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Use of urinary biomarkers to characterize occupational exposure to BTEX in healthcare waste autoclave operators

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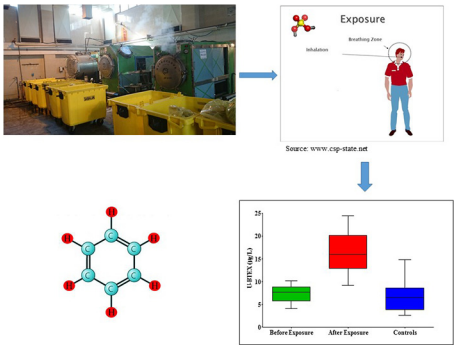
HIGHLIGHTS

- Urinary BTEX were measured in operators of healthcare waste treatment autoclaves.
- High urinary BTEX levels were found in operators.
- Significant relationship was observed between the urinary BTEX and type of autoclaves.
- Using existing personal protective equipment (N95 mask) didn't protect operators against BTEX exposure.
- Healthcare waste treatment autoclaves should be consider as a significant source of exposure for BTEX.

GRAPHICAL ABSTRACT



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ABSTRACT

Urinary benzene, toluene, ethylbenzene, and xylenes (BTEX) can be used as a reliable biomarker of exposure to these pollutants. This study was aimed to investigate the urinary BTEX concentration in operators of healthcare waste (HCW) autoclaves. This cross-sectional study was conducted in selected hospitals in Tehran, Iran between April and June 2017. Twenty operators (as the case group) and twenty control subjects were enrolled in the study. Personal urine samples were collected at the beginning and end of the work shift. Urinary BTEX were measured by a headspace gas chromatography-mass spectrometry (GC/MS). A detailed questionnaire was used to gather information from subjects. Results showed that the median of urinary benzene, toluene, ethylbenzene, m-p xylene, and o-xylene levels in the exposed group were 3.26, 3.36, 0.84, 3.94 and 4.48 μg/L, respectively. With the exception of ethylbenzene, subjects in the exposed group had significantly higher urinary BTEX levels than control group ($p < 0.05$). Urinary BTEX concentrations in the exposed case group were 2.5-fold higher than in the control group. There was a significant relationship between the amount of generated waste per day and the urinary BTEX in the exposed group. Smoking status and type of autoclave used were also identified as predictors of urinary BTEX concentrations. The healthcare waste treatment autoclaves can be considered as a

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significant BTEX exposure source for operators working with these treatment facilities. The appropriate personal protection equipment and control measures capable in reducing BTEX exposure should be provided to HCW workers to reduce their exposures to BTEX.

1. Introduction

Benzene, Toluene, ethylbenzene and xylenes (BTEX) are a class of volatile organic compounds (VOCs), which due to their hazardous and pervasive characteristics are classified as hazardous air pollutants (HAPs) (Durmusoglu et al., 2010; Hazrati et al., 2015). The U.S. Environmental Protection Agency (EPA) classified BTEX as preference pollutants, while the International Agency for Research on Cancer (IARC), classified benzene as human carcinogen and ethylbenzene as possible human carcinogen (Brajenović et al., 2015; IARC, 2008). Long-term exposure to BTEX has been associated with nose and throat irritation, asthmatic exacerbation (Rumchev et al., 2004; Zhou et al., 2011), leukemia, birth defects, allergies, (Reid et al., 2016; Song et al., 2017), bladder cancer, and neurocognitive deficit (Alwis et al., 2012).

BTEX are highly volatile and liposoluble compounds, which enhance their potential for human exposure (Saldarriaga et al., 2014). The concentration of BTEX and the duration of exposure to such compounds are among the most important factors that affect the health effects observed in humans exposed to BTEX (Tunsaringkarn et al., 2014b). Predominantly, inhalation is the common route of exposure to BTEX due to the volatility of these compounds, but dermal absorption should also be considered (Fustinoni et al., 2010; Hopf et al., 2012). Numerous workers in different occupations, are exposed to BTEX. People working in solid waste facilities such as composting plants (Gallego et al., 2012), landfilling (Durmusoglu et al., 2010; Liu et al., 2016), and recycling plants such as plastic waste recycling facilities (Huang et al., 2013) are potentially exposed to BTEX. Health care waste (HCWs) workers are exposed to various occupational hazards (Rafiee et al., 2016). Safety risks from using heavy machinery have been reported previously (Kontogianni and Moussiopoulos, 2017). Likewise, HCW workers are also at increased risk for the transmission of the hepatitis B (Mol et al., 2017), hepatitis C and human immunodeficiency viruses (HIV), generally linked to needle stick injuries and contact with contaminated blood (Beghdadli et al., 2009). But also, HCWs workers could be exposed to BTEX emission from handling and management of HCWs. Autoclaves have been applied to treat different types of HCWs as early as 1876 (Salkin, 2003). Autoclaves operate within a temperature range of 50–250 °C (Hossain et al., 2011), whereas BTEX vaporize between 80 °C and 144 °C. Hence it is highly likely that HCW would be exposed to BTEX vapors. Kontogianni and Moussiopoulos (2017) suggested that HCW workers should consider risks associated with exposure to various waste-derived emissions (Kontogianni and Moussiopoulos, 2017). Indeed, a great number of VOCs, including BTEX, carbon disulfide, acetone, and, to a smaller extent, styrene were found in air exhaust vents of autoclaves during cooling periods (Hadar et al., 1997). Farshad et al. (2014) also reported that exhaust emissions from autoclaves contain significant amounts of BTEX compounds (Farshad et al., 2014). Therefore, HCWs workers could be one of the important occupational groups at risk of BTEX exposure.

Exposure assessment in occupational settings can be done by characterizing environmental concentrations in different working environments (i.e. microenvironments) and/or working scenarios (i.e. different working tasks within the same or similar microenvironment) and subsequently calculating occupational exposures by considering the working patterns of workers (i.e. time spent in each characterized microenvironment or scenario). Biological monitoring (biomonitoring) is another approach extensively used to characterize exposure to various pollutants (Shahsavani et al., 2017). Biomonitoring is by definition the monitoring of exposures to toxic pollutants and their effects in body fluids of the exposed subjects. It is considered the gold standard in exposure assessment (Brajenović et al., 2015; Hoseini et al., 2016). It can be used to evaluate the possible toxicological effects of exposure to different pollutants such as BTEX. Human biomonitoring of BTEX has mainly focused on analyzing BTEX metabolites in two matrices, such as blood and/or urine (Brajenović et al., 2015; Ekpenyong and Asuquo, 2017; Fustinoni et al., 2011; Tsangari et al., 2017; Tunsaringkarn et al., 2014b). Urinary BTEX metabolites namely phenylmercapturic, methylhippuric and phenylglyoxylic acid, O-cresol, trans, trans-muconic acid (MA), catechol, have been widely used to assess exposure of different workers in various occupational settings to these chemicals (Weisel, 2010). In recent years, urinary un-metabolized BTEX concentrations has also been proposed as a reliable and sensitive BTEX biomarker, because it showed a significant correlation with airborne BTEX levels, particularly for exposures ranging from <0.01 to 3.5 ppm (Fustinoni et al., 2010; Waidyanatha et al., 2001).

Recently, many studies have been carried out biomonitoring BTEX exposures in occupational and non-occupational contexts. In particular, occupational studies were conducted in gasoline station workers (Campo et al., 2015; Inoue et al., 2001), petrochemical and refinery plants (Carrieri et al., 2010; Hoet et al., 2009; Lovreglio et al., 2010), traffic policemen (Crebelli et al., 2001; Manini et al., 2010; Manini et al., 2008; Tunsaringkarn et al., 2012), offshore workers (Hopf et al., 2012), street vendors (Tunsaringkarn et al., 2014a), paint and shoe plant workers (Janasik et al., 2010), motorcycle and public transportation drivers (Imbriani and Ghittori, 2005; Tunsaringkarn et al., 2014a). However, according to the previous studies, there is a lack of studies assessing BTEX exposures among HCWs treatment workers, and especially those who work with steam treatment technologies such as autoclaves, hydroclaves, etc. Thus, the aim of this study was to investigate the potential of urinary BTEX to be used as biomarkers of environmental exposure to BTEX for HCWs treatment facilities workers in hospitals of Tehran.

2. Material and methods

2.1. Study design and participants

This cross-sectional study was carried out in 10 public and private hospitals in Tehran, the capital of Iran. The characteristics of the studied hospitals are shown in Table 1. During the field survey it was found that all the studied HCW treatment autoclaves treated infectious wastes with similar composition, including HCW contaminated with blood, urine, bandages, gloves, cultures, stocks etc.

Subjects were selected from HCWs workers, who worked in the treatment unit and agreed to participate in the study. In total, 20 healthy male workers, between 24 and 35 years old, working in the treatment unit for >6 months, were selected as a case group and 20 administrative staff within the studied hospitals were selected as a control group. All subjects were informed about the study goals, protocol, and signed a consent form.

Field work was conducted between April and June 2017. All the participants were interviewed following a questionnaire administered by the researchers, which included demographic information, lifestyle conditions, period of employment, working hours per day, and working days over a week. The subjects were biomonitored for BTEX exposure as described below.