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INDOOR ENVIRONMENT – AIR QUALITY AND THE RISKS ON HUMAN HEALTH

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ABSTRACT. Indoor environment quality is a subject of great interest among scientists from worldwide, because people spend indoors the most of their time (i.e. homes, offices, vehicles, restaurants, etc.). In this time, they are exposed to the different type of pollutants such as volatile organic compounds and particulate matter, two of the most important sources of the poor indoor air and which have been associated with various adverse health effects. The aim of our experimental studies was to monitor the volatile organic compounds belonging to different chemical categories, such as aromatics, aldehydes, halogenated compounds, esters, and the particulate matter in indoor air of three residential spaces located in urban area of Bucharest, Romania. The compounds, selected based on the effect they may have on the human health, were monitored by using the equipment based on a photo-ionization detector (PID) that detects and records, in real time, the concentrations of compounds. Because the size and concentration of the particles matter are extremely important in setting their action on the occupants' health, were monitored the concentrations of fine and coarse particles fractions, in a volume of air taken at present time intervals, using an optical particle counter. The final purpose of this monitoring activity was, on the one hand to obtain useful information on the indoor air from residential spaces, and on the other hand, for the awareness of acute necessity for action to improve the quality of our daily indoor environment.

Key words: *indoor air quality, human health, VOC, particulate matter*

INTRODUCTION

Irritations (Slezakova et al., 2012), neurological (Grandjean and Landrigan, 2006), cardiovascular (Saraga et al., 2011; Nenciu and Vaireanu, 2014) and respiratory diseases (Leung et al., 2012; Lee et al., 2014) are just a few of health effects of the volatile organic compounds which have been shown by the previous epidemiological studies, while acute and chronic respiratory morbidity and mortality in children and adults (Crilley et al., 2014); have been associated with the particulate matter pollution. The potential of particles to cause mentioned health effects is linked to their capacity to enter the lungs, potentially carrying a number of toxic compounds with them (Buonanno et al., 2015).

Indoor environment quality degradation of the residential spaces is often unperceived by the occupants or even perceive may be different depending on age, sex, health status, sensitivity to certain substances or combinations of substances (Kuehn et al., 2007). Exposure occupants to the concentrations of volatile organic compounds is closely related to the duration of spending time in the home or duration into contact with various pollutants, activities, modalities of interaction with various contaminants by ingestion, inhalation, direct contact with skin and the cumulative nature of exposure (Baker et al., 2001).

In this context, the aim of the present study was to identify, qualitatively and quantitatively, a range of the volatile organic compounds, belonging to different chemical classes, selected based on the effect they may have on the human health, and particulate matter in indoor air of three residential spaces, located in urban area of Bucharest, Romania. Furthermore, we aimed for the comparison of the obtained results with the other previous studies or permissible limits existent on the European or International level.

MATERIALS AND METHODS

Indoor environmental quality monitoring was conducted by investigating residential premises in terms of concentrations of volatile organic compounds and particulate matter by measurements at different locations spaces, kitchen and bedroom. Selecting areas to monitor concentrations of volatile organic compounds was done on the assumption that in the kitchen there are a multitude of emission sources and space for the bedroom, is the area where emissions must be minimized. The main characteristics of the monitored residential spaces are presented in table 1.

The measurement of volatile organic compounds concentrations is performed using a direct detection method and the portable data-logging detector GrayWolf DirectSense, IQ-610 probe (GrayWolf Sensing Solutions, USA), that is able to detection of concentrations compounds in real-time, in range 20 – 20000ppb, with a resolution of 1ppb. The operating principle is based on electronic detection, having a photo-ionization detector (PID) sensor, consisting of a light source (lamp) with a specific potential ionization measured in electron volts (10,6eV)(Vasile and Cioacă, 2011). The equipment was calibrated before the measurements. The sampling of the volatile organic compounds concentrations was made in a single point (centre of the space), at a sampling height of 1.20m as against floor, at sampling interval of 5min and the sampling time of each compound in the investigated area was 4hours. For detection of formaldehyde presented in indoor air is used another device whose operating principle is based on photoelectric photometry, from GrayWolf Sensing Solutions, USA. Detection method is to issue a reflected beam of light on the surface of a standard form of pill samples (tab), containing an area treated with a chemical lightening agent. It was used FP-30 tabs, which detect in range 0-1,0ppm, with a measuring time of 15 minutes.

Table 1. *Characteristics of the monitored residential spaces*

Identification	Space 1		Space 2		Space 3	
	Bedroom	**Kitchen**	**Bedroom**	**Kitchen**	**Bedroom**	**Kitchen**
Orientation	North	North	East	East	East	East
Volume(m^3)	25,55	16,43	50,80	25,04	35,62	34,21
Area (m^2)	10,22	6,57	20,32	10,01	14,25	13,69
Type of finishes	Water-based paint for walls, wood parquet	Water-based paint for ceiling, ceramic tiles for walls and floor	Water-based paint for walls, wood parquet	Water-based paint for ceiling, ceramic tiles for walls and floor	Water-based paint for walls, wood parquet	Water-based paint for walls, parquet flooring
Type of joinery	PVC profiles and wood	PVC profiles and wood	PVC profiles and wood	PVC profiles and wood	Al profiles and wood	Al profiles and wood
Number of occupants	2	3	1	3	2	3
Furniture	bed, desk, wardrobe chair, chest	7 cabinets table, 4 chairs	2 beds, 3 desks, 2 wardrobes 2 shelves	4 cabinets, table, 3 chairs	bed, desk, 2 wardrobes shelf, chest	6 cabinets, table, 4 chairs, kitchen furniture
Equipment	PC, printer, radiator	cooker stove, cooker hood, refrigerator radiator	TV, PC, printer, radiator	cooker stove, cooker hood, refrigerator, toaster radiator	TV, DVD, radiator	cooker stove, cooker hood, refrigerator, toaster radiator
Type of ventilation	Natural					

For the monitoring of the particulate matter was used a handheld particle counter (GrayWolf Sensing Solutions, USA), with six particle-size channels starting at 0.3μm to 10.0μm, instrument which uses a laser-diode light source and collection optics for particle detection. The volume of air collected was 0.014 m^3 and the total duration of each sampling point was 30 minutes, at an interval of 5 minutes. Because we wanted a better characterization of the spaces, we have been considered necessary a step for determining the number of sampling points, so as to be able to obtain sufficient data to be subsequently processed statistically by a confidence level of 95%. The number of sampling points and thus the total sampling duration were different, depending on the analysed surface area, and are presented in table 2.

Table 2. *The number of sampling points for each analyzed space*

Analysed space	Area, m^2	Sampling points number	Total sampling duration/day
Space 1 - Kitchen	6,57	4	120 minutes
Space 1 - Bedroom	10,22	5	150 minutes
Space 2 - Kitchen	10,01	5	150 minutes
Space 2 - Bedroom	20,32	6	180 minutes
Space 3 - Kitchen	13,69	6	180 minutes
Space 3 - Bedroom	14,25	6	180 minutes

RESULTS AND DISCUSSIONS

The experimental obtained results are summarized for monitored VOCs in table 3 and for particulate matter in table 4.

Table 3. *Summary of the obtained results for VOCs*

Monitored compound	Average concentration (min/max), ppm						Permissible exposure limits (PELs) ppm
	Space 1 kitchen	Space 2 kitchen	Space 3 kitchen	Space 1 bedroom	Space 2 bedroom	Space 3 bedroom	
Phenol	0,2 (0,1/0,3)	0,2 (0,0/0,4)	0,4 (0,2/0,8)	0,2 (0,1/0,3)	0,07 (0,0/0,2)	0,2 (0,2/0,3)	5
Methylamine	0,2 (0,1/0,3)	0,5 (0,2/1,0)	0,4 (0,3/0,5)	0,4 (0,2/0,8)	0,04 (0,0/0,1)	0,3 (0,2/0,3)	10
Ethyl Acrylate	1,3 (0,8/1,7)	0,5 (0,0/1,1)	1,0 (0,6/1,6)	0,3 (0,2/0,4)	0,2 (0,1/0,3)	0,5 (0,3/0,7)	25
Methyl bromide	0,3 (0,1/1,0)	0,3 (0,1/0,8)	1,1 (0,2/2,1)	0,3 (0,2/1,1)	0,1 (0,0/0,2)	1,2 (0,4/1,8)	20
Form-aldehyde, ppm	< 0,01	< 0,01	0,03	< 0,01	0,04	0,02	Class E_0: ≤ 0.041 Class E_1: ≤ 0,08 Class E_2: ≤ 0,16 Class E_3: > 0,16
TCOV, ppm	0,34	0,22	0,36	0,22	0,16	0,25	-

Sources for volatile organic compounds (VOCs) are considered products such as paints, furnishings, carpets, and household cleaning products and nany of them can be respiratory and sensory irritants, carcinogens, developmental toxins, neurotoxins, hepatotoxins, and immunosuppressant. The effect of mucous membrane irritation is the strongest association with VOCs emissions (Bernstein et al., 2008).

For comparing the measured concentrations of VOCs in residential spaces that were the subject of this case study, we used the limits set by the Occupational Health and Safety Administrative the United States (OSHA PELs). All volatile organic compounds monitored in this stage in the indoor air were within limits, observing that these concentrations are directly influenced by the number of present occupants and indoor activities (higher values have been recorded in kitchen spaces).

Table 4. *Summary of the obtained results for particulate matter*

Space	Minim concentration μg/m³	10th Percentile	90th Percentile	Maxim concentration μg/m³	Average concentration μg/m³
$PM_{0,3\text{-}0,5}$					
Space 1 Kitchen	2,61	2,94	12,72	13,22	7,67
Space 1 Bedroom	5,44	6,58	10,43	16,16	8,72
Space 2 Kitchen	2,91	3,51	30,02	39,71	13,52
Space 2 Bedroom	9,36	9,95	19,00	27,06	13,20
Space 3 Kitchen	6,16	7,56	16,11	1090,00	16,76
Space 3 Bedroom	3,86	4,12	15,64	23,35	10,95
$PM_{0,5\text{-}1,0}$					
Space 1 Kitchen	0,82	0,97	4,54	5,29	2,53
Space 1 Bedroom	1,51	2,33	19,07	32,31	6,73
Space 2 Kitchen	1,17	1,57	11,33	101,00	5,69
Space 2 Bedroom	3,08	3,46	8,52	10,41	5,65
Space 3 Kitchen	1,93	2,35	4,94	7,11	3,51
Space 3 Bedroom	1,56	1,74	6,96	8,66	4,13
$PM_{1,0\text{-}2,5}$					
Space 1 Kitchen	1,37	1,81	7,44	9,49	4,06
Space 1 Bedroom	2,87	3,86	194,46	347,90	45,18
Space 2 Kitchen	1,63	2,11	7,60	19,26	5,34
Space 2 Bedroom	3,13	5,04	9,28	18,89	7,49
Space 3 Kitchen	3,43	4,01	13,98	21,93	7,64

Space 3 Bedroom	3,77	4,03	11,53	27,30	7,51
$PM_{2,5-5,0}$					
Space 1 Kitchen	2,51	3,18	24,44	39,01	12,62
Space 1 Bedroom	7,28	12,02	992,77	2112,71	237,65
Space 2 Kitchen	3,86	5,34	22,34	46,18	12,92
Space 2 Bedroom	6,19	13,58	43,91	73,19	27,35
Space 3 Kitchen	7,25	11,50	48,19	81,53	26,72
Space 3 Bedroom	10,73	13,87	37,51	58,04	24,93
$PM_{5,0-10,0}$					
Space 1 Kitchen	0,90	1,48	18,65	39,24	8,26
Space 1 Bedroom	3,51	9,50	721,22	2502,76	217,17
Space 2 Kitchen	1,25	2,42	12,42	44,04	6,92
Space 2 Bedroom	2,50	7,08	39,24	70,44	18,68
Space 3 Kitchen	2,69	5,93	24,47	1045,00	18,91
Space 3 Bedroom	3,47	7,13	29,28	63,38	15,34
$PM_{\geq 10}$					
Space 1 Kitchen	2,13	5,60	54,83	104,84	25,81
Space 1 Bedroom	8,32	24,59	754,67	3543,00	302,12
Space 2 Kitchen	2,31	4,25	44,77	98,65	20,16
Space 2 Bedroom	6,38	11,43	79,12	252,49	40,76
Space 3 Kitchen	4,81	10,06	58,85	330,52	33,68
Space 3 Bedroom	2,96	10,78	79,50	156,43	36,17

Regarding of the existing concentrations of particulate matter in indoor air, numerous studies [Fromme et al., 2007; Bernstein et al., 2008; Moghaddasi et al., 2014] indicates that these may affect occupant health even at very low values [Donaldson, 2003], making it very difficult to set a threshold concentration below which there are no effects on health. The magnitude of the effect is proportional to the concentration of respirable fraction of solids of mixed sizes.

The conclusions of this study highlight that in normal operating conditions of the monitored spaces, there are significant concentrations of both fractions of fine and coarse particulate matter, which over time can affect the health of occupants. The values shown in this study, for the residential one - bedroom, the $PM_{2,5-5,0}$ and $PM_{1,0-2,5}$ fractions, exceeding the value of 25μg/m^3, recommended by the World Health Organisation [Lin and Peng, 2010] and are at comparable levels to those reported in studies conducted internationally in Europe, Asia or America [Fromme, H., Particles in the Indoor Environment].

CONCLUSIONS

In the experimental campaign carried out, were monitored volatile organic compounds and particulate matter in residential spaces inside of three buildings located in urban area, which differ through spatial characteristics (different surface and volume), number of occupants and types of interior finishes. The conclusion at the end of the monitoring program has exposed that there are volatile organic compounds and particulate matter, in various concentrations, in indoor air of the analysed residential spaces. These values can have different sources: missing ventilation systems, of the malfunctions of the ventilation systems, reduced ventilations reduced cleaning of the surfaces and the floor (Ionescu et al., 2011).

Communication and education in the field of indoor air quality are important for programs relating to the management of pollutants and when occupants understand and realize aspects of the causes and consequences of problems that can arise from an indoor environment unhealthy; they may be prevented or solved more efficiently. The indoor air quality management is not an individual problem that concerns only the occupants, but becomes a problem which implies the society decision makers, who may establish a specific legislative framework so that people are not exposed to such risk factors and ultimately to enjoy a healthy indoor environment, thus increasing the comfort level of living.

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REFERENCES

Baker S.R., Driver, J., McCallum, D.B., 2001, Residential Exposure Assessment. New York: Kluwer Academic Publishers.

Bernstein, J.A.; Alexis, N.; Bacchus, H.; Bernstein, I.L.; Fritz, P.; Horner, E.; Li, N.; Mason, S.; Nel, A.; Oullette, J.; Reijula, K.; Reponen, T.; Seltzer, J.; Smith, A.; Tarlo, S.M, 2008, The health effects of nonindustrial indoor air pollution, *J Allergy Clin Immunol,* **121** (3), pp.585-591.

Buonanno, G., Giovinco, G., Morawska, L., Stabile, L., 2015, Lung cancer risk of airborne particles for Italian population, *Environ Res* **142**, pp.443-451.

Crilley, L.R., Ayoko, G.A., Stelcer, E., Cohen, D.D., Mazaheri, M., Morawska, L., 2014, Elemental composition of ambient fine particles in urban schools: sources of children's exposure, *Aerosol and Air Quality Research*, **14**, pp.1906-1016.

Donaldson, K., 2003, The biological effects of coarse and fine particulate matter, *Occup Environ Med*, **60**, pp.313-314.

Fromme, H., Twardella, D., Dietrich, S., Heitmann, D., Schierl, R, Liebl, B., Ruden, H., 2007, Particulate matter in the indoor air of classrooms exploratory results from Munich and surrounding area, *Atmospheric Environment* **41**, pp.854-866.

Fromme, H., Particles in the indoor environment, available at www.intechopen.com.

Grandjean P, Landrigan PJ., 2006, Developmental neurotoxicity of industrial chemicals, *Lancet*, **368**, pp.2167–2178.

Ionescu, A., Pop, I-C., Roşu, C., Gurzău, E.S., Neamţu, I., 2011, The exposure of primary school children to carbon monoxide, particulate matter and microclimate from Alba County, *Studia UBB Ambientum*, LVI, **1**, pp.67-71.

Kuehn C.M., Mueller, B.A., Checkoway, H. & Williams, M., 2007, Risk of malformations associated with residential proximity to hazardous waste sites in Washington State, *Environmental Research*, **103**, pp.405–412.

Lee, J.Y., Lee, S-B., Bae, G-N., 2014, A review of the association between air pollutant exposure and allergic diseases in children, *Atmospheric Pollution Research*, **5,** pp.616-629.

Leung, T.F., Ko, F.W., Wong, W.W., 2012, Role of pollution in the prevalence and exacerbations of allergic diseases in Asia, *J Allergy Clin Immunol,* **129**, pp.42-47.

Lin Chi-Chi, Peng, C-K, 2010, Characterization of indoor PM_{10}, $PM_{2,5}$ and ultrafine particles in elementary school classrooms: a rewiew, *Environ Engineer Sci*, **27**, pp.915-922.

Moghaddasi, Y., Mirmohammadi, S., Ahmad, A., Nejad, S.E., Yazdani, J., 2014, Health–risk assessment of workers exposed to flour dust: A cross-sectional study of random samples of bakeries workers, *Atmospheric Pollution Research* **5**, pp.113–118.

Nenciu F., Vaireanu D.I., 2014, A versatile system for indoor monitoring of some volatile organic compounds, *Rev.chim (Bucharest*), **65**, no.5, pp.565-570.

Saraga, D**.,** Pateraki, S., Papadopoulos, A., Vasilakos, C., Maggos, T., 2011, Studying the indoor air quality in three non-residential environments of different use: a museum, a printery industry an d an office, *Building and Environment* **46**, pp.2333-2341.

Slezakova, K., Morais, S., do Carmo Pereira, M., 2012, Indoor Air Pollutants: Relevant Aspects and Health Impacts, Environmental Health - Emerging Issues and Practice, Prof. Jacques Oosthuizen (Ed.), ISBN: 978-953-307-854-0, InTech, available at: *http://www.intechopen.com/books/environmental-healthemerging-issues-and-practice/indoor-air-pollutants-relevant-aspects-and-health-impacts*

Vasile, V., Cioacă, A., 2011, Metode şi tehnici experimentale pentru determinarea emisiilor provenite din materialele de construcţii, *Revista Urbanism. Arhitectură. Construcţii,* **2**, pp.63-66.