VOL. 11, NO. 21, NOVEMBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

ENVIRONMENTAL HEALTH RISK ASSESSMENT OF TSP (SI AND PB) TOWARD WORKERS DUE TO ROAD CONSTRUCTION PROJECT (CASE STUDY: CONSTRUCTION OF LINGKAR KALIWUNGU ROADWAY KM23+250 – KM23+450, INDONESIA)

Syafrudin Syafrudin, Pertiwi Andarani and Rafini Rahmadini
Department of Environmental Engineering, Faculty of Engineering, Diponegoro UniversityJalanProf. H. Sudarto, SH, Tembalang, Semarang, Indonesia
E-Mail: andarani@ft.undip.ac.id

ABSTRACT

Road constructions could generate air pollutants that have a negative impact to health. This research examined the analysis of risks of Total Suspended Particulates (TSP) at road construction areas, such as roadbed construction, rigid concrete casting, and joint cutting activities. The main purposes of this research are to measure the concentration of TSP in each aforementioned activity, to compare the measurement results with the air quality standard in Indonesia, and to analyze the risks of TSP exposure to the workers. The sampling method was undertaken according to SNI 19-7119.3-2005 and the risk characterization was done based on US-EPA method. Based on this research, all of TSP concentration in samples has exceeded the permissible limit (395.41-1200.15 µg/Nm^3). However, according to the risk characterization, it is found that the carcinogenic risks associated with Pb via inhalation and ingestion were still below the acceptable level (<1.0E-04) and the non-carcinogenic risks of Pb and Si were low (HQ<1.0).

Keywords: construction, TSP, Pb, Si, health risk characterization.

1. INTRODUCTION

Road construction or road widening is usually proposed to reduce traffic jam and to support the economic development, but there were little comprehensive assessment regarding the air quality surrounding the project (Matson et al, 2006). According to Zhi (1995), the risks of construction activity could come from two sources: the first source is from the environmental impact; usually called the external risk while the second source is from the uncertainties in the project itself; called internal risk. In addition, the construction activities showed 3.8% of total particulate emission from open source in the US (Evan and Cooper, 2012) which inevitably contribute to air pollution. According to The Act of Republic of Indonesia No. 32/2009 regarding the basics of environmental management and protection, air pollution is the existence of one or more pollutants in the air in a certain number of concentrations at a time that could cause problems in humans, animals, plants and other objects.

The air pollution coming from the concrete cutting and construction will take effect on the health and life quality of the residence and worker. Bergdahl, *et al* (2004) concluded that occupational exposure to dust increases mortality due to chronic obstructive pulmonary disease, even in never-smokers. Furthermore, asthma caused by occupational exposure to dust during construction has been found (American Thoracic Society, 2003). The risk of dust exposure on workers may vary according to place of activity, the activities carried out by an individual, and the lifestyle of each worker. There are three ways of entry of air pollutants into the human body, i.e. inhalation, ingestion, and skin penetration. Road pavement or more often called rigid pavement consists of Portland cement concrete slab and foundation layers (could also be done without foundation layer) put above the land ground and/or ground heap. According to Mustika(2006), rigid work stages in its order are as follows; measurement (determination) of elevation, installation of formwork/iron, distribution of concrete pavement, concrete maintenance/curring, slitting with saw cutter, and ended with the work of joint sealant. Based on a previous research by Qi (2013), TSP resulting from road construction activities were generated more from mechanical construction or physical work than the wind erosion of soil material. Therefore, it is necessary to assess the potential health risks on the construction workers according to their activities. The objectives of this study are to measure the concentration of Total Suspended Particulates (TSP) in a rigid pavement process which consists of roadbed construction, concrete casting, and concrete cutting activities in road construction of LingkarKaliwungu Km 23+250 - Km 23+450; and to analyze health risks of TSP of these activities towards the construction workers.

2. METHODS

2.1 Road construction and sample description

Road construction project has been selected as the research location because air pollution could be occurred due to the construction activities and could have effects on the construction workers' health, particularly TSP (Total Suspended Particulates). The construction project was carried out on LingkarKaliwungu KM 23+250 until KM 23+450. In this research, the project activities could be divided by three activities, as follows: **Roadbed construction**: The LingkarKaliwungu Roadway consists of two lanes. However, the samples were taken in one lane, according to the project schedule. The roadbed construction includes some demolition activities such as breaking, cutting, and crushing the previous asphalt or concrete of the road; Rigid concrete casting: in this activity, the TSP exposure of two lanes were analyzed. In this activity, concrete used cement and water as the glue between sand and crushed rock. Workers placed concrete into steel molds (forms); Joint Cutting: in this activity, TSP was sampled at two lanes. A finishing machine vibrated and trimmed to the necessary height. To prevent cracks, workers cut joints between the concrete slabs. Dust exposure at these three activities of road construction cannot be avoided. At each activity, sampling of the TSP has been conducted three times as reduplication and each sampling was done by 50 meters distance. The reduplication was conducted at KM 23+250, KM 23+350 and KM 23+450.

2.2 Sample collection

This research was conducted by taking TSP samples of the ambient air at the study site, namely LingkarKaliwunguroad which is Kendal City and Semarang City Borderline road. The TSP sampling was done using Dust Sampler DS 600 - MVS with maximum capacity 600 liters/min and glass microfiber filter Whatman GF/A 1820-110 (0.26-mm width, 110-mm diameter; 1.6-μm pore size). The microfiber filter was made of borosilicate glass. To remove volatile substances and other impurities, the filter membranes were baked at 105˚C for two hours and then put in a desiccator for 15 minutes.

The sampling method was undertaken according to SNI 19-7119.3-2005. The dust sampler was placed in 2-3 meters from the workers with 1.5 meters height and the sampler was mobilized according to the worker movement in order to measure the TSP inhaled by the worker. However, it should be noted that the worker must not be bothered by the dust sampler.

Background test was undertaken to assess the TSP concentration in ambient before construction activities. The background test was conducted at day and night because the construction took place at day and night according to the activity. For 50 meters construction, roadbed construction, concrete casting, and joint cutting needed approximately 1.5, 3.5, and 2 working hours, respectively. The sampling was undertaken in eight days during 3 weeks, including one day for background ambient sampling.

2.3 Sample analysis

The sample preparation was done prior to AAS (Atomic Absorption Spectrophotometer) analysis. The filter was cut into some pieces, then HNO_3 (± 200 ml) was added and then heated at 175^{o}C for 12 hours. Next, the sample was diluted to 25 ml, thenanalyzed using AAS with wave length for Pb and Si was 422.7 nm and 217.0 nm, respectively.

2.4 Calculation of TSP concentration

The calculation of TSP concentration was based on SNI 19-7119.3-2005, which was done in three steps, as follows:

Flow rate correction at normal condition

$$Qs = \mathrm{Qo} \times \left[\frac{\mathrm{Ts}\times\mathrm{Po}}{\mathrm{To}\times\mathrm{Ps}}\right]^{\frac{1}{2}} \quad (1)$$

where, Qs: corrected flow rate Qs (m^3/min) at normal condition; Q: as measured flow rate (m^3/min); To: measured temperature (°C); Ts: standard temperature (25°C); Po: measured pressure (mmHg); Ps: standard pressure (760 mmHg). These standard temperature and pressure is based on EPA (1999).

Sampled air volume

$$\mathrm{V} = \frac{\mathrm{Qs_1}+\mathrm{Qs_2}}{2}\times \mathrm{t} \quad (2)$$

where, V: sampled air volume; Qs_1: corrected initial flow rate; Qs_2: corrected final flow rate, t: sampling duration (minutes).

Total Suspended Particulate (TSP) concentration in ambient

$$\mathrm{C} = \frac{(\mathrm{W_2}-\mathrm{W_1})\mathrm{x}\ 10^6}{\mathrm{V}} \quad (3)$$

where, C: TSP concentration (μg/Nm^3); W_1: initial filter weight (g); W_2: final filter weight (g); V : sampled air volume (m^3).

Next, the concentration of Pb and Si element in the TSP samples was analyzed using SNI 19-7119.4-2005 which was calculated as the following equation:

$$\mathrm{C} = \frac{(Ct-Cb)\ x\ Vt\ x\ \frac{S}{St}}{V} \quad (4)$$

where, C: the concentration of Si and Pb element in the sample (μg/m^3); Ct: concentration in sample; Cb: concentration in blank; Vt: solution volume; $\frac{S}{St}$: ratio of exposed filter area and total filter area used; V: sampled air volume.

2.5 Exposure assessment

The workers in this project are potential receptors of TSP. Three exposure pathways were analyzed, e.g. inhalation, ingestion, and dermal contact. Based on the human health evaluation manual by US-EPA (2011), the chemical daily intake (CDI) was estimated to assess the risks posed by Pb and Si in TSP via inhalation, ingestion, and dermal contact. The equations were as follows (US-EPA, 2011):

$$\mathrm{CDI_{inh}} = \frac{\mathrm{C \times InhR \times ET \times EF \times ED}}{\mathrm{BW \times AT}} \quad (5)$$

$$\mathrm{CDI_{ingest}} = \frac{\mathrm{C \times IngR \times ET \times EF \times ED}}{\mathrm{BW \times AT}} \times \mathrm{CF} \quad (6)$$

$$\mathrm{DAD_{dermal}} = \frac{\mathrm{C \times SA \times AF \times ABS \times EF \times ED}}{\mathrm{BW \times AT}} \times \mathrm{CF} \quad (7)$$

ARPN Journal of Engineering and Applied Sciences

where, CDI: chemical daily intake for ingestion (ingest) and inhalation (inh) (mg/kg-day); C: concentration of contamination (mg/m^3 or mg/kg); DAD: dermal absorbed dose (mg/kg-day); InhR: inhalation rate (1.5 m^3/hour, this value is an inhalation rate for construction worker based on US-EPA (1997); IngR: ingestion rate (100 mg/day for age group greater than 6 years old according to US-EPA (2011); SA: surface area of skin that contacts the TSP (3300 cm^2 for adults); AF: skin adherence factor for TSP (0.2 mg/cm^2); ABS: dermal absorption factor (1.0% was used based on Hu, *et al* (2012)); ET: exposure time (8 hours/day for road bed construction; 13 hours/day for rigid concrete casting; 6 hours/day for concrete cutting); EF: exposure frequency (250 days/year, for worker according to US-EPA (2014)); ED: exposure duration (25 years, for worker according to US-EPA (2014)); BW: body weight (kg, the body weight was determined based on the questionnaire distributed to all of the workers); AT: averaging time of exposure (25550 days, for the average exposure time for carcinogenic risk according to US-EPA (1997)).

2.6 Risk characterization

Risk and hazard indices for both carcinogenic and non-carcinogenic effects were quantified for each exposure pathway analyzed (via inhalation, ingestion, and dermal contact). According to US-EPA (2011), the carcinogenic risk (CR) and non-carcinogenic risk (as the hazard quotient, HQ) are as the following equations:

$$CR = CDI_{inh} \times SFi = CDI_{ingest} \times SFo \quad (8)$$

$$HQ = \frac{CDI_{inh}}{RfCi \times \frac{1000 \mu g}{mg}} = \frac{CDI}{RfDo} = \frac{DAD}{RfDd} \quad (9)$$

where, SFi: inhalation unit risk (µg/m^3)$^{-1}$; SFo: oral slope factor ((mg/kg-day)$^{-1}$); RfCi: inhalation reference concentration (mg/m^3), RfDo: oral reference dose (mg/kg-day); RfDd: dermal reference dose (mg/kg-day). The SFi, SFo, and RfCiwere obtained from OEHHA Database (http://www.oehha.ca.gov/risk/ChemicalDB/index.asp)which are summarized in Table-1. Reference dose for Pbwas taken from WHO (1993).

Table-1. RfCi, RfDo, RfDd, SFi, and SFo for Si and Pb.

Substance	**SFi** (mg/kg-day)$^{-1}$	**SFo** (mg/kg-day)$^{-1}$	**RfCi**(mg/m^3)	**RfDo** (mg/kg-day)	**RfDd** (mg/kg-day)
Si	NA	NA	3.00E-03	NA	NA
Pb	4.20E-02	8.50E-03	NA	3.5E-03	5.25E-04

NA: Not available

Table-2. Si and Pb concentration in TSP.

Activity	**Average concentration**		
	TSP (µg/Nm^3)	**Si** (µg/m^3)	**Pb**(µg/m^3)
Background test (day)	286.57	0.053	0.01
Background test (night)	272.51	0.123	0.07
Roadbed construction	395,41 ± 93,720	0.24 ±0.030	0.19 ± 0.050
Rigid concrete casting	524.51 ± 129.539	0.12 ± 0.004	0.08 ± 0.020
Concrete cutting	1200.15 ± 76.870	0.25 ± 0.020	0.17 ± 0.003

Carcinogenic risk (CR) is the probability of an individual developing any type of cancer from lifetime exposure to carcinogenic hazards (Hu *et al,* 2012). The acceptable or tolerable risk for regulatory purposes is from 1E-06 to 1E-04 (US-EPA, 2011). Meanwhile, HQ (Hazard Quotient) is the potential for non-carcinogenic effect posed by a chemical. If the value of HQ is below one, it indicates that there is no significant risk of non-carcinogenic effect.

According to the classification group orders defined by IARC (International Agency for Research on Cancer, lead compounds are class 2A (IARC, 2011). Meanwhile, based on the IARC (2011), crystalline silica in the form of quartz or cristobalite dust is carcinogenic to humans (Group 1), but the cancer slope factor of Si is not found in the OEHHA database, hence, the carcinogenic risk of Si exposure in TSP was not assessed in this study.

3. RESULTS AND DISCUSSIONS

3.1 Assessment of TSP in the road construction work

TSP identification was done by measuring the concentration of TSP at the time before the execution of road construction activities during the day and night in order to determine the initial concentration in the location of activities before the activity of road construction has started. TSP concentration measurement results can be seen in Table-2. As seen in Table-2, the background tests, both at day and at night, show that there are increases in the concentration of TSP, including the element of Si and Pb. Therefore, the road construction works had contributed elevated TSP in the present study.

Based on a previous research by Qi, *et al* (2013), TSPs in the road construction activities are generated more from mechanical construction or physical work than the wind erosion of soil material. The quantity of dust emissions from construction operations is proportionally influenced by the area of land being worked and to the level of construction activity (Qi, et al, 2013). The particulate emission from construction not only came in a coarse fraction but also fine particulate (Kumar et al, 2012). The dust emission from construction activities is related to emissions from heavy construction operations are positively correlated to the silt content of the soil (that is, particles smaller than 75 µm in diameter), as well as with the speed and weight of the average vehicle, and are negatively correlated to the soil moisture content (Qi, et al, 2013).

The background tests (prior to the construction work) at the LingkarKaliwungu Road have already exceeded the permissible limit according to the Government of Indonesia Ordinance No. 41 in 1999 (the permissible limit is 230 µg/Nm^3 while the samples were 286.57 µg/Nm^3 at day and 272.51 µg/Nm^3 at night). The highest concentration of TSP was generated at concrete cutting activities, namely 1200.15 µg/Nm^3; and the lowest concentration was generated at roadbed construction, namely 395.41 µg/Nm^3. All levels in the construction activities being sampled have exceeded the quality standard according to the Government of Indonesia Ordinance No. 41 in 1999.

The highest concentration of TSP was in the concrete cutting activity area (1200.15µg/Nm^3) because the workers needed to use special cutting tools that generated concrete dust emission. In addition, a byproduct of the concrete cutting tools in the form of diesel exhaust can also become another source of TSP in concrete cutting activities.

As for the element Pb and Si, both of them were still below the permissible limit according to WHO (2010) and ISO 7708:1995 which are 0.5 µg/m^3 and 3µg/m^3, respectively. However, it should be noted that if all of Pb concentration were accumulated in those three activities, the concentration would be 0.44 µg/m^3. This value is very close to the permissible limit.

Among those road construction activities, the highest concentration of Si was at concrete cutting activity while the highest Pb concentration was at the road bed construction. The high concentration of Si could became from the soil, which is one of dust emission (Santoso et al, 2012). The soil was dredged using heavy equipment and the Pbcould be originated from the equipment or machine emission, saw cutter, agitator truck, loading truck, and vehicles passing the road or research location. The element Pb is resulted from the fuel combustion containing lead (Pb), particularly diesel fuel and gasoline (Kuvarega and Taru, 2008).

Based on Speciate Data Browser Construction Dust by EPA (2011), the percentages of elemental Si and Pb in construction dust are 7.1% and 0.0037%, respectively. Meanwhile, the accumulation of element Si and Pb in this study were 0.22% and 0.18%. If these results are compared to the speciate data, the percentage of Si in this research is smaller and the Pb is larger. The higher concentration of Pb could be due to the research location where the traffic activity occurred, hence, the emission of the vehicles could not be avoided.

3.2 Risk Assessment for Si and Pb in TSP due to road construction works

Inhalation exposure is typically the primary route of direct exposure to airborne metals (Hu et al, 2012). Based on the supplemental guidance for inhalation risk assessment, the element Pbis listed in carcinogenic risks in TSP while Si is included in non-carcinogenic risk. The carcinogenic and non-carcinogenic risks from the Pb and Si in TSP can be seen in Table-3.

Table-3. Carcinogenic and non-carcinogenic risks via inhalation and ingestion exposure (mean ± standard deviation).

Activity	Pb (carcinogenic)		Pb (non-carcinogenic)		Si (non-carcinogenic)
	inhalation	ingestion	ingestion	dermal contact	inhalation
Roadbed construction (n=14)	3.78E-07 ±5.37E-08	1.61E-09 ±2.29E-10	5.42E-05 ±7.70E-06	2.39E-05 ±3.39E-06	3.85E-09 ±5.47E-10
Rigid concrete casting (n=20)	2.44E-07 ±3.69E-08	4.84E-10 ±7.30E-11	1.63E-05 ±2.458E-06	7.15E-06 ±1.08E-06	3.12E-09 ±4.70E-10
Concrete cutting (n=6)	2.61E-07 ±3.17E-08	4.90E-10 ±5.94E-11	1.65E-05 ±2.00E-06	7.24E-06 ±8.79E-07	2.99E-09 ±3.63E-10

The carcinogenic risks from Pb for the construction worker were still within the acceptable level (<1E-04) according to EPA (2011). This result indicates that the carcinogenic risks posed by element Pb via inhalation are still acceptable. The most hazardous risk posed by Pb via inhalation is roadbed construction (3.78E-07), while the lowest risk is rigid concrete casting (2.44E-07). It has been proved that Pb is "urban" element that is mostly anthropogenic, the main sources appearing to be traffic, building construction/renovation, weathering and corrosion of building materials (De Miguel, *et al*, 1997) and industrial activities (Al-Khashman, 2004).

The carcinogenic risk of Pb also could happen via ingestion. However, the risk posed by element Pb is still below the acceptable limit. The roadbed construction has the highest carcinogenic risk of Pb via ingestion and the concrete cutting had the lowest carcinogenic risk of Pb. Studies concerned with the risk exposure of Pb via inhalation particularly in street dust (The risk posed by Pb via ingestion. Therefore, it can be concluded that roadbed construction had the highest risk of carcinogenic Pbboth via inhalation and ingestion.

For non-carcinogenic effect, ingestion of dust particle appears to be the route of exposure to street dust that results in a health risk for Pb, followed by dermal contact (Ferreira-Baptista and De Miguel, 2005). The reference dose of Pb via inhalation has not been defined yet. Similar to the carcinogenic risk, the roadbed construction appears to be the highest risk of non-carcinogenic effect via ingestion (HQ = 5.42E-05) and dermal contact (HQ= 2.39E-05). The activity of rigid concrete casting has the lowest risk of Pb exposure via ingestion and dermal contact.

Exposure to silica dust may be considered an important hazard in the construction activities (Flanagan, *et al*, 2006). In the present study, the highest risk posed by element of Si is at the roadbed construction activity (HQ = 3.85E-09), when the concrete cutting has the lowest risk (HQ = 2.99E-09). Since the HQ is still below 1.0, the risk of Si exposure via inhalation during construction activities in the present study is still acceptable. EPA has not yet established a cancer slope factor of Si. However, according to other studies, the construction workers (including building demolition workers) could potentially have unacceptable risk to lung cancer mortality (Normohammadi*et al*, 2016).

In this research, although the measured TSP concentrations of all the activities exceeded the permissible limit, the health risks of element Pb and Si exposure via inhalation, ingestion, and dermal contact are still acceptable. Therefore, the permissible limit of TSP in the construction project should be evaluated or enacted specifically in Indonesia.

4. CONCLUSIONS

From the results of the air monitoring that has been done at three activities of road construction works in LingkarKaliwunguRoad,the highest TSP concentration was found in the concrete cutting (1200.15 μg/Nm^3) and the lowest was found at the roadbed construction (395.41 μg/Nm^3). All of the measured TSP concentration has exceeded the permissible limit value of quality standards that had been assigned by the Government of Indonesia Ordinance No. 41 in 1999 (the permissible limit is 230 μg/Nm^3). However, the carcinogenic risks associated with Pb in TSP via inhalation and ingestion were within the acceptable level for all of the workers (<1.0E-04). There were also little non-carcinogenic risks from Pb and Si via ingestion, inhalation, and dermal contact (HQ < 1.0). The highest risk of Pb exposure was the activity during roadbed construction (3.85E-09).

ACKNOWLEDGEMENT

We would like to thank the following individuals: FadhilahKhairunnisa, ST; Dr.Haryono S. Huboyo, ST, MT; and TitikIstirokhatun, ST, MSc for their contribution to the data of elements in TSP in this research.

REFERENCES

American Thoracic Society. 2003. American Thoracic Society Statement: Occupational Contribution to the Burden of Airway Disease. American Journal of Respiratory and Critical Care Medicine.167, 787-797.

Al-Khashman O. A. 2004. Heavy metal distribution in dust and soils from the work place in Karak Industrial Estate, Jordan. Atmospheric Environment.38, 6803-6812.

Bergdahl I.A, Toren K., Eriksson K., Hedlund U., Nilsson T., Flodin R., danJarvholm B. 2004. Increased Mortality in COPD among Construction Workers Exposed to Inorganic Dust. European Respiratori Journal. 23, 402-406.

De Miguel, E., Llamas, J., Chacon, E., Berg, T., Larssen, S., Royset, Vadset, M. 1997. Origin and patterns of distribution of trace elements in street dust: unleaded petrol and urban lead. Atmospheric Environment. 31(17): 2733-2740.

Ferreira-Baptista, L. and De Miguel, E. 2005. Geochemistry and risk assessment of street dust in Luanda, Angola: A tropical urban environment. Atmospheric Environment.39: 4501-4512.

Flanagan, M.E., Seixas, N., Majar, M., Camp, J., Morgan, M. 2003. Silica dust exposure during selected construction activities. AIHA J (Fairfax, Va). 64(3): 319-328.

Evan J. S., Cooper W.W. 2012. An Inventory of Particulate Emissions from Open Sources. London: Harvard School of Public Health.

Hu X., Zhang Y., Ding Z., Wang T., Lian H., Sun Y., Wu J. 2012. Bioaccessibility and health risk of arsenic and heavy metals (Cd, Co, Cr, Cu, Ni, Pb,Zn and Mn) in TSP and PM2.5 in Nanjing, China. Atmospheric Environment.57, 146-152.

International Agency for Research on Cancer (IARC) 2011 Agents Classified by the Monographs.Vol. 1-102.

Kumar P, Mulheron M, Claudia S. 2012. Release of Ultrafine Particles from Three Simulated Building Processes. Journal of Nanoparticle Research. 14, 771.

Kuvarega A.T., Taru P. 2008. Ambiental dust specification and metal content variation in TSP, PM10, and PM2.5 in urban atmospheric air of Harare (Zimbabwe). Environmental Monitoring and Assessment. 144(1): 1-14.

Matson L., Taylor I., Lynn S., Elliott J. 2006. Beyond Transport Infrastructure: Lessons for the Future from Recent Road Projects. Report Summary for CPRE and the Countryside Agency. Campaign to Protect Rural England (CPRE), England.

Mustika S. 2006. Pembangunan BerwawasanLingkungandalam Usaha MenjagaKelestarianLingkunganHidup. Bulletin BPKSDM, BadanPembinaanKonstruksi (in Indonesian Language).

Normohammadi M., Kakooei H., Omidi L., Yari S., Alimi, R. 2016. Risk Assessment of Exposure to Silica Dust in Building Demolition Sites. Safety and Health at Work, 1-5 (article in press http://dx.doi.org/10.1016/j.shaw.2015.12.006).

US-EPA. 1997. Guidelines for Exposure Assessment. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC.

US-EPA. 1999. Compendium of Methods for the Determination f Inorganic Compounds in Ambient Air: Compendium Method IO-2.4, Calculation for Standard Volume.

US-EPA. 2011. Risk Assessment Guidance for Superfund. In: Part A: Human Health Evaluation Manual; Part E, Supplemental Guidance for Dermal Risk Assessment; Part F, Supplemental Guidance for Inhalation Risk Assessment, vol. I. http://www.epa.gov/oswer/riskassessment/human_health_exposure.htm.

US-EPA. 2014. Region 4 Human Health Risk Assessment Supplement Guidance. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC.

Office of Environmental Health Hazard Assessment (OEHHA). 2003. The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments. California Environmental Protection Agency.

Qi J., Nadhir A., Sven K. 2013. Measurement of dust emission from a road construction using exposure-profiling method. Natural Science. 5(12): 1255-1263.

Santoso M., Lestiani D.D., Markwitz. 2012. Characterization of airborne particulate matter collected at Jakarta roadside of an arterial road. Journal of Radioanalaytical and Nuclear Chemistry. 297(2): 165-169.

World Health Organization (WHO) 1993 Guidelines for Drinking Water Quality. Recommendation, (second ed), vol. I. Geneva: WHO.

Zhi H. 1995. Risk management for overseas construction project. International Journal of Project Management. 13(4): 231-237.