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Original Article

Estimation of the Increase in Cancer Cases Due to Exposure to Benzene and Ethylbenzene in Air Pollution Scenarios

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Abstract

Background: Air pollution, especially in large cities, is one of the most pressing environmental challenges and is linked to numerous diseases, including cancer. The aim of this study was to estimate additional cancer cases caused by exposure to benzene and ethylbenzene in Tehran.

Methods: The data of benzene and ethylbenzene concentration in a three-year period were obtained from the Tehran Meteorological Organization. Carcinogenic risk was calculated based on chronic daily intake (CDI) value. Also, the impact of air pollution control scenarios on risk reduction was estimated using the same approach.

Results: The average three-year concentrations of benzene and ethylbenzene were 1.87 ppb and 3.75 ppb, respectively. Under these conditions, the combined carcinogenic risk attributed to these pollutants was 3.76×10^{-5}. Depending on the control scenario, risk reduction ranged from 28% to 72%. To decrease carcinogenic risk below 1×10^{-6}, benzene and ethylbenzene concentrations would need to be reduced to 0.121 ppb and 0.206 ppb, respectively.

Conclusion: To reduce the excess cases of cancer attributed to benzene and ethylbenzene, it is necessary to improve gasoline quality, use modern vehicles, and reduce fossil fuel consumption by changes in urban travel patterns.

Keywords: Carcinogenic risk, Volatile Organic Compounds, Ambient air

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Introduction

Economic development and industrial growth in recent decades, accelerated by globalization, have increased the emission of various air pollutants, including volatile organic compounds (VOCs).[1,2] This issue is more severe in developing countries due to the rapid expansion of polluting industries and limitations in pollution control technologies.[3] For example, China's VOC emissions were reported at over 28 million tons in 2017, and based on current industrial trends, a 30% increase is projected by 2030.[4] Among VOCs, benzene and ethylbenzene are particularly significant due to their strong links to fossil fuel consumption.[5]

Exposure to more pollutants due to the increase in emission sources and also phenomena such as climate change that have led to an increase in the emission of pollutants such as particulate matter is one of the important health risks.[6] In many large cities, the severity of health consequences from air pollution is worsened by meteorological conditions like thermal inversion, which trap pollutants and increase exposure.[7] As a major health threat, air pollution is now a leading cause of various diseases, including cardiovascular and respiratory illnesses, as well as cancer.[8] The associated morbidity and mortality depend on several factors, with pollutant concentration and type being the most critical.[6] Short-term exposure to certain key pollutants, notably VOCs, can cause damage to organs like the kidneys, mucosal irritation, and central nervous system complications.[9] However, the primary concern regarding pollutants like benzene and ethylbenzene is chronic, long-term exposure, which is linked to asthma, cardiovascular diseases, and cancer.[10]

The primary sources of benzene and ethylbenzene emissions include fossil fuel combustion in motor vehicles, industrial processes, and the evaporation of chemical and petroleum products.[11] Consequently, the rise in vehicle use in recent decades, especially in developing countries and megacities like Tehran, has led to increased ambient concentrations of these compounds.[6] As one of the largest cities in the Middle East, Tehran's significant reliance on motor vehicles has intensified public exposure to benzene

and ethylbenzene.[12] Recent studies indicate that inhaling these pollutants affects the respiratory system, leading to complications such as lung inflammation, asthma, and reduced lung function. Furthermore, exposure is associated with cardiovascular effects like myocardial infarction and heart failure, as well as liver toxicity and dysfunction of the immune and nervous systems.[13] Although several studies in recent years have measured VOC concentrations in Tehran and evaluated their public health impacts, the cancer risk specifically associated with these pollutants and the predicted change in risk under future air pollution control scenarios have not been fully considered. Therefore, the aims of this study are to assess the current health risks associated with exposure to benzene and ethylbenzene and to project how these risks would change under various air pollution control scenarios compared to current conditions.

Materials and Methods

Study area

This study was conducted in Tehran, Iran. Tehran is the second most populous city in the Middle East and the 34th most populous city in the world, where nine million people live.[14] Also, three million additional people enter this city daily from neighboring cities and other parts of the country, which contribute to the noticeable traffic of this city. According to official data, there is one car for every two people in Tehran. Therefore, an important part of the air pollution in this city is caused by motor vehicles, including motorcycles, taxis, buses, and private cars, which was estimated up to 70%.[6] Moreover, there are many active industries in a radius of 40 kilometers around Tehran, which have a significant impact on the air pollution of this city.[6]

Data collection

The concentration of benzene and ethylbenzene in the ambient air of Tehran in 2019-2021 was obtained from the recorded official data by Tehran's Air Pollution Control and Monitoring Company. The collected data were analyzed and considered based on the annual average in the next steps.

Scenarios

The first scenario included the current conditions. However, the next scenarios based on implementation plans and policies that can lead to a reduction in the concentration of benzene and ethylbenzene were identified and the health risk reduction caused by them compared to the current conditions was evaluated. The second scenario included the development of public transportation in the city in a way that could reduce traffic by 40%. Therefore, in the second scenario, a reduction in benzene and ethylbenzene concentrations resulting from a 40% reduction in emissions from mobile sources was estimated and its health risk was assessed. In the third scenario, a 50% reduction in pollutant emissions from stationary sources (residential, commercial, and office buildings) was assumed by developing energy-saving methods and improving fuel quality. The fourth scenario considered a combination of the approaches of the second and third scenarios. In this scenario, a 30% reduction in pollutant emissions from mobile sources and a 60% reduction in pollutant emissions from stationary sources were assumed.

Risk assessment

The carcinogenic risk of exposure to benzene and ethylbenzene was assessed by determining Chronic Daily Intake (CDI) and Lifetime Carcinogenic Risk (LCR). First, the CDI was calculated using formula 1. This index indicates individual exposure to benzene and ethylbenzene. After calculating the CDI, LCR was calculated using formula 2. The parameters of the used formulas are shown in Table 1. The carcinogenic risk of exposure to each of the studied pollutants was assessed and compared for all scenarios equations 1-3.

$$\mathrm{CDI} = \mathrm{C} \times \mathrm{ED} \times \mathrm{EF} \times \mathrm{ET} / \mathrm{AT} \quad (1)$$

$$AT = (365 \times LT) \quad (2)$$

$$LCR = CDI \times SF \quad (3)$$

Results and Discussion

The annual average concentration of benzene and ethylbenzene in Tehran has been shown in Figure 1.

The results indicate that the concentration changes over the study years did not follow a consistent trend, although the differences among years were not statistically significant. The average benzene concentration during the study period was 1.87 ppb, while that of ethylbenzene was 3.75 ppb. Given the similar fossil fuel consumption patterns and fuel quality across the three years, the slight variations in concentration observed in this study may be attributed to environmental factors. In addition to the number of emission sources and their emission intensities, meteorological conditions—such as wind speed and temperature—also influence air pollutant concentrations.[15] These factors affect pollutant dispersion through vertical and horizontal air movements.[6]

Table 1. Detail of parameters in used formulas.[14]

Parameter	Definition	Unit
C	Pollutant concentration	μg/m^3
CDI	Chronic Daily Intake	μg
EF	Exposure frequency	days per year
ED	Exposure duration	year
ET	Exposure time	hours per day
AT	Averaging time (exposure duration)	days per year
LT	Life time	in years (70 years)
SF	Cancer slope factor	-
LCR	Lifetime Carcinogenic Risk	-

However, as shown in Figure 2, the variations in average wind speed and temperature during the study period were minimal. The temporal variations in wind speed and air temperature were 23 and 8.7%, respectively.

However, the geographical characteristics of Tehran, which is surrounded by the slopes of the Alborz mountain range and is limited to the desert from the south, can be effective in the accumulation of pollutants on some days.[16] During cold periods, when temperature inversions occur, stagnant air conditions trap pollutants—including VOCs such as benzene and ethylbenzene—near the ground surface.[8, 11] Therefore, the slight variations in pollutant concentrations observed in this study may be attributed to these meteorological and topographical factors. Nevertheless, the overall concentrations of benzene and ethylbenzene were relatively high, mainly due to heavy traffic and intensive fossil fuel consumption from stationary sources in Tehran.[17] The low price of fuel in Iran, resulting from government subsidies, has encouraged the excessive use of private vehicles and reduced reliance on public transportation. Moreover, the high per capita fuel consumption of vehicles in Tehran significantly contributes to benzene and ethylbenzene emissions. In addition, inefficient energy use in buildings and industries, caused by outdated technologies and poor design, has further increased fossil fuel consumption. Under these circumstances, the concentrations detected in this study can be reasonably explained.

Exposure to the detected concentrations of benzene and ethylbenzene can lead to adverse health effects, including cancer.[18] Table 2 presents the results of the carcinogenic risk assessment for exposure to these compounds in Tehran under different scenarios. The results indicate that under current conditions, exposure to benzene and ethylbenzene corresponds to an LCR value of 3.76×10^{-5}, meaning approximately 3.76 additional cancer cases per 100,000 residents of Tehran can be expected. This value substantially exceeds the acceptable risk threshold of 1×10^{-6}.

Among the proposed scenarios, the lowest carcinogenic risk was observed in Scenario 4. Compared with the current condition (Scenario 1), the carcinogenic risk decreased by 28, 15, and 72% in Scenarios 2, 3, and 4, respectively.

Previous studies on the health risk of exposure to volatile organic carbons such as benzene and ethylbenzene focused on indoor air. For example, the risk of lung cancer for restaurant workers due to exposure to volatile organic carbons was reported by 3.4×10^{-8} and 1.1×10^{-5}, which was much higher than the assessed risk in our work.[18, 19] This difference is due to the much higher concentration of these pollutants in indoor air caused

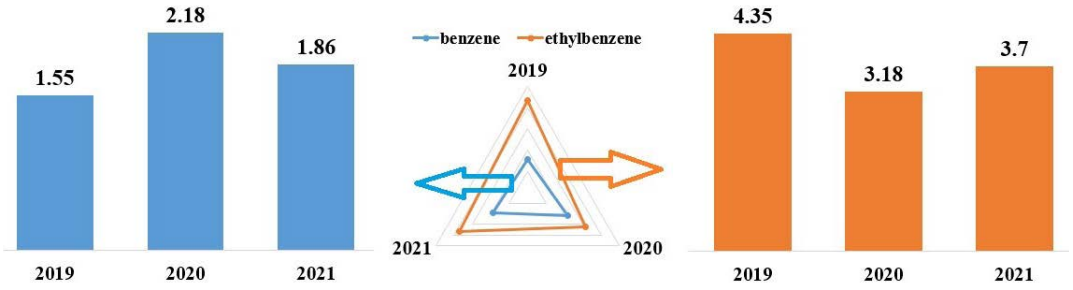

Figure 1. Concentration of benzene and ethylbenzene in the ambient air of Tehran (ppb)

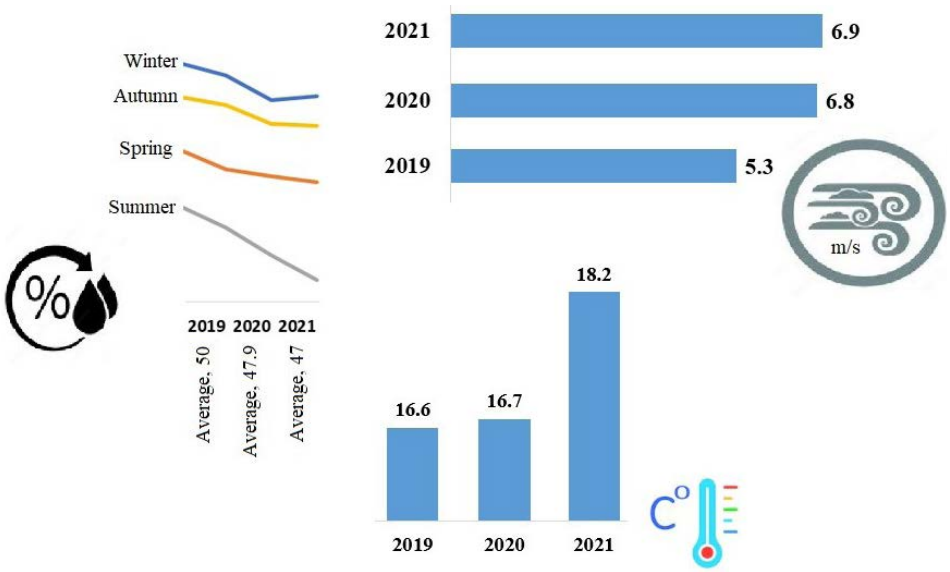

Figure 2. Climatic conditions of the study area

Table 2. Pollutant concentration and estimated carcinogenic risk in the studied scenarios

		Benzene	Ethylbenzene	Total
S1*	C*	7.156	16.282	23.438
	LCR	2.40E-05	1.36E-05	3.76E-05
S2	C	5.152	11.723	16.876
	LCR	1.72E-05	9.81E-06	2.71E-05
S3	C	6.083	13.840	19.923
	LCR	2.04E-05	1.15E-05	3.20E-05
S4	C	2.003	4.559	6.562
	LCR	6.72E-06	3.81E-06	1.05E-05

* S: Scenarios, C: Concentration (μg/m^3)

by cooking and heating devices compared to ambient air. Therefore, the comparison of reported carcinogenic risk in different studies should be based on the pollutant concentration in different environments. In addition to the indoor environment, especially restaurants, where the concentration of volatile organic carbons has been reported up to 1900 μg/m^3.[14], some urban areas will have a higher risk due to the release of oil vapors. For example, around gas stations, the concentration of VOCs is higher. The concentration of volatile organic carbons around gas stations in Iran has been reported as 5.1 μg/m^3 to 20,500 μg/m^3, which were often in the range of 300-1900 μg/m^3.[14,20]

The results of this study showed that in the current situation, according to the population of Tehran, there are 338 additional cases of cancer caused by inhalation of benzene and ethylbenzene. In this situation, it is possible to reduce the emission of benzene and ethylbenzene by improving fuel quality, improving technology in industries and motor vehicles, and paying attention to energy saving criteria. This plan, as evaluated in the fourth scenario, can reduce the additional cases of cancer caused by inhalation of benzene and ethylbenzene to 95. In addition to reducing the carcinogenic risk, this program can lead to the reduction of non-carcinogenic risk that has been reported in previous studies.[12] Given the changes in health risk observed across the evaluated scenarios, expanding urban transport capacity and promoting public transportation use are strongly recommended. Furthermore, the adoption of pollution-control technologies in vehicles, reduction in fossil fuel consumption, and transition toward renewable energy sources such as solar power can effectively reduce benzene and ethylbenzene emissions.

Conclusion

This study investigated the concentrations of benzene and ethylbenzene in the ambient air of Tehran and assessed the carcinogenic risks associated with their inhalation. The results showed that the average concentrations of benzene and ethylbenzene were 7.15 μg/m^3 and 16.28 μg/m^3, respectively. Under these conditions, the corresponding carcinogenic risks were 2.40×10^{-5} and 1.36×10^{-5}, indicating approximately 3.7 additional cancer cases per 100,000 people. Based on Tehran's population, this translates to an estimated 338 additional cancer cases attributable to exposure to these pollutants. Given the noticeable contribution of fossil fuel combustion from motor vehicles and stationary sources, including industries and residential buildings, improving fuel quality, upgrading vehicular and industrial technologies, and optimizing fuel consumption can effectively reduce this risk. The evaluation of three control scenarios demonstrated that, in the most effective case, the carcinogenic risk associated with benzene and ethylbenzene inhalation could be reduced by up to 72%. Therefore, the implementation of comprehensive emission control programs targeting VOCs, particularly benzene and ethylbenzene, is essential to minimize their environmental impact and protect public health.

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Authors' Contribution

Conceptualization: Leila Motaghi, Nabiollah Mansouri.
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Formal analysis: Leila Motaghi.
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Software: Leila Motaghi.
Supervision: Nabiollah Mansouri.
Validation: Leila Motaghi, Farideh Atabi.
Visualization: Leila Motaghi, Mohammad Hassan Vahidnia.
Writing–original draft: Leila Motaghi, Nabiollah Mansouri, Farideh Atabi, Mohammad Hassan Vahidnia.
Writing–review & editing: Leila Motaghi, Nabiollah Mansouri, Farideh Atabi, Mohammad Hassan Vahidnia.

Competing Interests

The author declares no conflict of interest.

Ethical Approval

There were no ethical considerations to be considered in this research.

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