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Personal exposure to benzene of selected population groups and impact of commuting modes in Ho Chi Minh, Vietnam

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ABSTRACT

Personal exposure to benzene of selected population groups, and impacts of traffic on commuters in Ho Chi Minh City were investigated. The study was carried out in June, July and November 2010. The preliminary data showed that on average, personal exposure to benzene for non-occupational people in Ho Chi Minh is ~18 μg/m^3 and most of the exposure is due to commuting. Benzene exposure during travelling by bus, taxi and motorcycle is, respectively, 22–30, 22–39 and 185–240 μg/m^3. Motorcycle–taxi drivers, petrol filling employees and street vendors suffer high daily exposures at 116, 52, 32 μg/m^3, respectively. Further measurements are needed for a better risk assessment and finding effective measures to reduce exposure.

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1. Introduction

Air pollution in urban areas is a serious problem of many developing countries. The rapid increase of the urban population and low transport infrastructure in East Asia has resulted in formation of megacities with dense motorcycle fleets like Kuala Lumpur, Bangkok, Delhi, Hanoi and Ho Chi Minh City. A consequence of this is decline of air quality due to volatile organic compounds (VOCs) and particulate matters discharged from vehicles. Many VOCs are considered toxic to humans, especially benzene since it is known as a carcinogenic substance. Benzene is highly volatile, so most exposure is via inhalation. The toxicity of benzene is stated on the US Environmental Protection Agency (EPA) website (2012b). Exposure to benzene increases the risk of leukaemia in humans (Bois et al., 1996; Crump, 1994; Rinsky et al., 1987). Experimental animal studies, both in inhalation and oral ingestion, showed evidence of increased risk of cancer in multiple organ systems including the haematopoietic system, oral and nasal cavities, liver, forestomach, lung, ovary, and mammary gland (Cronkite et al., 1985; Snyder et al., 1980, 1993). The risk of leukaemia associated with lifetime exposure to benzene at 17, 1.7 and 0.17 μg/m^3 is 10^{-4}, 10^{-5} and 10^{-6}, respectively (World Health Organization [WHO], 2000).

Benzene is carcinogenic; therefore, WHO and the US EPA do not recommend any safe level of exposure. Benzene in urban areas mainly originates from vehicle exhaust and evaporation from fuel tanks. Petrol-filling stations and garages contribute a significant amount of atmospheric benzene. Other sources that significantly increase indoor benzene levels are coal burning, tobacco smoking, off-gassing from building materials (paints, adhesives, etc.), use of benzene-containing consumer products and unflued oil and petrol heating. Evaporation from fuel tanks of motorcycle might be important source of benzene in Vietnam since each family owns several motorcycles and a guest room is common parking place for motorcycles. Human exposure to a pollutant is considered as the concentration of the pollutant in the air that one individual inhales, and differs from outdoor and indoor pollutant concentration. Exposure depends on pollution level in the urban air, as well as in microenvironments that an individual is exposed to, and the duration of exposure. Personal exposure to benzene of non-occupational non-smoking population was found to be higher than the outdoor ambient benzene level in Barcelona City metropolitan area and Catalan rural areas, Spain (Gallego et al., 2008); in Rouen, Île de France (Paris area), Grenobleand and Strasbourg, France (Gonzalez-Flesca et al., 2007); and in Copenhagen, Denmark (Skov et al., 2001). The right method for the assessment of toxicity of benzene to humans is to relate benzene exposure to health effects.

Ho Chi Minh City, with a population of around 8.5 million, is one of the most crowded cities in East Asia. Public transportation consists of buses and taxis; however, the usage rate is low.

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Motorcycles are preferred for their flexibility. The number of motorcycles and automobiles in March 2008 were 3,444,868 and 346,355, respectively, increasing to 3.9 million and 386,000 by June 2009. On average, vehicle population increases about 10% per year. Following this trend, the number of motorcycles at the end of 2011 was probably around 5 million. Traffic volume in the city is extremely high. Our traffic survey at 29 major and 22 minor roads on 24 November 2010 showed daily traffic volume in a range of 1.7×10^4–4.7×10^5 vehicles/day with an average at 1.4×10^5 vehicles/day. Traffic volume in rush hours (7 AM–8 AM and 5 PM–6 PM) was 1.4×10^3–4.8×10^4, with average of 1.2×10^4. Motorcycles contributed 90%–91% of a traffic fleet. On average, the moving speed of a motorcycle is 20 km/h in non-rush hours and 17 km/h in rush hours, road width is 18 m and buildings are mainly three-storey. Road area in rush hours was 10–200 m^2/vehicle with a same median and geometric value of 29 m^2/vehicle (unpublished data). Traffic jams are frequent. A large percentage of transportation means is made up of old technology. EURO II standard takes power in Vietnam since July 2008, but it is only applied for new imported vehicles.

According to Lan et al. (2011), a daily benzene concentration in street urban air in Ho Chi Minh was 7–117 μg/m^3 with a geometric mean value of ∼45 μg/m^3. A high concentration of benzene may badly affect human health. Up to date, there was not any published data on exposure to pollutants in Vietnam. This study aims to investigate personal exposure to benzene of selected population groups in Ho Chi Minh. The study was conducted from the end of 2009 to the end of 2010.

2. Material and methods

2.1. Study population

Ten people in three groups were recruited. The first group consisted of two housewives. Exposure in this group is equivalent to indoor benzene levels. Two houses were chosen. The first house was located in a narrow residential lane located ∼200 m away from a main street. The other house is a small shop located on and facing a main street. An entrance to the first house was just opened and closed few times in a day, while an entrance to the second house was opened from 8 AM to 9 PM. Windows on the second and third floors of the two houses were opened day around. None of houses had an air conditioner and/or ventilator. In Vietnam, most houses and building facing streets are shops. Commonly, shops are opened 12–14 h per day. The two houses are designated as off-road and roadside indoors, respectively.

Two students and a lecturer were in the second group for the study on exposure during commuting and working in university. Motorcycles are the most common means of urban transportation in Vietnam. Buses are mainly for university students and temporary visitors. Taxis and private cars are for high-income people. One student commuted by a city bus, another drove a motorcycle and the lecturer commuted by a 4-seat taxi. Departure and destination were two university Campuses, but routes were different. One-way mileage was about 25 km for the motorcycle and taxi, 32 km for the bus following definite route. One-way commuting time was 1.5 h by bus, 1 h by taxi and 1 h 10 min by motorcycle in the morning (6:30 AM–8 AM). The commuting time in the evening (after 6 PM) was a 10–15 min shorter than in the morning. About one third of the route was in crowded narrow streets, and the other two thirds were in open-space roads. From ∼8 AM to ∼7:30 PM, the students and lecturer stayed in the university campus, which is about 200 m away from a main road. Benzene exposure in the second group was designated as commuter/bus, commuter/taxi and commuter/motorcycle.

Individuals in the third group were persons at high risk of exposure: a street vendor, a motorcycle–taxi driver, a bus driver, a taxi driver and a petrol-filling employee. Working times of street vendors varied depending on cases. The vendor was working from 6 AM to 10 PM in the front of the roadside house. This selection enabled evaluation of influence of proximity to road to indoor benzene levels. Motorcycle–taxis are common in Vietnam. Motorcycle–taxi drivers have no definite working time, from a few to 14 h per day. The motorcycle–taxi driver in the study was on the streets for about 10 h/day. In this time, he was driving for 7 h, waiting in front of university about 2 h, and having lunch and dinner for more than 1 h. The remaining time in the day, he was at home. Commonly, street vendors and motorcycle–taxi drivers are low-income people and most of them are temporary residents of the city. They usually live in houses located in narrow lanes in dense residential areas.

In Ho Chi Minh City, departure of the first and last bus from a terminal is 5 AM and 8 PM. The bus in the study was a diesel 47-seater, and was air-conditioned like most of buses in Ho Chi Minh. The bus route was about 30 km. Working time of the bus driver is from 5 AM to 10 PM with a break after each round. Taxis in Ho Chi Minh run on petrol and operate throughout the day. A working shift of a taxi driver is normally 12 h. A 7-seat air-conditioned taxi was employed for a whole day for the study. All taxis and <9-seat cars in Ho Chi Minh are air-conditioned. Working time of the petrol-filling employee was 6 AM to 10 PM. The petrol-filling employee wore a facemask made of cotton-cloth layers. This type of mask is very common in Vietnam for protection from sunlight, particles and pollutants, and Vietnamese citizens wear them when commuting by motorcycles. The protection ability of facemasks from gas pollutants is not clear. Normally, petrol-filling employees, taxi drivers and bus drivers work one week on and one week off.

2.2. Sampling

Passive sampling was applied for measurement of daily exposure of taxi and motorcycle–taxi drivers, while active sampling was used for investigation of hourly exposure in other cases. Active sampling was performed according to the NIOSH 1501 method (NIOSH, 2003). Air was drawn into sample tubes (Sibata 80150-0541, 70 mm × ϕ 6 mm/4 mm, 200 mg of activated carbon) at a flow of 100 ml/min in 55 min or 110 min using a programmable minipump (MP ∑30, Sibata, Japan). The pump was calibrated using a bubble flow meter. A sample tube holder was attached on a breast pocket. Sampling was conducted throughout the day for the off-road house, 6 AM–10 PM for the roadside house, street vendor, commuters, bus driver and petrol-filling employee. To simulate the air that petrol-filling employee inhaled, sampling tube was attached through a small hole into a PVC bottle (6 cm diameter and 10 cm height), the mouth of which was covered by the same facemask that the petrol-filling employee had. Sample tubes after sampling were sealed with plastic caps. Passive sampling was performed using Lanwatsu passive samplers (Lan and Binh, 2012). Passive samplers were attached on breast pockets. Sampling duration was 24 h. Sampling rates of the Lanwatsu passive sampler at 30 °C were 17.7, 16.2, 15.3, 15.1 and 14.4 ml/min, respectively, for benzene, toluene, ethylbenzene, *p,m*-xylenes and *o*-xylene. Passive sampling was used in the second sampling campaign (November 2010) for taxi and motorcycle–taxi drivers, while active sampling was applied in the first sampling campaign (from June to July 2010) in other cases, Sampling was done in working days. Totally, 65 samples were taken. All samples were stored in a plastic bag sealed with a zippered laminar aluminium envelope and kept in an airtight box, cold-stored and brought to the laboratory.

Sampling campaigns, climatic conditions obtained from Ho Chi Minh City meteorological station (VVTS) and mixing layer depth obtained from HYSPLIT Trajectory Model (NOAA) are given in Table 1 and Fig. 1. Ho Chi Minh has tropical monsoon climate. A year has distinct dry season (December–April) and rainy season (May–November). Temperature is stable all year round with a monthly average of 26 °C–28 °C. The difference between daytime and nighttime temperature is 8 °C–10 °C. This difference is greater during the dry season compared with the rainy season. Commonly, wind velocity in the evening is stronger than in the morning. Surface thermal inversion is rather frequent in early morning in Ho Chi Minh. The frequency of surface stable layers of several hundred metres at 7 AM is up to 30% for any month in a year. Moreover, the thickness of surface stable layers during boreal winter time is double or triple that of the rainy season. From March to May, the frequency of surface stable layers decreases while their elevation above the surface increases and reaches 1.2 km. In addition, additional stable layers develop at 1.5–3.5 km height above unstable layers during the dry season (Nodzu et al., 2006). The above conditions enable accumulation of pollutants on the surface in the early morning.

2.3. Instrumental methods and materials

2.3.1. Chemicals and standards

All chemicals (puriss, anhydrous, analytical standard grade; with a purity >99.5%) were purchased from Sigma–Aldrich. Carbon disulfide was treated by adding 20 mL of concentrated sulphuric acid and 10 drops of concentrated nitric acid to 1 L of the solvent and shaking for two days. A CS_2 layer is then decanted off, dried with anhydrous sodium sulphate and distilled. The treated CS_2 was checked for benzene by gas chromatography (GC) analyses. Usually, one treatment is enough for complete benzene removal. The bottle with benzene-free CS_2 was stored in a steel box containing activated charcoal at 5 °C to avoid recontamination.

A calibration curved was constructed using six working standards containing benzene (0.110–3.52 μg/ml), toluene (0.215–6.88 μg/ml), ethylbenzene (0.0542–1.72 μg/ml), *p,m*-xylenes (0.108–3.46 μg/ml) and *o*-xylene (0.0550–1.76 μg/ml) and two internal standards (IS), fluorobenzene (3.20 μg/ml) and chlorobenzene (3.46 μg/ml). The working standard solutions were stored in darkness at −5 °C.

2.3.2. Analyses

Analysis was carried out within a week after sampling as it was described in our previous report (Lan and Binh, 2012). A six-point linear calibration curve showed correlation coefficients above 0.999 for all analytes. The limit of detection was 1.42, 1.35, 1.40, 1.41, 1.42 ng/ml, respectively, for benzene, toluene, ethylbenzene, *p*-

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