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Estimation of Benzene from Storage Tanks and Determination of the Permissible Distance from Gas Stations

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ABSTRACT

Benzene is considered a toxic and hazardous pollutant in Tehran metropolis. The storage tanks of petroleum products and refueling in gas stations are among the main sources of benzene emissions. Using the software AERMOD and reviewing the benzene dispersion maps at different distances from 412 storage tanks at 148 gas stations, it was found the permissible distance of the emission source is dependent on various variables such as the number of loading times and the storage capacity. When, storage capacity in the range of 60,000 L to 96,000 L and the number of loading is in the range of 675 to 1328 times a year, the concentration of benzene at a distance of 30 m of the emission source reaches the annual standard of 5 μg/ m^3. While, storage capacity in the range of 80,000 L to 128,000 L and the number of loading is in the range of 1329 to 1834 times a year, the concentration of benzene at a distance of 40 m of the emission source reaches the annual standard of 5 μg/ m^3. Also, based on the analysis of data and the linear regression equation, the permissible distance of the emission source can be predicted.

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INTRODUCTION

Gasoline vapors, including benzene, adversely affect the environment, and large volumes of such emissions cause an increase in the greenhouse gases, which in turn leads to global warming, climate changes, acid rains, chemical reactions, smog, etc. (Tsai, 2016). Due to the high vapor pressure and high volatility, gasoline is easily evaporated, leading to formation of volatile organic compounds (VOCs). VOCs emitted through industrial activities have negative impacts on human health and environment (Srivastava et al., 2005; Tohid et al., 2019; Niu et al., 2016). When decomposed in the atmosphere, VOCs react with nitrogen-containing compounds (NO_X) and form tropospheric ozone (Srivastava et al., 2006; Monod et al., 2001; Burghardt et al., 2016). Ozone is affecting global climate changes and causes damage to the respiratory, nervous and immune systems (Xu et al., 2017).

Gasoline vapors including benzene cause damage to the constructive tissue, genetic mutation, reduced generation of bone marrow cells, severe anemia, and immunodeficiency (Neghab et al., 2015; Okonkwo et al., 2016). Neurological complications caused by benzene inhalation include

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drowsiness, dizziness, headache, anesthesia, and tremor (Merchant-Borna et al., 2012; Correa et al., 2012). Benzene also adversely affects organs including heart, lung, brain, liver, and kidneys (Lan et al., 2004; Owagboriaye et al., 2017). Benzene has been classified by US Environmental Protection Agency as a Group A carcinogen. Benzene has also been introduced as a carcinogen to humans by the International Agency for Research on Cancer (Heibati et al., 2017; Hajizadeh et al., 2018). The Iranian Supreme Council for Environment recommends a standard concentration of 5 μg/ m^3 for benzene.

Researchers modeled benzene emissions using AERMOD (American Meteorological Society/Environmental Protection Agency Regulatory Model) software (Mcgaughey et al., 2009). Investigators Used AERMOD software to study and model concentrations of VOCs emitted from gasoline storage tanks (Ramavandi et al., 2016). Researchers using TANKS 4.0.9d software (US Environmental Protection Agency) investigated the emission of VOCs from gasoline storage tanks (Khosravi & Talaei Khozani, 2019). Investigators modeled atmospheric pollutants emitted from thermal power plants such as CO, NO_X, PM, SO_2, and VOCs with the help of AERMOD (Dos Santos Cerqueira et al., 2019). Researchers evaluated air pollutants produced by vehicles using AERMOD model in a street in the capital of Brazil. The dispersion map showed that the pollutants were mainly concentrated around emission sources. It was also found that mathematical modeling is a useful tool for studying dispersion of atmospheric pollutants (Macêdo & Ramos, 2020). The AERMOD air dispersion model was investigated for its performance in predicting concentration of pollution emitted from petroleum refinery. A set of statistical parameters was employed to evaluate model performance. Results indicated that AERMOD can provide good results (Thepanondh et al., 2016). According investigation above AERMOD is a validated software and it has been previously validated with Researchers.

Different programs are used to calculate emissions from organic liquids stored in petroleum tanks at gas stations. The TANKS 4.0.9d program can estimate VOCs and hazardous pollutants emitted from various types of storage tanks, including horizontal tanks. This software can be used to estimate emissions from tanks during storage and loading operations. The tanks studied of this project are horizontal and release vapors during storage, charge and discharge. Accordingly, in this study, the TANKS 4.09d program was used. The raw input data for this software include tank specifications, location, and the properties of stored liquids (USEPA, 1999). Direct measurement of concentration of pollutants and experimental analysis are usually impossible at all points and times due to topographical conditions and the lack of necessary equipment. Accordingly, the use of air pollution dispersion models can be the simplest and most useful method for monitoring and evaluating the concentration of pollutants and the effect of emission sources on the air quality (Hanna et al., 2007; Gurjar et al., 2010; Truong et al., 2016). As a continuous plume dispersion model, AERMOD software can be applied to rural and urban areas and both flat and uneven terrains. AERMOD is composed of a meteorological pre-processor called AERMET and a geological pre-processor known as AERMAP (USEPA, 2018).

Due to the high concentration of benzene in the air of Tehran (Atabi et al., 2013) and health problems and the destructive effects of benzene on the environment have caused, in this study attempts were made for the first time to evaluate all gas stations in Tehran city to determine benzene emissions and the determination permissible distance of gas station from sensitive and residential areas.

MATERIAL AND METHODS

In this study, 148 gas stations in 22 districts in Tehran city (Fig. 1) were examined.

First, the factors affecting the emission of gasoline vapors, including the number of gas stations, number of gasoline fuel storage tanks, maximum operating capacity of storage tanks, gasoline sales rate, number of loading and the number of active nozzles at gas station in Tehran was

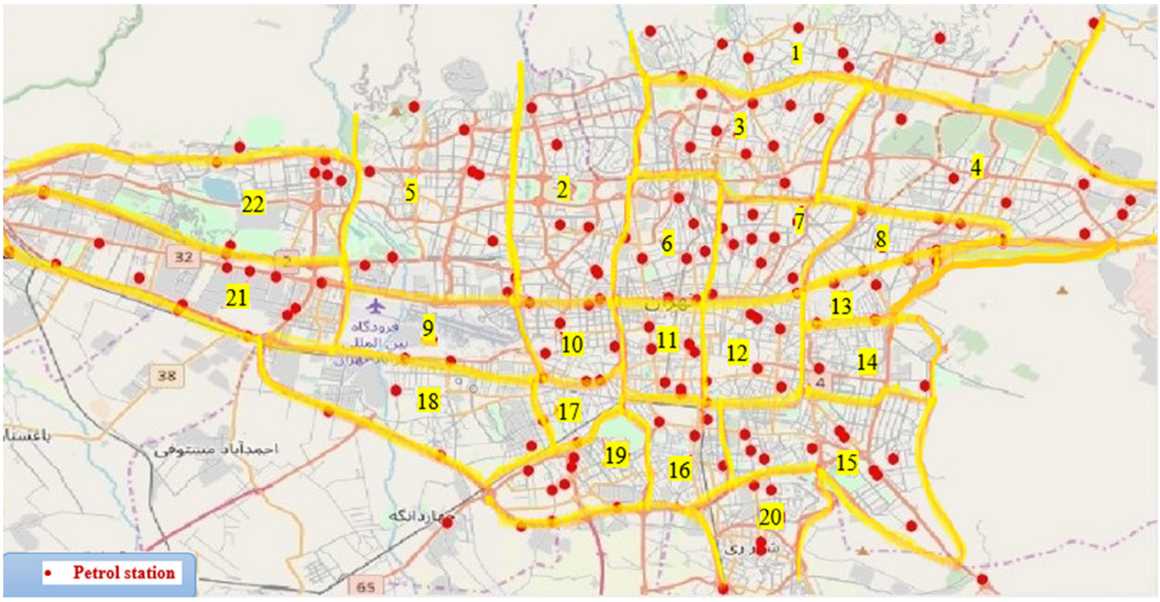

Fig. 1. The location of 148 gas stations in 22 districts in Tehran

investigated. In the next step, to evaluate benzene emissions, data on the following parameters for 412 storage tanks were used as inputs to TANKS 4.0.9d Software:

Physical specifications of the storage tank (length and diameter), the number of loading times, the maximum operating capacity of the tank, weather parameters, the average daily and annual ambient temperatures, the maximum and minimum daily and annual temperatures, the average wind speed, specifications of petroleum products stored in the tank, type of chemical compounds in the petroleum product, the weight percentage of compounds, pressure, and the vent vacuum of the storage tank. Based on information from the National Iranian oil products Distribution Company Fixed-roof horizontal underground tanks with a nominal capacity of 45,000 L and 24,000 L were considered. Due to the presence of gasoline vapors over the surface of the liquid stored in the tanks, the maximum operating capacity of the tanks is respectively 32,000 and 20,000 L.

Climatic information was obtained from the Meteorological Organization of Iran and related sites for MEHRABAD station in Tehran, which is the closest station to the study area. Based on the software outputs, the volume of gasoline vapors emitted from storage and the annual loading operations of underground tanks from 148 gas stations is about 2,037,660 gallons per year.

$$2{,}037{,}660.28 \text{ gal /year} \times 3.78 = 7{,}702{,}355.85 \text{ lit/ year} \quad (1)$$

Assuming a density of 0.72 g/cm^3 for the liquid gasoline, the rate of gasoline vapor emissions equals 12,242,997.14 pounds per year.

$$12{,}242{,}997.14 \text{ lb. / year} \times 453.59 = 5{,}553{,}301{,}072.73 \text{ gr/ year} \quad (2)$$

$$5{,}553{,}301{,}072.73 \text{ gr/ year} / (365\times24\times3{,}600) = 176.094 \text{ gr/ sec} \quad (3)$$

According to the above calculations (Eq. (1), Eq. (2) & Eq. (3)) and considering 1vol% of benzene concentration in gasoline accordance with the standards EN228 and ASTM D1319, the rate of benzene emitted from storage and the annual loading operations of underground tanks from 148 gas stations in Tehran is about 1.76 g/s.

Eventually Using the dispersion model AERMOD view 8.9 software, benzene concentrations in Tehran with a grid distance of 20-30-40-50 m were determined in a 12-month statistical period at an elevation of 1.5 m above the ground surface (respiratory height) (Correa et al., 2012) and benzene dispersion in the region was simulated.

AERMOD is capable of defining point, surface and volume sources. To model benzene dispersion, data such as emission rate of volume sources (g/s), pollutant release height, volume source center relative to the ground surface (m), the initial side dimension of the volume source (m), the initial vertical dimension of the volume source (m), and *x* and *y* coordinates of the center of the volume source relative to the origin selected for the volume source were entered into the model. AERMOD is composed of a meteorological pre-processor called AERMET and a geological pre-processor known as AERMAP. For the pre-processor AERMET, the raw surface and upper air meteorological data (a total of 8760 hourly data) including wind speed (FF), wind direction (DD), humidity (U), temperature (t) and cloud cover (n) for a 1-year were taken from Iran Meteorological Organization for MEHRABAD Station as the closest station to the study area. The collected data were then converted to format acceptable by AERMET.

For the pre-processor AERMAP, the digital elevation model (DEM) of Tehran was prepared to examine the effect of terrains on the concentration of pollutants and to process the topographical data of the region. This pre-processor has been designed based on the USGS topographical maps and analyzes topographical information of the region. Using the results of these two pre-processors and additional data on the emission sources and the receiving grid, AERMOD performs calculations and outputs the final results.

In this study to determine which variables are most influential on benzene concentration and in order to find the corresponding equation, data related to variables (number of loading times, tank capacity and permissible distance of the emission sources) were inserted into SPSS 20 software as primary data. Multivariate regression was used for the parameters of number of loading times and tank capacity as an independent variable and permissible distance as a dependent variable. The data obtained from modeling were analyzed using the above software and ANOVA test.

The ANOVA determines whether a regression model can significantly and appropriately predict the variations in dependent variables. To evaluate the statistical significance of the regression model, the last column of the table (sig) will be examined in the ANOVA test. If the value obtained in the (sig) part of the ANOVA was less than 0.05, it would mean that the regression model was significant.

RESULTS AND DISCUSSION

According to the software output and calculations performed, emissions of benzene vapor emitted from 412 storage tanks in 148 gas stations in Tehran city was investigated. The lowest emission rate of benzene is about 0.0023 g/s and the maximum emission rate is 0.0314 g/s. In order to determine the permissible distance of emission source from sensitive and residential areas, using AERMOD dispersion model, the dispersion rate of benzene concentration with a grid distance of 20-30-40-50 meters was determined and their distribution in the area was simulated.

As shown in Table 1, When the emission rate of benzene vapors is in the range of 0.0023 to 0.012 g/s, storage capacity in the range of 20,000 L to 64,000 L and the maximum number of loading is 675 times a year, the concentration of benzene at a distance of 20 m of the emission source reaches the annual standard of 5 $\mu g/m^3$. Therefore, it can be concluded that in order to construct a gas station with similar conditions, it should be at least 20 meters away from residential and sensitive areas.

While the emission rate of benzene vapors is in the range of 0.013 to 0.0218 g/s, storage

Table 1. Compare permissible distance of the emission sources

Row	The ranges of benzene emissions (g/s)	Storage capacity of tanks (L)	loading number (times per year)	Minimum permissible distance of residential areas (m)
1	0.00023-0.012	20000-64000	675	20
2	0.013-0.0218	60000-96000	675- 1328	30
3	0.0219-0.0314	80000-128000	1329-1834	40

Table 2. Selective one gas station and Comparison with the factors affecting benzene emissions

Gas station	Classification of emissions	Benzene emissions (g/s) output from Tanks 4	Storage Capacity L	Number of loading times per year	Benzene concentration (μg/m³) output from AERMOD at a distance of 20 m	Benzene concentration (μg/m³) output from AERMOD at a distance of 30 m	Benzene concentration (μg/m³) output from AERMOD at a distance of 40 m
134	Lowest emission range	0.009	64000	675	5.00	2.70	1.60
255	Average emission range	0.016	96000	1328	10.44	5.02	2.95
148	Highest emission range	0.022	128000	1834	12.84	6.38	3.81

capacity in the range of 60,000 L to 96,000 L and the number of loading is in the range of 676 to 1328 times a year, the concentration of benzene at a distance of 30 m of the emission source reaches the annual standard of 5 μg/m³. So, it can be concluded that in order to construct a gas station with similar conditions, it should be at least 30 meters away from residential and sensitive areas.

When the emission rate of benzene vapors is in the range of 0.0219 to 0.0314 g/s, storage capacity in the range of 80,000 L to 128,000 L and the number of loading is in the range of 1329 to 1834 times a year, the concentration of benzene at a distance of 40 m of the emission source reaches the annual standard of 5 μg/m³. Therefore, it can be concluded that in order to construct a gas station with similar conditions, it should be at least 40 meters away from residential and sensitive areas.

Based on the results, number of loading times and storage capacity are the main factors affecting benzene emissions from gas stations. The permissible distance from each gas station is determined based this factors.

According benzene emissions in this study and classifying them in three ranges (Lowest emission range of 0.0023 until 0.012 g/s), (Average emission range of 0.013 until 0.0218 g/s) and (Highest emission range of 0.0219 until 0.0314 g/s), As shown in Table 2, was selected one gas station as an example of each class for comparing it with the factors affecting benzene emissions.

Figure 2 displays benzene dispersion of gas station (no.134) (with benzene emissions 0.009 g/s, Storage Capacity 64,000 L and Number of loading 675 times per year), at a distance of 20 m falls within the annual standard limit of benzene, benzene dispersion of gas station (no.255)

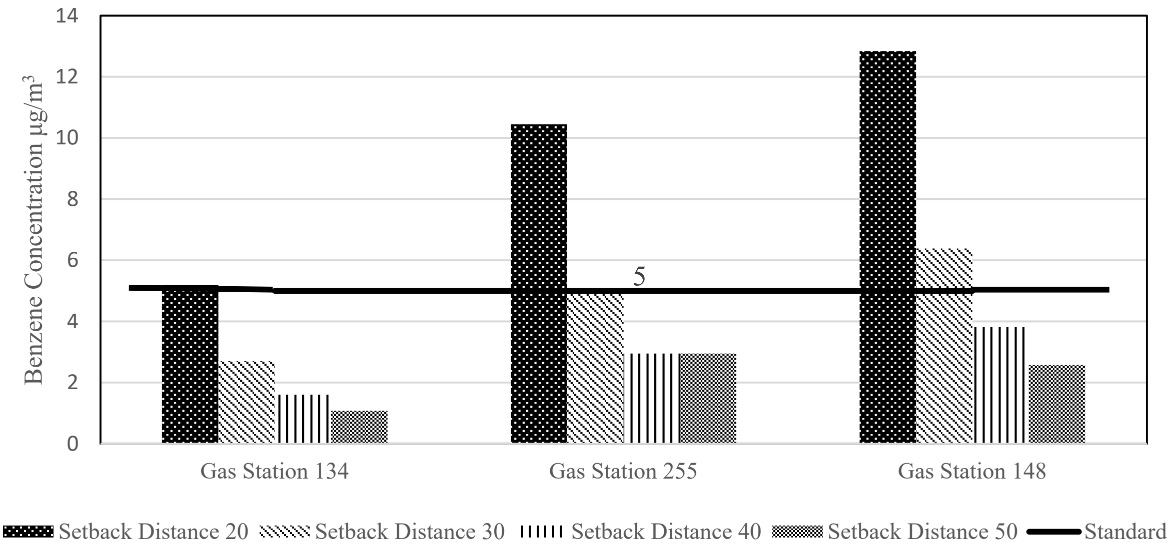

Fig. 2. Comparison of benzene emissions from gas stations selective with annual standard

(with Benzene emissions 0.016 g/s, Storage Capacity 96,000 L and Number of loading 1328 times per year), at a distance of 30 m falls within the annual standard limit of benzene and benzene dispersion of gas station (no.148) (with Benzene emissions 0.022 g/s, Storage Capacity 128,000 L and Number of loading 1834 times per year), at a distance of 40 m of the emission sources, falls within the annual standard limit of benzene 5 μg/m^3.

In Figures 3 Benzene concentration dispersion maps at different distances from emission source are shown. A gas station with a storage capacity of 64,000 L and a loading number of 675 times per year at a grid distance of 20, 30, 40, and 50 m (fig.3a), a gas station with a storage capacity of 96,000 L and the loading number of 1328 times per year at a grid distance of 20, 30, 40, and 50 m (fig.3b), a gas station with a storage capacity of 128,000 L and the loading number of 1834 times per year at a grid distance of 20, 30, 40, and 50 m (fig.3c).

According to studies conducted in Brazil on the emission of pollutants from gas stations, even regions at a distance of 150 m from gas stations contain high BTEX concentrations (Correa et al., 2012). Researchers studied the relative location of gas stations and public centers in Kano metropolis in Nigeria in accordance with the guidelines of Department of Petroleum Resources and Urban Development and Planning Agency. According to their results, the minimum distance of gas stations from public centers should be 100 m (Mohammed et al., 2014). Scientists investigated the emission rate of pollutants from gas stations in Umuahia and came to the conclusion that the minimum safe distance of the gas stations and residential areas should be 80 m (Okonkwo et al., 2014). Researchers studied emissions of pollutants and their effects in the vicinity of gas stations in Portugal. They found that the limit to protect human health for living or working around a gas station should be at least 150 m (Fontes et al., 2016). Scientists through measuring vapors from vent pipes in two large gas stations in the US and comparing them with estimates by the California Air Pollution Control Officers Association and considering the 91 m distance of large gas stations specified by the California Air Resources Board, found that evaporative losses are larger than estimates. In some cases, even at distances larger than 91 m, people are exposed to benzene emissions, and authorities must revise regulations based on these data (Hilpert et al., 2019).

According to the above studies and considering benzene emissions and dispersion at different distances of the emission sources and comparing the results with the annual standard limit of

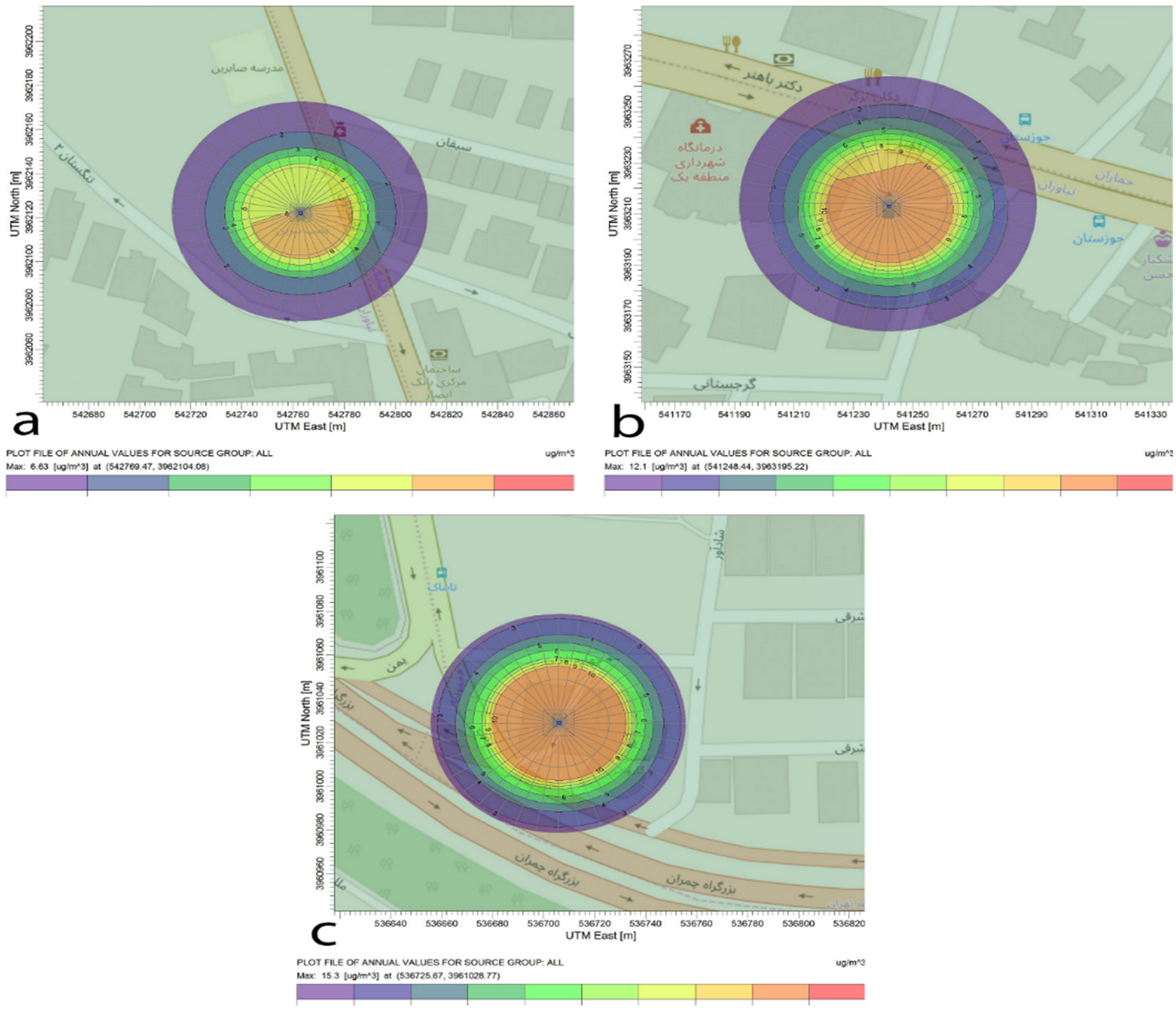

Fig. 3. Benzene concentration dispersion maps at different distances from emission sources

benzene 5 μg/m^3, it was determined that the permissible distance from the emission sources is dependent on various variables. The first factor is the number of annual loading times and the second factor is the storage capacity of tanks in each gas station. However, in the above research that has been done in this field, all researchers have set a fixed number as the permissible distance. As can be seen, the permissible distance depends on the operating volume of the gas station. Gas stations do not operate at a constant volume everywhere. The above two variables cause differences in the emission of gasoline and gasoline vapors. As a result a fixed number cannot be declared for the permissible distance. For a storage tank with a capacity of 64,000 L and the maximum loading of 675 times per year, the minimum permissible distance between the gas station and the residential areas equals 20 m. For a storage tank with a capacity of 96,000 L and the maximum loading of 1328 times per year, the minimum permissible distance between the gas station and the residential areas equals 30 m. For a storage tank with a capacity of 128,000 L and the maximum loading of 1834 times per year, the minimum permissible distance between the gas station and the residential areas equals 40 m. Accordingly, by increasing the capacity of storage tanks and the number of annual loads of the above declared values, permissible distance from residential areas more than 40 meters.

By examining statistical analysis it was found that there is a significant relationship between

Table 3. Values of linear regression equation

	Subject	Values
a	Constant	16.68
b_1	Unstandardized Coefficients for number of loading times	0.008
b_2	Unstandardized Coefficients for storage capacity of tanks	0.063
X_1	Independent variable: number of loading times	variable
X_2	Independent variable: storage capacity of tanks (m^3)	variable
Y	Dependent variable: permissible distance of the emission source	can be predicted

the variables of number of loading times and tank capacity with the permissible distance variable of the emission source ($P < 0.05$). As a result, the model used is a good predictor for determining the permissible distance from the emission source. Also, the constant value and the variables of number of loading times and tank capacity of all three are significant in the model. The standardized regression coefficient (beta) shows the share of the effect of independent variables on the dependent variable. Analysis of the enter regression method indicates that the share of the impact of the number of loading times (BETA=0.576) is greater than the share of the impact of the storage capacity (BETA = 0.433) in determining the permissible distance of the emission source.

R Squared (R^2 or coefficient of determination) is the square of the correlation coefficient. The closer the output is to one, the more accurate the predictive model is, and vice versa. According to regression model analysis, $R^2 = 0.679$.

To create a regression equation, we use the unstandardized regression coefficient (B). With the values obtained from the regression model and placing the data in the linear regression & Eq. (4), the permissible distance of the emission source can be predicted (table 3).

$$Y=16.68+0.008(X_1)+0.063(X_2) \tag{4}$$

Where

Y - the predicted benzene concentration (Benzene emitted from storage and the annual loading operations of underground tanks),

X_1 - the number of loading times and

X_2 - is the storage capacity of the underground storage tank.

For example, for a storage tank with a capacity of 128 m^3 and a loading of 1834 times per year, the minimum distance to residential areas is about 39.4 m.

CONCLUSIONS

Based on software output and calculations, the amount of benzene emitted from storage and the annual loading operations of underground tanks (charge and discharge) were obtained. Then, using the AERMOD program, benzene concentration in the environment surrounding the emission source was predicted. By comparing the predicted benzene concentration with the annual standard limit of benzene (5 $\mu g/m^3$), the minimum permissible distance of gas stations from residential and sensitive areas was determined.

On the other hand, In order to determine which variables (storage capacity and number of loading times) are most influential on benzene concentration and to find the equation for the permissible distance from the emission source, the parameter data (loading times, tank capacity, and permissible distance from the emission sources) were inserted into SPSS 20 as primary data.

Multivariate regression was calculated for the parameters of loading times and tank capacity (independent variables) and permissible distance (dependent variable).

In the presence of additional factors affecting the emission of benzene vapors in the environment (such as vehicle refueling, liquid gasoline spills, and evaporation from leaking hoses and connections), that this will be an underestimation of total gasoline vapor emissions from gas stations. Therefore, setback distances might even need to be larger than suggested in this study.

According to the results of this study, construction of new gas stations should be supervised by the authorities and supervisory organizations to take into account the minimum permissible distance of residential areas and critical points based on the storage capacity and the number of loading times. For the construction of gas stations, considering the population of cities (High and low in each region) and the demand for refueling and land prices and its limitations (Suitability of land prices and construction of green space around the gas station to increase the distance from sensitive areas or unsuitable land prices and only observing the minimums in those areas), by calculating the mentioned variable factors, the construction of gas stations with appropriate conditions (Construction of gas stations with high capacities in the areas where the maximum distances can be observed, and construction of gas stations with low capacities in the areas where only the minimums can be observed due to the mentioned restrictions) to meet the needs of the population of the region should be done.

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The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

REFERENCES

Atabi, F., Moattar, F., Mansouri, N., Alesheikh, A.A. and Mirzahosseini, S.A.H. (2013), Assessment of variations in benzene concentration produced from vehicles and gas stations in Tehran using GIS. IJEST . 10,283–294.

Burghardt, TE., Pashkevich, A. and Żakowska L. (2016). Influence of Volatile Organic Compounds Emissions from Road Marking Paints on Ground-level Ozone Formation: Case Study of Krakow, Poland. Transportation. Research Procedia., 14, 714-723.

Correa, S.M., Arbilla, G., Marques, M.R.C. and Oliveira M.P.G. (2012). The impact of BTEX emissions from gas stations into the atmosphere. APR., 3(2); 163-169.

Dos Santos Cerqueira, J., De Albuquerque, H.N., De Assis Salviano, F. (2019). Atmospheric pollutants: modeling with Aermod software. Air Qual Atmos Health., 12, 21–32.

Fontes, T., Barros, N. and Manso, MC. (2016 June). Human health risk for the population living in the vicinity of urban petrol stations. (Paper presented at the: International Conference on Urban Risks, CaixaGest, Lisboa)

Gurjar, BR., Molina, LT. and Ojha, CSP. (Eds)(2010). Air Pollution: Health &Environmental impacts.

(CRC Press)
Hajizadeh, Y., Mokhtari, M., Faraji, M., Mohammadi, A., Nemati, S., Ghanbari, R., Abdolahnejad, A., FouladiFard, R., Nikoonahad, A., Jafari, N. and Miri, M. (2018). Trends of BTEX in the central urban area of Iran: A preliminary study of photochemical ozone pollution and health risk assessment. APR 9(2); 220-229.

Hanna, SR., Paine, R., Heinold, D., Kintigh, E. and Baker, D. (2007). Uncertainties in air toxics calculated by the dispersion models AERMOD and ISCST3 in the Houston ship channel area. JAMC 46(9); 1372-1382.

Heibati, B., Pollitt KJG., Karimi A., Yazdani Charati J., Ducatman A., Shokrzadeh M. and Mohammadyan M. (2017). BTEX exposure assessment and quantitative risk assessment among petroleum product distributors. Ecotoxicology and environmental safety. 144,445-449.

Hilpert, M, Rule, AM, Adria-Mora, B. and Tiberi, T. (2019). Vent pipe emissions from storage tanks at gas stations: Implications for setback distances. Science of the Total Environment, 650(2); 2239-2250.

Khosravi, H. and Talaei Khozani, A.R. (2019). Evaluation of emissions of volatile organic compounds from gasoline storage tanks in Isfahan. Journal of Air Pollution Health. 3(2); 95-105

Lan, Q., Zhang, L., Li, G., Vermeulen, R., Weinberg, R.S., Dosemeci, M. et al. (2004). Hematotoxicity in workers exposed to low levels of benzene. Science, 306(5702); 1774-1776.

Macêdo, M.F.M. and Ramos, A.L.D. (2020). Vehicle atmospheric pollution evaluation using AERMOD model at avenue in a Brazilian capital city. Air Qual Atmos Health., 13,309–320.

Mcgaughey, G., Mcdonald-Buller, E., Kimura, Y. and Kim, H.S. (2009 October). Modeling and ambient monitoring of air toxics in Corpus Christi, Texas. (Paper presented at the 8th Annual CMAS Conference, Chapel Hill, NC)

Merchant-Borna, K., Rodrigues, EG., Smith, KW., Proctor, S.P. and McClean, M.D. (2012). Characterization of inhalation exposure to jet fuel among US Air Force personnel. Annals of occupational hygiene, 56(6); 736-745.

Mohammed, M.U., Musa, I.J. and Jeb, D.N. (2014). GIS-Based Analysis of the Location of Filling Stations in Metropolitan Kano against the Physical Planning Standards. IJER. 3(9); 147-158.

Monod, A., Sive, B.C., Avino, P., Chen, T., Blake, D.R. and Rowland, F.S. (2001). Mono aromatic compounds in ambient air of various cities: a focus on correlations between the xylenes and ethyl benzene. Atmospheric Environment. 35(1); 135-149.

Neghab, M., Hosseinzadeh, K. and Hassanzadeh, J. (2015). Early Liver and Kidney Dysfunction Associated with Occupational Exposure to Sub-Threshold Limit Value Levels of Benzene, Toluene, and Xylenes in Unleaded Petrol, Saf Health Work, 6(4); 312-316.

NIU, He., MO, Ziwei., SHAO, Min., LU, Sihua and XIE, Shaodong. (2016). Screening the emission sources of volatile organic compounds (VOCs) in China by multi-effects evaluation. Front.Environ. Sci.Eng 10, 1.

Okonkwo, U.C., Orgi, I.N. and Onwuamaeze, I (2014). Environmental impact assessment of petrol and gas filling station on air quality in Umuahia, Nigeria. Global journal of engineering research. 13(1); 11-20.

Okonkwo, C., Ehileboh, A.D., Nwobodo, E. and Dike, C. (2016). The effects of acute gasoline vapor inhalation on some hematological indices of albino Wistar rats. JAD. 5(2); 123-125.

Owagboriaye, F.O, Dedeke, G.A, Ashidi, J.S., Aladesida, A. and Olooto, W.E. (2017). Hepatotoxicity and genotoxicity of gasoline fumes in albino rats, Beni-Suef University Journal of Basic and Applied Sciences, 6(3); 253-259.

Pandey, G. and Sharan, M. (2019). Accountability of wind variability in AERMOD for computing concentrations in low wind conditions. Atmospheric Environment, 202,105–116.

Ramavandi, B., Ahmadimoghadam, M., SHahheidar, N. and Bighami, M. (2016). Estimation of volatile organic compounds emissions from the fuel storage tanks using tanks model and its distribution modeling by Aermod model. Journal of sabzevar university of medical sciences, 23(2); 253-261.

Srivastava, A., Joseph, A.E., More, A. and Patil, S. (2005). Emissions of VOCs at urban petrol retail distribution centres in India (Delhi and Mumbai). Environ Monit Assess, 109, 227–242.

Srivastava, A., Joseph, A.E. and Devotta, S. (2006). Volatile organic compounds in ambient air of Mumbai–India. Atmospheric Environment, 40(5); 892-903.

Thepanondh, S., Thanatrakolsri, P.O. and Saikomol, S. (2016). Evaluation of dispersion model performance in predicting SO_2 concentrations from petroleum refinery complex, International Journal of GEOMATE, 11(23); 2129-2135.

Tohid, L., Sabeti, Z., Sarbakhsh, P., Zoroufchi, KH., Shakerkhatibi, M., Rasoulzadeh, Y., Rahimian, R. and Darvishali, S. (2019). Spatiotemporal variation, ozone formation potential and health risk assessment of ambient air VOCs in an industrialized city in Iran. APR, 10(2); 556-563.

Truong, S.C.H., Lee, M.I., Kim, G. and Kim, D. (2016). Accidental benzene release risk assessment in an urban area using an atmospheric dispersion model. Atmospheric Environment. 144,146-159.

Tsai, W T. (2016). Toxic Volatile Organic Compounds (VOCs) in the Atmospheric Environment: Regulatory Aspects and Monitoring in Japan and Korea. Environments, 3(3); 23.

USEPA (1999). "User's Guide to TANKS, Storage Tank Emissions Calculation Software Version 4.0" Emission Factor and Inventory Group Emissions, Monitoring, and Analysis Division Office of Air Quality Planning and Standards. https://www3.epa.gov/ttnchie1/software/tanks/tank4man.pdf.

USEPA (2018). "User's Guide for the AMS/EPA Regulatory Model-AERMOD". Office of Air Quality Planning and Standards Air Quality Assessment Division Air Quality Modeling Group Research Triangle Park, North Carolina, EPA-454/B-18-001. https://gaftp.epa.gov/Air/aqmg/SCRAM/models/preferred/aermod /user guide.

Xu, Z., Huang, X., Nie, W., Chi, X., XU, Z., Zheng, L., Sun P. and Ding, A. (2017). Influence of synoptic condition and holiday effects on VOCs and ozone production in the Yangtze River Delta region, China. Atmospheric Environment, 168,112-124.