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Risk Assessment of Exposure to 1,3-Butadiene in Possible Air Pollution Control Scenarios in Tehran Using Monte Carlo Simulation

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Abstract

Background: Exposure to 1,3-butadiene leads to an increase in the carcinogenic risk and other related diseases. This study aimed to assess the carcinogenic and health risks of exposure to ambient 1,3-butadiene emitted from various sources in Tehran.

Methods: For this purpose, sampling and data analysis were done in 30 monitoring stations in Tehran in 2024. In addition, the contribution of motor vehicles to the emission of 1,3-butadiene was estimated by IVE and AERMOD. Also, the Carcinogenic Risk (CI) index and Health Quotient (HQ) were used to evaluate carcinogenic and non-carcinogenic risk affected by the current concentration and four other scenarios.

Results: The results showed that the average of 1,3-butadiene concentration caused by motor vehicles and stationary sources was calculated to be equal to 2.1E+1 and 7.86E+1 μg/m³, respectively. The detected concentration was 4 times higher than the estimated concentration, indicating a significant concentration of contamination. In the best scenario, the pollutant concentration was reduced by 48%. The carcinogenic risk in the current conditions and the best scenario was 7.48E-03 and 4.06E-03, respectively, which were still much higher than the acceptable level.

Conclusion: Scenarios of reducing the pollutant concentration made the non-carcinogenic risk for adults below the acceptable level. Therefore, modifying fuel consumption patterns, reducing fossil fuel consumption by implementing energy-saving measures in buildings and supporting the increase in electric vehicles, and monitoring air pollution control systems in industries are the main suggestions of this study to reduce the health risks of 1,3-butadiene.

Keywords: Health risk, Fossil fuel, Environmental pollutants, 1,3-butadiene, Carcinogens

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Introduction

Economic development in recent decades has led to an increase in polluting sources (1). The growth of industries and the diversity of productions, as well as the increase in sources of fossil fuel consumption in cities, are among the most important polluting sources caused by economic growth (2). Pollutants from different sources are released in different forms, including solid waste, wastewater, and air pollution (3,4). Pollutants released from these sources can be known as a threat to the environment and health due to the toxicity, carcinogenicity, and the presence of biological agents (5-7). Air pollution is one of these mentioned sources that can affect the health of citizens (8,9).

Exposure to air pollution can lead to various diseases depending on various factors, including pollutant concentration, duration of exposure, individual sensitivity, and individual factors such as age (10,11). For example, chronic lung disease and heart disease are among the most important diseases associated with air pollution (12). In addition, the carcinogenicity of some air pollutants leads to an increased risk of cancer in citizens, examples of which have been reported in numerous previous studies (13). Also, the association of diseases such as osteoporosis due to secondary consequences of exposure to air pollution has been reported (1). Therefore, in recent decades, significant studies have been conducted on the identification of air pollutants, assessment of pollutant concentrations, health risks associated with pollutant exposure, and air pollution control strategies. However, citizens' exposure to pollution concentrations higher than health standards is still one of the health challenges in developing countries (2).

The sources of air pollution generally include stationary sources such as industries, as well as mobile sources (2). The type and quantity of air pollutants depend on local factors such as the type of polluting sources and also climatic factors (8). For example, in big cities in developing countries, the majority of air pollutants are caused by cars and transportation (14). However, in arid and semi-arid regions, the activity of dust sources is known as one of the main sources of particulate matters, and in recent years, their activity has intensified in some regions such as the Middle East (2,15). Therefore, in order to control air pollution and reduce the resulting health consequences, it is necessary to know the polluting sources and the types of pollutants released from each source.

Volatile organic compounds (VOCs) are one of the most important types of air pollutants, which are emitted from a wide variety of natural and anthropogenic sources (16). VOCs include a large variety of species, such as oxygenated VOCs (OVOCs), chlorinated VOCs, and aromatic hydrocarbons, including benzene, toluene, ethylbenzene, and xylene (17). The main anthropogenic sources of VOCs include vehicle emissions, combustion, industrial emissions, fuel evaporation, and solvent usage (18). 1,3-butadiene is one of the types of VOCs that are emitted into the atmosphere from these sources. In addition to emissions from vehicles, the widespread use of 1,3-butadiene in various industries, such as rubber and plastic, has led to the possibility of the presence of this pollutant in the atmosphere of large and industrial cities (19).

Exposure to 1,3-butadiene is effective in cardiovascular diseases and is related to some cancers (20). However, the health consequences of this pollutant, like other air pollutants, are dependent on exposure time, pollutant concentration, and individual characteristics (21). Therefore, the factors affecting the concentration of 1,3-butadiene in the atmosphere are directly effective in the resulting health consequences. Although previous studies have reported numerous health risks of exposure to air pollution in Tehran (22), the risk of exposure to 1,3-butadiene in Tehran air remains a knowledge gap. The main question of this study included spatial and temporal variations in the concentration of this pollutant in Tehran and the health and carcinogenic risks associated with exposure to it. This study aimed to investigate the concentration of butadiene in ambient air, determine the contribution of mobile and stationary sources, and assess the health and carcinogenic risks resulting from exposure to this pollutant in current conditions and in air pollution control scenarios.

Methods and Materials

Study area

This study was conducted in one of the areas of Tehran. Tehran is the largest city in Iran with a population of nine million (2). Tehran is a city with a diverse climate that is located on the southern slopes of the Alborz Mountain range and continues to the desert in the south. In the past decades, the population of Tehran has increased due to population growth in the country as well as migration. Tehran constitutes 21% of Iran's gross domestic product. Tehran has 22 districts, and this study was conducted in District 9 with a population of 174,000 people. This district was located in the west of Tehran, and there was a different distribution of highways, streets, commercial areas, and residential areas.

Sampling

One of the aims of this study was to investigate the difference in 1,3-butadiene concentration in different land uses. Based on this, the sampling points were classified into commercial land-use, residential land-use, and urban routes. According to the difference of urban routes that included highways and streets, finally, the sample points were classified into four groups, including commercial areas, residential areas, highways, and streets. From each classification of residential areas and commercial areas, seven points and from each highway and street classification, eight points were defined for sampling. In total, sampling was done at 30 points of the study area. These points were located in 13 locations, which are: Jadde makhsous (H1), Fatah Highway (H2), Azadi Square (S1), Zarand (R1), Mehrabad Airport (C1), Azadi Street (S2), Ostad Moin (S3), Hashemi (C2), Dampezeshki (C3), Ayatollah Saidi (H3), Nuri Niarki (R2), Yadegare Emam Highway (H4), and Bakhtiari (R3).

Analysis and estimation

The concentration of 1,3-butadiene was measured by NOISH 1024. Based on this method, sampling was done using the SKC pump at a flow rate of 500 ml/min for 50 minutes. In this method, activated carbon adsorbent (226-09) made by SKC was used. The samples were transferred to the laboratory in less than 1 hour to determine the concentration of 1,3-butadiene by GC. The estimation of 1,3-butadiene emissions from vehicles in the studied land-uses was done according to variables including vehicle speed, ratio of types of vehicles, climatic conditions, and fuel quality using IVE software. The results of estimating the concentration of 1,3-butadiene emission by IVE were used to estimate the concentration of this pollutant in the ambient air using AERMOD software.

Scenarios

Reduction of the exposure to 1,3-butadiene and controlling the health risk caused by it was analyzed in 5 scenarios. The first scenario consisted of the continuation of the current conditions, which included the detected concentration and the estimated concentration. As shown in Table 1,

Table 1. Conditions and scenarios

		Description
Conditions	C1	The emissions from motor vehicles and the total concentration of pollutants in the ambient air remain constant, equal to the estimated and detected values.
	C2	Pollutant emissions were reduced by modifying the fossil fuel consumption pattern compared to the estimated and detected values.
	C3	Pollutant emissions were reduced by improving the fossil fuel quality standard compared to the estimated and detected values.
	C4	Pollutant emissions using the energy-saving activities compared to the estimated and detected values
Scenarios	S1	All buildings and motor vehicles are assumed in C1.
	S2	Reduction of emissions from mobile sources by 40% by applying C2 and C3.
	S3	Reduction of emissions from stationary sources by 30% by applying C3 and C4.
	S4	Reduction of emissions from mobile sources by 60% by applying C2 and C3. Also, a reduction of emissions from stationary sources by 25% by applying C3 and C4.
	S5	Reduction of emissions from mobile sources by 30% by applying C2 and C3. Also, a reduction of emissions from stationary sources by 50% by applying C3 and C4.

in the second scenario, managing fuel consumption and improving the quality of cars for reducing emissions from this source were the main priorities. In the third scenario, the main priority was to optimize fuel consumption in buildings. The fourth scenario included a combination of the second and third scenarios with a higher tendency to control pollutant emissions from cars. The fifth scenario included a combination of the second and third scenarios, with a higher tendency to control pollutant emission from buildings.

Risk assessment

In this study, the carcinogenic and non-carcinogenic risk of exposure to 1,3-butadiene was assessed for current conditions and scenarios based on the EPA method (19). For this purpose, the carcinogenic risk (CR) index was used, which was calculated based on the parameters described in Table 2. Formula 1 was used to calculate CR (23). As shown in Table 2, SF was equal to 0.6 (19), and CDI was calculated based on formula 2 (19,24). Finally, according to the calculated CR and based on an acceptable carcinogenic risk, which in this study was equal to 1×10^{-6} based on the EPA guideline (25), the situation of the studied scenarios was interpreted.

$$CR = CDI \times SF \quad (1)$$

$$CDI = C \times IR \times ED \times EF / BW \times AT \quad (2)$$

In this study, the non-carcinogenic risk was assessed using formula 3 to calculate the health quotient (19). Health quotient (HQ) is an index based on exposure concentration and reference concentration. The exposure concentration shown in the formula with EC was calculated using formula 4. If the HQ is equal to or greater than 1, it indicates an unacceptable non-carcinogenic risk (19,26).

$$HQ = EC / RfC \quad (3)$$

$$EC = \left(C \times ET \times ED \times EF\right) / AT \quad (4)$$

Table 2. Description of variables in formulas 1-5 (19).

EC	Exposure concentration (μg m^{-3})	Calculate by formula
CR	Cancerogenic Risk	Calculate by formula
CDI	Chronic Daily Intake (mg kg^{-1} day^{-1})	Calculate by formula
SF	Slope factor (mg kg^{-1} day^{-1}) $^{-1}$	0.6
C	Concentration of pollutant (mg m^{-3})	Estimated in scenarios
IR	Inhalation rate (m^3 day^{-1})	1.812
ET	Exposure time (hr day^{-1})	3
ED	Exposure duration (years)	70
EF	Exposure frequency (day $year^{-1}$)	365
BW	Body weight (kg)	70
AT	Average exposure time (ED × 365 days $year^{-1}$)	18980
HQ	Hazard quotient	Calculate by formula
RfC	Chronic inhalation reference concentration (mg m^{-3})	0.002

The health risk of exposure to 1,3-butadiene concentration was calculated using the Monte Carlo simulation method. The factors considered as variables in this simulation included those listed in Table 2. The distribution of variables with a range, including pollutant concentration, was log-normal. The Monte Carlo simulation was performed with 1000 interactions.

Results

Pollutant concentration

The results of the 1,3-butadiene measurement at the sampling points are shown in Table 3. The results showed that 1,3-butadiene concentration in the studied district had temporal and spatial variation. However, spatial variation was more than temporal variation. For example, the measurement results in the autumn showed that the lowest concentration was 22 ppb and the highest concentration was 86 ppb, which had a difference of about 290%. But the temporal in different seasons at sampling points 1, 5, and 10 based on the highest and lowest concentrations were 34.04, 52.17, and 86.2%, respectively. Comparing the results of the sampling points showed that the measured concentrations can be classified into

Table 3. Detected 1,3-butadiene concentration at sampling points (ppb)

Spatial variation	Sampling points (30)			
	Max	**Min**	**Ave**	**SD**
	110	**23**	**45.06**	**15.33**
Temporal variation	Spring		Ave	48.7
			SD	17.57
	Summer		Ave	38.46
			SD	12.33
	Autumn		Ave	47.13
			SD	16.47
	Winter		Ave	45.96
			SD	12.96

Table 4. Estimated concentrations of 1,3-butadiene emitted from vehicles in the studied locations by IVE (ppb)

Sampling location	Autumn	Winter	Spring	Summer
H1	10	11	11	12
H2	8	9	8	9
S1	15	16	15	16
C1	20	21	20	23
R1	13	13	12	14
S2	4	3	5	4
S3	5	6	4	6
C2	5	6	5	6
C3	12	11	14	15
H3	5	5	8	6
R2	20	21	20	22
H4	4	3	3	3
R3	4	4	3	4

seven groups according to Figure 1, where the highest contribution was observed in the concentration range of 30-50 ppb, and the lowest contribution was observed at concentrations of more than 70-80 ppb. Also, the concentration of 1,3-butadiene in highways was on average 14.38 times higher than in residential areas (Table 4).

The results showed that the estimated concentrations by AERMOD and IVE were lower than the measured concentrations in the studied area. Comparing the data of Table 3 with the data of Table 4 shows this difference. As shown in Figure 2, the range of measured concentrations and their ratio was different compared to the range of estimated concentrations and their ratio.

Spatial and temporal variation

The results showed that the maximum concentration of 1,3-butadiene was detected during the autumn in the studied district, with an average of 47.13 ppb. In contrast, the modeling estimated this value at 9.1 ppb. In the computational simulation, winter exhibited the highest concentration by 45.97 ppb, while the modeled figure was 9.4 ppb. The discrepancies for the spring and summer were 38.47 vs. 9.37 ppb and 48.7 vs. 10.23 ppb, respectively. These higher modeled values during the summer can be associated with specific meteorological parameters.

As shown in Figure 3, the estimated distribution of pollutant concentration in the studied area was proportional to the distribution of population density and urban land uses. However, the measured distribution of concentration at the sampling points was different from the estimated distribution.

Pollutant sources and related risk

Based on the results, the average of pollutant concentration caused by motor vehicles and stationary sources was calculated to be equal to 2.1E+1 and 7.86E+1 μg/m^3, respectively. As shown in Figure 4, the largest reduction in pollutant emission compared to the current situation was observed in the fifth scenario, which provides 45.78% less emission. While in the second scenario, the reduction of pollutant emissions compared to the current situation was only 8.4%. The change of 1,3-butadiene emission in the studied scenarios showed that the main focus in controlling this pollutant should be on stationary sources. The details of health risk reduction due to the studied scenarios are shown in Table 5.

Although the results showed that in the studied scenarios, carcinogenic risk and non-carcinogenic risk decreased compared to the current conditions in proportion to the decrease in pollutant concentration, in all scenarios, the carcinogenic risk was higher than the acceptable carcinogenic risk (Figure 5).

Discussion

According to the observed variation of 1,3-butadiene concentration in the sampling points, there is a possibility of different emission sources in the studied district. The emission sources of this pollutant include the combustion process and emissions from industries (27). Therefore, the change in the number of sources in each location can be effective in the difference in observed concentration. In addition, 1,3-butadiene is a highly reactive volatile organic compound that can quickly react with other air pollutants, especially in the presence of sunlight, to form secondary pollutants (28). These reactions can be an effective factor in the observed concentration. However, considering that in this study, sampling was done every day at three times, including 7-10, 10-14, and 14-18, the effect of photochemical reactions on the results was controlled. Therefore, the effective factor in the spatial variation of 1,3-butadiene concentration in the studied district was the difference in the number of sources and the intensity of their activity.

Although the rubber and plastic industries are among the most important sources of 1,3-butadiene emission,

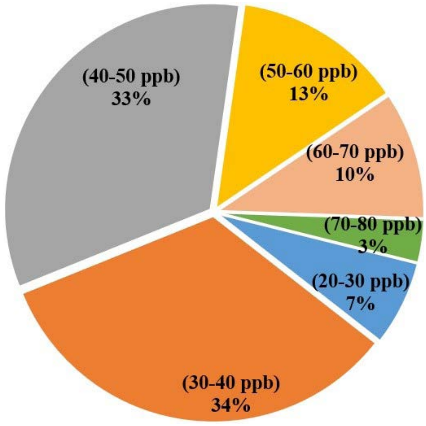

Figure 1. Distribution of the detected concentration of 1,3-butadiene in sampling points

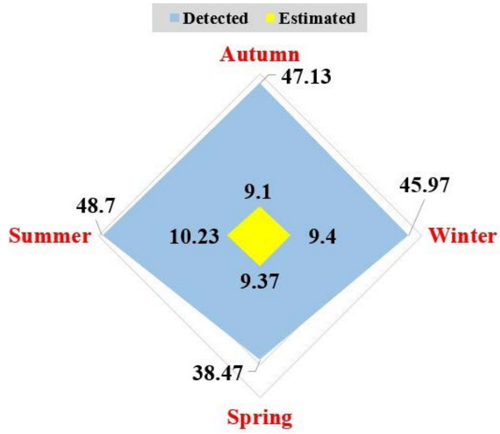

Figure 2. Comparison of the detected concentration with the estimated concentration in the studied area (ppb)

in big cities, the effect of vehicles on the concentration of this pollutant is significant (29). The concentration of 1,3-butadiene in the studied area was affected by some industries, but the ratio of observed spatial variation was very impressive, which was probably caused by other sources. The high density of cars on the highways and streets of Tehran is one of the reasons for air pollution in this city (30), which is also the most important source of 1,3-butadiene emission. Therefore, the possibility of higher concentrations of vehicle-related pollutants, including 1,3-butadiene, is higher in high traffic routes and highways than in streets. This effect was evident in the variation of the detected concentration in different land uses. In general, land-use is an effective factor in the quantity of pollution in the urban environment, the example of which has been proven in the case of urban litter (6). However, this effect on air pollution is due to the increase of pollutants in the distances close to the highways and also around sources of pollutant emission, such as gas stations (1).

Therefore, citizens' exposure to 1,3-butadiene is dependent on spatial variation in its concentration. In general, longer exposure to higher pollutant concentrations can have more severe health consequences (31). For example, longer exposure to higher concentrations of particulate matter was reported as an effective factor in increasing the risk of osteoporosis (1). Exposure to measured 1,3-butadiene in the studied area can have health consequences for citizens (21). These effects depend on the characteristics of this pollutant and the exposure time (32). Health damage can be acute, resulting from exposure to high pollutant concentrations, or chronic, as a result of prolonged exposure to low 1,3-butadiene concentrations. Chronic damage is of increasing concern, affecting millions globally and having significant health consequences because 1,3-butadiene is defined as Group 1 carcinogen, according to the International Agency for Research on Cancer (33), as its reactive metabolites can bind to DNA, leading to cancers such as haematolymphatic cancer (34,35). Therefore, more exposure to measured concentrations or being in locations with higher concentrations of 1,3-butadiene can be a factor in increasing health risk. For example, Ariyasiri et al found that traffic police and drivers have higher exposures to 1,3-butadiene compared to their peers in centers and offices (36). Furthermore, Lavogl and Yoshizumi (2009) observed that 1,3-butadiene concentrations were higher at night and on roads than in other parts of Tokyo city (37).

Estimating the concentration of air pollutants and the exposure time to them is a necessity in planning to reduce the subsequent health consequences (1,2). However, accuracy in monitoring the factors affecting the concentration of pollutants can be effective in the correct estimation and achieving the goals of air pollution control (2). For converting the ppb to μgr/m^3, variables such as temperature, humidity, and atmospheric pressure are effective. In addition, the increased temperature within the district is known as an additional explanation for the high concentration of 1,3-butadiene (28). The variation between the modeled results and the measured concentration might be due to the industries in the district, the fuel combustion in apartments, the accumulation of pollutants from vehicles intensified by tall structures, and insufficient air movement (38). For this reason and considering the climatic factors and the difference in the number and activity of 1,3-butadiene emission sources, it is expected that the concentration of this pollutant is higher in the center of the studied area.

Although climatic factors such as temperature and humidity, as well as equipment factors such as technical standards in industries and cars, are effective in the emission and concentration of pollutants (39,40), the difference between the measured concentration and the estimated concentration in the studied area indicates there were unaccounted factors in the estimation of 1,3-butadiene concentration. For example, considering the impact of pollutant emissions from vehicles on air

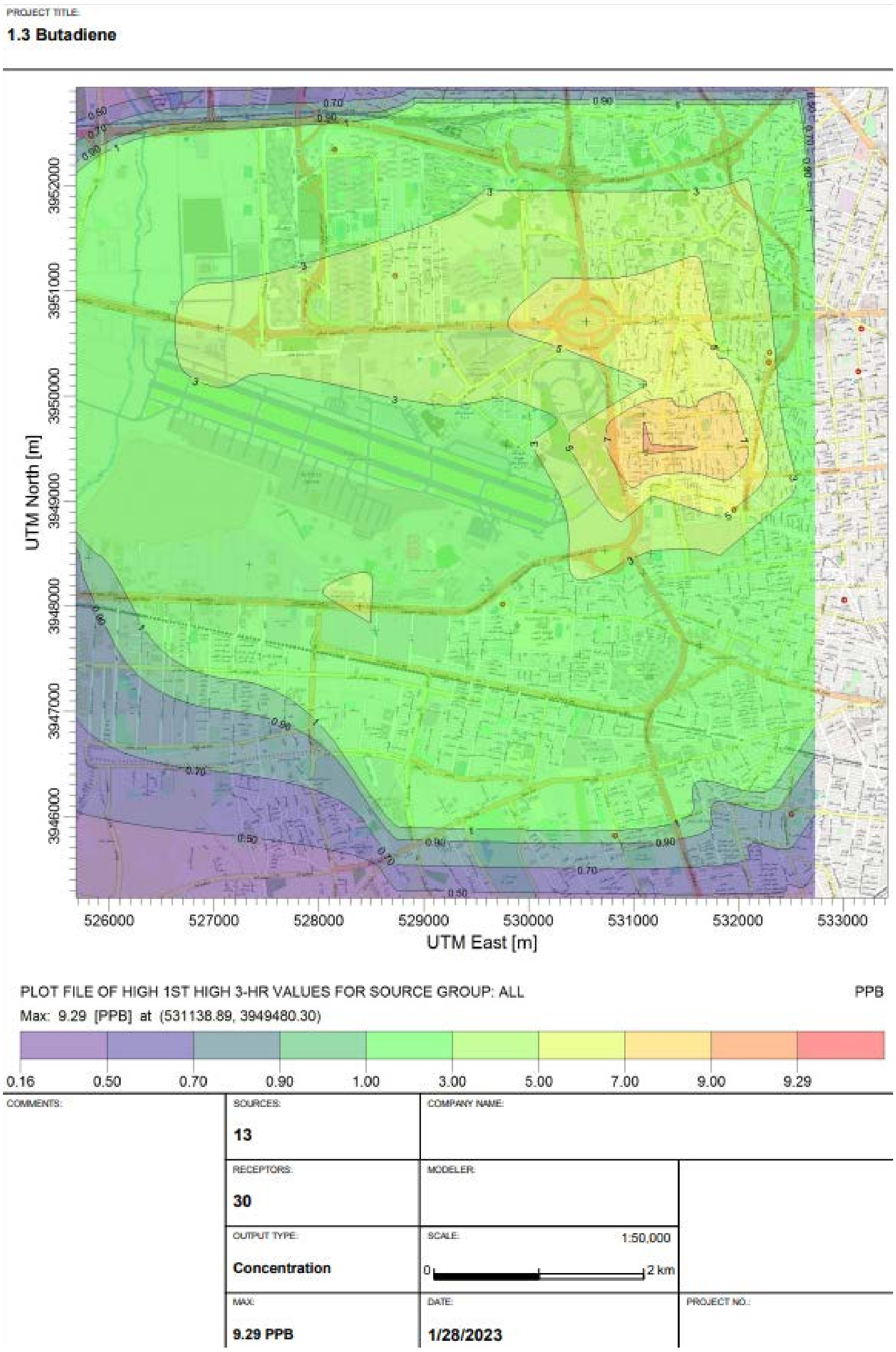

Figure 3. Estimated emission of 1,3-butadiene for the summer in the studied district

pollution (14), heavy traffic on the highways of the studied area can be an unaccounted factor in the estimation of 1,3-butadiene concentration. Also, the hourly variation in the speed of cars in the streets and highways of the studied area, which was affected by the traffic in Tehran, is one of the factors that can be known as an effective factor in the variation of the measured concentration and its difference with the estimated concentration. These variables were caused by the change in population density in different urban land uses. The impact of urban land-use on changes in population density and related pollution has been proven (41). Therefore, in commercial land uses where the density of population and traffic is higher, there is a possibility of increasing the emission of various pollutants, including 1,3-butadiene. In addition, considering the impact of fuel combustion in buildings for different purposes, such as heating, on the emission of pollutants (1), the impact of the distribution of residential, administrative, and commercial buildings was an unaccounted factor in the estimated concentrations. The effect of reducing the quality of fuel, as well as reducing the quality of cars, can also be considered

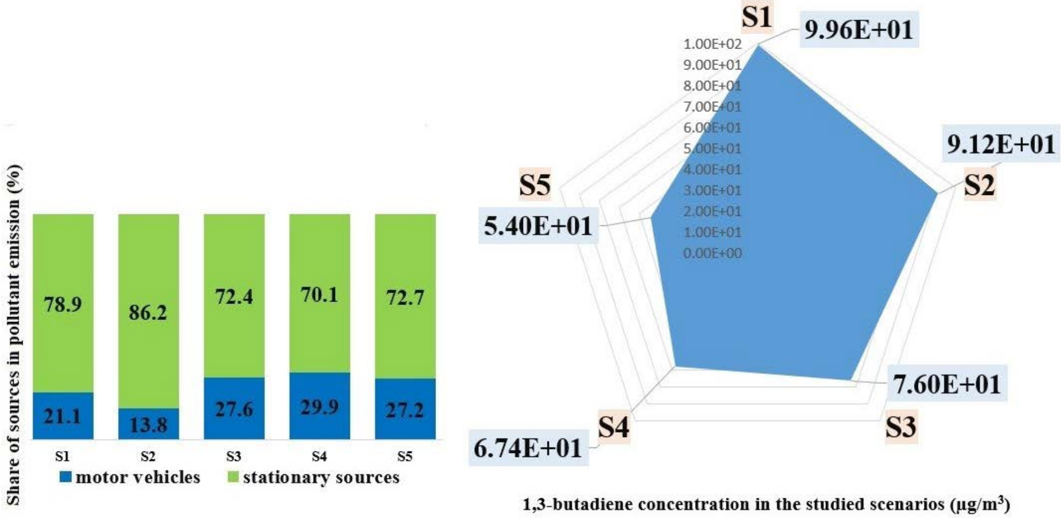

Figure 4. Details of the concentration of 1,3-butadiene in the studied scenarios

Table 5. The results of the risk assessment

		Scenarios				
		S1	S2	S3	S4	S5
Concentration of 1,3-butadiene (µg/m³)		9.96E+01	9.12E+01	7.60E+01	6.74E+01	5.40E+01
	Mean	7.48E-03	6.94E-03	5.28E-03	4.91E-03	4.06E-03
CR	Max	10.5E-03	9.88E-03	8.74E-03	8.08E-03	7.07E-03
	Min	5.55E-03	5.34E-03	4.95E-03	4.73E-03	4.38E-03
	Mean	8.4E+00	7.70E+00	6.75E+00	5.61E+00	4.55E+00
HQ	Max	1.29E+01	11.6E+00	10.3E+00	1.14E+01	7.90E+00
	Min	5.70E+00	5.38E+00	4.82E+00	4.50E+00	3.70E+00

as another unaccounted factor. The low quality of fuel and depreciation of cars can lead to an increase in the emission of pollutants. Therefore, in developing countries, the impact of the economic situation on the use of low-quality fuel, worn-out cars, or those lacking up-to-date standards can be an important factor in increasing the concentration of pollutants, which, if ignored, causes a reduction in estimated concentration compared to the measured concentration.

Although in the case of some types of air pollutants, such as $PM_{2.5}$, the share of motor vehicles is much higher, and it has been reported up to 70% in Iran (2), however, in the current situation, only 21% of 1,3-butadiene emissions are related to motor vehicles. For this reason, in the fifth scenario, despite the increase in the share of motor vehicles up to 27.2%, the total pollutant concentration was almost halved compared to the current situation. Considering the effect of fossil fuel consumption in stationary sources such as buildings and industries on the concentration of air pollutants (2), urban decision-makers should pay more attention to the management of fuel consumption in these areas. In this situation, the improvement of fuel quality can also be effective in reducing the 1,3-butadiene emission from both motor vehicles and stationary sources, as observed in the fourth and fifth scenarios. The activities leading to the reduction of 1,3-butadiene emissions, which were studied in different scenarios, are effective in reducing health risks, including carcinogenic and non-carcinogenic risks.

The acceptable carcinogenic risk based on the EPA guideline is 1 additional case of cancer per one million people (19), while in the current situation, the carcinogenic risk of exposure to 1,3-butadiene in the studied area was 7.4 additional cases of cancer per thousand people. The fifth scenario, as the best scenario in reducing the concentration of 1,3-butadiene, reduced the carcinogenic risk to 4.06 additional cases of cancer per thousand people, which is still higher than the risk. To be in the acceptable carcinogenic risk condition, the concentration of 1,3-butadiene in the ambient air of the studied area should be reduced by 1.8E-05 µg/m³. In other words, 98.9% current concentration of this pollutant should be reduced. In the current conditions, the calculated HQ is 8 times higher than the range of unacceptable non-carcinogenic risk. However, reducing the pollutant concentration in all the studied scenarios was enough to change the situation and move away from the non-carcinogenic risk.

Butadiene is classified by the Agency for Research on Cancer (IARC) in group 1A, which means carcinogenic to humans (26). Therefore, the results of this study

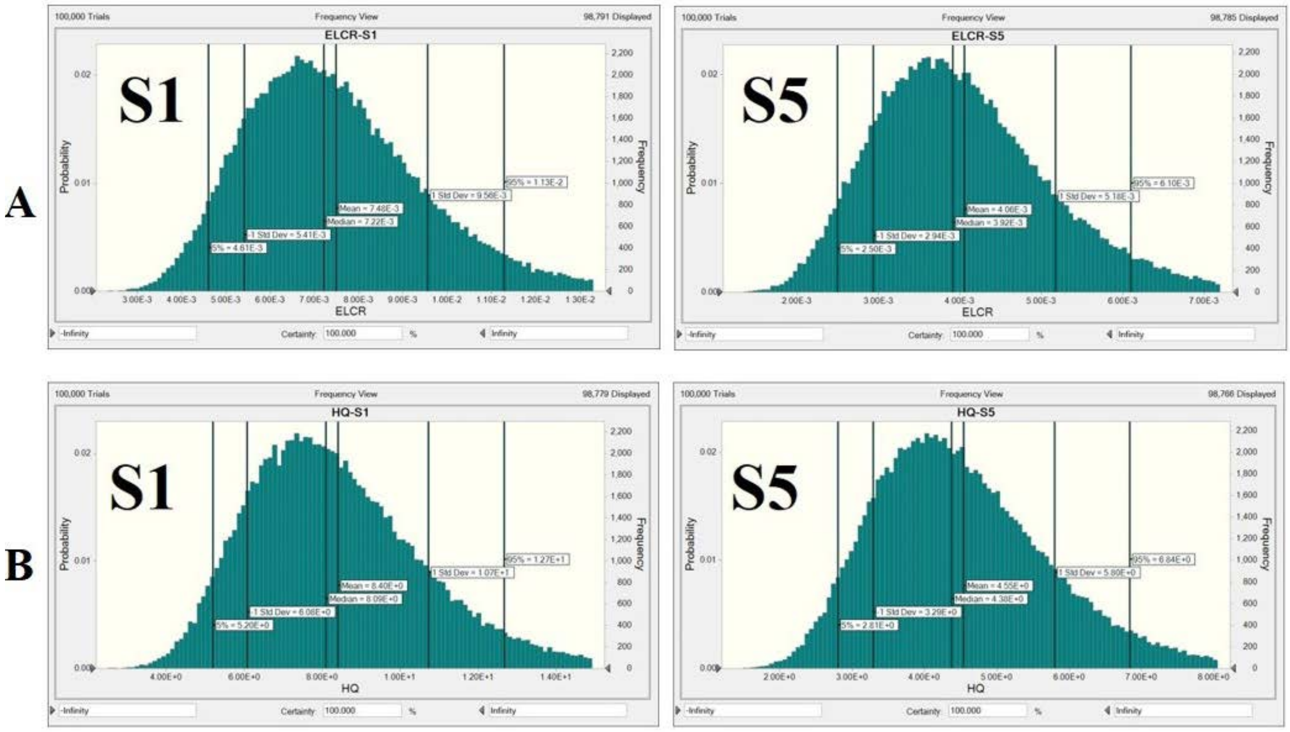

Figure 5. A, Comparison of CR in S1 (current situation) with S5 (best condition), B, Comparison of HQ in S1 (current situation) with S5 (best condition)

indicate the high level of this carcinogenic pollutant in the study area. These conditions are more severe for indoor air in industries and the carcinogenic risk to workers. Khoshakhlagh et al reported that the carcinogenic risk of exposure to 1,3-butadiene in carpet production workers in Tehran was 5.13E-3, which was much higher than the acceptable carcinogenic risk (19). Similar results of carcinogenic risk higher than the acceptable level have been reported in Iran, including in a petrochemical plant (23). These results confirmed the high emission of butadiene from Tehran industries and its effect on the detected concentration in our study. Also, the high concentration of 1,3-butadiene in industries has led to the report of HQ higher than the acceptable level in industries (19,23), which was more severe than the results of our study.

This study also had some strengths and limitations. The assessment of the risk of exposure to a hazardous air pollutant is a strength of this study. The assessment of the impact of different air pollution control scenarios on the concentration of the studied pollutant and its associated risk is another strength of this study. However, the assessment of risk based on demographic and occupational characteristics in the studied city is a limitation of this study that could be considered in future studies.

Conclusion

The concentration of 1,3-butadiene was measured in one of the districts of Tehran in one year at thirty sampling points. The concentration of this pollutant in the same area, considering climatic conditions and emission sources, was estimated by IVE and AERMOD. The results showed that the concentration of 1,3-butadiene in the studied area had significant spatial variation but had minor temporal variation. The lowest measured concentration was 22 ppb, while the highest measured concentration was 110 ppb. The most frequently measured concentration was in the range of 30-50 ppb, which constituted 67% of all annual samples. Hourly traffic variation, the difference in the number of cars and other sources of 1,3-butadiene emission, affected by the difference in land-use, distribution of buildings (commercial, residential, administrative), fuel quality, and quality of cars, are the most important factors that can effectively account for the difference between the estimated concentration compared to the measured concentration. By controlling these conditions, in the best scenario, the 1,3-butadiene concentration will decrease by 48%. However, the carcinogenic risk caused by exposure to this pollutant was 7.48E-03 in the current situation and decreased by 4.06E-03 in the best scenario, which is still much higher than the acceptable level of 1E-06. To control the risk, more than 99% of the 1,3-butadiene concentration should be reduced compared to the current conditions. The current HQ was 8.4E + 00, which was very close to the unacceptable level (≥ 1). However, all scenarios lead to a significant decrease in HQ. Therefore, the following are suggested:

Development of legal, equipment, and cultural factors that can lead to changes in fuel consumption patterns.

Reducing fossil fuel use with energy-saving factors in buildings and replacing gasoline vehicles with electric vehicles.

Monitoring the performance of emission control systems in industries.

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Authors' contributions

Conceptualization: Alireza Haji Mirzahosseini.
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