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Assessment of ambient particulate matter and trace gases in the Makassar urban area South Sulawesi Province of Indonesia

[1]Sattar Yunus, [2]Kusno Kamil, [3]Nani Anggraini, [4]Ramdiana Muis, [5]Rani Bastari Alkam

[1]Universitas Muslim Indonesia, Department of Mechanical Engineering, Makassar-90231

[3]Universitas Bosowa, Department of Environmental Engineering, Makassar-90231

[4]Universitas Muhammadiyah, Department of Urban and Regional Planning, Pare-Pare-91131

[5]Universitas Muslim Indonesia, Department of Civil Engineering, Makassar-90231

Abstract - This paper presents monitoring results on Air Quality of ambient in Makassar City South Sulawesi Province, Indonesia namely SO2, CO, NO2, O3, TSP, PM10 which is the average annual collected during the five years 2014 - 2019. The data are obtained from measurements made by the office of the Ministry of Environment Sulawesi, Maluku, and Papua and the Environment Board of the Province of South Sulawesi as well as the Environment agency of Makassar City. These three institutions are in a coordinated manner and responsible for the monitoring of air quality in Makassar. Subsequently, these values are compared to the air quality threshold recommended by the Indonesia National Ambient Air Quality Standards (INAAQS) and guidelines based on the World Health Organization (WHO). The results indicate that there are several pollutants that exceed the standard in a given year, but the most important to be attention is TSP and PM10. Efforts and strategies should be taken continuously to achieve clean and healthy air.

Index Terms - Air Quality, Air Pollutants, TSP, PM10

INTRODUCTION

Urban air pollution affects the health, well-being, and life of hundreds of millions of men, women, and children in the Asia region. It is responsible for approximately 537,000 premature deaths annually, with indoor air pollution being responsible for over double this number of deaths (WHO, 2002), Several studies were reported that air pollution seems to have various malign health effects in human life (Manucci and Franchini, 2017; Saini et al., 2018; Sattar et al., 2020). it requires special attention from both public and the government (Sattar. et al. 2012; Stafoggia et al., 2016; Masiol et al., 2017; Sattar et al., 2019; Sattar et al., 2021). The main cause of urban air pollution is the use of fossil fuels in transport, power generation, industry, and domestic sectors. In addition, the burning of biomass such as firewood, agricultural and animal waste also contributes to pollution levels (Schwela et al., 2006; Sattar et al., 2014). The rapid industrial development created more job opportunities and at the same time generating more revenue for a country. On the other hand, the impact of industrial development and activity is the reason for causing air pollution in many areas.

Many countries of the world have made great efforts to improve air quality through the adoption of clean air acts especially on the criteria of air pollutants such as carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxides (NO_2), particulate matter (PM_{10}) and ozone (O_3). As such, continuous air quality monitoring is being initiated to quantitatively measure and assess the level of air pollution in city centers where the major sources of air pollution are usually found.

Rashid and Griffiths (1994) used a source apportionment technique and successfully resolved that automobiles were one of the five major sources of air pollution in the Kuala Lumpur area. A study that has been conducted on elementary school students in Bandung of Indonesia found that a high level of lead in the blood of the school children was mainly due to vehicles emission, and it was recommended to eliminate the use of fuels containing lead in Indonesia (Lestari, 2005).

Makassar is the capital city of South Sulawesi Province. Makassar region is one of the important cities outside Java Island, as the traffic center connects the west and the east of Indonesia. All flight destinations from west to east and vice versa must transit in Makassar and being the most attractive of all regions in Sulawesi Island for the development of arriving and local tourism. Makassar is dense with development, industry, and transportation activities (Rashid et al., 2014; Muis et al, 2021; Anggraini et al, 2021). It is one of the major cities in Indonesia that full of urban activities. It is the gate and barometer to the development of Eastern Indonesia. Like other major cities in Indonesia, the growth and situation of Makassar portray the progress of development in all sectors. This may reduce the green space, which ultimately leads to negative impacts primarily on the environment. Studies on air pollution are very limited in Makassar South Sulawesi. This paper presents a review of the ambient air quality monitoring over a period of five years at selected sites in Makassar.

AMBIENT AIR QUALITY MONITORING IN INDONESIA

Air quality is one of the environmental components, which is easy to be influenced by the impact of urbanization. Air is an important factor in life but the increase of physical development in towns along with industrial activities has caused the change of air quality. Environmental changes are generally caused by air pollution, namely the entry of contaminants in the form of gases and particles into the air (Environment Board of the Province of West Java, 2009). In Indonesia, the monitoring of air quality 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, 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 central government of Indonesia sets ambient air quality standards as an attempt to control or minimize air pollution such as those from mobile and stationary sources. Although the Indonesia Air Quality Standards (IAQS) is available, each region could establish its own ambient air quality standards that are more stringent than the IAQS. The Province of South Sulawesi adopted a similar value as in the IAQS. Table 1 presents the list of the Indonesia Air Quality Standards (Ambient Standards) in comparison to the WHO Guidelines.

Table I. Indonesia's National Ambient Air Quality Standards and WHO Guidelines

Pollutant	Average Time	INAAQS	WHO Guidelines
SO_2 (µg/m^3)	1 hour	900	-
	24 hour	365	20
	1 year	60	-
CO (µg/m^3)	1 hour	30,000	30,000
	24 hour	24,000	-
	1 year	-	-
NO_2 (µg/m^3)	1 hour	400	200
	24 hour	150	-
	1 year	100	40
O_3 (µg/m^3)	1 hour	235	-
	8 hour	-	100
	1 year	50	-
Pb (µg/m^3)	24 hour	2	-
	1 year	1	0.5
TSP or SPM (µg/m^3)	24 hour	230	-
	1 year	90	-
PM_{10} (µg/m^3)	24 hour	150	50
	1 year	-	20

Sources; Department of Environment, 1999; World Health Organization, 2000

The ambient air quality standard is based on individual pollutants and the concentration at which they become harmful to public health and the environment. The standards are typically set without regard to the economic feasibility for attainment. Instead, they focus on public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly, and public welfare, including protection against decreased visibility and damages to animals, vegetation, aquatic resources, and buildings.

Indonesians Air Pollution Standard Index (APSI) 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. Table 2 presents the APSI values with respect to the air quality status and level of pollutants and health measurement in Indonesia.

Table II. APSI values with level of pollution and health measurement

Category	Range	Explanation
Good	0 - 50	The level of Air Quality that does not affect human health or animal and has no effect to plant, building, or aesthetic value
Medium	51 - 100	The level of Air Quality that does not affect human health or animal but affects sensitive plant and aesthetic value
Unhealth	101 - 199	The air quality levels that are harmful to humans or groups of animals that are sensitive or may cause damage to the plant or aesthetic value
Very unhealthy	200 - 299	The air quality levels that can harm health on a number of segments population exposed
Hazardous A	Above 300	Levels of hazardous air quality in general to serious adverse health on a population

Source; Department of Environment, 1999

MATERIALS AND METHODS

A. Sampling site description

South Sulawesi Province is one of the 34 provinces throughout Indonesia. Makassar City is the capital city of South Sulawesi Province. Based on the geographical location of Makassar City, it has regional boundaries namely the north of Maros Regency, South of Gowa Regency, West of Makassar Strait, and Eastern of Maros Regency. The area of Makassar City is 175.77 sq km which includes 15 sub-districts. This city is one of the cities in Indonesia which is densely populated by urban activities and it is a city that is developing very rapidly outside of Java. Population projections based on the population of Makassar City for 2019 are 1,508,154 people, consisting of 746,951 males and 761,203 females. When compared to the population of Makassar city in 2018, the population growth of Makassar City was 1.29 percent with each percentage of male population growth of 1.43 percent and female population of 1.36 percent. The number of industries in Makassar is 145 industries (base metals, fabricated metal products, chemicals, and chemical products, food and beverage products, textiles and apparel, wood and wood products, etc.). The number of vehicles operating in Makassar until October 2019 reached 1,563,608 units (1,156,759 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 resulted in land use for the need for housing and industrial areas which causes a reduction in green open space (RTH) which functions as the lungs of the city in cleaning the air, therefore unnatural air conditions will have an impact on the population living in the city of Makassar. In this study the sampling point measurement of ambient air carbon monoxide, namely Andi Pangeran Pettarani and Sultan Alauddin street. The sampling sites are illustrated in Figure 1. The sampling locations are very congested with motorized vehicles and all roadsides are full with buildings in the form of offices and business areas or shops and almost no more green open space.

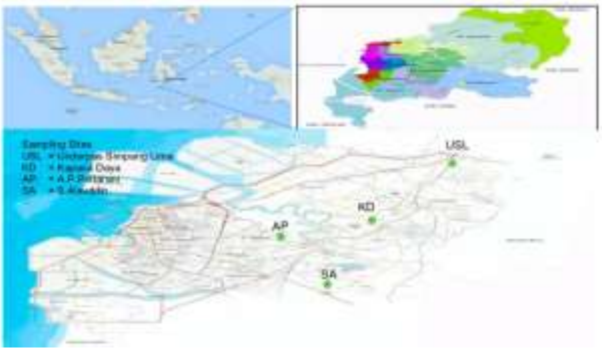

Fig.1 Location of the sampling sites in Makassar.

B. Sampling and data collection

The measurements of the ambient air quality in Makassar involve SO_2, CO, NO_2, O_3, TSP, PM_{10} were monitored from 2014 to 2019. The data reported in this paper are obtained from the office of the Ministry of Environment Sulawesi, Maluku, and Papua and the Environment Board of the Province of South Sulawesi, and also the Environment agency of Makassar City.

Sulfur dioxide (SO_2) is measured by pararosanilin method using a spectrophotometer, carbon monoxide (CO) by using Non-Dispersive Infrared Analyser (NDIR), Nitrogen dioxide (NO_2) by Saltzman method, Ozone (O_3) by Neutral buffer potassium iodine (NBKI), Total Suspended Particulate (TSP) and Particulate Matter < 10um or PM_{10} by Gravimetric Method (Bapedal, 1999).

RESULT AND DISCUSSION

In Makassar, there are three institutions that perform the monitoring of air quality, and these are the Office of Ministry of Environment Sulawesi, Maluku, and Papua and Environment Board of the Province of South Sulawesi as well as the Environment agency of Makassar City.

Table 3 presents the summary of the average concentration of pollutants, their standard deviations, and ranges found at each of the sampling sites i.e Underpass Simpang Lima (USL), Kapasa Daya (KD), Andi Pangeran Pettarani (AP), Sultan Alauddin (SA).

The annual average concentration of ambient SO_2 was recorded at Underpass Simpang Lima (USL), Kapasa Daya (KD), Andi Pangeran Pettarani (AP), and Sultan Alauddin (SA). respectively are 51.1 µg/m^3 (8.60 -124 µg/m^3), 87.8 µg/m^3 (29.3 - 209 µg/m^3), 68.3 µg/m^3 (15.1 - 162 µg/m^3), 83.3 µg/m^3 (23.5 – 184 µg/m^3. The annual average concentration of ambient SO2 recorded at four sites, three sites have been exceeded the Indonesia Air Quality Standard for SO_2 (60 µg/m3) namely Kapasa Daya, Andi Pangeran Pettarani, and Sultan Alauddin, just at Underpass Simpang Lima still below the National Indonesia Air Quality Standard, even at Kapasa Daya was far above the standard. Kapasa Daya is an area of dense vehicles because there are traditional markets, besides that it is near several big factories in Makassar Industrial Estate. SO_2 is usually the result of industrial activities, motor vehicles, and the combustion of Sulphur containing fossil fuels used in power generation (Ilyas, 2007; Pereira et al, 2007; Bade et al, 2009). Besides that, it is due to the composition of the sulfur compound, particularly from biomass burning (Clairac et al, 1988).

Table III. Average pollutant concentration at four different sites in Makassar from 2014-2019.

Parameter	Site	Average	Standard Deviation	Ranges	INAAQS	WHO Guidelines
SO_2 (µg/m^3)	USL	51.1	36.7	8.60 – 124	60	-
	KD	87.8	56.9	29.3 – 209		
	AP	68.3	49.2	15.1 – 162		
	SA	83.3	63.9	23.5 – 184		
CO (µg/m^3)	USL	866	600	166.1 – 1833	-	-
	KD	1,123	543	329.1 – 1832		
	AP	1,221	558	290.8 – 3709		
	SA	942	590	656.7 – 1692		
NO_2 (µg/m^3)	USL	31.6	19.4	10.3 – 68.5	100	40
	KD	47.8	25.1	12.4 – 91.8		
	AP	32.5	12.3	18.3 – 51.7		
	SA	33.1	6.3	15.5 – 36.9		
O_3 (µg/m^3)	USL	55.4	17.7	23.1 – 78.6	50	-
	KD	65.1	22.4	27.5 – 91.7		
	AP	64.8	58.7	29.4 – 136		
	SA	39.9	16.8	20.8 – 83.5		
TSP (µg/m^3)	USL	173	62.0	83.8 – 241	90	-
	KD	163	68.5	83.8 – 275		
	AP	168	69.7	46.4 – 231		
	SA	187	95.1	57.3 – 329		
PM_{10} (µg/m^3)	USL	64.6	19.3	37.1 – 85.7	-	20
	KD	61.3	13.7	41.7 – 72.7		
	AP	46.2	18.0	25.5 – 66.2		
	SA	53.6	18.5	28.3 – 76.4		

INAAQS = Indonesia National Ambient Air Quality Standard

Annual averages ambient of Carbon monoxide (CO) was clearly recorded at a higher concentration at Andi Pangeran Pettarani with average value of 1,221 µg/m^3 (290.8 – 3,709 µg/m^3) compared with Underpass Simpang Lima (866 µg/m^3, 166.5 – 1,833 µg/m^3), Kapasa Daya (1,123 µg/m^3, 329,1 – 1,832 µg/m^3), Sultan Alauddin (942 µg/m^3, 66.7 – 1,692 µg/m^3). Andi Pangeran Pettarani is an area with of density vehicles that high. Indonesia has not adopted an annual standard for CO. Carbon monoxide (CO) is a colorless, odorless, tasteless, and at much higher levels, poisonous gas. It is produced by the incomplete burning of carbon in fuels. The highest CO concentrations occur in close proximity to motor vehicles emissions (Liu et al., 1994; Chaloulakou et al., 2002; Duci et al., 2003).

Annual averages ambient of NO_2 a higher concentration at Kapasa Daya with a value of 47.8 µg/m^3 (12.4 – 91.8 µg/m^3) compared with Underpass Simpang Lima (31.6 µg/m^3, 10.3 – 68.5 µg/m^3), Andi Pangeran Pettarani (32.5 µg/m^3, 18.3 – 51.7 µg/m^3), Sultan Alauddin (33.1 µg/m^3, 15.5 – 36.9 µg/m^3. NO_2 concentrations are still relatively low, below the Indonesian Air Quality Standard for NO_2 (100 µg/m^3). However, if used as guidelines based on The World Health Organization (WHO), it is demonstrated that at Kapasa Daya have been exceeded the standard, where the standard for NO_2 is 40 µg/m^3. Whereas Underpass Simpang Lima, Andi Pangeran Pettarani, and Sultan Alauddin are below WHO standard. Nitrogen dioxide (NO_2) are emitted from automobiles, and from combustion processes (Hill, 2004; Ilyas, 2007; Vallero, 2008; Bade et al, 2009).

The annual O3 concentrations were recorded more high concentration at Kapasa Daya with the value of 65.1 µg/m^3 (27.5 – 91.7 µg/m^3) compared with Underpass Simpang Lima (55.4 µg/m3, 23.1 – 78.6 µg/m3), Andi Pangeran Pettarani (64.8 µg/m^3, 29.4 – 136 µg/m^3), There are three sites above the Indonesian Air Quality Standard for O3 (50 µg/m^3), namely Underpass Simpang

Lima, Kapasa Daya, and Andi Pangeran Pettarani while Sultan Alauddin under the standard. Ground-level ozone (O_3) is considered a pollutant. O_3 is secondary pollution and is not emitted directly into the air by pollution sources. O_3 is formed through the reaction of volatile organic compounds (VOCs) and NOx in the presence of sunlight. The main sources of VOCs and NOx are vehicles (Hill, 2004; Fardiaz, 1992; DOE, 2005)

The annual average concentration of ambient Total Suspended Particulates (TSP) was recorded at Underpass Simpang Lima, Kapasa Daya, Andi Pangeran Pettarani, Sultan Alauddin. respectively are 173 $\mu g/m^3$ (83.8 – 241 $\mu g/m^3$), 163 $\mu g/m^3$ (83.8 – 275 $\mu g/m^3$), 168 $\mu g/m^3$ (46.4 – 231 $\mu g/m^3$), 187 $\mu g/m^3$ (57.3 – 329 $\mu g/m^3$). The annual average concentration of ambient TSP recorded at all sites has been exceeded the National Indonesia Air Quality Standard for TSP (90 $\mu g/m^3$), a higher concentration at Sultan Alauddin compared to the other sites. Sultan Alauddin is dense with vehicles and commercial areas. whereas WHO Guidelines do not have value for the TSP with an average time of measurement of a year. Especially of air quality monitoring for PM_{10} in five years that is from 2014 – 2019, The annual average concentration of ambient PM_{10} recorded at Underpass Simpang Lima, Kapasa Daya, Andi Pangeran Pettarani, Sultan Alauddin. are 64.6 µg/m3 (37.1 – 85.7 µg/m3), 61.3 (41.7 – 72.7 $\mu g/m^3$), 46.2 µg/m3 (25.5 – 66.2 $\mu g/m^3$), 53.6 µg/m3 (28.3 – 76.4 $\mu g/m^3$. Indonesia does not have an annual standard for PM_{10}, thus compliance of the data with a national standard cannot be undertaken. However, if it is based on WHO Guidelines, all sites have been exceeded the annual standard for PM_{10} (20 µg/m3). The influence of a Particulate (TSP, PM_{10}, $PM_{2.5}$), especially size particulate around 0.3 - 10 µm is very dangerous for health (DOH, 2009), the main source of particulate matter (PM) is Industrial activities, vehicles emission, biomass burning (Hill, 2004; Tiwary and Colls, 2010; Haynes et al., 2010).

Based on the results of air quality monitoring has been produced in the Makassar city ten years 2014- 2019. It shows that there are several sites that exceed the Indonesia National Ambient Air Quality Standard (INAAQS), therefore starting in 2007 central government through the Office of Environmental Management Sulawesi, Maluku, and Papua (Region III), Governor of South Sulawesi as well as Mayor of Makassar have made efforts for the prevention and control of air pollution to achieve clean and healthy air in the Makassar city. The program is called “ Go Green “ namely trees planting in the around house, office, schools, and university at Makassar city. Another program will be held in which the community is invited to ride bikes together every Saturday. It is known as the “Relax Bicycle” program. Thus, it may reduce the congestion and emission from vehicles. Besides that, The government is continuously monitoring the vehicles emission level under the program “ Blue Sky “.

CONCLUSION

The annual averages concentrations of SO_2, CO, NO_2, O_3, TSP, and PM_{10} in five years monitoring of the period 2014 – 2019, which was conducted at four sites, representing the Makassar city. The results demonstrate that there are some pollutants that have exceeded the Indonesia air quality standard (INAAQS) and standard of WHO guidelines. Total Suspended Particulates and PM_{10} at all sites have exceeded both of the standards. Thus, Total Suspended Particulates and PM_{10} must get more attention and need further study. Therefore, efforts and strategies should be undertaken by the government and society to achieve better air quality levels, especially in Makassar city.

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REFERENCES

[1] Anggraini, N., Muis, R., Ariani, F., Sattar, Y, and Syafri, “Model of Solid Waste Management (SWM) in Coastal Slum Settlement: Evidence for Makassar City,” Nature Environment and Pollution Technology, vol. 20 no.2, pp. 459-466, June 2021.

[2] Bader N.A., Nassehi, V., Khan, A.R, “PSO2 and NOX Emissions from Kuwait Power Stations in Years 2001 and 2004 and Evaluation of the Impact of These Emissions on Air Quality Using Industrial Sources Complex Short-Term (ISCST) Model,” Water Air Soil Pollution 203, pp. 169-178, 2009

[3] Bapedal,”Guide Ambient Air Testing Methods,” 770, 1999.

[4] CAI – Asia. “Indonesia; Air Quality Profile, Manila.(Online)”, Http//www/Scribd.com/doc/Indonesia_Air_Quality_Profile_2010_Edition , Assessed July 2021.

[5] Chaloulakou,A., Duci A., Spyrellis,N., “Exposure to carbon monoxide in enclosed multi level parking garages in central Athens urban area,” Indoor Built Environment, vol .11, pp. 191-201, 2002.

[6] Clairac, B., Delmas, R., Cross B., Cachier H., Buat-Menard,P., Servant,J., “Formation and chemical composition of atmospheric aerosols in an equatorial forest area,” Atmospheric Chemistry, vol 6, pp.301-322.

[7] Department of Enviornment, Indonesia, “Indonesia Environment Status Report 2002”, 2002.

[8] Department of Environment, Indonesia, “Government Decree No.41/1999,Air Pollution Control,” 1999.

[9] Department of Environment, Indonesia, “Proceeding of Fuel Quality Monitoring in 10 Big Cities in Indonesia,” 2005.

[10] Department of Health, Indonesia, “Parameters Pollution on the Air and Effect to the Health”, (Online) http://www.depkes.go.id, In assessed July 2021.

[11] Duci,A., Chaloulakou,A., Spyrellis,N, “Exposure to carbon monoxide in Athens urban area during commuting,” The Science of the Total Environment 309, pp. 47 – 58, 2003.

[12] Environment Agency of Makassar City., “Air Quality Data,” 2014 – 2019.

[13] Environment Board of the Province of South Sulawesi, “Air Quality Data,” 2014 – 2015.

[14] Environment Board of the Province of West Jawa, “The Pollution on the Air From Transportation Sectors,” http://www.bplhjabar.go.id, In assessed September 2021.

[15] Fardiaz, S., “The Air Pollution and Water”, Jogjakarta, Karnisius, 1992.

[16] Haynes. E.N., Heckel. P., Ryan. P., Roda. S., Leung. Y.K., Sebastian. K., Succop, “Environmental Manganese Exposure in Residents Living near a Ferromanganese Refinery in Southeast Ohio; A pilot Study,” NeuroToxicology, vol 31, pp. 468 – 474. 2010.

[17] Ilyas, Z.S., “A Review of Transport and Urban Air Pollution in Paksitan,” Science Environment Management, vol.11, pp.113 – 121, 2007.

[18] Lestari, P., “Research of Blood Lead Level Test for Students in Bandung,” http://www.kbpp.org/Makalah_ind/Penelitian, Timbel Kota bandung 2005, assessed July 2021.

[19] Liu,J.J., Chan, C.C., Jeng,F.T., “Predicting personal exposure level to carbon monoxide (CO) in Taipei, based on actual CO measurement in microenvironments and a Monte Carlo simulation method,” Atmospheric Environment, vol.28, pp. 2361 – 2368, 1994.

[20] Manucci PM, Franchini M., “Health effects of ambient air pollution in developing countries. Int J Environ Res Public Health,” 2017, 14:1048. doi: 10.3390/ijerph14091048

[21] Masiol, M., Hopke, P.K., Felton, H.D., Frank, B.P., Rattigan, O.V., Wurth, M.J., LaDukeb, G.H., “Analysis of major air pollutants and submicron particles in New York City and Long Island,” Atmospheric Environment.148, pp.203-214, 2017.

[22] Muis, R., Anggraini, N., Ariani, F., Sattar, Y., and Zulkifli, “Survey of Environmental Baseline in the Nunukan Agriculture Area, Indonesia,” Nature Environment and Pollution Technology, vol.20 no.1, pp. 237-242, March 2021.

[23] Office of Ministry of Environment Sulawesi, Maluku and Papua, “Air Quality Data 2014 – 2019”.

[24] Pereira, M.C., Santos, R.C., Alvim-Ferraz, M.C.M., “Air Quality improvements using European environment policies a case study of SO2 in a coastal region in Portugal. Toxicology Environment Health,”, 70, pp.347 – 351, 2007.

[25] Rashid M, Sattar,Y.,Ramli, M., Sabariah., and Puji, L., “PM10 black carbon and ionic species concentration of urban atmospheric in Makassar of South Sulawesi Province, Indonesia.” Atmospheric Pollution Research.5, pp. 610-615, 2015. doi: 10.5094/APR.2014.070.

[26] Rashid, M. & Griffiths, R.F., “Source of aerosol in the Kuala lumpur area,” Proceeding of the 8th Annual Conference of the Aerosol Society United Kingdom, York Univesity, pp.131-136, 1994.

[27] Saini M., Rusdi, N., Sattar, Y., Ibrahim., “The Influence of Throat Length and Vacuum Pressure on Air Pollutant Filtration Using Ejectors,” AIP Conference Proceedings, 2018. doi.org/10.1063/1.5042939.

[28] Sattar Y, M. Rashid, M. Ramli and B. Sabariah.., “Black carbon and elemental concentration of ambient particulate matter in Makassar Indonesia,” IOP Conf.Series: Earth and Environmental Science, 18, 2014. 012099: doi: 10.1088/1755-1315/18/1/012099.

[29] Sattar Y, Makmur S, Rizal S, Rusdi N and Ibrahim, “The Effect of Ejectors on Reduction of Indoor Air Pollution in the Welding Room,” Nature Environment and Pollution Technology, vol. 19 no.4, pp.1695-1699, 2020.

[30] Sattar Yunus., Mohd. Rashid., Ramli Mat., Sabariah Baharun and Hasfalina C. Man., “Characteristics of The PM10 In The Urban Environment of Makassar, Indonesia,” Journal of Urban and Environmental Engineering, vol.13 no.1, pp.198-2017, 2019. doi; 10.4090/juee.2009.v13n1.198207.

[31] Sattar, Y., Fitri, A., Nani, A., Ramdiana, M., and Syarifuddin, A., “Total Suspended Particulate Matter And PM10 Concentrations Related Meteorological Conditions In Daya, Makassar,” Indian Journal of Environmental Protection, vol. 41. no.7, pp.790-795, 2021.

[32] Sattar., M Rashid., R Mat., and L Puji., “A Preliminary Survey of Air Quality in Makassar City South Sulawesi Indonesia,” Jurnal Teknologi (Sciences & Engineering), 57 pp.123-136, 2012.

[33] Schwela.D.,Haq.G., Huizenga.C., Ham.W.H., Fabian.H, Ajero. M., “Urban Air Pollution in Asian Cities,” UK. Earthscan, 2006.

[34] Tiwary, A and Colls, J., “Air Pollution: Measurement, Modelling and Mitigation,” (3rd ed) UK: Routledge, 2010.

[35] Vallero, D., "Fundamental of Air Pollution.(4thed.)" UK:Elseiver, 2008.

[36] WHO, "In; Air Quality Guidelines for Europe," WHO Regional Publications, European Series, Second ed, vol.91 WHO, Copenhagen, 2000.

[37] WHO., "The World Health Report 2002," Reducing Risks, Promoting Health Life, WHO, Geneva, 2002