the summer at the central area of Kanto, Japan. The analysis was done by modeling meteorological (The Mesoscale Model) and air quality modeling (Community Multiscale Air Quality Model) with 21 years (1985-2005) of ozone concentration data to see the long-term variation of ozone gas concentration and the data on the Moon in August 2005 to see Short-term variations in the concentration of ozone gas. The results of this study indicate that there is a fairly strong correlation between changes in meteorological conditions and variations of ozone concentration in the central area of Kanto, Japan.

Ozone has an important role in several processes in the environment that also affect the climate system. First by absorbing harmful ultraviolet radiation, ozone protects life on Earth from harmful effects. Second, as a strong oxidizing agent, along with water vapor, as a precursor of OH radicals, ozone has a very important effect on the strength of atmospheric oxidation and also determines the speed of decomposition of many natural and anthropogenic chemicals in the atmosphere. Human activities that encourage the reduction of atmospheric forces can indirectly affect the climate of greenhouse gases such as methane are described by OH will easily accumulate in the atmosphere [9].

3. Research methods

This study consists of a preliminary study, sampling gases and ozone in ambient air laboratory analysis. Preliminary studies conducted at three points in Padang city. Padang city as the capital of West Sumatra province lies in the lowlands at The West Coast of Sumatera Island, which is at 00°44'00" S up to 1°08'35" S in latitude coordinate and 100°05'05" E up to 0°34'09" E in longitude coordinate with 84 km beach long. Administrative area under Government Regulation of Indonesian Republic 17-1990 is 694.96 km^2, which is composed of 11 districts and 193 villages. Ozone gas sampling is taken at 52 sampling points at Padang City in July, September, and October 2013. Laboratory analysis of samples of ozone gas is done at the Air Quality Laboratory of Environmental Engineering Department, Andalas University.

3.1. Determination of sampling points and time sampling

Determination of sampling points is done by dividing Padang City area into sub areas in the form of a grid sampling. This grid is made in the range area of 2 km × 2 km. Determination of sampling time is determined based on a preliminary study to determine the daily variation of the concentration of ozone gas. Preliminary sampling is done with gas sampling measurements of ozone for 1 hour for 12 consecutive hours from 10:00 to 22:00 as well as variations in measurements 14 hours in a row at 6:00 to 20:00. Preliminary sampling conducted at three sampling points in the city of Padang. The results of preliminary studies showed that the pattern of variation in the concentration of ozone gas is almost always the same day in which the concentration of ozone gas is quite high and stable at 10:00 to 18:00 (see Fig. 1 and Fig. 2). The results of this preliminary study can be used to determine the concentration of ozone gas sampling time for the city of Padang, where the time to be used for sampling is from 10:00 to 18:00.

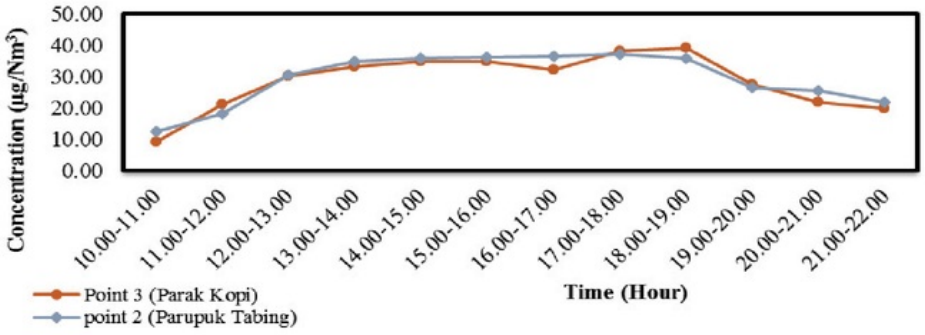

Fig. 1. Graph Daily Variation Gas Concentration Ozone at two sampling points in Padang

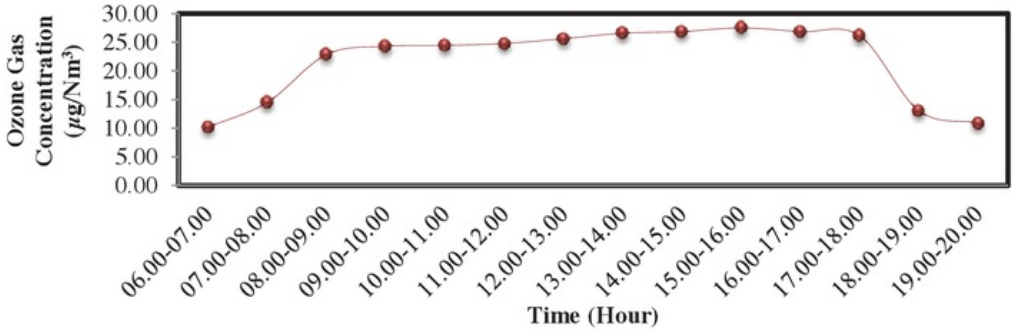

Fig. 2 Variation Daily Graphic Gas Concentration Ozone
at point 1 Measurement For 14 Hours

3.2. Gas concentration ozone

The ozone gas concentration measurement includes two stages. The first stage is the stage of sampling or sampling by using impinger for one hour measurement. The second stage is the measurement of samples in the laboratory. These measurements were performed using the method of NBKI (Neutral Buffer Potassium Iodide) with a spectrophotometer. Measurement of the ozone gas concentration which consists of sampling for one hour measurement and analysis of samples in the laboratory to produce data measured by a spectrophotometer absorbance. The ozone gas concentration data will then be compared with the Ambient Air Quality Standards. Quality standard used is Government Regulation of Indonesian Republic 41-1999 (235 μg/Nm^3). Wilcoxon Test is done to see the effect of transportation and meteorological factors has on the concentration of ozone gas. The Wilcoxon test will be performed using SPSS software. Processing Map of Padang which has been equipped with a sampling point and ozone gas concentration data at each sampling point will be processed using the Software Surfer 10.

4. Results and analysis

3.3. Analysis of ozone gas concentration in Padang city

The concentration of ozone gas at 52 sampling points in Padang City can be seen in Fig. 3. The concentration of ozone gas measured ranged from 6.32 to 87.06 μg/Nm^3. The highest concentration of ozone gas at Padang City is in the 52 sampling points are located in Point 52 at Teluk Bayur area. Ozone gas concentration measured at that point is equal to 87.06 μg/Nm^3. The lowest ozone gas concentrations measured at Padang City is equal to 6.32 μg/Nm^3 at 48 sampling points located in Bukit Gado-Gado. The average concentrations of measurement is 25,67 μg/Nm^3. The highest concentration of ozone gas was measured at 87.06 μg/Nm^3, where the concentration is still below the quality standard. It shows that the concentration of ozone in the area of Padang is in the range that does not harm the air.

Referring to research [1] who shows measurements of ozone gas at Pasar Raya Padang, a score of ozone gas concentration higher than the concentrations measured at the sampling point near Pasar Raya, in this study, namely point 43 are located in Berok Nipah. The concentration of ozone gas at point 43 of 29.44 μg/Nm^3, whereas the average concentration of ozone gas lows measured by [1] on the morning of 44.1 μg/Nm^3. The difference in the measured concentrations of ozone gas at Padang City on this study and previous studies are due to differences in sampling site conditions. Berok Nipah area whose location is about 1.5 miles from Pasar Raya, an area with quite different conditions with Pasar Raya Padang. Pasar Raya is a trading center at Padang City with high human activity and high transportation every day. The difference in these conditions will affect the factors that affect the ozone concentration causing concentration difference obtained at these two locations.

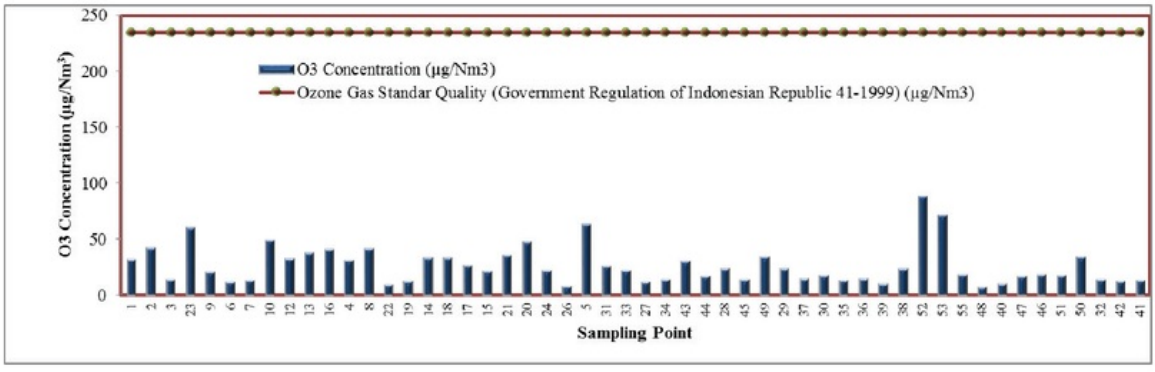

Fig. 3. Ozone Gas Concentration at Padang City against Ozone Gas Quality Standard

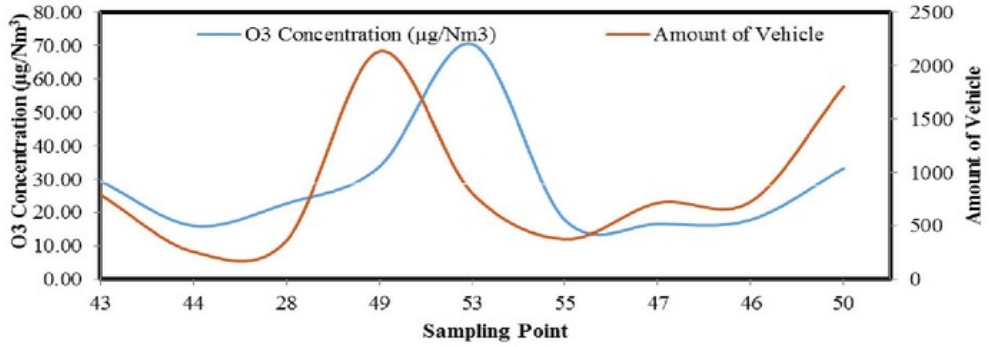

Fig. 4. Effect of Transportation Factor against Ozone Gas Concentration

3.4. Effect of transportation factor against ozone gas concentration in Padang city

Transportation is one of the influence on ozone concentrations. Effect of transportation on the concentration of ozone gas can be seen from the influence of the number of vehicles on the measured concentration of ozone gas. For more details about the effect of transport on the concentration of ozone gas, can be seen in Fig. 4. In Fig. 4 described a similar pattern between the transport and concentration of ozone gas. The increase in the number of vehicles affects the increase in the concentration of ozone gas. The greater the number of vehicles, the greater the value of the concentration of ozone. The influence of the number of vehicles on the concentration of ozone gas seen also through statistical test by Wilcoxon test. The Wilcoxon test showed that the Z value of -2.803 is outside the reception area. The Wilcoxon test showed that the number of motor vehicles significantly affect the concentration of ozone gas. This is consistent with the literature by [7] which states that the place that has the effect of emissions from transport showed levels higher ozone concentrations.

3.5. Effect of meteorological factors (air temperature, wind speed, and solar radiation) against ozone gas concentration in Padang city

This study also examined the influence of meteorological factors on the concentration of ozone gas. The Wilcoxon test resulted in significant value p-value of 0.001 for the temperature factor, the value of significance p-value of 0.00 for the wind factor, and the value of significance p-value of 0.00 for the factor of solar radiation. Thirdly the value of significance of these three meteorological factors showed a smaller value than the value of the 0.05 significance level. The Wilcoxon test also produces Z value of -3.256 for the temperature factor, Z value of -4.623 for the wind factor, and the Z value of -4.623 for solar radiation factor. Third Z value is outside the reception area H_0. This suggests that the three meteorological factors, namely air temperature, wind and solar radiation have a significant influence on the value of the concentration of ozone. This is consistent with the theory that there is a fairly strong correlation between changes in meteorological conditions and variations in ozone concentration.

In statistical tests to see the influence of meteorology on ozone gas concentration through the Wilcoxon test showed that the meteorological factors influence on the concentration of ozone gas is air temperature, wind speed, and solar radiation. Of these factors can be seen meteorological factors has the most influence on the concentration of ozone gas with a statistical test such as logistic regression. Through logistic regression test on all three factors meteorology and ozone gas concentration in this study, obtained regression coefficient is 1.520 for air temperature, wind speed regression coefficient is -0.298, and the regression coefficient of solar radiation is -0.122, while the constanta is -1.238. It is obtained that the three meteorological factors are in logistic regression, which the temperature has the highest regression coefficient. This indicates that the temperature of meteorological factors is the factor that has the most influence on the concentration of ozone gas in this study compared with two other meteorological factors namely wind speed and solar radiation.

3.6. Mapping of ozone gas concentration in Padang city

Mapping the concentration of ozone gas in Padang City was made based on measurements at 52 sampling points spread across the city of Padang. Figure 5 shows a map of the concentration of ozone gas in the city of Padang. The concentration map is divided into several levels of concentration. The concentration levels is distinguished using different colors starting from a concentration range of 5-10 µg/Nm3 (the blue color). The concentration levels change every increase in the concentration of 5 µg/Nm^3. Highest level of concentration in Fig. 5 is a concentration range of 85-90 µg/Nm^3 are indicated by the red color.

Deployment area of ozone concentration in Padang city as shown in Fig. 5 decreases when going from the Southwestern East to the South Area of Padang City. The area with the highest concentration range for the city of Padang is in Kecamatan Lubuk Begalung, where the ozone concentration range of 65-90 µg/Nm^3 are on the Southwestern city of Padang. Lowest concentration range at Padang City is at Kecamatan Lubuk Kilangan and Kecamatan Pauh located on the East and Northeast Padang with ozone gas concentration range of 5-20 µg/Nm^3.

Ozone surface mapping of Padang City by [1] which showed that the highest concentrations of ozone gas distribution found in the North, West, South and Padang where the measured concentration greater than 10.5 ppb (equivalent to 20 µg/Nm^3), while the Eastern area of Padang showed a lower concentration distribution of 8 ppb (equivalent to 15 µg/Nm^3) to 10.5 (equivalent to 20 µg/Nm^3). When compared with the research conducted on ozone mapping in Padang City, the resulting concentration ranges almost exactly the same in the East area in Kecamatan Lubuk Kilangan the concentration range of 5-20 µg/Nm^3. The concentration range is also similar to the North, Northwest, South area of Padang City where ozone gas concentration range in this study showed a greater concentration range of 20 g / Nm^3. In general, the resulting distribution pattern is similar to the pattern of spread of ozone gas concentration by [1], which is high in coastal areas located in the North, Northwest, South area of Padang City, and low in the mountainous area such as the East and the East area of Padang City.

5. Conclusion and recommendation

Measurements of the ozone concentration at Padang City shows the number of ozone gas concentrations ranging from 6.32 to 87.06 µg/Nm^3. The average concentration of ozone gas at Padang City is at 25.67 µg/Nm^3, while the highest concentrations of ozone gas is equal to 87.06 µg/Nm^3 and the lowest concentration of ozone gas is 6.32 µg/Nm^3. Based on the ambient air quality standards according to Government Regulation of Indonesian Republic 41-1999, the concentration of ozone at Padang City on the whole remained below quality standards established.

Effect of transportation on the concentration of ozone gas indicate that the transport factors significantly influence the concentration of ozone gas. Effect of meteorological (air temperature, wind speed, and solar radiation) against the concentration of ozone shows that the three meteorological factors significantly influence the ozone concentration. Mapping the concentration of ozone gas, illustrates that the ozone gas concentration decreased from the North, Northwest, South and to the East and Northeast Padang.

A further research is needed on secondary pollutant that are obtained from raw materials used in the process of cement manufacturing. On top of that, a roadside study is needed to be performed considering pollution that is caused by transporting raw material and cement distribution.

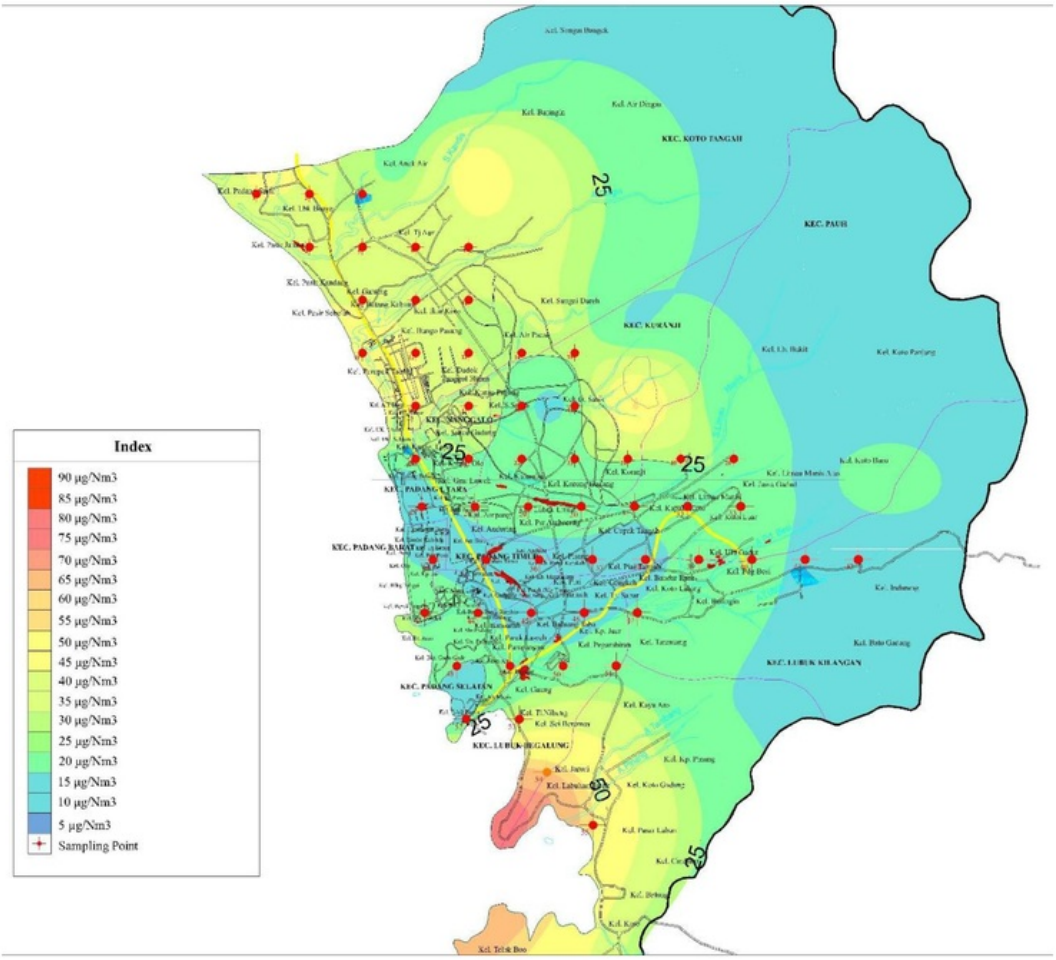

Fig. 5. Map of Gas Concentration Ozone in Padang

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