STUDY ON THE CONCENTRATIONS OF INORGANIC COMPOUNDS IN OFFICE SPACES

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ABSTRACT

Indoor environment affects equally the health, the productivity and the occupants comfort, the costs for employers, owners of the buildings and the society being significantly larger, in the case of an inadequate interior ambient. Therefore, a good indoor air, in the office spaces, leads to the improvement of the work performance and to the decreasing of the absenteeism. Moreover, the occupants of discomfortable spaces will have the tendency to react in order to reduce their own discomfort, with consequences on the energy consumption.

Keywords: indoor air; inorganic compounds; health; constructions

REZUMAT

Mediul interior afectează în mod egal sănătatea, productivitatea şi confortul ocupanţilor, costurile pentru angajatori, proprietari ai clădirilor şi societate, fiind considerabil mai mari, în cazul unei ambianţe interioare necorespunzătoare. Prin urmare, un aer interior de bună calitate, în spaţiile de birouri, conduce la îmbunătăţirea performanţelor de muncă şi la reducerea absenteismului. În plus, ocupanţii unor spaţii inconfortabile vor avea tendinţa de a recţiona în vederea reducerii disconfortului propriu, cu consecinţe asupra consumului de energie.

Cuvinte cheie: aer interior; compuşi anorganici; sănătate; construcţii

1. INTRODUCTION

At international level there is increasing public awareness of the risks associated with poor indoor air quality in homes and workplaces (Bernstein et al, 2008).

People spend more than 20 hours per day in the indoor environment, so the quality of air in the built environment has gained increased attention because of the occurrence of health problems (Saraga et al., 2011; Jones, 1999), reported by many studies, such as allergic diseases and asthma (Leung et al., 2007; Kim et al., 2011, 2013), skin diseases such as atopic dermatitis (Beltrani, 2003; Lee et al., 2014), respiratory and cardiovascular problems (Saraga et al., 2011; D'Ippoliti et al., 2003; Janssen et al., 2002; Peters et al., 2001; Hwang et al., 2010) even carcinogenic potential after long-term exposure. It is noted that in developed countries, the incidence of allergic diseases and asthma has doubled in the last two decades (Fanger, 2006), and that depreciation of indoor air quality is the main reason for these diseases (Bornehag et al., 2005).

Inorganic compounds present in indoor air, like nitric oxide (NO), nitrogen dioxide (NO_2), carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), ozone (O_3) and ammonia (NH_3), may result from the metabolic and burning processes as a result of inside activities or from outside sources. 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, 2011a), the approach of indoor air quality field can be led from the physical perspective, chemical perspective or biological perspective. Their correlation can lead ultimately to a complete characterization of air, so that there can be reported concentrations whose level is high by

comparison 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 detecting the generation source existing in the indoor environment.

2. MATERIALS AND METHODS

The experimental study was based on monitoring the concentration of inorganic compounds in four office spaces, located in the urban area of Bucharest, Romania. In office No. 4 a smoker occupant was present. Space dimensions, number of occupants, types of finishes, orientation in relation to the cardinal points, were variable parameters of the monitoring process. Sampling parameters, such as height (120 cm), total duration of monitoring and sampling interval were constants for all analyzed spaces.

The principle of the monitoring method is the qualitative and quantitative identification of the inorganic compounds and the recording of their concentrations in real-time by the electrochemical method, for six hours per day at an interval of five minutes. In addition to the monitoring of inorganic compounds, we chose to record for one hour the concentrations of carbon compounds (carbon monoxide and carbon dioxide), the temperature, the relative humidity, the value of the total concentration of volatile organic compounds (Vasile and Cioacă, 2011b), and the air velocity in the studied spaces, as indoor climate parameters.

The air velocity was recorded in the central point maintaining the height of 120 cm from the floor level.

The equipment used for determining the parameters analyzed in the monitoring program is presented in Table 1.

Table 1. *Analyzed parameters and equipment used*

Parameter	Equipment	Measuring principle	Range	Accuracy
Nitrogen monoxide (NO)	Gray Wolf Direct Sense TG-501	Electrochemical	0 to 250 ppm	-
Nitrogen dioxide (NO_2)			0 to 20 ppm	-
Sulphur dioxide (SO_2)			0 to 30 ppm	-
Ozone (O_3)			0 to 1 ppm	-
Ammonia (NH_3)			0 to 100 ppm	-
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
Total volatile organic compounds (TVOCs)		Photoionization detector (PID)	5 to 20.000 ppb	-
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
Air velocity	Trotec TA 300	Hot wire sensor	0,1-25,0 m/s 0,3-90,0 km/h	± 5% of the measured value

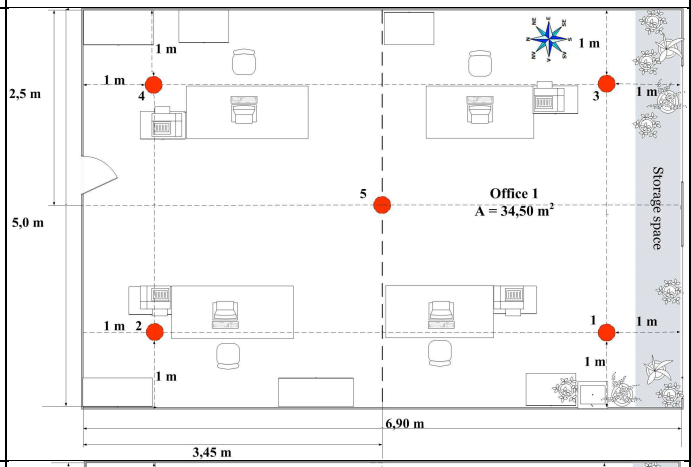
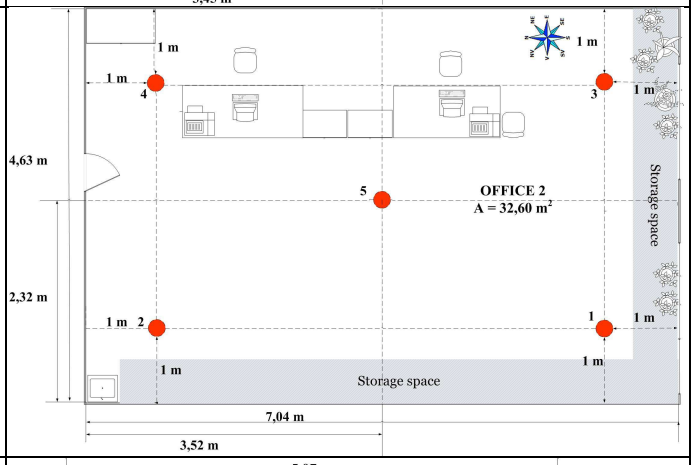
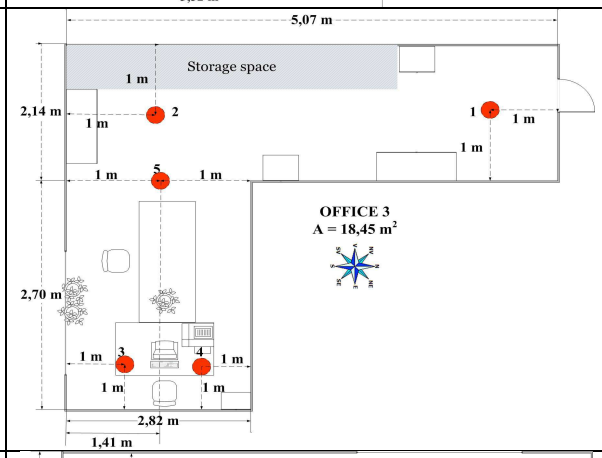
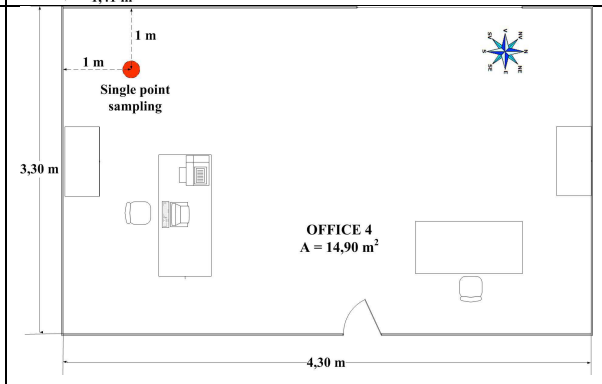
3. CHARACTERISTICS OF OFFICE SPACES

All four studied offices are located in a single-floor building, situated in the urban area.

The first three offices that are part of the monitoring segment have been recently renovated and the fourth office was used to observe changes in the concentrations of inorganic compounds when the space is not renovated and is occupied by a smoking person. The analyzed spaces are different in terms of surface size, number of occupants and office equipment. In addition, the interior finishing is different, and in offices No. 2 and No. 3 gas sources are present.

The summary of the analyzed spaces characteristics and the location of sampling points are presented in Table 2.

Table 2. Characteristics of the analyzed office spaces

Space ID	Floorplan and location of sampling points	Basic information	
Office No. 1		Number of occupants	4
		Type of ventilation at the time of monitoring	Natural ventilation
		Orientation	South
		Volume	133,17 m^3
		Area	34,5 m^2
Office No. 2		Number of occupants	2
		Type of ventilation at the time of monitoring	Natural ventilation
		Orientation	South
		Volume	125,82 m^3
		Area	32,60 m^2
Office No. 3		Number of occupants	1
		Type of ventilation at the time of monitoring	Natural ventilation
		Orientation	South
		Volume	71,27 m^3
		Area	18,45 m^2
Office No. 4		Number of occupants	1 (smoker)
		Type of ventilation at the time of monitoring	Natural ventilation
		Orientation	West
		Volume	54,77 m^3
		Area	14,19 m^2

4. RESULTS AND DISCUSSIONS

In this experimental study there were monitored concentrations of five inorganic compounds, as nitrogen monoxide, nitrogen dioxide, sulfur dioxide, ozone, ammonia, as well as climate parameters. The obtained values are summarized in Table 3.

Table 3. Summary of results

Monitored compound	Average concentrations (min/max concentration)			
	Office 1	**Office 2**	**Office 3**	**Office 4**
Number of occupants	**4**	**2**	**1**	**1**
Sulphur dioxide (SO_2), µg/m^3	0	2728,5 (1527,1/3450,7)	2372,6 (431,1/3076,9)	2413,1 (2277,9/2995,3)
Nitrogen monoxide (NO), µg/m^3	10 (0,1/57,3)	10 (0,1/26,9)	14,9 (0,4/66,3)	24,4 (3,2/70,2)
Ozone (O_3), µg/m^3	0,3 (0,01/6,69)	5,84 (0,01/32,15)	2,51 (0,02/18,16)	1,8 (0,10/13,40)
Total volatile organic compounds (TCOVs), ppm	0,31(0,24/0,55)	0,83 (0,17/3,68)	0,25 (0,09/0,51)	0,21 (0,11/0,41)
Carbon dioxide (CO_2), ppm	1428 (1305,0/1577,0)	1428 (1066,0/1668,0)	1157 (803,0/1729,0)	838 (800,0/888,0)
Carbon monoxide (CO), ppm	0,9 (0,6/1,2)	0,9 (0,4/1,4)	0,6 (0,3/1,1)	0,5 (0,3/0,7)
Air temperature (T), °C	25,8 (24,1/26,9)	28,3 (25,4/31,3)	24,7 (20,4/27,3)	25,7 (23,9/27,5)
Air relative humidity (RH), %	33,7 (29,7/37,7)	21,9 (15,0/31,5)	25,4 (15,7/33,1)	29,1 (24,1/35,2)
Air velocity, m/s	4,64 (3,95/6,68) at 24,91°C	4,90 (4,01/7,01) at 26,95°C	4,03 (3,83/6,69) at 23,97°C	4,13 (3,85/5,51) at 24,50°C
Airflow, m^3/min	9511,52	9574,00	4460,55	3515,52

Temperature and relative humidity are two paired parameters that can significantly affect the occupant comfort. From this point of view, the highest average value for air temperature (28,3°C) was recorded in Office No. 2, at the same time with a significant decrease of relative humidity average value (21,9%). A level of relative humidity below 25% is associated with an increase of the occupants discomfort; a long-term exposure in such conditions may cause problems associated with skin dryness or irritation.

In office spaces, a low value of relative air humidity can increase static electricity, which causes to occupants discomfort and blocks the proper operation of computers and auxiliary equipments (copiers, printers etc).

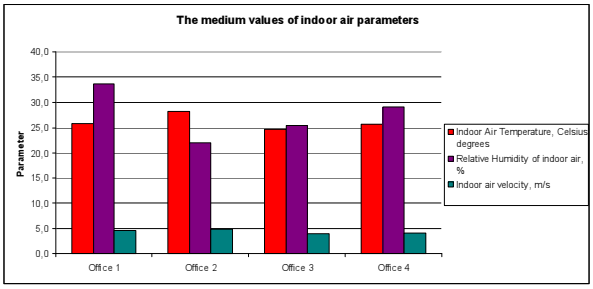


Fig. 1. Indoor air parameters

In all monitored offices, the average concentration of carbon dioxide exceeded the limit established by the Occupational Safety & Health Administration (OSHA) - PEL (800 ppm), while for carbon monoxide the allowable limit, 50 ppm according to OSHA – PEL, was not exceeded. Office No. 2 showed the highest values of indoor air velocity

(4,90 m/s), although at the time of monitoring there was no natural or mechanical ventilation. The only air exchange was done through a poor insulation of the enclosure elements and by dynamic indoor activities, related with a additional flow of persons, which led to the increased indoor air currents.

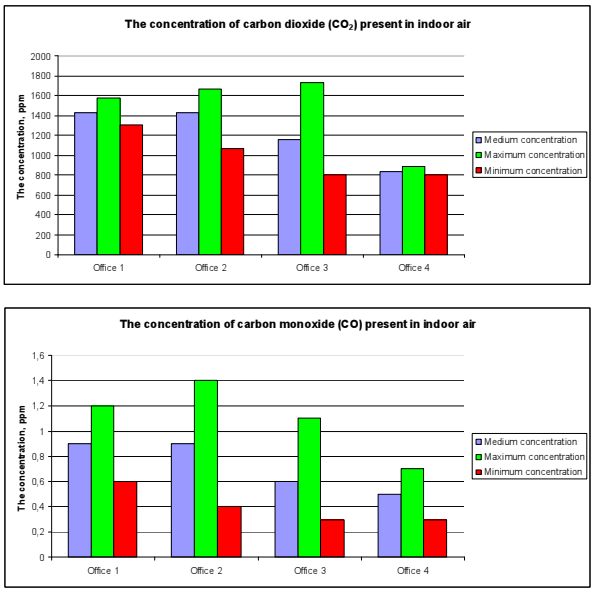


Fig. 2. The concentrations of carbon dioxide and carbon monoxide found in indoor air

Regarding inorganic compounds present in indoor air, in all four studied spaces there were not recorded concentrations of nitrogen dioxide and ammonia.

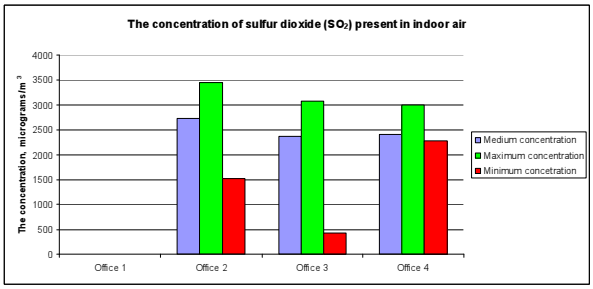


Fig. 3 The concentration of sulfur dioxide found in indoor air

The highest average concentration for SO_2 was recorded in Office No. 2, 2728,5 μg/m^3, with a minimum value of 1527,1 μg/m^3 and a maximum value of 3450,7 μg/m^3 while in Office No. 1 this compound was absent. In this case, the generation of sulphur dioxide was based mostly on the presence of the gas supply source. Although at the moment of monitoring of Office No. 4 the space was naturally ventilated, a significant concentration of SO_2 was recorded, with a maximum value of 2995,3 μg/m^3, the main reason being the presence of cigarette smoke as a generation source.

The highest average concentration of NO was observed in Office No. 4 (24,4 μg/m^3) with a maximum of 70,2 μg/m^3, in conditions of natural ventilation of the space. The potential source of NO is also in this case cigarette smoke.

For the recently renovated spaces, the highest average concentration of NO was recorded in Office No.3, with a value of 14,9 μg/m^3 and a maximum of 66,3 μg/m^3, recorded during to the entire monitoring period. In this situation, the emission source may be the existence of the gas supply path in the surrounding spaces.

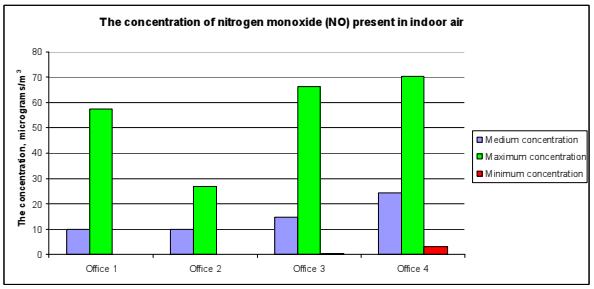


Fig. 4 The concentration of nitrogen monoxide found in indoor air

The O_3 concentration had the highest value in Office No. 2, 5,84 μg/m^3, with a maximum of 32,15 μg/m^3 recorded for the entire monitoring period, followed by Office No. 3, with a maximum of 18,16 μg/m^3.

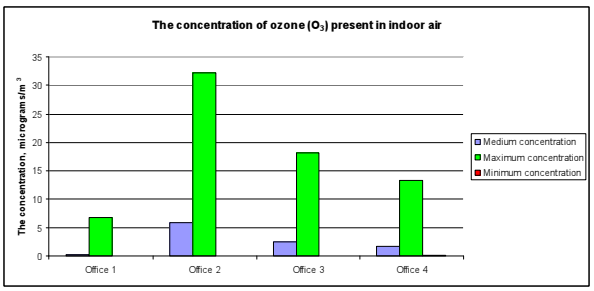


Fig. 5 The concentration of ozone found in indoor air

5. CONCLUSIONS

In the process of investigating the indoor air quality, it is important to correlate the recorded results with in-situ observations so that it can be achieved a hypothesis regarding to the possible causes that led to the issues of indoor air depreciation.

Knowing the causes, particular measures, customized for any spaces, can be adopted and so the occurring problems can be fixed, in order to maintain indoor air quality so that occupants' health is not affected.

So far, the important volume of technical and scientific information completes the data base content and develops the concept regarding the indoor air quality.

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