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Biomonitoring-based exposure assessment of benzene, toluene, ethylbenzene and xylene among workers at petroleum distribution facilities

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ABSTRACT

Elevated emissions of volatile organic compounds, including benzene, toluene, ethylbenzene, and o, p, and m-xylenes (BTEX), are an occupational health concern at oil transfer stations. This exploratory study investigated personal exposure to BTEX through environmental air and urine samples collected from 50 male workers at a major oil distribution company in Iran. Airborne BTEX exposures were evaluated over 8 h periods during work-shift by using personal passive samplers. Urinary BTEX levels were determined using solid-phase microextraction with gas chromatography mass spectrometry for separation and detection. Mean exposure to ambient concentrations of benzene differed by workers' job type: tanker loading workers (5390 $\mu g/m^3$), tank-gauging workers (830 $\mu g/m^3$), drivers (81.9 $\mu g/m^3$), firefighters (71.2 $\mu g/m^3$) and office workers (19.8 $\mu g/m^3$). Exposure across job type was similarly stratified across all personal exposures to BTEX measured in air samples with maximum concentrations found for tanker loading workers. Average exposures concentrations of BTEX measured in urine were 11.83 ppb benzene, 1.87 ppb toluene, 0.43 ppb ethylebenzene, and 3.76 ppb xylene. Personal air exposure to benzene was found to be positively associated with benzene concentrations measured in urine; however, a relationship was not observed to the other BTEX compounds. Urinary exposure profiles are a potentially useful, noninvasive, and rapid method for assessing exposure to benzene in a developing and relatively remote production region.

1. Introduction

Petroleum distribution worker exposures to volatile organic compounds (VOCs), specifically benzene, toluene, ethylbenzene, and o, p, and m-xylenes (BTEX) are prevalent in the oil industry. Evaporative loss of oil and refined petroleum from liquid surfaces, especially from fuel tanks and tanker trucks during fueling operations, and from fuel filling trucks, combines with emissions from tail pipe exhausts to provide several sources of potential human exposure (Avens et al., 2011; Reddy et al., 2012). Inhalation of these volatile contaminants can cause symptoms such as dizziness, nausea, vomiting and headaches (Mohammadyan et al., 2016; Sekhar and Subramaniyam, 2014). Exposures to high concentrations of toluene, xylene and ethylbenzene have also been associated with chronic neurotoxicity (Chen et al., 2002). Benzene is classified as a class 1 carcinogen by the International Agency for Research (IARC, 2012), and chronic exposure may cause bone marrow damage, aplastic anemia, and leukemia. Lifetime risk of leukemia has been estimated as about six cases per million among humans exposed to benzene concentrations of 1 $\mu g/m^3$ in air (WHO, 1996). The time-weighted average exposure guidelines by the American Conference of Governmental Industrial Hygienists' (ACGIH) for a conventional 8-h workday is 0.5 ppm for benzene, 20 ppm for toluene, 100 ppm for ethylbenzene and 100 ppm for xylene (ACGIH, 2011). Reliable and cost-effective approaches to detect the presence of BTEX exposure is an important part of a risk reduction strategy (Sekhar and Subramaniyam, 2014).

Personal exposure of workers to air pollutants can be evaluated using biological monitoring techniques. Chemical analysis of

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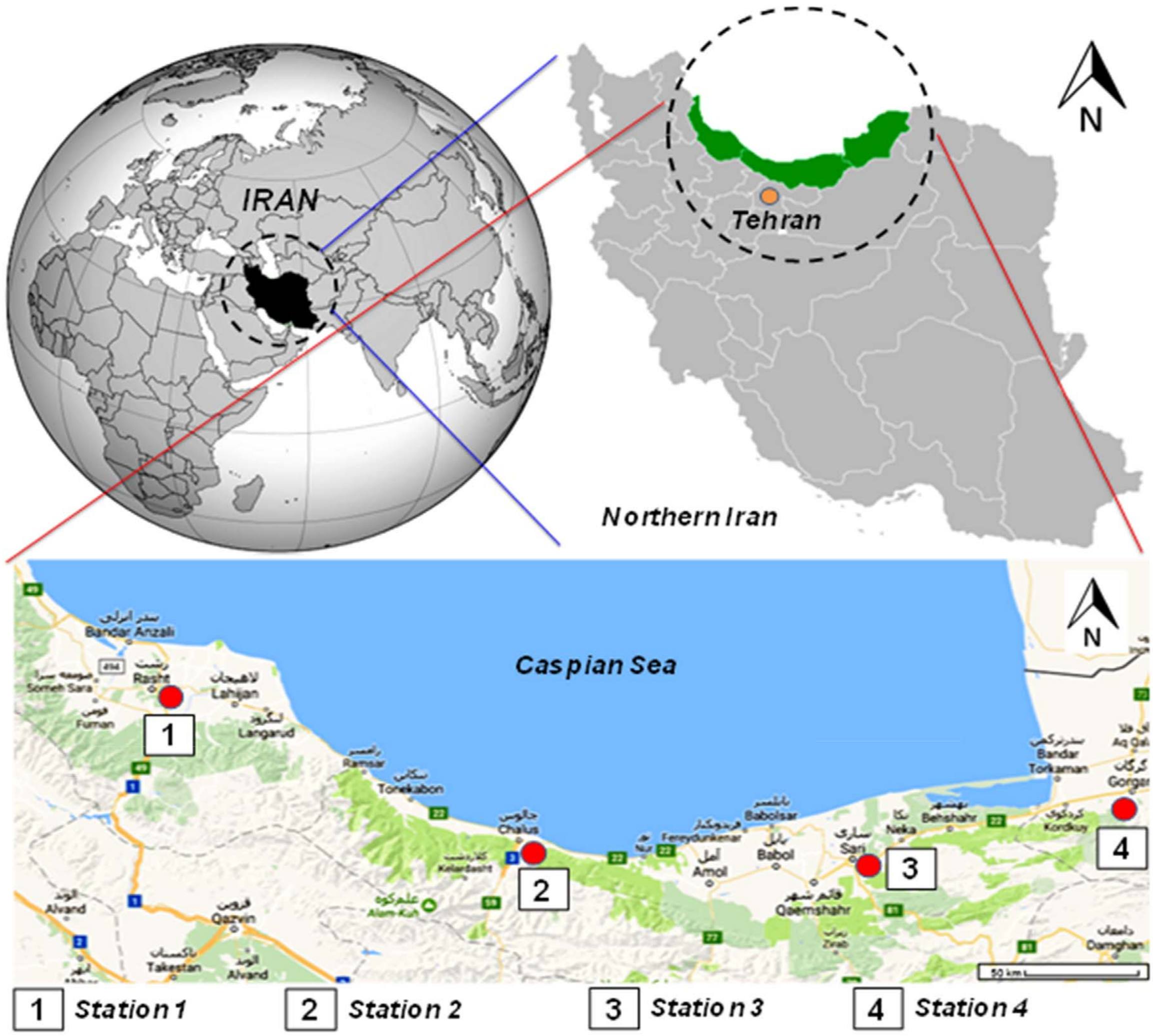

Fig. 1. Map and satellite image showing the location of monitoring stations where BTEX sampling was performed.

environmental pollutants and associated metabolites in urine has been a common biological monitoring approach (Lauwerys and Hoet, 2001; Lin et al., 2008). Several studies have explored occupational exposure to BTEX in urine samples collected from workers at oil refining facilities. Several oil industry workers job types, including those involved in the production process, were shown to have enhanced exposure to BTEX compared to the general populations (Edokpolo et al., 2015; Boogaard and Van Sittert, 1996; Carrieri et al., 2010; Rahimpoor et al., 2014). No studies to date have personal occupational exposure levels to BTEX in occupational environmental in developing countries, such as Iran. The main objective of this exploratory study, therefore, was to evaluate urinary BTEX for use as biomarkers of personal exposure in a developing economic region.

2. Materials and methods

2.1. Study population and sampling

This study was performed in November 2016 and included 50 employees at four locations of an oil distribution company in Northern Iran (Fig. 1). The sites consisted of a multiple tank storage facility with tank gauging equipment and pumps to transfer petroleum into tanker vehicles from storage tanks. In addition, there was an area where operating tankers parked during fueling operations. Clerical personnel worked in a small office area near the stations.

All workers were monitored once, during the same work-shift (7:00 to 15:00), while they were performing their usual activities. A combination of environmental and biological sampling was used for monitoring of exposure to BTEX. Information concerning the work-shift and working habits of the workers was collected by a questionnaire. The study was approved by the Ethical Committee of the Mazandaran University of Medical Sciences. Written informed consent was obtained from all participants.

Participants were categorized by job tasks which included tanker loading workers (tasked with loading and unloading trucks with petroleum, n = 16), tank-gauging workers (manual gauging of production tanker trucks or sampling, n = 6), drivers (transporting the petroleum and refinery petroleum products, n = 5), firefighters (n = 5) and office workers (n = 18). These office workers included managerial, engineering and clerical officials who work in the office building with only occasional visits to the operational stations.

Personal exposure samples were collected over 8-h work shifts. Each worker wore a Radiello passive monitor (Sigma-Aldrich) personal sampler in their breathing zone. At the end of the sampling period, samples were immediately transported to the laboratory and refrigerated in the glass storage tube at 4 °C until analysis (Violante et al., 2006).

Two spot urine samples were collected: (1) during the week before the personal air monitoring (pre-shift), and (2) immediately following end of the air sampling (post-shift). Urine samples were collected in disposable polyurethane bottles and were stored at 4 °C at the oil distribution facility. These biological samples were transported to the