European Journal of Sustainable Development (2017), **6**, 2, 187-192 ISSN: 2239-5938
Doi: 10.14207/ejsd.2017.v6n2p187

Benzene and 1, 3 Butadiene Concentration and Its Potential Health Impact in Chiang Mai, Thailand

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Abstract
Air pollution is contamination of the outdoor or indoor environment by any physical, biological or chemical agent that modifies the natural characteristics of the atmosphere. Air pollution can cause long-term and short-term health effects. An emerging air pollution issue in Thailand is the air toxics problem resulting from transportation and industrial activities. Cancer risk of benzene at Chiang Mai City Hall was within 3.00×10^{-6} – 1.20×10^{-6} and Yupparaj Wittayalai School was within 9.30×10^{-6} – 1.20×10^{-5} respectively. The excess lifetime cancer risk of the population was calculated as the product of the benzene level and the unit risk for benzene. The results indicated that the population was estimated to receive an excess lifetime cancer risk greater than 1.0×10^{-5}, which is proposed as the permissible maximum value for individual excess lifetime cancer risk by the Japan Environmental Agency (JEA). As for 1, 3-butadiene, cancer risk at Chiang Mai City Hall was within 3.00×10^{-6} – 1.20×10^{-6} and at Yupparaj Wittayalai School were 9.30×10^{-6} – 1.20×10^{-6}, respectively. The results indicated that the population was estimated to receive an excess lifetime cancer risk less than 1×10^{-5} at two stations, which is proposed as the permissible maximum value by Japan Ministry of the Environment.

Keywords: Benzene, 1, 3-butadiene, Cancer risk, Health impact

1. Statement of the Problem

Air pollution is contamination of the outdoor or indoor environment by any physical, biological or chemical agent that modifies the natural characteristics of the atmosphere. Air pollution causes damage to crops, animals, forests, and bodies of water. Another negative effect of air pollution is the formation of acid rain, which harms trees, soils, rivers, and wildlife. Some of the other environmental effects of air pollution are haze, eutrophication, and global climate change. Household combustion devices, motor vehicles, industrial facilities and forest fires are common sources of air pollution. It is a serious problem in overcrowded population and industrial areas especially in urban areas. Air pollution can cause long-term and short-term health effects. Short-term health effects include eye, nose, and throat irritation, headaches, allergic reactions, and upper respiratory infections. Some long-term health effects are damage to the lungs, brain and kidneys, heart and respiratory disease (US.EPA, 2012).
Volatile Organic Compounds (VOCs) means any compound of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate, which participates in atmospheric photochemical reactions VOCs include a variety of chemicals, some of which may have short-term and long-term adverse health effects (US.EPA, 2012). VOCs are major urban air pollutants, many are known carcinogens, mutagens, or are suspected to cause serious health problems

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(Kampa and Castanas, 2008). Large amounts of VOCs are emitted from mobile and stationary sources (Elbir, Cetin, Cetin, Bayram, & Odabasi, 2007). Organic chemicals are widely used as ingredients in household products. Paints, varnishes, and wax all contain organic solvents, as do many cleaning, disinfecting, cosmetic, degreasing, and hobby products. Fuels are made up of organic chemicals. All of these products can release organic compounds during use and to some degree, when these are stored.

Thailand is facing serious air pollution problems, especially in urban areas, due to rapid urbanization, industrialization, and motorization. The government designated the National Ambient Air Quality Standards (NAAQS) and implemented countermeasures for criteria air pollutants such as dust, suspended particulate matters (PM_{10} and $PM_{2.5}$), sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen dioxide (NO_2) and ground level ozone (O_3).

An emerging air pollution issue in Thailand is the air toxics problem resulting from transportation and industrial activities. The average levels of selected VOCs measured at outdoor sites in Bangkok were found to significantly vary, even over the relatively short period monitored. The transport and industrial sectors are major emission sources of air toxic pollution of the country. Emission sources of air toxic pollutants are mostly from automobiles, gas stations, storage tanks, petrochemical industries, oil refineries, chemical based factories, construction sites, forest fires, and the open burning of solid wastes. In the transportation sector, two-stroke motorcycles, diesel trucks and aging buses contribute significantly to air toxics pollution in urban areas. In the industrial sector, a different scale of business activity and industrial complex contributes air toxics to atmosphere at different levels.

VOCs emitted from industries and vehicles are considered as the significant sources of photochemical reactions that result in tropospheric ozone formation. Moreover, some VOCs are hazardous air pollutants, which cause various acute health problems as well as carcinogenic risk. They also contribute to secondary formation of suspended particulate matters. Under these circumstances, the Thai government decided to control VOCs by setting environmental and emission standards as an initial environmental control policy. Based on the awareness that adequate pollution control measures could not be implemented by regulations alone, the government incorporated pollution control elements into its industrial and transportation policy.

The Thai government designated national ambient air quality standards for VOCs. Nine compounds, verified as carcinogenic substances; namely Benzene, Vinyl Chloride, Chloroform, 1, 2 - Dichloroethane, Trichloroethylene, Dichloroethane, 1, 2 - Dichloropropane, Tetrachloroethylene, and 1, 3-Butadiene were set for their ambient air standard on an annual basis (PCD, 2009).

The concept of this study is utilizing the data obtained from current conventional air monitoring stations to monitor and assess the health risk caused by benzene and 1, 3 butadiene exposure in Chiang Mai, Thailand.

2. Methods

2.1 Data collection

The air monitoring data used in this study were from January 2008 to December 2015. VOCs were monitored at two monitoring stations in Chiang Mai area namely

Chiang Mai City Hall and Yupparaj Wittayalai School respectively. The monitoring sites are operated by Pollution Control Department (PCD). VOCs samples were collected by 6 liter evacuated canisters (0.05 mmHg) and were analyzed using Gas Chromatography/Mass Spectrophotometer (GC/MS). Analyze method was based on US.EPA. TO15. When the canisters were opened to the atmosphere, the VOCs sample was introduced into the canisters by the differential pressure between atmospheric pressure and vacuum pressure inside each canister. With a flow control, the sub-atmospheric sampling system maintained a constant flow rate from full vacuum to within about 7kPa (1.0 psi) or less below ambient pressure. Canister flow rate was controlled by flow controller and was adjusted to 3.3 ml/min for 24-hr sampling. After collecting the ambient VOCs, the sample canister was pressurized by humidified nitrogen about 20 psia in order to prevent the contamination entering the sample canister. Samples were transferred to the thermal desorption unit, working as a preconcentrator prior to being sent to GC/MS (Thepanondh, Varoonphan, Sarutichat, & Makkasap, 2011)

2.2 Data Analysis

Annual average of Benzene and 1, 3-butadiene data were used in this study.

2.3 Health risk assessment

The health risk assessment of benzene and 1, 3-butadiene due to inhalation was evaluated in this study. The Integrated Risk Information System (IRIS) is an Environmental Protection Agency (US EPA) database of human health effects that may result from exposure to various substances found in the environment suggested a unit risk of 2.9×10^{-5} $(\mu g/m^3)^{-1}$ of benzene concentration and 3×10^{-5} $(\mu g/m^3)^{-1}$ of 1, 3-butadiene concentration. Cancer risk of people living in Chiang Mai calculated based on US EPA guidance for inhalation risk assessment is as shown in Eq. 1 (US.EPA, 2014)

$$Risk = IUR \times EC \quad (1)$$

Where:

IUR = inhalation unit risk $(\mu g/m^3)^{-1}$

EC = exposure concentration $(\mu g/m^3)$

3. Results and Discussions

The plot of benzene and 1, 3-butadiene concentrations were examined from January 2008 to December 2015 as shown in Fig. 1 and Fig. 2. As for benzene, it was found that there were decreasing tendency of annual arithmetic mean concentrations from the year 2008 – 2015 were within 1.8 – 4.2 $\mu g/m^3$, 1.9 – 4.2 $\mu g/m^3$, 2.0 – 4.3 $\mu g/m^3$, 1.6 – 3.2 $\mu g/m^3$, 1.7 – 3.0 $\mu g/m^3$, 1.4 – 2.8 $\mu g/m^3$, 1.4 – 2.5 $\mu g/m^3$ and 2.2 – 3.0 $\mu g/m^3$ (annual average of benzene equal to 1.7 $\mu g/m^3$) respectively at two monitoring stations in Chiang Mai. As for 1, 3-butadiene, it was found that there were dramatically decreasing of annual arithmetic mean concentrations from the year 2008 – 2015 were within 0.10 – 0.31 $\mu g/m^3$, 0.08 – 0.25 $\mu g/m^3$, 0.16 – 0.19 $\mu g/m^3$, 0.05 – 0.01 $\mu g/m^3$, 0.06 – 0.03 $\mu g/m^3$, 0.03 – 0.03 $\mu g/m^3$, 0.03 – 0.03 $\mu g/m^3$ and 0.04 – 0.04 $\mu g/m^3$ (annual average of 1, 3-butadiene equal to 0.33 $\mu g/m^3$) respectively. The results have shown dramatically decreased at two monitoring stations especially in between the year 2011 to

2012 because Thailand enforcing Euro 4 standards on January 1, 2012 ("Data Archives for Air and Noise Pollution", 2013). Some of this decrease appeared to results from factors unrelated to the gasoline benzene standard (i.e., fleet turnover) (Yano, Morris, Salerno, Schlapia, & Stichick, 2016).

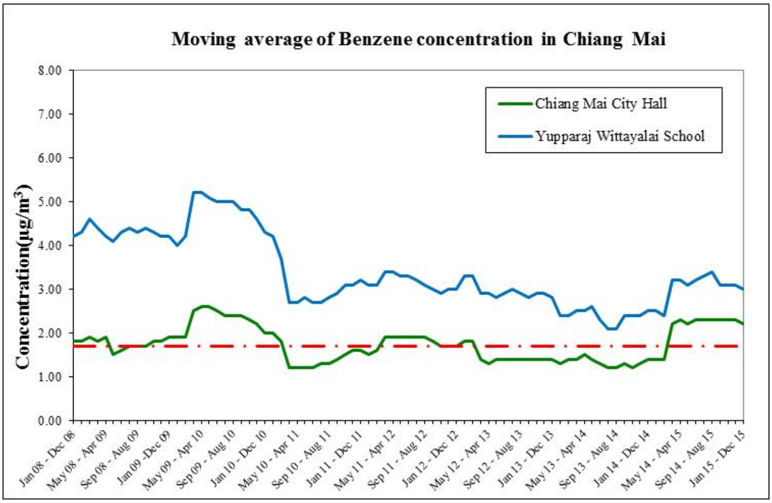

Figure 1: Moving average of Benzene concentration in Chiang Mai

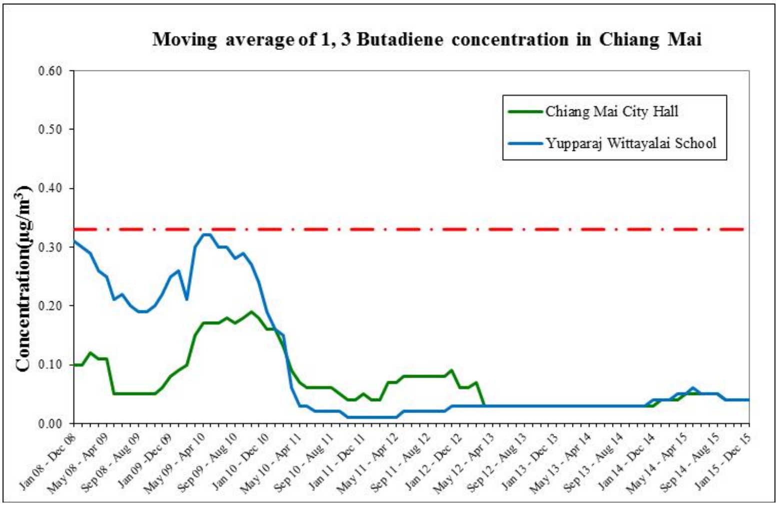

Figure 2: Moving average of 1, 3 Butadiene concentration in Chiang Mai

Calculated cancer risk of benzene and 1, 3-butadiene dramatically decreased at every monitoring stations in Chiang Mai as shown in Fig. 3 and Fig. 4. Cancer risk of benzene at Chiang Mai City Hall was within $3.00x10^{-6}$ – $1.20x10^{-6}$ and Yupparaj Wittayalai School was within $9.30x10^{-6}$ – $1.20x10^{-5}$ respectively. The excess lifetime cancer risk of the population was calculated as the product of the benzene level and the unit risk for benzene. The results indicated that the population was estimated to receive an excess lifetime cancer risk greater than $1.0x10^{-5}$, which is proposed as the permissible maximum value for individual excess lifetime cancer risk by the Japan Environmental Agency (JEA) (Thongkum & Thepanondh, 2014).

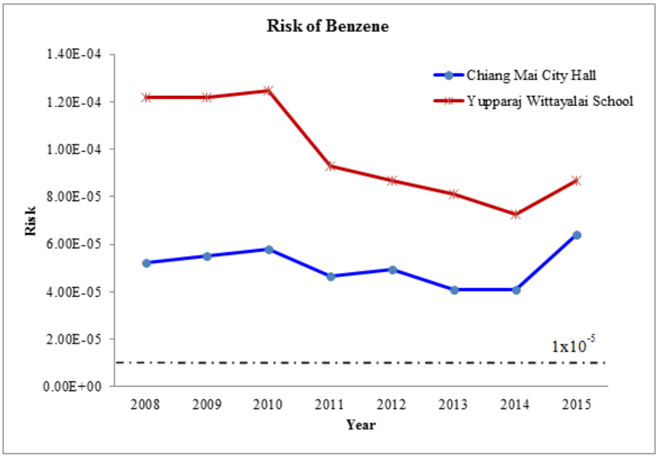

Figure 3: Cancer risk of Benzene in Chiang Mai

As for 1, 3-butadiene, cancer risk at Chiang Mai City Hall was within $3.00x10^{-6}$ – $1.20x10^{-6}$ and at Yupparaj Wittayalai School were $9.30x10^{-6}$ – $1.20x10^{-6}$, respectively. The results indicated that the population was estimated to receive an excess lifetime cancer risk less than $1x10^{-5}$ at two stations, which is proposed as the permissible maximum value by Japan Ministry of the Environment (Higashino, Mita, Yoshikado, Iwata, & Nakanishi, 2007; Thongkum & Thepanondh, 2014). However, the cancer risks in the year 2012 were found significantly decreased which indicated a success of utilization of better fuel quality to the reduction of air toxic concentration.

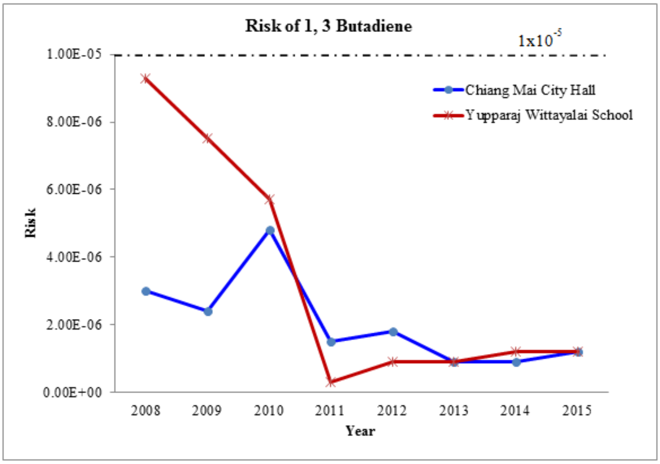

Figure 4: Cancer risk of 1, 3-Butadiene in Chiang Mai

Conclusion

This paper was presented the trend and cancer risk of benzene and 1, 3-butadiene from the year 2008 – 2015 in Chiang Mai, Thailand. Cancer risk of benzene was within $4.06x10^{-5}$ – $1.22x10^{-4}$ and 1, 3-butadiene was $3.0x10^{-7}$ – $9.30x10^{-6}$. The results have shown dramatically decreased at two monitoring stations especially in between the year 2011 to 2012 because Thailand enforcing Euro 4 standards on January 1, 2012.

Acknowledgement

The authors would like to thank the Pollution Control Department, Ministry of Natural Resources and Environment for providing the detailed data on air quality monitoring. This study was partially supported for publication by Mahasarakham University, Mahasarakham, Thailand.

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