Air Pollution at Incinerator and Health Risk Assessment

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Abstract
This study aimed to assess the health risk associated with the inhalation of air pollutants including VOCs and heavy metals for workers at waste incinerator site in the South of Thailand. Air samples were collected and analyzed followed by NIOSH standard method, air samples were collected for 8 hours continuously. The concentration of heavy metal; Hg, Cd, Pb, Mn, Ni were very low while mean concentrations of VOCs; benzene, toluene, ethylbenzene, xylenes, and styrene were determined as 0.080, <0.001, 0.031, 0.043, and <0.001 mg/m^3 respectively. Health risk assessment was employed to evaluate the carcinogenic and non-carcinogenic effects. The cancer risk for benzene exposure was estimated to be 1.26×10^{-5} that is higher than the acceptable risk level of 1×10^{-6}. Non-carcinogenic risk (Hazard Quotients; HQ) for toluene, ethylbenzene, xylenes and styrene was at acceptable level. Thus, workers in this plant were at risk to health effects associated with benzene via inhalation exposure. Health promotion and risk communication should be given to them in appropriated way.

Keywords : Waste Incinerator, Health Risk Assessment, Occupational Health, Air pollution

1. Introduction

Waste incinerator is one of solid waste management technology which has been gearing up in Thailand [1]. However, incomplete combustion is a cause of organic compound emission such as aldehydes, chlorinated hydrocarbons, PAHs, polychlorinated dibenzodioxins, dibenzofurans et.al, which is leading to environmental and health effects [2]. The previous studies have found that living within 3 kilometers from an incinerator plant indicates an increased risk of lymphoma and soft tissue sarcoma cancer up to 3.5% . More evidence is shown that living close to an incinerator has relation to respiratory disease [3-4]. In particular the incinerator related workers were exposed to particulates and heavy metals 10 to 100 folds greater than that of general population [5]. This study aimed to assess the health risk for the solid waste incinerator related workers.

2. Materials and Method

2.1 Study Area and Study Population

This study selected waste-to-energy plant in the Southern part of Thailand. Thirty incinerator related staff and workers were randomly selected under the condition of three different working environments which are including fuel feeding area, operation office and administrative office.

2.2 Personal information: Questionnaires were used to collect information for exposure assessment which are general information (gender, age, weight, height) and operating information (jobs description, working hour, working frequency and working period.

2.3 Air sampling and analysis procedure

Air pollution exposure study was conducted by environmental sampling and hygiene survey during March – April 2015. Workplace air sampling, air samples were collected 8 hours-working continuously by personal pump at each working environments. Sampling, preserving and analyzing followed NIOSH standard method.

This study was approved by the Ethics Review Committee for Research, Department of Health, Ministry of Public Health.

2.4 Health Risk Assessment

In this study, inhalation risk assessment was conducted following the Risk Assessment Guidance for Superfund [6] as following equations:

$$EC = (CA \times ET \times EF \times ED) / AT$$

Cancer risk for benzene (leukemia) and ethylbenzene (liver hepatocellular adenoma or carcinoma) was calculated as following:

$$\text{Cancer risk} = IUR \times EC$$

Non-carcinogenic risk for benzene, toluene, ethylbenzene, xylene and styrene was calculated as following:

$$\text{Hazard Quotient} = EC / RfC$$

Where

EC	is exposure concentrations (mg/m^3)	
CA	is contaminants concentration in air (mg/m^3)	Air monitoring during 8 hours
ET	is exposure time (hours/day)	8 hours/day (8 hours day-shift)
EF	is exposure frequency (days/year)	312 days/year
ED	is exposure duration (years)	5 years
AT	is averaging time - When estimating cancer risk, AT calculated by lifetime (70 years) x 365 days/year x 24 hours/day - When calculating HQ for non-cancer effect, AT calculated by ED (5 years) x 356 days/year x 24 hours/day	
IUR	is inhalation unit risk - IUR for Benzene (Leukemia) is 7.8×10^{-6} per $\mu g/m^3$ [7]	
RfC	is inhalation reference concentration - RfC for Benzene (decreased lymphocyte count) is 3×10^{-2} mg/m^3 [7] - RfC for Ethylbenzene (developmenta toxicity) is 1 mg/m^3 [8] - RfC for Toluene (neurological effects) is 5 mg/m^3 [9] - RfC for Xylene (impaired motor coordination) is 1×10^{-1} mg/m^3 [10] - RfC for Styrene (CNS effect) is 1 mg/m^3 [11]	
Cancer risk	Cancer risk of more than 10^{-6} considers an unacceptable level for carcinogenic effect of concern.	
HQ	HQ and HI of more than 1 consider an unacceptable level for non-carcinogenic effects.	
HI	Hazard Index (multiple substances)	

3. Results and discussion

3.1 General characteristic

Waste management technology is a stoker incineration with reverse-acting grate. The overall availability is 600 tons/day and generates electricity up to 14 MW for using in plant 24 hours continuously and sale for Provincial Electricity Authority. The pollution control systems are Semi Dry Scrubber, Bag Filter and CEMs.

Sample population is 30. Incinerator's staff included 18 men (60%) and 12 women (40%). There are 6 feeding staff (20%), 9 operation staff (30%), and 15 office staff (50%). The average age is 32.17 (±8.26) years.

3.2 Concentration of air pollution at the waste incinerator site

The 8 hours average of all heavy metal and VOCs concentrations in differences sampling areas are presented in **Table 1**. The concentration of mercury was under the detection limit, while concentrations of cadmium, lead, manganese, and nickel were less than 0.001 mg/m^3, they were not included in the calculation of cancer risk and non-cancer risk (HQ). However, mean concentrations of

benzene, toluene, ethylbenzene, xylenes and styrene were 0.080, <0.001, 0.031, 0.043, and <0.001 mg/m3 respectively. The concentration of each chemical was derived from sampling area, concentrations of benzene, ethylbenzene and xylenes in operation room and office are higher than at the feeding area. Ventilation may be related to the result because the operation office and the administrative office are closed systems while the feeding area is an open system.

Table 1 Concentration of air pollution at the waste incinerator site.

Sampling Area	Concentration (mg/m^3)									
	Air Heavy Metal					Air VOCs				
	Hg	Cd	Pb	Mn	Ni	Benzene	Toluene	Ethylbenzene	Xylene	Styrene
Feeding Area	ND	<0.001	<0.001	<0.001	<0.001	0.056	<0.001	0.0005	0.0005	<0.001
Operation Room	ND	<0.001	<0.001	<0.001	<0.001	0.097	<0.001	0.0417	0.0412	<0.001
Office	ND	<0.001	<0.001	<0.001	<0.001	0.087	<0.001	0.0502	0.0882	<0.001
Mean	ND	<0.001	<0.001	<0.001	<0.001	0.080	<0.001	0.0308	0.0433	<0.001
Standard (OSHA : TWA)	**0.1**	**0.005**	**0.05**	**5**	**1**	**1 ppm**	**-**	**-**	**100 ppm**	**100 ppm**

3.3 Cancer risk and Non-cancer risk

VOCs concentrations were lower than time-weighted average (TWA) recommended by OSHA [12]. However lifetime cancer risk (leukemia) of being exposed to benzene by inhalation from working in feeding area, operation room and office were 8.88×10^{-6}, 1.53×10^{-5}, and 1.38×10^{-5} respectively. **(Table 2)** The cancer risk was exceeding the acceptable of 1 in 1,000,000. While risk estimates of non-cancer effects did not exceed the risk level (both HQ and HI were lower than 1).

Table 2 Cancer risk and non-cancer risk

	Cancer Risk	**Non-Carcinogenic risk (Hazard Quotient : HQ)**				
	Benzene	**Toluene**	**Ethylbenzene**	**Xylene**	**Styrene**	**Hazard Index : HI**
Critical effect	Leukemia	Neurological effects	Developmenta toxicity	decreased rotarod performance	CNS effect	
	IUR: 7.8×10^{-6} per ug/m^3	RfC : 5 mg/m^3	RfC : 1 mg/m^3	RfC : 0.1 mg/m^3	RfC : 1 mg/m^3	
Sampling Area						
Feeding Area	8.88×10^{-6}	2.92×10^{-5}	1.46×10^{-4}	0.0015	1.46×10^{-4}	0.002
Operation Room	1.53×10^{-5}	2.92×10^{-5}	1.22×10^{-2}	0.12	1.46×10^{-4}	0.132
Office	1.38×10^{-5}	2.92×10^{-5}	1.46×10^{-2}	0.25	1.46×10^{-4}	0.272
Mean	1.26×10^{-5}	2.92×10^{-5}	8.99×10^{-3}	0.12	1.46×10^{-4}	0.135

Conclusion and Recommendation

Concentration of air heavy metal is quite not the problem in this study area and an average 8 hours of VOCs concentrations including benzene, toluene, ethylbenzene, xylene and styrene in this study are lower than the occupational limit of that defined by international organization. However, benzene, ethylbenzene and xylene are consistently higher indoor (operation office and administrative office) than outdoor (fuel feeding area). In the same way lifetime cancer risk from benzene exposure via inhalation is higher indoor than outdoor. Some prevention measures should be taken to reduce

risks, such as increasing of ventilation and using of air cleaners in indoor environment. In addition risk communication should be introduced to the staff to protect themselves properly.

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