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Health Risk Assessment of Xylene through Microenvironment Monitoring Data: A Case Study of the Petro-Chemical Industries, Thailand

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Abstract

In the absence of environmental health epidemiology, risk managers, policy makers and health-care authorities usually rely on estimates of human exposure level of proximity to hazardous waste site or regional ambient air quality data. Based on ambient concentrations without considering time-activity patterns, the estimation of personal exposure may be over- or underestimated. Twelve villages surrounding the petro-chemical industries located in the eastern region of Thailand were randomly selected to be a representative study area. In each village, air samples were collected at thirty-one microenvironments including indoor and outdoor of a household and workplace. The time-activity patterns of the commuters were also recorded. The ambient xylene concentrations were determined by thermal desorption gas chromatograhy/mass spectrometry. The indoor samples were determined by gas chromatography flame ionization detector. Commuters living in the vicinity of the industrial areas spent most of the time indoor (93.2%), especially at home (66.8%). Individuals spent a significant fraction of the day indoors. The concentrations of xylene ranged from less than 1 μg/m^3 to 291.3 μg/m^3. The highest level was found at the auto repair shop (291.3 μg/m^3). Given micro-environmental concentrations and activity times, the average concentrations of xylene to which commuters may be exposed daily ranged from 90.62 to 134.75 μg/m^3. The long term exposure level via inhalation was found to be very low. Collectively, no hazard was indicated by the hazard quotient and the results were found to be similar in all villages.

Keywords: xylene; health risk assessment; microenvironment monitoring; Thailand

1. Introduction

Emission of toxic air pollutants has been in public concern related to adverse health effects, particularly residential proximity to the industrial zone (Kim *et al*., 2001; 2002). Recently, Thailand has faced environmental problems thought to be contributed to a number of industrial estates situated in different regions of the country. Although the operation of these industries is approved and also complied with Thai legislations and regulations, there are local concerns from time to time about the possible health effects of the air emissions releasing from the industries. The concern about emission has been gradually increased because of, especially, the lack of transparent information and public engagement (Park and Jo, 2004). This constitutes a long-standing constrain for evidence-based policy making.

Xylene occurs in petroleum deposits and exists in three isomeric forms (ortho-, para- and meta-dimethylbenzenes). Xylene is used as intermediates in the production of a variety of products. It is also used as a solvent in a wide range of industrial processes (*e.g*., surface coating, adhesives, cleaning and degreasing agents) (Carpenter *et al*., 1975; Astrand *et al*., 1978; ATSDR, 1997). Resulting from use of these commercial products, xylene is widespread in the environment, significantly contributing, especially, to levels in the internal environment and personal exposure (Fishbein, 1985; Wallace and Pellizzari, 1986; WHO, 2000). Xylene liquid and vapour are absorbed slowly through the skin, but absorbed rapidly from the lungs. Breathing xylene vapours can cause negative health effects varying from minor symptoms to detrimental effect to neurological system (Dudek *et al*., 1990; Bond and Medinsky, 1995; Gandarias *et al*., 1995; Hass *et al*., 1997).

Currently, published information related to exposure of community living in the vicinity of the industrial area in Thailand to xylene is scarce. In particular, health risk taken into account time-activity in the microenvironments is rarely scientifically estimated whereas the community may perceive its risk from different perspectives. It appears that level of risk perceived by publics is likely to be higher than the actual risk. This would increase public outrage and concern (Suwansaksri *et al*., 2002; Greenberg and Crossney, 2006). So far, in Thailand a view of health risk of community exposed to xylene within microenvironments has not yet considered. The

interest of this study is to estimate public health risks from exposure to xylene in different commuting microenvironments at which community exposures typically occur.

2. Methodology

2.1. Sampling design

The study was carried out in the petro-chemical Industrial estate located in Chonburi province. Based on the characterisation of the zone of influence, the study area was about 8 x 8 km of the zones of influence. It covered 12 villages. For each village, Thirty-one places were randomly selected for microenvironment sampling. At each selected point, the microenvironment monitors were placed inside the building (houses and workplaces) and outside the building including public amenities. Following US EPA Method TO-1 (US EPA, 1984) and NIOSH Method 1501 (NIOSH, 1999), air samples were collected through a coconut shell charcoal using an air sampling pump (SKC Model 224-XR) at the flow rate 0.2-0.5 L/min (NIOSH, 1999). The first absorbing section contains 100 mg charcoal and the back-up section is 50 mg. For indoor air quality, as the ground level concentration was very low, each air sample was collected for 4 hours. All samples were kept in the glass storage tubes at 4 °C and analyzed within 2 weeks. Time activity information was recorded by residents in the areas.

2.2. Laboratory analysis

The ambient air samples were desorbed and then analyzed with Thermal Desorption Gas Chromatograhy/Mass Spectrometry (PerkinElmer GC/MS Clarus 560D, USA). In addition, the indoor air samples were analyzed with Gas Chromatography Flame Ionization Detector (PerkinELmer GC/FID Clarus 500, USA)

2.3. Estimation of xylene concentration in visited microenvironment

The basic concept of the calculation is that time-weighted average exposure is a sum of partial exposures in the visited microenvironments. Partial exposure is determined by the multiplication of concentration and the time spent at each micro-environment. Therefore, given activity time at each micro-environment, an average concentration of xylene to which a commuter may be exposed was calculated using the following expression:

$$Conc_{avr} = \frac{\sum_{i=1}^{n} conc_{Mei} t_i}{\sum t_i} \quad (1)$$

Where: $Conc_{avr}$ = average concentration to which a commuter may be exposed; $conc_{Mei}$ = concentration of xylene at each microenvironment (i = 1,2,3…n); and t = exposure time given time-activity.

2.4. Health risk calculation

The health risk assessment focused on chronic exposure to xylene through inhalation, rather than on acute toxicity and other routes (US EPA, 1986; 1989 and 1994; Adgate *et al*., 2004). The chronic daily inhalation intake (*CDII*) was performed to assess for non-cancer effects. The assessment was calculated by averaging daily intake over the exposure period (Longman 1994; Ortiz *et al.*, 2002). The exposure dose was estimated using the equation and guidance from US Environmental Protection Agency (US EPA, 1994). This is:

$$CDII\,(mg/Kg.d) = \frac{CI \times IR \times EF \times ED}{BW \times LT} \quad (2)$$

Where *CDII* = chronic daily inhalation intake (mg/Kg.d); *CI* = concentration of chemicals in indoor air (mg/m^3); *IR* = inhalation rate (m^3/h); *EF* = exposure frequency (days/year); *ED* = exposure duration (year);

Table 1. Equation parameters

Parameter	Value	Reference
Inhalation rate; IR (m^3/h)	20	US EPA, Superfund, 1998
Exposure frequency; EF (days/year)	350	US EPA, Superfund, 1998
Exposure duration; ED (years)	30	US EPA, Superfund, 1998
Body weight; BW (kg)	70	US EPA, Superfund, 1998
Lifetime; LT (days)	25550	US EPA, Superfund, 1998
Reference dose; RfD (mg/kg.d)	2	US EPA, IRIS, 1994

Table 2. Time spent in different micro-environment throughout a day

Microenvironment (ME)	Type	Average time (min)	Fraction of ME (%)
Inside building	Household	962.1	66.8
	Working office (*i.e.*, hospital, school)	331.2	23.0
	Municipal/ government office	9.0	0.6
	Temple	5.2	0.4
	Restaurant	6.3	0.4
	Mall	10.2	0.7
	Auto repair shop	18.0	1.3
	Total	**1342**	**93.2**
Outside building	Outdoor exercise	17.4	1.2
	Outside office	35.4	2.5
	Bus stop	7.0	0.5
	Open market	23.1	1.6
	Beach	9.4	0.7
	Park	5.7	0.4
	Total	**98.1**	**6.8**

BW = body weight (kg); and *LT* = life time of exposure (days)

It is assumed that: i) people living around the Industrial Estate could be exposed to xylene, which is emitted from a wide range of sources, throughout 24-hour activities and, ii) the potential route of exposure is through inhalation. Following these assumptions and the estimation of the non-cancer endpoint, the probability of developing adverse health consequence from a continuous exposure to xylene was estimated using the hazard quotient (HQ). The HQ is defined as the ratio of estimated exposure of an individual to the reference dose (Lemly, 1996).

$$HQ = \frac{CDII}{RfD} \quad (3)$$

Where *HQ* = Hazard quotient and *RfD* = reference dose (mg/Kg.d).

All parameters and toxicity values fed to equations 2 and 3 are presented in Table 1.

3. Results and discussion

3.1. Time-activity in different micro-environments

Table 2 presents the corresponding average times that the commuters daily spent in the different microenvironments. Commuters living around the industrial areas spent most of the time inside buildings (93.2%), especially at home (66.8%). The time fraction spent outdoors was 6.8 %. Similar time activity results have been reported in other studies (Sexton *et al.*, 2007). Individuals spent a significant fraction of the day indoor with variable ventilation rates. Therefore, the likelihood of exposures to air pollutants between individuals could be substantially different.

3.2. Microenvironmental exposure to xylene

Table 3 shows the average microenvironmental concentrations of xylene. Throughout the different microenvironments, the concentrations of xylene ranged from less than 1 μg/m^3 to 291.3 μg/m^3. The levels of xylene were found to be very low in most areas, except for the auto repair shop (291.3 μg/m^3).

Table 3. Average concentrations of xylene in different microenvironments

Microenvironments	Average conc of xylene	
	μg/m^3	ppb
Inside household	4.0	0.92
Outside household	4.7	1.07
Hospital	1.0	0.23
School	8.0	1.84
Temple	4.0	0.92
Municipal	3.0	0.69
Public park	3.4	0.81
Open stall market	7.6	1.76
Restuarant	6.5	1.50
Auto repair shop	291.3	67.00
Bus stop	3.8	0.87
Beach	< 1.0	< 0.23
Super mall	3.0	0.69

Table 4. Exposure levels and risk characterisation for xylene

Area	Activity time (hour)		DCE (μg/m^3)	CDII (mg/kg.d)	HQ
	Outside building	Inside building			
V1	1.18	22.82	108.77	0.013	0.043
V2	0.24	23.76	105.78	0.013	0.042
V3	3.08	20.92	90.62	0.011	0.036
V4	1.65	22.35	134.75	0.016	0.054
V5	1.19	22.81	133.47	0.016	0.053
V6	0.87	23.13	98.42	0.012	0.039
V7	0.55	23.45	108.69	0.013	0.043
V8	0.97	23.03	129.16	0.015	0.051
V9	2.59	21.41	104.17	0.012	0.041
V10	1.33	22.67	117.13	0.014	0.047
V11	0.45	23.55	121.94	0.015	0.049
V12	0.90	23.10	117.30	0.014	0.047

Note: DCE denotes daily concentration of exposure (Equation 1)
V denotes the villages randomly selected to be representative study area

This indicates that indoor pollutant was influenced by location proximity to the potential source of emission (Lebret *et al.*, 1986; Gill *et al.*, 1994; Raaschou-Nielsen *et al.*, 1997; Stocco *et al.*, 2008). Hence, the emission source of xylene may not be attributable to the factories only. In addition, these microenvironments cannot be related to the occupational status.

3.3. Microenvironmental exposure and risk characterization

In association with the activity times throughout a day, the average concentrations of xylene to which commuters may be exposed daily ranges from 90.62 to 134.75 μg/m^3. Given parameter values shown in Table 1, the long term exposure level via inhalation was found to be very low. Collectively, no hazard was indicated by the hazard quotient and the results were found to be similar in all villages. These results are presented in Table 4.

Although air pollutant exposure levels in various microenvironments are well studied (Leung and Harrison, 1998; Marco *et al.*, 2005; Sekton *et al.*, 2007), the association between microenvironmental concentrations and exposures cannot be clearly characterised. Therefore, it is not possible to derive precise risk estimates due to various uncertainties. These uncertainties include the availability of data and the risk models used for calculating the potency factors and effective concentration (Cohen *et al.*, 1989; Caldwell *et al.*, 1998; Morello-Froschb *et al.*, 2000).

In conclusion, the time spent in microenvironments during work or other activities play a major contributor to xylene exposure among commuters in the vicinity of the factories. Likewise, the proximity to a significant emission source of xylene may also potentially contribute to individual exposure levels. It is important to note that health risk assessment of Volatile organic compounds (VOCs) including xylene is related to mixture exposure and toxicity. The mixture exposure pathways usually involve substantial uncertainties (Cohen *et al.*, 1989; Caldwell *et al.*, 1998; Morello-Froschb *et al.*, 2000). Therefore, the health risk assessment of single chemical exposure needs to be interpreted with caution, recognising the uncertainties which include the generally poor understanding of the environmental health epidemiology and magnitude and nature of toxicological interaction.

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