EnvironmentAsia
The international journal published by the Thai Society of Higher Education Institutes on Environment

Available online at www.tshe.org/EA
EnvironmentAsia 7(1) (2014) 25-31

Health Risk Assessment of Hydrogen Sulfide Exposure among Workers in a Thai Rubber Latex Industry

Cheerawit Rattanapan [a], Thunwadee Tachapattaworakul Suksaroj [b], Jiraporn Chumpikul [a] and Thitiworn Choosong [c]

[a] *ASEAN Institute for Health Development, Mahidol University, Salaya, Phutthamonthon, Nakhonpathom, 73710 Thailand.*
[b] *Faculty of Environmental Management, Prince of Songkla University, Hat Yai, Songkhla, 90112 Thailand.*
[c] *Department of Community Medicine, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla, 90112 Thailand.*

Abstract

The research objective was to assess health risk from exposure to hydrogen sulfide among rubber latex workers. The results showed that the hydrogen sulfide concentrations of fifteen sample air sample were the rage between 0.0537-0.0610 ppm and avenge of 0.0612 ppm. Secondly, levels of knowledge, attitude and preventive behavior among rubber latex workers about exposure to hydrogen sulfide located in moderate. In additional, the receiving training and the knowledge were the strong predictor for preventive behavior ($p<0.05$). Finally, assessing health risk from exposure to hydrogen sulfide among workers was 0.1259, which was lower than 1 and acceptable based on United States Environmental Protection Agency. However, the health risk reduction approach among workers from exposure to hydrogen sulfide was recommenced. It divided two parts: (1) the reductions of hydrogen sulfide concentration from rubber latex process and (2) the health risk reduction with rubber latex workers.

Keywords: rubber latex industry; hydrogen sulfide; health risk

1. Introduction

Hydrogen sulfide (H_2S) is a colorless, flammable gas with a characteristic of rotten eggs. The odor threshold is 0.0007−0.014 ppm (Drimal *et al.*, 2010). In additional, H_2S is extremely toxic to living organisms and plants. At a level of 0–5 ppm in the air, it can be detected easily. At levels greater than 10 ppm it can affect human health, while levels of more than 600 ppm can cause death (Droste, 1997). Hence, H_2S is an important and frequently lethal occupational and environmental hazard that has a unique and consistent pattern of toxicity (Guidotti, 2010). The exposure-response curve for lethality is extremely steep for hydrogen sulfide (Prior *et al*., 1998; Guidotti, 1996). Concentration is much more important than duration of exposure. Fatal exposure to hydrogen sulfide in humans, for example, in theory may take place at 150 ppm for 6 hours (concentration × time product = 0.252) or 650 ppm for 8.5 minutes (0.005). This means that, for hydrogen sulfide, higher concentrations are much more toxic, even with proportionally shorter exposure levels, for both mortality and experimental pulmonary edema induced in the rat (Guidotti, 2010). Besides, the toxic effects of H_2S in occupational settings are well known (WHO, 2000) and many studies of background exposure due to H_2S from industry source indicated that H_2S may have negative effects on health (Guidotti, 1994; Drimal *et al*., 2010).

Thailand is the top rubber producers in the world, with production at approximately 2.5 million tons per year. At the present, there are more than 5 million acres of rubber plantations (Apron *et al*., 2010). Rubber latex is used as a raw material to produce several products such as rubber tires, medical gloves, condoms, rubber bands, flexible tubing, etc (Choosong *et al*., 2010). Thus, rubber industry in Thailand is economic and social importance because of its production value, the revenues from export and the employment in this sector, whereas about 0.6 million people work in rubber industries (MOL, 2008). The most important primary rubber products include concentrated latex, block rubber and ribbed smoked sheet rubber (Korwuttikulrungsee, 2002). From the report of Rubber Research Institute of Thailand in 2010 showed more than 325 rubber industries of the primary latex industries in Thailand (Rubber Research Institute of Thailand, 2010). In the process of latex product, many reports (Pollution

Control Department, 2005; Rattanapan *et al.*, 2011) recommend that the odor problem such as H_2S was found in this process because sulfuric acid is used extensively, producing a wastewater in large quality and with distinct characteristics. Hence, the rubber latex industry is a major source of environmental pollution in Thailand and many rubber-growing countries (Chaiprapat *et al*., 2011). However, many studies have not monitored the occupational exposure of H_2S concentration in the rubber latex process.

The assessment of the risk for the human health is commonly performed in the framework of the environmental impact assessment and is the emitted pollutants in order to evaluate the intake of the human subject arising from direct and indirect exposure and to assess the resulting final risk level through dose–response relationships (Lonati, 2012). Five steps including data collection, toxicity assessment, exposure assessment, risk characterization and risk management of a method of risk assessment of hazardous compounds was developed by USEPA (1989). This risk assessment method could be applied for H_2S by assessing the inhalation (Drimal *et al*., 2010). However, there has been a little report on health risk assessment of occupational H_2S exposure form the rubber latex industry.

Therefore, the objectives of this research were: (1) to determine the concentration of H_2S in a rubber latex industry in Songkhla province, Thailand; (2) to determine knowledge, attitude and preventive behavior among workers of a rubber latex industry form exposure to hydrogen sulfide; and (3) to assess health risk from exposure to hydrogen sulfide among workers of a rubber latex industry.

2. Materials and Methods

A cross-sectional study was conducted in a rubber latex industry in Bangklam district, Songkhla province, Thailand during year of 2011 to evaluate the health risk among 180 workers exposure to H_2S in working area and to determine knowledge, attitude and preventive behavior among workers of a rubber latex industry form hydrogen sulfide exposure. This industry consisted of concentrated latex, block rubber and skim cave processes. This study was approved by the ethics committee of Mahidol University Institutional Review Board (COA. No. MU-IRB 2011/122.1306).

2.1. Sample collection and analysis

H_2S concentrations of the air samples were collected and analyzed using NIOSH method 6103 (National Institute of Occupational Safety and Health, 1994). Open face sampling at breathing zone among workers was collected for full shift of eight hours using a personal air sampling pump (SKC Inc., Eighty Four, Pa., USA) connected with a charcoal tube (SKC Inc., Eighty Four, Pa., USA) at a flow rate of 0.7 liters per minute and connected with a portable battery-operated sampling pump, calibrated before and after use with a GilibratorTM flow meter (Sensidyne, Inc., USA). Field blanks were collected in a similar manner, except that no air was pulled through the sample. Samplers were placed in the area as close as possible to the breathing zone of the workers and the highest risk workers, as judged from observation during a walk through survey and preliminary results of H_2S gas detector tube with piston hand pump, were selected for air sampling throughout the industry area. In the wastewater treatment process areas such as treating and sedimentation ponds was applied. In the skim cave process areas such as skim ponds were taken. In block rubber department were include. After the sampling, the charcoal tubes were capped and packed securely with plastic caps and were stored in an icebox below 4°C after use, and then frozen until analysis in the laboratory. For H_2S analysis, Ion chromatography technique was used to investigate the concentration of H_2S in the charcoal tube according to the NIOSH method 6103 (National Institute of Occupational Safety and Health, 1994). The limits of detection and quantization were 11 μg per sample and 17 μg per sample, respectively.

2.2. Questionnaire and collecting data procedure

The total number workers of a rubber latex industry in 2011 were 180. The sample size was evaluated using a confidence interval of 95%, an acceptance error of 5%, and a proportion of low preventive behavior of 0.5. Thus, the required sample size was at least 123. Purposive sampling was used to select the participants, with department as the strata. Afterwards, they were interviewed by structured questionnaire from June 20, 2011 to July 20, 2011.The questionnaire used in this study comprised of 37 questions and divided into four parts: socio-demographic factors comprised eleven questions dealing with age, weight, gender, academic level, marital status, working department, income, working duration, and working positions, training, information.

The knowledge part comprised in¬formation about worker knowledge about H_2S, health effect of H_2S and protection of H_2S exposure. The number of questions was 11. In each questions, workers were given one point for the correct answer and no point for an incorrect answer. The total score of the knowledge part was classified into three categories: “poor” if the score was <60% of the total score; “fair” if from 60% to 80%; and “good” if >80%.

The attitude part addressed worker opinions and thoughts about preventing behavior of H_2S exposure. The attitude section had five questions. Scoring for each statement was 5, 4, 3, 2, and 1 corresponding to “strongly agree” “agree” “neutral” “disagree” and “strongly dis¬agree.” The score was reversed for nega¬tive statements. The total score was categorized into two groups: “positive attitude” (equal to or more than the median) or “negative attitude” (less than the median). A “negative attitude” indicated the workers think that preventing H_2S exposure is not very important.

The preventive behavior part considered with nine questions for preventing H_2S exposure. Five levels of answers were put in this part; 5 points: “always;” 4: “quite often;” 3: “sometimes;” 2: “rarely;” and 1: “very rarely.” The score was reversed for negative statements. The total score was classified into two categories; a total score which was equal to or more than the median was considered “good,” and less than the median was considered “poor.”

This questionnaire was pre-tested for reliability by selecting 30 workers from other rubber latex industry in same province with the result of Kuder-Richard son (KR20) of 0.805 for the knowledge section. Cronbach’s α for attitude and preventive behavior were 0.703 and 0.779, respectively.

Processed data were analyzed using SPSS software version 16. Univariate analysis was used to describe the mean, standard deviation, median, quartile deviation, minimum, maximum, number and percentage. χ2tests were used to determine a possible association between each qualitative independent variable and preventive behavior among workers. Correlation between quantitative variables was examined. Finally, multiple logistic regression analysis was used to determine the as sociation between independent variables and preventive behavior.

2.3 Chronic Diary Intake (CDI)

CDI was a measurement that uses to estimate the exposure of non-carcinogenic effects. CDI was calculated by the route specific mathematical algorithms that are based on the equation (1) below (Kolluru, 1996).

$$\mathrm{CDI}\ (\mathrm{mg/kg\text{-}day}) = \frac{\mathrm{CA}\times\mathrm{IR}\times\mathrm{ED}\times\mathrm{EF}\times\mathrm{L}}{\mathrm{BW}\times\mathrm{ALT}\times\mathrm{NY}} \qquad (1)$$

Where, CA = contaminant concentration in air (mg/m^3); IR =inhalation rate (m3/hr); ED =exposure duration (h/week); EF = exposure frequency (weeks/year); L = length of exposure (years); BW= body weight (kg); ATL = average time of lifetime (period over which exposure is averaged, say, 23.5 years); NY =number of days per year (say, 365 days).

2.4. Non-Carcinogenic Risk Evaluation

Hazard Quotient (HQ) expresses the risk estimation in this condition. The non carcinogenic effects are calculated by the relationship (2) below:

$$\text{Hazard Quotient (HQ)} = \text{Exposure} / \text{RfD} \qquad (2)$$

Exposure chemical exposure level, or intake (mg/kg-day) RfD reference dose (mg/kg/day) (0.0015 mg/kg-day), Where: HQ > 1 adverse non-carcinogenic effect concern; HQ <1 acceptable level (no concern).

3. Results

3.1. H_2S concentration in a rubber latex industry

H_2S concentration in a rubber latex industry results are presented in Table 1. The sampling point areas including wastewater treatment plant, skim pond, block latex department and housing worker area hold a rubber latex industry area, affected the health impact (Pollution Control Department, 2005), and primary survey by H_2S gas detector tube & piston hand pump (data not shown). The results showed that the range and average of H_2S concentrations in a rubber industry were 0.0000-0.1875 ppm and 0.0344 ppm, receptively. The highest and lowest concentration of H_2S was detected in the sedimentation pond of wastewater treatment and housing worker area, respectively.

3.2. Preventive behavior from H_2S exposure among rubber latex workers

The participants of this study consisted of 125 workers in a rubber latex industry in Songkhla province, Thailand. Range age of workers was 31-40 years. Gender distribution was nearly equaled at man. In additional, more than 60% of the workers were the part-time staffs. Regarding education level, 53.6% of the workers finished the primary school. Nearly 50% had been working as workers from one to five years. Besides, just over 61% of workers have passed the air pollution training and received the air pollution news by television. Moreover, about 54% of workers had

Table 1. H_2S concentration in a rubber latex industry

Sampling points	H_2S concentration (ppm)
Equalization pond	0.0062
Aeration pond II	0.0062
Aeration pond II	0.0292
Aeration pond III	0.1875
Sedimentation pond	0.0025
Skim pond I	0.0751
Skim pond II	0.0455
Skim pond III	0.0388
Skim pond IV	0.0581
Skim pond V	0.0360
Block latex department	0.0089
Housing worker area I	0.0000
Housing worker area II	0.0040
Housing worker area III	0.0015
Housing worker area IV	0.0165
Average Concentration = 0.0344 ppm	

moderate knowledge from exposure to hydrogen sulfide. More than 74% of workers had moderate attitude about hydrogen sulfide exposure in the process. Regarding the preventive behavior among workers about hydrogen sulfide exposure found that about 53% of workers had moderate preventive behavior.

The simple regression analysis result of the following variables had significant association with preventive behavior among workers: full time staff (p-value <0.5), the receiving air pollution training (p-value <0.5), and knowledge about exposure to hydrogen sulfide (Table 2). Then, these variables were included in multiple logistic regression analyses to find which variables were the best predictors for preventive behavior. The result shown in Table 3 that the receiving air pollution training and knowledge about exposure to hydrogen sulfide were statistically significant as the best predictors for preventive behavior at *p-value* <0.001.

Table 2. Association between the independent variables and preventive behavior among workers of a latex rubber

Independent variables	Correlation coefficients	Unstandardized regression coefficients	Std. error	*P-value*
Age (year)	0.143	0.110	0.069	0.115
Gender(Male) [a]	-	-2.489	1.334	0.064
Secondary school and above [b]	-	-1.764	1.308	0.180
Rubber department [c]	-	-1.207	1.316	0.361
Full time staff [d]	-	-3.173	1.317	0.018*
Work duration (Year)	0.177	0.310	0.157	0.051
The received training	-	5.598	1.249	<0.001*
Knowledge (score)	0.185	0.686	0.344	0.048*
Attitude(score)	0.134	0.406	0.274	0.141

Reference group: [a] Male, [b] Lower secondary school, [c] other departments, [d] Part time staffs, [e] The non-receiving training, *(*p-value<0.05*)

Table 3. Factor affecting the preventive behavior among workers of a latex rubber

Independent variables	Unstandardized regression coefficients	Std. error	Standardized regression coefficients	*P-value*
The received training (Yes) [a]	4.836	1.374	.315	*0.001
Knowledge(score)	.706	.332	.190	*0.036
Rubber department [b]	-1.296	1.276	-.086	0.312
Full time staff [c]	-2.731	1.430	-.178	0.059
Gender(Male) [a]	-1.913	1.308	-.126	0.147
Age (year)	.055	.069	.068	0.432

Reference group: [a] The non-receiving training, [b] other departments, [c] Part time staffs, [d] Woman,*(*p-value<0.05*)

Table 4. Parameter values for Chronic Diary Intake

Parameters	Value	Units	Sources
Avenged H_2S concentration	0.0478	mg/m^3	H_2S concentration analysis
Inhalation rate	0.83	m^3/hr	USEPA (2009)
Exposure duration	8	h/week	questionnaire
Exposure frequency	52	weeks/year	questionnaire
Length of exposure	7.3	year	questionnaire
body weight	55.8	kg	questionnaire
Average time	23.5	years	questionnaire

3.3. Health risk assessment

Health risk assessment was analyzed based on an integration of hydrogen sulfide analysis data and information from the questionnaire among workers in a rubber latex industry. A non-carcinogenic risk among workers was evaluated by the (1) and (2) equations. As table 4 shown, parameter values for chronic diary intake based on the USEPA recommendation and data from questionnaire. The result of calculation based on equation (1) showed that chronic diary intake value of H_2S exposure was 0.0003 mg/kg/day. Thus, health risk assessment with for chronic diary intake of H_2S exposure in a rubber industry was compute by equation (2). The result showed that non-cancer hazardous quotient (HQ) of hydrogen sulfide exposure among workers in a rubber latex industry was 0.1259, which was less than the acceptable level 1.0. However, some workers of a latex rubber industry had eye irritation during the working hour because of exposure to H_2S. Therefore, the reduction of H_2S concentration was developed for decreasing the health risk among workers in a rubber latex industry.

4. Discussion

This research was represented the study analyzing results of H_2S in the workplace of a rubber latex industry. H_2S concentrations of fifteen air samples in a rubber latex industry analyzed by NIOSH method number 6013 that was studied suggested the presence of a moderate air pollution, and these concentrations were lower than the H_2S concentration standard in workplace from international organization (OSHA:C 20 ppm; P 50 ppm/10 min, NIOSH: C 10 ppm/10 min, ACGIH: 10 ppm; STEL 15 ppm), similar with previous studies [0.0004 ppm: Hemminki and Niemi (1982), 0–0.0032 ppm: Toombs *et al.* (2010), 0-0.0021ppm: Drimal *et al*. (2010), 1.44 ppm: Puangjareain (2006)], but were higher than the H_2S odor threshold (0.0047 ppm). The several reports (Jaakkola *et al*., 1990; Drimal *et al*., 2010; Tiwari, 2008) recommended that the exposure of low H_2S concentration still affected with the human health. The eye irritation was presented at the mean annual hydrogen sulfide concentration of 6 ppb (Jaakkola *et al*., 1990). However, one hundred ppb daily exposure of H_2S concentration reported the ocular symptoms in human (Drimal *et al*., 2010). Furthermore, using the personal pump of H_2S concentration analysis for open environment was concerned in this study. Thus, the duplicated analysis of H_2S concentration was used for reducing the deviation of the results.

Moreover, the finding of this study showed that the range and average of H_2S concentrations in a rubber latex industry were 0.0000-0.1875 ppm and 0.0344 ppm, receptively. The highest H_2S concentration was detected in the aeration pond of wastewater treatment because the H_2S emission is directly sparged into the aeration tank as the air needed to satisfy the biological oxygen demand of the wastewater (Hardy *et al*., 2001). Therefore, the increasing H_2S concentration reduction in the production was required to solve this problem.

One hundred and twenty five workers of a rubber latex industry in Songkhla province, Thailand were selected as the participants of this study. The findings of this study are important as a contribution to improving health prevention in the rubber latex industry workplace. The results of this study mentioned that knowledge, attitude, and preventive behavior among workers about hydrogen sulfide exposure had moderate level. Moreover, full time staff was statistically significant with preventive behavior at *p-value* <0.05 with logistic regression analysis because the most of full time staffs had high academic level, high knowledge and received training more than part-time staffs. Besides, the received training and knowledge about exposure to hydrogen sulfide were statistically significant as the best predictors for preventive behavior at *p-value* <0.001. Thorn and Kerekes (2001) reported that the lack of knowledge of risk agents' symptoms, and diseases in that environment among workers at sewage treatment plants has spread concern. Also, awareness training should be conducted to impart education regarding safer work procedures and use of personal protective devices (Tiwari, 2008). Therefore, the good preventive behavior was affected by the received training of worker.

Health risk assessment of H_2S exposure among workers of a rubber latex industry was calculated using USEPA model. The different level exposures of H_2S were depending on their jobs. Then, fifteen air samples throughout all areas of a rubber latex industry were selectively collected for a good agent of assessing the health risk. This result showed that non-cancer hazardous quotient (HQ) of hydrogen sulfide exposure among workers in a rubber latex industry was 0.1259, which was less than the acceptable level 1.0. However, some health symptom of workers exposure to H_2S such as eye irritation was found in this study. Dyspnea may be attributed to the H_2S exposure which is the most characteristic gas exposure for workers at wastewater treatment plants (Batanony and El-Shafie, 2011). H_2S is an irritant even at low concentrations and can cause asphyx¬ia after massive exposure (Tiwari, 2008; WHO, 1981; Fahmy *et al.*, 2009). Therefore, a rubber latex industry should be developed the approach for reducing the H_2S in the process.

4.1. Recommendation of health risk reduction

Health risk reduction among rubber latex workers from H_2S exposure was developed by the literature review and brain storming with a rubber latex industry. The recommendation approach for reducing health risk among latex rubber workers to exposure H_2S in production processes consisted of two parts following: (1) H_2S concentration reduction in the production process such as the reduction and control of the odor from wastewater treatment and rubber tap pond, and the direct health risk among rubber latex workers such as the increase training and occupational and safety measurement to workers.

5. Conclusion

Our results could support the hypothesis that the health risk of H_2S exposure among rubber latex workers in Thailand. The findings of this study showed that H_2S concentration in this rubber latex industry was lower than the H_2S concentration standard of international organization in the workplace. The statistical significant of best predictors for preventive behavior of H_2S exposure among workers was the received training and knowledge about exposure to hydrogen sulfide. Health risk assessment from exposure to hydrogen sulfide among workers was acceptable based on USEPA. However, some health symptom of workers exposure to H_2S was found. Therefore, the H_2S reduction approach such as the odor reduction in process and the behavior change of workers should be proposed.

Acknowledgements

This research was supported by The Asthma Foundation of Thailand. We would like also to thank Mr.Weerawat Ounsaneha for his contribution.

Reference

Al-Batanony, El-Shafie. Work-related health effects among wastewater treatment plants workers. International Journal of Occupational and Environmental Medicine 2011; 2(4): 237-44.

Arporn S, Chaonasuan P, Prukthara V, Singhakajen V, Chaikitiporn C. A program for Thai rubber tappers to improve the cost of occupational health and safety. Industrial Health 2010; 48: 275-82.

Chaiprapat S, Mardthing R, Kantachote K, Karnchanawong S. Removal of hydrogen sulfide by complete aerobic oxidation in acidic biofiltration. Process Biochemistry 2011; 46(1): 344-52.

Choosong T, Chomanee J, Tekasakul P, Tekasakul S, Otani Y, Hata M, Furuuchi M. Workplace environment and personal exposure of PM and PAHs to workers in natural rubber sheet factories contaminated by wood burning smoke. Aerosol and Air Quality Research 2010; 10: 8-21.

Drimal M, Lewis C, Fabianova E. Health risk assessment exposure to malodorous sulfur compounds in central Slovakia. Carpathian Journal of Earth and Environmental Sciences 2010; 5(1): 119-26.

Droste RL. Theory and practice of water and wastewater treatment. John Wiley and Sons, New York, USA. 1997.

Fahmy Fc, Mansour TA, Kamel A, Moselhi M, Abbas F. Cardiorespiratory disorders among sewage workers. Egyptian Journal of Occupational Medicine 2009; 33: 197-209.

Guidotti TL. Occupational exposure to hydrogen sulfide in the sour gas industry: some unresolved issues. International Archives of Occupational and Environmental Health 1984; 66: 153-60.

Guidotti TL. Hydrogen sulfide. Occupational Medicine 1996; 46(5): 367-71.

Guidotti L. Hydrogen sulfide: advances in understanding human toxicity. International Journal of Toxicology 2010; 29(6): 569-81.

Hardy P, Burgess JE, Morton S, Stuetz RM. Simultaneous activated sludge wastewater treatment and odour control. Water Science and Technology 2001; 44(9): 189-96.

Hemminki K, Niemi M-L. Community study of spontaneous abortions: relation to occupation and air pollution by sulfur dioxide, hydrogen sulfide, and carbon disulfide. International Archives of Occupational and Environmental Health 1982; 51: 55-63.
Jaakkola JJ, Vilkka V, Marttila O, Jäppinen P, Haahtela T. The south Karelia air pollution study: the effects of malodorous sulfur compounds from pulp mills on respiratory and other symptoms. American Review of Respiratory Disease 1990; 142(6): 1344-50.
Jaakkola JJ, Partti-Pellinen K, Marttila O, Miettinen P, Vilkka V, Haahtela T. The south Karelia air pollution study: changes in respiratory health in relation to emission reduction to malodorous sulfur compounds from pulp mills. Archives of Environmental Health 1999; 54(4): 254-63.
Kolluru RV. Healh risk assessment: principles and practices. In: Risk assessment and management handbook for environment, health, and safety professionals (Eds: Kollura RV, Bartell SM, Pitblado RM, Stricoff RS). McGraw-Hill Inc., New York, USA. 1996.
Korwuttikulrungsee S. Natural rubber production. Prince of SongkhlaUniversity, Pattani Campus, 2002.
Lonati G, Zanoni F. Probabilistic health risk assessment of carcinogenic emissions from a MSW gasification plant. Environment International 2012; 44: 80–91.
MOL. Thailand labour statistic. Ministry of Labour. 2008. Available from: www.mol.go.th (accessed December, 2008).
National Institute for Occupational Safety and Health. NIOSH Manual of Analytical Methods (Methods 6013). 4th ed. DHHS (NIOSH) Pub., NIOSH, Washington DC, USA. 1994.
Poungjaroen P. Management of odor from hydrogen sulfide in dyeing wastewater treatment plant. Master of Engineering in Environmental Engineering. Mongkut's University of Technology Thonburi, Thailand, 2006.
Pollution Control Department. Good practices on pollution prevention and reduction smoked sheet rubber industry. Pollution Control Department, Ministry of Natural Resource and Environment, 2005.
Prior MG, Sharma AK, Yong S, Lopez A. Concentration-time interactions in hydrogen sulfide toxicity in rats. Canadian Journal of Veterinary Research 1988; 52(3): 375-79.
Rattanapan C, Boonsawang P, Kantachote D. Hydrogen sulfide removal from biogas using pure and mixed cultures of sulfide-oxidizing bacteria biofiltration. International Journal of Green Energy 2011; 8(7): 1-10.
Rubber Research Institute of Thailand. Thai rubber statistic. 2010. Available from: www.rubberthai.com/rubberthai. (accessed October, 2010).
USEPA. Human health risk assessment for hazardous waste combustion facilities; Report EPA/530/D-98 /001A, US EPA Office of Solid Wastes, 1998.
World Health Organization (WHO). Hydrogen sulfide: Environmental health criteria 19. Ge¬neva, 1981.
World Health Organization (WHO). Air quality guidelines for Europe, WHO Regional Publications, European Series, Copenhagen, WHO. 2000. Available from: www.euro.who.int/ document/e71922.pdfS (accessed February, 2009).
Tiwari RR. Occupational health hazards in sewage and sanitary workers. Indian Journal of Occupational and Environmental Medicine 2009; 12(3): 2465-85.
Thorn J, Kerekes E. Health effects among employees in sewage treatment plants: A literature survey. American Journal of Industrial Medicine 2001; 40: 170-79.
Toombs CF, Insko MA, Wintner EA, Deckwerth TL, Usansky H, Jamil K, Goldstein B, CooremanM, Szabo C. Detection of exhaled hydrogen sulphide gas in healthy human volunteers during intravenous administration of sodium sulphide. British Journal of Clinical Pharmacology 2010; 69(6): 626-36.

Received 3 October 2013
Accepted 12 November 2013

Correspondence to
Dr. Cheerawit Rattanapan
ASEAN Institute for Health Development,
Mahidol University,
Salaya, Phutthamonthon,
Nakhonpathom, 73170
Thailand
Tel: +66 2441 9040-3 ext. 62
Fax: +66 2441 9044
E-mail: cheerawit.rat@mahidol.ac.th,
cheerawit@hotmail.com