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Distribution of Total Volatile Organic Compounds at taxi drivers in Tehran

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ABSTRACT

Air pollution is currently the most serious environmental health threat worldwide. Volatile Organic Compounds (VOCs) are considered as the main effective factors in causing air pollution. Vehicles are among the major sources which emit these compounds, so it seems that automobiles' microenvironment is one of the places where people are exposed to high concentration of VOC. Evaluating the exposure amount of Total Volatile Organic Compounds (TVOC) can indeed be used as an indicator to estimate the amount of exposure to every individual VOC. This study was conducted on the concentration of TVOC inside Tehran taxies for a period of one year. For this purpose, a real time instrument equipped with photo-ionization detector (PID) was used. Consequently, the highest and the lowest measured TVOC in taxies equaled 3.33 ppm and 0.72 ppm, respectively. In addition, the arithmetic mean of TVOC concentration was 1.77±0.53 ppm inside the examined taxies. In this study, the parameters like measurement time, climate and vehicle conditions were found to have significant effect on the amount of exposure to TVOC.

Key words: TVOC, Taxi driver, Tehran, Occupational Exposure

INTRODUCTION

It is currently stated that developing urbanization and industrialization is declining atmosphere quality [1-3]. According to World Health Organization (WHO), approximately 7 million people died because of air pollution exposure in 2012 [4].

Volatile Organic Compounds (VOC) are significant participants in air pollution [5]. These compounds are potential to cause severe damage which affects the environment and human health. In numerous researches, the relationship between VOC and their harmful health effects was illustrated. These hurtful effects were ranged from fatigue and lack of comfort to central nervous system toxicity. Also, carcinogenic effects of some of these compounds like benzene were defined and declared. [6-17]. Additionally, VOC were known as preliminary factors which make photochemical smog and ozone [18-20]. Moreover, even low VOC concentration can have remarkable impact on plant lives and soil quality [21].

According to several researches, vehicles are one of the main leading sources in generating and emitting VOC [22-24]. In modern civilizations, people are increasingly spending more than an hour inside the vehicles when they are commuting [25]. So it seems that the inner part of vehicles is directly affected by pollutants, so it is a particular microenvironment with high VOC concentration.

Hazardous pollutants such as VOC are accumulated inside the cars, especially in heavy traffic. Consequently, air quality is worth in vehicles than in ambient air and it causes that drivers and commuters experience high level of pollutant concentration [26]. Due to the importance of some VOC such as benzene, toluene, ethyl benzene, and xylenes (BTEX), most of the previous studies had been carried out on these cases and they reported that drivers and passengers were exposed to a wide variety of compounds [27-34]. Furthermore, interactions among substances and the effects of chemical mixture like additive, synergistic, potentiating, or antagonistic should not be underestimated [17, 34]. Likewise, identifying and measuring individual VOC are expensive, time-consuming, and demanding, however measuring the amount of TVOC can contribute significantly to the initial assessment of exposure to mixture substances. Generally, few studies have been performed in

association with TVOC effects. In some of these studies, several effects such as chest tightness, upper respiratory symptoms, sick building syndrome, and even increasing cancer risk were mentioned [6, 11, 35].

Tehran ,the capital of Iran, is one of the metropolises in the world with more than 8 million population [36]. It is 700 square kilometers and is close to Alborz mountain range [23]. Tehran has been one of the most polluted cities for several reasons. In fact, there are five thousand industrial units in Tehran and 70% of all services and facilities are offered in this megacity. It is also worth mentioning that there are 4 million vehicles such as cars, trucks, and motorcycles moving in the city every day [37]. Meanwhile, there are approximately 87,000 taxis working on the streets of Tehran [38]. So, this investigation aimed to evaluate taxi drivers' and consequently passengers' exposure to TVOC as one of the main participants in air pollution and accordingly, as an indicator to estimate the amount of exposure to every individual VOC in taxis in Tehran.

MATERIAL AND METHODS

Study site and sampling design

As it is shown in Fig. 1, a downtown area which was about 32 square kilometers was considered for this study. Actually, there was traffic restriction for vehicles in this area which was conducted from 6 AM to 5 PM. Finally, 16 main streets among all paths were selected in this area. 72 volunteer male taxi drivers participated in this study for 72 days from November 2009 to October 2010 (the last week of each month, from Saturday to Thursday). All vehicles used gasoline. Sampling was done in rush hours from 9 a.m. to 1p.m. and from 4 p.m. to 8 p.m.

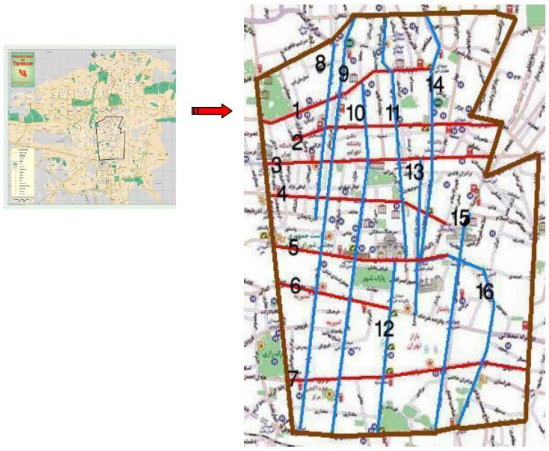

Fig. 1: The studied region and measurement locations (including 16 main streets)

Before sampling, a questionnaire was filled in by drivers. The questionnaires consisted of participant's age, their working hours, their working experience, and their vehicle information.

Temperature and relative humidity were recorded in and out of vehicle incessantly. Moreover, metrological information of wind speed, relative humidity, temperature, and atmospheric conditions was recorded by the automatic metrological station in Tehran which was managed by the municipality of Tehran.

Air sampling and analysis

A direct reading instrument equipped with photo-ionization detector (PID) lamp (FirstCheck 5000+ Made by IonScience–UK) was used for sampling. PID relies on specific chemical properties of the VOC. PID uses an ultraviolet light source to ionize VOC and measures the charge of ionized gas while the charge is the function of VOC concentration in the air. Considering that this device cannot distinguish different VOC, all evaluated amounts of volatile organic compounds were entitled TVOC. In each sampling, the instrument probe was located in driver's breathing zone and the measured values were recorded every 30 seconds. According to the manufacturer's recommendations, the instrument was calibrated by Isobutylene before each sampling [39].

To evaluate the correlation between the obtained data from portable gas detector and Individual exposure to ambient concentrations of BTEX, the amounts of these compounds were assessed by gas sampling charcoal tube during sampling and were analyzed by the use of gas chromatograph with flame ionization detector (GC/FID). Totally, 35 samples were attained and examined [40].

All statistical analyses were done by SPSS-16. Also the value of $P<0.05$ was considered statistically significant.

RESULTS

The average age of 72 participated drivers in this study was 43.79±9.05 while it was ranged from 22 to 66. Furthermore, the arithmetic mean of the years of drivers' working experience was 9.20±8.08. The life-long mean of examined taxies was obtained 2.18±1.88 years while none of them was more than 9 years old.

In-vehicle TVOC levels

Among 20819 data which were measured per 30 seconds inside the taxies, the highest and the lowest value of TVOC was obtained respectively 13.68 ppm and 0.05 ppm. Daily mean of measured TVOC equaled 3.33 and 0.72 ppm for the highest and the lowest exposure, respectively. Eventually, the

arithmetic mean of TVOC concentration was calculated 1.77±0.53 ppm inside taxies for a period of 72 days.

In addition, the amount of TVOC that the drivers were exposed to in mornings and evenings was 1.66±0.77 and 1.87±0.81 ppm, respectively. Also, an independent Samples T-Test confirmed that drivers experienced more TVOC in the evening hours than in the morning ones (P<0.001).

Weekdays and TVOC level

One way ANOVA test showed significant difference between the concentrations of TVOC through the weekdays.

As it is shown in Fig. 2, the highest TVOC concentration in the vehicle cabin was found on Saturdays whereas the lowest one was recorded on Thursdays. (1.91±0.98 and 1.59±0.59 ppm, respectively)

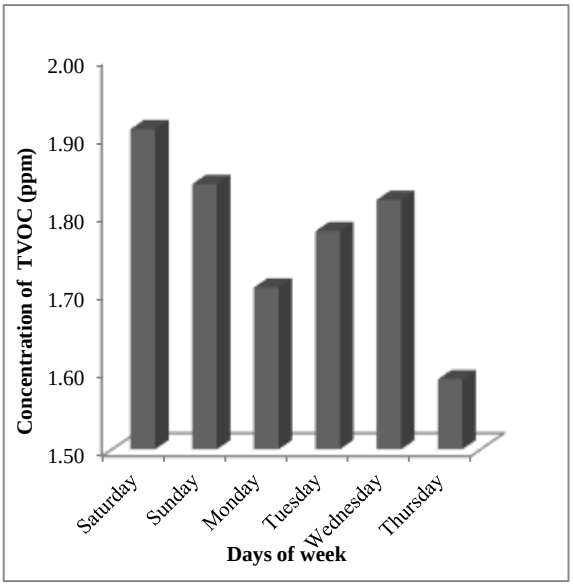

Fig. 2: TVOC concentration (ppm) in taxis according to weekdays

The relationship between months and the level of TVOC In vehicles

Different amounts of TVOC were experienced by drivers inside the taxies in different months. One way ANOVA test was performed and it confirmed this difference strongly (P<0.001). Totally, the concentration of TVOC in taxis was higher in cold months than in warm months.

Atmospheric condition and TVOC level

Taxi drivers' exposure to TVOC was analyzed in different climate including sunny, semi cloudy, cloudy, haze, and rainy weather. The highest exposure went to haze condition while the amount of exposure decreased dramatically in rainy days. The amount of concentration which the drivers were exposed to in haze and rainy weather was 1.88±0.70 ppm and 1.57±0.61 ppm, respectively.

The relationship between TVOC and vehicles' type and their life-long

In this study, the concentration of TVOC was assessed in two types of vehicles (Samand and Peugeot) that were used as main vehicles in Taxi fleet of Tehran. The lowest exposure level of TVOC was found in Samand while taxi drivers were exposed to the highest level of TVOC in Peugeot (1.68±0.85 and 1.80±0.80 ppm respectively). Also, vehicles with more than 2 years old demonstrated higher exposure in comparison with vehicles with less than 2 years old.

Path types and TVOC levels

Higher concentration of TVOC was observed in north-south routes in comparison with east-west ones albeit this difference was not significant. Also path details including street type, bridge, underpass, traffic light, and passengers' getting in and out of taxies were analyzed. As it is demonstrated in Fig. 3, the highest level of TVOC belonged to the time that the vehicles started again after stopping behind traffic lights.

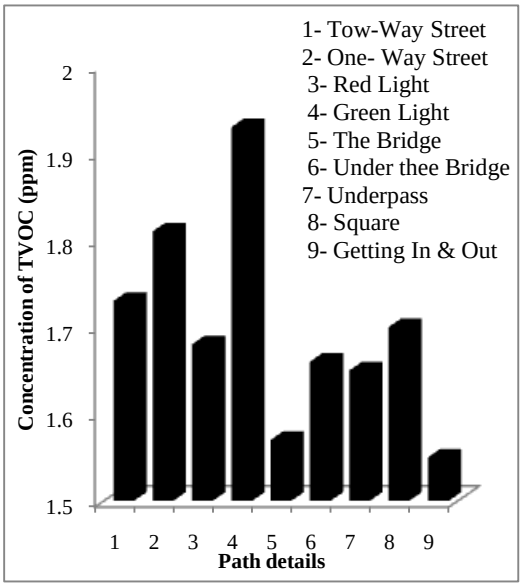

Fig. 3: TVOC concentration (ppm) in taxis according to path details

Correlation

Pearson Correlation test illustrated significant correlation between the measured TVOC in taxis and individual VOC concentration obtained from activated charcoal tubes (BTEX). Pearson Correlation coefficients for X, E, and T was respectively 0.714, 0.673, and 0.667 with P<0.001. About Benzene, despite the fact that its coefficient

correlation equaled 0.349, it was statistically significant (P=0.04).

DISCUSSION

There are thousands of VOC while a number of them have been known as particular health threat with definite exposure guidelines. However, no standard has been set for VOC in non-industrial settings [41]. Vehicles are the main factors which cause air pollution; consequently, high concentration of contaminants inside the vehicle is not unexpected. More than 260 VOC, were identified inside automobiles [51]. According to the suggestion of Molhave [17], a comfort range for TVOC concentration is <0.2 mg/m^3. So our findings showed that drivers experienced high concentrations of VOC inside their cars during the days (1.77 ppm ~ 6.69 mg/m^3). It appears that accumulation of contaminants in the closed space of the vehicle and lack of adequate ventilation are the main reasons of high exposure in vehicle cabins. As it was mentioned before, Motor vehicles, as the main reasons in producing and releasing these contaminants, are exactly in the center of such pollution and they are affected the most by the pollutant air. Moreover, while Tehran has the capacity for just about 700000 cars, we observe a lot more cars than this [42]. Thus, low car speed as the effect of high traffic volume can prevent air circulation which itself leads to increasing pollutants.

The present study demonstrated that exposure to TVOC inside the taxis elevated in the evening hours. In fact, traffic congestion and high amount of commuting in rush hours caused more TVOC in evening than in morning. However, it should be mentioned that domestic sources played significant role in concentrating TVOC inside the cars.

Saturdays as the first working day in the week led to increasing activities and Thursdays as the last working days led to decreasing activities, so as it was predictable, they allocated the highest and the lowest TVOC, respectively.

As it was illustrated in the results, there were some fluctuations in TVOC concentration during the year. The concentration was higher in cold months than in warm ones. Tehran experiences the inversion phenomenon for more than 200 days annually [43] due to its geographical conditions. This is mainly observed in cold months [44], so we can see an increasing air pollution in the inversion phenomenon . Moreover, when it is cold, all windows of vehicles except the front one are closed and intense accumulation of pollution can be observed inside the cabin. Different traffic patterns during the year which can be the result of school schedule, New Year feast, Ramadan, and the same were among other reasons of the fluctuations in TVOC concentration.

The findings of this study showed the effects of different climatic conditions on the level of exposure to TVOC. According to the results, the lowest exposure to TVOC in vehicles was obtained in rainy days. Rain is the most important natural cleaners and greatly reduces the amount of air pollutants.

Body of cars and technology of engines could be possible reasons for different pollutant levels in the examined vehicle types. Furthermore, vehicle depreciation, exhaustion of body of cars, and greater penetration of pollutants on the one hand and poor maintenance and low-quality services on the other hand, can cause high concentrations of pollutants in older vehicles.

The results of correlation test performed between TVOC and some dangerous volatile organic compounds (BTEX), showed a direct and statistically significant relationship. This means that increasing exposure to TVOC is an alarm for exposing to dangerous and even carcinogenic compounds such as Benzene. As an instant, Costagliola and his colleagues stated in their study that Carcinogenic VOC showed the same pattern of total VOC [45] and Guo claimed that road commuters were endangered to cancer more than railway drivers [35].

The findings of several studies conducted by researchers in various areas, confirmed the results of the present investigation. Among those results, density of vehicles, measurement period, atmospheric conditions, and some other related factors to vehicle can be mentioned. [26, 29, 42, 46-51]

CONCLUSION

On the base of current study, taxi drivers and accordingly, passengers' exposure to VOC is really high in Tehran. Several factors were examined in association with high concentration of VOC. Variables like traffic density, weather condition and vehicle type affected the concentration of air pollution in taxies. In conclusion, according to the results of correlation between the measured TVOC in taxis and individual VOC concentration that was obtained from activated charcoal tubes, TVOC can possibly be used as an indicator to estimate the amount of exposure to VOC inside the vehicle cabin.

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ETHICAL ISSUES

Ethical issues such as plagiarism have been observed by the authors.

COMPETING INTERESTS

Authors declare that there is not any competing interest.

AUTHORS' CONTRIBUTIONS

Kakooei was designer and leader of the study. Golhosseini conducted the study. Shahtaheri and Rezazadeh Azari were advisors of air sampling and analyzing. Azam was statistic advisors.

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