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A PRELIMINARY SURVEY OF AIR QUALITY IN MAKASSAR CITY SOUTH SULAWESI INDONESIA

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Abstract. Makassar has a strategic position as it is located in between the south and north in the provinces of South Sulawesi. Thus, the rapid growth of urbanization and industrialization within the area is unavoidable, resulting Makassar to be an area of mixed commercial-residential-industrial along with the problem of air pollution. Hence, it is important to monitor the quality of air in Makassar. This paper presents a preliminary survey of urban air quality in Makassar area based on SO_2, CO, NO_2, O_3, Pb, and TSP (Total Suspended Particle) sampled over ten years period (2001 to 2010), while PM_{10} was monitored for five years (2006 to 2010). The air quality data were obtained from measurements made by the Office of Ministry of Environment Sulawesi, Maluku and Papua and Environment Board of the Province of South Sulawesi as well as Environment agency of Makassar City. The average annual concentrations of SO_2, CO, NO_2, O_3, Pb, TSP and PM_{10} recorded were 76 μg/m^3 , 1041 μg/m^3, 43.2 μg/m^3 , 54.5 μg/m^3, 0.7 μg/m^3, 188 μg/m^3, 54.6 μg/m^3, respectively. Subsequently, these data are compared to the air quality threshold limits recommended by the Indonesia National Ambient Air Quality Standard (INAAQS) as well as guidelines of the World Health Organization (WHO).

Keywords: Air quality; sulfur dioxide; carbon monoxide; nitrogen dioxide; ozone; lead; total suspended particulate; Makassar city

Abstrak. Makassar mempunyai kedudukan strategik kerana terletak diantara selatan dan utara di wilayah Sulawesi Selatan. Dengan demikian, pertumbuhan yang cepat daripada urbanisasi dan perindustrian di kawasan tersebut tidak dapat dielakkan, sehingga Makassar menjadi kawasan campuran komersial-perumahan-industri bersama-sama dengan masalah pencemaran udara. Oleh kerana itu, adalah penting untuk memantau kualiti udara di Makassar. Kertas kerja ini melaporkan kajian awal tahap pencemaran udara bandar di kawasan Makassar berdasarkan SO_2, CO, NO_2, O_3, Pb, TSP dalam jangkamasa sepuluh tahun (2001-2010) dan PM_{10}dipantau selama lima tahun (2006-2010). Data diperolehi dari ukuran yang dilakukan oleh Pejabat Kementerian

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Alam Sekitar Sulawesi, Maluku dan Papua dan Dewan Persekitaran Hidup Daerah Sulawesi Selatan serta lembaga Persekitaran Bandar Makassar. Kepekatan purata tahunan SO_2, CO, NO_2, O_3, Pb, TSP and PM_{10} mencatatkan 76 μg/m^3, 1041 μg/m^3, 43.2 μg/m^3, 54.5 μg/m^3, 0.7 μg/m^3, 188 μg/m^3, 54.6 μg/m^3 masing-masing. Selanjutnya data ini dibandingkan dengan tahap kualiti udara yang di syorkan oleh *Indonesia National Ambient Air Quality Standard* (INAAQS) dan *World Health Organization (WHO)*.

Kata kunci: Kualiti udara; sulfur dioksida; karbon monoksida; nitrogen dioksida; ozon; plumbum; Jumlah Zarah Terampai (TSP), Bandar Makassar

1.0 INTRODUCTION

Urban air pollution, with its long- and short-term impacts on human health, well-being and environment, the main cause of urban air pollution is the use of fossil fuels in transport, power generation, industry and domestics sector. In addition, the burning of biomass such as firewood, agricultural and animal waste also contributes to pollution level [1]. The rapid industrial development created more job opportunity and the same time generated more revenue for a country. On the other hand, the impact of industrial development and activity is the reason for causing the air pollution in many areas.

Five criteria pollutants are being monitored many countries namely 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. In the developing countries such as Malaysia and Indonesia, the old-age vehicles have been badly maintained hence became the main source of air pollution in many cities. For an example; with using a source apportionment technique and successfully resolved that automobile was one of the five major sources of air pollution in Kuala Lumpur area [2]. A study that has been conducted on elementary school students in Bandung of Indonesia found that a high level of lead in 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 [3].

The currently air pollution is an important issue. 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 has an area 175.77 km square, with total population in the year 2009 is 1,273,349 people. Number of Industry in Makassar is 135 Industri (Basic

metal, fabricated metal products, chemicals and chemical products, food products and beverages, textil and wearing apparel, wood and products wood etc). Number of vehicles operating in Makassar 843,473 unit (passenger mobile 102,027 unit;bus mobile 16,691 unit; truck car 43,145 units; motorcycles 681,269). The rapid growth of urbanization and industrialization this may reduce the green space and contribute to the air pollution problem that will impacting the residents who live in the Makassar city. Studies on air pollution are very limited in Makassar. This paper presents a preliminary survey of the ambient air quality over a period of ten years at selected sites in Makassar. Details on the air pollution trends are reported in this paper.

2.0 AMBIENT AIR QUALITY MONITORING IN INDONESIA

The monitoring of ambient air quality are carried out in ten major cities in Indonesia namely Jakarta, Bandung, Semarang, Surabaya, Denpasar, Medan, Pekanbaru, Jambi, Pontianak, Palangkaraya [4]. The city of Makassar South Sulawesi Province is also included in the monitoring program.

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 National Ambient Air Quality Standards (INAAQS) is available, each region could establish its own ambient air quality standards that are more stringent than the INAAQS. The Province of South Sulawesi adopted a similar value as in the INAAQS. Table 1 presents the list of the Indonesia Air Quality Standards (Ambient Standards) in comparison to the WHO Guidelines [5],[6].

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. 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.

Table 1 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

Unit : (μg/m^3)

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 [5].

3.0 MATERIALS AND METHODS

3.1 Sampling Site Description

Makassar is located between 119º24´38" East longitude and 5º8´19" South latitude this regency bounded by Maros Regency at the North Side, Maros Regency at the East Side, Gowa Regency at the South Side, and Makassar Strait at

the West Side. The area of Makassar is 175,77 Square km Which include 14 district (Figure 1).

Table 2 APSI values with level of pollution and health measurement

Category	Range	Explanation
Good	0 - 50	The level of Air Quality that does not affect to human health or animal and no effect to plant, building or aesthetic value
Medium	51 - 100	The level of Air Quality that does not affect to human health or animal but effect to sensitive plant and aesthetic value
Unhealthy	101 – 199	The air quality levels that are harmful to humans or group 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	Above 300	Levels of hazardous air quality in general to serious adverse health on population

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

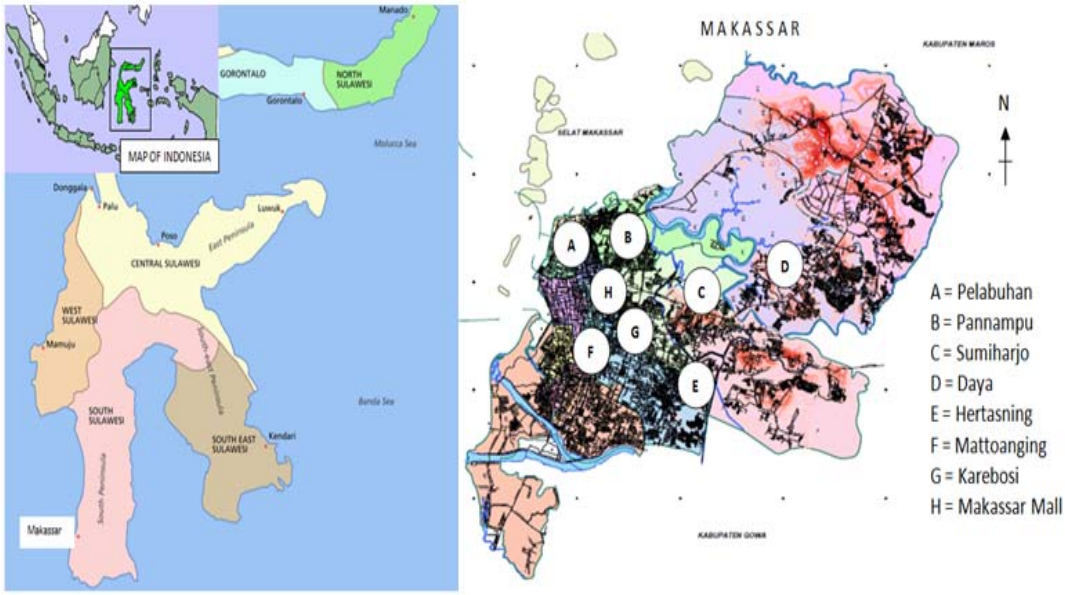

Figure 1 Map of Sulawesi Island, the sampling sites in Makassar

3.2 Sampling Methods

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

4.0 RESULTS AND DISCUSSION

Table 3 presents average pollutant concentration for all sites in Makassar including its standard deviation and ranges through out the sampling period.

Table 3 Average pollutant concentration during the periods of 2001-2010

Parameter	Average	Standard Deviation	Range	INAAQS	WHO Guidelines
SO_2	76	51.7	8.6 – 253	60	-
CO	1041	534	66.7 –3709	-	-
NO_2	43.2	21.1	10.3 – 99.5	100	40
O_3	54.5	27.8	17.3 – 226	50	-
Pb	0.7	0.37	0.14 – 2.28	1	0.5
TSP	188	85.6	46.4 – 565	90	-
PM_{10}	54.6	16.9	20.6 – 85.72	-	20

INAAQS = Indonesia National Ambient Air Quality Standard; WHO = World Health Organization
Unit : ($\mu g/m^3$)

The average concentration of SO_2, CO, NO_2, O_3, Pb, TSP and PM_{10} in Makassar was 76 ± 51.7 $\mu g/m^3$, 1041 ± 534 $\mu g/m^3$, 43.2 ± 21.1 $\mu g/m^3$, 54.5 ± 27.8 $\mu g/m^3$, 0.70 ± 0.37 $\mu g/m^3$, 188 ± 85.6 $\mu g/m^3$, 54.6 ± 16.9 $\mu g/m^3$, respectively. The overall average of sulfur diokside (SO_2) exceeded the Indonesian Air Quality Standard for SO_2 (60 $\mu g/m^3$). Indonesia and WHO guidelines do not have an standard of carbon monokside (CO), therefore compliance of the data with standard cannot be undertaken. The concentrations of nitrogen diokside (NO_2) was still relatively low, below the Indonesian standard (100 $\mu g/m^3$), however exceeded WHO guideline (40 $\mu g/m^3$). The overall average O_3 concentrations was slightly above the Indonesian Air Quality Standard for O_3 (50 $\mu g/m^3$). While the average concentration of Pb was below the Indonesian Air Quality Standard (i.e 1 $\mu g/m^3$), and WHO (i.e 0.5 $\mu g/m^3$). However, TSP exceeded more than twice the Indonesian Air Quality Standard of 90 $\mu g/m^3$. Similarly, the PM_{10} concentrations exceeded the WHO guidelines limits of 20 $\mu g/m^3$.

Table 4 presents the yearly average pollutant concentration measured through out the city area, while Figure 2 presents the graphical view of the yearly trends of pollutants from 2001 to 2010 (except for PM_{10} only from 2006 to 2010) at all sites in Makassar, which shows their respectives of either upward or downward trends.

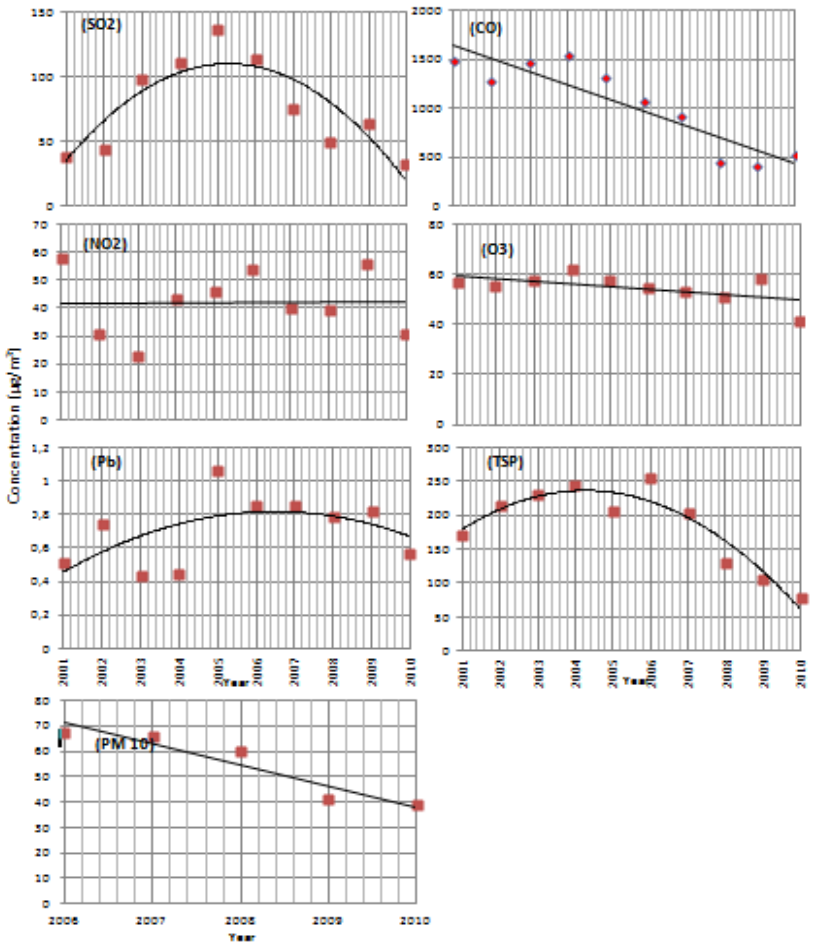

Figure 2 Yearly trends of pollutant concentration for all sites in Makassar

As shown in Figure 2, the SO_2, CO, TSP and PM_{10} showed a marked downward trends through out the years. While other pollutants (i.e NO_2, O_3 and Pb) did not seem to show any significant trends or remain the same through out the years. These pollutats are much related to automobile emissions (also CO), and their concentrations seemed to remain consistent in the ambient air.

Since July 2006, the effort to reduce lead content in gasoline has been enforced in Indonesia [7]. Evidently, the ambient Pb showed a declining trend beginning 2006. Makassar city recorded among the highest Pb concentration in Indonesia back in 2005 [8]. In addition, the effort made by the government of relocating two

bus stations (Panaikang and Mallengkeri) to the edge of the city in 2007, widening the higways and constructing of fly-overs has tremendously allevaited the air pollution problem in the city. Furthermore, program seeks to encourage members of the community to ride bikes every Saturday known as "bicycle relax" program was also iniatiated. Of course all these efforts reduced the number of vehicles in downtown also reduce vehicle emission including ambient of Pb and CO.

Table 4 The yearly average pollutant concentrations from 2001- 2010

Para meter	YEAR									
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
SO_2 ($\mu g/m^3$)	37.6 ± 13.9	43.9 ± 24.0	97.9 ± 62.0	110 ± 16.0	136 ± 38.6	113 ± 68.9	75.1 ± 57.7	48.7 ± 29.9	63.5 ± 32.7	31.6 ± 4.72
CO ($\mu g/m^3$)	1,479 ± 469	1,280 ± 408	1460 ± 302	1537 ± 276	1315 ± 218	1061 ± 369	914.5 ± 408	447 ± 373	404 ± 336	524 ± 173
NO_2 ($\mu g/m^3$)	57.6 ± 14.1	30.6 ± 5.3	22.8 ± 13.3	43.3 ± 11.6	45.6 ± 12.6	54.0 ± 29.5	39.9 ± 19.7	39.6 ± 22.7	55.7 ± 25.9	30.7 ± 11.8
O_3 ($\mu g/m^3$)	56.9 ± 69.5	55.4 ± 18.3	57.5 ± 19.3	61.8 ± 14.0	57.3 ± 26.2	54.2 ± 19.5	53.4 ± 19.9	50.8 ± 17.1	58.5 ± 22.1	41.6 ± 19.7
Pb ($\mu g/m^3$	0.51 ± 0.29	0.74 ± 0.33	0.43 ± 0.10	0.45 ± 0.15	1.06 ± 0.65	0.85 ± 0.43	0.85 ± 0.45	0.75 ± 0.52	0.82 ± 0.31	0.57 ± 0.28
TSP ($\mu g/m^3$)	171 ± 60.3	215± 47	231 ± 10.0	244 ± 49.6	207 ± 17.0	255 ± 149	204 ± 62.9	130 ± 31.0	106 ± 30.8	78.5 ± 22.3
PM_{10} ($\mu g/m^3$)	-	-	-	-	-	67.6 ± 8.17	65.7 ± 11.2	59.8 ± 4.68	41.1 ± 13.5	38.7 ± 16.5

± = Standard Deviation

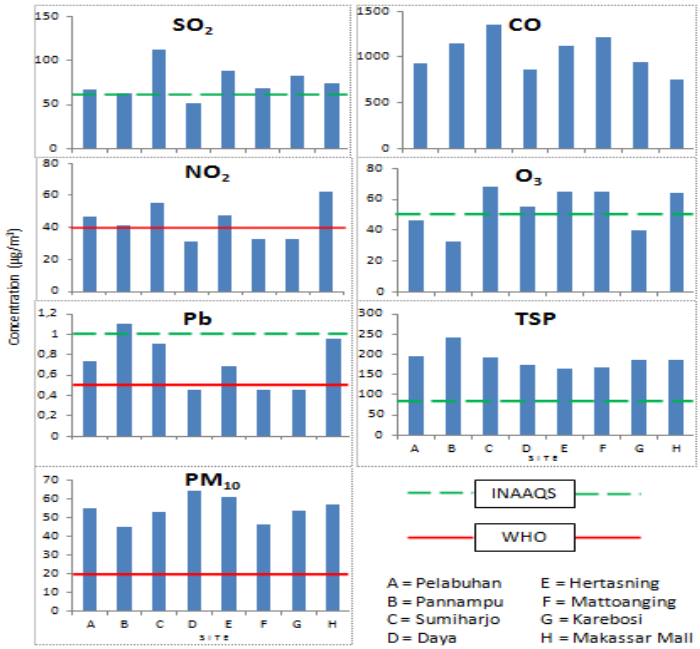

Figure 3 The yearly average pollutant concentration at eight locations

Table 5 presents the summary of the average concentration of pollutants, standard deviation and ranges of pollutant concentrations at each of the specific site namely Pelabuhan (A), Pannampu (B), Sumiharjo (C), Daya (D), Hertasning (E), Mattoanging (F), Karebosi (G), Makassar mall (H), while the graphical representation of data is given in Figure 3.

As in Figure 3, the average concentration of ambient SO_2, CO and O_3 recorded the highest at Sumiharjo compared to the other sites. Sumiharjo is a densed vehicular area apart that it is where the Sermani Steel Corporation and Barawaja Iron Factory are located, in addition to the power plant at Tello about 3 kilometers. It was observed that the concentration of SO_2 at all sites have been exceeded the Indonesian Air Quality Standard for SO_2 (60 µg/m^3) except at Daya which is still below the Indonesian Air Quality Standard. The presence of SO_2 in the air is usually as a result of industrial activities mainly from the combustion of sulphur containing fossil fuels used in power generation [9][10][11]. Also it is as a result of the biomass burning [12].

Carbon monoxide (CO) is a colorless, odorless, tasteless and at much higher levels, a poisonous gas. It is produced by incomplete burning of carbon in fuels. The highest CO concentrations occur in close proximity to motor vehicles emissions [13][14][15].

As for the concentration of O_3, there are five sites recorded above the Indonesian Air Quality Standard for O_3 (50 μg/m^3), namely Sumiharjo, Daya, Hertasning, Mattoanging and Makassar mall. Ground level ozone (O_3) is considered as a pollutant. Ozone is secondary pollutant and is not emitted directly into the air by pollution sources. It is formed through the reaction of volatile organic compounds (VOCs) and NOx in the presense of sunlight. Emission from vehicles is the main source of VOCs and NOx [16].

In general, the NO_2 concentration are still relatively low for all eight sites, below the 100 μg/m^3 of the INAAQS level. However, based on the WHO guidelines, it is demonstrated that NO_2 at Pelabuhan, Pannampu, Sumiharjo, Hertasning and Makassar mall has exceeded the 40 μg/m^3 level, but not at Daya, Mattoanging and Karebosi.

The Pb and TSP recorded the highest concentration at Pannampu compared to the other sites. The concentration of Pb at all other sites was below the Indonesian Air Quality Standard. Pannampu is a commercial area and dense with vehicles. Thus, emission from motor vehicles using lead gasoline is the main source of Pb pollution especially in the urban environment.

The average concentration of ambient TSP recorded at all sites exceeded the Indonesian Air Quality Standard of 90 μg/m^3.The TSP concentration recorded at Pelabuhan, Pannampu, Sumiharjo, Daya, Hertasning, Mattoanging, Karebosi and Makassar mall were 196 μg/m^3, 241 μg/m^3, 193 μg/m^3, 173 μg/m^3, 163 μg/m^3, 168 μg/m^3, 187 μg/m^3 and 185 μg/m^3, respectively. These were all sigficantly high compared to the limits.

The average concentration of ambient PM_{10} recorded at Pelabuhan, Pannampu, Sumiharjo, Daya, Hertasning, Mattoanging, Karebosi and Makassar mall was 55.5 μg/m^3, 45.3 μg/m^3, 52.9 μg/m^3, 64.6 μg/m^3, 61.3 μg/m^3, 46.2 μg/m^3, 53.6 μg/m^3 and 57.2 μg/m^3, respectively. Indonesia has yet to have a standard for PM_{10}, however, based on WHO guidelines, the all sites were violating the guideline limits of 20 μg/m^3. The impact of particulate matter (TSP,PM_{10},$PM_{2.5}$), especially particulate of lower sizes range from 0.3 - 10 μm, is very dangerous for health [17], Industrial activities, vehicles emission, biomass burning are among the main sources of particulate matter [18][19].

Table 5 The summary of the average concentration of pollutants and standard deviations at each of the sampling sites

Parameter	SITE								INAAQS	WHO Guidelines
	A	B	C	D	E	F	G	H		
SO_2 ($\mu g/m^3$)	66.8 ± 33.6	63.4 ± 16	112 ± 75.3	51.1 ± 36.7	87.8 ± 56.9	68.3 ± 49.2	83.3 ± 63.9	74.2 ± 51.5	60	-
CO ($\mu g/m^3$)	926 ± 484	1,144 ± 623	1348 ± 458	866 ± 600	1123 ± 543	1221 ± 558	942 ± 590	755 ± 178	-	-
NO_2 ($\mu g/m^3$)	47.1 ± 20.8	41.5 ±7.8	55.1 ±26.9	31.6 ± 19.4	47.8 ± 25.1	32.5 ± 12.3	33.1 ± 6.3	62.2 ± 25.3	100	40
O_3 ($\mu g/m^3$)	46.1 ± 11.1	32.9 ± 7.13	67.8 ± 19.3	55.4 ± 17.7	65.1 ± 22.4	64.8 ± 58.7	39.9 ± 16.8	64.3 ± 17.8	50	-
Pb ($\mu g/m^3$)	0.73 ± 0.32	1.1 ± 0.56	0.91 ± 0.41	0.45 ± 0.18	0.69 ± 0.30	0.46 ± 0.20	0.46 ± 0.25	0.96 ± 0.49	1	0.5
TSP ($\mu g/m^3$)	196 ± 92.8	241 ± 144	193 ± 64.6	173 ± 62.0	163 ± 68.5	168 ± 69.7	187 ± 95.1	185 ± 64.0	90	-
PM_{10} ($\mu g/m^3$)	55.5 ± 15.5	45.3 ± 22.4	52.9 ± 16.9	64.6 ± 19.3	61.3 ± 13.7	46.2 ± 18.0	53.6 ± 18.5	57.2 ± 5.8	-	20

INAAQS = Indonesia National Ambient Air Quality Standard; WHO = World Health Organization
A = Pelabuhan, B = Pannampu, C = Sumiharjo, D = Daya, E = Hertasning, F = Mattoanging, G = Karebosi, H = Makassar mall

5.0 SUMMARY AND CONCLUSION

The preliminary survey of the ambient concentrations of SO_2, CO, NO_2, O_3, Pb, TSP monitored over ten years i.e from 2001 – 2010 and PM_{10} from 2006 – 2010 at eight locations in Makassar city were reported in this paper. The average annual concentrations of SO_2, CO, NO_2, O_3, Pb, TSP and PM_{10} recorded was 76 $\mu g/m^3$, 1041 $\mu g/m^3$, 43.2 $\mu g/m^3$, 54.5 $\mu g/m^3$, 0.7 $\mu g/m^3$, 188 $\mu g/m^3$, 54.6 $\mu g/m^3$, respectively. The study showed that the SO_2, CO, TSP and PM_{10} showed a marked downward trends during the sampling years while other pollutants (i.e NO_2, O_3 and Pb) did not seem to show any significant trends or remain the same through out the years. However, some of the selected pollutants had exceeded the Indonesia National ambient air quality standard or WHO guidelines at several sites i.e at Pelabuhan (these were SO_2, TSP and PM_{10}), Pannampu (SO_2, NO_2, Pb,

TSP and PM_{10}), Sumiharjo (SO_2, NO_2, O_3, TSP and PM_{10}), Daya (O_3, TSP and PM_{10}), Hertasning (SO_2, NO_2, O_3, TSP and PM_{10}), Mattoanging (SO_2, O_3, TSP and PM_{10}), Karebosi (SO_2, TSP and PM_{10}) and Makassar mall (SO_2, NO_2, O_3, TSP and PM_{10}). Therefore, more efforts and strategies should be taken by the local relevant authority and society to attain good air quality levels within the city area of Makassar.

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