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EVALUATION OF VOLATILE ORGANIC COMPOUNDS EMISSION FROM GASOLINE STORAGE TANKS IN ISFAHAN METROPOLITAN

Heydar Khosravi[1], Amirreza Talaiekhozani[1, 2]*

[1] Department of Safety, Health and Environment, Najafabad Branch, Islamic Azad University, Najafabad, Iran
[2] Civil Engineering Department, Jami Institute of Technology, Isfahan, Iran

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CORRESPONDING AUTHOR:

atalaie@jami.ac.ir
Tel: (+98 31) 52636319
Fax: (+98 31) 52636320

ABSTRACT:

Introduction: Nowadays, air pollution has become one of the problems of human society. In order to control air pollution, it is essential to know the sources of pollutants and rate of pollutants emission. Although various studies have been done to determine the airborne emission in Isfahan metropolitan, no studies have yet been conducted on the emission of volatile organic compounds (VOCs) from gasoline storage tanks in this city. Therefore, the aim of this study was to determine the rate of VOCs emission from gasoline storage tanks in Isfahan metropolitan and to model dispersion of VOCs in the atmosphere of this city.

Materials and methods: The TANKS model was used to determine the emission rate of VOCs. Input data for the TANKS model was provided through the Isfahan Oil Refining & Distribution Company. The AERMOD model was also used to model VOCs distribution. The basic information required by the AERMOD model was also collected through relevant organizations such as the Islamic Republic of Iran Meteorological Organization and Iran National Cartographic Center.

Results: The research showed that there are 21 large gasoline storage tanks in Isfahan metropolitan. The gasoline storage tanks emit 494839 tons of VOCs into the atmosphere annually. The amount of VOCs emitted from the 21 gasoline storage tanks was estimated as much as 154618081 g / year. The results showed that 99.9 % of VOCs emitted through the pipe connections in the gasoline storage tanks into the atmosphere.

Conclusions: The results showed that gasoline storage tanks of Isfahan metropolitan are responsible for about 0.001 % of the VOCs emission in this metropolitan.

INTRODUCTION

Nowadays, in most of the metropolitan cities, air pollution has become a major dilemma [1]. The Isfahan metropolitan is characterized by the presence of hundreds of different industries and high population density [2]. Volatile Organic Compounds (VOCs) are considered as important air pollutants. Therefore, it is important to study their

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emission in Isfahan [3]. Unfortunately, due to the high amounts of VOCs released by a wide range of resources such as industries, vehicles, fuel refining and its distribution system, the number of days with clean air in Isfahan metropolitan has been reduced. Generally, VOCs are organic compounds with high vapor pressure. They are composed of a wide range of organic compounds [4]. The high vapor pressure of VOCs is due to their low boiling point. Compounds with low boiling point can be easily evaporated and emitted into the atmosphere [5]. VOCs have the highest emission into the atmosphere after suspended particles. According to the US Environmental Protection Agency, compounds with vapor pressure of more than 0.1 mm Hg are categorized as VOCs. However, some of these compounds, such as methane, carbon monoxide, carbon dioxide and some aldehydes, are excluded from this definition [4]. Many VOCs have adverse effects on human health [6]. Aromatic hydrocarbons, alkanes, alkenes, aliphatic hydrocarbons, aldehydes, halocarbons, cyclocarbon are some important VOCs [7]. Some of VOCs are naturally found [8] and others are created by humans [9]. The exposure limit value (ELV) for these harmful substances in the environment is legally determined by governments [10]. One of the most important anthropogenic sources of VOCs is the use of solvents, vehicles, oil and petrochemical industries, fuel storage tanks, fuel production and distribution systems [9]. These VOCs have an important contribution to the emission of pollutants in the atmosphere and, by creating health problems, annually impose significant costs on oil companies and fuel storage terminals [11]. Long - term exposure to VOCs may have harmful effects on human health [12]. Some effects of VOCs on human health are eyes and nose irritation caused by stimulation of mucosal membrane, carcinogenicity, headache, dry skin and nausea. For this reason, any large - scale leakage of VOCs from storage tanks can threaten public health [9].

In fuels such as gasoline compounds like benzene can be found [13]. Benzene is a highly toxic and carcinogenic compound [14]. The storage of fuel for vehicle refueling is essential in cities. In the process of fuel storage, evaporation of fuel is almost inevitable. Since millions ton of fuel are stored annually in the large fuel storage tanks of Isfahan metropolitan, it is clear that a careful examination should be down to find the amount of VOCs emitted from them. Determining the emission rate and distribution pattern of VOCs emitted from gasoline storage tanks in the Isfahan atmosphere can provide a platform for air pollution control planning.

Nowadays, air pollution modeling is a powerful instrument in atmospheric studies, and it can be used to model the concentration of pollutants and their distribution in different atmospheric conditions and in different location situations [15]. Computer modeling in air pollution engineering is an interesting science that is progressing [16]. Considering that no research has been conducted on the distribution of VOCs from gasoline storage tanks in the Isfahan metropolitan, in this study, the rate of VOCs emission was investigated. Also, the distribution of VOCs emitted from the gasoline storage tanks in the Isfahan metropolitan was studied. In this study, the TANK software developed by the US Environmental Protection Agency was used to estimate the amount of VOCs emission from the gasoline storage tanks of Isfahan metropolitan. After determining the VOCs emission rate, the distribution of VOCs on the Isfahan metropolitan atmosphere was investigated by AERMOD model. The results of this study can be used by the relevant authorities to plan a right policy of air pollution control.

MATERIALS AND METHODS

Estimation of emission rate

The purpose of this study was to evaluate the emission of VOCs from gasoline storage tanks in Isfahan metropolitan. In the first step of this study, by referring to Isfahan Oil Refining & Distribution Company, information about the number of gasoline storage tanks, location, size, shape, type of gasoline storage tanks, color of gasoline storage tanks and its dimensions were collected. In this study, TANKS 4.09 b model was used to estimate the amount of VOCs emission from gasoline storage tanks of Isfahan. The TANKS model allows users to consider information such as the physical shape of the gasoline storage tanks, connections, location of gasoline storage tanks, type of stored compounds, climatic conditions, and location of the gasoline storage tanks [17].

In the TANKS model, the storage tanks are categorized as (1) horizontal fixed - roof tanks; (2) external floating roof tanks; (3) internal floating roof tanks; (4) domed external floating roof tanks; (5) horizontal tanks and (6) vertical fixed - roof tanks. Therefore, the shape of storage tanks is very important to determine the emission of VOCs by TANKS model [17]. Regarding the type of storage tanks, Eqs. (1) or (2) are used by TANKS model to determine the rate of VOCs emission.

$$LT = LS + LW \quad (1)$$

$$LT = LR + LWD + LF + LD \quad (2)$$

Where, LT is total emission of VOCs from gasoline storage tanks in lb / year, LS is emission of VOCs in full state standing storage losses in lb / year, LW is emission of VOCs during working losses in lb / year, LR is emission of VOCs from Rim seal loss in lb / year, LWD is emission of VOCs during withdrawal loss in lb / year, LF release of VOCs from foam fixing per pound per year, and LF is emission of VOCs from deck fitting loss. Different information are needed to estimate the amount of VOCs emission from gasoline storage tanks by TANKS model [18]. This information is shown in Table 1.

In order to validate the results of the modeling, the amount of VOCs in the atmosphere of Isfahan metropolitan was measured by a VOC meter manufactured by the company MIC model of 38518. Then the obtained results were matched with the modeling data.

Modeling of VOCs dispersion

The most important models for the dispersion of airborne pollutants are Eulerian, Gaussian, and Lagrangian models. In this study, AERMOD model was used to study the dispersion of VOCs in the Isfahan metropolitan atmosphere. The AERMOD model is used a modified Gaussian model to estimate concentration of VOCs in each location. To model the dispersion of VOCs in the atmosphere, several of parameters such as wind speed, wind direction, direction Ceiling height, hourly precipitation, global horizontal radiation, dry bulb temperature, humidity, Station pressure, opaque cloud cover and topographical data were needed. This information was collected through relevant organizations such as the Islamic Republic of Iran Meteorological Organization and Iran National Cartographic Center. Due to the lack of VOCs emission control systems in gasoline storage tanks of Isfahan metropolitan, it was assumed that all VOCs calculated by the TANKS model will be distributed in the atmosphere.

RESULTS AND DISCUSSION

The rate of VOCs emission

The results showed that there are 21 gasoline storage tanks in Isfahan metropolitan that each

Table 1. The input data of TANKS model

Parameters	Amount
User Identification	29
City	Isfahan
State	Isfahan
Company	Isfahan National Iranian Oil Products Distribution Company
Type of Tank	External Floating Roof Tank
Description	Petrol tank
Tank Dimensions	
Diameter (ft)	170
Volume (gallons)	10566882
Turnovers	36
Paint Characteristics	
Internal Shell Condition	Light Rust
Shell Color/Shade	White/White
Shell Condition	Good
Roof Characteristics	
Type	Pontoon
Fitting Category	Detail
Tank Construction and Rim-Seal System	
Construction	Welded
Primary Seal	Mechanical Shoe
Secondary Seal	Shoe-mounted

tank has a capacity of 10566882 gallons. It also revealed that gasoline storage tanks in the Isfahan metropolitan are external floating roof tanks. These gasoline storage tanks are located in the northwest of Isfahan metropolitan and in the vicinity of the Isfahan Oil Refinery. The calculations performed with the TANKS model revealed that thousands of tons of VOCs are emitted monthly from the gasoline storage tanks to the atmosphere of Isfahan metropolitan. The amount of VOCs emitted per month for a gasoline storage tank is shown in Fig. 1 and for the total of 21 gasoline storage tanks in Fig. 2. The highest emission of VOCs from these gasoline storage tanks occurs in late September through mid - October. The emission of VOCs in the months of November and February is also higher than other months of the year 2017. The total amount of VOC emission from 1 gasoline storage tank and the total of 21 gasoline storage tanks over a year is shown in Tables 2 and 3, respectively. According to the results, 494839.8 tons of VOCs are annually emitted from each gasoline storage tank. The results revealed that 494834 tons of VOCs were annually released into the Isfahan atmosphere. Also, it is indicated that the most important place for emission of VOCs to atmosphere is rim seals of gasoline storage tanks. The results showed that 99.9 % of VOCs were released through rim seals. 5.88 tons of VOCs are also released from the gasoline storage tanks sealing systems, which accounts for 0.001 % of the total emission of VOCs in a gasoline storage tank.

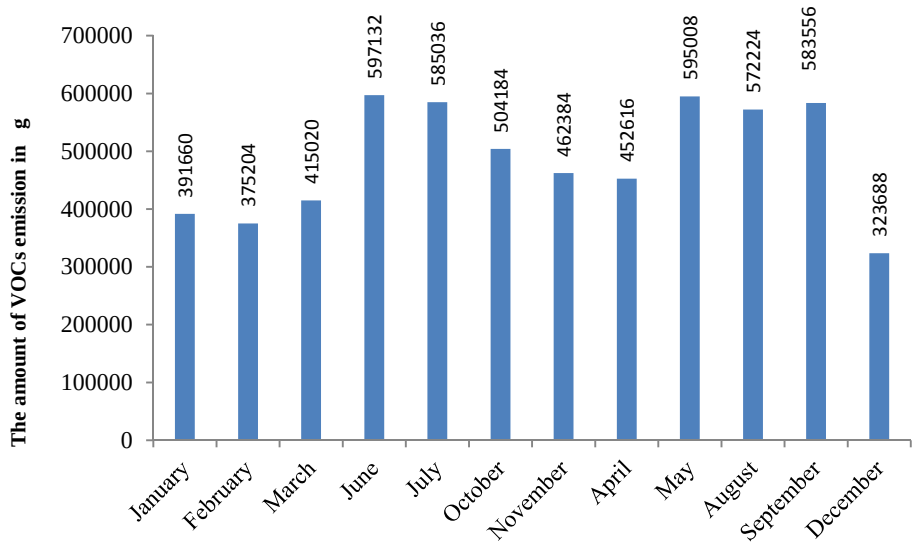

Fig. 1. The rate of VOCs emission from a gasoline storage tank in Isfahan metropolitan by month

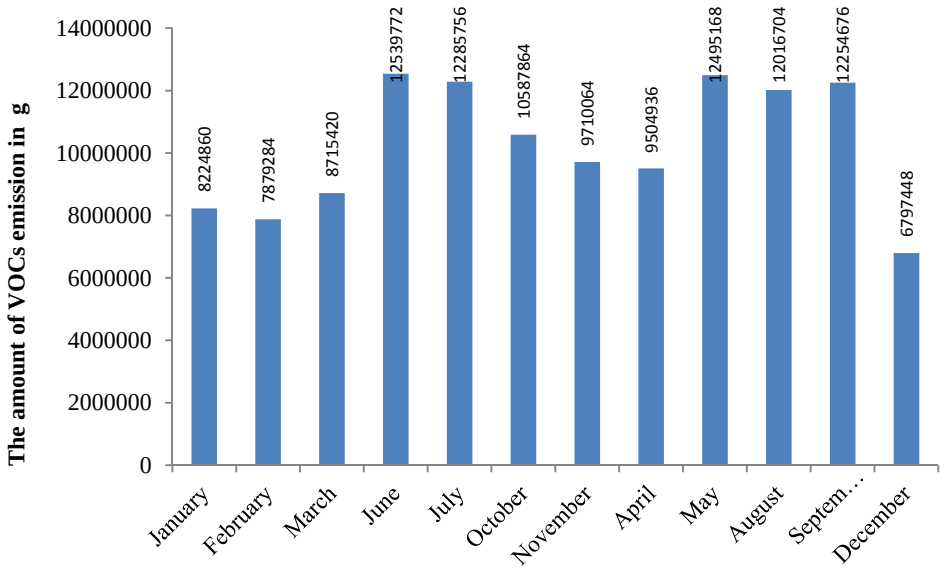

Fig. 2. The rate of VOCs emission from 21 gasoline storage tanks in Isfahan metropolitan by month

Table 2. Annual VOCs emission for different parts of a gasoline storage tank

Annual VOCs emission	(g)	7362765
Rim seal loss (RIM_LOSS)	(g)	7232743
	(%)	99.9
Withdrawal loss (WD_LOSS)	(g)	130022
	(%)	0.001
Deck fitting loss (DECKF_LOSS)	(g)	0
	(%)	0
Deck seam loss (DECKS_LOSS)	(g)	0
	(%)	0

Table 3. Annual VOCs emission for different parts of 21 gasoline storage tanks

Annual VOCs emission	(g)	154618081
Rim seal loss	(g)	151887608
(RIM_LOSS)	(%)	99.9
Withdrawal loss	(g)	2730472
(WD_LOSS)	(%)	0.001
Deck fitting loss	(g)	0
(DECKF_LOS)	(%)	0
Deck seam loss	(g)	0
(DECKS_LOSS)	(%)	0

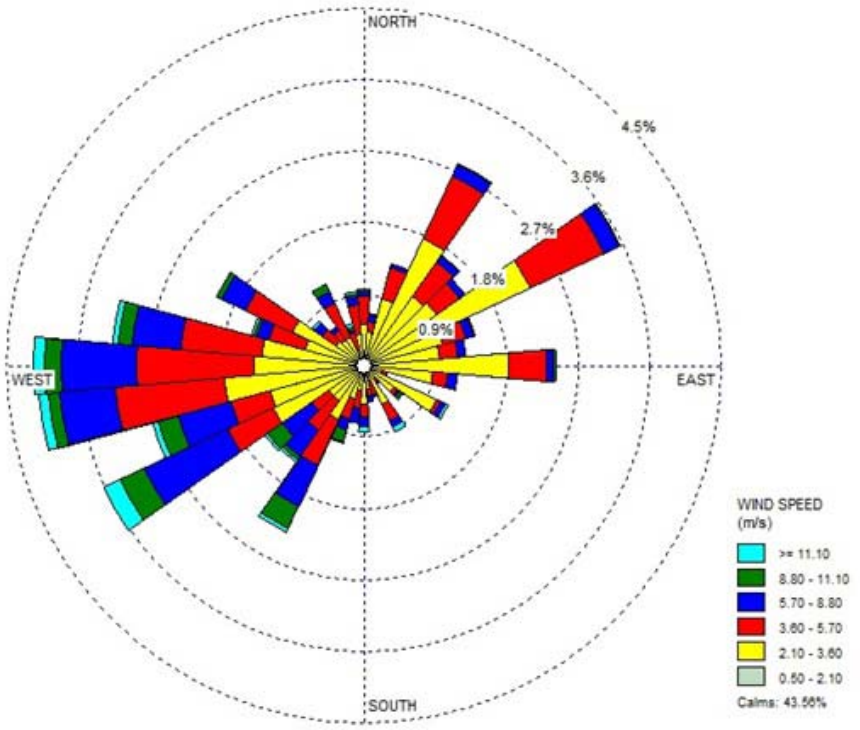

Fig. 3. Wind rose of Isfahan metropolitan

VOCs dispersion into the atmosphere

The speed and direction of the dominant winds in the Isfahan metropolitan are shown in Fig. 3. The collected data showed that 43.5 % of the Isfahan metropolitan winds are very slow and 56.5 % of them have significant speed. Based on the wind rose of Isfahan metropolitan, the dominant winds are from the east to the west. In the most of times VOCs are not able to travel from the gasoline storage tanks toward Isfahan metropolitan due to the location of these tanks. Wind speeds of more than 8.3 m / s are known as effective winds to disperse pollutants into the atmosphere [19].

The distribution of VOCs emitted from all 21 Isfahan gasoline storage tanks in the atmosphere for each month is shown in Figs. 4 to 15. The modeling results illustrated that lowest amount of VOCs concentration in the atmosphere in Isfahan metropolitan is in December. The concentration of VOCs in the Isfahan metropolitan in Decem-

ber was estimated to be between 0.4 to 0.5 µg / m^3. The highest concentration of VOCs in Isfahan metropolitan was from 0.4 to 4 µg / m^3 in April and November. Fig. 4 shows that in January the concentration of VOCs in the small area around the gasoline storage tanks was more than 50 µg / m^3.

The concentration of pollutants in Shahin Shahr city, parts of Khomeini Shahr city and Isfahan metropolitan in January was estimated to be between 0.9 and 3 µg / m^3. In January, most of the city of Isfahan received a concentration between 0.9 and 1 µg / m^3 of VOCs (Fig. 4). In the other months, similar conditions were observed. The modeling results show that the average annual concentration of VOCs in the atmosphere was between 3 and 5 µg / m^3 for Khomeini Shahr and Shahin Shahr cities. The average annual concentration for Isfahan metropolitan was between 0.8 and 3 µg / m^3 (Fig. 16).

In order to verify the results of this study, four air samples were collected from around the gasoline storage tanks of Isfahan metropolitan. The results of this section of the study are also shown in Fig. 16. Several other sources such as vehicles and industries are emitted the VOCs into the atmosphere. Using Eq. (3), the approximate contribution of gasoline storage tanks to emit VOCs was determined.

Where, S is the share of VOCs emitted from the gasoline storage tanks of Isfahan metropolitan compered by the total emission of VOCs from different sources in Isfahan metropolitan in percent, C_T is the measured concentration of VOCs in the atmosphere in µg / m^3 and C_F is estimated concentration by the AERMOD model in µg / m^3. The results showed that gasoline storage tanks of Isfahan metropolitan are responsible for about 0.001 % of the VOCs emission in this metropolitan. The results of VOCs measurement in Isfahan air are illustrated in Table 4. Based on the measurement of VOCs in the air, VOCs released from gasoline storage tank of Isfahan metropolitan are negligible compared to the total amount of VOCs in the air.

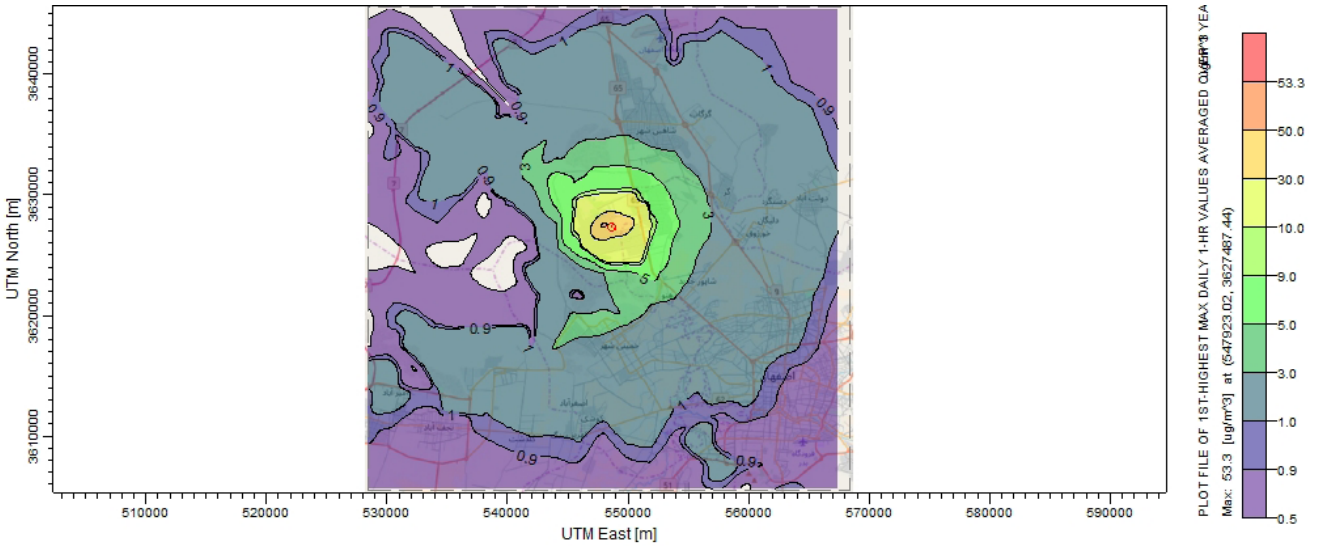

Fig. 4. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in January

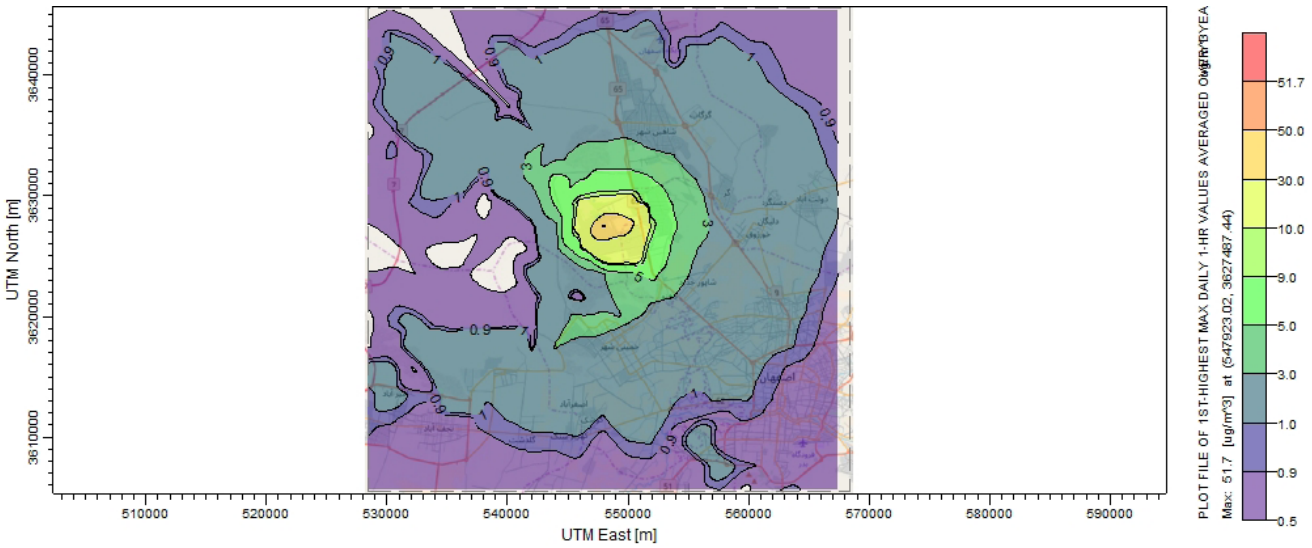

Fig. 5. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in February

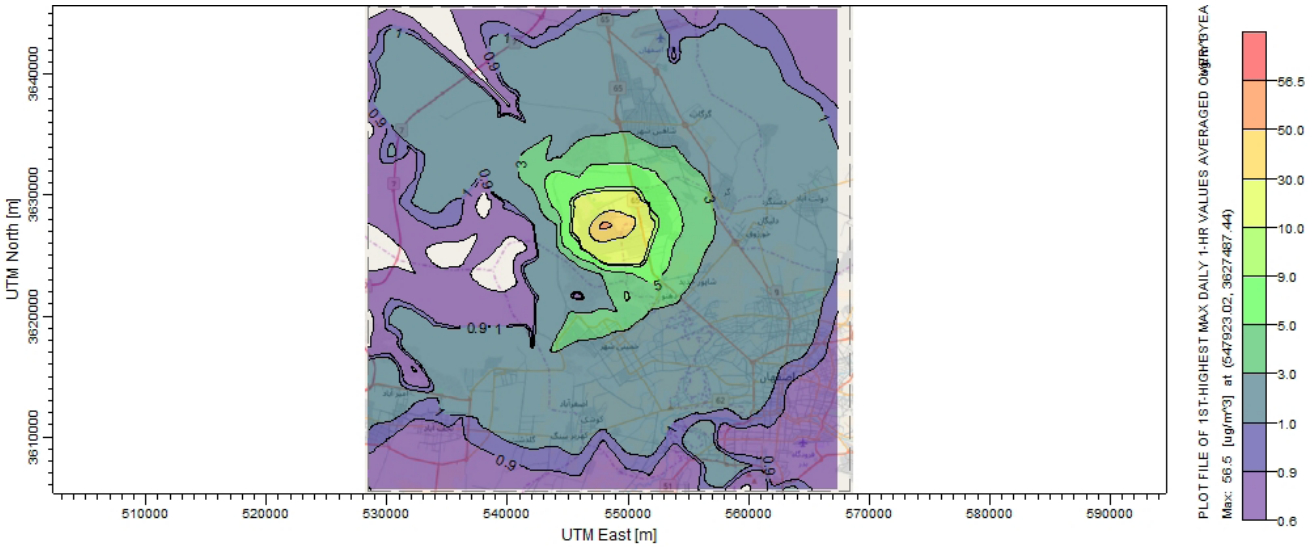

Fig. 6. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in March

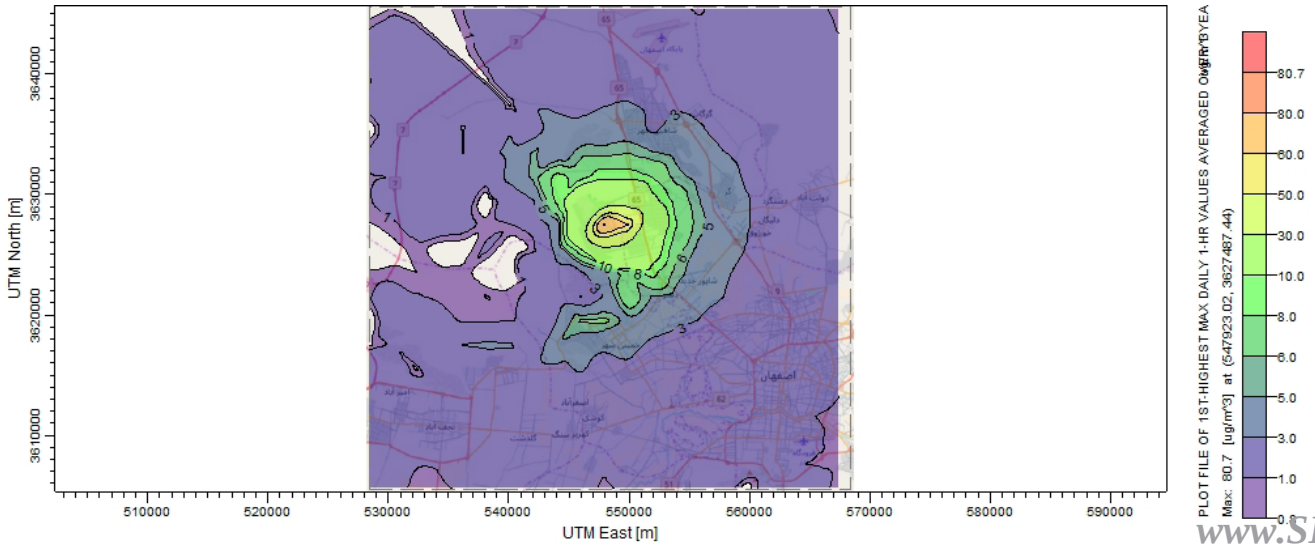

Fig. 7. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in June

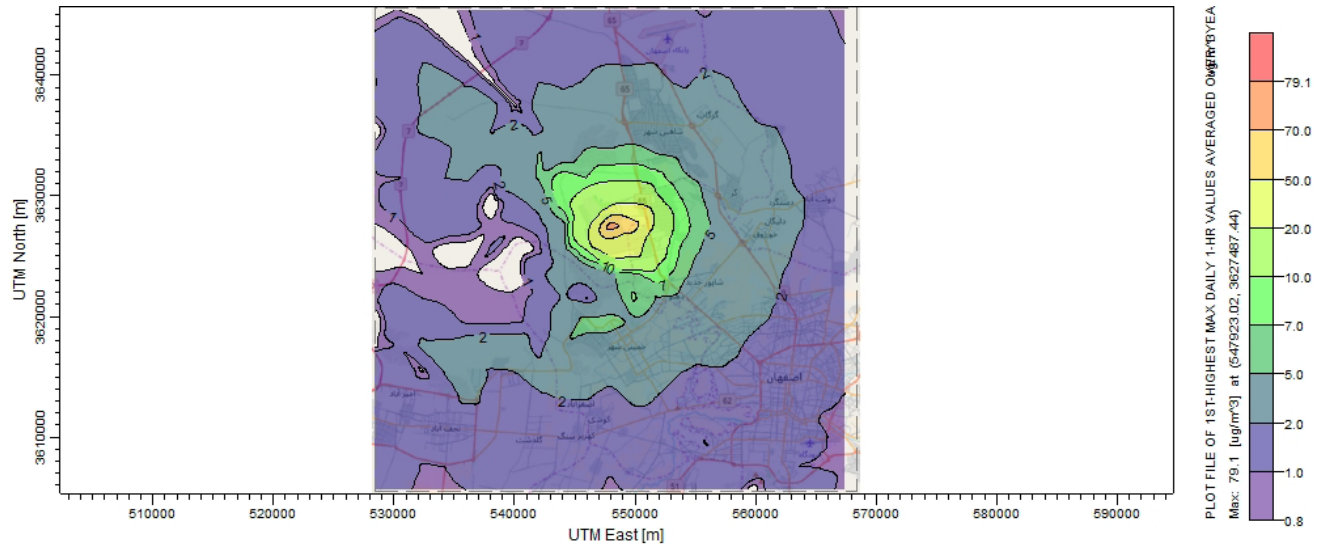

Fig. 8. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in September

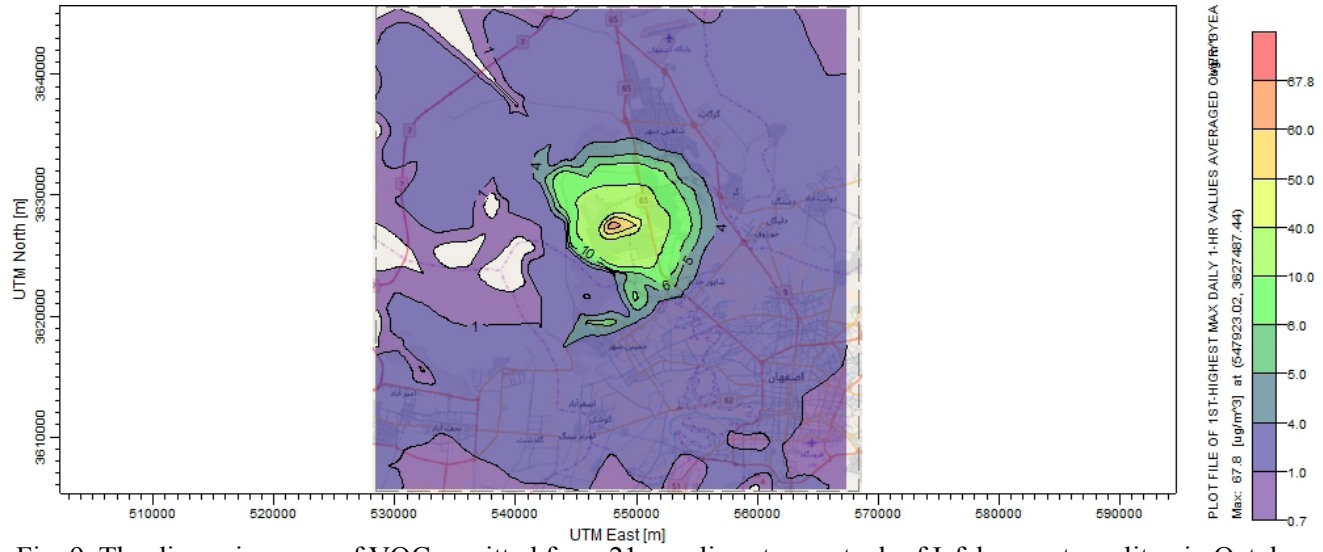

Fig. 9. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in October

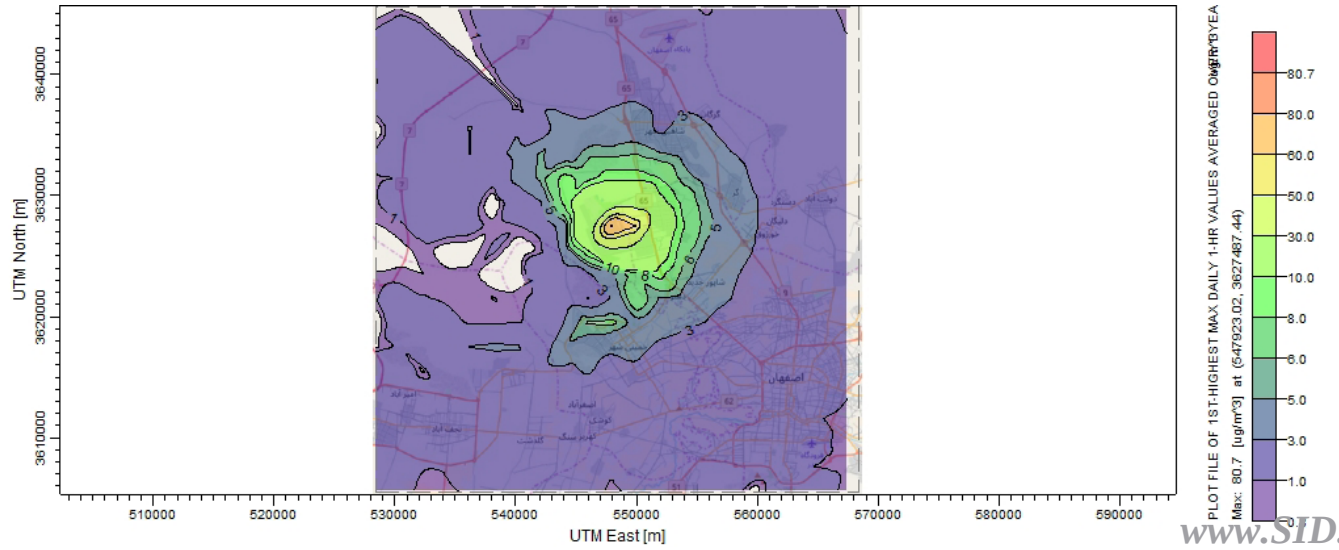

Fig. 10. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in May

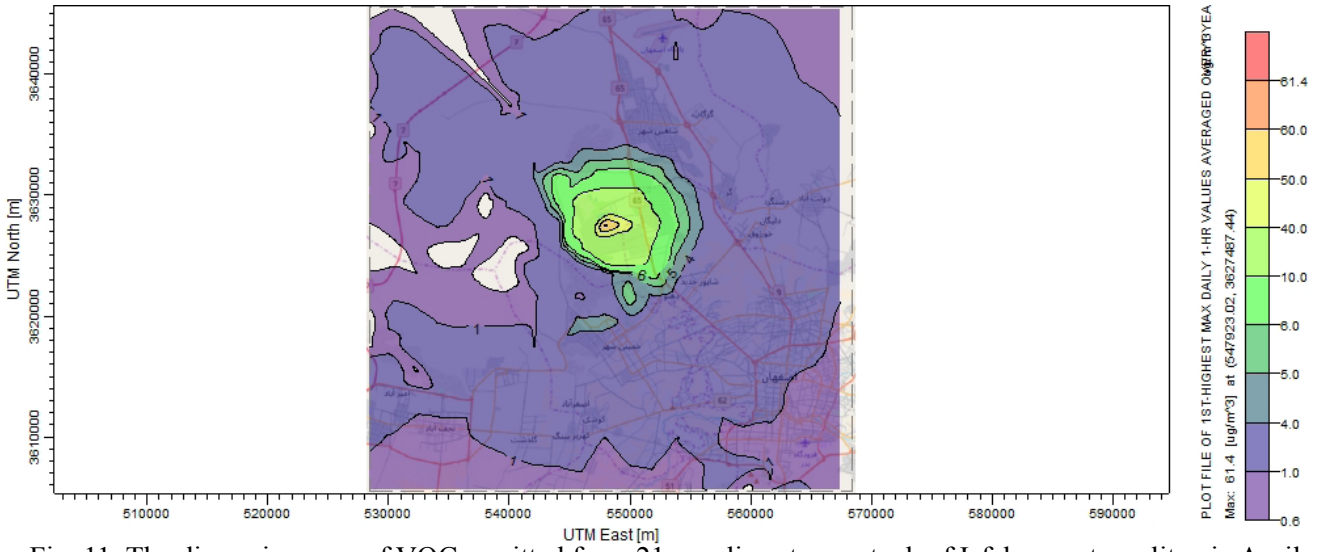

Fig. 11. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in April

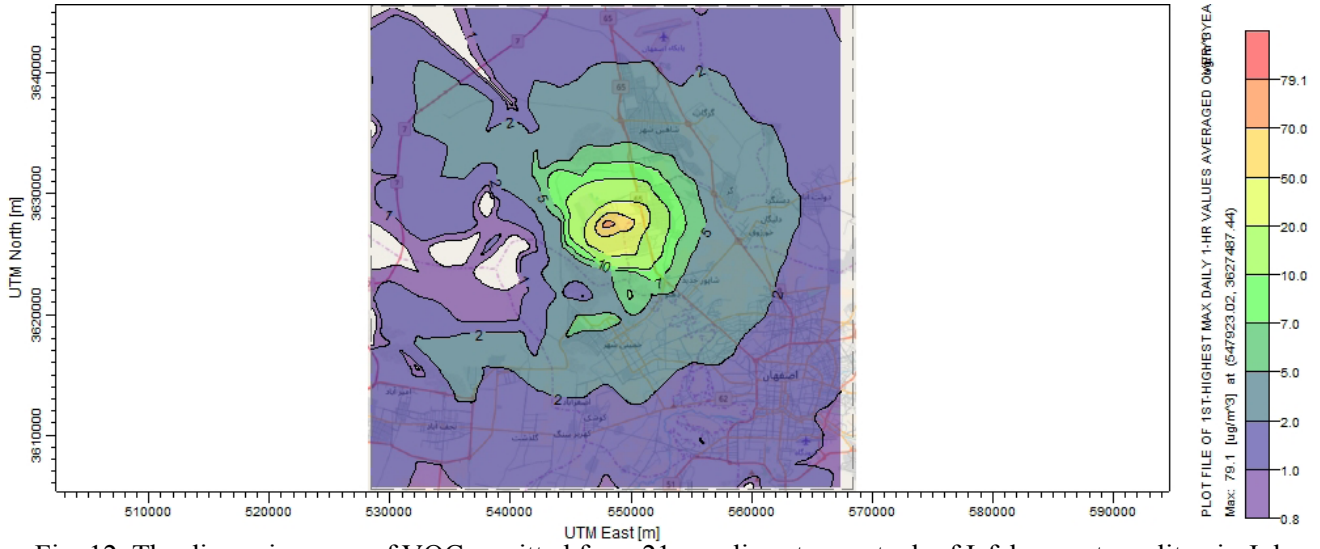

Fig. 12. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in July

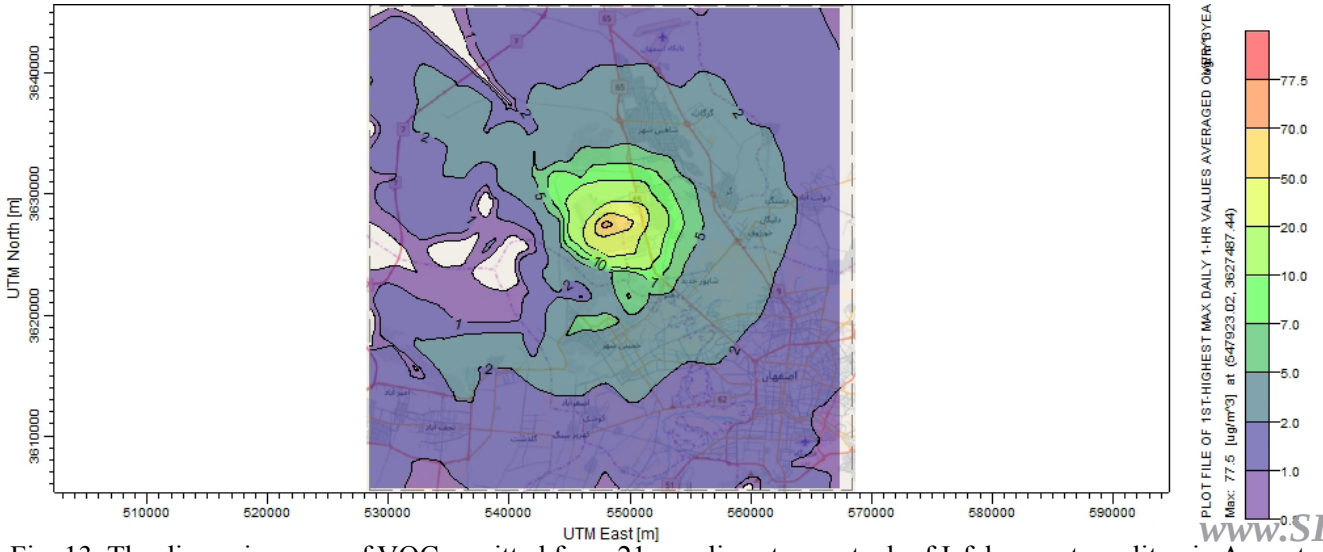

Fig. 13. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in August

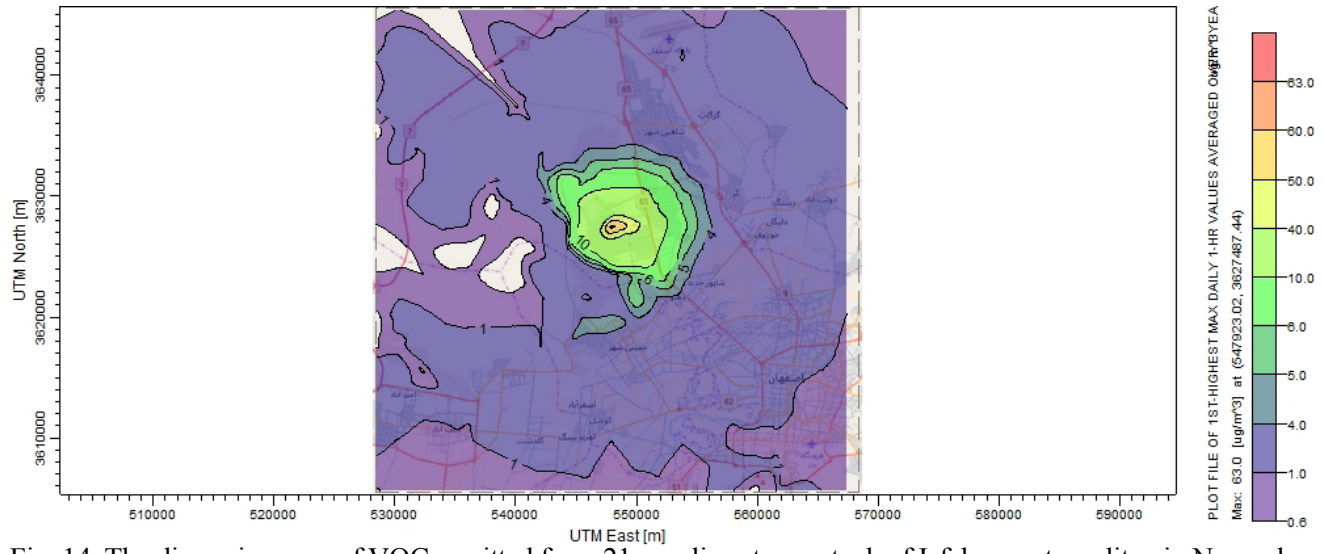

Fig. 14. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in November

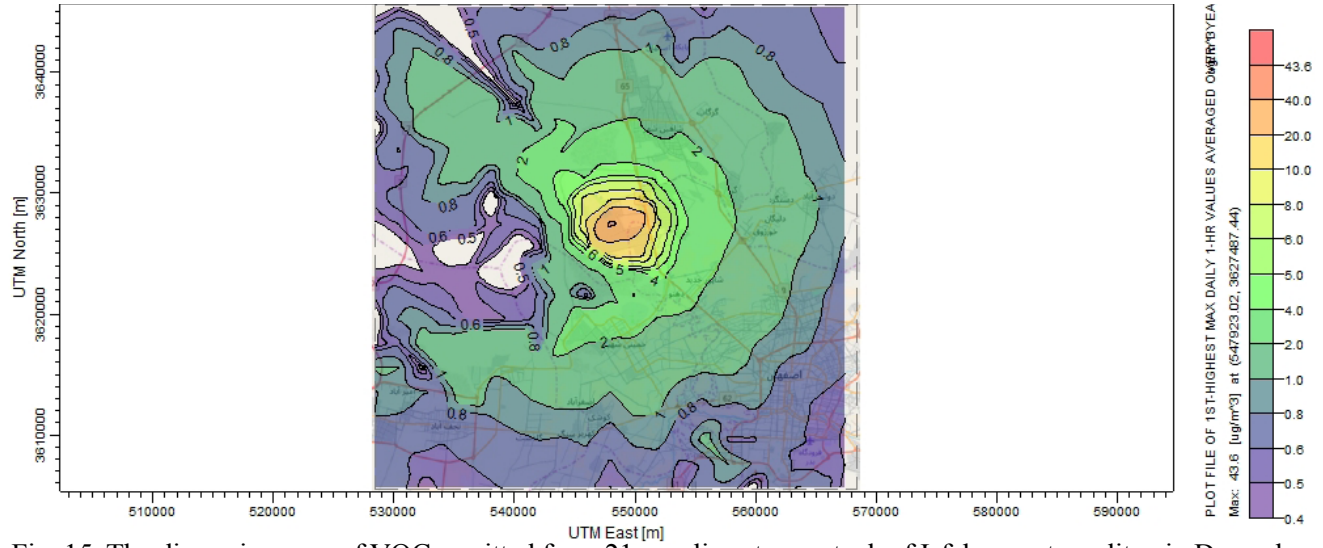

Fig. 15. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in December

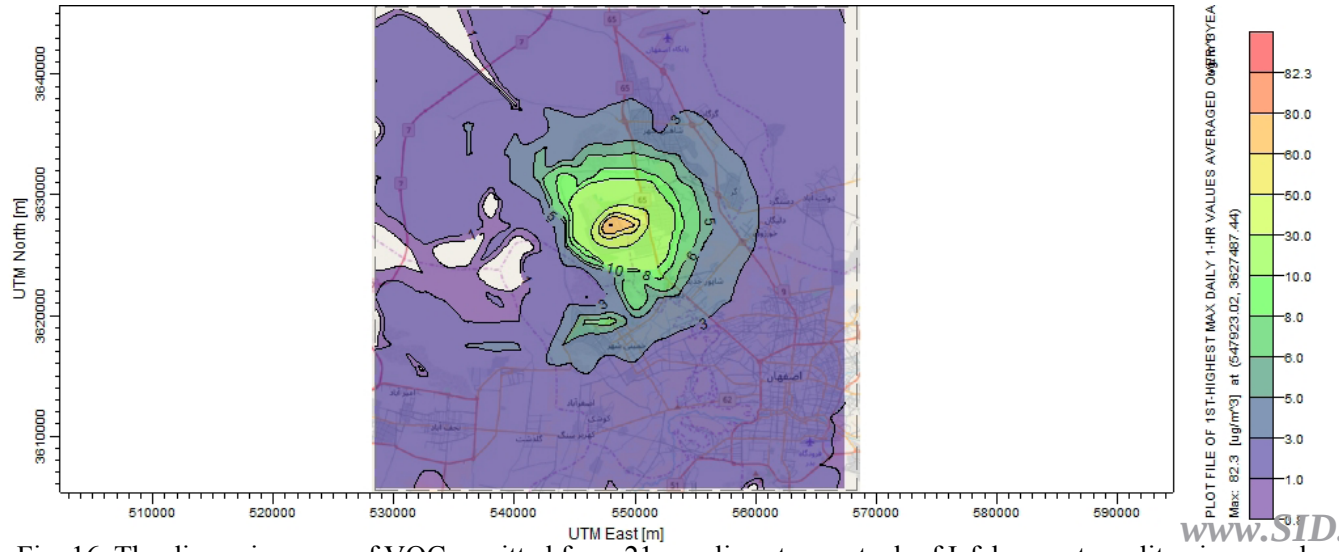

Fig. 16. The dispersion map of VOCs emitted from 21 gasoline storage tank of Isfahan metropolitan in annual

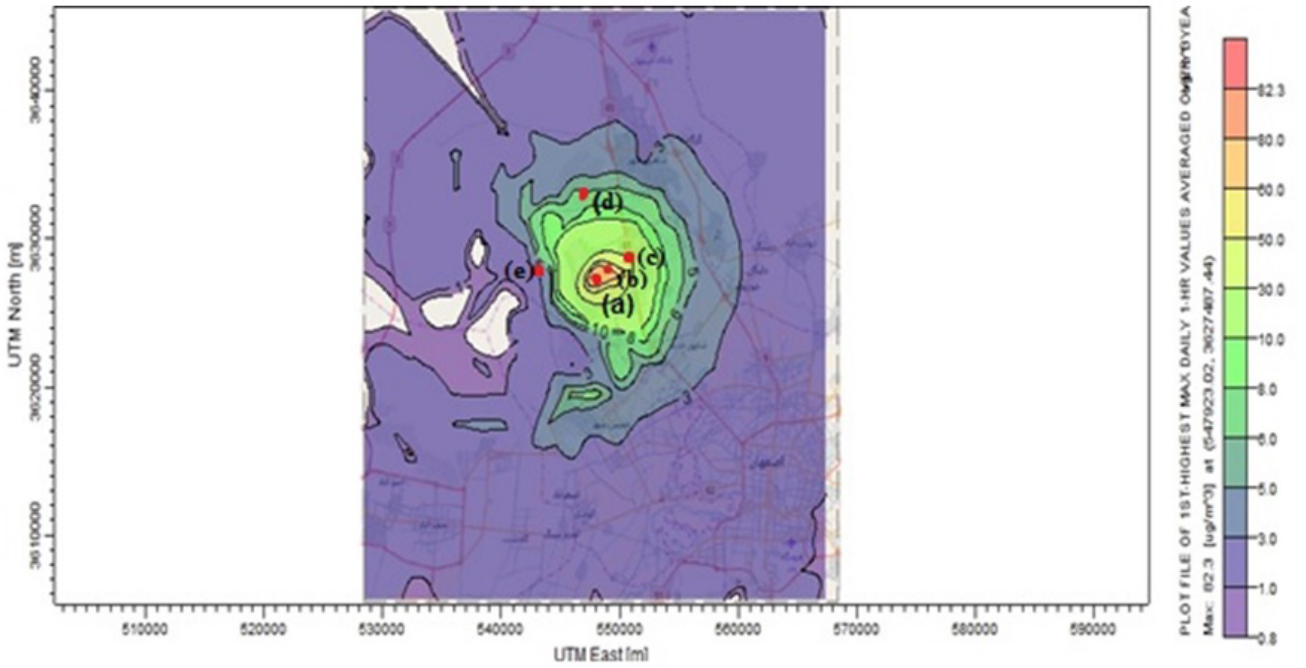

Fig. 17. Locations of VOCs measurement

Table 4. The measured VOCs in four location of Isfahan metropolitan

The total measured VOCs in air (ppm)	The estimated concentration of VOCs emitted from gasoline storage tank of Isfahan metropolitan	Locations
10	0.00008-0.000082	a
9.8	0.00005-0.000082	b
8.8	0.00001-0.00003	c
6	0.000008-0.00001	d
5.5	0.000005	e

CONCLUSIONS

The results of this study showed that 154618081 g of VOCs from gasoline storage tanks of Isfahan metropolitan are emitted into the atmosphere. 2730472 g of the VOCs are emitted from withdrawal loss of gasoline storage tanks and 151887608 g of VOCs are emitted from Rim seal loss. 99.9 % of the total VOCs emitted into the atmosphere is emitted form Rim seal loss of gasoline storage tanks. VOCs emissions from gasoline storage tanks in various months of the year were different. The highest rate of VOCs emission was in June. In this month, 12539772 g of VOCs were emitted from gasoline storage tanks. Modeling the distribution of VOCs in the atmosphere showed that significant amounts of VOCs can reach the Isfahan metropolitan and surrounding cities. The average annual concentration of VOCs in the atmosphere was estimated between 0.3 and 5 μg / m^3 for Khomeini Shahr and Shahin Shahr cities. The average annual concentration for Isfahan metropolitan was estimated between 0.8 to 3 μg / m^3 (Fig. 16). The results showed that about 0.001% of the VOCs emitted in Isfahan metropolitan are related to the gasoline storage tanks.

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COMPETING INTERESTS

The authors declare that there is no conflict of interest that would prejudice the impartiality of this scientific work.

AUTHOR'S CONTRIBUTIONS

It is certified that all of the authors have made the same contribution in the experiments and manuscript writing.

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ETHICAL CONSIDERATIONS

Authors are aware of, and have complied with, best practices in ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests and compliance with policies on research ethics. Authors adhere to publication requirements that the submitted work is original and has not been published elsewhere in any language.

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