Ecotoxicology and Environmental Safety 144 (2017) 445–449

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

journal homepage: www.elsevier.com/locate/ecoenv

BTEX exposure assessment and quantitative risk assessment among petroleum product distributors

Behzad Heibati[a], Krystal J. Godri Pollitt[b], Ali Karimi[c], Jamshid Yazdani Charati[d], Alan Ducatman[e], Mohammad Shokrzadeh[f], Mahmoud Mohammadyan[g,*]

[a] Student Research Committee, Health Sciences Research Center, Faculty of Health, Mazandaran University of Medical Sciences, Sari, Mazandaran, Iran
[b] Department of Environmental Health Sciences, School of Public Health and Health Sciences, University of Massachusetts, Amherst, MA 01003, USA
[c] Department of Occupational Health, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran
[d] Department of Biostatics, Faculty of Health, Mazandaran University of Medical Sciences, Sari, Iran
[e] Department of Occupational and Environmental Health Sciences, West Virginia University School of Public Health, Morgantown, WV, USA
[f] Department of Toxicology-Pharmacology, Faculty of Pharmacy, Mazandaran University of Medical Sciences, Sari, Iran
[g] Health Sciences Research Center, Faculty of Health, Mazandaran University of Medical Sciences, Sari, Mazandaran, Iran

ARTICLE INFO

Keywords:
BTEX
Health risk
Oil distribution facility
Workers
Environmental carcinogens

ABSTRACT

The aim of this study was to evaluate benzene, toluene, ethylbenzene, and xylene (BTEX) exposure among workers at four stations of a major oil distribution company. Personal BTEX exposure samples were collected over working shift (8 h) for 50 workers at four stations of a major oil distribution company in Iran. Measured mean values for workers across four sites were benzene (2437, 992, 584, and 2788 μg/m^3 respectively), toluene (4415, 2830, 1289, and 9407 μg/m^3), ethylbenzene (781, 522, 187, and 533 μg/m^3), and xylene (1134, 678, 322, and 525 μg/m^3). The maximum mean concentration measured across sites for benzene was 2788 μg/m^3 (Station 4), toluene was 9407 μg/m^3 (Station 4), ethylbenzene was 781 μg/m^3 (Station 1) and xylene was 1134 μg/m^3 (Station 1). The 8 h averaged personal exposure benzene concentration exceeded the recommended value of 1600 μg/m^3 established by the Iranian Committee for Review and Collection of Occupational Exposure Limit and American Conference of Governmental Industrial Hygienists. Mean values for excess lifetime cancer risk for exposure to benzene were then calculated across workers at each site. Estimates of excess risk ranged from 1.74 ± 4.05 (Station 4) to 8.31 ± 25.81 (Station 3). Risk was assessed by calculation of hazard quotients and hazard indexes, which indicated that xylene and particularly benzene were the strongest contributors. Tanker loading was the highest risk occupation at these facilties. Risk management approaches to reducing exposures to BTEX compounds, especially benzene, will be important to the health of workers in Iran.

1. Introduction

Petroleum refineries and petrochemical plants are major sources of volatile organic compounds (VOCs) in the environment (Lin et al., 2004; Liu et al., 2008). These industrial releases primarily include benzene, toluene, ethylbenzene, and xylenes, collectively known as BTEX (Kennes and Veiga, 2004; Yassaa et al., 2006). Inhalation is the important exposure pathway for these volatile contaminants (Salminen et al., 2004) and can lead to symptoms such as dizziness, nausea, vomiting, and headaches (Mohammadyan et al., 2016; Sekhar and Subramaniyam, 2014). Dermal uptake can also be important in situations where there is potential for spill and other manual contact with petroleum products (Galea et al., 2014). In particular, benzene has been classified as a carcinogen because of persistent bone marrow damage and risk of neoplastic change leading to myeloid leukemia (Bloemen et al., 2004; Mohammadyan et al., 2016; Rinsky et al., 1987; Smith et al., 1997; Smith, 2010; IARC, 2012).

Occupational exposure to BTEX is elevated among workers in the oil distribution industry, certain types of chemical manufacturing, employees of filling stations, professional (truck) drivers, and operators of machinery powered by internal combustion engines (Tompa and Jakab, 2005). BTEX exposure in oil distribution facilities is related to emissions from fuel tank emissions, and evaporative loss from fuel filling trucks (Weisel, 2010). Employees of oil distribution facilities are exposed during refueling of trucks and also from tail pipe emissions. These employees may be exposed during the entire working shift (8 h). The American Conference of Governmental Industrial Hygienists' (ACGIH) has proposed an 8-h time-weighted average (TWA) threshold limit

* Corresponding author.
E-mail address: Mohammadyan@yahoo.com (M. Mohammadyan).

http://dx.doi.org/10.1016/j.ecoenv.2017.06.055
Received 30 March 2017; Received in revised form 21 May 2017; Accepted 20 June 2017

value of 0.5 ppm for benzene (ACGIH, 2011).

Systemic reviews of published case-control and cohort studies investigating occupational benzene exposure have reported enhanced risk of non-Hodgkin lymphoma (Mehlman et al., 2006; Smith et al., 2007). In China, benzene exposed workers, working at painting, shoe-making, rubber synthesis, leather, and adhesive and organic synthesis factories were found to experience elevated rates of leukemia and lung cancer mortality compared to nonexposed workers (Yin et al., 1989). A trend towards increased rates of liver, stomach, esophagus, intestine and nasopharynx cancers have also been reported. Similar results for enhanced rates of leukemia and multiple myeloma has been reported for petroleum workers (Kirkeleit et al., 2008).

The petroleum industry in Iran is a major producer and exporter of crude oil, and increasing export production suggests the need to evaluate the health and safety of workers at oil distribution facilities. No data have been reported on BTEX exposure within the oil distribution sector in Iran. The aim of this study is to evaluate BTEX exposure among workers at four stations of a major oil distribution company in Iran.

2. Materials and methods

2.1. Study population and exposure assessment

The study population included 50 workers (tanker loading workers, tank-gauging workers, drivers, firefighters, and office workers), working at Station 1, Station 2, Station 3 and Station 4 of an oil distribution company in Northern Iran (Fig. 1).

The stations house central stores for petroleum products. A station consists of multiple tank storage units with tank gauging equipment and pumps, transfer pump equipment for mobilizing large volumes of petroleum products into tank trucks for delivery to several smaller petrol filling stations, and an idling area where tankers not being fueled can park until fueling operations are undertaken. There is a small office area for clerical personnel.

The study was conducted in November 2016. Personal exposure measurements were evaluated over the course of a 8-h working shift. Each worker was equipped with a personal sampler (Radiello® Passive monitor) worn in the respiratory zone while subjects were performing their usual activities. Tanker loading and tank-gauging workers were stationed 3–4 m above ground level and the sampling was performed at this height. At the end of each exposure period, the samples were kept in the glass storage tube at 4 °C until analysis, which occurred within 30 days of collection. BTEX collected on sorbent tubes was desorbed at room temperature for 30 min with 2 mL of benzene-free carbon disulfide (CS_2, Sigma-Aldrich) in the presence of an internal standard, containing benzene-d6 (C_6D_6, Sigma-Aldrich) in methanol (Fustinoni et al., 2010; Violante et al., 2006). This solution was analyzed using a gas chromatograph (GC, Varian, CP-3800, US) equipped with a flame ionizing detector (FID). BTEX separation was performed on silica capillary column (0.53 mm I.D., 50 m length, 0.25 μm film thickness, CP-Sil 8 CB). The GC analysis was performed at the following conditions: helium carrier gas at a constant flow rate of 30 mL/min. The injector, column, and detector temperatures were set at 200, 130, and 210 °C, respectively.

Calibration curves were constructed with a stock solution prepared in CS_2. An internal standard stock solution (0.19 g/L CS_2) was prepared from benzene-d6 pure standards. Five calibration levels were prepared using blank cartridges in the presence of chemical and internal standards ($R^2 > 0.998$). BTEX air concentrations (expressed in μg/m^3) were calculated using the following equation:

$$C(\mu g/m^3) = \frac{m(\mu g)}{Q_x(mL/\ min) \times t(min)} \times 1,000,000 \quad (1)$$

where m is the mass of analytes determined in desorbing solvent; Q_x is the uptake rate of substances onto the 35–50 mesh charcoal cartridge

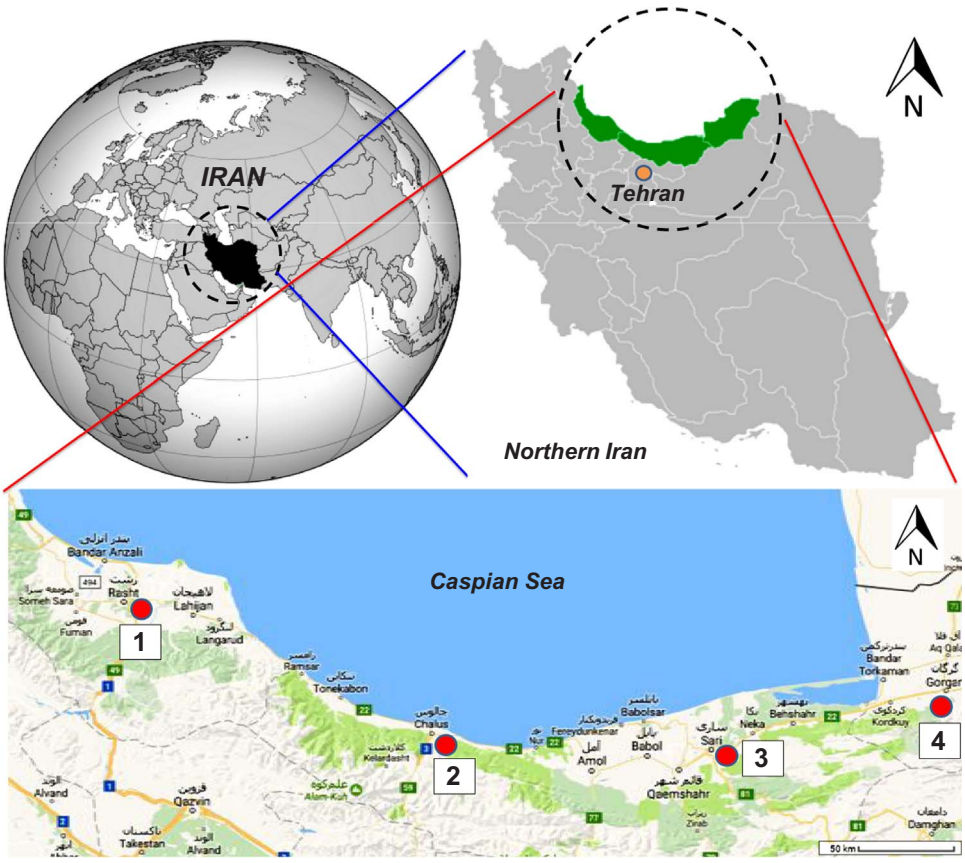

Fig. 1. Map and satellite image showing the location of monitoring stations where BTEX sampling was performed.