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Benefit Analysis of Implementation of Alternative SO_2 Quality Standards on Acute Respiratory Infections (ARIs) Incidence Reduction in Indonesia

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Abstract

Indonesia Quality Standard (QS) for ambient SO_2 for 1 hour time average i.e. 900 μg/m^3 (equivalent to 360 μg/m^3 in 24 hour time average) regulated in the Government Regulation No. 41 of 1999 is the most loose compared to the ambient SO_2 standards of other countries in the world including WHO QS guideline. This QS is not expected to guarantee the protection of public health in Indonesia. Therefore more stringent QS alternative for ambient SO_2 is required. This research examines benefit values in public health aspect if Indonesia tightens its ambient SO_2 QS. Two alternative QS for SO_2 are used i.e 196 μg/m^3 (equivalent to 78 μg/m^3 in 24 hour time average) referring to U.S. EPA and 750 μg/m^3 (equivalent to 360 μg/m^3 in 24 hour time average) referring to Pusat Sarana Pengendalian Dampak Lingkungan Hidup (PUSARPEDAL). First step is to map distribution of SO_2 ambient concentrations in Indonesia. The result indicates that Provinces of Jakarta and Banten have exceeded both alternative QS while Provinces of Yogyakarta, West Java, Central Java, East Java, Bali, and North Sumatra only exceed the alternative QS of 196 μg/m^3. From the public health aspect, by attaining to the alternative QS of 750 μg/m^3, Jakarta and Banten will reduce incidence of Acute Respiratory Infections (ARIs) by 95% and 98%. By attaining to the alternative QS of 196 μg/m^3, East Java, Bali and North Sumatra will reduce the incidence of ARIs by 59%, 51%, and 5%.

Abstrak

Analisis Nilai Manfaat dari Penerapan Baku Mutu SO_2 Alternatif pada Penurunan Kejadian ISPA di Indonesia. Baku mutu (BM) SO_2 ambien Indonesia untuk rata-rata waktu 1 jam sebesar 900 μg/m^3 (setara dengan 360 μg/m^3 dalam rata-rata waktu 24 jam) yang diatur di dalam PP No 41 Tahun 1999 paling longgar dibandingkan dengan BM SO_2 ambien negara-negara lain di dunia termasuk BM panduan WHO. BM ini diperkirakan belum menjamin perlindungan kesehatan masyarakat di Indonesia. Oleh karenanya diperlukan BM alternatif untuk SO_2 ambien yang lebih ketat. Penelitian ini mengkaji nilai manfaat dari aspek kesehatan masyarakat jika Indonesia melakukan pengetatan BM SO_2 ambien. Dua alternatif BM untuk SO_2 yang digunakan adalah 196 μg/m^3 (setara dengan 78 μg/m^3 dalam rata-rata waktu 24 jam) mengacu pada U.S. EPA dan 750 μg/m^3 (setara dengan 300 μg/m^3 dalam rata-rata waktu 24 jam) mengacu pada Pusat Sarana Pengendalian Dampak Lingkungan Hidup (PUSARPEDAL). Langkah pertama adalah memetakan persebaran konsentrasi SO_2 ambien di Indonesia. Hasilnya mengindikasikan bahwa Provinsi DKI Jakarta dan Banten telah melebihi kedua BM alternatif sedangkan Provinsi DIY, Jawa Barat, Jawa Tengah, Jawa Timur, Bali, dan Sumatera Utara hanya melebihi BM alternatif 196 μg/m^3. Dari aspek kesehatan masyarakat, jika DKI Jakarta dan Banten memenuhi BM alternatif 750 μg/m^3 akan menurunkan kejadian ISPA 98% dan 95%. Untuk Jawa Timur, Bali, dan Sumatera Utara, jika memenuhi BM alternatif 196 μg/m^3 akan menurunkan kejadian ISPA masing-masing 59%, 51%, dan 5%.

Keywords: ARI, benefit value, emission, quality standard, SO_2

Introduction

Government Regulation No. 41 of 1999 regarding the Regulation of Air Pollution is an implementation regulation related to the management of air quality.[1] One of the issues regulated by this Government Regulation is the Indonesian National Ambient Air Quality Standards (NAAQS), including parameter for Sulphur Dioxide standards (SO_2 NAAQS). However, compared to SO_2 NAAQS of other countries, SO_2 NAAQS in Indonesia for short term time measurement, especially for 1 hour time, is very loose.[2] Unfortunately, the Government

Regulation No. 41 of 1999 does not explain the basis for determining of the value of the Quality Standard (QS) for several parameters of air quality, including SO_2. Indonesian SO_2 NAAQS for 1 hour time measurement is highest (900 µg/m^3), followed by Hong Kong (800 µg/m^3). Even compared to other countries in the South East Asia region, Indonesian SO_2 NAAQS is far higher.

In 2010, U.S. EPA revised the SO_2 Primary Standards for 1 hour time measurement into 75 ppb (equivalent to 196 µg/m^3).[3] U.S. EPA determined that this new QS after conducting the NAAQS Regulatory Impact Analysis for the SO_2 (RIA SO_2) prior to that. It is stated in the RIA SO_2 that in determining the SO_2 NAAQS, the legal responsibility of the U.S. EPA is to determine the QS to protect human health regardless of the cost incurred in order to fulfil the QS.

Looking at the large discrepancy between Indonesian SO_2 NAAQS for 1 hour time measurement and that of other countries' around the world and the above explanation regarding the consideration for human health from the U.S. EPA in determining the QS, it can be said that Indonesian SO_2 NAAQS does not guarantee the health of its people from diseases caused by concentration of SO_2 in the air. Therefore, Indonesia needs to consider tightening its SO_2 NAAQS for the 1 hour time measurement.

The purpose of this research is to: a) map out the spatial distribution of SO_2 emission and ambient SO_2 concentration in Indonesia; b) determine a stricter SO_2 QS which can be an alternative in Indonesia (alternative SO_2 QS); and c) analyse the benefit values should Indonesia implement the alternative SO_2 QS from the public welfare aspect. Analysis of the public welfare aspect of this research is limited to the analysis of the reduction of incidence of Acute Respiratory Infection (ARI) in Indonesia.

Methods

This research was conducted using quantitative approach, with ex-post facto method, which is the analysis of benefit values of tightening up the Indonesian SO_2 NAAQS from the public welfare aspect using secondary data from 2010.

The first step in this research was to estimate and analyse SO_2 emission in 2010 per province in Indonesia. Source of emission was categorised into four sectors, namely, power plant, industry, domestic, and transportation. SO_2 emission from these four sectors was estimated based on fuel consumption. For petroleum oil, emission (E_o) was estimated using Equation (1), while for solid fuel such as coal, emission (E_s) was estimated using Equation (2) (Hamonangan, Esrom, *et al*., 2002).[5]

$$E_0 = F_0 \times 2 \times S_0 \times \rho_0 \quad (1)$$

$$E_s = F_s \times 2 \times S_s \quad (2)$$

Where *o* and *s* represent petroleum oil and solid fuel respectively. *F* is fuel consumption (kl/year for petroleum oil or tonne/year for solid fuel). *S* is sulphur content of the fuel (% mass) and *ρ* is density of petroleum oil (kg/l).

Estimated emission was mapped according to population distribution based on Geographical Information System (GIS) approach. This data was spatially distributed into 12×12 km sized small grids according to those used in U.S. EPA RIA SO_2. Ambient SO_2 value in 2010 in Indonesia was estimated based on average ambient SO_2 ratio to emission (RCE) produced in the RIA SO_2. Gridded emissions value was then obtained. Emission from coal-fuelled Steam-Powered Power Plants was not included in the spatial distribution because this emission source is a large point source which coordinates were known.

Given the large number of grids in all over Indonesia, certain grids were randomly selected for calculation as monitor grids in each province in Indonesia using GIS software. To calculate the concentration on one monitor grid, a 9×9 emission grid matrix was used, where the monitor grid was located at the centre of the matrix as seen on Figure 1.

In the U.S. EPA RIA SO_2, it was stated that the 9×9 matrix represents the maximum domain size allowed to calculate the scope of near-field dispersion, which is by drawing a radius of 50 km from the point of emission.
Maximum SO_2 concentration on the monitor grid (CSO_{2i}) was then calculated as follows:

$$CSO_{2i} = ESO_{2i} \times RCE \quad (3)$$

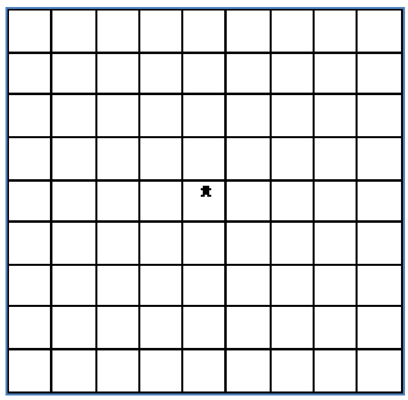


Figure 1. Sample 9×9 Emission Grid Matrix where SO_2 Monitor Grid was located at the Centre of the Matrix (Marked with Star Symbol)

Where ESO_{2i} is total SO_2 emission from monitor grid *i* (tonne), which was calculated using the above method and RCE was the average of maximum SO_2 concentration ratio for 1 hour per emission (µg/m^3/tonne), which was processed from the U.S. EPA RIA SO_2.

The U.S. EPA allotted 10 RCE values for 10 monitor grids which had exceeded the alternative QS of 196 µg/m^3 which was analysed in the RIA SO_2, namely 0.0044, 0.0279, 0.0420, 0.0475, 0.0124, 0.0091, 0.0072, 0.0031, 0.0052, and 0.0063. From this data, it can be seen that the distribution of RCE values was not normal. Therefore, RCE data normality was tested to observe the number of outliers.

Data normality testing here used a procedure explained by Hibbert DB and Gooding JJ (2006) in Data Analysis for Chemistry (page 72-77).[6] From the result, four outliers were obtained, namely, RCEs 0.0124, 0.0279, 0.0420, and 0.0475 µg/m^3/tonne. After omitting these outliers, data distribution became linear with R^2 = 0.959.

From the remaining normalised data, average RCE value of 0.0059 µg/m^3/tonne was obtained. However, after using this value for all monitor grid in this research, the researcher obtained a concentration value that was too high for several monitor grids, with maximum value up to 2,643 µg/m^3. Therefore, and considering emission data distribution vs RCE in the U.S. EPA RIA SO_2, two RCE values were used for concentration estimation, namely, 0.0059 µg/m^3/tonne if total emission from one grid is less than 100,000 tonnes and 0.0044 µg/m^3/tonne if total emission exceeds 100,000 tonnes.

After emission was estimated and mapped, the next step was determining alternative SO_2 QS for 1 hour time measurement. The U.S. 1 hour QS of 196 µg/m^3 is the ideal QS according to the 2010 U.S. EPA RIA SO_2. However, this number is too strict for developing countries such as Indonesia. With the current QS of 900 µg/m^3, the reduction to 196 µg/m^3 is very drastic. In 2011, the PUSARPEDAL (Centre of Environmental Impact Control Facility) compiled the Ambient Air Quality Standard Analysis Report Appendix of Government Regulation No. 41 of 1999.[7] In this report, SO_2 QS for 1 hour time measurement was proposed to be changed into 750 µg/m^3. The QS of 750 µg/m^3 proposed by the PUSARPEDAL and the U.S. EPA QS of 196 µg/m^3 were used as alternative QS to be analysed in this research.

The next step was to collect environmental data of incidence of ARI in Indonesia in 2010 for each province that exceeded the alternative SO_2 QS. From these data, the SO2 QS benefit value from the public welfare aspect, namely the decline in the incidence of ARI, could then be estimated.

There has been several research that linked SO_2 concentration in the air to incidence of ARI in a particular area. Unfortunately, similar research has not been found to have been conducted in Indonesia. Research that specifically studies the correlation between SO_2 and the incidence of ARI outside Indonesia has also yet to be found. Therefore, health impact function from Schwartz et al. (in Abt Associates Inc., 2010)[8] was used in this research, as presented in Equation (4). This research was conducted in six American cities in 1994, involving participants within the age group of 7 to 14 years. It was assumed that this impact function could be applied to age groups.

$$\Delta I = y_0 \times \left(1 - \frac{1}{(1-y_0)\times e^{\beta\times\Delta SO_2} + y_0}\right) \times pop \qquad (4)$$

Where ΔI is the decline in incidence of ARI (number of persons), y_0 is baseline ARI incidence rate, β of 0.008618 is the SO_2 coefficient for ARI incidence, ΔSO_2 is the difference between baseline and end SO_2 value (in this case, the alternative QS) in 24 hour time average (µg/m^3). *Pop* represents the affected population.

Much secondary data was collected for this research. Consumption of fuel in the domestic sector was obtained and processed from BPS (Central Statistic Body),[9] Djajadilaga, Tejalaksana, Harnowo, Gusthi, & Sudarmanto,[10] and Nasution.[11] Consumption of fuel in the transportation sector was obtained and processed from the BPH Migas (Oil and Gas Downstream Regulatory Body).[12,13] Consumption of fuel in the industry sector was obtained and processed from BPS (Central Statistic Body),[14] Bosowa Corporation,[15] Harinowo & Sari,[16] Indocement,[17] Chemical Engineering Faculty of Institut Teknologi Sepuluh Nopember,[18] Semen Gresik,[19] and Suherman.[20] Fuel consumption from the power plant sector was obtained and processed from DJLPE (Electricity and Energy Utilisation Directorate General),[21] PLN (State Electricity Company),[22-24] PT Indonesia Power,[25] PT PJB,[26] and Suherman.[20] Fuel specification per type was obtained and processed from Pertamina (National Oil and Gas Mining Company),[27-31] RETScreen International,[32] and Riauwati.[33] The number of population affected by ARI and the incidence rate were obtained and processed from the Health Ministry of the Republic of Indonesia.[34]

Results and Discussion

Indonesia's total SO_2 emission in 2010 was estimated to be 1,213,387 tonnes (Table 1). The biggest contributor of emission was the power plant sector with total contribution of 60%. Oil-fuelled power plants (petroleum and diesel fuelled) was the biggest contributor with 35%, followed by coal-fuelled steam-powered power plants with 25%.

Table 1. Estimated SO_2 Emission (Tonne) per Sector per Province in Indonesia in 2010

Province	Domestic	Transportation	Industry	Power Plants			Total Emission
				Diesel	Petroleum	Coal	
Aceh	3,211	2,165	173	6,187	0	0	11,735
North Sumatera	7,649	7,317	1,903	1,599	76,776	9,370	104,615
West Sumatera	4,023	2,576	11,305	1,147	161	7,586	26,797
Riau	3,183	4,840	8,934	2,716	0	0	19,673
Jambi	2,695	1,884	305	1,298	621	0	6,801
South Sumatera	4,962	3,888	2,580	1,298	2,532	9,861	25,120
Bengkulu	1,551	578	18	513	0	0	2,660
Lampung	8,386	3,555	1,935	2,897	371	8,924	26,069
Bangka Belitung Islands	624	1,384	757	2,686	0	0	5,451
Riau Islands	813	1,655	2,912	5,532	0	0	10,911
DKI Jakarta	302	8,104	1,899	174	93,265	0	103,745
West Java	19,430	13,749	98,065	3	25,096	0	156,344
Central Java	27,253	10,527	18,353	0	75,524	21,564	153,221
DI Yogyakarta	2,776	1,096	400	0	0	0	4,273
East Java	32,028	12,767	36,063	145	45,056	43,360	169,419
Banten	4,852	4,657	19,373	0	0	169,774	198,657
Bali	3,079	2,409	282	820	15,594	0	22,184
West Nusa Tenggara	5,076	1,002	9	4,195	0	6,279	16,561
East Nusa Tenggara	5,177	916	9	3,531	0	0	9,632
West Kalimantan	3,726	1,812	252	6,549	666	0	13,005
Central Kalimantan	2,071	1,352	675	2,354	0	0	6,453
South Kalimantan	3,140	2,081	4,437	4,044	457	4,931	19,090
East Kalimantan	1,588	2,581	291	8,397	0	2,175	15,032
North Sulawesi	1,933	1,119	348	3,440	0	0	6,840
Central Sulawesi	2,821	848	68	3,410	0	964	8,111
South Sulawesi	6,072	3,180	11,447	3,108	6,462	3,720	33,989
Southeast Sulawesi	2,110	649	57	2,263	0	0	5,079
Gorontalo	975	272	68	1,750	0	0	3,065
West Sulawesi	1,127	233	13	241	0	0	1,614
Maluku	1,284	613	34	3,169	0	0	5,100
North Maluku	908	243	2	2,294	0	0	3,447
West Papua	628	394	158	1,267	0	0	2,447
Papua	2,841	634	253	3,591	0	8,928	16,247
INDONESIA	168,291	101,081	223,378	80,619	342,582	297,436	1213,387

Java Island very dominantly contributed to 65% of the emission. This happens because Java Island has become the centre of population and industry in Indonesia. Aside from that, there were several large capacity coal-fuelled steam-powered power plants did not have the flue gas desulfurization (FGD) system. Of all coal-fuelled steam-powered power plants in Indonesia, there were only three coal-fuelled steam-powered power plants known to use the FGD system, namely, Paiton I and II coal-fuelled steam-powered power plants and Tanjung Jati-B coal-fuelled steam-powered power plant. Emission from these three coal-fuelled steam-powered power plants were corrected according to the efficiency of their respective FGD emissions (94% for Paiton I and II coal-fuelled steam-powered power plants[35] and 97% for Tanjung Jati-B coal-fuelled steam-powered power plant).[36]

From the estimated concentration, the following results were obtained: 10 monitor grids in two provinces in Indonesia have exceeded the prevailing QS of 900 µg/m^3, 11 monitor grids which was also in the same two provinces have exceeded the alternative QS of 750 µg/m^3, and 65 grids from eight provinces have exceeded the QS of 196 µg/m^3 (Table 2).

Banten and Jakarta were two provinces which exceeded all QS with maximum 1 hour SO_2 concentration of 1971 and 1645 µg/m^3 respectively. To fulfil this QS, Jakarta had to reduce its emission by 243,409 tonnes, meanwhile Banten had to reduce its emission by 169,318 tonnes. As seen from Table 1, emission reduction in Jakarta was more than twice of the estimated emission of the province itself. It means that the concentration of SO_2 in Jakarta was caused by emission from other provinces around it (Figure 2b), which are Banten and West Java provinces.

To fulfil the QS of 750 µg/m^3, Jakarta and Banten should reduce their emission even more. Jakarta has to reduce SO_2 emission by up to 277,500 tonnes while Banten has to reduce its emission by 203,409 tonnes. Emission reduction for Banten exceeds the estimated emission in the province itself (Table 1).

Assuming that incidence of ARI in eight provinces in Indonesia which has exceeded the alternative and existing QS is only caused by SO_2, benefit value from fulfilment of the alternative and existing QS in 2010 in the form of decline in ARI incidence was estimated using Equation (4) (Table 3). Existing QS was also calculated because it has been exceeded by Banten Province and Jakarta. One hour SO_2 QS value was converted to 24 hour average because the impact function uses 24 hour SO_2 concentration.

By fulfilling the existing QS of 900 µg/m^3, Banten Province could reduce the incidence of ARI by up to 97% whereas Jakarta, 92%. If they fulfil the alternative QS of 750 µg/m^3, Banten Province and Jakarta could reduce ARI incidence by 98% and 95% respectively. However, if they fulfil the alternative QS of 196 µg/m^3, Banten and Jakarta could reduce ARI incidence by almost 100%. This could be said to be impossible or very difficult to achieve because the difference from the existing QS is too big (≥ tenfold).

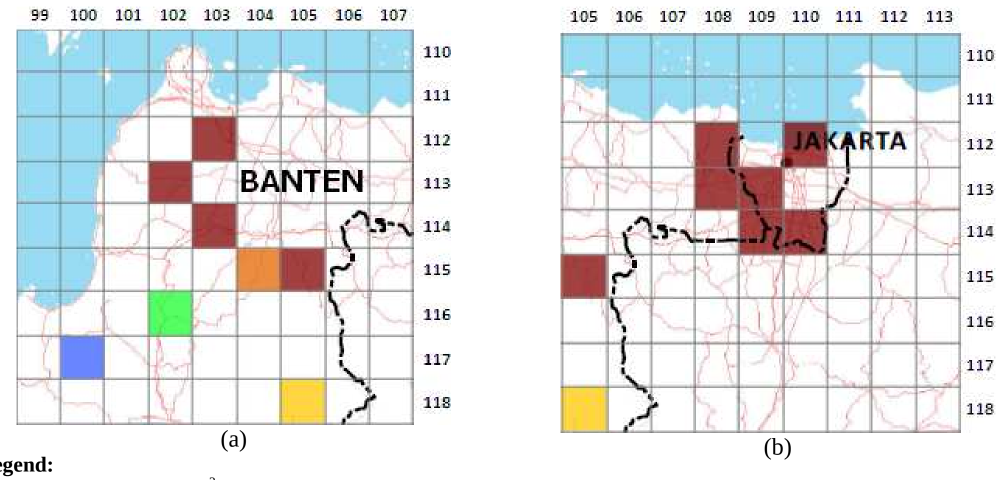
Daerah Istimewa Yogyakarta (DIY), West Java, and Central Java could reduce ARI incidence by 80% to 82% if they could fulfil the alternative QS of 196 µg/m^3. East Java could reduce the incidence by up to 59%, while Bali up to 51% of ARI incidence. North Sumatera could only reduce ARI incidence by 5% because it only exceeded the QS by 6 µg/m^3.

This research has provided the best estimates based on all available data. This research will provide a description of the benefit value if Indonesia applies an SO_2 QS than is stricter than the existing one (Government Regulation No. 41 of 1999). This benefit value is in the form of decline in the incidence of ARI.

Table 2. Monitor Grid with Highest Scores according to Provinces Exceeding Maximum 1 Hour SO_2 QS of 196, 750, and 900 µg/m^3 in 2010

Province	Monitor Grid		Max 1 hour SO_2 (µg/m^3)	Alternative SO_2 QS for 1 hour (µg/m^3)					
				196		750		900	
	Column	Row		ΔSO_2	ΔE (Tonnes)	ΔSO_2	ΔE (Tonnes)	ΔSO_2	ΔE (Tonnes)
Banten	103	114	1,971	1775	403,409	1,221	277,500	1071	243,409
DKI Jakarta	109	114	1,645	1449	329,318	895	203,409	745	169,318
DI Yogyakarta	143	126	690	494	112,273				
West Java	123	120	676	480	109,091				
Central Java	128	123	659	463	105,227				
East Java	160	124	460	264	44,746				
Bali	187	133	407	211	35,763				
North Sumatera	46	36	212	16	2,712				

Legend: ΔE= tonnes of SO_2 emission to be reduced to fulfil the alternative QS; ΔSO_2=difference between estimated maximum 1 hour SO_2 concentration and the alternative QS



Legend:
SO_2 Concentration (µg/m^3):

300-400 **500-600** **700-800** **800-900** **>900**

Figure 2. Footage of Ambient SO_2 Distribution Map: (a) 9×9 Monitor Grid Matrix with Column 103 Row 114 as Its Centre; (b) 9×9 Monitor Grid Matrix with Column 109 Row 114 as Its Centre

Table 3. Benefit Value from Fulfilment of Alternative & Existing SO_2 QS in the Form of Decline in ARI Incidence (ΔI)

Province	Population	y_0	Max 24-hour[b] SO_2 (µg/m^3)	Alternative 24-hour SO_2 QS (µg/m^3)					
				78		300		360	
				ΔSO_2	ΔI |%|	ΔSO_2	ΔI |%|	ΔSO_2	ΔI |%|
Banten	11,407	0.0115	788	710	11,382 |99,8|	488	11,235 |98|	428	11,119 |97|
DKI Jakarta	15,254	0.0192	658	580	15,149 |99,3|	358	14,543 |95|	298	14,062 |92|
DI Yogyakarta	1,710	0.0049	276	198	1,398 |82|	-	-	-	-
West Java	193,980	0.0487	271	192	155,437 |80|	-	-	-	-
Central Java	30,240	0.0110	263	185	24,050 |80|	-	-	-	-
East Java	52,774	0.0200	184	106	31,287 |59|	-	-	-	-
Bali	3,739	0.0144	163	85	1,922 |51|	-	-	-	-
North Sumatera	37,719	0.0261	85	6	1,977 |5|	-	-	-	-

a. 24-hour alternative SO_2 QS was obtained from 1 hour alternative SO_2 QS multiplied by the conversion factor of 0.4 (U.S. EPA, 1992).[37]
b. Maximum 24 hour SO_2 was obtained from 1 hour maximum SO_2 concentration value multiplied by the conversion factor of 0.4 (U.S. EPA, 1992).[37]

Conclusions

With the estimated fuel consumption and emission of all sectors in 2010, eight provinces in Indonesia have exceeded the ideal alternative QS of 196 µg/m^3. Seven are located in the Java Island and one in Sumatera Island. This shows that the distribution of SO_2 concentration in Indonesia is very uneven.

The higher the difference between ambient SO_2 concentration and the QS, the higher the benefit value that could be reaped. However, on the other hand, it also means the higher the emission that needs to be reduced to fulfil said QS. Therefore, a very strict QS cannot be applied in provinces with high concentration. The difference which is still possible for application of a certain QS in an area should not exceed threefold.

It is not possible for Banten and Jakarta to fulfil the alternative QS of 196 µg/m^3 because the concentration difference from the QS is tenfold. This two provinces might still be able to fulfil the 750 µg/m^3 QS by working together and involving West Java in order to reduce the emission. The provinces which could most possibly fulfil the QS of 196 µg/m^3 are East Java, Bali, and North Sumatera.

This research has provided the best estimates of the benefit value of the application of alternative SO_2 QS in Indonesia. Uncertainties could be reduced by doing further research to obtain RCE and impact function of SO_2 against the ARI incidence that applies to Indonesia.

Based on the result of this research, Indonesia could apply the SO_2 QS for 1 hour measurement time that is stricter than the existing QS of 900 µg/m^3. The 1 hour QS of 750 µg/m^3 (equivalent to 300 µg/m^3 in 24 hour time average) suggested by the PUSARPEDAL KLH is worth applying especially for Banten and Jakarta. However, governments of other provinces, especially the six provinces which in this research have exceeded the alternative 1 hour SO_2 QS of 196 µg/m^3 (equivalent to 78 µg/m^3 in 24 hour time average) could apply a stricter QS to avoid high ARI incidence in the respective provinces.

References

1. Republik Indonesia. Peraturan Pemerintah No. 41 tahun 1999 tentang Pengendalian Pencemaran Udara.1999. [In Indonesia]
2. CAI-Asia. *Factsheet No. 4 – Sulfur dioxide (*SO_2*) Standards in Asia*. (internet) 2010. Available from: www.cleanairinitiative.org.
3. U.S. Government Printing Office. *Primary National Ambient Air Quality Standard for Sulfur Dioxide: Final Rule*. Environmental Protection Agency. (internet) Available from: www.epa.gov/ttnnaaqs/standards/SO2 /fr/20100622.pdf. 2010.
4. U.S. EPA. *Final Regulatory Impact Analysis (RIA) for the* SO_2 *National Ambient Air Quality Standards (NAAQS)*. (internet) Available from: www.epa.gov/ ttnecas1/regdata/RIAs/fSO2ria100602full.pdf. 2010.
5. Hamonangan E., Kondo A, Kaga A, Inoue Y, Soda S, Yamaguchi K, Simulation and Monitoring of Sulphur Dioxide and Nitrogen Oxides in the Jakarta Metropolitan Area. *Asian J. Energy Environ.* 2002; 3(3-4):159-183.
6. Hibbert, Brynn D, Gooding, Justin J. *How to Test If Your Data Are Normally Distributed. Data Analysis for Chemistry: An Introductory Guide for Students*. New York: Oxford University Press, Inc, 2006:72-77.
7. PUSARPEDAL KLH. *Laporan Kegiatan Pengkajian Baku Mutu Kualitas Udara Ambien Lampiran PP 41 Tahun 1999*. (internet) Available from: http://pusarpedal. menlh.go.id/wp-content/uploads/2012/05/ Laporan-Pengka jian-Baku-Mutu-Kualitas-Udara-Ambien. pdf. 2011. [In Indonesia]
8. Abt Associates, Inc. *Environmental Benefits Mapping and Analysis Program: User's Manual Appendices. Prepared for Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, NC.* (internet) Available from: www.cmascenter.org/help/mo del_docs/benmap/4.0/BenMAPManualAppendices.pdf. 2010.
9. BPS. *Hasil Olah Cepat Penduduk Indonesia SP 2010*. Jakarta, Indonesia: Direktorat Diseminasi Statistik, Subdirektorat Layanan dan Promosi Statistik, Badan Pusat Statistik, 2011. [In Indonesia]
10. Djajadilaga, Maulyani, et al. *Emisi Gas Rumah Kaca Dalam Angka 2009*. Jakarta: Asisten Deputi Urusan Data dan Informasi Lingkungan, Kementerian Negara Lingkungan Hidup, 2010. [In Indonesia]
11. Nasution M. *Minyak jarak lebih untung dari briket batu bara*. (internet) 2011. Available from: http://www.energi. lipi.go.id/utama.cgi?artikel&1135219550&3. [In Indonesia]
12. BPHMIGAS. *Kuota Volume Jenis BBM Tertentu Per Propinsi Tahun 2009 (Berdasarkan Keputusan Menteri ESDM 2711/2009)*. (internet) 2009. Available from: http://www.bphmigas.go.id/p/bphmigaspages/statistik/ku ota_bbm_APBNP_2009.html. [In Indonesia]
13. BPHMIGAS. *Realisasi Penjualan BBM Subsidi 2010*. (internet) 2011. Available from: http://www.bphmigas.go.id/p/bphmigaspages/statistik/rea lisasi_penjualan_bbm_2010.html. [In Indonesia]
14. BPS. *Raw Data IBS 2009, Variabel Terpilih: Konsumsi Bahan Bakar*. Jakarta, Indonesia: Direktorat Diseminasi Statistik, Subdirektorat Layanan dan Promosi Statistik, Badan Pusat Statistik, 2011. [In Indonesia]
15. Bosowa Corporation. *Beranda - Unit Usaha - Semen*. (internet) 2011. Available from: http://www.bosowa.co. id/content/view/26/34/lang,indonesia/. [In Indonesia]
16. Harinowo C, Sari MF. *Industri Semen Menggeliat Kembali*. WinPlus Capital (internet) 2006. Available from: http://www.winpluscapital.com/winplus/Profil% 20Industri%20Semen.pdf.
17. Indocement. Laporan Tahunan 2010. Jakarta: PT Indocement Tunggal Prakarsa Tbk., 2011. [In Indonesia]
18. Jurusan Teknik Kimia, Institut Teknologi Sepuluh Nopember. *Laporan Pertanggung Jawaban Study Excursion 2011*. (internet) 2011. Available from: http://xa.yimg.com/kq/groups/3004572/427049765/name/ 62898738-Laporan-Pertanggung-Jawaban-Study-Excursie-2011.pdf. [In Indonesia]
19. Semen Gresik. *Laporan Tahunan 2010*. Jakarta: PT Semen Gresik (Persero) Tbk, 2011. [In Indonesia]
20. Suherman I. *Masa Kini dan Masa Depan Batubara Indonesia*. Prosiding Kolokium Pertambangan 2009; Bandung: Pusat Penelitian dan Pengembangan Teknologi Mineral dan Batubara, Departemen Energi dan Sumber Daya Mineral; 2009. [In Indonesia]
21. DJLPE. *Statistik Ketenagalistrikan dan Energi Tahun 2009*. Jakarta: Direktorat Jenderal Listrik dan Pemanfaatan Energi, Kementerian Energi dan Sumber Daya Mineral, 2010. [In Indonesia]
22. PLN. *Laporan Tahunan 2010*. Jakarta: PT PLN (Persero), 2011. [In Indonesia]
23. PLN. *Laporan Keberlanjutan 2010*. Jakarta: PT PLN (Persero), 2011. [In Indonesia]
24. PLN. *Rencana Usaha Penyediaan Tenaga Listrik PT PLN (Persero) 2011-2020*. Jakarta: PT PLN (Persero), 2011. [In Indonesia]
25. PT Indonesia Power. *Lapooran Statistik Indonesia Power Tahun 2010*. Jakarta: PT Indonesia Power, 2011.
26. PT PJB. *Statistik Perusahaan 2005-2009*. Jakarta: PT Pembangkitan Jawa-Bali, 2010. [In Indonesia]
27. Pertamina. *Material Safety Data Sheet: Minyak Bakar I (Marine Fuel Oil)*. PT Pertamina (Persero) (internet) 2007. Available from: http://www.pertamina.com/uploads/ download/MinyakBakar.pdf. [In Indonesia]
28. Pertamina. *Material Safety Data Sheet: Minyak Disel (Diesel Oil)*. PT Pertamina (Persero). (internet) 2007. Available from: http://www.pertamina.com/uploads/ download/MinyakDisel.pdf. [In Indonesia]
29. Pertamina. *Material Safety Data Sheet: Minyak Tanah (Kerosine)*. PT Pertamina (Persero) (internet) 2007.

Available from: http://www.pertamina.com/uploads/download/MinyakTanah.pdf. [In Indonesia]
30. Pertamina. *Material Safety Data Sheet: Premium (Gasoline 88)*. PT Pertamina (Persero) (internet) 2007. Available from: http://www.pertamina.com/uploads/download/premium.pdf. [In Indonesia]
31. Pertamina. *Material Safety Data Sheet: Solar (Diesel Fuel)*. PT Pertamina (Persero). (internet) 2007. Available from: http://www.pertamina.com/uploads/download/Solar.pdf. [In Indonesia]
32. RETScreen International. *Thermal Equipment: Fuels and Combustion*. (internet) 2006. Available from: www.retscreen.net/fichier.php/994/Fuels%20and%20Combustion.pdf.
33. Riauwati, Dolaris. *Pencemaran dari Industri*. (internet) 2006. Available from: http://www.scribd.com/doc/50079849/Pencemaran-Dari-Industri. [In Indonesia]
34. Kementerian Kesehatan RI. Profil Kesehatan Indonesia 2010. Jakarta: Kementerian Kesehatan Republik Indonesia, 2011. [In Indonesia]
35. Siemens. Siemens (internet) 2012. Available from: http://www.siemens.co.id/jawa_power/jp_environmental.htm.
36. Salimy, Djati H, Finahari, Ida N, Amitayani, Elok S. *Analisis Biaya Eksternal PLTU Batubara*. (internet) 2009. Available from: http://jurnal.sttn-batan.ac.id/wp-content/uploads/2010/03/C-18.pdf. [In Indonesia]
37. U.S. EPA. *Screening Procedures for Estimating the Air Quality Impact of Stationary Sources, Revised*. U.S. Environmental Protection Agency (internet) Available from: http://www.epa.gov/opptintr/exposure/pubs/usepa_1992b_sp_for_estim_aqi_of_ss.pdf.