RISK ANALYSIS STUDY OF NOx, and SOx FROM TRANSPORTATION (CASE STUDY: MAIN STREETS OF D.I. JOGJAKARTA)

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ABSTRACT

The air pollution problems have been progressively set attention to the world especially industrial countries recently. These problems not only give affect at health like emphysema, bronchitis, and other inhalation disease but also make plants and properties destruction causes very big loss. This research is concerned with the risk level which is accepted by people who reside in roadside because most of air pollutants come from transportation facilities such as motor vehicle. The limitation of the research is air pollutants exposure such like NOx, and SOx which enter the body through respiration. This risk analysis research is broken down into four step as follow; hazard identification showing NO_2, and SO_2 concentration in 15 sampling locations where the highest value of NO_2 is 56,5 µg / m^3 and SO_2 is 28,87 µg/m^3. According to DIY Governor Regulation No. 153 Year 2002 about the value of ambient air quality standard, quality standard of NO_2 is 400 µg / m^3, and SO_2 is 900 µg / m^3. It can be concluded that concentration of NO_2 and SO_2 in 2005 within all sampling locations is still under of quality standard. The step of exposure assessment involves the exposed population including pedicab worker, park worker, and cloister merchant. From calculation, the intake range of NO_2 enters the body is 0,0025-0,0075 mg/kg.day and SO_2 is 0,0008-0,0038 mg/kg.day. Third step is dose-response assessment to find out what will be faced by people if exposure of pollutants occurs in a certain dose. The last step is risk characterization, the result of research is that risk value / Hazard Index (HI) less than 1 that still acceptable. It can be summarized that the ambient air quality of Jogjakarta especially NO_2 and SO_2 gas do not too adverse to health.

Key word: NO_2, SO_2, risk analyze, Jogjakarta

Introduction

Rapid development of technology and the need of transportation, automatically rise up the air pollutions emission level from motor vehicles, industries and household or domestic combustion. The harmful effects of air pollutions are a serious problem faced by in-dustrial countries around the globe. The pollution not only affects directly to human being but also cause environ-mental destruction. For human being, the influ-ence of air pollutions can be found in the respiration system, skin and mucous membrane. Moreover, if the pollutants enter the blood circulation, the systematic effect is hard to avoid.

According the previous researches for 20 years, the mortality rate caused by air pollutions increases up to 14 % or increases up to 0,7 % per year. Besides, the material loss caused by air pollutions is massive. BPLHD of DKI Jakarta province notes down the exis-tence of an annual significant degradation of the amo-unt of days in a good category to breath, which clearly is something to concern about.

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Therefore, there is a possibility that Jogyakarta is familiar with the similar matter. The monitoring of air quality in Jogyakarta is conducted to find out the concentration of air contaminant within the area. The monitoring result then compared to the value of air quality standard by Governor DIY Regulation No. 153/2002, where maximum concentration of NO_2 is 400 µg/m^3, and SO_2 is 900 µg/m^3. The higher air pol-lutions level of NOx, and SOx, the higher risks that human will have to deal with in the future.

The aims of this research are as follow:

1. To find out the NOx, and SOx concentration in the Jogjakarta roadside and
2. To find out the amount of risk of NOx, and SOx exposure to people who reside in the roadside will face that.

The scopes of this research are below:

1. Analyzing the concentration of NOx, dan SOx in the roadside compared to standard air quality.
2. Analyzing of road users in the roadside who get effected by NOx, and SOx.

3. Risk analyzing of air pollutions level, including; hazard identification, exposure assessment, dose-response assessment, and risk characterization to the road user in the roadside.

The air pollutions is an abnormal condition of air that contaminated by strange materials, components or substances. The processes could happen either naturally or artificially by human activities. It ends up in a degradation and a disfunction of air quality. Air pollutions influences life system of human being such as health problems, ecosystem related to human kind (Table 1). The main source of pollution is divided into 2 categories; first is natural source of pollution such as SO_2 and H_2S from erupted mountain, NO and NO_2 from bacteria activities. According to Peavy (1985), another pollutant is from CO of methane (CH_4), hydrocarbon from pinuses, H_2S and CH_4 from anaerobic decomposition of oranic material. Second is from artificial air pollution due to human activities such as industrial acivities, transportation or domestic / household combustion, that cause the increase of pollution level in the air (Kamala, 1993).

Table 1 Air Pollutant and The Impact of Human Health

No	Pollutant	Matter	The kinds of health problem
1	Carbon Monoxide	CO	The capacity of O_2 in blood decreases, infant health problem, heart disease and less functioning of panca indera.
2	Nitro Oxide	NOx	Emphysema, artillery and heart disease, bronchitis
3	Sulphur	SOx	Respiratory problems, heart disease, blurry sight.
4	Hydrocarbon	HC	Iritation of moscous membrane, eyes / sight problems, respiratory problems.
5	Particulat		Sight impairment / problems, respiratory irritation.

Source: Anonim, 1997.

According to Kastiyowati (2001), air pollutions can be clasified into:

1. Primary pollutant, is a pollutant where the shape and the composision is the same when it is exposed, such SO, NO, Ozone as well as many of particulats.
2. Secondary pollutant, is a pollutant which sometimes reacts to each other, producing a new kind of more dangerous pollutant. For example; Ozone dan *Peroxy Acyl Nitrate* (PAN).

Risk Analysis

According to EPA, the definition of risk analysis is characteristic of potentially dangerous materials that affect the human heath and the environment (www.epa.gov/iris/). Ruchirawat (1996) mentioned that, risk analysis can be described as a scientific process by which one attempts to characterize in as quantitative manner as data permits, the dose (exposure)-response curve in humans to provide scientific support for management decisions designed to decrease risks from chemical exposure. Scientific procedure and methods are used to identify hazard, define the dose response relationship, and conduct exposure assessment.

There are several objectives in risk analyzing such as below:

1. To find out the limit or the result of the worst case scenario with or without prediction.
2. To assist in a making process of government regulation.
3. To forecast the acceptable amount of risks in the future.

The first step of risk analysis is hazard identification in order to examine data for all chemical contaminants detected in any media and select a subset of chemicals, consisting of the specific chemicals of concern and representative of all detected chemicals. Risk identification is required to distinguish the potential danger that has to be concerned more.

The chosen chemicals are selected on the basis of which compounds best represent the risk posed by the site;

a. the most toxic persistent and mobile
b. the most prevalent in terms of spatial distribution and concentration
c. those involved in the more significant exposures, (Garg, 2004).

The second step of risk analysis is exposure assessment. It is a process of measuring or estimating the magnitude, frequency and duration of human exposure to a compound in the environment, or estimating future exposure for one that has not yet been released, (Ruchirawat, 1996). The pathway of chemicals exposure is divided into three ways which are ingestion, inhalation, and dermal contact. The affect factors contaminant intake are lifestyle, frequency, duration exposure, and receptor body weight. The equation to measure contaminant intake is as follows:

$$I = \frac{CxCRxEFxED}{BWxAT} \quad (1)$$

Where:

I = Intake (mg/kg of body weight. Day)
C = Chemical concentration in air (mg/m^3)
CR = Contact rate (m^3/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (Years)
BW = Average body weight (kg)
AT = Averaging time (days)

The third step of risk assessment is dose-response assessment. This stage defines the toxicity (dose-response relationship) for each substitute chemical, (Garg, 2004). Dose-response evaluation involves the quantitative relationship between the amount of exposure to a substance and the extent of toxic injury or disease, (Ruchirawat, 1996).

In risk characterization, the last step of risk analysis, the information on toxicity and exposure are integrated into an estimate of health risk posed by the compound under the conditions modeled in the exposure assessment. First, risks are calculated for exposure to each individual substance, then, the overall risks are assessed by adding the individual risks, (Ruchirawat, 1996).

Carcinogen Risk

The computation is below;

Risk = CDI x SF (2)

where;

CDI = chronic daily intake (mg/kg.day)
SF = carcinogen slope factor (kg.day/mg)

Non-Carcinogenic Risk

The hazard index is calculated as follows:

$$HI = \frac{CDI}{RfD} \quad (3)$$

Where;

HI = hazard index
CDI = chronic daily intake (mg/kg.day)
RfD = reference dose (mg/kg.day)

If the hazard index is less than 1, therefore the risks are acceptable. An exposure involves multiple chemicals, and an index must be calculated for each surrogate chemical for all pathway and exposure routes. For exposure to multiple non-carcinogens, the hazard index scores for all non-carcinogens normally are summed to provide the final measure of the risk for non-carcinogenic toxic effects. It should be noted that the acceptable target for the sum of hazard indices remains as less than 1 (La Grega, 2001).

Research Methodology

Flow diagram of this research can be seen as figure 1 below.

Figure 1 Research Flow Diagram

Examination Methods

1. CO use Monoxor II Carbon Monoxide Analyzer
2. NO_2 use gas absorption methods and then the absorptive is read at spectrophotometer 550 nm.
3. SO_2 use gas absorption methods by TCM (Tetra Chloro Mercurat) absorbent, and then the absorptive is read at spectrophotometer 575 nm.

Findings And Discussion

Identification of Selected Location

All of selected research locations spread in Jogjakarta and was assumed to represent of Jogjakarta because locations are the roads that have density traffic level which vary such as:

a. The roads with high density level
    1. Prambanan street (Janti)
    2. Sudirman street
    3. C. Simanjuntak street
    4. Ahmad Dahlan street (PKU Muh)
    5. Godean street
b. The roads with medium density level
    1. Magelang street
    2. Malioboro street
    3. Solo street
    4. Diponegoro street
    5. kaliurang street
c. The roads with low density level
    1. Wates street
    2. Parangtritis street
    3. Gedongkuning street
    4. Bantul street
    5. Menteri Supeno street

Ambient Air Quality Analyze

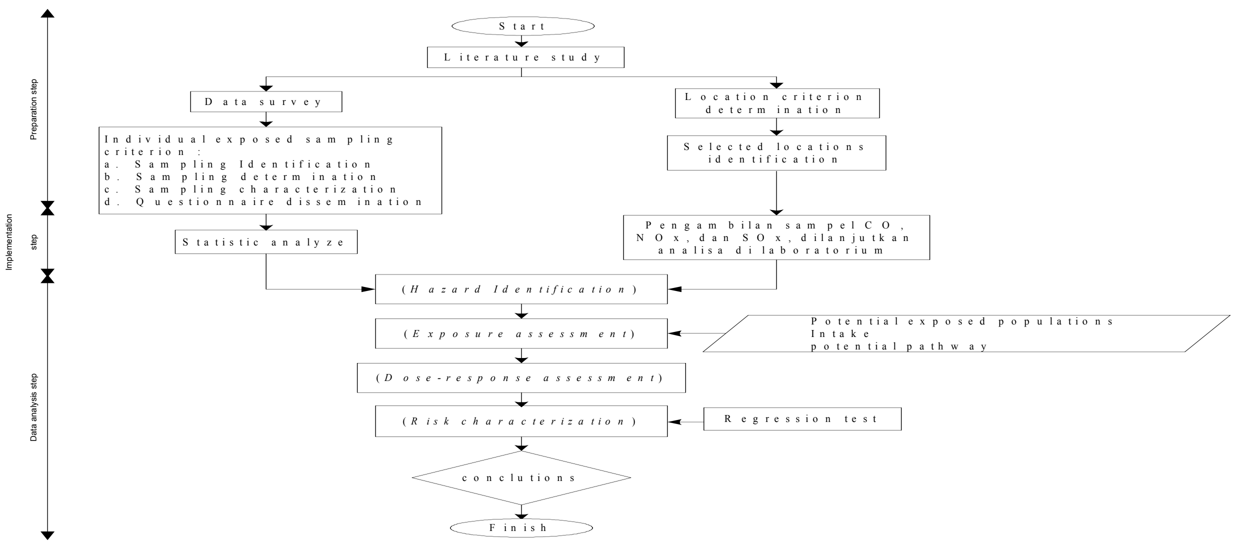

Table 2 shows the concentration analysis result of NO_2, and SO_2 in 15 sampling locations that have been done in BTKL laboratory of Jogjakarta.

Table 2 Concentration of NO_2 dan SO_2

No	Location	Gas Concentration (ug/m^3) NO_2	SO_2
	Air Quality Standard (ug/M^3)	**400**	**900**
1	Ruko Bayeman Jl. Wates	20,46	5,95
2	Kec. Jetis Jl. Diponegoro	35,07	18,37
3	Ruko Janti Jl. Prambanan	34,85	20,24
4	TVRI Jl. Magelang	29,27	10,55
5	Pizza Hut Jl. Sudirman	34,22	7,98
6	Mirota Jl. Godean	32,34	7,24
7	Hotel Matahari Jl. Parangtritis	22,25	8,55
8	Hotel Saphir Jl. Solo	30,82	7,14
9	PKU Muhammadiyah	56,50	28,87
10	STTL Jl. Gedongkuning	28,81	7,26
11	Beringharjo Jl. Malioboro	26,15	21,19
12	Mirota Jl. C. Simanjuntak	30,49	6,55
13	Pasar sepeda Jl. Mentri Supeno	21,92	9,04
14	Toko besi Jl. Ring Road	29,04	5,86
15	Apotik Tina Farma Jl. Kaliurang	27,56	8,35

Source: Analysis Result, 2006.

Hazard Identification

The first step in risk analysis is hazard identification. Hazard identification is the step to find out if contaminant exposure can cause harming impact to health of human being and what possibility happens if exposure of contaminants occurs. In this research, the possible air contaminants which give negative impact to the health are NOx, and SOx. Off those which have been identified in sampling locations are NO_2 and SO_2 phase. The contaminants are non-carcinogen where respiration diseases like emphysema often happened. NO_2, and SO_2 effect is chronic due to the accumulation of small value below the health standard of those gases in a long-exposure. The concentration of contaminant above the health standard causes acute effect in a short-exposure.

The measurement result of ambient air quality of NO_2, and SO_2 parameter show that almost in each sampling location have different concentrations. This is influenced by the contaminant sources which in this study come from motor vehicles emissions. Of NO_2 gas, maximum concentration for health standard is 100 μg/m^3 while maximum concentration in sampling locations is 56,5 μg/m^3 in roadside of Ahmad Dahlan street. Meanwhile, maximum concentration for health standard and the highest average concentration of SO_2 in sampling location is 28,87 μg/m^3 in roadside of Ahmad Dahlan street (PKU Muhammadiyah). Off all sampling locations of ambient air quality, measurement result shows the concentration is below the standard quality of health so that no adverse to human health in short-exposure, consequently if it happen in long-exposure, it will accumulate in the body and affect in human health.

From questionnaire spreading in 15 sampling locations can be seen that the respondents possibly exposed to NO_2, and SO_2 is the respondents who reside in the roadside for along time of day where they do not wear any protection to minimize the contaminant intake into body. It gets worse for smoking-habit respondents which cause the increase of the contaminant concentration in the body by inhaling cigarette smoke.

Exposure Assessment

a The population exposed identification
Health risks related to air pollutions has been progressively getting much attention. In cities, motor vehicles emission causes discomfort to people who reside in the roadside. Off field observation result, the individual populations which air contaminants exposed in high risk level can be found. Population with high risk is individuals who live in roadside, close to the source of contamination which is vehicle emission. The exposed potential populations in this research are: pedicab worker, park worker, and cloister merchant. The identification of that population is considered to represent the other population within the area.

b The Contaminants pathway identification
The entrance processes of air contaminants into body occur in three ways; inhalation, ingestion, and dermal contact (La Grega, 2001). The pathway of this research is inhalation. The main source of air contaminants come from motor vehicles emission which spreads on the air and influences the ambient air quality which enters into the body through respiration.

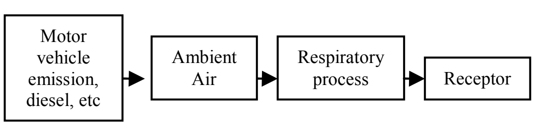

Figure 2 Contaminants pathway of NO_2, and SO_2 into the body

1.

Figure 3 Pollutant pathway of NO_2, and SO_2 in the roadside

c The Contaminants intake into the body measurement
The intake value of NO_2 and SO_2 into the respondents body influenced by contaminants exposure duration, the highest average intake suffered by respondents who have profession as pedicab worker because they have longer average time to work so that possibility contaminants exposure higher. Furthermore, pedicab workers need more energy hence requirement of the oxygen gets higher and so does the contaminants within oxygen which enter into the body. The intake value of NO_2 and SO_2 is shown on Table 3 and Table 4;

Table 3 NO_2 Intake

No.	Location	NO_2 Intake			Average
		Pedicad Worker	Park Worker	Cloister Merchant	Intake
1	Wates Street	0,0025	0,0030	0,0020	0,0025
2	Diponegoro Street	0,0055	0,0040	0,0030	0,0042
3	Prambanan Street	0,0040	0,0060	0,0035	0,0045
4	Magelang Street	0,0030	0,0030	0,0035	0,0032
5	Sudirman Street	0,0045	0,0035	0,0045	0,0042
6	Godean Street	0,0045	0,0035	0,0035	0,0038
7	Parangtritis Street	0,0040	0,0030	0,0050	0,0040
8	Solo Street	0,0065	0,0030	0,0035	0,0043
9	Ahmad Dahlan Street	0,0085	0,0060	0,0080	0,0075
10	Gedongkuning Street	0,0030	0,0030	0,0030	0,0030
11	Malioboro Street	0,0055	0,0035	0,0030	0,0040
12	C. Simanjuntak Street	0,0065	0,0030	0,0037	0,0044
13	Mentri Supeno Street	0,0035	0,0020	0,0030	0,0028
14	Bantul Street	0,0030	0,0050	0,0030	0,0037
15	Kaliurang Street	0,0050	0,0050	0,0035	0,0045

Source : Analysis result, 2006.

Table 4 SO_2 Intake Gas

No.	Locations	SO_2 Intake			Average
		Pedicad Worker	Park Worker	Cloister Merchant	Intake
1	Wates Street	0,0008	0,0009	0,0006	0,00075
2	Diponegoro Street	0,0028	0,0020	0,0015	0,00208
3	Prambanan Street	0,0022	0,0034	0,0021	0,00255
4	Magelang Street	0,0011	0,0012	0,0013	0,00118
5	Sudirman Street	0,0010	0,0009	0,0010	0,00095
6	Godean Street	0,0011	0,0007	0,0008	0,00088
7	Parangtritis Street	0,0016	0,0014	0,0019	0,00160
8	Solo Street	0,0015	0,0008	0,0009	0,00107
9	Ahmad dahlan Street	0,0043	0,0032	0,0038	0,00377
10	Gedongkuning Street	0,0008	0,0008	0,0009	0,00082
11	Malioboro Street	0,0044	0,0032	0,0025	0,00335
12	C. Simanjuntak Street	0,0015	0,0007	0,0008	0,00099
13	Mentri Supeno Street	0,0017	0,0010	0,0013	0,00128
14	Bantul Street	0,0007	0,0011	0,0007	0,00083
15	Kaliurang Street	0,0015	0,0014	0,0010	0,00128

Source : Analysis result, 2006.

Dose-Response Assessment

a Nitrogen Dioxide (NO_2)

From the calculation result of NO_2 intake, the highest average intake of NO_2 enters into the body is 0,0075 mg/kg.day and the lowest is 0,0025 mg/kg.day. While the highest NO_2 concentration is 0,03 ppm and the lowest is 0,011 ppm. According to Peavy (1985), NO_2 concentration below 0,12 ppm do not have effect to the human being. However, if exposed at high concentration will adverse of health like emphysema.

Based on the experimental study, using animals, the dangerous influence; for example the respiratory system, happens after the exposed NO_2 intake is 100µg/m^3. In human being, the value of NO_2 as much as 250 µg/m^3 and 500 µg/m^3 can influence the respiratory system of a asthma patient and a healthy person. Therefore, the small amount or below standard NO_2 intake is not too dangerous for human being.

b Sulfur Dioksida (SO_2)

From the sampling result in all locations, the highest average concentration SO_2 in 2005 was 0.0111 ppm in PKU Muhammadiyah and the lowest was 0.0022 ppm in Bantul street, the average concentration was 0.0044 ppm. According to Wardhana (1994), SO_2 can be detected from the smell at concentration of 0,3-1 ppm. Therefore, in Jogjakarta the SO_2 cannot be detected by scent

Risk Characterization

Table 5 shows The risk level of NO_2, and SO_2 contaminants still under 1, hence the risks is acceptable into the body. The highest risk level in Malioboro street equal to 0,3870 and the lowest 0,1647 in Wates street. The responders which have highest average risk is the padicab worker.

Table 5 The average risks pursuant to work type

No.	Locations	Work Type of Risks			Average
		Pedicab worker	Park Worker	Cloister Merchant	Risks
1	Wates Street	0,166	0,199	0,129	0,1647
2	Diponegoro Street	0,389	0,288	0,216	0,2977
3	Prambanan Street	0,195	0,293	0,169	0,2190
4	Magelang Street	0,172	0,177	0,205	0,1847
5	Sudirman Street	0,278	0,235	0,278	0,2637
6	Godean Street	0,386	0,250	0,274	0,3033
7	Parangtritis Street	0,354	0,300	0,434	0,3627
8	Solo Street	0,413	0,220	0,242	0,2917
9	Ahmad Dahlan Street	0,300	0,222	0,249	0,2570
10	Gedongkuning Street	0,176	0,176	0,170	0,1740
11	Malioboro Street	0,517	0,372	0,272	0,3870
12	C. Simanjuntak Street	0,554	0,275	0,307	0,3787
13	Mentri Supeno Street	0,300	0,175	0,207	0,2273
14	Bantul Street	0,145	0,236	0,136	0,1723
15	Kaliurang Street	0,391	0,373	0,254	0,3393

Source: Analysis result, 2006.

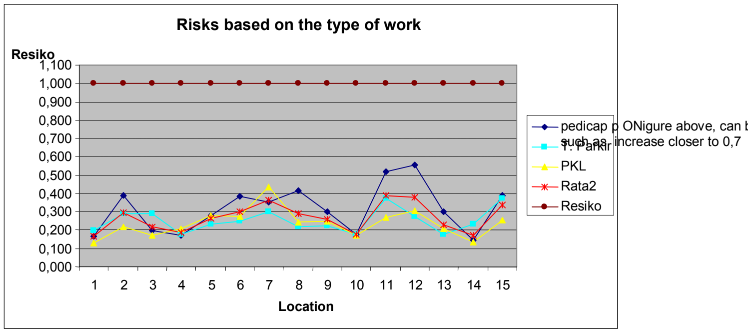

Figure 4 Occupational Type of Risk

From the figure 4 above, the pedicap workers have the highest average of risk.

Conclusion

1. Concentration of NO_2, and SO_2 in 15 sampling locations are still below quality standard according to DIY Governor Regulation No. 153/2002 about the ambient air quality standard. The highest average concentration of NO_2 (56,5 $\mu g/m^3$) and SO_2 (28,87 $\mu g/m^3$) in PKU Muhammadiyah Ahmad Dahlan street.
2. The risks level of NO_2, and SO_2 that respondents accepted in the surrounding sampling locations is still safe / acceptable because of total HI value < 1. The highest risk level was suffered by respondent who live in Beringharjo market, Malioboro street (0,3870) and the lowest was suffered by respondent in wates street (0,1647). The risk value only measured when the respondents work or live in the roadside and probability to the different concentrations exposed in another places, along with different contaminants type so that the real risk to be suffered will be higher.

Acknowledgement

This research project hopefully can be fulfilling the wide space in the related area. For that reason, this research project should be considered as a work in progress. The contribution of Emma Nurmala, Haryono Setiyo Huboyo, Mochamad Adhi Kurniawan is highly appreciated. The author is really thankful for their input, collaboration and support within the research project.

References

1. Anonim, 1997, *Rekayasa Lingkungan*, Gunadarma, Jakarta.
2. Garg, M.R., 2004, *Environmental Pollution and Protection*, Deep & Deep Publications PVT. LTD., New Delhi.
3. Kamala, A dan D. L. Kanth Rao, 1993, *Environmental Engineering*, McGraw-Hill, New Delhi.
4. Kastiyowati, Indah, 2001, *Dampak Dan Upaya Penanggulangan Pencemaran Udara*, http://buletinlitbang.dephan.go.id/index.asp?vnomor=7&mnorutisi=8,24 Desember 2005
5. Peavy, Howard S., 1985, *Environmental Engineering*, McGraw Hill, Singapura.
6. Ruchirawat, M., 1996, *Environmental Toxicology Volume 3*, Chulabhorn Research Institute, Thailand.
7. U. S. EPA, 1991, *Air Pollution and Health Risk*, http://Www.Epa.Gov/Ttn/Atw/3_90_022.Html, 27 Desember 2005.
8. U. S. EPA, 1993, *Reference Dose (RfD): Description and Use in Health Risk Assessments*, http://www.epa.gov/IRIS/rfd.htm, 31 Desember 2005.
9. U.S. EPA, 2005, *Risk Assessment process*, http://cfpub.epa.gov/ncea/cfm/nceariskassess.cfm, 27 Desember 2005.
10. Wardhana, Wisnu Arya, 1994, *Dampak Pencemaran Lingkungan*, Andi Offset, Jogjakarta.