
INDOOR AIR QUALITY IN A CHEMISTRY LABORATORY ENVIRONMENT

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ABSTRACT

The indoor built environment is the result of the interaction between the site, climate, building type (original design and later modifications of it), construction techniques, sources of chemical, physical and biological pollutants (building materials and furnishings, processes and activities within the building, and outdoor sources), and building occupants. Physical factors such as temperature, moisture, light, vibration and noise, contribute to the worsening of indoor air quality problems. Thus, we are dealing with a complex situation, involving combined action of physical factors with the pollutant chemical species, taking into account the emission rate and inadequate ventilation, all leading ultimately to negative effects on occupants' health.

Keywords: indoor air; built environment; pollutants; health

1. INTRODUCTION

Indoor air quality (IAQ) and, more broadly, indoor environmental quality (IEQ) have received considerable attention from the public as well as researchers (Zhong et al., 2017), because relatively higher pollutant concentrations in combination with longer time spent indoors can result in higher

REZUMAT

Mediul construit este rezultatul interacțiunii dintre amplasarea acestuia, climă, tipul de clădire (cea inițială și modificările ulterioare aduse acesteia), tehnicile de construcție, sursele de poluanți chimici, fizici sau biologici (materialele de construcție și mobilier, procesele și activitățile din interiorul clădirii și sursele externe) și ocupanții clădirii. Factorii fizici precum temperatura, umiditatea, lumina, vibrațiile și zgomotul, contribuie la intensificarea problemelor legate de calitatea aerului interior. Așadar, avem de-a face cu o situație complexă, ce implică acțiunea combinată a factorilor fizici cu cea a speciilor chimice poluante, luând în considerare rata de emisie și ventilarea inadecvată, toate acestea conducând, în final, la efecte negative asupra stării de sănătate a ocupanților.

Cuvinte cheie: aer interior; mediu construit; poluanți; sănătate

exposures and associated adverse health effects (Ugranli et al., 2015).

Some of important indoor air exposure concerns can be listed as volatile organic compounds (VOCs), carbon monoxide (CO), carbon dioxide (CO₂) and particulate matter (PM). VOCs are a group of substances frequently associated with building related symptoms such as tiredness, irritation of

respiratory tract, eyes, and skin, headache, blurred vision and shortness of breath (Ugranli et al., 2015). A few of VOCs such as aliphatic and aromatic hydrocarbons (benzene, styrene, toluene and xylene), phenol, ethylene dichloride, formaldehyde were reported to be carcinogenic, whereas some of them, with mutagenic effects, such as amines. PM is a significant threat to respiratory system (Zhong et al., 2017) and causes toxicity depending on the substance present in its structure. The knowledge in the field of indoor air quality involves the use of multiple approaches for complete characterization and accurate quantification of chemical compounds concentrations.

Considering the main sources of pollution in buildings (Vasile and Cioacă, 2011), the approach of indoor air quality domain can be led from the physical perspective, chemical perspective or biological perspective and their correlation can lead ultimately to a complete characterization of air, so that can be reported concentrations whose level is high compared to a maximum permissible value, the effect that these concentrations may have on the human body from the health point of view

and the possibility of detection the generation source present in indoor environment.

2. MATERIALS AND METHODS

The experimental study aimed to identify the quality and quantity of the main volatile organic pollutants present in the air inside the spaces for the educational process in higher education (chemistry lab), formaldehyde and benzene, and total volatile organic compounds (TVOC) along with inorganic compounds type carbon monoxide (CO) and carbon dioxide (CO₂).

Monitored spaces are on the first floor of a building in the area with urban traffic. The sampling of pollutants was performed in a single point situated in the central area of the space at a height of 120 cm from the floor. The average length of sampling of these compounds was 1 h and the sampling interval was 1 min.

The equipment used for determining the parameters monitored in the experimental study and their measuring principles are presented in Table 1.

Table 1. Information about monitored parameters, equipment used and their measuring principles

Parameter	Equipment	Measuring principle	Range	Accuracy
Carbon dioxide (CO ₂)	Gray Wolf Direct Sense IQ-610	Non-dispersive infrared	0 to 10.000 ppm	± 3% rdg, ±50 ppm
Carbon monoxide (CO)		Electrochemical	0 to 500 ppm	± 2 ppm, < 50 ppm ± 3% rdg, >50 ppm
Benzene and Total volatile organic compounds (TVOCs)		Photoionization detector (PID)	5 to 20.000 ppb	1ppb
Air temperature		Thermal resistance Pt 100	-10 to 70°C	1%rdg±0,3°C
Air relative humidity		Capacitive	0 to 100 %	± 2% rh < 80% rh ± 3% rh > 80% rh
Formaldehyde	Riken Keiki	photoelectric photometry	0-0,4 ppm 0-1,0 ppm	0,01ppm
Particulate matter	Gray Wolf Handheld 3016	light scattering	0,3μ - 10,0 μ	-

A summary of analyzed spaces characteristics and location of sampling points is presented in Table 2.

Table 2. The characteristics of the monitored chemistry lab

Monitored space and location of sampling point 	Basic information	
	Orientation	West
	Area	59,675 m ²
	Volume	230,578 m ³
	Type of ventilation	Natural
	At the time of monitoring	No ventilation

3. RESULTS AND DISCUSSIONS

The obtained results in this experimental study are summarized in Table 3.

Table 2 Summary of obtained results and the comparison with permissible limits established internationally (where are available)

Monitored parameter	Minimum concentration	Median value	Maximum concentration	Average concentration	Standard deviation	Permissible exposure limits, ppm (OSHA –PELs)
TCOV, ppm	0,20	0,24	0,35	0,25	0,05	-
C ₆ H ₆ , ppm	0,10	0,10	0,20	0,13	0,04	1
HCHO, ppm (15 min)	< 0,01					Class E ₀ : ≤ 0,041 Class E ₁ : ≤ 0,08 Class E ₂ : ≤ 0,16 Class E ₃ : > 0,16
CO, ppm	1,20	1,30	1,50	1,35	0,10	9
CO ₂ , ppm	912,00	953,00	990,00	952,36	16,76	800
PM _{0,3} , µg/m ³	9,26	15,02	17,41	13,58	3,13	-
PM _{0,5} , µg/m ³	4,89	8,02	9,49	7,08	1,87	-
PM _{1,0} , µg/m ³	12,36	14,46	23,80	16,19	3,98	-
PM _{2,5} , µg/m ³	27,42	34,54	179,96	78,50	59,73	25 µg/m ³ (WHO)
PM _{5,0} , µg/m ³	26,35	35,28	273,01	99,86	90,88	-
PM _{10,0} , µg/m ³	32,07	53,23	459,17	145,39	137,49	-
Indoor air temperature, °C	23,40	25,00	25,60	24,89	0,61	-
Relative humidity of indoor air, %	38,70	40,15	45,00	40,64	1,79	-

In the monitored space, the total concentration of volatile organic compounds (TCOV) had an average value of 0.25ppm

(minimum 0.20ppm – maximum 0.35ppm), in isobutylene units 573.72µg/m³ (minimum 458.97µg/m³ - maximum 803.21µg/m³). The

results are comparable or higher to those of previous studies conducted internationally. Recently, Ugranli et al (2015) reported TVOC concentrations values (3-day average) between 33.3ppb and 43.1ppb, in isobutylene units, below $300\mu\text{g}/\text{m}^3$, and in the range of 85 to $393\mu\text{g}/\text{m}^3$ (37ppb-171ppb), in chemistry and chemical engineering laboratories at Izmir Institute of Technology. Also, Kumar et al (2014) reported average values of TVOC concentrations of $465.8\mu\text{g}/\text{m}^3$ (145.3 - $1503.2\mu\text{g}/\text{m}^3$) recorded in the winter season and $321.8\mu\text{g}/\text{m}^3$ (90.7 - $1100.9\mu\text{g}/\text{m}^3$) in the summer season in the indoor air of Jawaharlal University Library Nehru from New Delhi; values from 100 - $538\mu\text{g}/\text{m}^3$ for TVOC concentrations were monitored in the indoor air of classrooms in Japanese University (Hori et al., 2012). Sarkhosh and colleagues (2012) measured concentrations of TVOC in a range from 113.4 to 486.3 ppb (227 - $973\mu\text{g}/\text{m}^3$ isobutylene units) photo-copy centers and Chan and colleagues (2009) showed concentrations the TVOC in the guest rooms of a regional plants, which ranged between 416 and $2900\mu\text{g}/\text{m}^3$. It is interesting to note that the maximum concentration of TVOC specified in the LEED Reference Guide for design and construction of green buildings (2009 edition) is $500\mu\text{g}/\text{m}^3$ (for measurements over a minimum of 4 hours).

The average concentration of benzene was 0.13ppm ($415.30\mu\text{g}/\text{m}^3$), with a minimum of 0.10ppm ($319.59\mu\text{g}/\text{m}^3$) and a maximum of 0.20ppm ($638.94\mu\text{g}/\text{m}^3$). The recorded values for benzene concentration is within Permissible Exposure Limits (PELS) given by the Occupational Safety & Health Administration (OSHA), but higher than those recorded in the indoor air of some office space in Cairo, Egypt, (4.32 ppb, Khoder et al., 2006) or library Jawaharlal Nehru University, New Delhi (7.2 - $12.2\mu\text{g}/\text{m}^3$) (Kumar et al., 2014), or in the indoor air of Aghia Paraskevi offices in Athens (15.3 - $17.6\mu\text{g}/\text{m}^3$). Regarding the human health effects, previous studies mention that inhalation of benzene can cause a lot of problems, for example, an exposure greater than 1000 ppm, an unspecified period of time, can cause

dizziness, nausea and pain head arrhythmias. The major toxicity of benzene can cause diseases such as anemia and leukemia.

To analyze the concentration of carbon dioxide has been used the admissible limit value of 800ppm, established by the Occupational Safety & Health Administration (OSHA) - PELs and was observed that the recorded values between 912 and 990ppm, much higher than in similar studies, 663.2ppm in Pickett et al., 2011 or <650ppm in Ugranli et al., 2015, were over this limit. The time variation of carbon dioxide concentration is presented in figure 1.

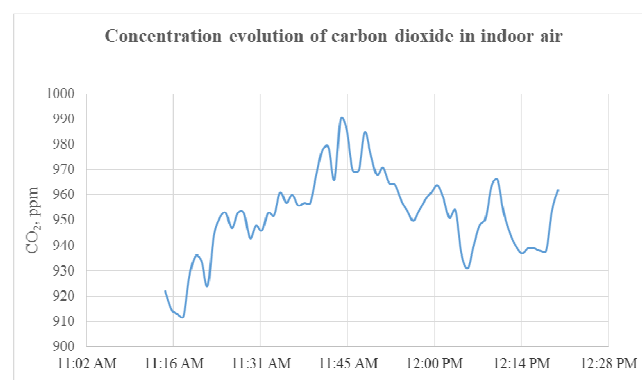


Fig. 1. Time variation of carbon dioxide concentration

The average value of the recorded concentration of carbon monoxide in the analysed area was 1.35ppm with a minimum of 1.20ppm and a maximum of 1.50ppm, higher values than those in other studies (0.85ppm in Pickett et al., 2011 and <1ppm in Ugranli et al., 2015), but it stands in permissible limits as specified by OSHA - PEL in which the permissible value for this compound is 50ppm.

The recorded values in this study for the fractions of $\text{PM}_{2.5}$ are higher than the value of $25\mu\text{g}/\text{m}^3$, the recommended value by WHO (Lin and Peng, 2010) and $\text{PM}_{5.0}$ and $\text{PM}_{10.0}$ concentrations are at comparable levels or higher with those mentioned in performed studies, internationally, in Europe, Asia or America (Fromme, H., Particles in the Indoor Environment; Fromme et al., 2007, Ugranli et al., 2015). Time evolution of particulate

matter concentrations is presented in figures 2 and 3.

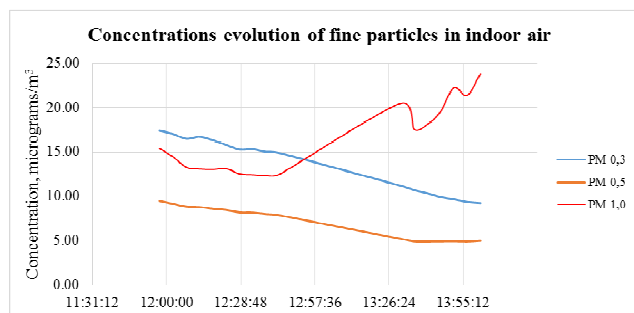


Fig. 2. Time evolution of the fine particulate matter concentration ($0.3\mu\text{m} < \text{PM} < 2.5\mu\text{m}$)

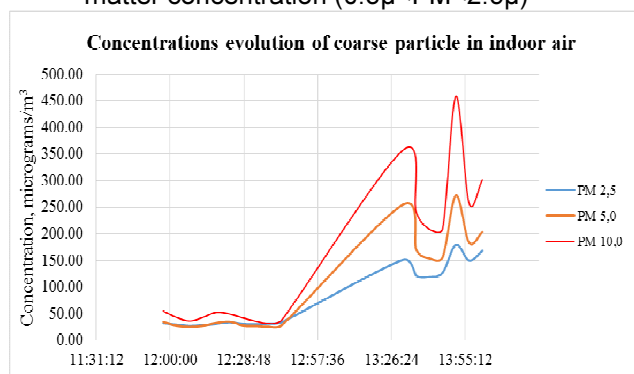


Fig. 3. Time evolution of the coarse particulate matter concentration ($2.5\mu\text{m} < \text{PM} < 10.0\mu\text{m}$)

4. CONCLUSIONS

In this research paper, the main volatile organic pollutants such as formaldehyde and benzene, and total volatile organic compounds (TVOC) were monitored, along with inorganic compounds like carbon monoxide (CO) and carbon dioxide (CO₂), and PM in the indoor air of the chemistry laboratory from an educational building. The results are comparable or higher to those of previous studies conducted internationally, for TVOC, benzene, formaldehyde and CO, but in permissible limits as specified by OSHA - PELs. In the analysed space there are significant concentrations both of fine and coarse particles fractions, what in time can affect the health of occupants, PM_{2,5} concentrations being higher than the value of 25 µg/m³, the recommended value by WHO. Also, CO₂ concentrations values are higher than the admissible limit value of 800 ppm, established by the Occupational Safety & Health Administration (OSHA) – PELs. In

the process of monitoring the indoor air quality it is important to correlate the recorded results with in-situ observations so that can achieved a hypothesis regarding to the possible causes who led to the problems of indoor air depreciation. In this study, the obtained results suggest that a ventilation system is necessary, as this can solve the occurring problems, aiming to maintaining indoor air quality so that occupant's health may not be affected.

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