scientific reports

Check for updates

OPEN

Assessment of health risks of university professors through exposure to BTEX compounds from white board markers

Roohollah Ghasemi[1], Behzad Saranjam[1], Ahmad Zarei[2], Amin Babaei[1], Hamid Reza Ghaffari[3,6]✉ & Mehdi Fazlzadeh[4,5,7]✉

This case-control study aimed to investigate the health risks faced by university professors as a result of using whiteboard markers. The study included 30 professors who used the whiteboard markers for teaching and 20 professors who used other teaching aids. Samples of urine and breathing air were collected from the participants, and then analyzed in the laboratory using gas chromatography (GC) to measure the concentrations of BTEX compounds. The carcinogenic and non-carcinogenic risks of these compounds were assessed using a probabilistic method. The mean concentrations (ug/L) of compounds in the urine differed significantly ($p < 0.05$) between the case and control groups for benzene (82.59 vs. 65.36), toluene (128.47 vs. 85.65), and ethylbenzene (9.09 vs. 25.16). The mean lifetime cancer risk (LTCR) for benzene (8.27×10^{-8}) and ethylbenzene (9.38×10^{-8}) as well as the non-carcinogenic risk of all compounds in the control group were below the acceptable limit. Due to the higher concentration of compounds in the urine of the case group compared to the control group, it is essential to utilize alternative teaching methods in educational settings instead of traditional whiteboards and chemical markers.

Keywords Classrooms, BTEX, University professors, Health risks

Technology has played a significant role in education from ancient times to the present. Various tools such as slates, blackboards, green board, brown boards, whiteboards, and interactive boards have been used to enhance the learning experience. Whiteboards, also known as dry-erase boards, began to be utilized in the late 1980s. These boards have a smooth, glossy white surface that is suitable for writing on. Instead of chalk, whiteboard markers are used for writing. Due to concerns about the health effects of chalk and the cost-effectiveness, most classrooms had transitioned from blackboards to whiteboards by the 1990s [1].

Even though the application of the new technologies encountered resistance by some teachers [2], numerous studies have shown that many teachers have a positive attitude toward their use [3–5]. Nowadays, teachers commonly use a variety of dry-erase markers to write on whiteboards [6]. The whiteboard markers contain organic solvents in their inks, which can pose various health risks for users, such as central nervous system toxicity, respiratory effects, and eye irritation [7]. When teachers use markers in the classroom, they may be exposed to various chemicals, including solvents, fragrances, and other volatile organic compounds (VOCs) [8,9].

A study found 60 chemicals, such as carbonyls and a large number of other VOCs, in the emissions from markers that are frequently used in schools [10]. VOCs can be easily evaporated while using markers to write on a whiteboard. Given that inhalation is the primary route of exposure, teachers are at risk of inhaling these substances emitted by markers. Benzene, toluene, ethylbenzene, and xylene, known as BTEX, are a significant group of VOCs that have been the subject of numerous toxicological and health studies [11–14]. Additionally,

[1]Department of Occupational Health Engineering, School of Public Health, Ardabil University of Medical Sciences, Ardabil, Iran. [2]Department of Environmental Health Engineering, School of Public Health, Gonabad University of Medical Sciences, Gonabad, Iran. [3]Social Determinants in Health Promotion Research Center, Hormozgan Health Institute, Hormozgan University of Medical Sciences, Bandar Abbas, Iran. [4]Social Determinants of Health Research Center, Ardabil University of Medical Sciences, Ardabil, Iran. [5]Lung Diseases Research Center, Ardabil University of Medical Sciences, Ardabil, Iran. [6]Department of Environmental Health Engineering, Faculty of Health, Hormozgan University of Medical Sciences, Bandar Abbas, Iran. [7]Department of Environmental Health, School of Health, Ardabil University of Medical Sciences, Ardabil 5615731567, Daneshgah St, Iran. ✉email: ghaffarihrz@gmail.com; m.fazlzadeh@gmail.com

previous studies have shown that BTEX can have various effects on human health ranging from minor symptoms such as fatigue, loss of appetite, confusion, infertility reduction, and weakness to different types of cancer [12,14–17]. Exposure to toluene can affect on premature delivery as well as the neurobehavioral and reproductive systems [18,19]. International Agency for Research on Cancer (IARC) has classified benzene as a known carcinogen (group 1) and Ethylbenzene as a possible carcinogenic agent to humans (group 2B) [20,21].

Most of the teachers in classrooms lack safety training and are therefore not well-informed about the health risks of using whiteboard marker pens [22–24]. Information about the chemical components in markers is accessible in Safety Data Sheets (SDSs); although, SDSs often do not make a complete list of components and do not provide possible contaminants or by-products in solvent mixtures [10].

Currently, there is limited research available on BTEX emissions from markers and the potential health effects of exposure to these air pollutants. This study focuses on analyzing the levels of BTEX emissions from markers frequently used by Iranian university teachers. Additionally, the study aims to evaluate the real exposure levels to BTEX compounds emitted by these markers and their associated health risks for the user.

Materials and methods

Study population

The present study is cross-sectional research carried out to evaluate the potential exposure of professors to BTEX compounds in the university located in Ardabil, Iran. The study involved 30 professors selected as the case group, who used various types of markers in their teaching methods. Additionally, a control group of 20 office workers who did not use markers was included in the study.

Demographic and other personal characteristics of the participants, including age, weight, height, job, history of teaching (year and teaching time (h/day) were collected through a questionnaire.

The research was approved by ethical committee of Ardabil university of medical sciences (IR.ARUMS.REC.1398.403) and all the experiments were performed in accordance with relevant guidelines and regulations of ethical committee. The participants filled informed consent form before entering into the study.

Air sampling and analysis

Air sampling and analysis was done in academic seasons (autumn and winter). Air sampling was conducted in accordance with the NIOSH 1501 method, utilizing a sampling pump and a charcoal sorbent tube from the standing breathing zone of the selected individuals [25]. Air sampling was performed at a flow rate of 0.2 l/min for 50 min to collect a total air volume of 10 l. The details of air sampling techniques were fully explained elsewhere [25].

For sample analysis, briefly, the charcoal was placed in 5 ml screw-top glass vials. 2 ml of carbon disulfide (CS_2) was added to each vial and then the vials containing CS_2 and charcoal were shaken for 30 min using an ultrasonic agitation device. The extracted samples were then analyzed using gas chromatography (GC Agilent 7890) equipped with a flame ion detector (FID) and capillary column (30 m, BD-5). The details of samples analysis were fully described in Mokammel et al. [26].

Quality control

The calculated LOD and LOQ were 0.03 and 0.05 μg/m^3 for benzene, 0.03 and 0.06 μg/m^3 for toluene, 0.04 and 0.11 μg/m^3 for ethylbenzene and 0.02 and 0.05 μg/m^3 for xylene, respectively. Also, recovery of analytical method was tested by injecting 10 μg of BTEX compounds into fresh charcoal tubes. On average, a recovery rate of 93% (ranging from 81 to 110%) was obtained for BTEX compounds.

Urine sampling and analysis

Spot urine samples were also taken from both the case and control groups at the end of the work shift on the weekend. Several n-hexane solutions with specified concentrations of BTEX were prepared and injected into GC-MS (Agilent, USA). A nonpolar 30 m × 0.25 mm capillary column at constant helium (> 99.999%) flow rate of 1.0 mL min^{-1} was used for chromatographic separation. Extraction and analysis of samples has been done according to the previous study [27]. The calculated LOD and LOQ (Calibration standards in n-hexane = 10, 20, 50, 100, and 200 ng/L) for benzene (1.59, 4.76), toluene (0.07, 0.22), ethylbenzene (0.03, 0.08), and xylene (0.02, 0.06) were applied to purification of the resulted concentrations in the samples.

Health risk assessment

Quantitative risk assessment was done according to the US Environmental Protection Agency (EPA) method. Hazard ratio (HQ), as the non-carcinogenic index, and lifetime carcinogenic risk (LTCR) was calculated BTEX.

According to this methodology, estimated daily intake (EDI, mg/kg.day), and exposure concentration (EC, μg/m^3) were calculated as follows:

$$EDI = \left(\frac{C \times IR \times ET \times EF \times ED}{BW \times AT}\right) \quad (1)$$

$$EC = \left(\frac{C \times ET \times EF \times ED}{AT}\right) \quad (2)$$

where C (mg/m^3) is pollutant concentration, IR (m^3/day) is inhalation rate of adults, ET (hr/day) is the exposure time, EF (day/year) is the exposure frequency, ED (year) is the exposure duration, BW (kg) is body weight and AT (hr) is the averaging time. For assessing the non-cancer risk, the HQ was obtained as follows:

$$HQ = \frac{EDI}{Rfd} \tag{3}$$

where Rfd (mg/kg.day) is the reference dose which was calculated from inhalation reference concentration (RfC) by the Eq. (4) as follows:

$$Rfd = \frac{Rfc \times 20}{70} \tag{4}$$

where 20 is the inhalation rate in m^3/day and 70 is the body weight of adults in Kg. By summing the HQ of each BTEX compound, the Hazard Index (HI) for BTEX was obtained. U.S. EPA presumed that the likelihood of noncarcinogenic risk is low when HQ or HI < 1. It indicates that long term exposure may not result in adverse health effects. Otherwise, HQ or HI > 1 show that the occurrence of non-carcinogenic effects is possible and the probability will be increased at higher risk levels [28,29].

For assessing the cancer risk of benzene, as a known carcinogen, LTCR was calculated using Eq. (5):

$$LTCR = EC \times UR \tag{5}$$

where IUR (m^3/μg) is the inhalation unit risk. LTCR is the probability for an individual to develop an additional cancer as a result of lifetime exposure to a carcinogen. According to U.S. EPA LTCR > 1.0E-04 is considered as an unacceptable level which show high risk of cancer. For regulatory purposes, the LTCR values ranged from 1.0E-06 to 1.0E-04 is known as an acceptable or tolerable range [29]. The risk parameters applied to estimate non-carcinogenic and carcinogenic risk (HQ and LTCR) of BTEX were presented in Table 1.

Results and discussion

Study population characteristics

Table 2 shows the demographic characteristics of the control and case groups. The average age is 40.53 years in the case group and 40.4 years in the control group. The independent t-test showed no significant difference ($p > 0.05$) in demographic characteristics (age, weight, height, and BMI) between the control and case groups.

Urinary BTEX concentration

Table 3 shows the concentrations of BTEX compounds in the urine of both the case and control groups. The average concentrations (μg/l) of benzene (82.59 ± 21.63 vs. 65.36 ± 15.22), toluene (128.47 ± 42.67 vs. 85.65 ± 24.52), ethylbenzene (9.09 ± 11.65 vs. 25.16 ± 21.62), xylene (64.45 ± 28.29 vs. 55.59 ± 24.06), and total BTEX (284.6 ± 94.17 vs. 231.76 ± 70.23) show a statistically significant difference ($p < 0.05$) between the case and control groups. However, there is no statistically significant difference in the concentration of urinary xylene (64.45 ± 28.29 vs. 55.59 ± 24.06) between the two groups ($p > 0.05$).

Parameter	Probability distribution	Statistical Parameters	Reference
Benzene concentration (mg/m^3)	Log normal	Mean: 0.0058 Std: 0.0026	This study
Toluene Concentration (mg/m^3)	Log normal	Mean: 0.0301 Std: 0.0088	This study
Ethylbenzene concentration (mg/m^3)	Log normal	Mean: 0.0011 Std: 0.0013	This study
Xylene concentration (mg/m^3)	Log normal	Mean: 0.0134 Std: 0.0054	This study
Inhalation rate (m^3/day)	NA	18.7	IRIS EPA
Body weight (Kg)	Log normal	Mean: 75.67 Std: 5.77	This study
Exposure Frequency (week/year)	NA	34	This study
Exposure time (h/week)	Log normal	Mean: 3.82 Std: 1.52	This study
Exposure duration (year)	NA	30	IRIS EPA
Averaging time (hour)	NA	Carcinogenic:613,200 Non-carcinogenic: 262,800	IRIS EPA
Inhalation Unit risk (UR) $(\mu g/m^3)^{-1}$	NA	Benzene: 2.2×10^{-6} Ethylbenzene: 2.5×10^{-6}	IRIS EPA
Inhalation reference concentration (RfC)* (mg/m^3)	NA	Benzene: 3×10^{-2}	IRIS EPA
		Toluene: 5	IRIS EPA
		Ethylbenzene: 1	IRIS EPA
		Xylene: 1×10^{-1}	IRIS EPA

Table 1. Risk parameters applied to estimate non-carcinogenic and carcinogenic risk (HQ and LTCR) of BTEX. NA: not applicable.

Characteristic	parameter	Group	*N*	Mean	Std. Deviation	*P*-value
Demographic	Age (year)	Case	30	40.53	3.80	0.944
		Control	20	40.40	9.21	
	Weight (kg)	Case	30	75.67	5.91	0.331
		Control	20	73.80	7.51	
	Height (cm)	Case	30	172.73	5.19	0.851
		Control	20	172.45	5.24	
	BMI (kg/m^2)	Case	30	25.4	2.26	0.449
		Control	20	24.8	2.65	

Table 2. Demographic characteristics of case ($n = 30$) and control ($n = 20$) groups.

Characteristic	Variable	Group	*N*	Mean	Std. Deviation	*P*-value
Urinary concentration (µg/l)	Benzene	Case	30	82.59	21.63	0.003
		Control	20	65.36	15.22	
	Toluene	Case	30	128.47	42.67	< 0.001
		Control	20	85.65	24.52	
	Ethylbenzene	Case	30	9.09	11.65	0.001
		Control	20	25.16	21.62	
	Xylene	Case	30	64.45	28.29	0.256
		Control	20	55.59	24.06	
	Total BTEX	Case	30	284.60	94.17	0.037
		Control	20	231.76	70.23	
Indoor air concentration (µg/m^3)	Benzene	Case	30	5.83	2.62	0.049
		Control	20	4.56	1.25	
	Toluene	Case	30	30.07	8.74	< 0.001
		Control	20	18.70	4.37	
	Ethylbenzene	Case	30	1.13	1.30	0.088
		Control	20	0.54	0.96	
	Xylene	Case	30	13.41	5.29	0.030
		Control	20	10.52	2.80	
	Total BTEX	Case	30	50.43	14.60	< 0.001
		Control	20	34.32	5.82	

Table 3. Concentration of BTEX compounds in the urine and workplace indoor air of case ($n = 30$) and control ($n = 20$) groups.

With the exception of ethylbenzene, the levels of other compounds as well as total BTEX in the urine of the case group were higher compared to the control group. The whiteboard marker ink contains volatile solvent, binder resin, surfactants (fluorinated and non-fluorinated), including a preferred cationic amide oxide, release agent, and poly (oxyalkylene) substitute dye. The solvent evaporates easily, allowing the mark to dry on the surface of the whiteboard. During this process, compounds in the solvent, including volatile organic compounds (VOCs), are released into the air and can easily come into contact with the eyes and skin of teachers. They can also be inhaled or swallowed by teachers and students [30].

To the best of our knowledge, there is no research on the levels of BTEX in the urine of university professors. Previous studies have focused on different occupational groups. For example, Moradi et al. studied the levels of BTEX compounds in the urine of employees working in women's beauty salons. These employees had higher concentrations of these compounds in their urine compared to the university professors in our study.

The elevated levels of these compounds in the urine of beauty salon employees, can be attributed to the variety of cosmetics used, while in classrooms, the sources of these compounds are restricted to the markers and some equipment within the building [31].

Indoor air concentration

Table 3 shows, the concentrations (mg/m^3) of benzene (5.83 ± 2.62 vs. 4.56 ± 1.25), toluene (30.07 ± 8.74 vs. 18.70 ± 4.37) and ethylbenzene (1.13 ± 1.30vs 0.54 ± 0.96), xylene (13.41 ± 5.29 vs. 10.52 ± 2.80) and total BTEX (50.43 ± 14.60 vs. 34.32 ± 5.82) in the indoor air of classrooms of the case group and working place of control groups. as can be seen, the concentrations in the case group is significantly higher than in the control group ($p < 0.05$). Box plots of concentrations of BTEX compounds in urine and indoor air of classrooms for two studied groups are shown in Figs. 1 and 2, respectively.

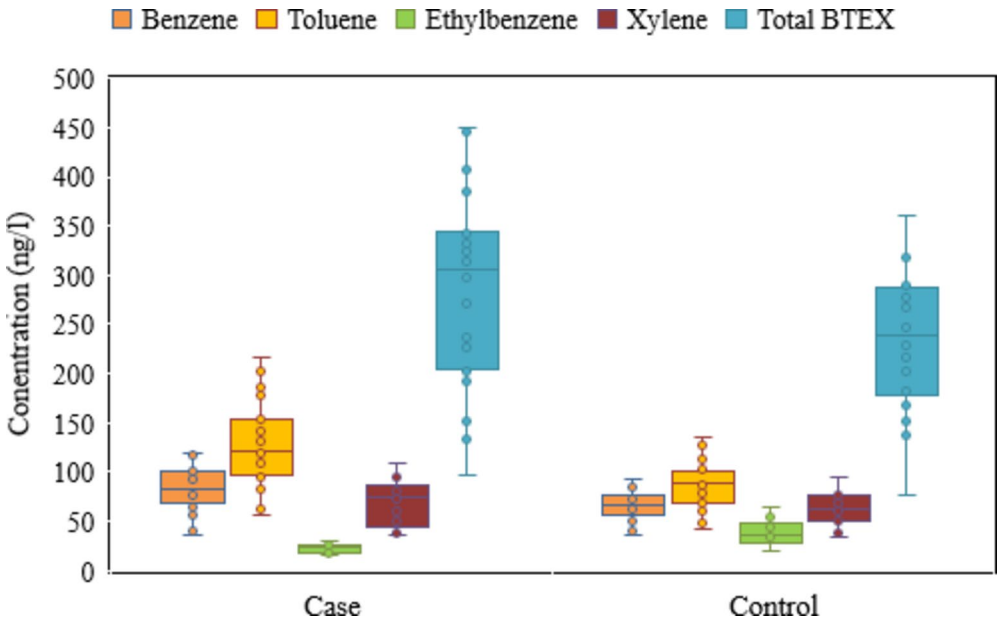

Fig. 1. Urinary concentration of BTEX compounds for case ($n = 30$) and control groups ($n = 20$).

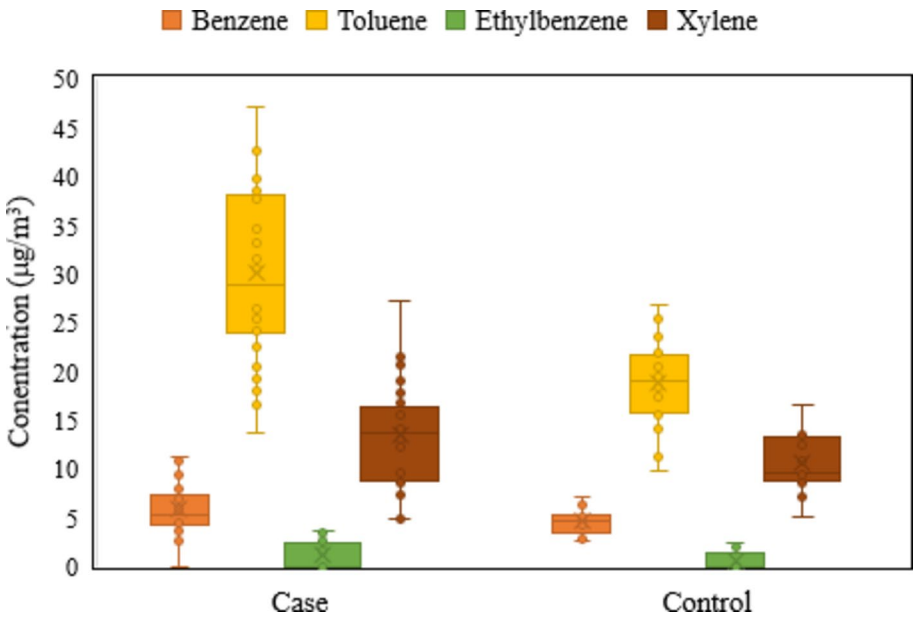

Fig. 2. Indoor air concentration of BTEX compounds for case ($n = 30$) and control groups ($n = 20$).

In a study by Kalinmalee et al., the researchers investigated the concentration of BTEX compounds in the indoor air of university classrooms where blackboard and chalk were used for teaching [32]. The results showed that the concentrations of all compounds, except for ethylbenzene, were lower compared to classrooms with whiteboards and chemical markers in the current study. BTEX compounds in classrooms without whiteboard markers detected by Kalinmalee et al. are due to sources such as vinyl flooring, floor adhesive, solvent-based paints, and cleaning products [33,34]. In addition, new furniture and poor ventilation contribute to the accumulation of these pollutants, particularly volatile organic compounds (VOCs), in indoor air [34].

Also, the findings of this study align with those of Dorizas et al.'s study on indoor air quality in primary schools in Greece. They found that schools using whiteboard markers had higher levels of VOCs compared to schools using chalk. The researchers highlighted whiteboard markers as a significant source of VOC emissions in the indoor air of the classroom [34].

Studies comparing compound VOC and BTEX concentrations in indoor and outdoor classroom air have yielded conflicting results. Guo et al. found indoor air concentrations lower than outdoor air [35], while Klinmalee

et al.[32] and Madureira et al.[31] reported higher indoor concentrations in university classrooms. Van Nguyen N. et al. found that the ratio of indoor to outdoor BTEX concentration in the nursery school ranged from 0.4 to 14.4 [29].

Possible reasons for contradictory findings in studies on indoor/outdoor air quality in classrooms include variations in building materials and equipment, teaching equipment, proximity to traffic and other pollution sources, and levels of ventilation. It has emphasized that materials like PVC, paints, and solvents in the classroom can contribute to higher indoor air concentrations of these compounds compared to outdoor air [33,36].

The benzene concentrations measured were higher than the annual ambient EU limit of 5 μg/m^3. As a carcinogenic compound, the World Health Organization (WHO) has not set a safe limit for benzene [37]. Nevertheless, the levels of toluene and xylene in indoor air of both case and control group were below the WHO guidelines (260 μg/m^3 for toluene over 1 week and 4.8 mg/m^3 for xylenes over 24 h). The results of this study showed that the mean concentrations of BTEX in indoor air of both case and control group were lower than the NIOSH [38], ACGIH [39], ANSES [40] and HSE [41] recommended values.

Several studies have linked exposure to low levels of benzene and toluene to increased risks of cancer and eye and airway irritations [42]. Therefore, it is important to use proper ventilation and equipment that minimizes the production of these compounds in all settings to reduce indoor air concentrations.

The concentration of compounds in the indoor air of classrooms investigated in this study is lower than other environments that have been reported in previous studies. For example, in Isak et al.'s study on the concentration of BTEX compounds in office environments, the concentrations of these compounds in school environments were lower than those in office environments, shopping malls, and restaurants [35].

Correlation between urinary and indoor air BTEX

Table 4 displays the correlation between BTEX compound concentrations in the urine of professors who used markers and whiteboards for teaching. The results of the correlation between the concentration of BTEX compounds in urine and indoor air alone, as well as the concentration of these compounds in urine and indoor air, are shown in the Table 4. The correlation between urinary concentration of benzene, toluene and xylene and their concentrations in the indoor air of the classrooms is significant based on Spearman's correlation test. This relationship is not significant for ethylbenzene ($p < 0.05$). Also, this statistical test shows that there is a significant correlation between the urinary concentration of benzene, xylene and toluene, and ethylbenzene. However, the relationship between toluene and ethylbenzene is not significant.

The concentration of benzene, toluene and xylene compounds in indoor air have a statistically significant relationship with each other, but the relationship between the concentration of these compounds and ethylbenzene is not statistically significant.

Heath risk assessment

Table 5; Figs. 3 and 4 display the carcinogenic risk of benzene and ethylbenzene, as well as the non-carcinogenic risk of BTEX compounds for teachers using whiteboard markers.

These results show that the mean carcinogenic risk of benzene (8.27E-08) and ethylbenzene (1.74E-11) for these teachers is below the recommended limit by USEPA (10^{-6}) and WHO (10^{-4}–10^{-6}).

While the risk of BTEX compounds for university professors has not been specifically investigated, studies have been conducted in other educational settings, including primary schools, nursery schools, and science laboratories. The cancer risk of benzene is lower than the risks reported by Gülçin Demirel et al. in the primary school of Eskişehir in Turkey [43], Trinh Dinh Tran et al. in nursery school in Vietnam [33], and Hamid et al. in a science laboratory in Vietnam [44], and also by Sofuoglu et al. in primary schools in turkey [45].

Variations in reported risk results across different studies may be attributed to factors such as the specific construction and educational equipment utilized in the places, as well as their proximity to sources of pollution like heavy traffic streets.

The non-carcinogenic risk index (HQ) for all BTEX compounds is below the recommended limit (HQ < 1). Previous studies have consistently found that the non-carcinogenic risk of BTEX compounds in educational settings is below the permissible limit [33, 44, 43], which aligns with the findings of this study.

		Urinary concentration				Air concentration			
		Benzene	Toluene	Ethylbenzene	Xylene	Benzene	Toluene	Ethylbenzene	Xylene
Urinary concentration	Benzene	1	0.878**	0.290*	0.705**	0.412**	0.453**	0.204	0.621**
	Toluene	0.878**	1	0.146	0.718**	0.404**	0.509**	0.239	0.581**
	Ethylbenzene	0.290*	0.146	1	0.477**	0.065	0.027	0.089	0.159
	Xylene	0.705**	0.718**	0.477**	1	0.425**	0.445**	0.354*	0.739**
Air concentration	Benzene	0.412**	0.404**	0.065	0.425**	1	0.538**	0.201	0.485**
	Toluene	0.453**	0.509**	0.027	0.445**	0.538**	1	0.209	0.475**
	Ethylbenzene	0.204	0.239	0.089	0.354*	0.201	0.209	1	0.163
	Xylene	0.621**	0.581**	0.159	0.739**	0.485**	0.475**	0.163	1

Table 4. Correlation between urinary and air concentration of BTEX compounds.

Parameter	LTCR		HQ			
	Benzene	Ethylbenzene	Benzene	Toluene	Ethylbenzene	Xylene
Mean	8.27E-08	1.74E-11	2.51E-03	7.86E-05	1.49E-05	1.73E-02
STD	5.25E-08	2.22E-11	1.61E-03	4.09E-05	2.25E-05	1.02E-02
10%	3.34E-08	2.96E-12	1.00E-03	3.69E-05	2.98E-06	7.03E-03
20%	4.32E-08	4.59E-12	1.29E-03	4.59E-05	7.10E-06	9.29E-03
30%	5.20E-08	6.24E-12	1.55E-03	5.38E-05	1.14E-05	1.12E-02
40%	6.07E-08	8.05E-12	1.83E-03	6.18E-05	1.58E-05	1.31E-02
50%	6.97E-08	1.04E-11	2.12E-03	7.01E-05	2.03E-05	1.50E-02
60%	8.03E-08	1.35E-11	2.45E-03	7.93E-05	2.48E-05	1.74E-02
70%	9.39E-08	1.76E-11	2.87E-03	9.01E-05	3.03E-05	2.01E-02
80%	1.13E-07	2.44E-11	3.46E-03	1.05E-04	3.70E-05	2.39E-02
90%	1.48E-07	3.86E-11	4.50E-03	1.31E-04	4.75E-05	3.02E-02

Table 5. Carcinogenic and non-carcinogenic risk characteristics of BTEX for case group.

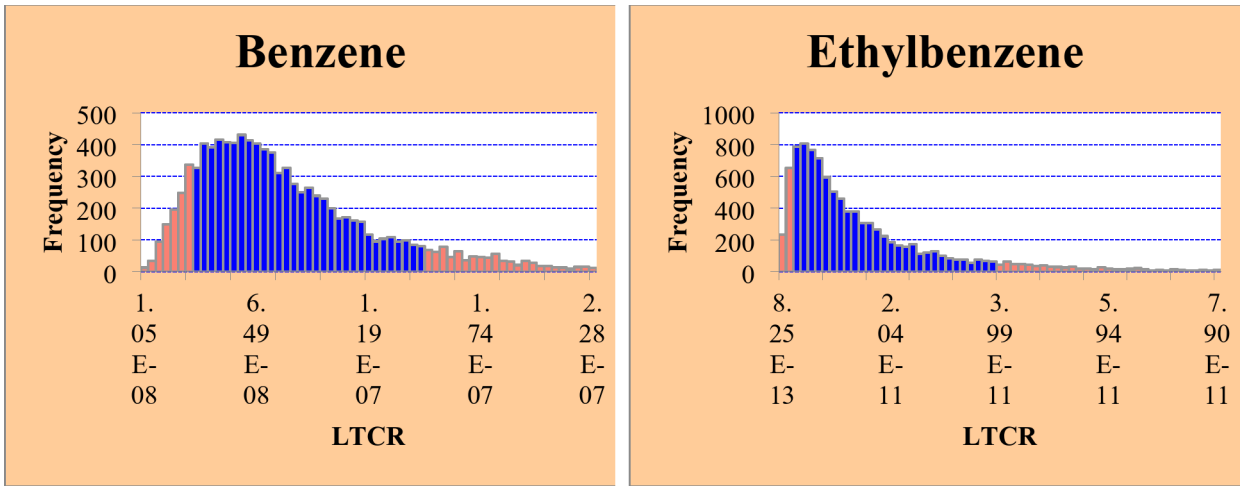

Fig. 3. Lifetime cancer risk (LTCR) of benzene and ethylbenzene for case group.

The uncertainty analysis results for carcinogenic and non-carcinogenic risk (Figs. 5 and 6) indicate that the concentration of compounds has the most significant impact on the uncertainty of these results, followed by exposure time and body weight.

Conclusions

In this research, the concentrations of BTEX compounds in the urine of two groups were examined. The case group consisted of university professors who utilized whiteboard markers for teaching, while the control group included individuals who did not use these teaching aids. The study also examined the levels of BTEX concentrations in the indoor air of the case group places. The professors in the case group (Those who use whiteboards and chemical markers) have a lower risk of exposure to carcinogenic and non-carcinogenic BTEX compared to the recommended safe limits. Despite this, the concentrations of these compounds in the urine of the case group professors were higher than those in the control group.

With respect to the above, the risks to the health of teachers and university professors in classrooms, such as chemical exposure, can be addressed through the following prioritized measures. The most effective control measure is the elimination of the hazardous factor. Following that, substituting the hazardous substance with a less harmful alternative such as switching from traditional whiteboards and markers with chemical colors to electronic methods or non-chemical markers, in classrooms is recommended. Separating the teachers from the hazardous substance, reducing the duration of exposure to the hazardous substance, and using personal protective equipment are also advisable.

The primary limitations of this study which should be considered in future studies are as follows:

1. (1) Inability to assess the impact of construction equipment and devices in the classroom on urinary concentration of BTEX compounds and their concentration in indoor air of the study area.
2. (2) Discrepancies in the work environments between the control and the case groups.

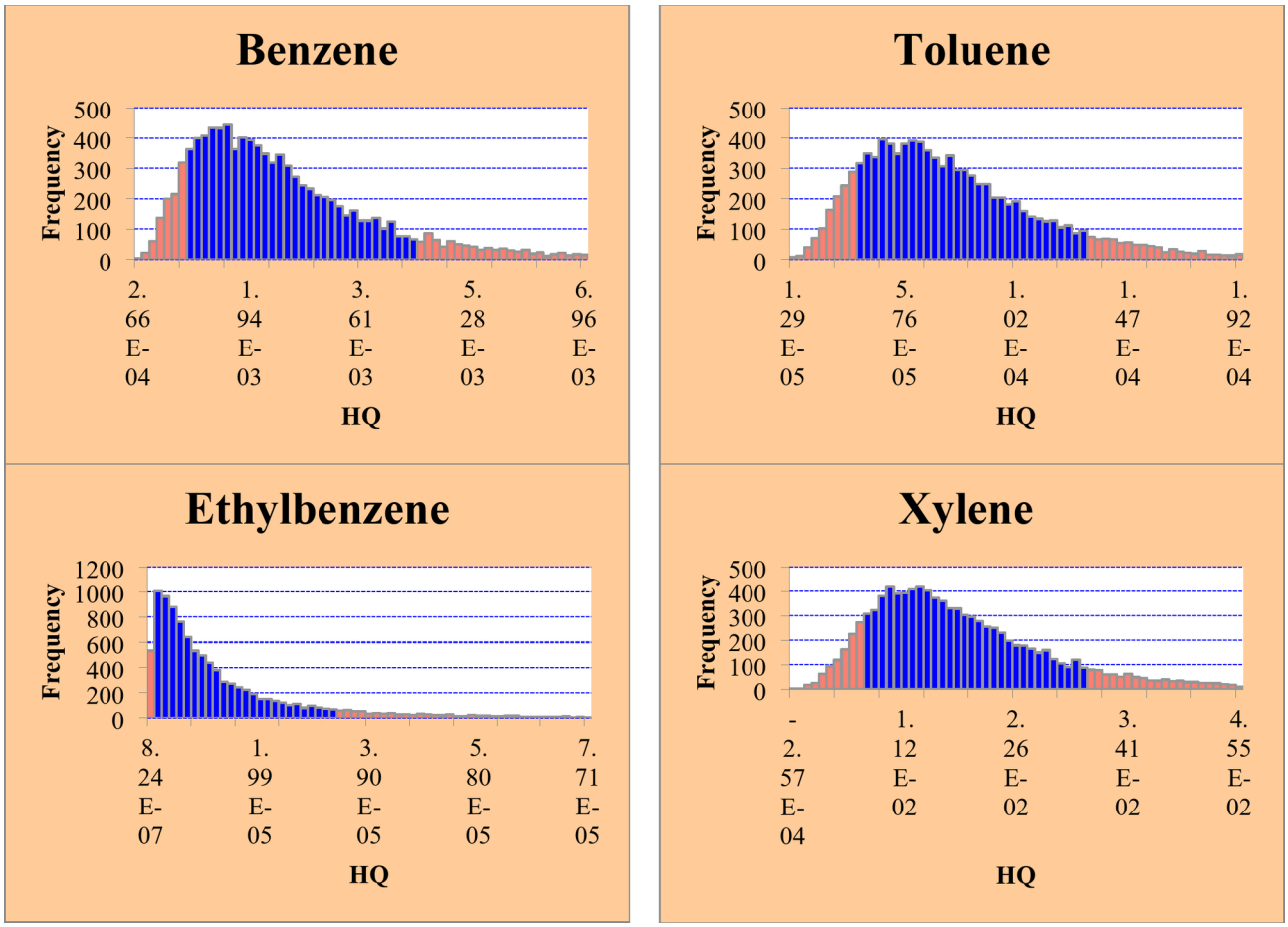

Fig. 4. Hazard quotient (HQ) of BTEX for case group.

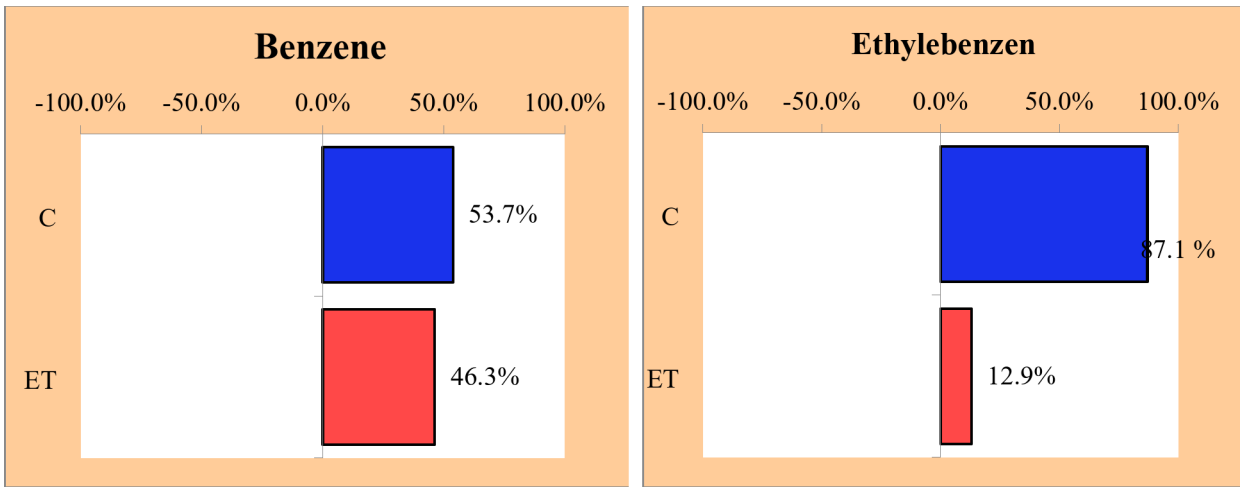

Fig. 5. Sensitivity analysis for probabilistic carcinogenic risk of benzene and ethylbenzene for case group.

3. (3) Lack of data on compound concentrations in the ambient air of the control group, leading to an inability to compare it with the case group.

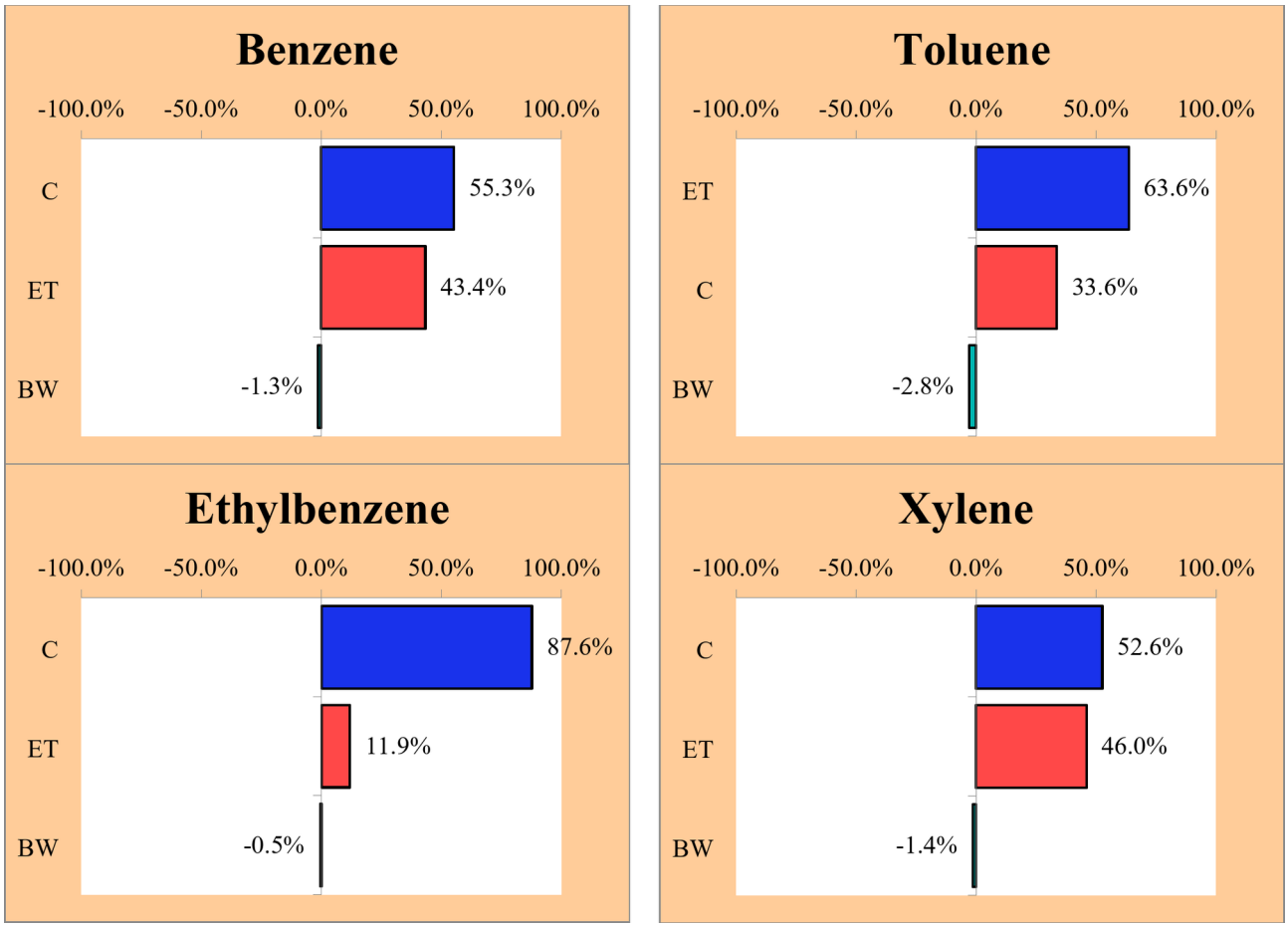

Fig. 6. Sensitivity analysis for probabilistic non-carcinogenic risk of BTEX for case group.

Data availability

The data are available from the corresponding author upon request.

Received: 12 October 2024; Accepted: 26 February 2025
Published online: 11 March 2025

References

1. Muttappallymyalil J, Mendis S, John LJ, Shanthakumari N, Sreedharan J, Shaikh RB. Evolution of technology in teaching: Blackboard and beyond in Medical Education. *Nepal journal of epidemiology.* 2016;6(3):588.
2. Enayati T, Modanloo Y, Kazemi FSM. Teachers' attitudes towards the use of technology in education. *Journal of Basic and Applied Scientific Research.* 2012;2(11):010958–010963.
3. Özdamlı F, Hürsen Ç, Özçinar Z. Teacher candidates' attitudes towards the instructional technologies. *Procedia-Social and Behavioral Sciences.* 2009;1(1):455–463.
4. Yalcin SA, Kahraman S, Yilmaz ZA. Primary school teachers of instructional technologies self-efficacy levels. *Procedia-Social and Behavioral Sciences.* 2011;28:499–502.
5. Zanguyi S. Review of teachers' attitudes towards the use of educational technology in teaching process. *Educational Technology.* 2011;6:165 – 159.
6. Majumdar D, William SP. Chalk dustfall during classroom teaching: particle size distribution and morphological characteristics. *Environmental monitoring and assessment.* 2009;148:343–351.
7. Malik S, Ajaz N, Jumani N. Professional Knowledge, Attitude and Practice of Teachers. *Pakistan Journal of Social Sciences.* 2016;36(1):199–208.
8. Pegas PN, Evtyugina MG, Alves CA, et al. Outdoor/indoor air quality in primary schools in Lisbon: a preliminary study. *Quimica nova.* 2010;33:1145–1149.
9. Zhang G, Spickett J, Rumchev K, Lee A, Stick S. Indoor environmental quality in a'low allergen' school and three standard primary schools in Western Australia. *Indoor Air.* 2006;16(1):74–80.
10. Castorina R, Tysman M, Bradman A, et al. Volatile organic compound emissions from markers used in preschools, schools, and homes. *International Journal of Environmental Analytical Chemistry.* 2016;96(13):1247–1263.
11. Dehghani MH, Baghani AN, Fazlzadeh M, Ghaffari HR. Exposure and risk assessment of BTEX in indoor air of gyms in Tehran, Iran. *Microchemical journal.* 2019;150:104135.
12. Hazrati S, Rostami R, Fazlzadeh M. BTEX in indoor air of waterpipe cafés: Levels and factors influencing their concentrations. *Science of the total environment.* 2015;524:347–353.
13. Rostami R, Fazlzadeh M, Babaei-Pouya A, et al. Exposure to BTEX concentration and the related health risk assessment in printing and copying centers. *Environmental Science and Pollution Research.* 2021;28:31195–31206.

14. Mohammadzadeh M, Khoshakhlagh AH, Calderón-Garcidueñas L, Cardona Maya WD, Cai T. Inhaled toxins: A threat to male reproductive health. *Ecotoxicology and Environmental Safety.* 2024;286:117178.
15. Hoskins JA. Health effects due to indoor air pollution. In: *Survival and Sustainability: Environmental concerns in the 21st Century.* Springer; 2011:665–676.
16. Niri VH, Mathers JB, Musteata MF, Lem S, Pawliszyn J. Monitoring BTEX and aldehydes in car exhaust from a gasoline engine during the use of different chemical cleaners by solid phase microextraction-gas chromatography. *Water, air, and soil pollution.* 2009;204:205–213.
17. Khoshakhlagh AH, Yazdanirad S, Moda HM, Gruszecka-Kosowska A. The impact of climatic conditions on the carcinogenic and non-carcinogenic risk of BTEX compounds: A systematic review and meta-analysis. *Journal of Hazardous Materials Advances.* 2024;16:100470.
18. Hazrati S, Rostami R, Fazlzadeh M, Pourfarzi F. Benzene, toluene, ethylbenzene and xylene concentrations in atmospheric ambient air of gasoline and CNG refueling stations. *Air Quality, Atmosphere & Health.* 2016;9:403–409.
19. Fazlzadeh Davil M, Rostami R, Zarei A, et al. A survey of 24 hour variations of BTEX concentration in the ambient air of Tehran. *Journal of Babol University of Medical Sciences.* 2011;14(1):50–55.
20. Ghobakhloo S, Khoshakhlagh AH, Alwan N, Carlsen L. Health Risk Assessment of Exposure to BTEX and PAH Compounds in Workers of Burnt Oil Recycling Factory: Simulation Using Monte Carlo Method. *Environmental Processes.* 2024;11(3):37.
21. Khoshakhlagh AH, Morais S. Volatile organic compounds in carpet manufacturing plants: Exposure levels and probabilistic risk assessment using Monte-Carlo simulations. *Human and Ecological Risk Assessment: An International Journal.* 2022;28(9):972–982.
22. Eastlake A, Hodson L, Geraci C, Crawford C. A critical evaluation of material safety data sheets (MSDSs) for engineered nanomaterials. *Journal of Chemical Health & Safety.* 2012;19(5):1–8.
23. Larson EL, Liverman CT. Using PPE: Individual and Organizational issues. In: *Preventing Transmission of Pandemic Influenza and Other Viral Respiratory Diseases: Personal Protective Equipment for Healthcare Personnel: Update 2010.* National Academies Press (US); 2011.
24. Muchemi SM. Knowledge, attitudes and practices on use of White board marker pen ink among school teachers. 2018.
25. Hydrocarbons A. Method 1501. *NIOSH Manual of Analytical Methods (NMAM), Foure Available from: http://www cdc gov/niosh/docs/2003 – 154/pdfs/1501 pdf Accessed May.* 2015;2.
26. Mokammel A, Rostami R, Niazi S, Asgari A, Fazlzadeh M. BTEX levels in rural households: Heating system, building characteristic impacts and lifetime excess cancer risk assessment. *Environmental Pollution.* 2022;298.
27. Ghobadi H, Rostami R, Saranjam B, Aslani MR, Fazlzadeh M, Ghaffari HR. Urinary concentrations of BTEX in waterpipe smokers and nonsmokers: Investigating the influence of conventional activities and multiple factors. *Ecotoxicology and Environmental Safety.* 2022;241.
28. Ghaffari HR, Kamari Z, Hassanvand MS, Fazlzadeh M, Heidari M. Level of air BTEX in urban, rural and industrial regions of Bandar Abbas, Iran; indoor-outdoor relationships and probabilistic health risk assessment. *Environmental Research.* 2021;200.
29. USEPA. Integrated risk information system (IRIS) (Online Database of Toxicity Values). *United States Environmental Protection Agency, Washington, DC, .* 2018.
30. Muchemi SM. *Influence of occupational exposure to white board marker ink on symptoms of allergic conjunctivitis among secondary school teachers in Nakuru County, Kenya*, Egerton University; 2019.
31. Moradi M, Hopke P, Hadei M, et al. Exposure to BTEX in beauty salons: biomonitoring, urinary excretion, clinical symptoms, and health risk assessments. *Environmental monitoring and assessment.* 2019;191:1–10.
32. Klinmalee A, Srimongkol K, Kim Oanh NT. Indoor air pollution levels in public buildings in Thailand and exposure assessment. *Environmental monitoring and assessment.* 2009;156:581–594.
33. Tran TD, Nguyen TX, Nguyen HTT, et al. Seasonal Variation, Sources, and Health Risk Assessment of Indoor/Outdoor BTEX at Nursery Schools in Hanoi, Vietnam. *Water, Air, & Soil Pollution.* 2020;231:1–18.
34. Dorizas PV, Assimakopoulos M-N, Helmis C, Santamouris M. Analysis of the indoor air quality in Greek primary schools. 2013.
35. Guo H, Lee S, Li W, Cao J. Source characterization of BTEX in indoor microenvironments in Hong Kong. *Atmospheric Environment.* 2003;37(1):73–82.
36. Madureira J, Alvim-Ferraz M, Rodrigues S, et al. Indoor air quality in schools and health symptoms among Portuguese teachers. *Human and Ecological Risk Assessment.* 2009;15(1):159–169.
37. Organization WH. *WHO guidelines for indoor air quality: selected pollutants.* World Health Organization. Regional Office for Europe; 2010.
38. NIOSH. NIOSH Manual of Analytical Methods (NMAM), Fourth Edition, Hydrocarbons, Aromatic. *Centers for Disease Control and Prevention, 1600 Clifton Rd Atlanta, GA 30329e4027, USA.* 2003.
39. ACGIH. TLV/BEI Guidelines. American Conference of Governmental Industrial Hygienists 1330 Kemper Meadow Drive, Cincinnati, Ohio 45240. 2007.
40. ANSES. Indoor Air Quality Guidelines (IAQGs). French Agency for Food, Environmental and Occupational Health & Safety 94701 Maisons-Alfort Cedex FRANCE. 2008.
41. HSE. EH40/2005 workplace exposure limits, Second edition ed. Health and Safety Executive, London. 2011.
42. Centro Universitário Positivo U. Indoor air quality assessment of elementary schools in Curitiba, Brazil.
43. Demirel G, Özden Ö, Döğeroğlu T, Gaga EO. Personal exposure of primary school children to BTEX, NO2 and ozone in Eskişehir, Turkey: Relationship with indoor/outdoor concentrations and risk assessment. *Science of the total environment.* 2014;473:537–548.
44. Hamid H, Nadzir M, Lee K, Ayatillah A, Latif M, Othman M. Indoor level of BTEX and health risk assessment at science laboratories in a university. Paper presented at: IOP Conference Series: Earth and Environmental Science2023.
45. Sofuoglu SC, Aslan G, Inal F, Sofuoglu A. An assessment of indoor air concentrations and health risks of volatile organic compounds in three primary schools. *International journal of hygiene and environmental health.* 2011;214(1):36–46.

Acknowledgements
The authors of current work would like to especially thank the Ardabil university of medical sciences for financial support to conduct this research.

Author contributions
The research was designed by R. Ghasemi and M. Fazlzadeh. Sampling, experiment and data collection were done by B. Saranjam, and A. Babaei. Experiment and data collection were done by M. Fazlzadeh, A. Zarei and H. Ghaffari performed the statistical analysis. R. Ghasemi, H. Ghaffari, and M. Fazlzadeh wrote the manuscript; the final manuscript was investigated and approved by all the authors.

Declarations

Competing interests
The authors declare no competing interests.

Ethical approval
The research was approved by ethical committee of Ardabil university of medical sciences by ethical code of IR.ARUMS.REC.1398.403. The participants filled informed consent form before entering into the study.

Additional information
Correspondence and requests for materials should be addressed to H.R.G. or M.F.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.