MAPPING ANALYSIS OF AIR QUALITY INDEX FROM PM_{10} CONCENTRATION IN MEDAN CITY BASED ON GEOGRAPHIC INFORMATION SYSTEM

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ABSTRACT

Particulate matter size 10 μm (PM_{10}) is one of the pollutants that has an impact on human health and the environment. Data on the presence of PM_{10} in ambient air is essential in order to prevent such impacts. Mapping of PM_{10} concentrations from various emission sources in urban areas will provide basic information in the determination of policies, programs and regulations related to air pollution control. This study aims to map and analyze the air quality index of PM_{10} in ambient air of Medan City. This research was conducted by taking PM_{10} samples at 12 (twelve) points in Medan City. PM_{10} concentration was measured using Laser Dust Monitor Model LD 1. The results showed that the concentration of PM_{10} in Medan City varied between 24 μg / m^3 - 224 μg / m^3 for sampling time of 1 (one) hour and 16 μg / m^3 – 126 μg / m^3 for 24 hour duration sampling. The PM_{10} concentration of the measured results was converted to a air qulaity ndex obtained an index value of 23 (good) - 155 (unhealthy). The mapping of the standard air pollutant index for PM_{10} using Surfer 10 and Geographic Information System describes the unhealthy category areas located in Medan Belawan Sub District. The main factors that influence the concentration of PM_{10} are the sources of emissions in the form of transportation and industry as well as meteorological factors.

Keywords: Air quality index, geographic information system, mapping, PM_{10}.

INTRODUCTION

The decrease in ambient air quality in an urban area is influenced by several factors such as emission sources, meteorological fator and receptor conditions. One source of emissions in urban areas comes from motor vehicle emissions. Increasing the number of motor vehicles will reduce the quality of ambient air that affects human health problems.

One of the pollutant parameters that affect human respiratory distress is PM_{10}. PM_{10} becomes one of the causes of pneumonia or asthma in children and cardiovascular disorders in the elderly [1]. Research results in the United States show that high PM_{10} concentrations in ambient air have a large and negative impact on adults [2]. In addition, particulate diameter affects the respiratory tract function. The smaller the particulate diameter the greater the risk received by the receptors [1, 3, 4,5].

Particulate material is dispersed in the air, both solid and liquid, of which the grain size is larger than the molecular size (0.002 μm) and smaller than 500 μm [6]. Particles of less than 2.5 μm are commonly called fine particles while particles larger than 2.5 μm are called coarse particles. In general the difference between these two types of particles lies in the origin of the formation, transformation, the process of elimination mechanism, chemical composition, and optical properties [7].

The condition of ambient air quality in Medan City also decreased due to increased vehicle mobilization and directly proportional to the increase of population. The impact of increasing the number of vehicles in the city of Medan affect mainly on public health. When viewed based on the data of 10 most diseases suffered by residents of Medan City the last five years is respiratory infection (Acute Respiratory Infection). The number of ARI patients in 2014 was 221635 persons or ± 10% of the total population of Medan City [8].

This study aims to determine the quality of ambient air of Medan City by mapping the concentration and index of air quality ambient Medan City. This map of ambient air quality index of Medan City can be used as the basis for consideration for the government in planning the control and management of urban air. The scope of this study is 12 (twelve) sampling points representing transportation, industrial, trade, urban and residential sources. The parameters studied in this research are 10 μm particulate matter (PM_{10}). Selection of PM_{10} parameters due to its chemical and physical characteristics. PM_{10} consists of primary PM_{10} and PM_{10} secondary formed from nitrogen oxide (NOx) and sulfur oxide (SOx) [1].

Medan has 4 (four) air pollution monitoring station, unfortunately all of the stations have been inactive since 2012. The previous study [9, 10, 11] explained that modeling the spatial distribution of pollutants could help to estimate the concentration of pollutants in an area that does not have an air pollution monitoring station. Additionally, it can determine the areas that exceed air pollution standards. Furthermore, modeling the spatial distribution of pollutants can be used for assessment of exposure and epidemiological studies.

METHODOLOGY

Determination of the number of sampling points using a curve approximation [12]. The population of the city of Medan is 2.210.624 people [8] with a lower limit concentration which means that the concentration of ambient air pollutant parameters such as SO_2, NO_2 in Medan City is still below ambient air quality standard [13]. Based on the relationship between population and the level of pollution is seen on approximating curves obtained amount of ambient air quality monitoring points which are representative of 12 (twelve) the sampling point.

Sampling of PM_{10} using Laser Dust monitors by laser light sensor method from photodiodes. The sampling was conducted at 12 (twelve) sampling points, recording the coordinates and counting the type and number of vehicles by using

counter meter. The sampling result is the concentration of each point plotted to the Surfer 10 to obtain a map of the dispersion PM_{10} concentration in Medan City.

PM_{10} concentration in the ambient air in μg / m^3 was converted to the Air quality index value that refers to Decree of the Head of the Environmental Impact Management Agency Number: Kep- 107/Kabapedal/11/1997 about Technical Guidelines Calculation and Reporting Information as well as the Air Pollution Standards Index (API). The equation to calculate the Air Pollution Index (I) is given by:

$$I = \frac{Ia-Ib}{Xa-Xb}(Xx - Xb) + Ib \quad (1)$$

Where *Ia* and *Ib* are Air pollution index upper limit and A pollution index lower limit, respectively. The parameter *Xa, Xb, Xx* represent Ambient upper limit, Ambient lower limit, and Concentration of measured gas, respectively. Air quality index value obtained from the calculation determined according to its category, as shown in Table 1.

Table 1. Numbers and air pollutant index categories

No.	Index	Category
1	1 – 50	Good
2	51 – 100	Moderate
3	101 – 199	Unhealthy
4	200 – 300	Very unhealthy
5	300 – more	Dangerous

Source: [14]

Calculation results of air quality index are plotted to Surfer 10 and over lay with administration map of Medan city to produce a map of the air quality index for each region in the city. The map of ambient air quality index can be used to determine critical areas related to ambient air quality. In addition, it should also be seen what factors contribute to the high concentrations of ambient air at every point. It is necessary to test the correlation between the number of emission sources with ambient air concentrations as well as the influence of meteorological factors such as temperature and humidity of the ambient air concentrations by using a correlation equation as equation 2.

$$R = \frac{n\cdot\sum xy-(\sum x)\cdot(\sum y)}{\sqrt{(n\cdot\sum x^2-(\sum x)^2(n\cdot\sum y^2-(\sum y)^2))}} \quad (2)$$

where *R, X,* and *Y* are correlation, dependent variable, and independent variable, respectively. If the R value approaching +1 or equal to +1, it means strong positive correlation. If the R value close to -1 or equal to -1, it expresses strong negative correlation and when R = 0 means no correlation.

RESULTS AND DISCUSSION

The results will be discussed in 4 subsections, comparing concentration of PM_{10} to national ambient air quality standard, map of distribution PM_{10} concentration in ambient air, map of PM_{10} air pollution index in Medan city and factors affecting the concentration of PM_{10} in the ambient air.

Comparison Concentration of PM_{10} to Air Quality Standards (Government Regulation No.41 Year 1999 and WHO Standard)

The ambient PM_{10} concentration was taken at 12 (twelve) sampling points. The standard of ambient air quality as a reference in this study is the national air quality standard namely Government Regulation No. 41 of 1999 with the standard quality for PM_{10} concentration is 150 μg/m^3. The results showed that the concentration of PM_{10} in Medan City varied between 24 μg / m^3 - 224 μg / m^3 for sampling time of 1 (one) hour and 16 μg / m^3 – 126 μg / m^3 for 24 hours duration sampling. Meanwhile the WHO standard for PM10 is 70 μg/m^3. The result of comparison of sampling of ambient air PM_{10} concentration with national ambient air quality standard and WHO standard can be seen in Figure 1.

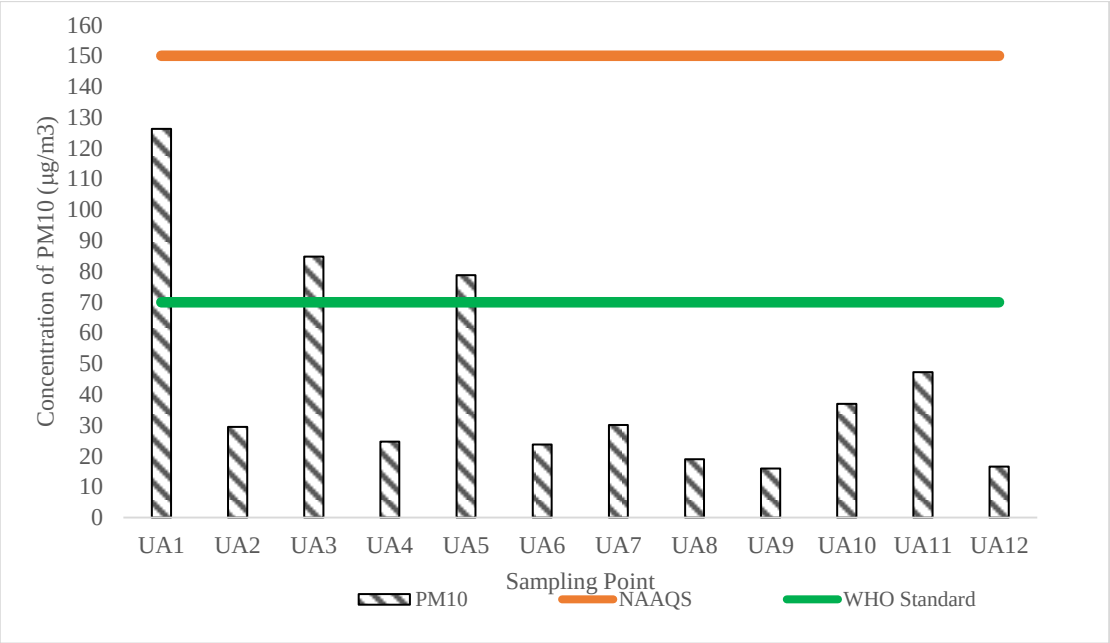

Figure 1. Comparison concentration of PM10 in ambient air with national air quality standard and WHO standard

Figure 1 shows that ambient PM_{10} concentrations of the sampling result still meet the national ambient air quality standard (PP No. 41 of 1999). When compared to WHO standards there are 3 (three) points that exceed the standards, namely UA1, UA3 and UA5. UA1 is located in Medan Belawan Subdistrict, this point is adjacent to emission source such as industry of palm oil processing and container warehouse. UA3 and UA5 are representatives with indications of the largest source of emissions from motor vehicles. UA3 is a cross-national road connecting between provinces while UA5 is a traffic intersection. The more sources of emissions the greater the emission load produced and the higher the pollutant in the ambient air .

The source of emissions in urban areas is predominantly derived from transportation activities. Type of land transportation modes in Medan city is quite heterogeneous, such as motorcycles, motor rickshaws, cars, urban transport, buses, trucks and trains. An increase in the number of vehicles in Medan City averaged ± 10% per year. The dominant vehicle type is motor that is ± 50 - 60%. In the research location obtained correlation value (R^2) for the relationship of the number of vehicles with PM10 concentration is 0.5 which means the relationship between the number of vehicles and PM10 concentration is moderate. The presence of concentration of PM10 in ambient air is not only influenced by emission sources alone but is also influenced by other factors such as meteorology, land use and receptors [6, 15, 16].

Map of distribution PM10 concentrations in ambient air

Map of ambient PM_{10} concentration distribution in Medan City was made by using Surfer 10 program and GIS (Geographical Information System). The input for this program is the coordinates (langitude and latitude) and concentration values at each sampling point. Map of ambient PM_{10} isopleth concentration distribution in Medan City can be seen in Figure 2.

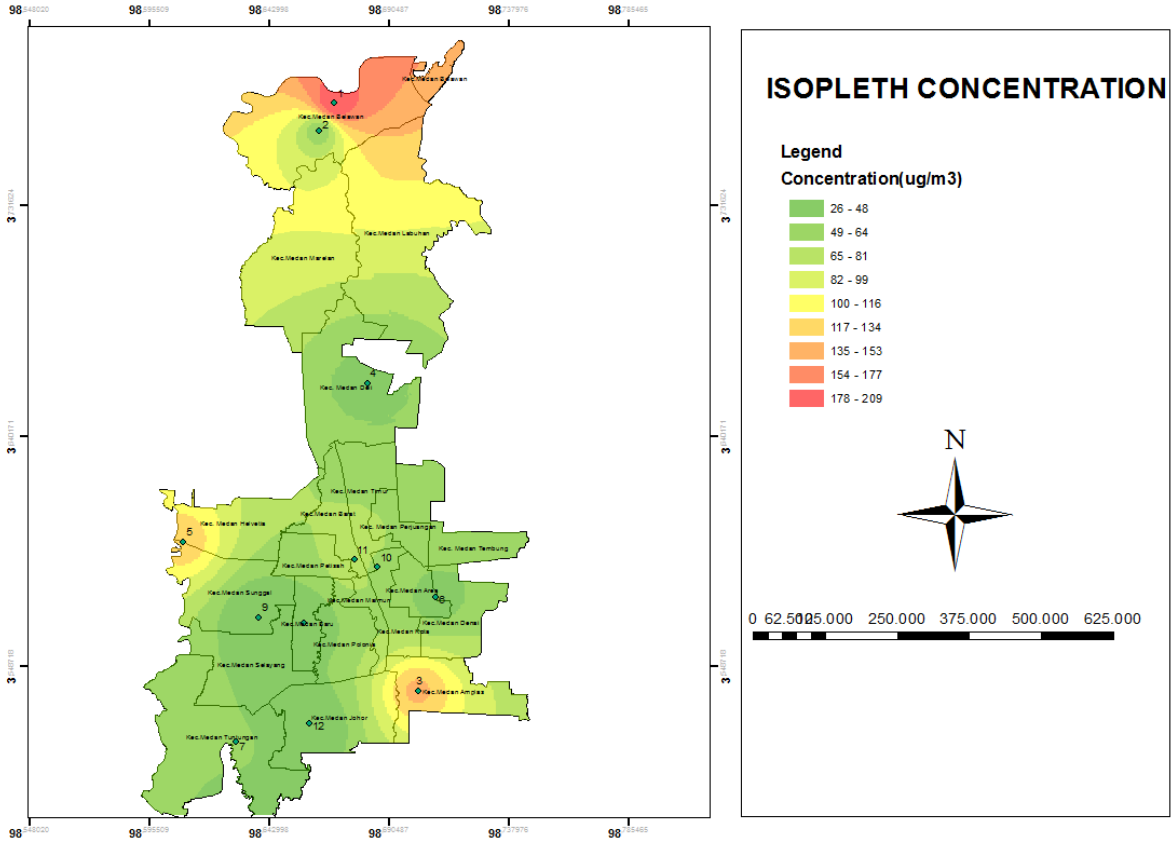

Figure 2. Map of PM_{10} isopleth concentration in ambient air in Medan City

In Figure 2, it can be seen that the highest ambient PM_{10} concentration is found in some areas, Medan Belawan, Medan Labuan, Medan Amplas, and Medan Helvetia. The high concentration of PM_{10} in Medan Belawan sub district not only comes from motor vehicles but also comes from industry. One of the largest industrial areas in Medan City is located in Belawan District, Medan Industrial Estate (KIM). The types of industries that exist in KIM vary like the palm oil processing industry, food processing industry, fertilizer industry, iron and steel industry, and other industries.

The high concentration of PM_{10} in Medan Belawan sub-district causes disturbance to the human respiratory tract. This is in accordance with data from Medan City Health Office in 2015 which states coverage of pneumonia case finding in Medan city with the highest position is in Belawan Health Center with coverage (98.2%), Teladan Health Center (10,2%), Titi Papan Health Center (6.2%), Medan Denai Health Center (5.6%) and Medan Deli Health Center (4.9%).

Map of PM_{10} Air Quality Index in Medan City

Ambient air quality index for PM_{10} is calculated using equation (1). The results vary from 27 to 130. The index value is categorized as good to unhealthy condition. Map of PM_{10} air quality index is presented in Figure 3.

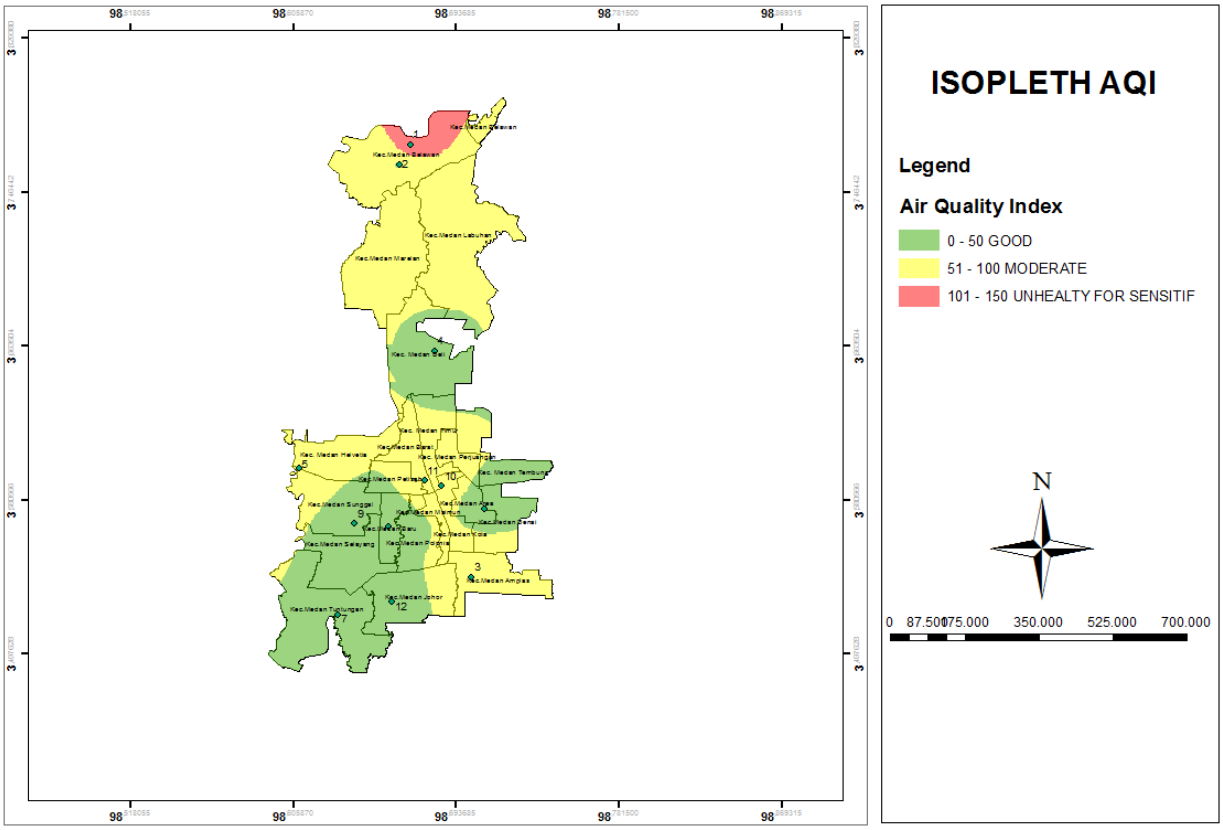

Figure 3. Map of PM_{10} Air Quality Index in Medan City

In Figure 3, it can be seen that the index of ambient air quality for PM_{10} parameters including unhealthy category is found in the area around Medan Belawan Subdistrict, Medan Amplas Subdistrict and Medan Helvetia Subdistrict. Directly proportional to the concentration isopleth map in Figure 2, then the location that belongs to the unhealthy dominant category in Medan Belawan Subdistrict. This is related to the dominant emission source characteristics derived from industrial activities and vehicular traffic. The existence of industrial area in Medan Belawan Subdistrict so that the dominant vehicle type at this point is freight truck (± 30%) of total all kinds of vehicle.

Unhealthy category means the air quality level is detrimental to humans or groups that are sensitive or can cause damage to the plant or aesthetic value. Meanwhile, for the very unhealthy category means the level of air quality that can be detrimental to health in a number of exposed population segments.

Factors affecting the concentration of PM_{10} in the ambient air

Factors affecting air pollution are the amount of pollutants emitted, meteorological conditions, and source formations [17, 18, 19]. Meteorological factors that affect air pollution include wind direction and velocity, temperature and humidity [20]. In addition from transportation sources, at each sampling point was also done taking the meteorological data of temperature and humidity.The statistical test obtained correlation value for temperature to ambient PM_{10} concentration is 0.429 and correlation value for moisture to ambient PM_{10} concentration is – 0.256. This means that 42.9% of PM_{10} concentration in ambient air is affected by temperature and 25.6% is affected by moisture. In addition from the correlation test obtained for the temperature there is a positive correlation to ambient PM10 which means the higher ambient air temperature then the ambient PM_{10} concentration is also higher. This condition is inversely proportional to the moisture that is negatively correlated to ambient PM_{10} which means the higher the moisture the lower the ambient PM_{10} concentration.

In line with the results of the study [21-23], that the air temperature is positively correlated with the pollutants. Positive correlation is every increase of variable air temperature then PM_{10} concentration variable also increased. Increased temperatures on the Earth's surface can cause a decrease in air humidity [20].

CONCLUSION

The results of the research and analysis show that ambient PM_{10} concentrations in Medan City for average 24 hour measurements ranged from 16 $\mu g/m^3$ – 126 $\mu g/m^3$. The 24-hour sampling rate still meets the national ambient air quality standard in Indonesia (150 $\mu g/m^3$) but there are 3 (three) locations that have exceeded WHO standards (70 $\mu g/m^3$) is UA1, UA3 and UA5. The highest ambient PM_{10} concentration is at point UA1, the high concentration at this point due to the influence of dominant emission sources derived from industrial and transportation activities. The dispersion map of ambient air PM_{10} concentration shows that the highest ambient PM_{10} concentration is located in the District of Medan Belawan. An ambient air quality index related to PM_{10} parameter shows good category until unhealthy where unhealthy category occurred in Medan Belawan Subdistrict. The concentration of PM_{10} in ambient air is influenced by several things, in this research which influences to PM_{10} concentration in ambient air that is emission source such as industry, transportation and meteorology factor such as temperature and humidity.

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