



LEARNING TOXICOLOGY
THROUGH OPEN EDUCATIONAL
RESOURCES

INDOOR POLLUTION

Dana PERNIU, Ileana MANCIULEA

Transilvania University of Brasov

d.perniu@unitbv.ro, i.manciulea@unitbv.ro



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1. INTRODUCTION

Indoor pollution, an important subject considering that the modern people spend the overwhelming majority of the time in indoors – house, workplace, spaces for leisure. The interiors are very diverse, the air quality is characterized by heterogeneity and many times it may produce adverse health effects.

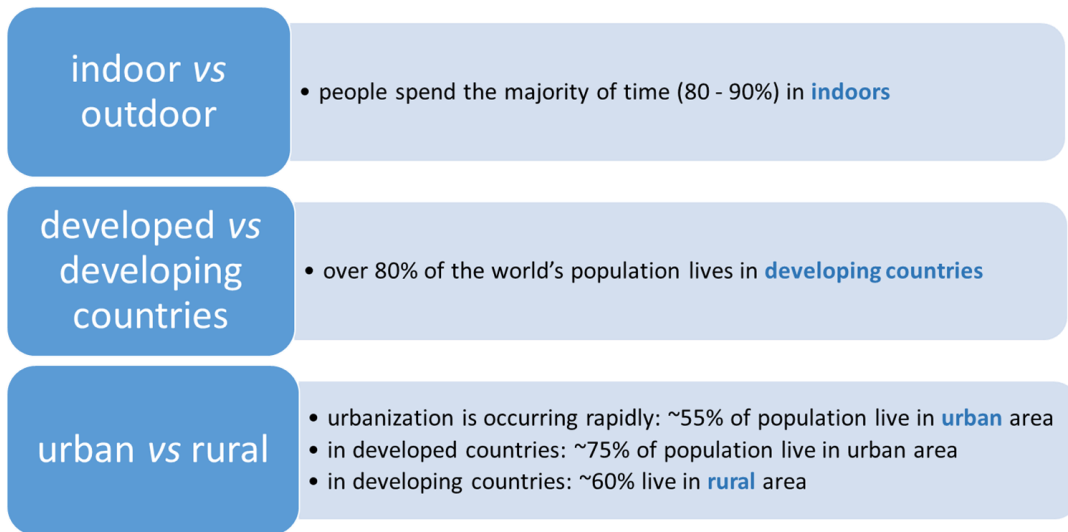
2. MICROENVIRONMENTS WHERE PEOPLE LIVE

Human exposure to pollutants occurs when individuals are in contact with a pollutant of a certain concentration, during a certain period of time. Exposure happens thus in the place where people often stay, in an area generically referred as “microenvironment”. Microenvironment is defined as the three-dimensional space where the pollutant level at some specified time is uniform. The microenvironment is thus characterized by constant statistical concentration of species. Considering a scheme for classification of global environment, including natural, and socio-economic environment) and also considering international statistics, one can roughly deduce that the majority of the population lives, for the most of the time in rural indoor microenvironments, in developing countries.

However, a significant part of the population lives in urban area and work in office environment, since the postindustrial era brought a shift from the manufacturing sector towards the service and knowledge-based sector.

In this section, we will present aspects related to the problem of indoor air quality, in different microenvironments, from different zones.

Obviously, the indoor air quality depends on factors like outdoor environment quality, socio-economic features of the indoor occupants, and also by their activity and lifestyle.



3. INDOOR AIR QUALITY - TERMINOLOGY

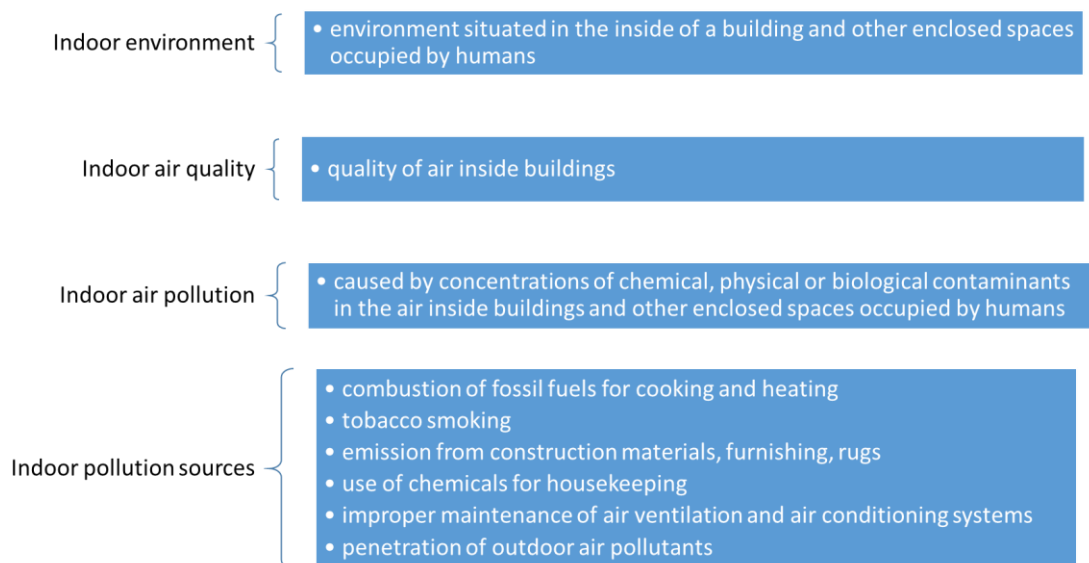
Considering the terminology, we should pay attention to several terms frequently used.

The *indoor environment* is situated inside a building or other enclosed spaces, occupied by people. As example, an office building, an apartment in a block of flats, the interior of a bus.

The *indoor air quality* is the quality of the quality of the air inside the building (or enclosed space) where it is analyzed.

The *indoor pollution* is caused by the presence in the indoor air of increased concentrations of chemical species (as example carbon monoxide), physical processes (noise of example) or biological contaminants (dust mites, as example).

Among *indoor air pollution sources*, we mention the burn of fossil fuels for heating and cooking, the smoking, the emissions from building materials, furniture, rugs, the use of chemicals for housekeeping, the incorrect ventilation, or improper maintenance of air conditioning systems, infiltration of atmospheric pollutants from outdoor proximity.



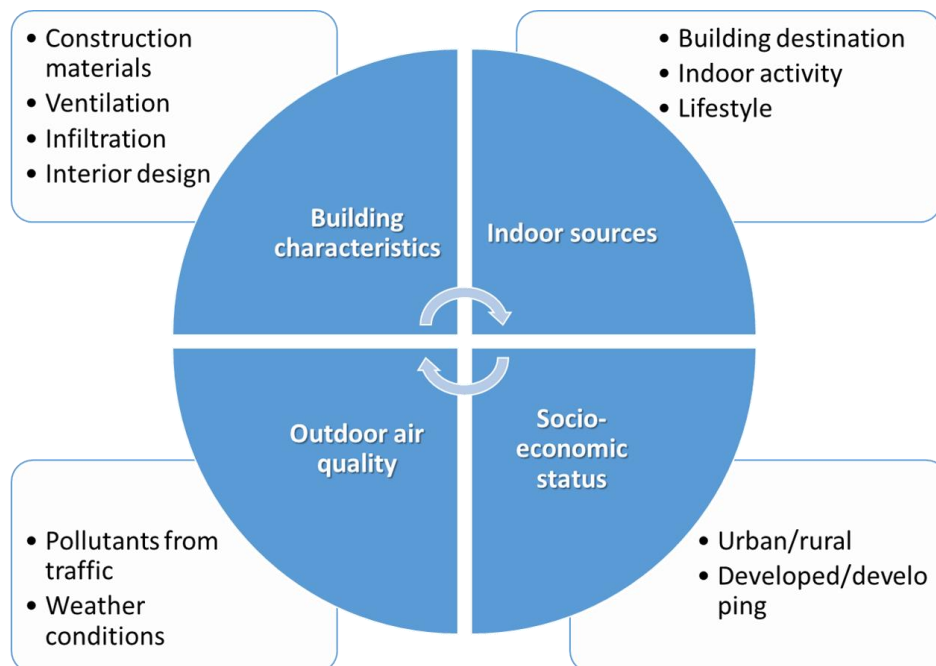
4. FACTORS AFFECTING INDOOR AIR QUALITY

The indoor air quality depends on several factors, here mentioned.

Firstly, the *socio-economic status* of the area where the building exists. Then, buildings differ by *constructive characteristics and design*. Thus, by design and construction, the building allows the natural or artificial ventilation and/or favors the pollutants infiltration. Ventilation and infiltration are processes involving the exchange of pollutants between outdoor and indoor. The ventilation, the intentional process, is linked to the occupants' habits, and depends on season and meteorological conditions. The infiltration is unintentional, and allows the penetration from outdoor of pollutants with very low dimensions, usually submicronic particulates.

From *outdoors*, usually pollutants from road traffic are introduced in indoors. Thus, the building location in the proximity of a pollution source is one of the important factors affecting the indoor air quality, but this strongly depends on socio-economic status of the occupants.

Not at least, the *indoor pollution sources* depends on building destination, the occupants' activities, their lifestyle and habits, elements strongly influencing the indoor air quality.



5. Pollutants in indoors and examples of their sources

In interiors a myriad of pollutants may exist, and as mentioned, they are produced by both indoor activities/sources and outdoor sources.

Gaseous pollutants, like *carbon monoxide*, *nitrogen dioxide*, *sulfur dioxide* are mainly generated from combustion of fossil fuels. In case of use of unvented combustion appliances, nitrogen dioxide concentration in homes may greatly exceed those from outdoors, especially in kitchens, during cooking. Carbon monoxide is a tasteless, odorless, colorless and nonirritating gas produced by incomplete combustion of organic material and is one of the leading causes of poisoning. It is emitted in indoors where are used gas appliances, unvented kerosene heaters, and also tobacco

smoke is present. The main effect of CO is result of its ability to impair the oxygen binding capacity of hemoglobin. The poisoning effect is dependent on concentration, length of exposure and the general health status of the exposed person.

The free radicals like *hydroxyl*, *hydroxyperoxil* radicals, and also *ozone*, are produced by chemical reactions. Ozone, a secondary pollutant is mostly penetrated from outdoor, especially during summer, sunny days, in buildings situated in proximity of roads with intense traffic. An important source for the indoor ozone is the use of air purifiers which provide relief from numerous respiratory illnesses, or reduce the odors and destroy microbes.

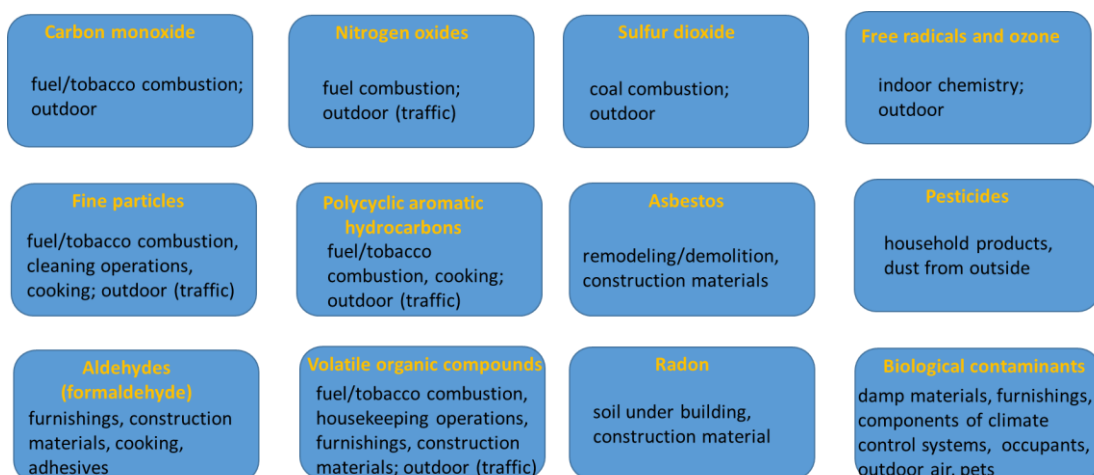
Particulates, which can accommodate a large variety of pollutants, like polycyclic aromatic hydrocarbons, pesticides, volatile organic compounds, biological contaminants, are the result of burning, in indoor, of fuels, tobacco, and also form outdoor penetration. Particulates might be directly released or they can be the result of chemical reactions of gas-phase precursors, (secondary particulates) originating from both indoor and outdoor sources. Particulates characteristics depend on the sources form which they are produced and on the post-emission processes involving the particulates.

Another indoor pollution source, generating aerosols rich in *volatile and semi-volatile organic compounds* is the use of chemicals for cleaning. Among sources for volatile organic compounds (VOC) emissions in indoors there are mentioned the new furniture, carpets, tiles, vinyl wall coverings, paints, adhesives. *Formaldehyde*, a toxic compound, may exist in indoors where wood furniture and various adhesives are used. The combination of sources releasing VOC in indoors can result in the occupants being exposed to a complex “chemical soup” comprising between 50 to 300 different individual VOC.

The *tobacco smoke* contains more than 4000 chemicals in the form of particles and gases, many of which are known as suspected carcinogens.

There are indoors, where, due to the soil or building materials, the radioactive material *radon* is released.

Not at least, it has to be mentioned the presence in indoors of *biological contaminants*, like home dust mites, bacteria.



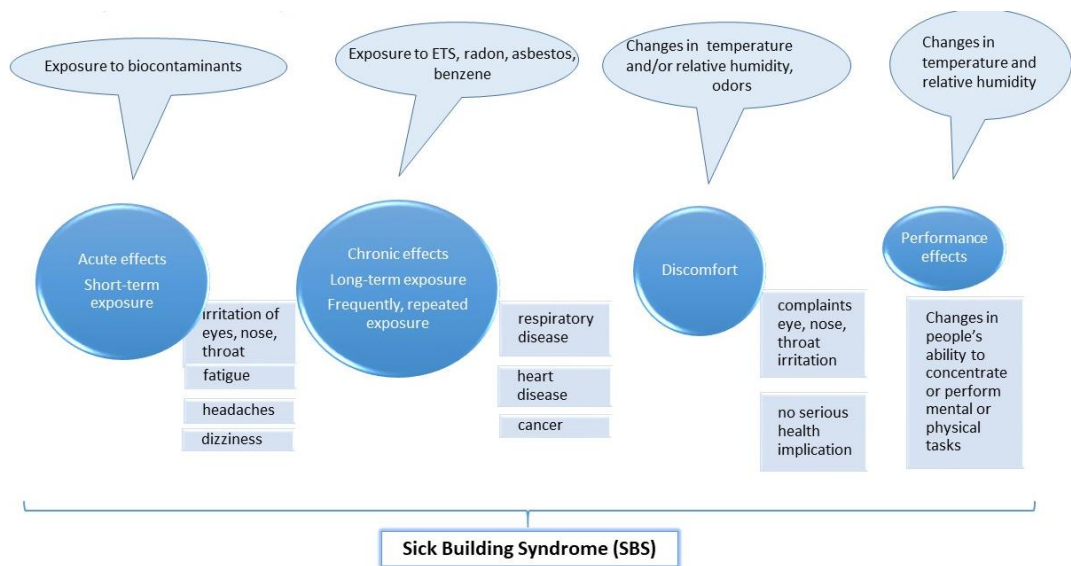
6. Effects of exposure to indoor polluted air

The effect of individual's exposure to indoor pollution mainly depends on pollutant type, and on exposure duration. The response time after exposure, is an important factor in effect evaluation. Immediately after exposure the acute effects like irritations, fatigue, headaches, and dizziness are manifested. Usually these are caused by exposure to biological contaminants, emissions from building materials, but mainly are caused by improper ventilation of the space.

As response to long-time exposure, or to repeated exposures, chronic effects are manifested, the cancer is one of example. Among pollutants, the tobacco smoke, the radon, the benzene, the asbestos are mentioned.

Effects without serious health implications, are the discomfort and the diminution of work performances, caused by the changes in physical parameters of indoor air.

Generally, it is used the "umbrella" - concept to integrate the occurrence of acute effects of indoor pollution exposure, the "sick building syndrome". As consequence of improper ventilation, and of gaseous pollutants and/or biological contaminants accumulation in indoors, the building occupants report a series of complaints for which there is no obvious cause and medical tests do not reveal particular abnormalities. The symptoms are present when individuals are in the building, but disappear when they leave. But usually they lead to absenteeism, and/or diminution of work performance and efficiency of the exposed persons.



EXAMPLES

A myriad of indoor pollutants, having inorganic, organic or biological nature, with potential risk for human health have in indoor concentration levels higher than outdoor. Thus, the population exposure can be significantly higher in indoors than outdoor. In this context we selected examples of microenvironments with potential risk for occupants' health.

7. ENERGY ACCESS IN HOUSEHOLDS

Energy use in homes is a vital feature of human society. Energy is used for a wide variety of purposes, including cooking, space heating, lighting, various household tasks, entertainment. The energy access is defined as "a household having a reliable and affordable access to both clean

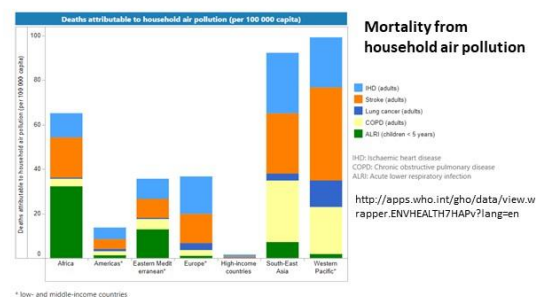
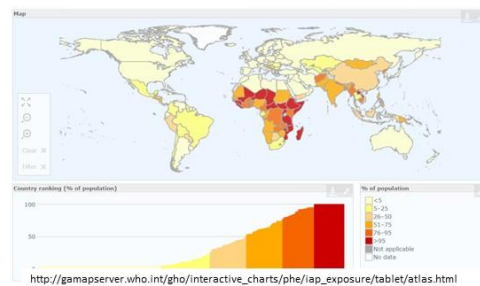
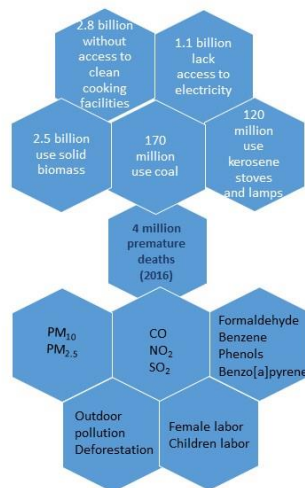
cooking facilities and to electricity, which is enough to supply basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average” (I.E.A.) As it has been mentioned in the beginning of this section, the majority of the population spends the most of the time in indoors, in rural environment, in developing countries. Due to low income and low level standard of life, the access to resources for basic needs as food and house defines the existence of a significant part of the world population.

Recent international statistics mention 2.8 billion people without access to clean fuel for cooking and 1.1 billion have no access to electricity. To ensure the basic needs for cooking and heating, 2.5 billion of people use solid biomass, 170 million use coal, and 120 million use kerosene as fuel for heating and cooking. Thus, a huge number of persons is exposed, in their own houses, to pollutants like particulate matter, carbon monoxide, nitrogen dioxide, sulfur dioxide, volatile and semi-volatile organic compounds. As mentioned by World health Organization, air pollution from households fuel combustion is the most important global environmental health risk today. As result to indoor air pollution, in 2016, 4 million of premature deaths were registered caused, in developing countries, by cardiovascular diseases, lung cancer, acute respiratory diseases.

Beyond direct effects on human health, the indoor pollution caused by fossil fuel use for cooking and heating, leads to pollution of outdoor air in proximity, affecting the neighborhood, to deforestation – as result of using wood as energy source.

Women and children are most affected by this kind of pollution. Women are the ones who traditionally ensure the food for entire family, thus the exposure to indoor pollution is long. Children, due to immune system incompletely developed, are strongly affected by indoor pollutants.

ENERGY ACCESS IN HOUSEHOLDS



8. Sleep microenvironment

Worldwide is appreciated that people sleep on average, 8-9 hours per day, meaning one-third of time. Thus, the sleep microenvironment is significant in terms of exposure to indoor pollutants.

The sleep microenvironment can be defined as space encompassing a mattress, pillow, bedding materials, bed frame and the volume of air above these items. All these components can be assumed as indoor pollution sources, since they are in immediately proximity of individuals, thus exposure over long time occurs via inhalation and dermal contact. Exposure is much more intense in the case of children, especially for the smallest, considering their long times allocated for sleeping and also to the low body weight.

In sleep microenvironments a large spectrum of species with harmful effects on human health may be found. The mattresses, pillows, bedding materials accumulates biological material, as dust mites, fungi, bacteria. They are also sources for pollutants either directly emitted, or accumulated on dust particles. We present here several examples.

Chemical compounds for the category of plasticizers, and flame retardants added in mattresses foam are known as substances with adverse effects on respiratory system, they can produce skin damages, and cancers. Even some of these chemicals are banned for introduction in bed items, they can be present in bedrooms.

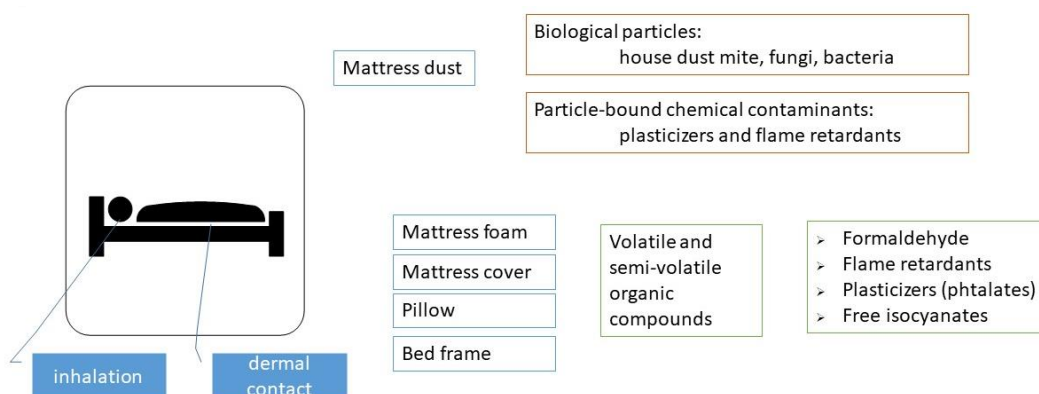
The flame retardants are introduced by fabrication in polyurethane foam mattresses. Over the time, different organic persistent compounds like polybrominated diphenyls, organophosphates were used

The plasticizers, like phthalates, are added to enhance softness and flexibility to the most of infant crib mattresses.

Diisocyanates are used in as additives in polyurethanic-foam mattresses, thus they may be source for emission of highly toxic residual isocyanate.

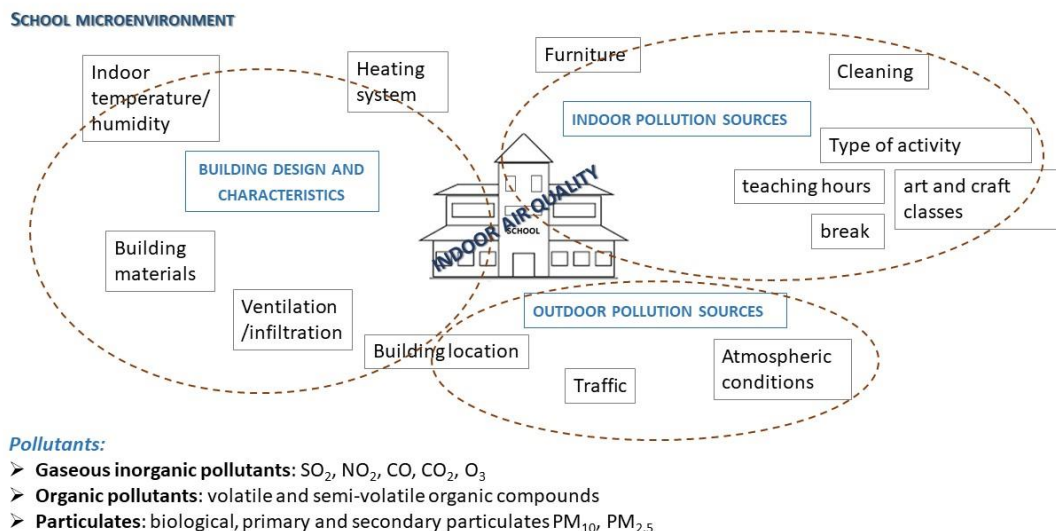
From the category of volatile organic compounds emitted in sleep microenvironment we mention the formaldehyde as it is largely used in wood composites, adhesives for construction of bed structure.

The concentration of pollutants is influenced by room ventilation, but also by personal factors as body temperature during sleep, body humidity, personal hygiene and personal behavior during sleep.



9. School microenvironment

Without doubts, school is a key-element in humanity development, thus offering children quality schools is an obligation for each generation. The quality of the school refers not only to didactical issues, but also to the quality of the microenvironment were children learn and develop.



The schools critical microenvironments in terms of indoor air quality, because they are usually located in the proximity of zones with intense road traffic. On the other hand, the students have increased vulnerability to insecure air quality, due to their age, but also as consequence of long time spent in schools. In school the occupation density is high, children are very active, and spaces are not always well ventilated.

Due to activities in school environment, due to outdoor infiltration, and due to constructive characteristics of the building, as function of season and occupants habits and behaviors, in schools exist a large number of gaseous pollutants, with inorganic, organic, or biologic nature. When fossil fuels are used for heating, gaseous pollutants as *sulfur oxide*, *nitrogen dioxide*, *carbon oxide and dioxide* are emitted. If not ventilated, these pollutants can reach high concentrations.

As result of outdoor pollutants infiltration, *ozone* is present in schools situated close to intense traffic, during summer sunny days.

Carbon dioxide can reach very high concentrations in poor ventilated rooms with intense activity of big number of children. Carbon dioxide is usually considered a reference parameter for indoor air quality and for adequate ventilation. The effect is a reduced performance of pupils and also the possible accumulation of other indoor pollutants.

Significant increases of *organic pollutants* concentration is correlated to the use of paints and glues and also occurred during cleaning activities, when *detergents* are used. Also, the fabrics, furnishing, construction materials can be source of organic compounds with highly adverse effects on children health, like *formaldehyde*, *polychlorinated biphenyls*.

For *particulate matter* both indoor and outdoor sources play a role. Sometimes, the PM values may significantly higher in indoor than outdoor, largely due to resuspension and especially for the finer size fraction of particulates. The harmful potential of particulate matter is related to their ability to penetrate in the deepest areas of human respiratory tract, carrying compounds as heavy metals, polycyclic aromatic hydrocarbons and dioxins/furans attached onto particle surface.

During winters, closed doors and windows lead to accumulation of pollutants in the indoor environment, air tightening may also lead to growth of biological contaminants, as bacteria, fungi, and mold.

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ИКИТ

<https://toxoeer.com>

Project coordinator: Ana I. Morales
Headquarters office in Salamanca.
Dept. Building, Campus Miguel de Unamuno, 37007.
Contact Phone: +34 663 056 665