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Air Pollution Effects on Aircrafts Movement in and Around Airport: Solutions and Recommendations (Case Study: Djalaluddin Airport, Gorontalo, Indonesia)

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Abstract: The study was conducted by collecting information/data from Djalaluddin airport, Gorontalo, Indonesia in order to measure, prevent or minimize the air pollution impacts on airports and its surrounding, such that air pollution impacts can be managed and monitored effectively and efficiently not only in the current situation but also in the future conditions. The data used were primary and secondary data. The primary data were based on field survey, interview and discussion with official government and people who live next to the airport while secondary data was based on data collected from various agencies, namely the directorate general of air transport department, the statistic central bureau and so on. Analytical tools used to measure the passenger and aircrafts movement by regression analysis and air pollution impacts by Gaussian Plume formula. The solutions and recommendations of the study were based on the information of distinctive standard, technology, procedures methods and tools regarding to the air pollution measures from data collected. In general, the solutions and recommendations of this study can be summarized that air pollution impacts at almost measured points were still below the range of air pollution standards; beside aircraft take-off and landing, air pollution impacts also comes from vehicles traffic activities, not only to/from airport but also from traffic flows in and around airport, caused by housing area located next to the airport, such that this conditions influence the airport operation activities.

Key words: Air pollution, aircrafts movement, airport operation, technology, Indonesia

INTRODUCTION

Transportation development sector has an important role and strategic in supporting, encouraging and supporting all aspects of life in economic, social, cultural, political and defense security and so on. Air transportation sub-sector in Indonesia is important, due to the very broad region separated by many islands. The integrated of air transport management system should be supported by the improving of human, technical and technology resources quality (Adisasmita, 2007a-c, 2012, 2013). The one of the airports in Indonesia is Djalaluddi airport, Gorontalo Province. Even though, Djalaluddin airport is small comparing with other airports in Indonesia but its located in Kapet Batui known as Batui integrated economy region (between Central Sulawesi and North Sulawesi Provinces), located in a strategic location as a transit areas of all commodities. Djalaluddin airport, Gorontalo is the main entrance in Kapet Batui region, such that the airport is expected to provide good services in terms of technical, environmental, safety, security and comfort. Djalaluddin airport development is expected to support the demand for passenger, aircraft and cargo movements. The increasing number of passengers, aircrafts and cargoes will affect the level of regional income and welfare. Airport operations is estimated to have an impact on the surrounding airport, both effects are positive or negative, so the impact of airport operations needs to be managed either by increasing the positive impacts and minimize the negative impacts (Anonymous, 1997). Djalaluddin airport continues in development to meet the needs of airport service quality. The purpose of this study is to identify the air pollution impact towards the airport operation activities and assessing the solution and recommendations to prevent and tackle the air pollution problems.

Airport operations and air pollution: On the operational activities, the impacts sources on air quality comes from a machine burning activities, vehicles or aircrafts on airports and its surroundings and also people activities. Also, an operational airport will have an impact on gas emissions into the atmosphere, such that needs to reduce gas emissions into the atmosphere. Convention on the Kyoto protocol Article 1 and 2 require that greenhouse gas emissions of civil aviation and shipping activities which are not regulated in the montreal protocol must be controlled by the International Aviation organization and the International Maritime organization without exception. In Indonesia already ratified the Kyoto protocol in Law No. 17, year of 2004 (Adisasmita, 2007a).

Contribution of aircraft engines for global warming can be minimized through control of CO_2 (by reducing the burning of fuel) and emissions of NO_X, CO_2 and H_2O which is the main emissions generated by a turbine engine aircraft while NO_X carbon monoxide and unburned hydrocarbon emissions is the second. Civil aviation sector up to now contribute about 3% of global carbon dioxide emissions from a total of 10% derived from air transport sector.

Analysis of atmospheric pollution is always associated with the analysis use of energy sources due to emissions of gases that are exposed either fuel for aircraft engines, vehicle at the airport as well as for energy power plants (Adisasmita, 2007b).

The amount of combustion products are distributed into the atmosphere depends on the type of aircrafts and engines, phase or mode of operation and how long the engine operated in each phase. Operation phase of aircraft includes take-off or silent at place with the engine life; climb (since raised to a height of 3000 ft); dived (from 3000 ft to touch the ground) and landed (Boeing, 2008; David, 1995; Ghobrial and Kanafani, 1995).

Air pollution is the most serious environmental impacts caused by airport operations. Air pollutants can be caused by particles, carbon monoxide; photochemical oxidants; nitrogen oxide; sulfur dioxide and hydrocarbons. Air pollution at airports can be sourced on the aircraft exhaust fumes; distribution of aircraft fuel; aircraft refueling systems; passengers vehicles, employees and visitors; ground service equipment; heating plant; evaporation of fuel spilled during refueling and emissions from combustion gases in the incinerator (Ashford and Wright, 1992).

Air quality is one of the impacts in activities both in the airport construction and operation. To know the environmental situation of air quality at the site and surrounding, measurement should be taken at several airport locations using low volume sampler equipment. The samples were analyzed by standard methods in the laboratory to determine the amount of SO_2, CO, NO_x, O_3, dust, lead (Pb) and hydrocarbons parameters levels (Anonymous, 2003).

The SO_2, sulfur dioxide emissions arose mainly from burning of fossil fuels which containing of sulfur can cause asthma attacks and since this gas settled in the air, react to perform particles and acid. Based on the results of field measurements showed that levels of SO_2 in the entire site was above 26.15 $A\mu g\ m^{-3}$. This condition was below the air quality standard in accordance to the government rules No. 41, 1999 amounting to 900 $A\mu g\ m^{-3}$.

NO_2, nitrogen oxides occured when the heat of combustion causes the union of oxygen and nitrogen, contained in the air could give a variety of hazards. After reacting in the atmosphere will perform nitrate particles that penetrate the part of lungs if joined with water in lung or water vapor in clouds will perform acid. NO_2 also reacts with unburned of gasoline fumes and other hydrocarbon substances in sunlight to perform low ozone or smog (reddish-brown fog) covering most of the cities in the world. Based on the results of field measurements indicated that the levels of NO_2 at all sites was below 10-15.62 $A\mu g\ m^{-3}$. This condition was below the ambient quality standard in accordance to the government rules No. 41, 1999 amounting to 400 $A\mu g\ m^{-3}$.

Traffic fumes are a source of almost carbon monoxide (CO) released in many urban areas. Therefore, levels of carbon monoxide should be decreased, the strategy were mainly depends on the auto emission controls such as catalytic converter which converts most of carbon monoxide into carbon dioxide. Most of the world's developing countries has increased in carbon monoxide levels, represented in vehicles and traffic density. Based on the results of WHO studies, shown that carbon monoxide was routinely reaches unhealthy levels in many cities, can lead to small fetal weight, increased infant mortality and brain damage. Based on the results of field measurements indicated that CO levels at all sites was below 1,000 $A\mu g\ m^{-3}$. This condition was below the ambient air quality standard in accordance to the government rules No. 41, 1999 amounting to 30,000 $A\mu g\ m^{-3}$.

The O_3 Ozone, consisting of hundreds of chemical substances contained in foq smoke, performed when hydrocarbons concentrated in urban areas react with nitrogen oxides. Scientists regard as the most toxic of air pollutants. Based on the results of field measurements showed that levels of O_3 at all sites ranged from 1.22-3:24 $A\mu g\ m^{-3}$. This condition was below the ambient air quality standard in accordance to the government rules No. 41, 1999 amounting to 235 $A\mu g\ m^{-3}$.

Hydrocarbons (HC) is sometimes referred to as volatile organic compounds, as well as reactive organic gases. Hydrocarbons are unburned gasoline fumes and by-products of incomplete combustion. Other types of hydrocarbons which in part led to leukemia, cancer or other serious diseases, as a liquid to wash and dry for clothes to fat-loss agent for the industry. Based on the results of field measurements indicated that levels of hydrocarbons in the entire site was approximately

6.53 Aμg m^{-3} and the highest at the point of 13.06 Aμg m^{-3} at sampling locations on the apron. This condition was below ambient air quality standard in accordance to the government rules No. 41, 1999 amounting to 160 Aμg m^{-3}.

Dust is a common name for a number of particles with a diameter of <500 μm. In Earth's atmosphere, dust comes from several sources, i.e., loess, volcanic eruptions, pollution, etc. Air-dust is considered, as an aerosol and could have strong local radiation energy in the atmosphere and climate affect. Dust responsible for causing lung diseases, such as pneumoconiosis. Based on the results of field measurements showed that the highest dust levels at the apron which was equal to 53.62 Aμg m^{-3}. This condition was below ambient air quality standard in accordance to the government rules No. 41, 1999 amounting to 230 Aμg m^{-3}.

Lead (Pb) is from smoke exhaust or vehicles emission. During the process of combustion, partial of volatile fuel (Pb), accumulate in the ash particles as smoke. Pb metal concentrations will arise significantly followed by a decrease in particle size that is wasted in the atmosphere. In the water, Pb concentration is not stable due to the dynamic nature of water, depending on environment and climate. Pb in the excess of threshold can cause brain toxicity. Based on the results of field measurements showed Pb levels at all locations were below 0.02 Aμg m^{-3}. This condition was below the ambient air quality standard in accordance to the government rules No. 41, 1999 which equal to 2 Aμg m^{-3}.

Regulations: In Indonesia environmental regulations refers to government law No. 23, 1997 on environmental management; government regulation No. 27, 1999 on environmental impact assessment; government regulation No. 41, 1999 on air pollution control; ministerial rules, including environmental ministerial decree No. 02/MENKLH/1/1998 on guidelines for environmental quality standards; transport ministerial decree No. 44, 2002 on on national airport management and No. 50, 2004 djalaluddin airport masterplan; head of environmental agency decision, including Kep.299/11/1996 on technical on guidelines for social aspects study in preparation of environmental impact assessment; Kep.124/12/1997 on public health guidelines in preparation of environmental impacts analysis; directorate general of air transport decree, including directorate general of air transport decree No. 124/V/2009 on guidelines for environmentally friendly airport (Eco airport); regulation of Gorontalo Province, including regional regulation No. 5, 2004 on environmental management in gorontalo province and International regulations, including Annex 16, ICAO on environmental management; airport planing manual part 2 on land use and environmental control.

MATERIALS AND METHODS

Gorontalo region is strategic, viewed from economic aspect because located on the center of economic growth regions between 2 Integrated Economic Zone, i.e., Batui, Central Sulawesi and Bitung, Manado, North Sulawesi provinces. This strategic location can be used as transit areas of all commodities to and from the 2 integrated economic zone. As a result of commodities, flows activities gives positive benefits towards economic activities in North Sulawesi, Central Sulawesi, Southeast Sulawesi and South Sulawesi Provinces. In addition, Gorontalo also located on the line of Pacific Ocean adjacent to the country of Korea, Japan and Latin America which will gives good opportunity to the business and trades development. Overall Gorontalo Province has an area of 12,215.44 km². When compared to the Indonesia region, an area of the province amounted to only 0.64%. Gorontalo Province consists of 5 regencys and 1 city, namely: Gorontalo, Pohuwato, Bone Bolango Regencys and Gorontalo City. Djalaluddin airport located in the city of Gorontalo Province. Gorontalo Province is located in the Northern island of Sulawesi, directly adjacent to the North Sulawesi Province in the East and Central Sulawesi Province in the West while its Northern face the sea of Sulawesi and the South by the Gulf of Tomini (Anonymous, 2004). Map of Indonesia and Gorontalo shown in Fig. 1.

Fig. 1: Map of Indonesia and Gorontalo

The data used were primary and secondary data. The primary data were based on field survey, interview and discussion with official government and people who live next to the airport while secondary data was based on data collected from various agencies, namely the directorate general of air transport department, the statistic central bureau and so on. The analytical tools used to measure the passenger and aircrafts movements was regression analysis and air pollution impacts was Gaussian Plume formula. In this study, survey conducted and measured the number of traffics during peak hours from 7:00 a.m., until 16:00 in November, 2013 to predict of maximum emission value on roads in and around airport.

RESULTS AND DISCUSSION

Infrastructure and means of airport: Airport infrastructure consists of airside and landside areas where the runway areas is 2,500×45 m, taxiway A 115×23 m and taxiway B 115×23 m and apron 230×80 m. At the existing conditions, number of arrival and departure aircraft movements were 5,710 aircrafts annually and arrival, departure and transit passenger movements were 264,320 passengers annually (Anonymous, 2004, 2010). It is predicted in 2025, using regression model, number of arrival and departure aircraft movements are 7,640 aircrafts and arrival, departure and transit passenger movements are 696,517 passengers.

Air quality of airport: The following of layout and air quality measurment results at Djalaluddin airport and its surroundings presented in Fig. 2, Table 1 and 2 (Anonymous, 1999).

Thus, based on the analysis results showed that all parameters were still earlier the ambient air quality standard in accordance to government rules No. 41, 1999 on air pollution control.

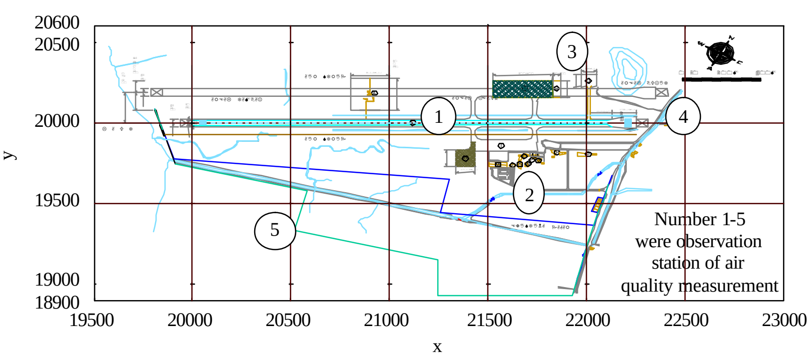

Fig. 2: Layout of Djalaluddin airport

Table 1: Air quality analysis results

	Results						
Parameters (μg m^{-3})	1	2	3	4	5	Air quality*	Methode
Sulfur dioxide (SO_2)	30.23	28.36	<26.15	<26.15	27.16	900/1H	Pararosanilin
Carbon monoxide (CO)	1000	1000	<1000	<1000	<1000	30000/1H	Electrochemical
Nitrogen dioxide (NO_2)	15.62	12.54	<10.00	<10.00	<10.00	400/1H	Saltzzman
Hydrocarbon (CH_4)	13.06	6.53	<6.53	<6.53	<6.53	160/1H	Flame Ionization
Dust particulate	53.62	39.86	38.14	33.14	34.78	230/24H	Gravimetric
Ozon (O_3)	3.24	2.06	1.48	1.22	1.38	235/1H	Chemiluminescent
Lead (Pb)	<0.02	<0.02	<0.02	<0.02	<0.02	2/24H	AAS

Analysis results; *government rules No. 41, 1999

Table 2: Meteorological data of ambient air quality measurements results

	Results				
Description	1	2	3	4	5
Temperature (°C)	32.6-33.2	32.8-34.1	31.9-33.8	32.1-33.9	30.4-31.2
Relative humidity (%)	38.6-40.7	42.7-47.2	41.9-46.8	40.7-44.8	39.2-40.8
Wind speed (m sec^{-1})	0.7-1.3	0.7-1.0	0.7-1.0	0.7-1.0	0.7-1.0
Wind direction (-)	SW-NE	SW-NE	SW-NE	SW-NE	SW-NE
Weather (-)	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy

Analysis results; 1 = Apron (00° 38' 19.68' LU, 122° 51' 05.6" BT); 2 = Parking area (00° 38' 22.4" LU, 122° 51' 01.3" BT); 3 = DPPU (00° 38' 23.9" LU, 122° 50' 47.8 "BT); 4 = Up-wind (00° 38' 07.4" LU, 122° 51' 39.0" BT); 5 = Down-wind (00° 38' 30.7" LU, 122° 50' 43.6" BT)

Table 3: Vehicles traffic at peak hours

	No. of units per locations/sites (at peak hours)				
	B1	B2	B3	B4	B5
Vehicle types	12.00-13.00	12.00-13.00	11.00-12.00	11.00-12.00	10.00-11.00
Motorcycle	649	126	328	248	249
Car	110	42	131	205	144
Truck	25	35	4	25	36
Bus	4	0	0	2	2
Bicycle	27	7	14	18	5
Bentor	413	75	176	218	41
Total	1,228	285	653	1,649	1,677

Field survey results; B1 = To/from airport; B2 = Jl. Isimu-Bangomeme; B3 = Jl. Isimu-Kwandang; B4 = Jl. Isimu-Paguyaman; B5 = Jl. Isimu-Limboto

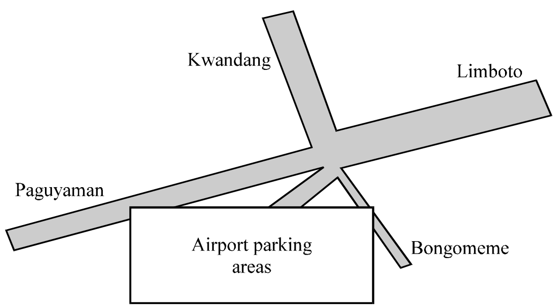

Fig. 3: Accsess road in and around airport

Airport operation activities: On the operational activities, the impacts sources on air quality comes from a machine burning activities, vehicles or aircrafts on airports and its surroundins and also people activities. Especially for vehicles, the impacts derived from vehicles movements in and around airport. The vehicles traffic at peak hours and layout of access road shown in Table 3 and Fig. 3.

Based on number of vehicles movements, it can be determined the concentration of each parameters in the air at a certain distance by each vehicle types at some location (point). The formula uses is Gaussian Plume Model (Adisasmita, 2009).

$$C(x, y = 0, z = H) = \frac{Q}{22\ \text{¶}\ V\ \hat{I}y\ \hat{I}z}\left\{1 + \exp\left[\frac{-(2H)^2}{2\hat{I}z^2}\right]\right\}$$

Where:

- C = Values of pollutant ambient (ug m^{-3})
- Q = Values of pollutant emission (ug sec^{-1})
- V = Average wind speed (m sec^{-1})
- $\hat{I}fy$ = Horizontal dispersion coefficient (m) Pasquill-Gifford curves
- $\hat{I}fz$ = Vertical dispersion coefficient (m)
- H = Emission source height (m)

With reference to the earlier formula and wind speed data for 3 m sec^{-1}, so will find the estimates of ambient concentrations produced by vehicles at certain distance. Based on the calculations results, the levels of all parameters of each type of vehicles in all locations of roads were still within the safe limits for the receiving area for a minimum distance of 100 m where the values for all parameters were still in the range of quality standart accordance to government rules No. 41, 1999 equals to 160 Aμg m^{-3} for hydrocarbons, 400 Aμg m^{-3} for NO_2 and 30,000 Aμg m^{-3} for carbon dioxide. The highest contribution in producing these emissions comes from the motorcycles.

As for the impact sources from aircraft emissions occured during approach, taxi-in, idle, taxi-out and take-off. At the approach, values of Hydro Carbons (HC) will increase while values of NO_x will increase when aircrafts take-off, idle and RON (Remain Over Night). At idle, aircrafts use APU (Auxiliary Power Unit) to operate the air conditioning and lighting. Similarly, if the aircrafts stop over, then the next day it will require electric propulsion energy from the GPU (Ground Power Unit). The values of potential global warming of hydrocarbons was 21 times greater than CO_2 and NO_x was 310 times greater than CO_2. Overall gas will comes out as emissions and mixes with ambient air.

To calculate the value of ambient air quality due to aircraft movements at Djalaluddin airport, required characteristic data of aircraft engine emissions (landing and take-off) at the airport (refer to ICAO). The pollutants dispersion on the atmosphere was affected by several things, including pollutants sources, meteorological conditions, atmospheric stability conditions and characteristics of the receiving areas. In this study, it is known that for aircraft activities, required safe distance from the sources to the receiver at least as far as 200 m where the cumulative concentration of NO_x, HC and CO were 370, 45.25 and 478.93 Aμg m^{-3}, respectively. These values were still below the quality standard in accordance with the government rules No. 41, 1999 on control of air pollution. Thus, the calculation results on the ground-traffic and air-traffic showed that the closer sources distance of the pollutant, the greater pollutant concentration received. The safe distance for humans as recipient was about 200 m.

Even though, the air pollution in and around Djalaluddin airport were below the air quality standard but prevention pollution action, environmental management and monitoring its better done before exceed the air quality standard, such that airport operator could anticipate the solutions in near future.

CONCLUSION

The solutions in this study were introduce local and global environment friendly airport which can reduce the air quality impacts and reduce the emission of atmosphere pollutants and greenhouse gases for local environment friendly airport, the efforts are no open burning of garbage, etc., for atmosphere component, restrictions of aircraft movements, use quiter aircraft, prevention of falling objects from aircraft and monitoring air quality while for global environment friendly airport, the efforts are using electrical power consumption, GPU usage drive, introduction of low-pollution vehicles, implement co-generation systems and solar power generation and stop engine idling campaign.

RECOMMENDATIONS

The recommendations in this study were preparing the environmental management plan, done with technological approaches, such as limiting the age of the aircraft operating. The recommended age of aircrafts not >10 years and plant crops that have ecological and aesthetic functions, such as trees planting (shrubs and flowers) around parking areas. Trees planting functioning as an ornamental (aesthetic), also to reduce the air pollution, especially CO_2 and produces O_2, such as trees of cape, sea pines, mahogany, sengon and other trees; social approaches, such as requiring workers at airport to wear protective equipment, i.e., mask covering the nose and institutional approaches, such as cooperation with department of transportation agency in Gorontalo to test the mobile source emission/vehicles and in collaboration with departments of hygiene and environmental in terms of planting and maintenance of shade trees. The period of environmental management of air quality at least 6 months or 2 times a year and reforestation carried out periodically with a period of at least 1 years during the airport operation (depend on green plants conditions), preparing environmental monitoring plan where the impacts sources occur on take-off the aircrafts and vehicles traffic growths in line with the airport operation. The environmental component parameters monitored were air quality pollutant parameters consisting of dust, SO_2, CO, NO_2, CH_4, O_3 and Pb. The period of environmental monitoring plan of air quality at least 6 months or 2 times a year.

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