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Risk assessment of exposure to released BTEX in district 12 of Tehran municipality for employees or shopkeepers and gas station customers

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ABSTRACT: Owing to environmentally-destructive impact of aromatic hydrocarbons, such as benzene, benzene ethyl, toluene, and xylenes or BTEXs, these materials are classified as hazardous pollutants in the air. This study studies cancer and non-cancer risk in District 12 of Tehran Municipality, through these components for two groups of employees or storekeepers and gas station customers. By measuring pollutant concentrations along with doing related calculations, the areas and gas stations of the study area with the highest risk have been found. Results show that Station 7, located in Zone 4, is one of the most dangerous spots in terms of cancer and non-cancer risk to employees or storekeepers in the area. Additionally, there is no risk of non-cancerous disease for the customers, using these stations, during their lifetime. Finally, the study proposes some solutions for making appropriate decisions, concerning the sustainable management plan.

Keywords: air organic pollutions, BTEX, district 12 of Tehran municipality, health risk assessment of humans.

INTRODUCTION

Population growth and increasing urbanization reduce air quality around the world. Air pollutants encompass volatile organic compounds, among which aromatic hydrocarbons such as benzene, benzene ethyl, toluene, and xylenes or BTEXs with carcinogenic potentials are allegedly harmful to humans, and the diffusion of which has caused growing concern.

This study deals with cancer and non-cancer risk through these components for two groups of employees or storekeepers, on one hand, and gas station customers, on the other, in District 12 of Tehran Municipality. Table 1 briefly presents negative effects of BTEXs through inhalation.

There are many potential sources of BTEX in the air, e.g. smoking cigarette, combustion of gasoline and diesel in motor engines, and petrochemical industries (Cetin et al., 2003; Lee et al., 2002; Lin et al., 2004). Health risk assessments of toxic VOCs are widely used as a regulatory decision-making process to combat air pollution and protect its exposure to human health (Guo et al., 2004; Yeh et al., 2011; Cho et al., 2008; Yang et al., 2012).

Many studies have specifically focused on petrol refueling stations, gasoline exhaust emissions, and health risks, related to petrol station workers (for example Das

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et al., 1991; Edokpolo et al., 2014; Hein et al., 1989; Keretetse et al., 2008; Onunkwor et al., 2004; Rekhadevi et al., 2010; Singh et al., 2013; Udonwa et al., 2009).

Habeebullah (2015) examined health risk assessment in the city of Mecca for different age groups. Moolla et al. (2015) evaluated occupational exposure to BTEX compounds at a bus diesel-refueling bay. Yan et al. (2015) tested health risk assessment of toxic VOCs species for coal fire well drillers. In addition to age, population, and health conditions, amount of toxic substances and contact to them are important factors in the risk assessment of human health (USEPA, 1998).

This study aims at analyzing the concentration of benzene, toluene, benzene ethyl, and xylene (BTEX), assessing their impacts on the health of employees or storekeepers and gas station customers in District 12 of Tehran Municipality.

MATERIALS AND METHODS

District 12 of Tehran Municipality is one of the oldest parts of the city, located approximately at the center, with an area of 16.19 square kilometers to be divided into six zones. This district is limited from north to Enghelab-e-Eslami Street, from south to Shoush Street, from east to Hefdah-e-Shahrivar Street, and from west to Vahdate-e-Eslami Street (Fig. 1). The most important features of this area are a non-stationary population of approximately 1.5 million people, many centers and government agencies, as well as ministries and embassies. Due to commercial and administrative positions of this district, a large number of motor vehicles commute daily with different age groups. Old textures, different class activities, and narrow streets with intensive traffic lead to the emission of chemicals into the air of this district.

Measuring stations of air pollutants

As Figure 1 shows 22 points have been set as air sampling points. Table 2 gives the coordinates of the selected locations**.** Each of these points has various specifications in terms of contaminant emissions, affecting human activities. The selected points include gas stations, terminals, public vehicles, and high traffic areas. Human sources to produce VOCs in this region

Table 1. Health effects, associated with chronic inhalation exposure to BTEX concentrations (Romieu et al., 1999; Keretetse et al., 2008; Tunsaringkarn et al., 2012; World Health Organization, 2012; Moolla et al., 2013; Edokpolo et al., 2014)

Compound	Health effects from inhalation exposure
Benzene	Neurological (central nervous system (CNS) depression: drowsiness, tremors) Respiratory and eye irritant Hematological (blood disorders- aplastic anemia) Reproductive/developmental (animals: low birth weight, bone marrow damage) Cancer (leukemia)
Toluene	Respiratory (throat irritation, chest constriction) Kidney, liver, eye effects Neurological (CNS toxicity)
Benzene Ethyl	Neurological (CNS depression: drowsiness, tremors) Kidney, liver impairment Reproductive/developmental effects
Xylenes	Eye, nose, skin, throat irritation Neurological (dizziness, memory loss, headache) Gastrointestinal (nausea, vomiting)

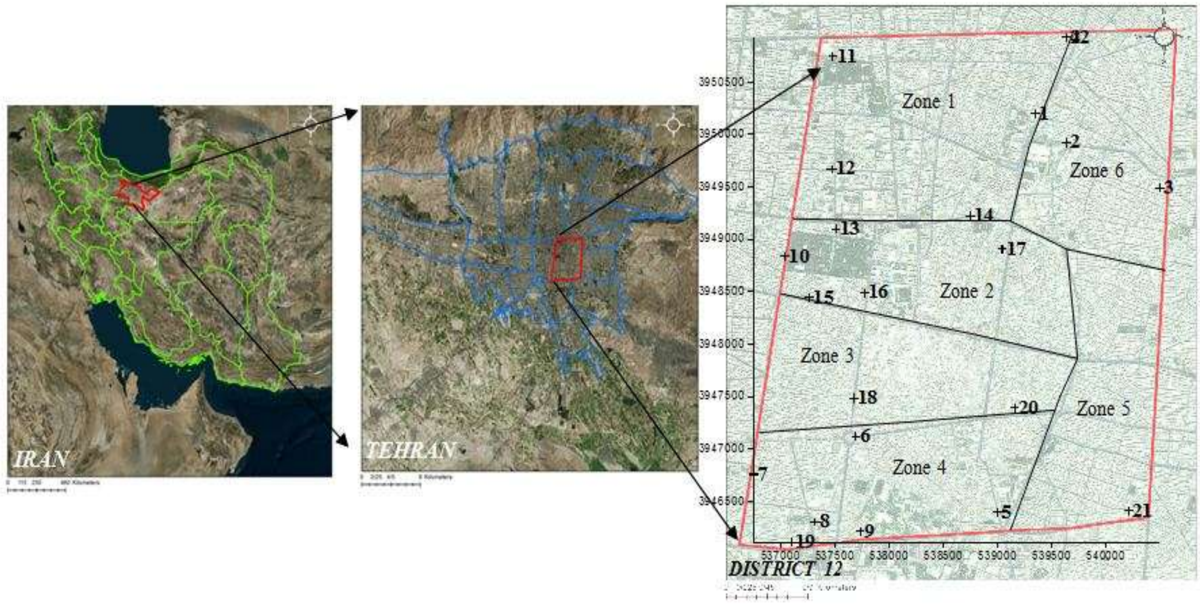

Fig. 1. Area of district 12 of Tehran municipality

include solvents and related products (such as cosmetics, air fresheners, chemicals for house cleaning, etc.), construction equipment (such as paint), heating and cooking (such as a stove or heater and kerosene petroleum), smoke, fuel burning, and gasoline evaporation (which may occur when filling or transferring gasoline at gas stations and terminals). The major pollutants of gas stations are hydrocarbon emissions and gasoline vapors. Gasoline is a mixture of various hydrocarbons, some of which are on the list of dangerous air pollutants. These emissions are from the four following different sources:

- Filling underground tanks
- A waste of evacuation and ventilation of underground tanks
- Transportation of vapor from vehicle fuel tank during refueling operations
- Gasoline leaks during automobiles' fueling at the stations.

In this light, the first three sources are in the form of evaporative emissions from the tank.

Once the measuring stations have been identified, sampling was done in two phases in January and March (2016/01/01 and 2016/02/13).

Table 2. Coordinates of the sampling points of BTEX compounds in District 12

Sampling site	Longitude	Latitude	Sampling site	Longitude	Latitude
1	539338.88	3950199.68	12	537464.65	3949670.3
2	539632.36	3949922.6	13	537502.35	3949098.15
3	540492.07	3949490.59	14	538746.01	3949221.05
4	539633.58	3950925.8	15	537260.78	3948442.76
5	538995.38	3946395.56	16	537767.35	3948488.15
6	537689	3947119.17	17	539038.76	3948906.23
7	536744.69	3946756.97	18	537667.55	3947480.65
8	537313.2	3946301.28	19	537093.14	3946110.7
9	537727.24	3946212.08	20	539154.02	3947389.47
10	537035.63	3948834.44	21	540208.32	3946407.06
11	537476.4	3950745.08	22	539633.58	3950925.8

Sampling and measuring air pollutants

For sampling purpose, pump of SKC AIRCHEK from SKC Company and for measuring environment gases, the AEROQUAL device was used. In order to measure hydrocarbon compounds, the standard method of NIOSH1501 ، EPA0030 and OHSA12 was used according to the terms.

Assessment of the risk of exposure through inhalation

In this study, the exposure risk assessment for the BTEX was conducted to review risk possibility of cancerous and non-cancerous diseases due to these contaminants. Based on the fact that benzene is carcinogenic and benzene ethyl is suspected to carcinogen materials (IARC, 2010), the cancer risk assessment was determined only for these two pollutants. Adsorption through inhalation was measured by calculating the amount of the Chronic Daily Intake[1] by means of Equation (1) and (2), proposed by the RAIS.

$$CDI_{inhal-NC}\left(\frac{\mu g}{m^3}\right)=\frac{C_{air}\left(\frac{\mu g}{m^3}\right)\times EF\left(\frac{day}{yr}\right)\times ED(yr)\times ET\left(\frac{hr}{day}\right)\times\left(\frac{day}{24hr}\right)}{BW\left(\frac{365day}{yr}\times ED\right)} \quad (1)$$

$$CDI_{inhal-c}\left(\frac{\mu g}{m^3}\right)=\frac{C_{air}\left(\frac{\mu g}{m^3}\right)\times EF\left(\frac{day}{yr}\right)\times ED(yr)\times ET\left(\frac{hr}{day}\right)\times\left(\frac{day}{24hr}\right)}{BW\left(\frac{365day}{yr}\times LT\right)} \quad (2)$$

where C_{air} is the concentration of the pollutants in the air; EF the frequency; ED the duration of contact; ET the contact time; BW the average weight of an adult; and LT the person's lifetime.

Afterwards, Equation (3) was used to calculate the cancer risk.

$$Risk=CDI_{inhal}\times CSF \quad (3)$$

where CSF is the Carcinogenic Slope Factor in $(mg/kg\text{-}day)^{-1}$. The air adsorption rate for adults is considered 20 m^3/day by default (rais.ornl.gov).

To calculate the risk of non-cancerous diseases, Equation (4) was used. The non-cancerous risk was expressed as Hazard Quotient (HQ), calculated by dividing CDI into the RfC.

As described in Equation (5), the non-cancerous HI (Hazard Index) is equal to the sum of the hazard quotients, where HQ_{inhal} is the hazard quotient through inhalation; HQ_{oral}, the hazard quotient through oral contact; and HQ_{dermal}, the hazard quotient through dermal contact. Negative effect on the health, based on references for HI≤1, was not expected. In this study, the main contact was considered for only through inhalation. Table 3 indicates the exposure and risk assessment parameters, used for this study.

$$HQ=\frac{CDI}{RfC} \quad (4)$$

$$HI=\sum HQ=HQ_{inhal}+HQ_{oral}+HQ_{dermal} \quad (5)$$

In order to calculate the health risk, the average measured concentrations in January and February 2014 were used. In this study, the concentration of BTEX varied from one point to another. The maximum value in January for total BTEX was in station 1 in Zone 4. As for benzene and toluene, and in March, it belonged to Station 7 in Zone 4, while for benzene ethyl, it was located at Station 10 in Zone 2, and for xylene, at Station 11 in Zone 1.

RESULTS AND DISCUSSIONS

Risk assessment of carcinogenic diseases for employees or storekeepers

Results of cancerous risk calculation from Equations (2) and (3) show that for benzene Station 7 posed the highest risk of

1. (CDI)averaged over 70 years, mg/kg-day

cancer for employees or storekeepers with a minimum contact of 8 hours per day, with the amount of 0.0024 (i.e. the cancerous risk of twenty-four out of ten thousand people during a lifetime), while this risk for benzene ethyl was 0.000028 at Station 9 (i.e. twenty-eight out of hundred thousand people). Figure 2 illustrates the schematic depiction of the distribution of calculated cancerous risk in the district via the software program, called Surfer, for employees or storekeepers in case of benzene and benzene ethyl.

Risk assessment of carcinogenic diseases for the gas station customers

Table 4 shows the calculated cancerous risk values for customers at any of the gas stations. As the table shows, the most probable place for developing cancerous diseases in this target group from benzene was Station 7 with a value of 0.000049 (approximately five out of one hundred thousand people), while for ethyl, it was Station 9 with a value of 0.00000059 (approximately six out of ten million people).

Table 3. Parameters of contact and risk assessment

Parameters of Assessment	Amount: Customers of Gas Stations	Amount: Employees or Shopkeepers	Compound	RfC (inhal) mg/m^3	CSF $(mg/kg.day)^{-1}$
ET	15 (min)	8 (hr)	Benzene	(IRIS)(RAIS) 0.03	(RAIS) 0.1 (CALEPA)
EF	2 (day/week) 52 (week/yr)	6 (day/week) 52 (week/yr)	Toluene	1 (RAIS)	___
ED	50 (year)	30 (year)	Benzene Ethyl	5 (IRIS)(RAIS)	0.0087 (RAIS)
BW	70 (Kg)	70 (Kg)	Xylene	0.1 (RAIS)	___
LT	70 (year)	70 (year)			

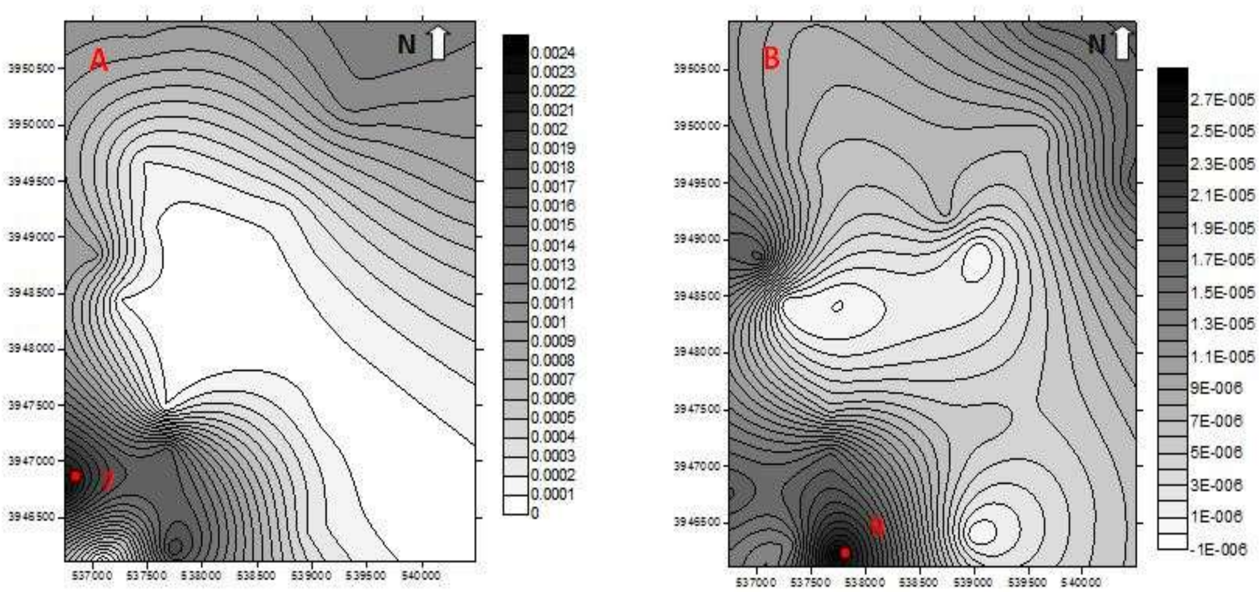

Fig. 2. Dispersion of cancer risk at the studied area A) Benzene, B) Benzene Ethyl

Table 4. Cancer risk assessment of the BTEX pollutants for the customers of gas stations

Sampling site	Xylene	Benzene Ethyl	Toluene	Benzene
1	_	1.96581E-07	_	2.45667E-05
2	_	1.54893E-07	_	1.98298E-05
3	_	3.76695E-07	_	1.8856E-05
4	_	3.45255E-07	_	2.71134E-05
5	_	0	_	5.28419E-06
6	_	3.61839E-07	_	3.23907E-05
7	_	3.86253E-07	_	4.99856E-05
8	_	3.00573E-07	_	1.55205E-05
9	_	5.95042E-07	_	3.78551E-05
10	_	3.90169E-07	_	1.94861E-05
15	_	0	_	1.94458E-06
22	_	0	_	8.54094E-07

Risk assessment of non-carcinogenic diseases

Figures 3 and 4 present the results of risk assessment of non-carcinogenic diseases, using Equations 1 and 4 for employees or storekeepers and gas stations customers respectively. As Figure 3 shows, the amount of hazard quotient (HQ) only for benzene and only at Gas Station 4, 6, 7, and 9 surpassed the threshold limit (i.e. number one), indicating damage possibility to the employees' health within these stations' range; while, the rest of pollutants and stations posed no significant threat with the possibility of non-carcinogenic disease risk to the employees or storekeepers at this intended region. Figure 4 shows the hazard quotient (HQ) for the customers of the gas stations.

As Figure 4 shows, the HQ for all stations and pollutants were lower than the threshold limit (i.e. HQ<1) and the risk of non-carcinogenic diseases during the customers' lifetime using these gas stations would not exist.

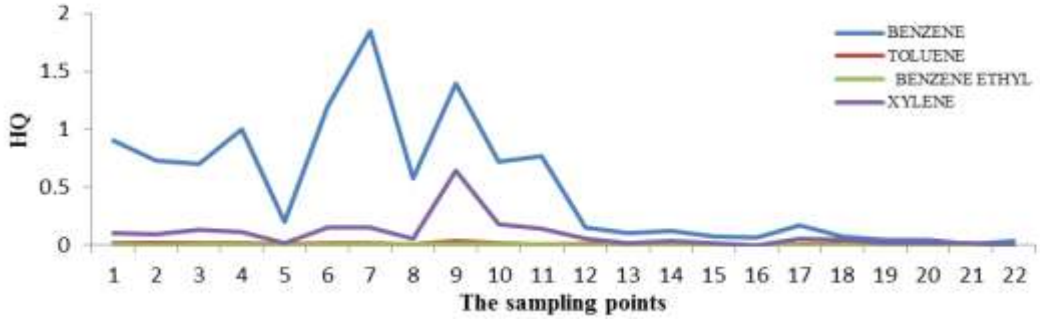

Fig. 3. Risk assessment of non-carcinogenic diseases for employees or storekeepers

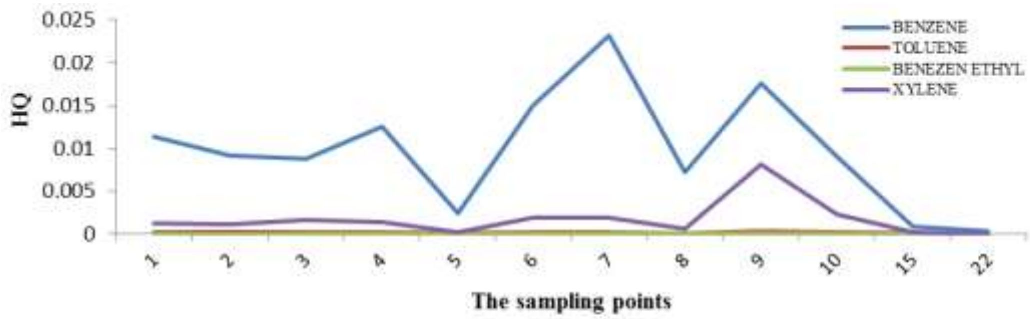

Fig. 4. Risk assessment of non-carcinogenic diseases for the customers of gas stations

CONCLUSION

This study employed health risk assessment methods for BTEX compounds as a decision-making process to combat air pollution in District 12 of Tehran Municipality. The concentration of the BTEX compounds differed from one point to another and the maximum value in January for total BTEX pollutants belonged to to Station 9 in Zone 4, while in March and for benzene and toluene it was Station 7 in Zone 4. As for benzene ethyl this value was located at Station 10 in Zone 2 and for xylene at Station 11 in Zone 1. Results showed that the risk was different in various parts of the district due to the varied activities in different geographical locations of the aforementioned area. According to the results of this assessment, for benzene and benzene ethyl, introduced as carcinogenic pollutants, Gas Station 7 and 9 had the highest risk of carcinogenic diseases for employees and storekeepers with a minimum work of 8 hours per day and the gas station customers with a minimum contact of fifteen minutes, respectively.

Calculations for gas stations customers of this area showed that the risk of carcinogenic diseases was very low. In other words, the risk of cancer in this target group was much less than employees and storekeepers. Furthermore, the amount of hazard quotient (HQ) only for benzene and only in Gas Station 4, 6, 7, and 9 surpassed the threshold limit (i.e. number one), indicating the damage possibility to the employees' health within these stations' range. It should be noted that the amount of hazard quotient (HQ) for the gas station customers was lower than the threshold limit and there were not any non-carcinogenic disease risk in these locations.

Generally, Station 7, located in Zone 4, was one of the most dangerous spots in terms of carcinogenic and non-carcinogenic risk to employees or storekeepers in the area, requiring long-term planning to prevent people from catching various diseases, particularly the residents of the area.

Totally, these studies in a wider range were proposed to have a better understanding of the effects of the BTEX and other air pollutants in order to implement sustainable management and make proper decisions.

Given the strategic location of District 12 and the potential of carcinogenic and non-carcinogenic disease risk in this study, suggestions and management solutions to control the air pollution in accordance with this area can be stated as follows:

In stationary sources, it is recommended to use vapor recovery systems, high quality fuel, catalytic converters at passenger terminals, and renewable sources such as wind and solar sources for domestic and commercial purposes, and to technically diagnose machine room, while offering low emission zone or LEZ in mobile sources. It is also useful to expand public transportation system, set emission standards, phase out old vehicles in public transportation, and design network paths of public transportation, such as solutions that significantly contribute to the reduction of these pollutants' emissions. As such, air pollution, caused by gas stations, can be controlled.

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