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Indoor Air Pollution in the Romanian Homes

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1. Introduction

Environmental pollution is one of the most important issues in the world today. Environmental pollution includes outdoor pollution and indoor pollution. For many decades the scientists have been studied outdoor pollution. This area of interest includes the pollution of ambient air, the pollution of water, soil, housing, the effects of ionizing and non-ionizing radiation, wastes.

The indoor environment has several aspects that are of importance. One aspect is linked to the chemical pollution of the indoor air. Other aspects can be linked to the biological contamination of air and surfaces, or to radiation pollution of indoor air linked especially to the presence of radon and radon daughter.

Health can be negatively affected by all types of environmental pollution. The outdoor and the indoor environments are linked. The two elements cannot be separated. Man spends around 85% -90% of a day indoor. There are category of population like infants and young children, elderly people, sick people and convalescent which spend 100% of a day time indoor.

Vulnerable groups are represented by children, pregnant women, elderly persons over 65 years of age, persons suffering of asthma or other respiratory diseases, persons suffering from cardiovascular diseases. Immunodeficiency may render people more vulnerable especially for biologic pollutants (SCHER, 2007). In the indoor environment are various sources of pollutants like: heating and cooking appliances, open fires, building and insulation materials, furniture, fabrics and furnishings, glue, cleaning products and other consumer products (P.T.C. Harrison, 2002).

A lot of diseases can originate in the indoor environment. Environmental immunologic diseases are both allergic and non-allergic (Ledford K Dennis, 2002). Diseases categorized under the generic name of "building related illnesses" were identified, as well as another group of health problems that can be linked to the buildings. This category includes the so called "sick-building syndrome" or "tight-building syndrome".

The group of diseases in the "building related illnesses" category includes diseases like humidifier fever, hypersensitivity pneumonitis, some infectious diseases like Legionnaire's disease, Pontiac fever, tuberculosis, viral illnesses like flu, diseases of the childhood like measles, chicken pox, etc (Burge H.A. , 1995, Berglund at all,1992). The contamination of indoor air can induce allergic problems like rhinitis and asthma that can be related to indoor allergens such as dust mite, cockroaches, animals and mold. Some molds can release disease-causing toxins. These toxins can damage a variety of organs and tissues in the body, including the liver, central nervous system, digestive tract, and immune system. In the case of certain diseases, like humidifier fever, it is not certain whether the disease is an allergic reaction or a toxic response.

Indoors there are several sources of biological contaminants like:

- air handling system condensate,
- cooling towers,
- water damaged materials,
- high humidity indoor areas,
- damp organic material,
- porous wet surfaces,
- humidifier,
- hot water systems,
- outdoor excavation,
- plants,
- animal excreta,
- animal and insects,
- food and food products.

Symptoms of exposure to biologic contaminants include sneezing, watery eyes, coughing and shortness of breath, dizziness, fever and digestive problems.

Irritants such as certain volatile hydrocarbons may aggravate existing asthma via non-immunologic mechanisms.

Hypersensitivity pneumonitis is a non-allergic, immunologic pulmonary disease resulting from the inhalation of organic dusts from contaminated humidifiers, moldy organic debris, animal proteins and certain chemicals. This disorder is often misdiagnosed as an acute infectious respiratory condition because of the fever, chest infiltrates and cough. Interstitial fibrosis with permanent scarring of the lung may result if repeated acute or chronic episodes occur.

The etiology of the symptoms of “sick building syndrome” is usually due to some environmental features of the building, but the exact cause is difficult to ascertain. Potential causes include poorly functioning ventilation systems with inadequate fresh air, the presence of inorganic chemicals such as ozone or nitrogen dioxide and organic chemicals such as mycotoxin or formaldehyde. The symptoms often include mucosal irritation, skin irritation, neuropsychiatric complaints of fatigue and limited ability to concentrate, odor and taste complaints.

Another important pollutant that can be identified indoors is radon and radon daughters from soil, construction materials used for building the house, water, and the use of natural gas. This element can induce lung cancer in a long term exposure taking into account the lag time until the appearance of the disease.

That makes the indoor environment very important in connection to human health.

2. Purpose of the Study

The purpose of this study is to make an assessment of the indoor condition in the homes in Bucharest and the possible impact on health of the inhabitants.

For that purpose 34 apartments in city of Bucharest were studied. All the investigated homes were in blocks of flats. All flats were situated on different floors, starting from the ground floor until the 11-th floor. The geographical orientations of the flats were in all direc-

tions N, S, E, W. There were flats with a single room as well as flats with two, three and four rooms.
In all the flats the chemical pollution was investigated.
The biological pollution of indoor air was investigated in 10 apartments.
Indoor chemical pollution
The levels of several chemical pollutants were investigated: nitrogen dioxide, total aldehydes, formaldehyde, total suspended particles, carbon monoxide and benz (a)pyrene.
All the pollutants were measured in the kitchen and in the living room, in the winter and in the summer time.
Indoor biological pollution
The bacteriological and fungal pollution was also investigated in the flats, in the summer and in the winter time, in three compartments of each flat respectively: the living room, the bedroom and the bathroom.
Health assessment
The impact of this type of pollution on health of the inhabitants of those flats was investigated as well.
Methods used in the study
The chemical evaluation focused on several chemical pollutants.

- Nitrogen dioxide was measured by a colorimetric method.
- Total aldehydes and formaldehyde were measured through colorimetric methods.
- Total suspended particle were identified with a reflectometric method.
- Carbon monoxide was identified using a colorimetric method.
- Benz (a) pyrene was identified using a chromatographic method.

The chemical evaluation was made twice: once in the summer time and once in cold season.
For this study a biological investigation of the indoor air was performed. The biological evaluation included a bacteriological evaluation and an assessment of fungal contamination of the air.
The sampling method used was a passive method with exposure of a Petri dish with blood-agar for 10 minutes in the investigated rooms of each home.
This study investigates: the total number of bacteria, expressed in CFU/m^3 (CFU/m^3 – colony–forming units/cubic meter), the presence of Streptococcus alpha and beta hemolytic, Staphylococcus aureus and non-aureus with and without hemolytic proprieties and coliform bacteria as an indicator of enteric contamination of air.
For the assessment of fungi contamination of indoor air, the sampling method was a passive method with exposure of a Petri dish with Chapek with antibiotics support, for 10 minutes in each home, in the kitchen, in the bathroom and in the living room.
This study investigates the total number of fungi, expressed in CFU/m^3 (CFU/m^3 – colony–forming units/cubic meter) and the presence of different types of fungi.For an accurate assessment of the biological contamination of indoor air, the measurements were made twice in a year, in the winter and in the summer.

3. Results

The apartments can be divided into two categories: the first category was formed of apartments in which you can pass from one room in another and the second type was formed of

apartments with independent rooms separated by a hall. 38.2% apartments belonged to the first category and 61.8% apartments belonged to the second category.
The geographical orientation of the flats can divide the apartments into the following categories: 11.8% of the apartments were orientated EV, 14.7% of the apartments were oriented N, 23.5% NE, 5.9% NS, 14.7%NV, 8.8% S, 2.9%SE, 11.8%V and 5.9% SV.
70.6% of the investigated flats were situated on the inferior floors and 29.4% on the superior floors of the blocks of flats.
Taking into account the number of rooms in each flat, the situation was: 5.9% of flats had one room, 23.5% of flats had two rooms, 50% of flats had three rooms and 20.6% were flats with four rooms.
The building material used was: concrete - 58.9%, bricks - 29.4%, preformed walls - 11.7%.
The heating system was: a centralized system in 94.1%, gas heating in 5.9% of investigated flats.
The fuel used in the kitchen was gas in all investigated apartments.
In some of the apartments, the owners made some improvements like the use of wall paper for the living rooms and bedrooms, some dye work, faience and sandstones for the kitchen and bath wall and floors.
In 30% of apartments, the inhabitants smoked under 10 cigarettes per day and 70% of the inhabitants smoked over 10 cigarettes per day or more.
The inhabitants of the investigated apartments were divided by age as follows: 8.1% of the inhabitants were with age between 0 – 10 years old, 12.9% of the inhabitants were with age between 10 – 20 years old, 12.9% of the inhabitants were with age between 20 – 30 years old, 19.4% of the inhabitants were with age between 40 – 50 years old, 21% of the inhabitants were with age between 50 – 60 years old, 17.7% of the inhabitants were with age between 60 – 70 years old and 8% of the inhabitants were with age over 70 years old.
The inhabitants of the investigated apartments were divided by sex as follows: 51.6% were female and 48.4% were male.
The distribution according to the two types of apartments was equal.
The distribution of the inhabitants of the studied apartments according to the number of hours spent in the kitchen, where the main source of gas is located, showed the following situation: 22.6% of the inhabitants spend one hour per day in the kitchen, 11.3% of the inhabitants spend two hours per day in the kitchen, 12.9% of the inhabitants spend three hours per day in the kitchen, 33.9% of the inhabitants spend four hours per day in the kitchen, 12.9% of the inhabitants spend five hours per day in the kitchen and 6.40% of the inhabitants spend six hours per day in the kitchen.
According to the number of cigarettes smoked per day, 67.7% of the inhabitants were non-smokers, 12 % of the inhabitants smoked under 10 cigarettes per day and 20.3% of the inhabitants smoked more than 10 or more cigarettes per day, even more than a pack per day.
The levels of the chemical pollutants identified in indoor air were:

Levels of nitrogen dioxide (µg/m^3)	Kitchen -summer	Living room - summer
Minimum values	81	55
Maximum values	2770	1631
Average values	478	33

Table 1. Levels of nitrogen dioxide in indoor air in summer

Levels of nitrogen dioxide (μg/m³)	Kitchen-winter	Living room- winter
Minimum values	164	80
Maximum values	6903	1698
Average values	1629	586

Table 2. Levels of nitrogen dioxide in indoor air in winter

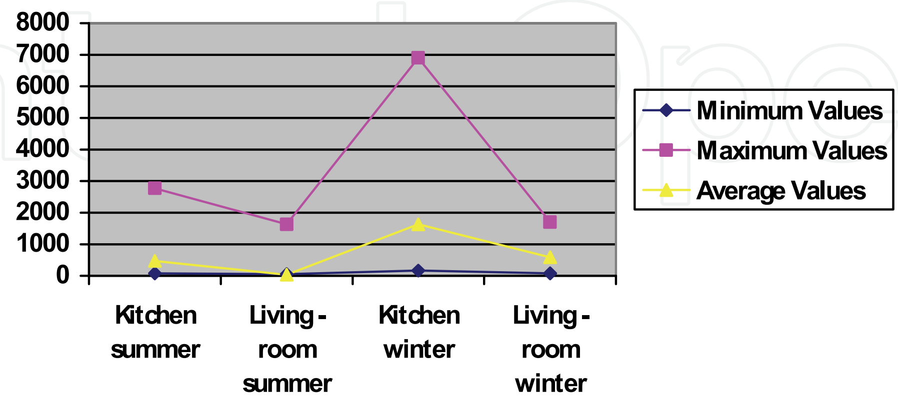

Fig. 1. Comparison between levels of nitrogen dioxide (μg/m³) measured indoor in summer and in winter

Levels of total aldehyde (μg/m³)	Kitchen -summer	Living room -summer
Minimum values	50	40
Maximum values	350	1280
Average values	108	148

Table 3. Levels of total aldehyde in indoor air in the summer

Levels of total aldehyde (μg/m³)	Kitchen-winter	Living room- winter
Minimum values	19	16
Maximum values	6769	240
Average values	459	136

Table 4. Levels of total aldehyde in indoor air in the winter

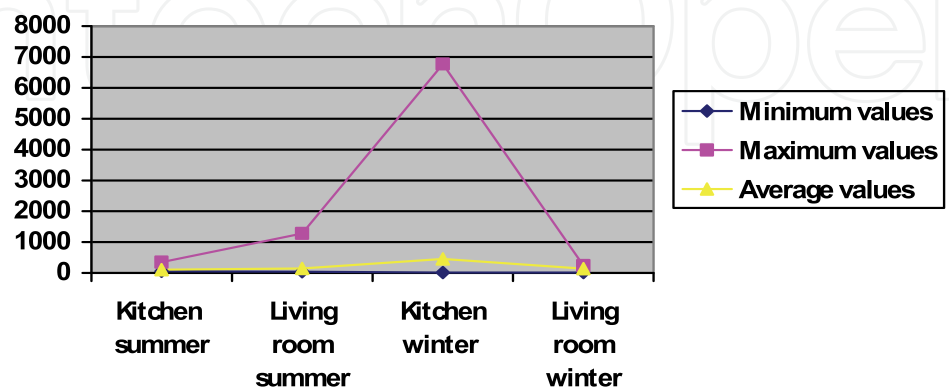

Fig. 2. Comparison between levels of total aldehydes (μg/m³) measured indoor in summer and in winter

Levels of formaldehyde (μg/m³)	Kitchen-summer	Living room -summer
Minimum values	3	8
Maximum values	91	122
Average values	35	34

Table 5. Levels of formaldehyde in indoor air in summer

Levels of formaldehyde (μg/m³)	Kitchen-winter	Living room- winter
Minimum values	2	4
Maximum values	860	188
Average values	142	65

Table 6. Levels of formaldehyde in indoor air in winter

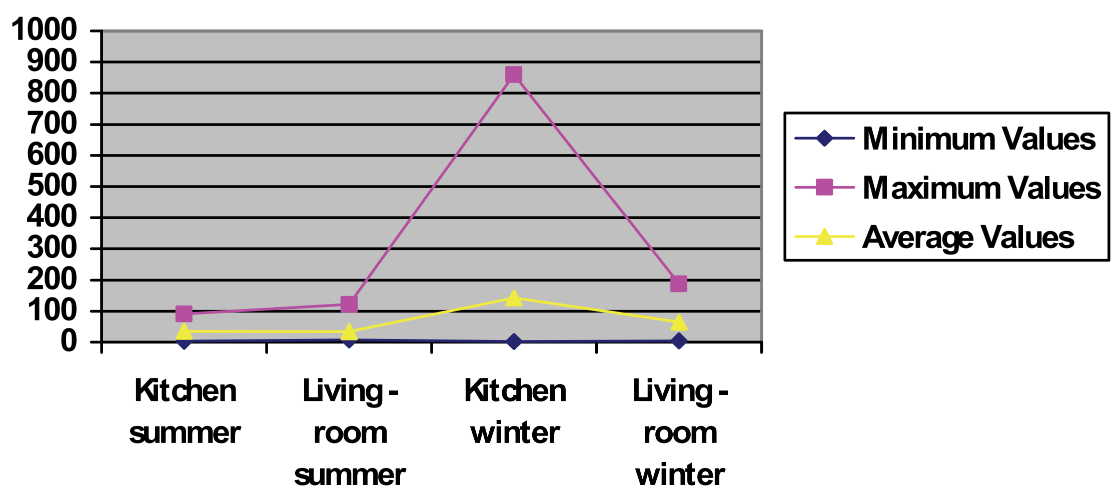

Fig. 3. Comparison between levels of formaldehyde (μg/m³) measured indoor in summer and in winter

Levels of carbon monoxide (mg/m³)	Kitchen -summer	Living room -summer
Minimum values	3.38	2.480
Maximum values	58	49
Average values	9	6.76

Table 7. Levels of carbon monoxide in indoor air in summer

Levels of carbon monoxide (mg/m³)	Kitchen-winter	Living room - winter
Minimum values	4.28	3.38
Maximum values	10	9.45
Average values	6.65	5.60

Table 8. Levels of carbon monoxide in indoor air in winter

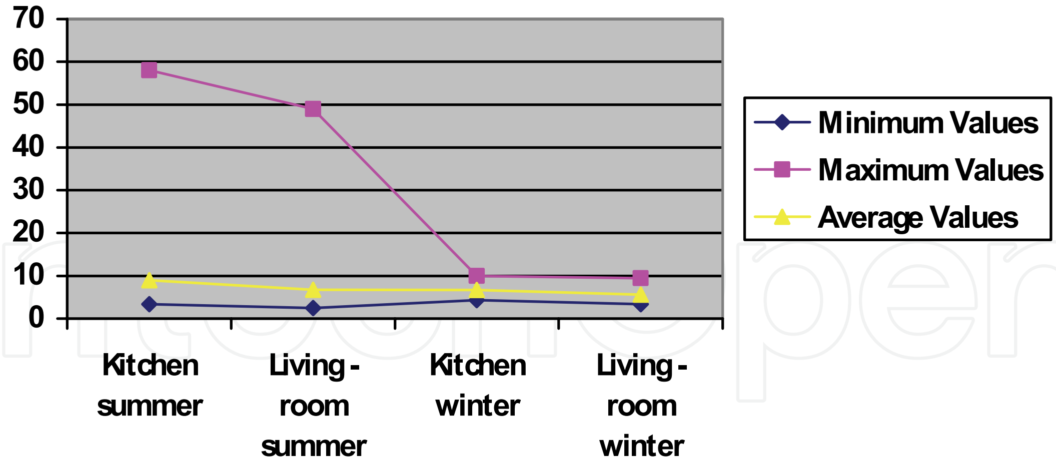

Fig. 4. Comparison between levels of carbon monoxide (mg/m³) measured indoor in summer and in winter

Levels of total suspended particles (µg/m³)	Kitchen-summer	Living room -summer
Minimum values	34	17
Maximum values	326	66
Average values	165	46

Table 9. Levels of total suspended particles in indoor air in the summer

Levels of total suspended particles (µg/m³)	Kitchen-winter	Living room- winter
Minimum values	117	1
Maximum values	365	326
Average values	245	224

Table 10. Levels of total suspended particles in indoor air in the winter

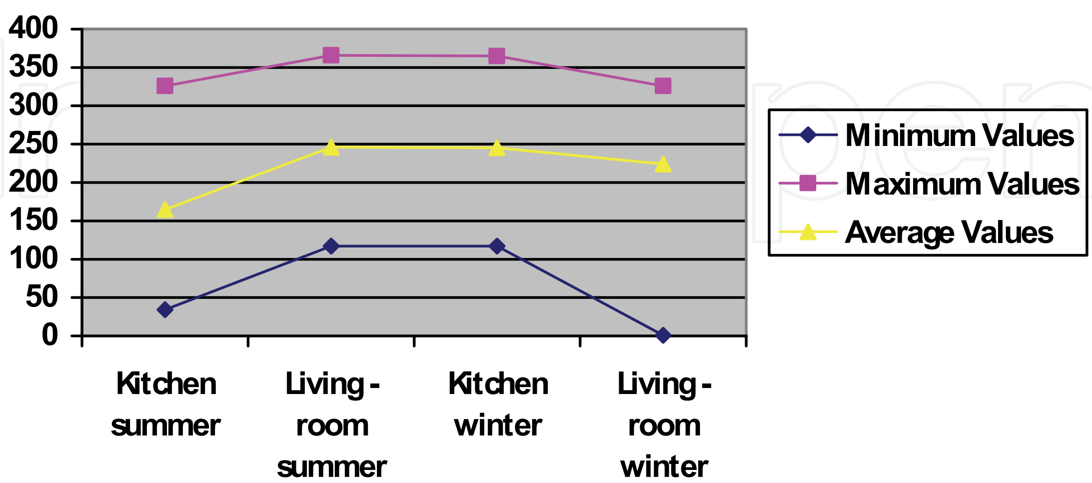

Fig. 5. Comparison between levels of total suspended particles (µg/m³) measured indoor in summer and in winter

Levels of benzo(a)pyrene (ng/m³)	Kitchen -summer	Living room -summer
Minimum values	81	55
Maximum values	2770	1631
Average values	478	33

Table 11. Levels of benzo (a) pyrene in indoor air in the summer

Levels of benzo(a)pyrene (ng/m³)	Kitchen-winter	Living room-winter
Minimum values	164	0
Maximum values	6903	698
Average values	1629	86

Table 12. Levels of benzo (a) pyrene in indoor air in winter

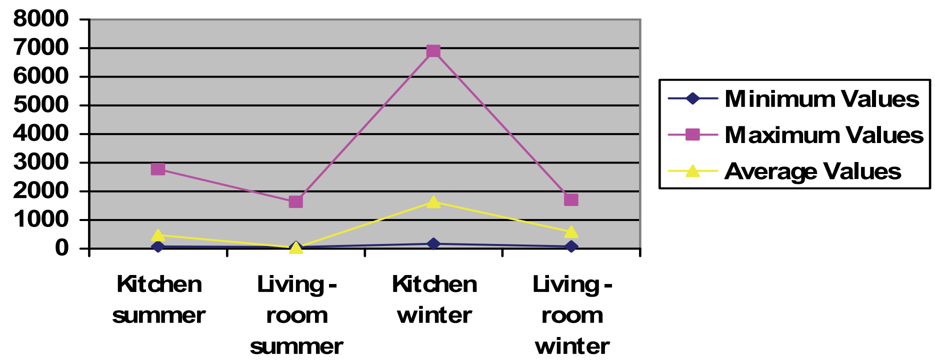

Fig. 6. Comparison between levels of benzo (a) pyrene (ng/m³) measured indoor in summer and in winter

Biological pollution of indoor air in the studied apartments from Bucharest city:
For the bacteriological evaluation the results were:

CFU/m³	In the kitchen	In the bathroom	In the living room
Minimum values	850	1500	120
Maximum values	57500	57500	32500
Average values	9367	13241	6090

Table 13. The total number of bacteria found in the summer time

Fig. 7. The total number of bacteria found in the summer time

CFU/m³	In the kitchen	In the bathroom	In the living room
Minimum values	625	688	63
Maximum values	12600	50400	6300
Average values	3124	7903	2406

Table 14. The total number of bacteria found in the winter time

Fig. 8. The total number of bacteria found in the winter time

CFU/m³	In the kitchen	In the bathroom	In the living room
Minimum values	250	134	200
Maximum values	38750	55000	26125
Average values	6338	7200	4308

Table 15. The total number of Staphylococcus found in the summer time.

Fig. 9. The total number of Staphylococcus found in the summer time

CFU/m³	In the kitchen	In the bathroom	In the living room
Minimum values	188	313	0
Maximum values	10250	55000	36500
Average values	3219	6421	4488

Table 16. The total number of Staphylococcus found in the winter time

Fig. 10. The total number of Staphylococcus found in the winter time

The presence of Staphylococcus with hemolytic elements was identified in one home, in the bathroom, at a level of 313 CFU/m³.
The presence of Streptococcus beta hemolytic was found in one house at the level of 938 CFU/m³ in the kitchen, 700 CFU/m³ in the bathroom and 1188 CFU/m³ in the living room. The presence of hemolytic Staphylococcus and Streptococcus beta hemolytic was confirmed in diferent houses.
The fungi contamination was assessed in 10 flats. The obtained results were:

Number of the house	The fungi level in the kitchen (CFU/m³)	The fungi level in the bathroom (CFU/m³)	The fungi level in the living room (CFU/m³)
1	1142	Layer	728
2	908	990	776
3	Layer	Layer	1271
4	0	0	0
5	180	110	52
6	0	250	0
7	1142	Layer	728
8	600	400	290
9	908	990	776
10	580	Layer	350

Table 17. The level of fungi measured in houses in the summer time

Number of the house	The fungi level in the kitchen (CFU/m^3)	The fungi level in the bathroom (CFU/m^3)	The fungi level in the living room (CFU/m^3)
1	728	Layer	350
2	378	28	12
3	Layer	1500	1550
4	0	0	0
5	160	80	36
6	29	941	36
7	3313	Layer	1820
8	0	0	47
9	1217	630	1710
10	633	3600	720

Table 18. The level of fungi measured in houses in the winter time

The species of fungi identified were:
- Penicilium,
- Aspergilium,
- Rhizopus,
- Mucor,
- Cladosporium,
- Fusarium.

Health evaluation
Health evaluation of those living in the investigated apartments showed the presence of respiratory symptoms like coughing, wheezing and respiratory diseases like bronchitis and pneumonia. The presence of irritations localized to the nose, throat and eyes and facial pains were linked to the indoor exposure.
The frequency of appearance of different symptoms to the inhabitants of the investigated apartments was:
- The cough was present in 12.1% of investigated inhabitants,
- Wheezing was present in 7.3% of investigated inhabitants,
- Shortness of breath was present to 4% of investigate inhabitants,
- Bronchitis and pneumonia were present in a percentage equal to 6.5%,
- Asthma was not identified among inhabitants of the investigated houses,
- Ocular irritations were present in 25% of investigated inhabitants,
- Nose and throat irritations were present in 22.6% of the investigated people,
- Irritations of the skin were not identified among the investigated inhabitants of the flats,
- Headaches were present in a percentage of 21.8% of investigated inhabitants,
- Facial pains were present in a percentage of 16.1% of investigated inhabitants,
- Infection of sinuses were present in a percentage of 6.5% of investigated inhabitants,
- Ischemic cardiopaty was present in a percentage of 11.3% of the inhabitants.
- Cancer was not identified among the inhabitants of the investigated houses.

Risk assessment

- Ocular irritation correlated with nitrogen dioxide exposure had an OR = 5.90 (95%CI: 1.67 - 22.88) for summer time and an OR = 1.19 (95%CI: 0.40 - 3.55) for winter.
- Ocular irritation correlated with total aldehyde exposure had an OR = 1.61 (95%CI: 0.45 – 6.36) for winter.
- Ocular irritation correlated with fomaldehyde exposure had an OR =1.26 (95%CI: 0.43 – 3.66) for summer time and an OR = 1.13 (95%CI: 0.36 - 3.69) for winter.
- Nose and throat irritations in correlation with nitrogen dioxide exposure had an OR = 2.76 (95%CI: 0.99 – 7.91) in the summer time and an OR = 1.70 (95%CI: 0.61 – 4.87) in the winter.
- Nose and throat irritations in correlation with total aldehyde exposure had an OR = 2.14 (95%CI: 0.61 – 8.22) in the winter.
- Nose and throat irritations in correlation with formaldehyde exposure had an OR = 0.54 (95%CI: 0.19 – 1.49) in the summer time and an OR = 2.81 (95%CI: 0.81 – 10.71) in the winter.
- Facial pains in correlation with nitrogen dioxide exposure had an OR = 3.18 (95%CI: 1.02 – 10.28) for the summer and an OR = 3.70 (95%CI: 1.05 -14.30) for the winter.
- Facial pains in correlation with total aldehyde exposure had an OR = 0.92 (95%CI: 0.17 – 7.02) for the summer and an OR = 1.62 (95%CI: 0.45 -6.36) for the winter.
- Facial pains in correlation with formaldehyde exposure had an OR = 1.26 (95%CI: 0.43 – 3.66) for the summer and an OR = 2.12 (95%CI: 0.59 -8.23) for the winter.
- For ischemic cardiopaty the correlation with exposure to carbon monoxide an OR = 1.15 (95%CI: 0.30 – 4.41) for the summer and an OR = 2.50 (95%CI: 0.64 – 2.74) for the winter.

Results discussion

The chemical substances identified in the indoor air reached very high levels of pollution, with positive correlations to effects on human health due to exposure to nitrogen dioxide, total aldehyde, formaldehyde, carbon monoxide WHO (c). A positive correlation between exposure to benzo (a) pyrene, formaldehyde and cancer could not be established, possibly because of the lag time the cancer has in inducing effects on human health.

No standards exist for acceptable levels of indoor air contamination with microorganisms, since the infectivity of pathogens is extremely species dependent, although a number of guidelines exist for indoor fungi levels and a few exist for indoor bacterial levels. As limit to refer to, it is possible to use the limit proposed by ACGIH (American Conference of Government Industrial Hygienists) and AIHA (American Industrial Hygiene Association) that stipulates 1000 of viable CFU/m^3 of air as an upper limit for concentration in indoor environment (Rao et.al., 1995). CEC (Commission of the European Communities) (2004) and WHO (a, b, d, e) defines as a "very high" level the value equal to 2000 CFU/m^3. A value of 10,000 CFU/m^3 of nondescript airborne microbes could therefore be considered a hazardous level for indoor environment.

In this respect, the values that were obtained in this study are much higher, both in the summer and in the winter time, for the maximum values. For Staphylococcus the obtained levels were over the limit presented above, also in the case of the average value.

For fungi in non-industrial spaces the limit that can be used to compare the results to is

equal to 100 CFU/m^3 (CEC).
The results obtained in the study were much higher than 100 CFU/m^3 and in the bathrooms, where there are areas with high humidity, a layer of fungi was frequently found.
The health of inhabitants of investigated houses was affected, especially due to the presence of respiratory symptoms and diseases and the presence of irritations.
It can be concluded that a high biological contamination in indoor spaces can be a threat to human health.
Further research must to be done to develop guidelines and to propose measures to reduce the possibility of having a high level of indoor pollution and to protect in this way the human health. Regarding the development of the guidelines, World Health Organization (e) as well as other organization like US-EPA (Environmental Protection Agency of The United States of America), IARC (International Agency for Research on Cancer) and other scientific organizations propose developments of guidelines for formaldehyde, benzene, naphthalene, nitrogen dioxide, carbon monoxide, radon, particulate matter ($PM_{2..5}$ and PM_{10}), polycyclic aromatic hydrocarbons (PAH), especially Benzo-a-pyrene (BaP) and halogenated compounds like tetrachloroethylene. For this group of substances a number of relevant systematic reviews and risk assessment for pollutants present in indoor environments is identified. There is another group of substances for which there is uncertain or insufficient evidence for development of guidelines. This group includes toluene, styrene, xylenes, acetaldehyde, hexane, nitric oxide (NO), ozone (O_3), phthalates, biocides, pesticides, asbestos, glycol ethers, carbon dioxide, limonene, pinene.
For biologic agents development of quantitative guidelines requires research for all agents (WHO, e). Guidance can be provided for pathogenic agents like viruses and bacteria, bacteria (non pathogenic), fungi, toxin and other microbial products, microbial compounds, algae and amoebae, mites, pet allergen (cats and dogs), pest allergens (cockroaches and other insects, rats), pollen, fungal allergens (e.g. Alternaria, Cladosporium), ventilation (humidity control, pollutant removal), ventilation (components – as sources of contamination), dampness, moisture control, condensation, chemical degradation and microbial growth, hygiene and lack of cleaning, use and mis-use of cleaning and disinfection products and use of air fresheners.

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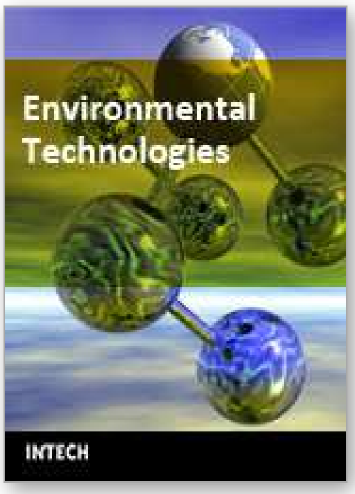

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This book on Environmental Technology takes a look at issues such as air, soil and noise pollution problems, environmental quality assessment, monitoring, modelling and risk as- sessment, environmental health impact assessment, environmental management and envi- ronmental technology development. It represents institutional arrangements, financial mechanisms and some sustainable technologies. The user can always count on finding both introductory material and more specific material based on national interests and problems. The user will also find ample references at the end of each chapter, if additional information is required. For additional questions or comments the user is encouraged to contact the author.