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Total Suspended Particulate Matter And PM_{10} Concentrations Related Meteorological Conditions in Daya, Makassar

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Ambient TSP (Total Suspended Particulate Matter) and PM_{10} (ie; particulate diameter less than in size) which can affect changes in ambient air quality produced by human activities such as motorized vehicle emissions and industry. On the other hand, the Makassar City Power area as a sampling site which is now turning into a densely populated area due to the rapid development of residential areas and this fact enables more opportunities exposed to many residents and disruption of human health because of the decreased ambient air quality especially due to the presence of particulate matter, while the concentration of TSP and PM_{10} is influenced by meteorological conditions. In this study, Pearson's coefficient of correlation was applied to study the relationship between TSP, PM_{10} and meteorological variables (ie: humidity, temperature, wind speed and Rainfall). TSP and PM_{10} sampling uses the High Volume Air Sampler (HVAS) tool, for meteorological factors using the Hygrometer, Thermometer and Anemometer, while Rainfall data is obtained from the Office of Meteorological and Geophysics area IV Makassar. In this study concluded that the temperature was found as a significant factor compared with other factors that influence the concentration of TSP and PM_{10}. Increased rainfall, humidity and wind speed have a negative correlation with the average concentration of TSP and PM_{10} in Daya, Makassar.

KEYWORDS

Air Pollutants, Particulate matter, Meteorological parameters, Statistical analysis, Makassar

1. INTRODUCTION

At present, the Urban Air Pollution problem is an issue that needs to be taken seriously, both of which have long-term and short-term impacts on human health, not only in the developed countries but also in developing countries such as India and Indonesia [1,2]. Various studies have shown that concentrations of outdoor pollutants are higher for urban locations, especially near highways and near industrial sites, while rural areas are found to be of lower concentration.[3,4,5]. Epidemiologic studies show that there is a significant influence between air pollution, both gas and particulate matter and health problems, the onset of diseases such as upper respiratory tract infections, cardiovascular, asthma, TSP and PM_{10} contain heavy metal which can increase the risk of getting cancer [6,7,8,9,10]. Even, Epidemiologists have documented statistically significant associations between particulate matter mass concentrations and increased human mortality and morbidity [11,12]. Air pollution has emerged as a worrying problem in Makassar City as one of the cities outside of Java which is becoming a very densely populated urban area which consequently increases the need for transportation while a proper public transportation mode that meets the standards is not yet available so private vehicles, cars and bicycles motorbikes are filling up the road which causes congestion in almost all roads [13]. In addition, that the potential threat to the population of Makassar is predicted from the results of studies that reveal sources of air pollution especially particulate matter in ambient air in the city of Makassar due to factors contributing to the increase in the number of vehicles and the presence of industries that are also increasing drastically, airport activities and dense ports, in general contribute substantially to ambient concentrations both for gaseous compounds and atmospheric particles [14,15,16]. Various attempts have also been made to reduce industrial exhaust emissions, among others, with tools known as ejectors, but their use has not yet been widespread in the industrial world, still requiring broader recognition efforts [17].

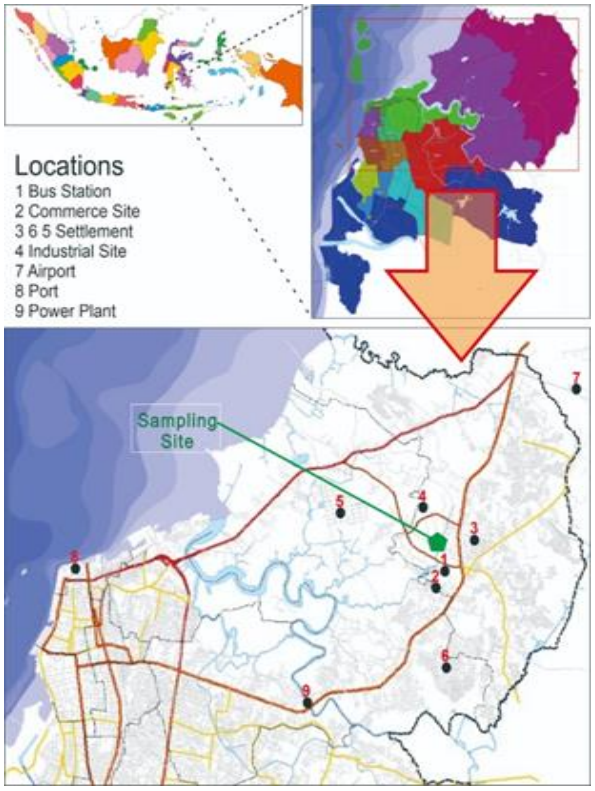

Figure 1. *Sampling sites at Daya Makassar City*

Ambient TSP (Total Suspended Particulate Matter) and PM_{10} contribute to the chemical and physical processes in the atmosphere that produce a variety of characteristics over time. In addition, meteorological conditions play a major influence on the increase in concentrations of TSP and PM_{10}, an increase in concentrations of TSP and PM_{10} is actually not expected as a result of meteorological conditions [18, 19]. Air in urban areas is not only determined by the amount of emissions but is also influenced by a combination of various meteorological factors. Important combinations of meteorological variables include temperature, wind, radiation, atomospheric humidity, and mixing depth [20, 21]. Measurement of wind speed and direction, temperature, humidity, rainfall and solar radiation are important parameters used in air quality studies and can help in facilitating understanding of chemical reactions that occur in the atmosphere, so that meteorological conditions play a role in influencing air quality [22, 23]. Several other studies have shown that meteorological conditions have a significant influence on composition in the aerosol atmosphere. Furthermore, meteorological factors have a big influence on the dispersion of air pollution in the atmosphere. Dispersion is mainly influenced by layers of atmospheric boundaries, wind speed and temperature direction, humidity, rainfall and solar radiation [24, 25].

In Indonesia, air quality monitoring is carried out in ten major cities through the Air Quality Monitoring Network System (AQMS), namely Jakarta, Bandung, Semarang, Surabaya, Denpasar, Medan, Pekanbaru, Jambi, Pontianak and Palangkaraya. While other cities including Makassar, South Sulawesi Province are still monitored by Manual Air Quality Monitoring (MAQM). The Government of Indonesia has also set ambient air quality standards in an effort to control or minimize air pollution such as those from mobile and non-mobile sources. Standards are usually set without regard to economic viability and other factors. Instead, they focus on public health, including the health of "sensitive" populations such as asthma sufferers, children and the elderly as well as community welfare, including protection against decreased visibility, animal death, the damage to vegetation, water resources and buildings (DOE, 2002). In addition to IAAQS Indonesia has an air pollution standard index (APSI) based on concentrations of several pollutants such as PM10, SO2, CO, NO2 and O3. The calculation is used to see the state of air quality in certain areas as a basis for decision making and policy to overcome the impact of air pollution on health [17]. Studies on air pollution specifically of particulate matter are very limited in Makassar South Sulawesi. This study aims to measure TSP (Total Suspended Particulate) concentrations and PM_{10} levels during the rainy and dry seasons, In addition, the influences of the local meteorological conditions on the TSP and PM_{10} concentrations in the study area are reported in this study.

2. MATERIALS AND METHODS

2.1. Sampling site description

Makassar is located between 119°24'17'38 "East Longitude and 5°8'6'19" South Latitude. In terms of geographic position, Makassar Municipality has boundaries as follows: North-Maros Regency; South-Gowa Regency; West-Makassar Strait; East-Maros Regency, The area of Makassar Municipality is 175.77 square km which includes 15 districts. Makassar is the capital city of the Province of South Sulawesi. It is one of the cities in Indonesia that full of urban activities. Makassar Municipality population based population projections for 2018 were 1,508,154 people consisting of 746,951 inhabitants

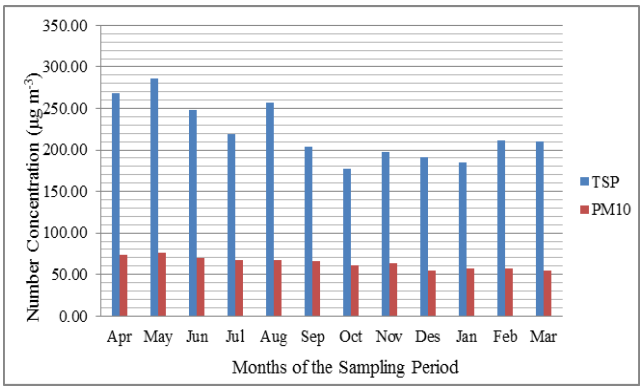

Figure 2. *Monthly average total suspended particulate and PM_{10} concentrations*

Table 1. *Mean, Standar Deviation and Ranges of particulate matter concentration and meteorological parameters*

Parameter	Mean	Standard Deviation	Range
TSP (µg/m^3)	230	97.43	104.7-551.3
PM_{10} (µg/m^3)	66.64	7.89	51.03-88.37
Rainfall (mm)	182.46	214.93	0.0-792.42
Humadity Rate (%)	75.27	12.41	53.9-91.8
Temperature (° C)	29.2	3.74	23.2-34.7
Wind speed (m/s)	3.06	1.52	1.14-6.40

of the male and 761,203 female. This compares with a total of Makassar Municipality Population in 2017, the Population growth of Makassar Municipality is 1.29 percent with each percentage of the male population growth of 1.43 percent and 1.36 percent for female population. Number of Industry in Makassar is 145 Industries (basic metal, fabricated metal products, chemicals and chemical products, food products and beverages, textile and apparel, wood and wood products etc). The number of vehicles operating in Makassar up to October 2019 reached 1,563,608 units (1,156,759 units of motorcycles, 213,985 passenger cars; 74,603 freight cars, 17,306 buses and 403 special vehicles. The rapid growth of urbanization and industrialization in the city of Makassar reduces green space and contributes to the problem of air pollution which will have an impact on the population living in the city of Makassar. In this study, the sampling site was located at the Daya in Makassar. Sampling site is illustrated in Figure 1. Sampling site is located between the Daya Regional Bus Terminal and Daya Business Area, Makassar Industrial area is in the west, north about 6 kilometers is Sultan Hasanuddin International Airport Makassar, south and east are densely populated residential areas residents namely Citra land estate and several other residential areas, about 5 kilometers to the south there is the Tello Makassar Power Plant. Daya becomes an area that is densde with traffic flow, even almost every day there is traffic jam on the road to and leaving for Daya area.

2.2. Method

Mass of total suspended particulate (TSP) and PM_{10} (particulate less in 10µm in size) were determined gravimetrically. The mass concentration was obtained by dividing the gravimetric mass by the volume of air that passed through the sampling filter. The TSP and PM_{10} was monitored on a weekly basis from April 2016 to March 2017. The 24-hr of the PM_{10} sampling was performed by using a standard size-selective high volume air sampler (HVAS, Sierra Anderson) with a glass type fiber filter (8 x 10 inch) as the collection medium with a flow rates of 1.13 m^3/min. TSP was sampled using the Portable High Volume Air Sampler (HVAS, Staplex-USA). The TSP was collected on a glass fiber type filter of 4 inch diameter. Then, meteorological data i.e rainfall obtained from the Office of Meteorological and geophysics area IV Makassar, for humidity, temperature, speed and direction wind were measured in the sampling site using Hygrometer, Thermometer, Anemometer, respectively.

2.3. Statistical Analysis

In this study, a statistical technique was used to find out the relationship of each individual meteorological parameter (as independent variable) on the TSP and PM10 (as dependent variable). After categorizing data in different data sets, meteorological assessments affecting TSP and PM_{10} pollution concentrations were completed using Excel spreadsheets and then the data were analyzed using the SPPS statistical software version 16. Descriptive statistical parameters such as mean, standard deviation and ranges of the data were constructed in order to show differences between categories. In this study, it was also using the conditional probability function (CPF) for understanding point sources windblown contribution particulate matter pollutants.

3. RESULT AND DISCUSSION

During the study period, the average concentration of Total Suspended Particulate (TSP) was 230 µg / m3 and the highest reached 551.13 µg / m3, for PM_{10} the average concentration was 66.64 µg / m3 and the highest was 88.37 µg / m3. The average for meteorology parameters (Rainfall, Humidity Rate, Temperature and wind speed) were 182.46 ± 214.93 mm, 7527 ± 12.41%, 29.2 ± 3.74 ° C, 3.06 ± 1.52 m/s, respectively.

Tabel 2. Correlation (r value) between Air Pollutants and Meteorological Parameter

Pameter	TSP	PM_{10}	Rainfall	Humadity	Temp	Wind Speed
TSP	1	0.340**	-0.057	-0.169	0.265**	-0.475
PM_{10}	0.340**	1	-0.058	-0.102	0.370**	-0.114**
Sig.(2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
N	48	48	48	48	48	48

**. Correlation is significant at the 0.01 level (2-tailed)
*. Correlation is significant at the 0.05 level (2-tailed)

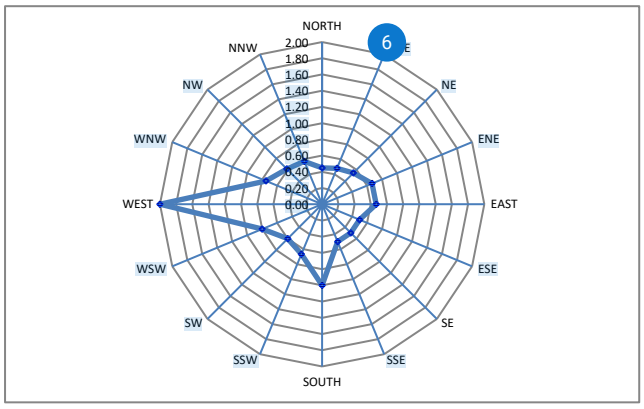

Figure 3. *Polar plots of CPF for the highest 25% of PM10 for the sampling site.*

Table 1 presents descriptive statistics of TSP and PM10 concentrations and meteorological paramenters used in the analysis during sampling at Daya Makassar. The overall study results of the average monthly data obtained during the sampling exercise as shown in **Figure 2** show that the monthly average of TSP and PM_{10} concentrations during the dry season (April-September) are higher compared to the wet season (October-March). This is closely related to local climatic factors, where rainfall can be a washing atmosphere and reduce pollutants, especially particulate matter (Faisah and Ulfah, 2009), another study also reported that the Higher concentrations of PM_{10} during the 2005 dry season and lowest median concentration during the 2006 wet season in Morogoro, Tanzania [28, 29].

Furthermore, the mean concentrations of TSP and PM_{10} in this study as shown in Table 1, namely TSP (230 µg/m^3) and PM_{10} (66.64 µg/ m^3) are higher than other studies reported several years earlier in the Makassar area, namely TSP of 188 µg/m^3 and PM10 of 54.6 µg/m^3 (Sattar et al, 2012), this can be explained that the cause of the increase in Particulate Matter Concentration in Ambient Air in Makassar is sourced from motorized vehicles and industries which tend to rise sharply from year to year in Indonesia especially in Makassar, as well as other developing countries such as India and Malaysia (Rahman et al., 2011; Kothai et al., 2008; Santoso et al., 2008). It was further reported in this study that the ratio between PM_{10}/TSP was 0.29. The overall correlation coefficient in the form of the correlation matrix between the Total Suspended Particulate (TSP), PM_{10} pollutants and meteorological parameters is presented in **table 2**. As seen on the **table 2**, the results show that the correlation coefficient between particulate matter (TSP, PM_{10}) concentration and rainfall, humidity are negative, where rainfall is closely related to humidity. The reason that causes a negative relationship between both (rainfall and humidity) is because relative humidity is generally influenced by the amount of rainfall through the atmospheric aerosol washing process and reducing the concentration of material particles in the air [34].

The relationship between particulate matter (TSP, PM_{10}) and wind speed is also negative, due to the increase in wind speed will cause particulate matter to be diluted by dispersion and cause a reduction in the concentration of particulate matter in the atmosphere [35]. On the contrary, there is a positive relationship between Particulate Matter and temperature in this study, this shows that ambient temperature affects the concentration of PM, the temperature increases the chemical reaction in the atmosphere which results in the formation of particles naturally, thus contributing to an increase in PM concentration. Wind (wind direction and wind speed) plays an important role in the distribution of pollutants in the atmosphere. The average wind direction is divided into 16 sectors each 22.5 ° with respect to the sampling location. The sectors are north (N), north-northeast (NNE), northeast (NE), east-northeast (ENE), east (E), east-southeast (ESE), southeast (SE), south-southeast

(SSE), south (S), south-southeast (SSW), southwest (SW), west-southwest (WSW), west (W), west-northwest (WNW), northwest (NW) and north-northwest (NNW). By analyzing the wind rise data, it was found that the wind blows mainly from the west and south. This is in accordance with wind direction data analysis conducted by the Makassar Meteorology and Geophysics Office that winds blow about 60% - 65% of the wind direction from the west (**Figure 3**), it was found that most of the Particulate Matter to the west and south, where in the west is the area Makassar industry and in the south is the Daya market business area which is densely populated with vehicles and open burning in residential areas.

4. CONCLUSION

This study concludes that the concentration of particles in the atmosphere varies by seasons. TSP and PM_{10} concentrations are higher in the dry season than the rainy season. A statistically significant positive relationship was observed between particulate matter and temperature. Correlation analysis results also found a negative and statistically significant correlation between particulate matter with rainfall and relative humidity shows the washing effect as evidenced by the negative. The negative correlation between particulate matter and wind speed, where with an increase in wind will cause a reduction in concentration due to the movement of pollutants in the atmosphere. This study also shows that the concentration of particulate matter is not only determined from emissions of moving and non-moving pollutant sources but which also plays an important role is a meteorological factor. The source of pollutants is the number of vehicles and industries in Makassar, therefore strategic steps are needed for those in authority to be able to reduce the rate of increase in the concentration of pollutants in ambient air.

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