HEALTH ASPECTS OF INDOOR AIR POLLUTION IN SCHOOLS

Training materials for teachers

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A. Introduction

Surveys conducted in different climates around the world show that people generally spend about 80-90% of their time indoors. The quality of air in these indoor spaces therefore plays a very important role in the health status of the people regularly staying there.

(Slide 3.) First of all, we have to define: what do we mean by indoor spaces?

An indoor space or indoor area is any closed area surrounded by boundary elements (including the indoor space of vehicles)**.**

Indoor Air Quality (IAQ) refers to the quality of the air inside buildings as represented by concentrations of pollutants and thermal (temperature and relative humidity) conditions that affect the health, comfort, and performance of the people staying inside. (*Note: Indoor air pollution is not considered to include technology-related air pollution in the workplace!)*

(Slides 4-5.) **IAQ issues are especially important in schools** because most children spend 6-8 hours or more (one third or one fourth of their time) at school where they have to perform intensive intellectual activity. The school is a special environment because it has to ensure optimum conditions for teaching and learning various kinds of subjects (mathematics, natural sciences, literature, physical education, foreign languages, etc.) for both the children and the teachers. Poor IAQ in school can interfere with the children's ability to concentrate and learn. We have to take into account that children – as developing organisms – are more sensitive to environmental impacts than adults. Low level of comfort leads to dissatisfaction. Acute effects of exposure to toxic chemicals like asthma attacks, headaches, nausea, drowsiness, and dizziness can be troubling in schools. Toxic chemicals can cause not only acute symptoms like irritations but long lasting adverse health damage, as well.

The Regional Priority Goal 3 "on preventing disease through improved outdoor and indoor air quality" of the Parma Declaration (2010) of WHO Europe, endorsed by 53 countries during the Fifth Ministerial Conference on Environment and Health, stated: "We aim to provide each child with a healthy indoor environment in childcare facilities, kindergartens, schools and public recreational settings, implementing WHO's indoor air quality guidelines…"

(Slide 6.) There are several reasons why the quality of indoor air has attracted more and more attention in the past few decades. First of all, due to national and international efforts, the general level of outdoor air pollution has significantly decreased and so the indoor air sources until then disguised by the strong outdoor air pollution have come to light. Secondly, change of heating methods and construction materials (bricks replaced by air-tight concrete materials in the prefabricated technology) and the architectural efforts that have focused on reducing air exchange for better heat conservation and the increased insulation in existing buildings have led to increased pollutant concentrations in the indoor air. Thirdly, more and more plastics and other man-made materials and adhesives have been used in the construction and equipment of buildings, which emit a lot of highly volatile compounds and cause a great deal of new, unprecedented exposure. Fourthly, by reducing ceiling height and generally indoor air space, pollutants released into the indoor air can become very rapidly concentrated and reach concentrations that may already be harmful to health.

B. Types and sources of indoor air pollutants

(Slides 7-9) The concentration of pollutants in a building depends on many factors like outdoor air quality, extent of air exchange, the binding capacity of indoor surfaces and the indoor pollution sources.

The fundamental difference between indoor and outdoor air is in the mixing volume. The mixing volume of the buildings is much smaller than that of the outdoor air. In this way, a pollutant that does not cause harmful effects outdoors, at most in the immediate vicinity of the emission, in the case of similar emission can reach dangerous concentrations indoors.

Indoor air is basically derived from ***outdoor air***. Its quality thus largely determines the limits of indoor air quality. In case of contaminated ambient air, clean indoor air can be provided only by costly artificial methods. The most frequent outdoor air pollution sources influencing indoor air quality include traffic (proximity of busy roads for car and trucks, fuelled either by petrol or diesel), industry (power plants and other industrial plants), construction, waste deposit sites, and various kinds of agricultural activity (e.g. spraying pesticides).

Infiltration of outdoor air pollutants can be influenced by various factors. E.g. particulates tend to accumulate in the lower floor levels, especially in case of classrooms facing the street, while volatile organic compounds of outdoor origin can be measured in higher concentrations in classrooms in the upper than in the lower floor levels.

A large number of combustion products (carbon monoxide /CO/, nitrogen dioxide /NO_2/, sulphur dioxide /SO_2/, nitrogen oxides /NO_x/, particulates /PM/, polycyclic aromatic hydrocarbons /PAH compounds/) originate from various different sources like ambient air (traffic, power plants, industry), heating (stoves and fireplaces), environmental tobacco smoke (ETS), garages, parking lots nearby classroom windows, candles, sparklers and incenses, mosquito coils, etc.

(Slide 10) However, special attention should be paid to substances released by indoor pollution sources. Accordingly, their concentration in indoor spaces will be higher than in the outdoor environment ($C_{indoor} / C_{outdoor} > 1$).

The figure taken from the SEARCH -1 study illustrates the ratios of the indoor and outdoor concentrations of the measured chemicals. It can be concluded that nitrogen dioxide (NO_2) and particulate matters with diameter less than 10 micrometres (PM_{10}) measured in the classrooms originate from the outdoor air while the other chemicals (benzene, ethyl-benzene, xylenes, toluene, and especially, formaldehyde) must have some indoor sources (as well).

(Slides 11-13) Indoor sources of air pollutants in the classrooms also include dust, construction and insulating materials, wall and floor coverings and other surface

materials, furnishing, paints, waxes, repellents, glues and resins, solvents, cleaning and disinfecting products, mould, photocopiers, inks, biocides, personal care products, humans, pets, rodents and insects.

Pollutants released by indoor sources include formaldehyde and other volatile organic compounds (VOCs), phthalates, polybrominated flame retardants, per- and polyfluorinated chemicals, vinyl chloride, trichloroethylene, tetrachloroethylene, ammonia, terpenes (limonene, alpha-pinene), phenol, naphthalene, asbestos.
Pollutants of outdoor origin entering and cumulating in the indoor air include radon, trichloroethylene, dust, particulates, polycyclic aromatic hydrocarbons, pollens, etc.

(Slides 14-15) Besides the chemical air pollutants *biological air pollutants* (bacteria, viruses, mould, animal hair, skin flakes, faeces, urine, insects, dust mites, pollen, etc.) play also important role in the indoor air quality. Humidifiers, condensation water of poorly maintained air conditioners and indoor stagnant waters can serve as a substrate for bacterium proliferation. Moist surfaces and materials are most favourite places of mould growth. Allergens of animal origin (faeces of house-dust mites, birds' feather, cats' and dogs' fur, etc.) can be present in the indoor air months after the removal of the source. Droplets from coughing and sneezing of infected people contain high number of bacteria and viruses which can live on in the indoor environment for several days.

Most frequent sources of mould development are rising dampness (capillary-like absorption of groundwater into the structural elements of the building due to bad insulation), penetrating dampness due to leaking, rain, melted snow (through the roof, walls or joints) and condensation due to excessive vapour production or inadequate ventilation, inadequate heating, large cold surfaces or cold bridges.

C. Health impact of indoor ir pollution

(Slides 16-19). Pollutants occurring in the indoor air may cause adverse effects in various organs and organ systems of the human body. The most obvious signs of health impairment appear at the entrance of the exposure route, i.e. in the respiratory system, but the cardiovascular, the central nervous and the immunological system as well as the endocrine system may also be affected by short term (acute) or long-term (chronic) exposures.

Acute effects in the respiratory system elicited by indoor air pollutants include mucous membrane irritation in the eyes and the upper respiratory tracts, coughing (symptom of bronchitis), asthmatic symptoms like wheezing, attacks of dyspnoea (heavy breathing), increased responsiveness of the airways to allergens and increased acute respiratory morbidity (due to upper- and lower respiratory tract infections, pneumonia, otitis media, etc.) reflecting impairments of the immune system, too. The increased risk of infection is also indicated by the increased absenteeism from school due to sore throat, cough, and cold, and by increased levels of biomarkers of oxidative stress and inflammation. Chronic exposure to certain pollutants may cause reduction of lung function and development of chronic obstructive pulmonary disease (COPD) and even lung cancer.

Some indoor pollutants may cause elevations in the arterial blood pressure and the heart rate.

Impacts of exposure to certain indoor air pollutants on the central nervous system may manifest themselves in headache, fatigue, dizziness, nausea and impaired task performance. Chronic exposure may cause impairments in different neuropsychological development outcomes (cognitive and psychomotor development delays, decreased global IQ, learning disabilities, difficulties in reading comprehension, memory functions, reading and maths scores, reduced reaction speed, attention deficit, coordination problems). Prenatal and early childhood exposure can result in neurodevelopmental diseases (attention deficit/hyperactivity, autism spectrum disorders, etc.).

Some chemicals exert endocrine disrupting effects manifesting themselves in impairments of the reproductive system, disorders in the brain development, contribution to later onset of diabetes, obesity, hyper- or hypothyroidism.

Exposure to certain air pollutants are known to be associated with childhood leukaemia and some central nervous system tumours in children. Childhood exposures may also contribute to the development of other cancers in the later life, as well.

D. Sources and health impacts of individual indoor air pollutants

(Slide 20). Nitrogen dioxide (NO_2)

Most of the nitrogen dioxide in the classroom air comes from vehicle exhaust gases of the outdoor air (indoor/outdoor concentration ratio is about 0.8), and from heating (in case of schools with gas heating appliances with inadequate ventilation). In addition, smoking may significantly contribute to the indoor NO_2 concentration where it is not yet prohibited.

Human sensory organs are particularly sensitive to NO_2 pollution. The odour threshold is 230 $\mu g/m^3$, while adaptation to the dark is already impaired by the concentration of 140 $\mu g/m^3$.

Epidemiological studies have shown an increase in the incidence of chronic lower respiratory tract diseases at chronic concentrations of 94 to 282 $\mu g/m^3$. Further health effects observed: increased bronchial reactivity, reduced respiratory function, reduced immunological protection, middle ear, nose-, ear-, and pharynx inflammation, eczema, increased blood coagulation in adults and increased allergenic effect of allergens (e.g. food allergy). Children and asthma patients are particularly sensitive to the effects of NO_2.

Health-based limit values for indoor NO_2 concentrations were recommended by the WHO: 200 μg/m^3 (1 hour average) and 40 μg/m^3 (annual average).

(Slide 21-23). Carbon monoxide (CO)

Indoor carbon monoxide may come from a variety of sources: the inflow of ambient air pollution produced mainly by cars, buses and trucks, or any kind of other outdoor CO sources (power plants, incinerators and other industrial pollution) as well as the use of poorly adjusted gas appliances, and smoking.

The health-damaging effect of carbon monoxide is primarily due to its strong tendency to bind to haemoglobin, as it impedes the binding and transport of oxygen by haemoglobin and thus causes tissue hypoxia throughout the body. As a result, the most sensitive organs to oxygen deficiency (myocardium, central nervous system), may be affected, producing more and more serious acute symptoms depending on the exposure level (headache, vertigo, tiredness, heavy breathing, nausea, vomiting, irritability, drowsiness, confusion, disorientation, loss of consciousness, coma and death). Chronic CO exposure may cause ischemic heart disease, acute myocardial infarction (AMI), increased cardiovascular and total mortality, asthma, sinusitis and pneumonia. Patients with impaired cardiac muscle, anaemia, chronic respiratory disease and cerebrovascular disease, and the elderly are particularly susceptible to this damage. Lack of oxygen can also adversely affect foetal development, which can result in retardation in foetal development, reduced birth weight and congenital malformations.

Blood carboxy-haemoglobin (COHb) levels are a good indicator of the body's exposure to carbon monoxide. Despite significant individual differences in CO sensitivity, there is a clear relationship between COHb concentration and toxic symptoms. With COHb levels below 2.5-3.0%, no adverse health effects are likely to occur even in sensitive individuals.

WHO Guideline recommends a limit value of 100 mg/m^3 for 15 minutes, 35 mg/m^3 for 1 hour, 10 mg/m^3 for 8 hours and 7 mg/m^3 for 24 hours.

(Slide 24). Ozone (O_3)

At ground level ozone is not emitted directly, but it is created by chemical reactions between NO_x and VOCs in the presence of sunlight and heat. Increased indoor ozone level of anthropogenic origin can be the result of intensive use of copy machines and other ozone producing instruments. Ozone generators have become popular in some industrialized countries. They are used to produce high concentrations to disinfect, deodorize, or for chemical decontamination of spaces not intended for human staying. Scientific evidence shows that, at concentrations that do not exceed public health standards, ozone has little potential to remove indoor air contaminants: there is no approval for its use in occupied spaces.

When inhaled, ozone can damage the lungs. Relatively small amounts can cause chest pain, coughing, shortness of breath and throat irritation. Ozone may also exacerbate chronic respiratory diseases such as asthma and compromise the ability of the body to fight respiratory infections. People vary widely in their susceptibility to ozone. (*www.epa.gov/iaq/pubs/ozonegen.html)*

WHO Air Quality Guideline for Europe (2^{nd} ed.) set a guideline value of ozone for 8 hours at 120 µg/m^3.

(Slides 25-26). Formaldehyde

Formaldehyde can be released from a variety of plastics and furnishings, insulation materials, laminated and extruded plastic products based on urea, melamine or phenol-formaldehyde resins, adhesives, disinfectants and preservatives. The amount of formaldehyde released depends on the technology used and the conditions of use. Raising air temperature or relative humidity and intense UV radiation can increase emissions by several times. Traffic (exhaust emission) is an important outdoor source of formaldehyde concentration.

Formaldehyde has been classified by the WHO International Agency for Research on Cancer (IARC) as a human carcinogen (Group 1). Formaldehyde causes irritation of the mucous membranes of the respiratory tract (irritation), inhibits ciliary movement of the mucous membranes in the respiratory tract and thus impairs the local defence mechanism. It is a strong allergen (sensitizer). The irritant effect is usually observed at concentrations above 100 μg/m^3, while the sensitizing effect can be detected at lower concentrations. People exposed to chronic formaldehyde exposure are more likely to have chronic rhinitis and coughs, chronic airway obstruction and difficulty in breathing. People with allergic or inflammatory respiratory disease may be particularly sensitive to formaldehyde exposure.

The odour threshold for 10% of the population is at 30 μg/m^3, for 50% is at 180 μg/m^3 and for 90% is at 600 μg/m^3. The WHO recommended a guideline value of 100 μg/m^3 for 30 minutes.

(Slide 27-28). Benzene

Benzene is formed during dry distillation of several carbon compounds. Especially large amount can be found in coal-tar. Benzene is widely used in the petrochemical industry for the production of solvents, pharmaceuticals, paints, explosives and pesticides. Sources of benzene in ambient air include cigarette smoke, combustion and evaporation of benzene-containing petrol (up to 5% benzene), petrochemical industries, and combustion processes. Benzene concentrations in air are higher near such sources of benzene emission as filling stations.

Benzene is present in both outdoor and indoor air. However, indoor concentrations are generally higher than those in outdoor air owing to the infiltration of benzene present in outdoor air and to the existence of many other indoor sources. Main sources of indoor benzene concentration in schools may include varnishes, paints, adhesives, solvents and chemicals used for cleaning, or some building materials that off-gas benzene.

Inhalation is the dominant pathway of benzene exposure in humans. Acute toxicity of inhaled benzene manifests itself in euphoria, nausea, vertigo, cramps, loss of consciousness, and respiratory arrest. Chronic exposure to benzene may result in asthmatic symptoms, immunological disturbances, chromosome aberrations and haematological disorders (bone marrow anaplasia, leukaemia). Benzene is a genotoxic carcinogen in humans (IARC Group 1) and no safe level of exposure can be recommended. The geometric mean of the range of estimates of the excess lifetime risk of leukaemia at an air concentration of 1 μg/m^3 benzene is 6×10^{-6}. According to

WHO estimations, the concentrations of airborne benzene associated with an excess lifetime risk of 1/10,000, 1/100,000 and 1/1,000,000 are 17, 1.7 and 0.17 µg/m^3, respectively. Based on these estimates WHO recommended a yearly average guideline value of 5 µg/m^3.

(Slide 29). Toluene

Toluene occurs naturally at low levels in crude oil and is a by-product in petrol production or the production of coke from coal. Toluene is a common solvent, e.g. for paints, paint thinners, silicone sealants, many chemical reactants, rubber, printing ink, adhesives (glues), lacquers, leather tanners, and disinfectants.

Toluene has moderately or strongly toxic properties: it damages the brain and the nervous system, though it is much less toxic than benzene, and as a consequence, largely replaced it as an aromatic solvent in chemical preparation.

Direct inhalation of toluene in low to moderate levels can cause tiredness, confusion, weakness, drunken-type actions, memory loss, nausea, loss of appetite, hearing loss, and colour vision loss. Some of these symptoms usually disappear when exposure is stopped. Inhaling high levels of toluene in a short time may cause light-headedness, nausea, or sleepiness, unconsciousness, and even death. Chronic toluene exposure may cause disruption of foetal development resulting in spontaneous abortion, developmental disorder or intrauterine growth restriction (IUGR). However it is neither genotoxic, nor carcinogen.

As a guideline value, WHO recommends a weekly average concentration of 260 µg/m^3, which has a good protective effect in terms of reproduction, too.

(Slide 30). Xylenes

The xylene isomers or their mixture, called *as xylenes, are used as a solv*ent. They are used in printing, rubber and leather industries and they are a cleaning agent, too. Xylenes are a common component of ink, rubber and adhesives. Due to their less toxic properties, xylenes can be substituted for toluene.

Direct inhalation of xylenes may affect the central nervous system causing headache, dizziness, nausea and vomiting. Long-term exposure may lead to headaches, irritability, depression, insomnia, agitation, extreme tiredness, tremors, liver and kidney damage, hearing loss, impaired concentration and short-term memory loss. Xylenes are also a skin irritant.

Xylenes are metabolized to methylhippuric acids. The presence of methylhippuric acid in urine can be used as a biomarker to determine exposure to xylenes.

(Slide 31). Naphthalene

Most naphthalene is derived from coal tar. It is used mainly as a precursor to other chemicals like azo-dyes and certain insecticides, deodorants and disinfectants. In a sealed container naphthalene vapours may build up to levels toxic to both the adult and larval forms of moths that attack textiles.

Exposure to large amounts of naphthalene may damage or destroy red blood cells, most commonly in people with the inherited condition known as glucose-6-phosphate dehydrogenase (G6PD) deficiency. Humans, in particular children, have developed the condition known as haemolytic anaemia, after ingesting mothballs or deodorant blocks containing naphthalene. Symptoms include fatigue, lack of appetite, restlessness, and pale skin. Exposure to large amounts of naphthalene may cause confusion, nausea, vomiting,

The International Agency for Research on Cancer (IARC) classifies naphthalene as possibly carcinogenic to humans and animals (Group 2B). The IARC also points out that acute exposure causes cataracts in humans, rats, rabbits, and mice; and that haemolytic anaemia can occur in children and infants after oral or inhalation exposure or after maternal exposure during pregnancy.

The WHO Indoor Air Quality Guideline recommended an annual average guideline concentration of 10 µg/m^3.

Mothball and other products containing naphthalene have been banned within the EU since 2008.

(Slides 32-33). Trichloroethylene (TCE)

Trichloroethylene (TCE) is a chlorinated solvent, its artificial production is justified by its wide-ranging industrial use (degreasing of metals, cleaning of textiles, extraction processes, etc.). 60-90% of the trichloroethylene produced annually is eventually released into the environment, partly to air and partly to water. Concentrations of TCE in cities were generally found to be three times higher than in rural areas.

Inhalation of airborne trichloroethylene is the major route of exposure for the general population. This may result from the use of TCE-containing materials (wood stains, varnishes, coatings, lubricants and adhesives, paint strippers and cleaning agents) in poorly ventilated areas or from TCE contamination of tap water.

The main health effects of concern with trichloroethylene are cancer, and effects on the liver and the central nervous system. IARC classified trichloroethylene as a Group 2A carcinogen (probably carcinogenic to humans). This classification was based on sufficient evidence in animals and limited evidence in humans. In epidemiological studies positive associations were observed between exposure to trichloroethylene and risks for cancer of the liver and biliary tract and non-Hodgkin lymphomas. A study summarizing the findings of more than 80 human carcinogenicity reports found that TCE exposure increased the risk of liver cancer by 90%, the risk of kidney cancer by 70%, and the risk of non-Hodgkin's lymphoma by 50%, but increased risks of cervical cancer, Hodgkin's disease, and bone marrow malignancy (multiple myeloma) were also found.

In subjects exposed to trichloroethylene for prolonged periods, central nervous system symptoms (headache, fatigue, irritability, alcohol intolerance) are most common, but signs of renal and hepatic impairment have also been observed.

Because the available evidence indicates that trichloroethylene is genotoxic and carcinogenic, no safe level could be recommended by the WHO Air Quality Guideline (WHO, 2000). On the basis of the most sensitive endpoint, Leydig cell tumours in rats, a unit risk estimate of 4.3×10^{-7} per $\mu g/m^3$ was derived. The ranges of ambient air concentrations of trichloroethylene corresponding to an excess lifetime risk of 1:10,000, 1:100,000 and 1:1,000,000 are 230, 23 and 2.3 $\mu g/m^3$, respectively.

(Slide 34). Tetrachloroethylene

Indoor air levels of tetrachloroethylene may be increased in close proximity to dry-cleaning operations where tetrachloroethylene is used as a cleaning solvent or in homes where dry-cleaned clothing is often worn. Inhalation of tetrachloroethylene is the major route of exposure in the general population.

The main health effects of concern are cancer and effects on the central nervous system, liver and kidneys. Tetrachloroethylene is classified by IARC as a Group 2A carcinogen (probably carcinogenic to humans). Epidemiological studies in humans showed positive associations between exposure to tetrachloroethylene and risks for oesophageal and cervical cancer and non-Hodgkin lymphoma. These studies, however, provided only limited evidence for the carcinogenicity of tetrachloroethylene in humans. Therefore WHO based the derivation of a guideline value on non-neoplastic effects rather than on carcinogenicity as the critical endpoint. On the basis of the kidney effects of long-term tetrachloroethylene exposure in dry-cleaning workers, a guideline value of 0.25 mg/m^3 was calculated.

(Slides 35-36). Vinyl chloride

Vinyl chloride is a volatile chemical intermediate in the production of PVC. In the environment it is created in water under anaerob circumstances from trichlorethylene and tetrachlorethylene. It gets from the water into the air where its half-life is calculated to be 20 hours. The primary exposure route of VC is inhalation, or in a lesser extent, per os. After entering the body, vinyl chloride is converted into highly reactive and mutagenic metabolites.

The acute toxicity of VC is low but it is toxic to the liver, even at low or short term exposure. VC has been shown to be mutagenic in various in vivo and in vitro systems. There is sufficient evidence of human carcinogenicity of VC (IARC Group 1). Haemangiosarcoma of the liver has clearly been shown to be causally related to human vinyl chloride exposure. Several studies have confirmed that VC exposure can cause other cancers as well: liver cancer, brain cancer, lung cancer, and malignant lymphatic and haematopoietic malignancies.

Since the liver is the primarily sensitive organ to VC exposure, the guideline values that are acceptable concentrations for haemangiosarcoma and liver (cell) cancer, also provide adequate protection for other malignancies, as well.

Concerning its guideline value, vinyl chloride is a human carcinogen and the critical concern with regard to environmental exposures to VC is the risk of malignancy. Therefore no safe level can be indicated. Estimates based on human studies indicate a lifetime risk from exposure to 1 $\mu g/m^3$ to be 1×10^{-6}. (WHO, 2000)

(Slide 37). Polycyclic aromatic hydrocarbons (PAHs)

PAHs are complex mixtures of hundreds of chemicals formed during incomplete combustion or pyrolysis of organic materials and in connection with the worldwide use of oil, gas, coal and wood in energy production. Additional contributions to air levels arise from tobacco smoking, and the use of unvented heating sources can increase PAH concentrations in indoor air. Because of such widespread sources, PAHs are present almost everywhere. The biological properties of the majority of these compounds are as yet unknown. Benzo[a]pyrene (BaP) is the PAH most widely studied, and the abundance of information on toxicity and occurrence of PAHs is related to this compound (WHO, 2000).

Data from animal studies indicate that several PAHs may induce a number of adverse effects, such as immunotoxicity, genotoxicity, carcinogenicity and reproductive toxicity (affecting both male and female offspring), and may possibly also influence the development of atherosclerosis. The critical endpoint for health risk evaluation is the well documented carcinogenicity (IARC Group 1) of several PAHs (IARC, 1983).

In experimental animals BaP produces tumours of many different tissues, depending on the species tested and the route of application. Based on epidemiological data from studies in coke-oven workers, a unit risk for BaP as indicator air constituent for PAHs is estimated to be 8.7×10^{-5} per ng/m^3, which is the same as that established by WHO in 1987. The corresponding concentrations of BaP producing excess lifetime cancer risks of 1/10,000, 1/100,000 and 1/1,000,000 are 1.2, 0.12 and 0.012 ng/m^3, respectively (WHO, 2000).

(Slide 38). Phthalates

Phthalates are a group of industrial chemicals that add flexibility and resilience to many consumer products like tablecloths, furniture, vinyl flooring, shower curtains, garden hoses, inflatable swimming pools, plastic clothing such as raincoats, children's toys, automobile upholstery, etc. Some phthalate compounds are used in nonplastic consumer items as fixatives, detergents, lubricating oils, and solvents and can be found in carpets, paints, glue, insect repellents, time release capsules, and personal care products such as soap, shampoo, hair spray, nail polish, deodorants, and fragrances. In schools, e.g. pvc flooring may contain phthalates as plasticizers. Phthalates are easily released from the plastic products in which they are used as there is no covalent bond between phthalates and the plastics in which they are mixed.

People are exposed to phthalates through inhalation of contaminated air, orally by consumption of contaminated water or food (as the phthalates in plastic packaging may leach into the food they hold), or through direct contact with consumer products containing phthalates.

Several studies have reported associations between phthalate exposure and asthma and allergic diseases, and certain adverse neurodevelopmental outcomes. The importance of reproductive and developmental effects of some phthalate exposure should be underlined in relation to the school environment. Adverse effects of phthalate exposure may begin in utero and in one study it was strongly associated with a shorter pregnancy duration. Another study also found that phthalate exposure at environmental levels was associated with altered male reproductive development in humans. Later research documented altered male reproductive hormone levels in baby boys most highly exposed to phthalates in their mother's breast milk.

Although people are continually exposed to phthalates because they are ubiquitous, you can minimize re-exposure to phthalates by avoiding products containing PVC plastic, e.g. when remodelling schools, kindergartens and other childcare facilities avoid the use of PVC/vinyl floors.

Figure 1 illustrates the above mentioned associations: prevalence of asthmatic symptoms and doctor-diagnosed asthma or allergy was found significantly higher among children living in homes with pvc floor and even much higher among those whose floor in both the flat and the classroom was fitted with pvc than those children without exposure to pvc floor.

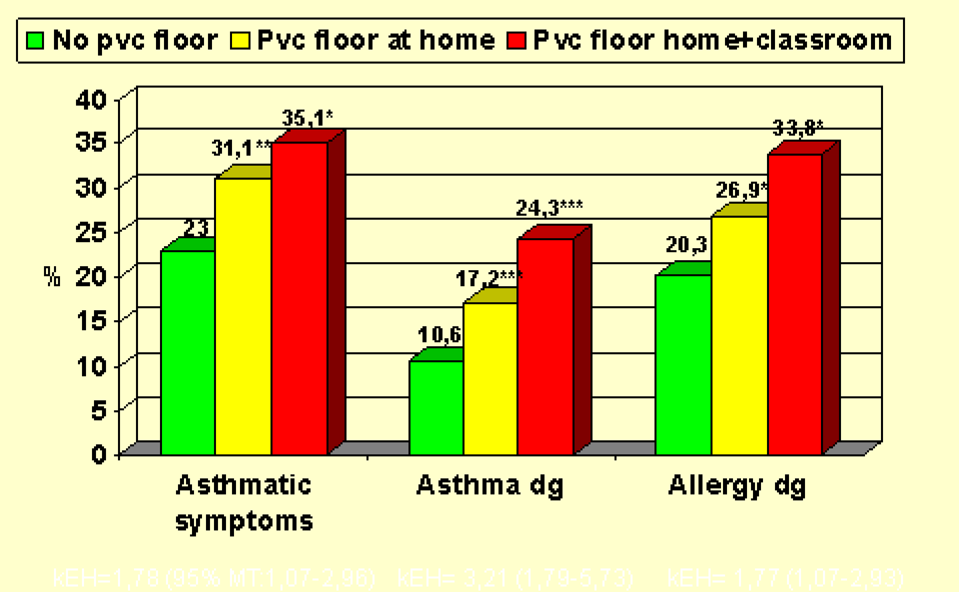

Fig. 1. Association between pvc floor and prevalence of respiratory symptoms / diseases among Hungarian schoolchildren (SEARCH Project, 2009)

(Slide 39). Pesticides

Pesticides are chemicals that are used to kill or control pests (bacteria, fungi, termites, insects and rodents). Products used indoors most often are insecticides and disinfectants in the form of sprays, liquids, sticks, powders, crystals, and balls. Pesticides are classified as semi-volatile organic compounds.

Pesticides are inherently toxic. Problems related to the indoor use of pesticides may be due to the fact that generally greater concentrations of pesticides can be found and stay on longer near the floor and can be resuspended (e.g. in the classroom air). Sometimes pesticide application is too frequent, too extensive and in some cases unnecessary.

Exposure to pesticides may result in irritation to eye, nose and throat, damage to the central nervous system and kidney and may increase the risk of cancer. Acute exposure generally happens incidentally and may induce symptoms like headache, dizziness, muscular weakness and nausea. Chronic exposure to some pesticides can result in asthma and allergies, damage to the liver, the kidneys, the endocrine and the nervous systems, degenerative diseases (Parkinson’s disease) and cancer (leukaemia, non-Hodgkin lymphoma). However, there is insufficient understanding at present about what pesticide concentrations produce these effects.

(Slides 40-41). Asbestos

Asbestos has been used in buildings for decades because of its excellent thermal and electrical insulation and refractory properties. Other possible sources of environmental exposure include corrugated and flat roofing sheets, car breaks, pipes transporting air, gas, water, and wastewater, etc. Asbestos fibres can enter the body by inhalation or ingestion, and a few decades later may cause cancer of the pleura and peritoneum (mesothelioma) and lung cancer. Once installed, asbestos can be safe for long periods of time if left undisturbed. However, aging asbestos structures can release more and more fibres into the air and thus into the body. However, the greatest danger can be the removal of asbestos if it is carried out by a person with inadequate skills and without proper protective equipment.

Due to its carcinogenic property (IARC Group 1) use of asbestos has been banned in most countries, with some very few exceptions. However, due to its long –term usage asbestos fibres are expected to occur in the outdoor and indoor air for many decades. No safe level can be proposed for asbestos because a threshold is not known to exist. Exposure should therefore be kept as low as possible. Based on the results of epidemiological studies, WHO estimated a lifetime exposure to 1000 fibres/m^3 to cause 1 excess lung cancer death per 100,000 – 1,000,000 population.

(Slides 42-43). Radon

Exposure to radon and radon progeny is the dominant source of exposure to ionizing radiation in most countries. The radon levels vary considerably between indoor spaces, and depend primarily on the inflow of soil gas, water pipes and the type of construction materials (additives, e.g. fly ash from thermal power plant, blast furnace slag, etc. added to the natural radioactive material content of the building material). Basements and cellars play important role in reducing exposure. Good ventilation can also greatly improve the situation.

Inhalation is the main route of radon exposure. Radon is a well-documented human carcinogen (IARC Group 1) causing lung cancer. Smoking increases the risk of lung cancer in a multiplicative way. Leukaemia has also been proven to be associated with radon exposure.

As radon is a known human carcinogen with genotoxic action, no safe level of exposure can be determined and no guideline value for radon concentration can be recommended. Nevertheless, the risk can be reduced effectively based on procedures that include optimization and evaluation of available control techniques. In general, simple remedial measures should be considered for buildings with radon progeny concentrations of more than 100 Bq/m^3 equilibrium equivalent radon as an annual average, with a view to reducing such concentrations wherever possible (WHO, 2000).

(Slide 44). Microbial pollutants

During sneezing, coughing and speaking, mucus - especially the mass of saliva droplets - leaves the body, carrying microorganisms from the nose, pharynx and lungs (bronchi). For example, when sneezing, hundreds of thousands of droplets smaller than 100 microns and thousands of larger droplets get into the air. Larger droplets settle on the floor or the surface of objects within a few seconds, within 1-2 meters. The smaller droplets evaporate immediately, leaving behind solid particles of 1-10 microns in size which remain suspended in the air and are thus easily inhaled. The settled dust may re-mix during increased air movement or human activity. The sedimentation rate of the particulates depends on the size of the particles. Some pathogen bacteria can survive for days, weeks, and sometimes months at room temperature, especially when not exposed to sunlight. After using the toilet, the aerosol formed during flushing may remain in the air for 4 hours and disperse the intestinal bacteria and viruses contained therein, which may settle in large quantities on the surface of the equipment or be inhaled.

Some of the aspects that will help to reduce the amount of microorganisms in the indoor air, or keep it at an acceptable level without increasing the incidence of the disease are listed below:

Providing adequate natural ventilation, the concentration of airborne microorganisms will "cool down", meaning that the number of microorganisms per specific volume of air will decrease.

Classrooms should be exposed to direct sunlight containing UV rays, which can kill most bacteria (bactericide effect). It is especially important to take advantage of the natural sunlight's bactericide effect in the toilet as well. (It is worth mentioning that not only direct sunlight but also spread daylight has a bactericide effect.) Classrooms should be constructed in such a way that cleaning can be thorough and efficient. In particular, the surfaces of floors, walls and ceilings should be so smooth that they are easy to clean. All the zigzags in the school building should be accessible for cleaning, and dust traps should be avoided wherever possible. Providing a relative humidity of about 50% significantly reduces the content of airborne microorganisms. Proper use of the indoor spaces (proper ventilation, regular cleaning, disinfection of the toilet and bathroom, avoiding overcrowding, etc.) is also required to ensure a low germ count. When vacuuming, open the windows so that fine dust particles escaping from the vacuum cleaner bag can escape freely and no longer circulate in the classroom air.

(Slide 45). Fungi, especially mould

Moulds are a large and diverse number of fungal species. These simple nutrient demanding fungi grow fast in the presence of high relative humidity (>70%), producing a large number of tiny spores that are easily transported through the air. The size of the spores ranges from 1 to 100 µm and can get down to different depths of the respiratory system. Allergic symptoms caused by spores are related to the location of the spores: spores larger than 10 µm in the nasal passages may cause allergic rhinitis, 4-10 µm spores in the bronchi and bronchioles may cause asthma, and the spores smaller than 1 µm can cause alveolitis (inflammation of the wall of the alveoli). Other allergic symptoms may include rash, eczema, gastrointestinal allergy (diarrhoea), allergic conjunctivitis.

Under normal conditions, the body can cope with 100 to 500 spores per cubic meter. However, a higher spore load will eventually lead to a state of hypersensitivity, whereby a lower number of spores that has not previously elicited a response will trigger an allergic reaction.

The underlying cause of mould is excessive humidity in the indoor air and condensation. The following circumstances make this possible: increased humidity production, lack of ventilation, insufficient ventilation because of deficiencies due to highly air-tight doors and windows or blocked vents, plastic coverings that cannot remove moisture, and wall structures that reduce vapour diffusion. Reduced, often intermittent heating causes the boundary surfaces to cool down and condensation appear. Reduced air temperature may lower the humidity capacity of the air, so excess water is precipitated. (It is known that the humidity capacity of the air depends on the temperature: the air can contain more water at higher temperatures and less water at lower temperatures. The difference will precipitate at lower temperatures.) Due to construction defects (e.g. thermal bridges) or poor insulation, the boundary walls are cooled in various areas and condensation may occur.

Since the conditions leading to mould formation in the various indoor spaces vary greatly, the specific cause should always be identified in order to be able to eliminate the underlying conditions.

(Slides 46-50). Sick Building Syndrome (SBS) and Building Related Illnesses should also be mentioned among the health impacts of IAQ. The SBS is characterized by non-specific symptoms (headache, fatigue, eye, nose or throat irritation, itchy skin, wheezing, change of taste sensation, hoarseness of voice, etc.) that are apparently linked to the time of learning/teaching/working indoors and clear when away from the building. Their appearance is difficult to trace to a specific source. Some specific features were identified, e.g. SBS tends to occur in air-conditioned buildings where the windows can't be opened, or in buildings with very bright and/or flickering lights, or where ventilation, heating, lighting can be insufficiently controlled, where there are carpets or upholsteries with large surfaces or many open shelves or storage compartments. New furniture, carpet or painted surface, neglected maintenance, insufficient cleaning, high temperatures or large temperature fluctuations, very low or very high humidity, chemical pollutants like cigarette smoke, ozone, or VOCs from

building materials or equipment, particulate matters and fibres in the air, as well as computer monitors have been identified in some or other cases as possible causes of SBS but not every building can be considered sick where one or more of the mentioned factors occur.
A lot of complaints are associated with inadequate ventilation either through ineffective removal of indoor air pollutants or by insufficient supply of fresh air. Insufficient natural ventilation causes increased moisture/mould, enhanced concentration of bacteria/viruses/fungi and chemical pollutants (e.g. several volatile organic compounds like benzene, xylenes, toluene) and unpleasant odours. In classrooms the total volume of air should be exchanged 5 times/hour.

Symptoms may not disappear upon leaving the building. Recognized building related diagnoses include infections (cold, flu, Legionnaires' Disease, Aspergillosis in immune-compromised individuals) and allergic reactions (rhinitis, asthma).

(Slides 51-54). Contribution of indoor air pollution to the disease burden in Europe
Public health significance of indoor air pollution was evaluated in the Final Activity Report of the ENVIE Project (Co-ordination Action on Indoor Air Quality and Health Effects) by presenting the contribution of non-ideal IAQ to symptom and disease burden in the European countries expressed in DALYs (Disability-Adjusted Life Years). From these figures it can be concluded that the quality of outdoor air is responsible for about 54% of the life years lost due to poor indoor air quality and the indoor-related components (water systems, mould, heating and ventilation systems, etc.) are responsible for the remaining 46%. Among the indoor air pollutants combustion products have the biggest share of life years lost (39%) but bioaerosols are not much behind them (36%), and VOCs are in the third place (16%). Asthma (30%) and cardiovascular diseases (31%), as well as Sick Building Syndrome (23%) are the leading health problems as far as life years lost due to poor indoor air quality.
(Slides 55-57). The health impact of indoor environment of schools on the children's health has been studied by *epidemiological investigations*. Such studies need careful planning and implementation throughout each phase of the study (sampling, assessment of both exposure and health effects, statistical analysis and

interpretation). Biological monitoring of the pollutants or their metabolites measured in the children's biological materials (in most cases in urine samples) may make the association even stronger and quantitatively more apparent. In the last two decades very successful international epidemiological studies have been carried out in Europe which resulted in clear messages about the need to improve planning, design, construction, maintenance and operation of schools in order to ensure healthy environment for both the children and the teachers.

E. Teachers' role in the management of indoor air quality in schools

Teachers, staff, and other members of the personnel together with the school maintainer can contribute to the improvement of indoor air quality in the classrooms and the school. There are some suggestions that we'd like to offer to promote those efforts.

(Slides 58-59) The first things a teacher should check when entering a classroom are *general cleanliness* and *indoor air quality*. Signs of regular cleaning, dusting and trash removal can be observed first of all in the early lessons but a generally „clean look" of the classroom contributes to a positive atmosphere and better conditions for teaching and learning in the later lessons, as well.

Physical arrangement of the *classroom environment* is also important. Furniture and equipment should be arranged to best assist teaching and learning and to allow for easy moving. All students should be seated in areas that allow them to see the blackboard. Students and teachers should have adequate personal work space. A floor space of at least 2 m^2/child should be guaranteed in the classroom. Overcrowding in the classroom should be avoided because it results in higher levels of chemical air pollutants (CO_2, PM, etc.), increased risk of pathogen transmission (infection), higher noise level, decreased attention, more frequent cases of fatigue and headache, and increased risk of accidents.

Comfort environment (appropriate temperature and humidity, ventilation and light) should be provided for optimal teaching efficiency. Optimal classroom temperature is about 22-26 ºC, relative humidity between 30-60%. Short-term variation of indoor temperature may be the result of intensive ventilation during the breaks which quickly reconcile due to increased heat emission of the pupils' body after their break-time activity. During lessons classroom temperature and relative humidity tend to rise due to heat and water vapour loss from the occupants if ventilation is inadequate. Therefore, in case of lack of mechanical ventilation, moderate natural ventilation through windows is preferred even during lessons if outdoor noise or air pollution conditions allow. Draughtiness is to be avoided. External noise levels should not interfere with learning. Direct glaring sunshine should be prevented by shading.

(Slides 60-64). **Provision of adequate indoor air quality** needs to take three aspects of IAQ into consideration: source control, ventilation and air cleaning.

Source control. Concentrations of indoor air pollutants should be kept as low as possible but in no ways should the concentration exceed the guideline values set by national or international bodies.

WHO recommended guideline values for some frequently occurring indoor air pollutants, which are expected to be internalized by national legislation. In some countries there are health limit values or at least guideline values for indoor air pollutants while in others they are still missing. In this latter case, ambient air limit values may be considered as reference values but their relevance to indoor air, especially in the case of children, may be questioned.

Minimize chemical exposure: avoid any unnecessary potential contaminants, do not bring in or use air fresheners, candles, pesticides. If you need to use chemicals, review supplies and their labels; ensure that Material Safety Data Sheets are accessible; develop and implement spill clean-up procedures; label all chemicals accurately with date of receipt/preparation; store supplies according to the manufacturer's recommendation; follow the recommended procedures for disposal of used substances; use diluted substances rather than concentrates, wherever possible and minimize exposure to hazardous materials (i.e. use non-hazardous materials and pre-mixed products, if possible).

(Slides 65-74) Ventilation and air cleaning. Special attention should be paid to ventilation because it has triple functions: it provides fresh air, removes accumulated pollutants or at least dilutes their concentrations and reduces air temperature. Fresh air demand is influenced by occupancy, activity, age and state of health of the occupants, size and function of the premises. CO_2 concentration is generally used as an indication of the efficiency of ventilation. 0.1% CO_2 concentration produces perception of stuffy air, 1% CO_2 causes discomfort/malaise, and 10% CO_2 is life threatening.

Generally the fresh air demand is 30 m^3/hour per person. Based on the required floor space of 2 m^2/child in the classroom and a ceiling height of 3 metres, the air demand of a child in the classroom is 6 m^3. In order to fulfil the 30 m^3/hour per person fresh air demand, the total volume of classroom air should be exchanged 5 times per hour. Therefore thoroughly ventilate the classrooms before and after lessons, as well as during breaks. Ensure proper ventilation of other rooms (corridors, cabinets, gyms), too.

Proper ventilation, as well as excess moisture, is also important from the point of view of mould formation. Excess moisture should be avoided by wiping condensate from windows, windowsills and window frames, and indoor surfaces of exterior walls should also be free of condensate. Find any water leaks, moisture on surfaces, mould and pest activity. Avoid dampness.

F. Specific actions aimed at reducing the health risks due to indoor chemical pollutants

(Slides 75-85) Management of improving indoor air quality in schools can be successfully operated by a well-designed and organized ***action plan***. The action plan

is based on the assessment of the current state of the school environment and on the identification of the problems.

IAQ problems related to school environment are often non-specific symptoms rather than well-defined diseases. Symptoms commonly attributed to IAQ problems include: eye, nose, throat and skin irritation; sinus congestion, coughing and sneezing; shortness of breath; headache and fatigue. These symptoms may be caused by the deterioration of air quality in the school environment (indoors and outdoors), or may also be linked to other factors. Due to varying individual sensitivity, IAQ problems may affect different groups of people or specific individuals particularly susceptible to the effects of pollution like people with allergies, asthma or other chronic respiratory diseases (e.g. COPD).

Teachers should be aware of the possibility of occurrence of IAQ-related symptoms or diseases, though diagnosing IAQ-related symptoms in schools can be sometimes rather difficult as these non-specific symptoms may be caused by other factors, too. However, there are some indications which may suggest a link between certain symptoms and possible indoor air quality problems. Most obvious, if symptoms appear suddenly after certain changes have been carried out at school (e.g. installation of new furniture, painting or pesticide application). It is also very suspicious if the symptoms appearing widespread within a class or school and disappearing when the children leave the school building at the end of the school day or for longer periods of time. Certainly, a doctor can diagnose the symptoms or the disease as being IAQ related with more confidence.

(Anyway, a teacher should be aware of the possibility that acute asthmatic attack may also be elicited at school by the indoor environment in children with asthma and he/she should know what to do in such cases.)

Whether the observed symptoms or health effects are linked to an IAQ-related problem can be objectively identify by monitoring the indicators that are known to relate to the most common health- or building-related IAQ problems in schools. Such monitoring may include a walk-through inspection of the school building, measuring the physical, chemical and biological stressors suspected of causing the health problem, or associating the outcome of the previous investigations to information related to the school building's characteristics (design, building components, furnishings, equipment and climate), occupants' behaviour and potential indoor and outdoor sources, to be gathered from specific questionnaires, clinical tests and tools.

The action plan can only be fulfilled if supportive legislation, group of public health experts, supportive school management, intersectoral cooperation and financial background are all available. Some of the action can be carried out by using structural (e.g. EU) funds, some other programmes can be incorporated in the plans of regular maintenance of the school building, but some practical actions can be done without money like ventilation of the classrooms by regular opening the windows.

The action plan includes issues of proactive operation (preventive maintenance activity on buildings and equipment, right and accurate cleaning procedures and practices complemented by awareness training of the school board and staff), reactive measures like immediate provision and correction of building and equipment breakdowns and investigation of all IAQ concerns/complaints to resolve problems, as well as carrying out compliance policy and action (cooperation with stakeholders and keeping all local, state regulations and standards relating to IAQ in schools).

An action plan should be adaptable to individual school needs, implementable at no cost / low cost, no specialized training is required, it is voluntary, on common sense basis.

If there is a general understanding that good IAQ is important for teaching and learning, and it enhances the learners' and teachers' productivity, IAQ teams can be established in the schools, including the teachers and the students, their parents, the school board, the administrative staff, the school nurse / physician and the school operators. Members of the IAQ team regularly check the checklist items, inspect the school, set priorities and share information with the respective partners. This procedure would result in better productivity of learners and teachers, quicker and more cost-effective response to problems, peaceful atmosphere for staff, learners and parents, reduction of upkeep cost and expenses for repairs.

(Slides 86-97) Proposed action plans to lower the concentration of indoor air pollutants

- 'Prevent' the entry of particles from the outside air

Thoroughly ventilate the classrooms before and after lessons, as well as during breaks when the outdoor traffic is low. Avoid the opening of windows at the time of traffic jams, and at the time when parents park near school. Ask parents not to wait for children with running engines.

When PM concentration is elevated in the ambient air and the ventilation possibilities are limited, avoid activities that cause dust in enclosed spaces.

Plan the outdoor activity of pupils according to the forecast about ambient air pollution level.

Ensure proper ventilation of other rooms (corridors, cabinets, gyms), mechanical ventilation of the kitchen and sanitary facilities.

- Clean the classrooms after the lessons

Use wet cleaning practices for the floor and furniture. Undust the rooms and furniture every day. The best solution is the use of wet vacuum cleaners with HEPA filters. If the HEPA filter is too clogged, it stops and no longer performs its role. It is important to clean them frequently (washing HEPA filters) or replace them.

Install air cleaning devices that absorb PM and chemical pollutants.

- Lower the indoor concentration of CO_2

Install a CO_2 concentration monitor in the classroom.
In case of lacking a mechanical ventilation system, open completely the windows of the classrooms during every break. Ventilate the rooms thoroughly in the morning and in the afternoon before and after the lessons.

- Lower the indoor concentration of formaldehyde, benzene and other VOCs.

Select suitable, dedicated furniture and cover materials, equip the rooms with interior equipment that does not contain formaldehyde, or as little as possible. If you plan to change the furniture of the classrooms, do it during the summer holiday. Ascertain that the furniture can be ventilated by keeping the windows completely open as long as possible. The high formaldehyde emissions of new furniture and coverings will drop off after 6-8 week ventilation. Ventilate the indoor areas during and after using products containing benzene and other volatile organic compounds (e.g. during painting/use of colours). Buy and stock the products that are the sources of VOCs in the quantities to be spent immediately. Do not store products that are a source of VOCs in rooms where children stay.

Put special flowers in the classrooms which can absorb formaldehyde and several volatile organic compounds like benzene, xylenes, toluene, etc. (Scindapsus /Golden Lotus, Sansevieria, Dracena marginata, Filodendron, Peace lily etc.).

G. Action plan to maintain optimal temperature and humidity and combat the health impacts of climate change

(Slides 98-100). Put a thermometer in the classroom. Ensure optimal temperature during winter, do not overheat the room.

Monitor the humidity in the classroom as well. Avoid dry air by placing plants and humidifiers in the classroom on the one hand, and avoid overcrowding or other sources of high air humidity on the other.

Assure right ventilation of the classrooms.

Be aware of the impact of climate change, prepare for the high outdoor temperature during late spring and early autumn months.

The external thermal insulation of schools not only reduces the heat loss in winter but also prevents the heat loss and cooling of the classrooms at night in the summer. Therefore, it is necessary to solve the night ventilation by keeping the windows open in tilted position and propping them against possible stormy winds.

During heat waves it is important to change the day schedule flexibly: children should spend the breaks in the shade; gentle, light gimnastics lessons, if possible, are important to avoid discomfort of the children.

Drinking fountains in the corridor and in the yard can be realized at a relatively low cost with proper planning and implementation.
In case of smaller children, it is important to pay attention to proper clothing and use of sunscreen and sun caps outdoors, in addition to proper liquid consumption. In many places, it is a customary practice for children to make the sun caps wet before going out.

H. Conclusions

(Slide 101) Good IAQ is the guarantee of comfort, health and safety. It is especially important in the school because growing children are very sensitive to hazardous chemicals.

Exposure to poor IAQ in school can keep back learner's task performance. Materials with low emission, adequate ventilation and cleaning methods, adequate temperature, humidity and mould control are essential components of a healthy school environment.