original article

Determination of benzene, toluene, ethyl benzene and xylene in administration room's air of hospitals using solid phase micro extraction/gas chromatography/flame ionization detector

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ABSTRACT

Aims: The aim of this study was to compare the concentration of volatile organic compounds in administration rooms of the hospital.

Materials and Methods: The present study assessed indoor concentration levels benzene, toluene, ethyl benzene and xylene (BTEX) in eight hospitals of Yazd province from January 16 to February 25 of 2012. Management, accounting and personnel rooms were selected as sampling units. Samples collected in three sequential daytimes by Tedlar bag. Gas chromatography-flame ionization detector method was applied for analysis of the component.

Results: Total BTEX concentrations were relatively below (<10 μg/m^3) in all hospitals. There was no significant difference in amounts of the compounds among studied parts, except for benzene ($P < 0.05$). According to sampling units, the mean of BTEX component concentrations (in units of μg/m^3) were for benzene 1.03 ± 1.21, toluene 0.96 ± 1.79, ethyl benzene 0.78 ± 1.92 and xylene 0.86 ± 0.73, respectively.

Conclusion: The accounting unit showed highest concentrations of BTEX that its possible due to usage of the numerous numbers of electronic devices (computers, printer and copier), official supply (ink varnish, adhesive, etc.) and the air-conditioner.

Key words: Benzene, toluene, ethyl benzene and xylene, gas chromatography, hospital, indoor air, office building, solid phase micro extraction

INTRODUCTION

Indoor air pollution by harmful chemical and its special effect on human health is a considerable national and global public issue.[1] Today's modern technology has produced dramatic changes in the construction of industrialized materials.[2] Changes in building design and interior decoration have improved usage of adhesive, resins, detergents and paints increasingly containing volatile organic compounds (VOC).[3-5] Furthermore following industrialization the use of double windows and fillers is increased to save energy in buildings and the exchange of indoor and outdoor air is considerably reduced. In addition, the usage of materials such as plastic flooring, parquets, carpets, woods of decoration, books or newspapers and office equipment affects the distribution of VOC in indoor environments.[6-10] Benzene, toluene, ethyl

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benzene and xylene (BTEX) are residues of most solvents and also the indicators of these compounds.[11] These compounds even in a small amount have unpleasant effects on human health, ranging from the irritation of the eyes and throat to carcinogenic effects.[12,13] A study in sealed and non-sealed buildings in Brazil revealed high concentration of aromatic compounds, with vigorous amount of benzene and toluene.[14] Furthermore, they were detectable inside of museum in Italy and concentrations of these components were significantly different in some parts.[15]

Exposure to VOCs should be monitor regularly in the workplace.Suitable indoor air quality (IAQ) is required for a healthy indoor work environment. Complex organizations such as hospitals cause multifaceted developments in the society.[16] Therefore, healthcare systems have to pay specific care to indoor air problems. Air quality standards in these places differ from other non-industrial environments.[17] Air quality within a hospital is influenced by many internal and external factors. Due to the wide variety of health activities, a high dissimilarity of the indoor air contamination is anticipated in hospitals. Several research papers have been published regarding to the possibility of exposure healthcare staff and patients with a large number of chemical compounds emitted from various products such as disinfectant materials, anesthetic gases and laboratory or pharmaceutical products. Studies show that patients in a controlled environment generally have more quickly physical recovery than do those in an uncontrolled environment.[16] However a few studies have assessed the IAQ in different hospital areas.[18]

In Iran, hospitals administrative units are almost set in the central building of hospital and close to the clinical area. In this section, many staffs are employed with different characteristics; such as age, sex, hidden disabilities. There are not regular examinations for screening of hazard factors exposure in the workplace for these staffs.[19] On the other side, excessive consumption of paper, printing devices (laser printers, copy and scan), changes in air circulation, temperature, humidity and air exchange in low rate increase sensitivity and irritability in employees.

Indoor chemical compounds have been monitored in several indoor microenvironments in Iran, e.g., vehicles, schools, copying setting and other public places, but limited investigations have done in offices and clinical sections of hospitals in Iran.[20-25]

Numerous methods have been offered for the analysis of VOCs in internal atmospheres at the workplace by creditable organizations. Many of these methods need substantial sampling competence and expensive devices, prolonged sample collection, preparation periods and complex cleaning and extraction process.[26] Solid phase micro extraction (SPME) properties (high sensitivity, not uses solvent, easily implement), capabilities for the measurement and analysis of air pollutants have caused, this method to be an appropriate alternative to conventional techniques based on the solid adsorbents and solvent uptake in air pollutants sampling.[27] SPME has already been utilized for diverse usage, some air applications were advanced for the control of workplace atmospheres. In Iran, the few studies has been done to assess occupational exposures and environmental on gas matrices by SPME.[28]

The aim of this study was to investigate the IAQ of administration rooms of hospitals to explore possible sources of BTEX.

MATERIALS AND METHODS

In this study, eight general hospitals (H_1-H_8) were selected in Yazd province. The hospitals are located in four direction of the geographical Yazd province with semi-arid and arid climates [Figure 1].[44] Management, personnel and accounting units were selected randomly between the office units. All of these places were located on the ground floor. Except management and accounting units of 2th hospital were located on the first floor. Real conditions of locations were considered as a sampling unit. Therefore, except the accounting unit of the 8th hospital, all of the windows were closed and the doors opened. On the selected sites, employees are working from 7:30 am to 2:00 pm and were not present in the workplace for a ½-h from 00:30 pm for prayer. We set sampling time from 8:00 to 12:00 am because all of the equipments were in standby mode during the prayer time that changes in concentration of the compounds in the air. The samples were collected each week in the months of January 16 and February 25 of 2012. According to the values of $Z_{1-\alpha/2} = 1.96$, standard deviation (SD) = 0.78, $d = 0.25$, (Z: Confidence coefficient and *d*: Acceptable margin of error) sample size was estimated 48.

In order to prepare standard concentration of compounds, BTEX, acetonitrile and methanol were purchased from Merck, Germany (at least 99% pure).

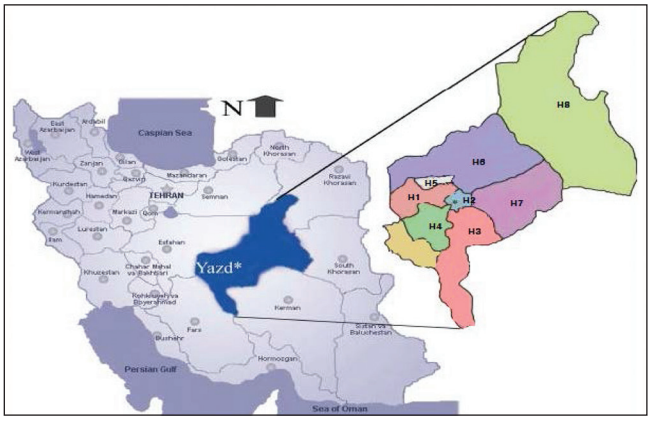

Figure 1: Situation of Yazd province* on Iran's map and the locations of studied hospitals (H) in Yazd counties

Samples collecting

There are different approaches to the collection of indoor air samples such as passive and dynamic. Dynamic model was used to collect the samples by using 5 L Tedlar bag (SKC, UK). Airflow rates into the bag were controlled with portable personal sampling pump (SKC, UK). The pump was operated at 0.5 L/min 80% of the volume of bag filled during in 8 min (calibrating of all parts was done by soap bubble flow meter). Regarding the manufacturer's instructions, after each sample extraction, Tedlar bags were purged 3 times with nitrogen gas (N_2) or air-helium mixture. Then, the air of the bags was analyzed by gas chromatography-flame ionization detector (GC/FID) to warrant cleans up. Since selected office rooms space were small, samples were gathered in the center of the room at a height of 1.3 m above the ground and at least 1.5 m of adjacent walls and nearly desk staff. By the time of sampling, temperature and humidity of the sampling units were determined using a digital hygrometer (model HD 3008:$^+$type K). The airflow rate was measured by dry Kata thermometer (model CASELLA T6409) with the average temperature of the cooling 53.5°C and kata factor 502. To avoid the influence of environmental climate, samples were transferred in the laboratory at least time. To equalize environmental conditions, same laboratory and one GC device were be used for analysis.

Selection and preparation of fiber

Applicability of common fibers such as poly dimethyl siloxane (PDMS)/divinyl benzene: 65 μm, PDMS/carboxan (CAR): 75 μm and PDMS: 100 μm to absorption and extraction VOC like benzene has been examined in previous studies.[29,30] Results have shown that the sensitivity of the PDMS/CAR fiber to the analyte is significantly more than other fibers. Therefore, in this study, the PDMS/CAR fiber (Supelco, UK) was used to absorption and extraction BTEX compound. Before use, fiber was conditioned in the injection port of the gas chromatograph at 280°C for 30 min. The SPME fiber was placed in air samples collected in Tedlar bags for 7 min. After SPME fiber desorption in the GC inlet, the fiber was laid in the inlet during the chromatographic separation to re-absorb all analytes on the fiber and prepare it for the next sampling. The most optimum desorption time of analytes of on the fiber in the injector was 1 min.

Analysis method

Taking into sensitivity, ability to provide necessary information and availability devices, GC-FID analysis was selected. Furthermore, GC-FID is the standard method and the most popular technique recommended by the National Institute for Occupational Safety and Health, the Occupational Safety and Health Administration and the Environmental Protection Agency (EPA) for the analysis of BTEX in occupational environments.[31] Quantitative measurement were done by GC (model YL6100, Younglin, Korea) attached to the FID. Separation of the compounds was obtained with a capillary column (DB-5MS- J and W Scientific): Column length of 60 m, column internal diameter 0.25 mm, and film thickness of 0.25 μm and temperature range of 60-325 °C. Optimal conditions analysis was provided with injector temperatures 260°C, detector temperature 280°C, hydrogen gas flow 30 ml/min and the flow of carrier gas (helium) 0.8 ml/min. The devices' programmed temperature started at 40°C (isothermal for 1 min), then increased to 90°C at a rate of 15°C/min (isothermal for 4 min) and finally heating at 10°C/min-170°C (isothermal for 4 min). For the quantitative determination of BTEX, the device was calibrated by using four standard concentrations. Analytical standards were prepared by injecting a certain volume of mixture of liquid (BTEX) (by diluting each compound in acetonitrile in the proportion 0.5:1000) into a fixed volume of free air in Tedlar bags. Then, the sample extracted by the SPME was injected into GC system and peak heights of BTEX were determined. The limit of detection the analytical procedure was based on the response/error ratio for benzene (16 ppb), ethyl benzene (16 ppb), toluene (25 ppb) and xylenes (5 ppb), respectively. To check the precision the analytical method, each sample was injected three times into the GC capillary column and a standard deviation between 2% and 3% was obtained.

Statistical method

SPSS version 16.0 for windows (IBM SPSS, 2007 Microsoft Corp, *Birstol*, UK) was used for data analysis. For comparison of quantitative variables among hospitals, we used one-way ANOVA. General linear model (multivariate) was applied for controlling confounders, significant relationships among variables. $P < 0.05$ were considerable for significance level.

RESULTS

This research was carried out at three administration locations of eight general hospitals in January and February 2012. All hospitals had the same condition except 2th hospital that restored and painted management and accounting room 2 months before sampling. This hospital located in the high traffic area in the center of Yazd city. All sampling sites have been cleaned once a day and at various times of a shift with only water. Furthermore, due to the smoking prohibition in public places, no environmental tobacco smoke (ETS) was available. Air change rate per room were not examined in this study. Furthermore, the aim of our study was to find the amount of the indoor pollutants therefore outdoor air samples were not collected. The atmospheric and environmental factors of studied hospitals and sampling sites are shown in Tables 1 and 2. Relative humidity (RH) showed significant differences between hospitals ($P = 0.02$).

All BTEXs were identified in the administration rooms of hospital indoor air. The BTEXs concentrations spectrum was largely distinct in the office rooms (not detected-9.18 μg/m^3) that have been reflected in a wide range of SD. A significant difference was found in the benzene concentration among hospitals ($P = 0.04$). Benzene was the most dominant among

Table 1: The values of mean and standard deviation of environmental factors in assessed hospitals

Hospital	H_1*	H_2	H_3	H_4	H_5	H_6	H_7	H_8	*P*
Last time re-construction building (years)	2.5 (0)	0.25 (0)	1.66 (0.57)	3.1 (5.1)	3.00 (0)	3.33 (2.3)	0	0	0.18
Temperature (°C)	24.13 (2.05)	21.96 (3.47)	23.66 (1.52)	24.76 (1.15)	21.6 (1.49)	23.53 (1.9)	25.53 (0.15)	23.66 (0.2)	0.17
Relative humidity (%)	18.46 (0.83)	22.3 (2.63)	19.8 (1.6)	18.86 (4.03)	32.63 (6.49)	22.7 (5.45)	22.66 (2.95)	26.76 (6.38)	0.02
Airflow velocity (m/s)	0.69 (0.01)	0.61 (0.01)	0.74 (0.01)	0.58 (0)	0.62 (0.2)	0.61 (0.11)	0.62 (0.12)	0.52 (0.00)	0.33

*H: hospital. Significance $P < 0.05$

Table 2: The values of mean and standard deviation of atmospheric and environmental factors in assessed sampling locations

Unit	Last time re construction building (years)	Temperature (°C)	Relative humidity (%)	Air flow velocity (m/s)	Volume of room (m^3)
Management	1.2 (1.35)	23.43 (1.09)	22.3 (4.84)	0.62 (0.15)	100.78 (65.49)
Personnel	2.18 (2.99)	23.07 (3.01)	23.03 (7.22)	0.61 (0.09)	49.96 (21.23)
Accounting	1.7 (2.13)	24.08 (1.04)	22.93 (4.67)	0.60 (0.09)	88.5 (36.56)
Total	1.7 (2.19)	23.53 (1.9)	22.75 (5.45)	0.61 (11.25)	79.36 (48.79)
P	0.68	0.58	0.96	0.98	0.091

Significance $P < 0.05$

BTEXs, followed by xylenes isomers. The amounts of BTEXs specified in hospitals presented in Figure 2. The mean of BTEX components concentrations (in units of $\mu g/m^3$) for sampling locations were for benzene 1.03 ± 1.21, toluene 0.96 ± 1.79, ethyl benzene 0.78 ± 1.92 and xylene 0.86 ± 0.73. Except 8th hospital, findings from the study showed that the mean concentration of benzene in the unit of accounting was over the other sampling locations ($P = 0.005$). The highest concentration of benzene was obtained in the accounting units of hospitals 3 and 2, respectively. Toluene concentration ranges (0.13-8.32 $\mu g/m^3$) were variable. Maximum of toluene level was determined in accounting units hospitals 7 and 2, respectively. Although, the lowest amount of toluene was observed on accounting unit of hospital 1. Average concentrations of ethyl benzene in accounting unit 2th hospital showed up (not detected 9.18 $\mu g/m^3$) and for the xylene concentrations range were (0.53-1.2 $\mu g/m^3$). The findings obtained were showed maximum concentrations of BTEX lower than all values recommended by the Office of Environmental Health Hazards Assessment of the EPA.

DISCUSSION

Four compounds (BTEX) were measured in the hospitals indoor air. Benzene and xylene were the most prevalent BTEX in almost all samples. Xylenes are usually reported in literature coexistence with benzene and toluene.[32] Except in some of the studied locations, the values of the other 2 combinations did not show explicit margins. The findings show a substantial variety by reason of the different internal emission source, conditionings rates, kind and age of buildings and outdoor environment associated with indoor locations (e.g., vehicular parking area, clinical section and butler's pantry). Maximum benzene, toluene and ethylbenzene concentrations were dominant in accounting unit compared with other units that were perhaps due to continuous use of electronic devices such as printers, copiers and computers, to apply the stamp and also the aggregation of archival paper.[6,33] Previous studies showed that the printed material such as magazines and newspapers are responsible for indoor air toluene.[9,34] The flow of a complex mixture of chemicals in the hospital air through heating, ventilation and air exchange to take place continuously.[35] The influence compounds might be constantly happen moved from clinical sections to administrative units along off with the hospital personnel and patients' family. Furthermore, by reason of the closed of windows in winter season, the low intake of fresh air will also influence the indoor temperature value of the building that leads to higher volatilization of compounds.[32,36]

The most important indoor sources of benzene are smoking and emissions from consumer products.[32] The highest concentration of benzene was observed in the accounting sites of hospitals H_3 and H_2, respectively. Accounting and personal sits surrounded with no access to windows, which it leads to limit air exchange between the indoor and outdoor

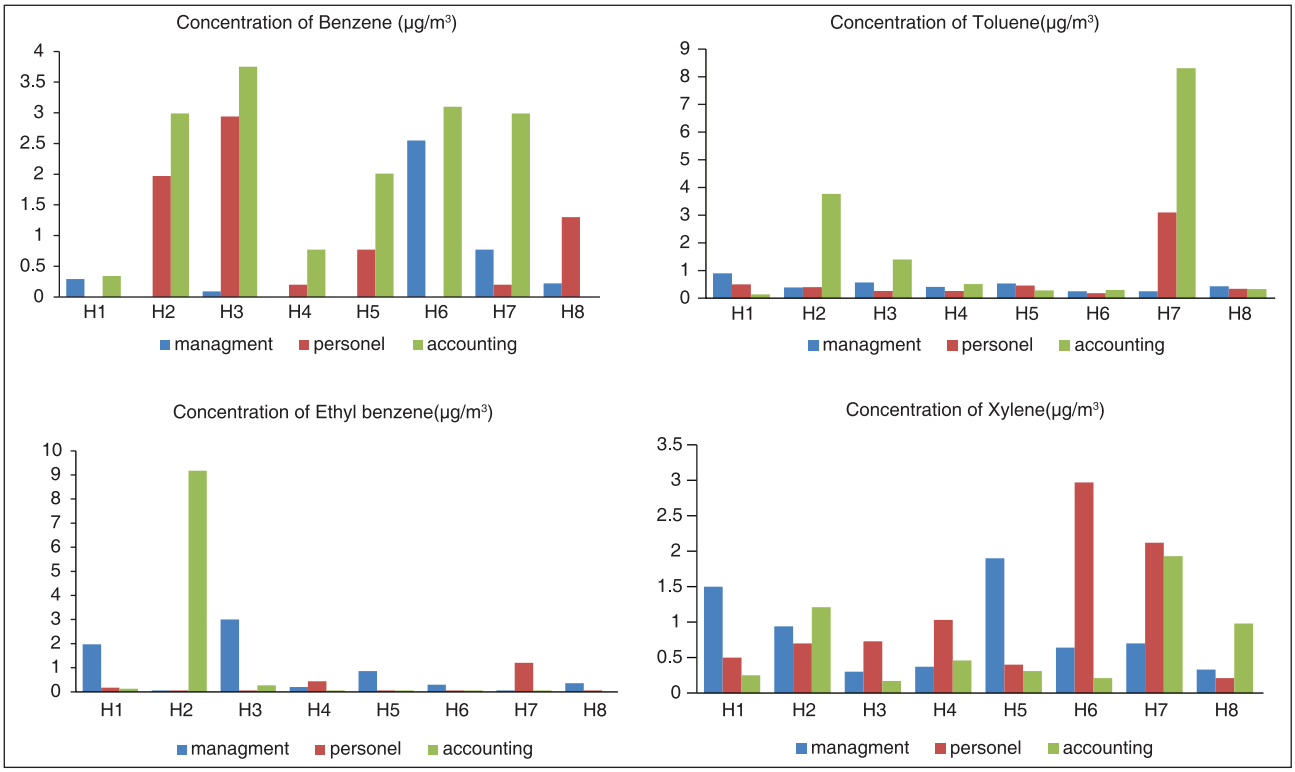

Figure 2: Concentrations of benzene, toluene, ethyl benzene and xylene in the sampling locations (H: Hospital)

environment. Therefore, it may lead to more persistent compound in the air of H_3 area, but in comparison the large surface area and recently renovated accounting rooms justified the high level of benzene in the air of H_2. The stricter regulation of usage of benzene in producing countries and identification of benzene as a known human carcinogen by International Agency for Research Cancer, have caused by the deletion of its using in consumer materials.[37] The lower amounts of the substance in indoor environmental probably linked to the guidelines.

Toluene is almost present in indoor air in many studies. Due to it has been as a solvent in a variety of products. The toluene was ubiquitous in studied locations that this seems to be due to cause by the presence of toluene in lot of internal resources.[38] Merely in accounting site of 7th hospital, toluene showed higher levels than in the others. Nevertheless, this difference was not significant. The continuous usage of fan which to allow air exchange between the indoor and outdoor (vehicular parking area) can be increase abnormal component. In the 2th hospital, many of printers and copy machines are the main cause of the differences in concentration of composition among hospitals. Toluene as a solvent often is utilized in the production of electronic apparatus. Available studies obviously explain that printers and copiers emit a range of VOCs, particularly for toluene, xylene, styrene and other alkyl benzene.[39]

There were significant differences between administrative locations regarding ethylbenzene. Also partial correlations were between temperature, RH and wall coverings and the concentration of ethylbenzene. Therefore, the high level of ethylbenzene in accounting unit H_2 might be connected with a cover of walls (Belk: Cellulose coating) and a large amount heat due to electronic devices. Presence of cellulosic fibers exaggerated the air incarceration and thereby to prevent heat loss. In general, the emission rate of VOC is associated with changes in temperature. Sulaiman and Mohamed outcomes indicated there were significant association between indoor air parameters namely RH, temperature and total volatile organic compounds (TVOC).[36] Some studies have shown that concentrations of these compounds in the warm seasons (spring and summer) are more than cold seasons.[40] In contrast, other papers have mentioned that during spring and summer, repeated opening of windows increase air exchange rate and it decreases of the concentration of indoors VOCs.[32,41]

Xylenes are widely used in the chemical industry as solvent for products such as paints, ink, dyes, pharmaceutical and detergents.[32] The sum of xylene combination (o, m and p-isomers) was determined in all office locations. Though the highest concentration of xylene was seen in personnel units of hospital 6, but average values were higher in both personnel and management room. Similar to accountancy site, there are some parameters such as ink varnish, printed paper in personnel location. However, trace amounts of xylene were seen in personnel unit that might be associated to circulation of air from outdoor (clinical wards) to indoor. In some cases, the ventilation system could bring a contaminant air of the outdoors into a building. Because it is a part of the

most products the concentration of xylene are given in public buildings. Missia *et al*. in their study have reported mean indoor concentrations usually were between range 0.7 and 11.8 μg/m^3 that it was in connection with building age and materials.[41]

Because the limitation of data in searched literature about air quality of official departments of hospitals, the concentrations reported from similar environments were considered. The amounts of BTEX in this study were in good condition accordance with those reported in some other studies, For example, Allou *et al*. measured BTEX value for 20 libraries of university and reported average concentration of those compounds for benzene 0.2, toluene 3.8, ethylbenzene 0.8 and xylene isomers 0.7 μg/m^3.[42] Also Bakó-Biró *et al*. has specified equivalent concentrations in offices air, 1.3 and 0.3 μg/m^3 for toluene and xylene isomers, respectively.[39] Concentrations of BTEXs in our study were lower than what reported by Bessonneau *et al*. Their reports were as follows benzene 1.6, toluene 4.7, ethylbenzene 1.8, m, p-xylene 3.6, o-xylene 1.6 μg/m^3.[18] Our findings were significantly inconsistent with some previous studies reported. Rios *et al*., have estimated benzene and toluene concentrations in sealed buildings indoor air was higher than 50 μg/m^3 in Brazil.[14] The measured BTEX concentrations lower than the range of those reported by Zuraimi *et al*. in Singapore office buildings. However, their results were generally over 50 μg/m^3.[38] Also European studies showed that the mean concentration of these compounds were below 20 μg/m^3 which indicating a substantial difference with our studies.[38,43] Concentration of TVOC measured in the office rooms and meeting rooms of Jiang and Zhang study were ranged from 47 to 451 μg/m^3 that it was higher than of our study.[13] Difference among concentrations of VOC may be due to the higher number of compounds detected in their study than our study.

Some of these differences are related to normally environmental conditions (e.g., temperature, RH and ETS), type of studied buildings (old age of the building, maintenance and ventilation system) and making use of devices.[38,43] Also using new construction goods and improved analysis techniques justified these differences. The organic compounds may have innovation during the last decade. Considering to the complexity of the indoor air matrices and the generally low concentration of VOCs, we need a susceptible method of measurement for determining of exact values air components.

CONCLUSION

Our study illustrated the highest concentrations of BTEX in accounting and personnel unit, due to crowded equipments in these areas. Although, in this study, BTEXs were not in harmful level and they are not perceived really adverse to occupational health. However, we cannot be commented surely about the safety of the office environment and occupational exposures.

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