

# Total Suspended Particulate Matter And PM<sub>10</sub> Concentrations Related Meteorological Conditions In Daya, Makassar

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Ambient total suspended particulate matter (TSP) and PM<sub>10</sub> (that is particulate diameter less than 10 µm in size) produced by human activities, such as motorized vehicle emissions and industries can affect ambient air quality. 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 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<sub>10</sub> is influenced by meteorological conditions. In this study, Pearson's coefficient of correlation was applied to study the relationship between TSP, PM<sub>10</sub> and meteorological variables, that is humidity, temperature, wind speed and rainfall. TSP and PM<sub>10</sub> sampling was done using the high volume air sampler (HVAS) tool, for meteorological factors using the hygrometer, thermometer and using anemometer, while rainfall data was obtained from the Office of Meteorological and Geophysics area IV Makassar. This study concluded that the temperature was found as a significant factor compared with other factors that influence the concentration of TSP and PM<sub>10</sub>. Increased rainfall, humidity and wind speed have a negative correlation with the average concentration of TSP and PM<sub>10</sub> 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, that 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 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<sub>10</sub> 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 concentra-

tions 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 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, the potential threat to the population of Makassar was 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 of both gaseous compounds and atmospheric particles [14,15,16]. Various attempts have 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 and efforts [17].

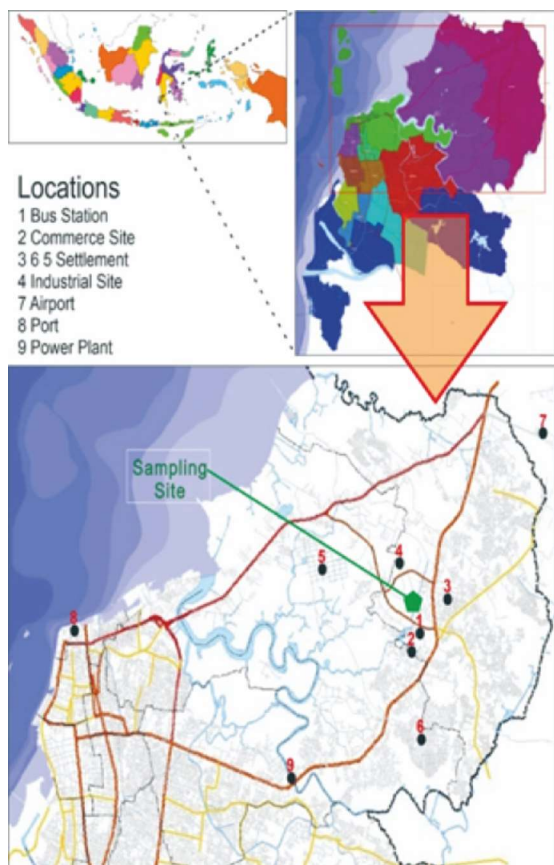


Figure 1. Sampling sites at Daya Makassar city

Ambient total suspended particulate matter (TSP) 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, atmospheric 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 understanding chemical reactions that occur in the atmosphere which influence air quality [22,23]. Several other studies have shown that meteorological conditions have a significant influence on composition of the aerosol in the 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

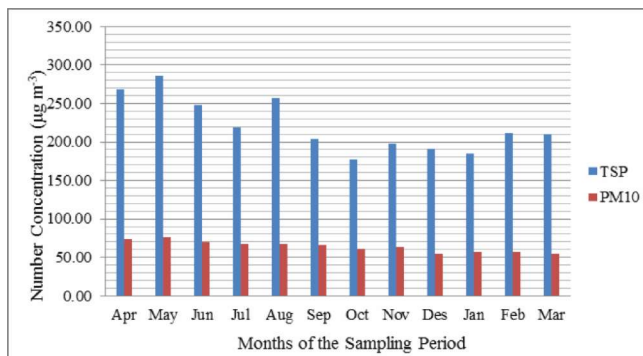
and temperature direction, humidity, rainfall and solar radiation [24,25].

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, damage to vegetation, water resources and buildings [26]. In addition to IAAQS Indonesia has an air pollution standard index (APSI) based on concentrations of several pollutants, such as  $PM_{10}$ ,  $SO_2$ , CO,  $NO_2$  and  $O_3$ . 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 [27]. Studies on air pollution specifically particulate matter are very limited in Makassar South Sulawesi. This study aims to measure TSP 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. MATERIAL AND METHOD

### 2.1 Sampling site description

Makassar is located between  $119^{\circ}24'17'38''$  east longitude and  $5^{\circ}8'6'19''$  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 km<sup>2</sup> which includes 15 districts. Makassar is the capital city of the Province of South Sulawesi. It is one of the cities in Indonesia that is full of urban activities. Makassar Municipality population-based population projections for 2018 were 1,508,154 people consisting of 746,951 inhabitants as male and 761,203 as female. When compared with Makassar Municipality population in 2017, the population growth of Makassar Municipality is 1.29% with each percentage of the male population growth of 1.43% and 1.36% for female population. The number of industry in Makassar is 145



**Figure 2.** Monthly average total suspended particulate and PM<sub>10</sub> concentrations

**Table 1.** Mean, standard deviation and ranges of particulate matter concentration and meteorological parameters

| Parameter                             | Mean   | Standard deviation | Range       |
|---------------------------------------|--------|--------------------|-------------|
| TSP (µg/m <sup>3</sup> )              | 230    | 97.43              | 104.7-551.3 |
| PM <sub>10</sub> (µg/m <sup>3</sup> ) | 66.64  | 7.89               | 51.03-88.37 |
| Rainfall (mm)                         | 182.46 | 214.93             | 0.0-792.42  |
| Humidity 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   |

(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 upto 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. The sampling site is illustrated in figure 1. The sampling site is located between the Daya regional bus terminal and Daya business area; Makassar industrial area is in the west; in north about 6 km is Sultan Hasanuddin International Airport Makassar; south and east are densely populated residential areas, namely Citra land estate and several other residential areas; about 5 km to the south there is the Tello Makassar Power Plant. Daya has become an area with dense traffic flow, almost every day there is a traffic jam on the road to and fro for Daya area.

## 2.2 Method

Mass of total suspended particulate (TSP) and PM<sub>10</sub>

(particulate matter less than 10 µm in size) was 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<sub>10</sub> were monitored on a weekly basis from April 2016 to March 2017. The 24 hr of PM<sub>10</sub> sampling was performed by using a standard size-selective high volume air sampler (HVAS, Sierra Anderson) with a glass type fibre filter (8x10 inch) as the collection medium with a flow rate of 1.13 m<sup>3</sup>/min. TSP was sampled using the portable high volume air sampler (HVAS, Staplex-USA). The TSP was collected on a glass fibre type filter of 4-inch diameter. Then, meteorological data, that is rainfall obtained from the Office of Meteorological and Geophysics area IV Makassar; for humidity, temperature, wind speed and direction were measured at 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 an independent variable) on the TSP and PM<sub>10</sub> (as dependent variable). After categorizing data in different data sets, meteorological assessments affecting TSP and PM<sub>10</sub> pollution concentrations were completed using Excel spreadsheets and then the data were analyzed using the SPSS 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, conditional probability function (CPF) was used for understanding point sources of wind blown contribution to particulate matter pollutants.

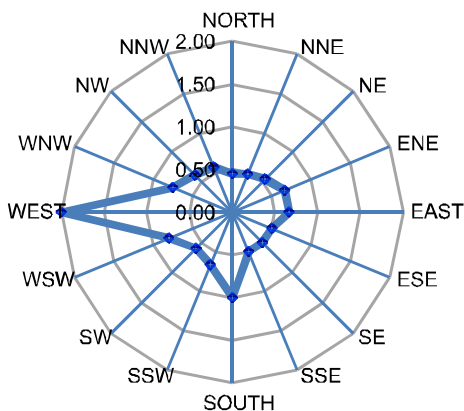
## 3. RESULT AND DISCUSSION

During the study period, the average concentration of total suspended particulate (TSP) was 230 µg/m<sup>3</sup> and the highest value recorded was 551.13 µg/m<sup>3</sup>. For PM<sub>10</sub> the average concentration was 66.64 µg/m<sup>3</sup> and the highest value recorded was 88.37 µg/m<sup>3</sup>. The average for meteorology parameters (rainfall, humidity rate, temperature and wind speed) were 182.46 ± 214.93 mm, 75.27 ± 12.41%, 29.2 ± 3.74°C, 3.06 ± 1.52 m/s, respectively. Table 1 presents descriptive statistics of TSP and PM<sub>10</sub> concentrations and meteorological parameters 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<sub>10</sub> concentrations during the dry season (April-September) are higher compared to the

**Table 2. Correlation (r-value) between air pollutants and meteorological parameters**

| Parameter        | TSP     | PM <sub>10</sub> | Rainfall | Humidity | Temperature | Wind speed |
|------------------|---------|------------------|----------|----------|-------------|------------|
| TSP              | 1       | 0.340**          | -0.057   | -0.169   | 0.265**     | -0.475     |
| PM <sub>10</sub> | 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 PM<sub>10</sub> for the sampling site**

wet season (October-March). This is closely related to local climatic factors, where rainfall can be washing atmosphere and reducing pollutants, especially particulate matter. Another study also reported that the higher concentrations of PM<sub>10</sub> was observed 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<sub>10</sub> in this study as shown in table 1, namely TSP (230 µg/m<sup>3</sup>) and PM<sub>10</sub> (66.64 µg/m<sup>3</sup>) are higher than other studies reported several years earlier in the Makassar area, that is TSP of 188 µg/m<sup>3</sup> and PM<sub>10</sub> of 54.6 µg/m<sup>3</sup>. 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 [30,31,32,33]. It was further reported in this study that the ratio between PM<sub>10</sub>/TSP was 0.29. The overall correlation coefficient in the form of the correlation matrix between the total suspended particulate (TSP), PM<sub>10</sub> pollutants and meteorological parameters is presented in table 2. As seen in table 2, the results show that the correlation coefficient between particulate matter (TSP, PM<sub>10</sub>) concentration and rainfall, humid-

ity is negative, where rainfall is closely related to humidity. The reason that causes a negative relationship between both (rainfall and humidity) is that 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<sub>10</sub>) and wind speed is also negative, as increase in wind speed will cause particulate matter to be diluted by dispersion and causes 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 particulate matter, the temperature increases the chemical reaction in the atmosphere which results in the formation of particles naturally, thus contributing to an increase in particulate matter concentration. Wind (direction and 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-southwest (SSW), southwest (SW), west-southwest (WSW), west (W), west-northwest (WNW), north-west (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 in which 60-65% of the wind direction is from the west (Figure 3). It was found that most of the particulate matter comes from the west and south, wherein the west is the Makassar industry area 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 par-

ticles in the atmosphere varies with seasons. TSP and PM<sub>10</sub> concentrations are higher in the dry season than in 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 that shows the washing effect. The negative correlation between particulate matter and wind speed, where an increase in the wind will cause reduction in concentration due to the dispersion 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 meteorological factor also plays an important role. The source of pollutants is the number of vehicles and industries in Makassar, therefore, strategic steps are needed to be taken by authorities to reduce the rate of increase in the concentration of pollutants in ambient air.

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