Asian Jr. of Microbiol. Biotech. Env. Sc. Vol. 21, No. (2) : 2019 : 298-303
© Global Science Publications
ISSN-0972-3005

THE RELATION BETWEEN METEOROLOGICAL FACTORS AND POLLUTANTS CONCENTRATIONS IN MAKASSAR CITY OF SOUTH SULAWESI PROVINCE INDONESIA

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(Received 14 September, 2018; accepted 30 October, 2018)

Key words *: Air quality monitoring, Atmosheric pollutants, Meteorological parameters, Statistical analysis*

Abstract – Makassar is strategically situated between the southern and northern provinces of South Sulawesi. This happens to be one of the major reasons why rapid urbanization and industrialization growth within this area is unavoidable, thereby making Makassar a region of mixed commercial-residential-industrial area. It is also faced with the problem of air pollution. However, the meteorological parameters, plays an important role in determining the pollutants responsible for these pollution. This paper presents the relationship between meteorological factors and pollutants concentrations. The pollutants concentrations data used consists of SO_2, CO, NO_2, O_3, Pb, TSP and PM_{10}. They were obtained from measurements made by the Office of the Ministry of Environment Sulawesi, Maluku and Papua and Environment Board of the Province of South Sulawesi as well as Environment agency of Makassar City. Whereas, meteorological data like rainfall, relative humidity, temperature, wind speed and wind direction were obtained from the Office of Meteorological and geophysics area IV Makassar. Pearson's coefficient of correlation was applied to study the association between the Pollutants and meteorological variables. The correlation of the Pollutants (SO_2, CO, NO_2, O_3, Pb, TSP, PM_{10}) and meteorological parameters (Rainfall, relative humidity, temperature and wind speed) were found to be positive and negative correlations.

INTRODUCTION

Urban air pollution, is associated with its long- and short-term impacts on human health, human well-being and the environment. The main cause of urban air pollution is the use of fossil fuels in automobiles, power generation plants, industries, and in the domestics' sectors. In addition, the burning of biomass such as firewood, agricultural and animal waste also contributes to air pollution. Over the past five decades, these has been a widely recognised problem (Schwela *et al*., 2006), thereby making air pollution a vital topic for discussion. The air pollutants consists of gases made up of airborne particulate matter (APM), ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide and lead (Vallero, 2008). The rapid industrial development created more job opportunities and also generated more revenue for a country. However, it is also causing harm to the human environment by emitting air pollutants which are harmful to humans and their surrounding environment including Indonesia (Sattar *et al*., 2012)

In most developing countries such as Malaysia and Indonesia, old vehicles are not properly maintained. These old vehicles have been analyzed to being one of the major source of air pollution in many cities as they tend to emit poisonous air owing to their poor state. Using a source apportionment technique, Rashid and Griffiths (1994) successfully

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resolved that automobile was one of the five major sources of air pollution in Kuala Lumpur area. A study conducted on elementary school students in Bandung Indonesia, found that the high level of lead in the bloodstream of the school children was mainly due to gasses emitted by vehicles. Vehicle owners were hence advised to dissociate from the use of fuels containing lead in Indonesia (Lestari, 2005).

The level of air pollution concentrations in an urban area is not only determined by the amount of gasses emitted, but it is also influenced or correlated with combination of various meteorological factors. A combination of meteorological variables important to these conditions includes temperature, winds, radiation, atomospheric moisture, and mixing depth (Rost *at al*., 2009; EPA, 2009). The measurements of wind speed and direction, temperature, humidity, rainfall and solar radiation are important parameters used in the study of air quality and will assist us to further understand the chemical reactions that occur in the atmosphere (Vallero, 2008; Hills, 2010; Kastner and Rotach; 2004; Colls, 2002). Asides that the meteorological data is also used to predict various events that could led to air pollution using multiple approaches, one of which is statistical modelling (Pearce *et al*., 2010).

Meteorological parameters can affect pollutants through direct physical mechanisms with the ozone, through radiation or indirectly through influences on other meteorological parameters such as the association between high temperatures and low wind speed (Jacob and Winner, 2009) Several studies showed meteorological conditions to have a significant influence upon the composition at atmosphere aerosol. It also proved that meteorological factors have a substantial influence on the atmospheric dispersion of air pollution. Dispersion is particularly affected by the atmosphere boundary layer, wind speed and direction, temperature, humidity, rainfall and solar radiation (Karpinen *et al*., 2000). Black carbon concentration was higher during the dry months which may be attributed to rampant biomass burning during hot and dry weather conditions (Rashid *et al*., 2014), as well concentration of ionic species are different dry season and rainy season (Sattar *et al*., 2014).

In Indonesia, air quality is monitored in ten major cities through the Air Quality Monitoring Network System (AQMS), namely Jakarta, Bandung, Semarang, Surabaya, Denpasar, Medan, Pekanbaru, Jambi, Pontianak, Palangkaraya (Department of Environment, 2002). While the other cities including Makassar South Sulawesi Province are monitored with Air Quality Monitoring Station of Manual (MAQM).

The government of Indonesia sets ambient air quality standards as an attempt to control or minimize air pollution such as those from the mobile and stationary sources. Although, the Indonesia Ambient Air Quality Standards (IAAQS) is available to all region, each region could also establish its own ambient air quality standards that are more stringent than the IAAQS. The Province of South Sulawesi adopted a value similar to that of the IAAQS. The Ambient Air Quality Standard is based on individual pollutant and the concenrations at which they become harmfull to the public health and environment. The standards are typically set without regards to the economic feasibility for attainment but with focus on public health which includes those of the sensitive population such as as asthmatics, children and the elderly and public welfare, including protection against decreased visibility and damages to animals, vegetation, aquatic resources, and buildings (DOE, 2002). Apart from IAAQS the Indonesians have the Air Pollution Standard Index (APSI) which is based on the concentrations of several pollutants such as PM_{10}, SO_2, CO, NO_2 and O_3. The calculation is used to view the state of the air quality in a given area as a basis for policy decision making to overcome the effects of air pollution on health (DOE, 1999).

Makassar is the capital city of the Province of south Sulawesi. It is one of the cities in Indonesia full of urban activities. Makassar covers a landmass of 175.77 km square. Its total population in the year 2009 was 1,273,349 people. Makassar has a total of 135 industries (Basic metal, fabricated metal products, chemicals and chemical products, food products and beverages, textil and wearing apparel, wood and products wood etc) with a total number of 843,473 vehicles (passenger mobile 102,027 units; bus mobile 16,691 units; truck car 43,145 units; motorcycles 681,269). The rapid growth of urbanization and industrialization is likely to increase the greenhouse effect on the environment thereby contributing to air pollution and having adverse effects on resident of Makassar city. This study has been conducted in eight different sites in Makassar, with the sole aim of examining the influences of meteorological conditions on Makassar city.

MATERIALS AND METHODS

Sampling site description

Makassar is located between 119º24´38" East longitude and 5º8´19" South latitude. It is bounded by Maros Regency at the North, Maros Regency at the East, Gowa Regency at the South, and Makassar Strait at the West. It landmass is 175,77 Square km which includes 14 district regions as shown in Figure 1.

Sampling was conducted at eight sites in Makassar namely Karebosi (a commercial field and office area), in front of Mattoangin (a football stadium with high traffic concentration), Hertasning Street (a residential and office area), Sumiharjo street (a high traffic concentrated region), Pannampu traditional market (a traffic congestion and commercial area), Makassar Industrial estate (an industrial estate), Makassar mall (a high traffic concentration and commercial area), and in front of Eastern Pearl Flours Mills firm (an industrial commercial area). Figure 1 shows all the eight locations and three meteorological stations in the Makassar area.

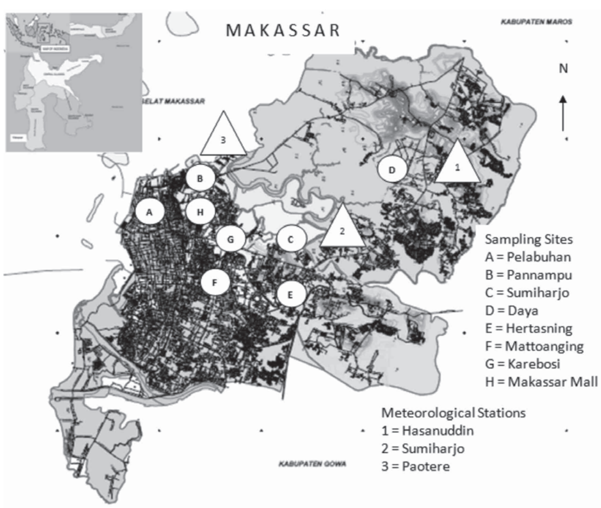

Fig. 1. The sampling sites and Meteorological Stations in Makassar.

Air quality and meteorological data

The pollutants data were obtained from measurements made by the Office of Environmental Management Sulawesi, the Maluku and Papua, Regional Environmental Management Agency of South Sulawesi Province and by the Environment Agency Makassar City. The data obtained include the air quality of ambient in Makassar which consist of SO_2, CO, NO_2, O_3, Pb, TSP. The meteorological data obtained from the Office of Meteorological and geophysics area IV Makassar, include rainfall, relative humidity, temperature and wind (speed and direction). These data are to be analyzed using matric correlation to evaluate the relationship between the pollutants and the influence of meteorological factors on the air pollution as well as using the conditional probability function (CPF) for understanding point sources and windblown contribution particulate matter pollutants.

METHODS

Spectrophotometer (Model DR - 2010) was used to determine SO_2, NO_2, O_3, and other pollutants. Non Dispersive Infrared Analyzer (NDIR, NGA 2000) was used to analyze CO, Atomic Absorption Spectrophotometer (AAS, Perkin Elmer Model 600) was used for lead (Pb). Similarly, particulate matter mass of PM_{10} (particulate less than 10 µm in size) and total suspended particulate (TSP) 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 PM_{10} and TSP were sampled using the size selective high volume air sampler and a standard high volume air sampler, respectively, with flow rates of 1.13 m^3/min. The particulate was collected on a glass fiber type filter of about 8in x 10in size.

RESULTS AND DISCUSSION

Table 1 presents the descriptive statistics of pollutant concentration and meteorological parameters for all sites in Makassar.

The average concentration of SO_2, CO, NO_2, O_3, Pb, TSP and PM_{10} in Makassar was 75 ± 51.7 µg/m^3, 1038 ± 534 µg/m^3, 42.1 ± 21.1 µg/m^3, 53.5 ± 27.8 µg/m^3, 0.70 ± 0.37 µg/m^3, 169 ± 85.6 µg/m^3, 53.8 ± 16.9 µg/m^3, respectively. The average meterology parameters (Rainfall, Relative humadity, Temperature and wind speed) was 251.8 ± 136.7mm, 77.3 ± 18.3%, 27.2 ± 5.4 °C, 1.6 ± 0.9 m/s, respectively. The overall correlation coefficient in the form of correlation matrix between the pollutants and meteorological parameters is presented in Table 2.

The results shown in table 2, proves Pb and NO_2 to be at the a highest degree of positive correlation between pollutants (R= 0.527). The lowest correlation was between PM_{10} and NO_2 (R= 0.060). Table 2 also shows the various relationship between the pollutants with a good number of these pollutants having a correlation significant of 0.01including CO and SO_2, NO_2 and SO_2, O_3 and SO_2, Pb and SO_2, NO_2 and CO, TSP and CO, PM_{10} and CO, O_3 and NO_2, Pb and NO_2, Pb and O_3, PM10 and O3, TSP and Pb as well as PM_{10} and TSP. These pollutants had a correlation coefficient of 0.381, 0.384, 0.262, 0.315, 0.282, 0.394, 0.317, 0.478, 0.527, 0.470, 0.276, 0.355 and 0.471, respectively.

The correlation of the Pollutants (SO_2, CO, NO_2,O_3, Pb, TSP, PM_{10}) and meteorological parameters (Rainfall, relative humadity, temperature and wind speed) were found to consist of positive and negative correlations. Nevertheless, the correlation between rainfall and pollutants are negative, while those between rainfall and SO_2, as well as those between rainfall and TSP are positive correlation. Relative humidity and pollutants were all negative correlation with only relative humidity and SO_2 being positive correlation. On the contrary, the correlation between temperature and pollutants shows positive correlation. While wind speed and pollutants displayed positive correlations (wind speed and $NO_{2,}$ O_3,TSP).Wind speed and SO_2, wind speed and CO, wind speed and Pb, and wind speed and $PM_{10,}$ all displayed negative correlation as shown in Figure 2.

Winds (wind direction and wind speed) play an important role in the distribution of pollutants in the atmosphere. The average wind directions were divided into 16 sectors of 22.5 ° each with respect to the sampling sites. 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-north west (WNW), northwest (NW), and north-northwest (NNW). By analyzing the wind data, it was found that wind blows mainly from the west direction. It is also in line with the data analysis obtained by the Office of Meteorology and Geophysics Makassar which has it that about

Table 1. Descriptive statistics of pollutant concentration during the periods of 2009 – 2014

Parameter	Average	Standard Deviation	Minimum	Maximum
SO_2 (μg/m^3)	75	51.7	8.6	253
CO (μg/m^3)	1038	534	66.7	3709
NO_2 (μg/m^3)	42.1	21.1	10.3	99.5
O_3 (μg/m^3)	53.5	27.8	17.3	226
Pb (μg/m^3)	0.7	0.37	0.14	2.28
TSP (μg/m^3)	169	85.6	46.4	565
PM_{10} (μg/m^3)	53.8	16.9	20.6	85.72
Rainfall (mm)	251.8	136.7	1.0	1087
Relative humadity (%)	77.3	18.3	56.1	91.3
Temperature (°C)	27.2	5.4	21.6	34.7
Wind speed (m/s)	1.6	0.9	0.0	8.07

Table 2. Correlation (r value) between Air Pollutants and Meteorological Parameter at all site

Pameter	SO_2	CO	NO_2	O_3	Pb	TSP	PM_{10}	Rainfall	Humadity	Temp	Wind Speed
SO_2	1										
CO	0.381**	1									
NO_2	0.384**	0.282**	1								
O_3	0.262**	0.196*	0.478**	1							
Pb	0.315**	0.177*	0.527**	0.470**	1						
TSP	0.161	0.394**	0.138**	0.107	0.355**	1					
PM_{10}	0.196*	0.317**	0.060	0.276**	0.164*	0.471**	1				
Rainfall	0.115	0.142	-0.059	-0.230**	-0.121	0.082	-0.037	1			
Humadity	0.080	-0.114	-0.009	-0.273**	-0.094	-0.058	-0.001	0.381**	1		
Temp	0.078	0.203*	0.115	0.288**	0.353**	0.373**	0.492**	-0.284**	-0.407**	1	
Wind speed	-0.151	-0.165*	0.039	0.149	-0.038	0.18	0.215**	-0.324**	-0.483**	0.083	1

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

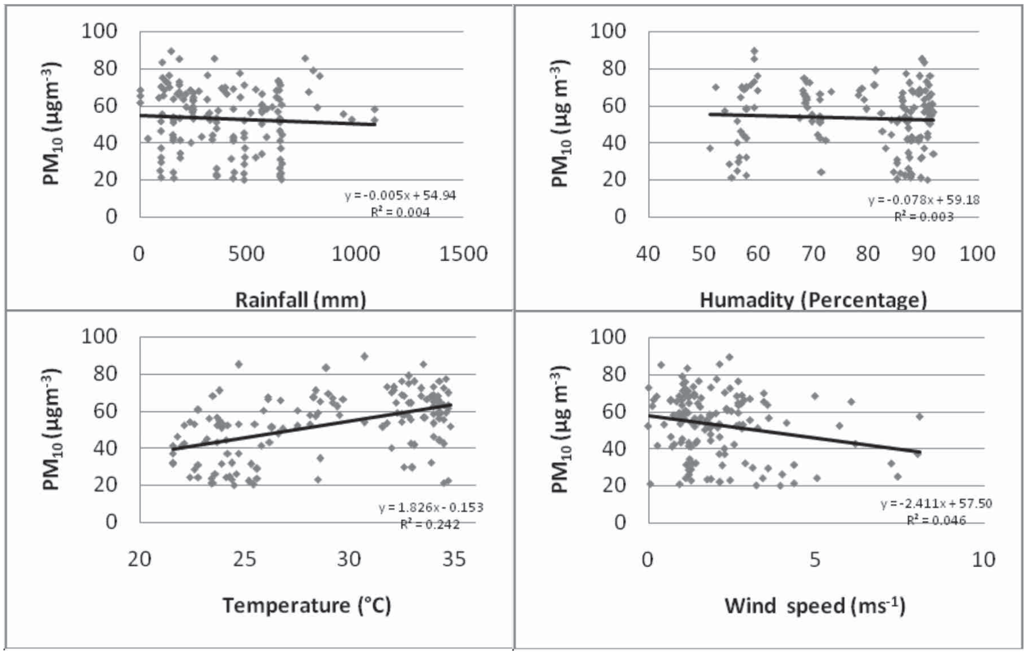

Fig. 2. Trend and correlation between PM_{10} and meteorology

60% - 65 % of the wind, comes from the west. From the eight sampling sites namely Pelabuhan, Pannampu, Sumiharjo, Daya, hertasning, mattoanging, karebosi and makassar mall (Fig. 3) it can be deduced that PM_{10} comes from the WSW, WEST, NORTH, NW, SOUTH, WEST, WEST, EAST, respectively. Malaysia, India, Indonesia and other countries have analyzed Industry and vehicle to being the major source of PM10 (Rahman *et al*., 2011; Kothai *et al*., 2008; Lestari and Mauliadi, 2008; Santoso *et al*., 2008).

CONCLUSION

In Makassar city, the correlation between rainfall and pollutants are negative correlation. However, those between rainfall and SO_2, and those between rainfall and TSP were positive correlation. In terms of relative humidity, all pollutants were negatively correlated apart from those between the relative humadity and SO_2 which were positively correlated. On the contrary, correlation between temperature and pollutants shows positive correlation, while for wind speed and pollutants there were positive

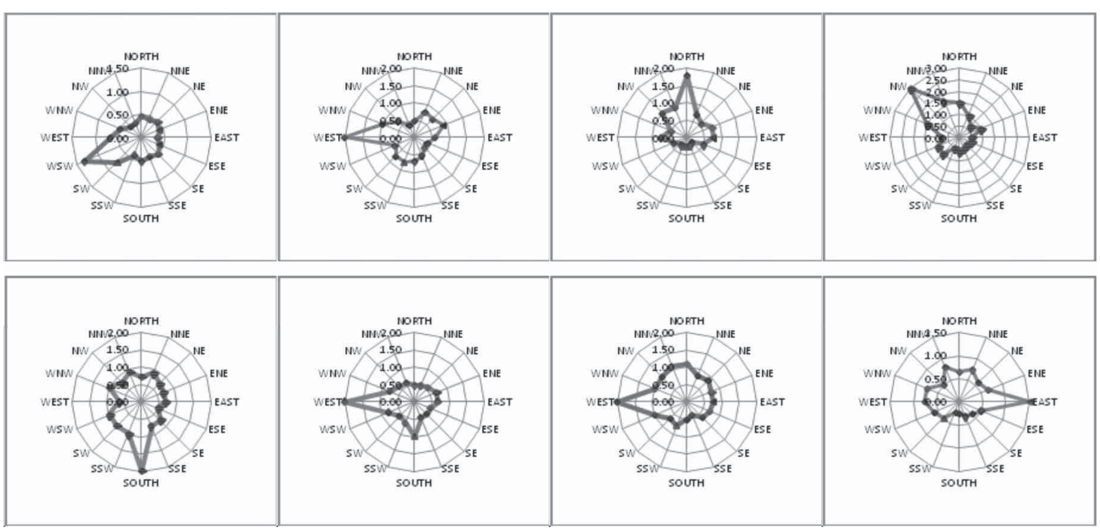

Fig. 3. Polar plots of CPF for the highest 25% of PM_{10} for the all sampling sites in Makassar

correlations (wind speed and NO_2,O_3,TSP). Negative correlation was wind speed and SO_2, wind speed and CO, wind speed and Pb as well as wind speed and PM_{10}. Wind from the east, west-southwest, south, west, north, northwest remained dominant throughout the study. The results showed that rainfall, humidity, temperature and wind (wind speed, wind direction) are the most important factors influencing the pollutants concentrations in Makassar city.

ACKNOWLEDGMENT

The authors wish to express their profound gratitude to the Governor of the South Sulawesi Province, Indonesia for their financial support and for the approval of this study under the contract No. 410.5/PD4/1112a/2010.

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