

TAKING
COOPERATION
FORWARD

 Training material for teachers and school maintainers

 **Health aspects of indoor air pollution in schools:**
Specific actions aimed at reducing the health risks due to
indoor pollutants

 National Public Health Center

Indoor Air Quality

Factors influencing IAQ

Primary sources of IAQ contaminants

- Outdoor sources
- Indoor sources

Overview of air pollutants

Health impacts of indoor air pollution

Contribution of indoor air pollution to the disease burden

Indoor epidemiological studies and human biomonitoring

Sick Building Syndrome

Indoor Environmental Quality (IEQ)

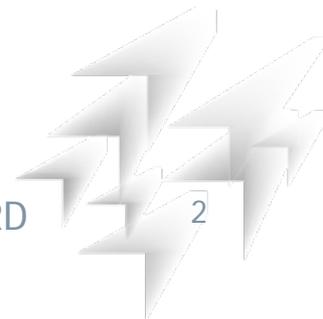
Health impacts of climate change

Investigation of school IAQ

- Source control
- Ventilation
- Air cleaning

Tools for schools

Action plans for improving indoor air quality in classrooms

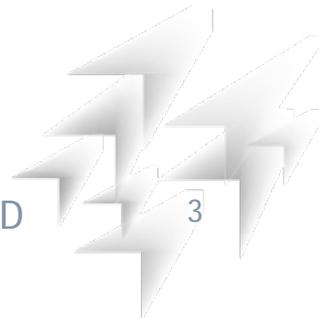


Indoor Air Quality (IAQ)

Indoor space: any closed area surrounded by boundary elements (including the indoor space of vehicles)

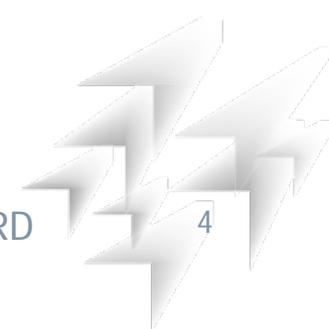
Indoor Air Quality refers to the quality of the air inside buildings as represented by concentrations of pollutants and thermal (temperature and relative humidity) conditions that affect the health, comfort, and performance of people staying inside.

Indoor air pollution does not include technology-related air pollution in the workplace!



Why IAQ issues important in schools?

- Children spend 90% of their time indoors (classrooms, homes, vehicles)
- Studies have indicated that indoor air often contain higher levels of contaminants than outdoor air.
- In Hungary there are 3585 primary schools with 735 thousands pupils. This is about 7.5% of the population! Number of teachers in primary schools: 78 thousand (in 2018).
- Focus on Children's Health and healthy environmental issues according to the European Environment and Health Process (WHO/Euro, UN ECE) has high priority.



What is the significance of IAQ in schools?

- Growing children with developing their physiological capability are very sensitive to hazardous chemicals.
- Exposure to poor IAQ in school can interfere with a learner's ability to able to learn.
- Asthma, headaches, nausea, drowsiness, and dizziness can be troubling.
- Toxic chemicals can cause not only acute symptoms like irritations, but long lasting adverse health damage.
- Low level of comfort leads to dissatisfaction.



Why did IAQ come into focus?

- Reduction of outdoor air pollution
- Changing construction practices
 - construction material (concrete) - air permeability
 - widespread use of plastics and adhesives
- Prefabricated homes - lower ceiling height
- New heating methods
- Energy conservation aspects - thermal insulation
- Different habits in the usage of indoor spaces
- Time spent indoors: 80-90%



- Outdoor air quality
- Extent of air exchange
- The binding capacity of indoor surfaces
- Indoor pollution sources (people, animals, furniture, building- and covering materials etc.)

Indoor Air = Outdoor Air + f (Building) + φ (Activities)



Outdoor sources of pollution

- Traffic (proximity of busy roads, petrol vs. diesel, cars vs. trucks)
- Power plants
- Other industrial plants
- Pollution from constructions
- Waste deposit sites
- Agricultural activity (e.g. spraying pesticides)

Architectural factors that influence the pollutants' infiltration from outdoor

- Orientation
- Storey level
- Classrooms facing the street or the yard
- Role of vegetation
- Parking places, smoking area near the windows of the classrooms



Combustion products:

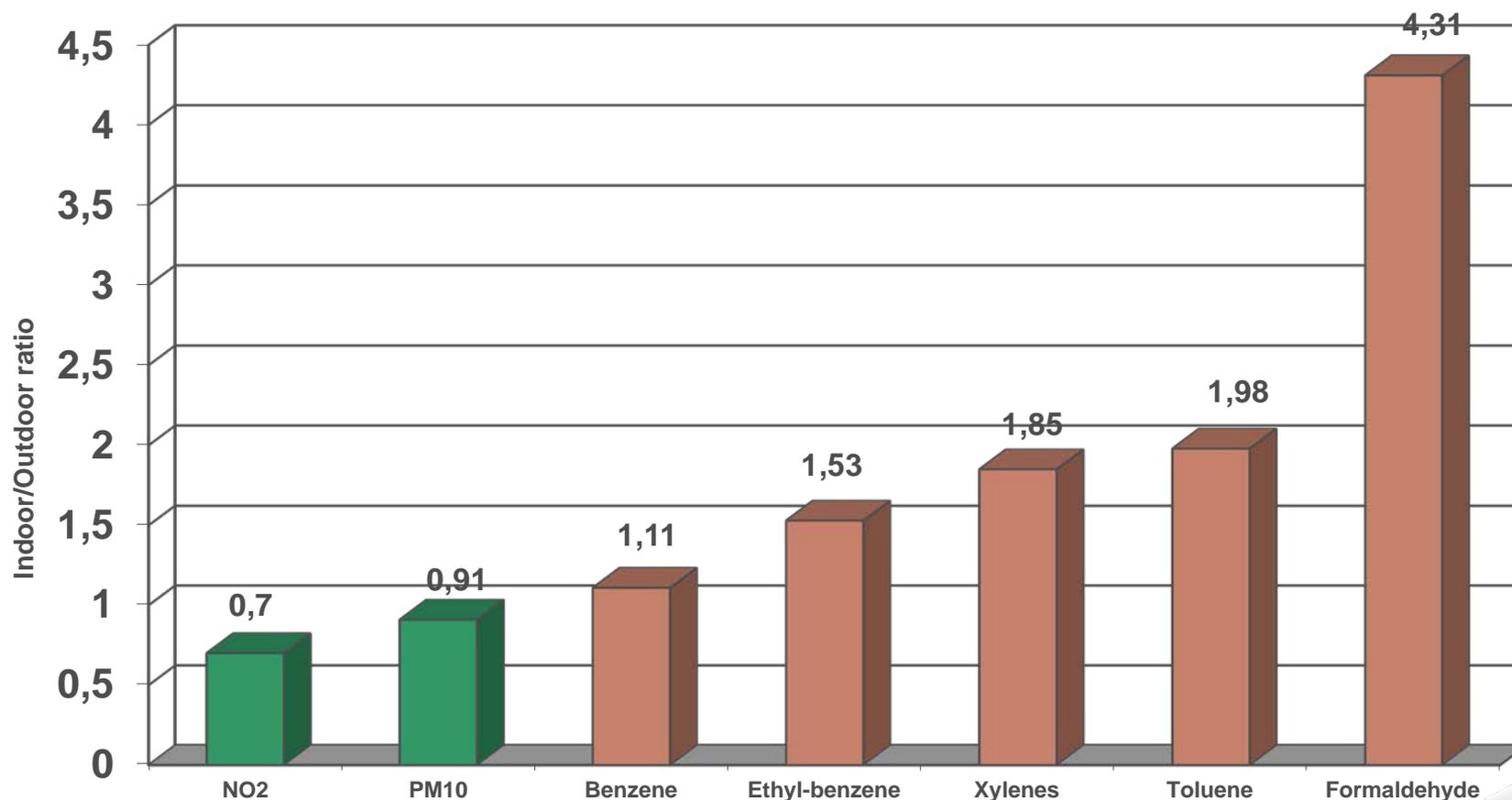
- Carbon monoxide (CO)
- Nitrogen dioxide (NO₂)
- Sulphur dioxide (SO₂)
- Nitrogen oxides (NO_x)
- Particulates (PM)
- PAH compounds

Sources:

- 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



The ratio of pollutant concentrations measured outdoors and in the classrooms



- Dust
- Construction and insulating materials
- Surface materials (wall covering, carpets, blinds, curtains)
- Furnishings
- Evaporation of volatile chemicals from new materials
- Paints
- Waxes, repellents
- Glues and resins
- Solvents
- Photocopiers, inks
- Cleaning/disinfecting products
- Biocides
- Personal care products
- People (exhaled air, smoking?)
- Pets, rodents, insects
- Mould (from moisture)

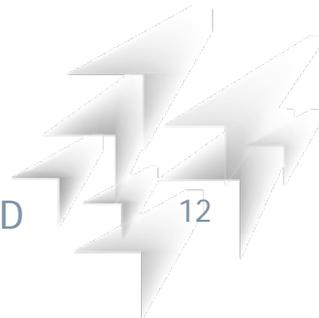
Secondary material emissions:

- e.g., due to moisture
- ozone from laser printers
- outdoors and nitrogen oxides reacting with VOCs
- cleaning materials can react with surfaces



Pollutants released indoors

- Formaldehyde
- Other Volatile Organic Compounds
- Phthalates, polybrominated flame retardants, per- and polyfluorinated chemicals
- Vinyl chloride
- Trichloroethylene, tetrachloroethylene, ammonia
- Terpenes (limonene, alpha-pinene)
- Phenol
- Naphthalene
- Asbestos



Pollutants that enter and accumulate in the indoor environment

- Radon
- TCE
- Dust, PM
- PAH compounds
- Pollen



- mould
 - bacteria, viruses
 - pet hair, skin flakes, faeces, urine
 - insects (cockroach faeces, dust mites, etc.)
 - pollen
-
- Outdoor sources: mould, pollen in outdoor air
 - Indoor sources - major concern:
 - humidifiers and stagnant waters
 - moist surfaces and materials
 - vapour from showering
 - air conditioning
 - upholstered furniture and carpets
 - animals (the allergens can be present months after the removal of the source)
 - infected people



Rising dampness

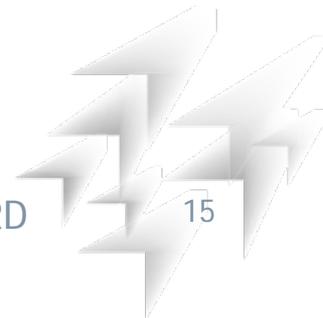
- The capillary-like absorption of groundwater into the structural elements of the building (bad insulation)

Penetrating dampness

- leaking, rain, melted snow (through the roof, walls or joints)

Condensation

- Excessive vapour production or inadequate ventilation
- Inadequate heating
- Cold surfaces



Health effects of indoor air pollution



Health effects of exposure to indoor air pollutants in children /1.

IMPACTS ON RESPIRATORY SYSTEM

Acute effects:

- Mucous membrane irritation (eyes, upper respiratory tracts)
- Coughing (bronchitis symptoms)
- Wheezing, attacks of dyspnoea (heavy breathing) (asthmatic symptoms)
- Increased responsiveness of the respiratory tracts to allergens
- Increased acute respiratory morbidity (upper- and lower respiratory airway infections)

Chronic effects:

- Decreased lung function
- Contribution to later pulmonary diseases (COPD, malignant tumours)

IMPACTS ON CARDIOVASCULAR SYSTEM

- Elevations in arterial blood pressure and heart rate
- Increased levels of stress hormones



Health effects of exposure to indoor air pollutants in children /2.

IMPACTS ON IMMUNE SYSTEM

- Increased risk of infections (pneumonia, otitis media)
- Absenteeism from school due to sore throat, cough, and cold
- Increased levels of biomarkers of oxidative stress and inflammation

IMPACTS ON CENTRAL NERVOUS SYSTEM

Acute effects:

- Headache, fatigue, dizziness, nausea
- Impaired task performance

Chronic effects:

- Impairments in different neuropsychological development outcomes (cognitive and psychomotor development delays, global IQ, learning disabilities, reading comprehension, memory functions, reading and maths scores, reaction speed, attention, coordination)
- Changes in brain white matter, grey matter and basal ganglia assessed by neuroimaging methods were associated with air pollution
- Prenatal and early childhood exposure can result in neurodevelopmental diseases (attention deficit/hyperactivity, autism spectrum disorders, etc.)



Health effects of exposure to indoor air pollutants in children /3.

CANCER INDUCING EFFECT

- childhood leukaemia, and some central neural system tumours in children are associated with certain air pollutants
- childhood exposures may contribute to the development of other cancers in the later life as well

ENDOCRINE DISRUPTING EFFECTS OF SOME CHEMICALS

- Impairments on reproductive system
- Disorders in brain development
- Contribution to later diabetes and obesity
- Contribution to later hyper- or hypo-thyroidism



Nitrogen-dioxide (NO₂)

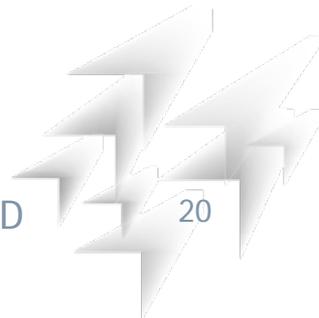
I/O ratio ~ 0.8

Health effects: Asthmatics are especially sensitive (!)

- Increased bronchial reactivity
- Reduced respiratory function
- Increased respiratory morbidity
- Reduced immunological protection
- Middle ear, nose-, ear-, pharynx inflammation
- Increases the allergenic effect of allergens (e.g. Food allergy!)
- Eczema
- Increased blood coagulation in adults

Guideline values:

- WHO: indoor 1 hour: 200 µg/m³
 annual: 40 µg/m³



Carbon monoxide (CO)

I/O ratio ~ 1.0

It is caused by incomplete combustion. Sources:

- Heating and cooking devices
- ETS
- Running car engines in the garage!
- Car traffic
- Other outdoor CO sources (power plant, incinerator, industrial pollution)

CO binds 250 times stronger to haemoglobin (Hb) than oxygen. Foetal Hb also has a stronger affinity to CO. CO causes tissue hypoxia.



Carbon monoxide (CO)

Increasing COHb concentration

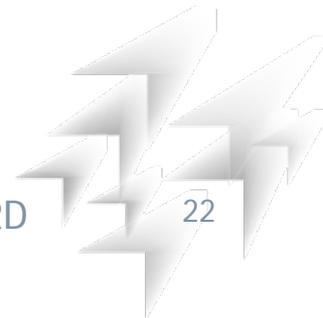


Acute symptoms:

- Headache, vertigo, tiredness, heavy breathing
- Nausea, vomiting
- Irritability
- Drowsiness, confusion, disorientation
- Loss of consciousness, coma
- Death

Chronic exposure:

- Ischemic heart disease, myocardial failure, AMI
- retardation in foetal development, reduced birth weight, congenital malformation
- Increased cardiovascular and total mortality
- Asthma, sinusitis, pneumonia



Carbon monoxide (CO)

Taking sensitive populations into account (!)

WHO Guideline:

- 15 min: 100 mg/m³
- 1 hour: 35 mg/m³ (INDEX project: 30 mg/m³)
- 8 hours: 10 mg/m³
- 24 hours: 7 mg/m³



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.

OZONIZERS - as air purifiers

Ozone is harmful to health

- Chest pain, coughing, throat irritation, airway inflammation, lung damage

The air purifying effect of ozone is ineffective in concentrations under the limit values

- WHO AQG for Europe (2nd ed.) $120 \mu\text{g}/\text{m}^3$ (8 hours),

It is used in high concentrations to disinfect, deodorize, or for chemical decontamination of spaces not intended for human staying.



Sources:

- Furniture
- Wood products
- Insulation (urea formaldehyde insulators - UFFI)
- Disinfectant - preservatives (paints, varnishes, parquets, wallpapers)
- Laminated and extruded plastic products (urea- and phenol-formaldehyde resins)
- Polymers (polyacetates, melamine-resins)
- Traffic (exhaust emissions)
- Cigarette smoke

Emission increases
with temperature
and humidity!

Acute health effects of exposure:

- Mucous membrane irritation (lacrimation, sneezing, throat ache, increased expectoration)
- Inhibits ciliary activity
- Skin irritation (rash, itching)
- Allergenic, sensitizing effect
- Sinusitis, headache, nausea, insomnia
- Weak mutagenic effect, but synergism (UV, x-ray)

Chronic health effects of exposure:

- Chronic rhinitis, bronchitis
- Asthma bronchiale
- Allergy
- Carcinogen (IARC Group 1)



Odour threshold:

10% = 30 $\mu\text{g}/\text{m}^3$; 50% = 180 $\mu\text{g}/\text{m}^3$; 90% = 600 $\mu\text{g}/\text{m}^3$

WHO guideline: 100 $\mu\text{g}/\text{m}^3$ - 30 minutes

Exposure reduction:

- Reduced formaldehyde-emitting products
- Temperature and humidity control
- Proper ventilation



Sources:

- Varnishes, paints, adhesives
- Cigarette smoke (430-590 µg/cigarette),
- Combustion, oil heating
- Traffic (gasoline),
- Garages
- Oil industry
- Chemical- and pharmaceutical industries

Health effect (less toxic with toluene) :

- Acute poisoning: euphoria, nausea, vertigo, cramps, loss of consciousness, respiratory arrest
- Chronic poisoning: haematological disorders (bone marrow anaplasia, leukaemia - IARC 1 carcinogen), chromosome aberrations, immunological disturbances, asthmatic symptoms



Guideline values: No safe concentration (!)

- USEPA lifetime cancer risk:
 $1 \mu\text{g}/\text{m}^3 = 2.2\text{-}7.8 / 1.000.000$
- WHO excess lifetime risk (leukaemia):
 $1 \mu\text{g}/\text{m}^3 = 6 / 1.000.000$
 $0.17 \mu\text{g}/\text{m}^3 = 1 / 1.000.000$
 $1.7 \mu\text{g}/\text{m}^3 = 1 / 100.000$
 $17 \mu\text{g}/\text{m}^3 = 1 / 10.000$
- WHO guideline value: $5 \mu\text{g}/\text{m}^3$ - yearly average



Source: Chemical industry (to replace benzene!)

Health effects: liver and kidney damage, central nervous system damage (glue sniffers!), reproductive damage, disruption of foetal development (spontaneous abortion, developmental disorder, IUGR). Not genotoxic, not carcinogen

Guideline values:

- **WHO Guideline value:**

 - 260 $\mu\text{g}/\text{m}^3$ (weekly avg. concentration)

 - (also good protective effect in terms of reproduction)

 - based on odour threshold: 1 mg/m^3 (30 min average)

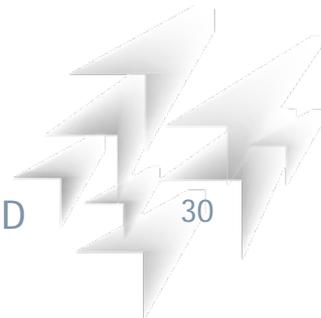


Xylenes

Less toxic than benzene.

Acute effect: skin irritation

Chronic effect: liver and kidney damage



Naphthalene

Sources: coal tar, industry (phthalate production), car exhaust, moth repellents, disinfectants, deodorants

Health effect:

- Respiratory damage (inflammation, cancer- in animals)
- Carcinogen (IARC 2B) - possibly

Guidelines:

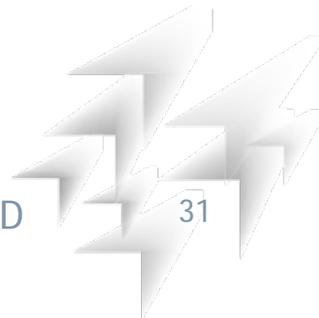
- WHO IAQ Guideline: $10 \mu\text{g}/\text{m}^3$

Limonene

Source: Cleaning products

Values measured in Hungarian schools:

$37.3 \pm 41.8 \mu\text{g}/\text{m}^3$ (range: 4.9-149.5)



Trichloroethylene (TCE)

Sources:

- ambient air (18 µg/day on average)
- indoor air (woodstains, varnishes, coatings, lubricants and adhesives, paint removers, cleaning products)
- drinking water (6 µg/day on average)

Health effects:

- **Toxic effect:** - central nervous system (headache, tiredness, irritability, alcohol intolerance, it was used as a general anesthetic)
 - liver
 - kidneys
- **Adverse pregnancy outcomes** (spontaneous abortion (+/-), heart malformation)
- **Carcinogenic effect:** IARC 2A category (probably human carcinogen), liver and biliary cancer (risk increase by 90%), non-Hodgkin lymphoma (risk increase of 50%), leukaemia, myeloma multiplex, cervical cancer, renal cancer (risk increase by 70 %)



According to WHO Air Quality Guideline for Europe , 2000:

NO SAFE CONCENTRATION (!)

Excess lifetime risk values:

in case of $2.3 \mu\text{g}/\text{m}^3$: 1/1million,
in case of $23.0 \mu\text{g}/\text{m}^3$: 1/100thousand,
in case of $230.0 \mu\text{g}/\text{m}^3$:1/10thousand.



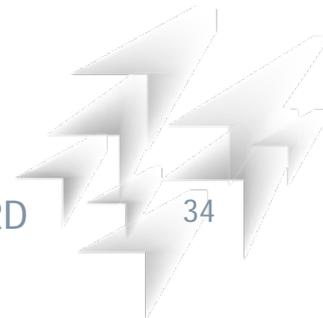
Tetrachlorethylene

Source: clothes cleaning (service and detergent residue)

Exposure: inhalation

Health effects:

- carcinogenic (IARC 2A, ie. Probably carcinogenic to humans)
- nephrotoxic effect (derived guideline value: $250 \mu\text{g}/\text{m}^3$)



Source:

Vinyl chloride is produced in water under anaerobic circumstances from trichloroethylene and tetrachloroethylene. It gets into the air where its half-life is around 20 hours. After it is inhaled it transforms into very reactive and mutagenic metabolites.

Health effects:

- Its acute toxicity is low, but even in low concentrations (whether short or long exposure) it is toxic to the liver.
- It is mutagenic, carcinogenic (IARC 1, liver hemangiosarcoma and other tumours: liver tumour, brain tumour, lung cancer, and malignancy of the lymphatic and haematopoietic system). Liver is the most sensitive to VC exposure.



The different regulations contain the following limit values and guideline values for VC

COUNTRY	$\mu\text{g}/\text{m}^3$
Hungary: 4/2004. (IV.7.) KvVM-ESZCSM-FVM Joint Decree occupational limit value: $10 \text{ mg}/\text{m}^3$	5 (annual)
The Netherlands, 1984, carcinogenic life-time unit risk: for 10^{-6}	0.35
EPA/IRIS carcinogenic life-time unit risk: $1 \mu\text{g}/\text{m}^3 \Rightarrow 4.4 \times 10^{-6}$ from childhood: 8.8×10^{-6}	0.23 (for 10^{-6}) 2.3 (for 10^{-5}) 0.11 (for 10^{-6}) 1.1 (for 10^{-5})
WHO (1987) carcinogenic life-time unit risk: $1 \mu\text{g}/\text{m}^3 \Rightarrow 1.0 \times 10^{-6}$	10 (for 10^{-5})
WHO, Geneva, 2000 as above	



Polycyclic aromatic hydrocarbons (PAHs)

- PAHs are complex mixtures of hundreds of chemicals formed in ambient air during incomplete combustion of organic matter, smoke, diesel exhaust, etc.

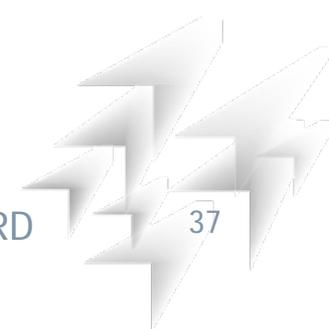
In indoor air: use of unvented heating sources and smoking

Health effects.

- carcinogenicity (especially BaP) IARC Group 1
- immunotoxicity
- genotoxicity
- reproductive toxicity (both sexes)
- atherosclerotic

WHO estimation:

Excess lifetime cancer risk of 1/100 000 for BaP is 0.12 ng/m³



- Phthalates are a group of industrial chemicals that add flexibility and resilience to many consumer products (among others, pvc floors in schools). Other phthalate compounds are used in nonplastic consumer items as fixatives, detergents, lubricating oils, and solvents. They are easily released from the plastic products.
- **Routes of exposure:** inhalation, per os, direct skin contact

- **Health effects.**
 - reproductive toxicity (males!)
 - neurotoxicity
 - asthma and allergic diseases



Pesticides (insecticides, herbicides, rodenticides, etc.)

Problems arising from the indoor use of pesticides:

- Greater concentration near the floor
- They stay longer on certain surfaces (e.g. carpets)
- Sometimes too frequent, too extensive and in some cases unnecessary application

Insecticide types commonly used indoors:

- Pyrethroids: allergens, damage central nervous system (in large concentrations)
- Cholinesterase inhibitors: neurotoxins, inhibit the neuro-development
- Hydramethylnon (relatively new)
- Insect repellents
- Mosquito coils

Health effect:

- Acute poisoning - usually accidental
- Allergic and general symptoms are frequent due to inhalation
- Long term pesticide exposure has been linked to the development of asthma? central neural system disorders (attention deficit and hyperactivity disorder, ADHD) and degenerative diseases (Parkinson's disease); cancer(leukaemia, non-Hodgkin lymphoma)



Types : chrysotile (white asbestos) (90-95%)
crocidolite (blue asbestos)
(amosite - brown asbestos) tremolite, actinolite, anthophyllite

**Dangerous: > 5 μm long and <3 μm wide fibre
length / width > 3**

Exposure:

Mining, construction, oil refineries, automotive industry, paper production, rubber industry

During the production of asbestos textiles (PPE, sealants), friction pad production, seals, (automotive industry), thermal insulation, flame retardants (buildings, vehicles, heaters), spraying technology, during the installation of filters (food industry, air purifying), through the usage of additives (paper production, rubber industry), contamination (talcum).

Corrugated and flat roofing sheets, pipes transporting air, gas, water, wastewater



PREVENTION:

- Legislation: ban
- Limit value: NO SAFE CONCENTRATION
acceptable risk (10^{-5} – 10^{-6}): WHO:1000 F/m³ lifetime exp.

The built-in asbestos, until it is in a good condition, is better left alone
Removal has to be done by experts and with appropriate protection!
Has to be treated as hazardous waste after removal



SOURCES:

- Soil - significant geographical differences
 - - basements, cellars play important role in reducing exposure
- Soil gas
- Water pipes
- Construction materials (natural radioactive material content + additives, e.g. Fly ash from thermal power plant, blast furnace slag)
- Good ventilation can greatly improve the situation



Health effect: lung cancer (IARC Group 1)

Multiplicative effect with smoking

leukaemia is more-or less also proven

NO SAFE CONCENTRATION

Risk increase of 16% / 100 Bq/m³, largely independent of smoking

Lifetime (75 years) unit risk (WHO): 0,6 x 10⁻⁵ (non-smokers)

and 15 x 10⁻⁵ (smokers) per 1 Bq/m³

WHO reference level: 100 Bq/m³ - minimal risk

Max. 300 Bq/m³ - due to local circumstances



Microbial pollutants

Airborne microorganisms (viruses, bacteria, fungi) get into the indoor air mostly in droplets of saliva during coughing, sneezing or speaking, or in aerosol formed during toilet flushing.

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. Some pathogen bacteria can survive for days, weeks, and sometimes months at room temperature, especially when not exposed to sunlight.

Children, elderly people and people with breathing problems, allergies, and lung diseases are particularly susceptible to disease-causing biological agents in the indoor air.



Moulds grow fast in the presence of high relative humidity (>70%), producing a large number of tiny (from 1 to 100 µm) spores that are easily transported through the air. Allergic symptoms caused by spores are related to the size and location of the spores.

Under normal conditions, the body can cope with 100 to 500 spores per cubic meter.

Higher spore load will lead to hypersensitivity, whereby a lower number of spores that has not previously elicited a response will trigger an allergic reaction.

Health consequences: increased risk of allergic rhinitis, development of asthma, exacerbation of asthma, hypersensitivity pneumonitis, allergic alveolitis and other respiratory symptoms, respiratory infections.

Other allergic symptoms: rash, eczema, gastrointestinal allergy (diarrhoea), allergic conjunctivitis. N.B.: Atopic and allergic people are particularly susceptible!

The underlying cause of mould is excessive humidity in the indoor air and condensation.

WHO Indoor Air Quality Guidelines on Dampness and Mould (2009):

„As the relationships between dampness, microbial exposure and health effects can not be quantified precisely, no quantitative, health-based guideline values or thresholds can be recommended for acceptable levels of microorganism contamination.

Instead, it is recommended that dampness and mould-related problems be prevented. When they occur, they should be remediated because they increase the risk of hazardous exposure to microbes and chemicals.“



Building with known problems

Sick Building Syndrome

Sick Building Syndrome

People staying inside experience acute health and comfort effects that are apparently linked to the time learning/teaching/working indoors

Building-Related Illnesses

A relatively small number of people staying inside experience health problems accompanied by physical signs that are identified by a physician and/or laboratory findings, and can be attributed to environmental agents in the air



Sick Building Syndrome vs. Building-Related Illness

Sick Building Syndrome

building related non-specific symptoms

- Headaches
- Fatigue
- Irritated eyes, nose, throat and/or skin
- Dry mucous membranes dry or itchy skin
- Hoarseness of voice and wheezing

Difficult to trace to a specific source.
Symptoms clear when away from building .

Building-Related Illness

recognized building related diagnoses

- infection
 - Legionnaires' Disease
 - Aspergillosis (immune- compromised)
 - cold, flu
- allergic reaction
 - asthma,
 - rhinitis

The cause is clearly related to the building.
Symptoms may not clear upon leaving the building.



- Causes may originate during planning and construction or during operation, maintenance and usage.
- It is difficult to find the cause in individual cases.
- The problems can be sorted into 4 categories (WHO):
 - local factors
 - construction materials, equipment, problems connected to the function of the building (chemical release of construction materials and furniture, lighting, heating)
 - problems independent of the structure of the building (dust-, mould-, or pollen allergy)
 - psychological problems (societal, physical attributes and other factors)



Frequent (not exclusive) attributes in sick buildings (WHO)

(Not every sick building has all of them and not every building is sick where the following occur.)

- Building was constructed after 1960
- Air-conditioned building, windows can't be opened
- Very bright and/or flickering lights
- Ventilation, heating, lighting can be insufficiently controlled
- Carpets or upholsteries with a large surface
- 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 (cigarette smoke, ozone) or VOC from building materials, equipment
- Particulate matter and fibres in the air
- Computer monitors

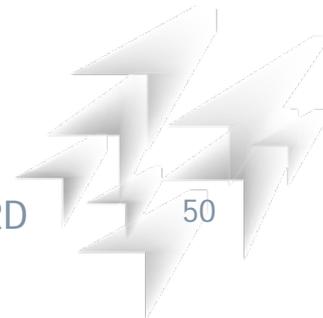


PLANNING

- are there hidden problems at the building site? (e.g. High ground water, radon, other contamination)
- every potential risk factors should be taken into consideration (proper ground plan, cleaning properties, appropriate heating factors)
- what is the quality of the local ambient air? If it is bad, was this taken into consideration in the planning of the ventilation and insulation?

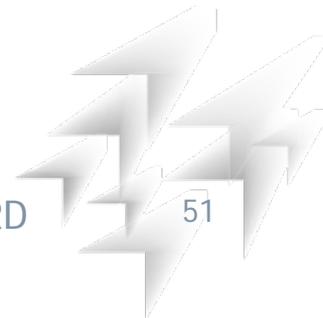
OPERATION

- **Ventilation:** bad ventilation (inadequate ventilation or draught) is a frequent cause of SBS
- **Cleaning:** the contamination of surfaces is a frequent cause; hidden nooks; damp places; ventilation equipment, filters, grating etc., cleaning properties
- **Comfort factors:**
 - noise (from the equipment, ventilation system etc.)
 - high temperature (>21°C), fumes, microorganisms, RH
 - lack of natural lighting

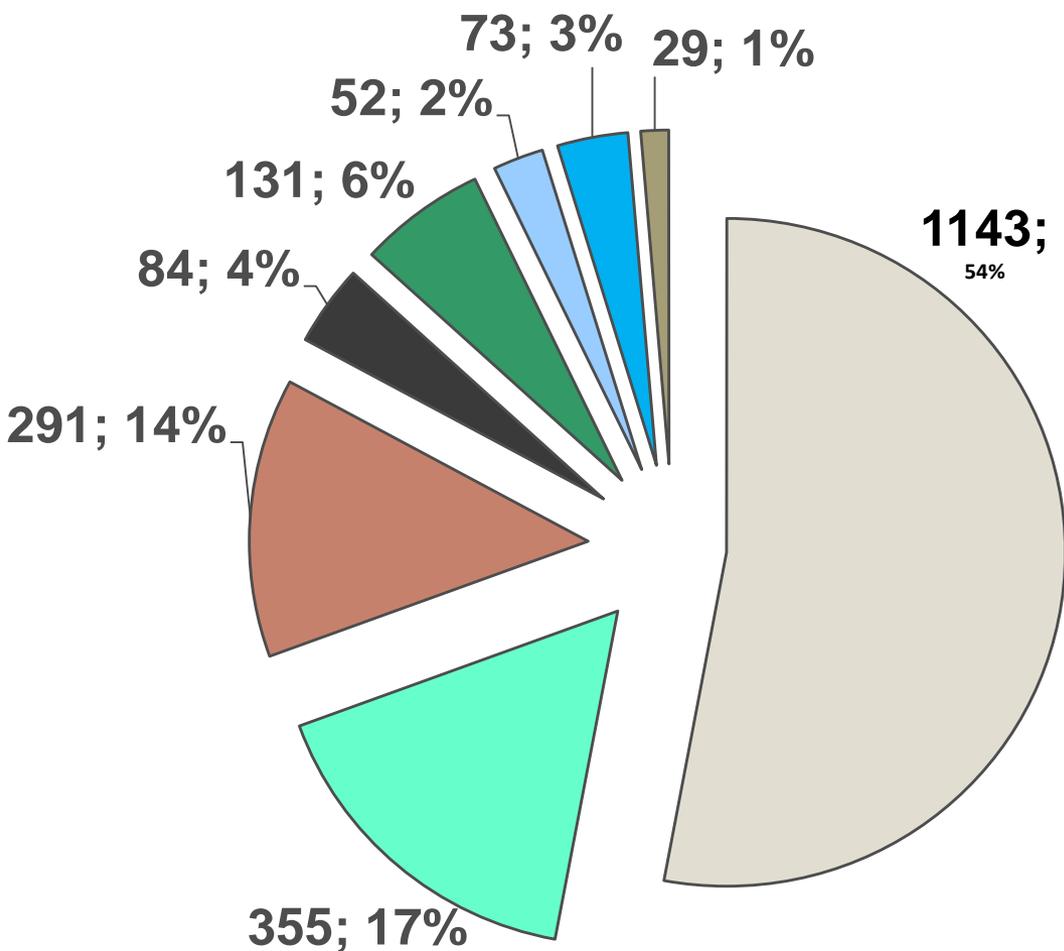


DALY (Disability-Adjusted Life Years)

- ❑ DALY is the sum of Years of Life Lost (YLL) due to premature mortality
- ❑ and the Years Lost due to Disability (YLD) for people living with the health condition or its consequences. (WHO)



The contribution of indoor air pollution to the European symptom- and burden of disease (x 1000 DALY/year) not including environmental tobacco smoke



-  Ambient air quality
-  Water systems, dampness and mould
-  Heating and combustion equipments/appliances
-  Building site (Radon from soil)
-  Furnishing, interior materials, and electric appliances
-  Ventilation and conditioning systems
-  Cleaning and other household products
-  Building materials

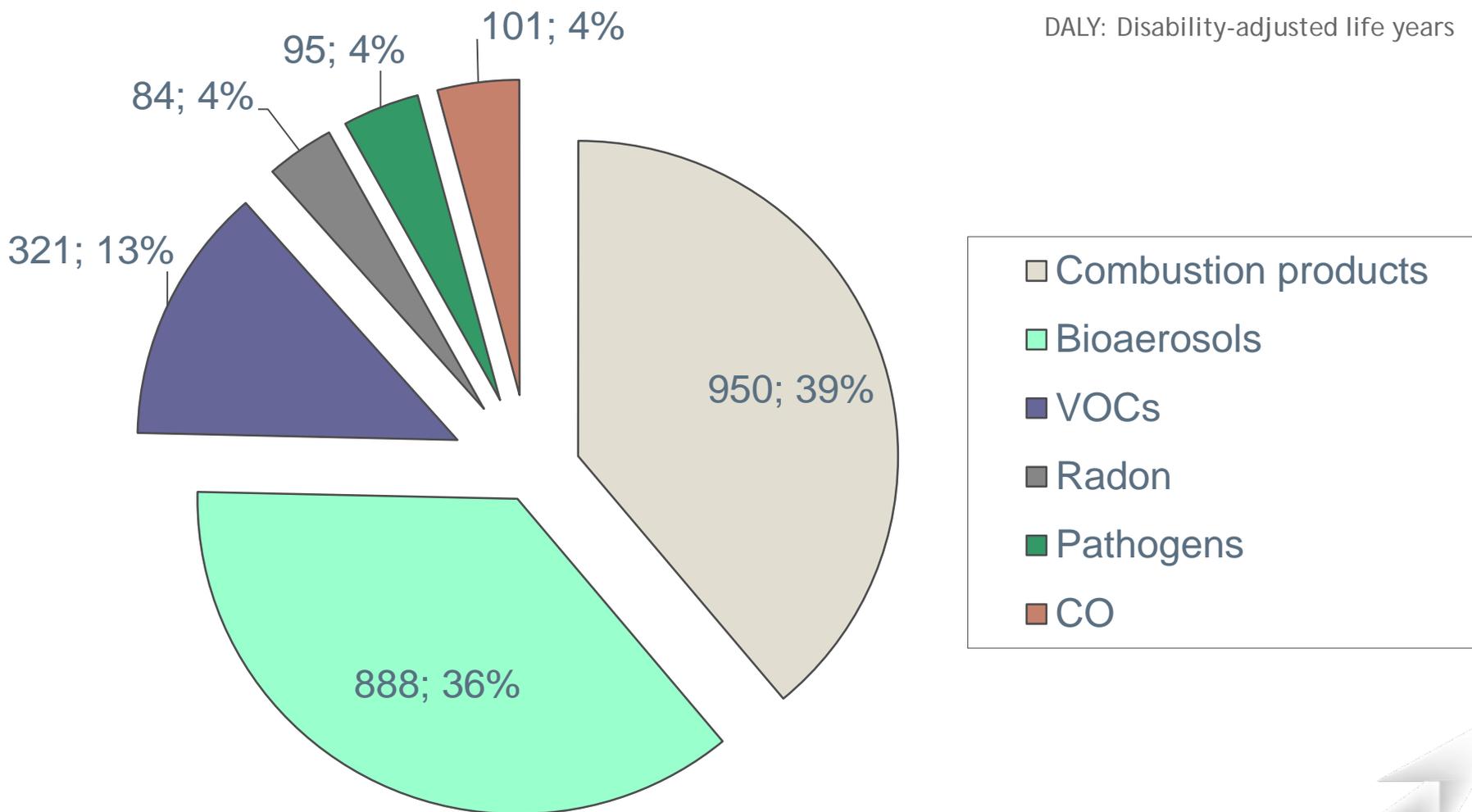


Source: ENVIE Final Report, 2008

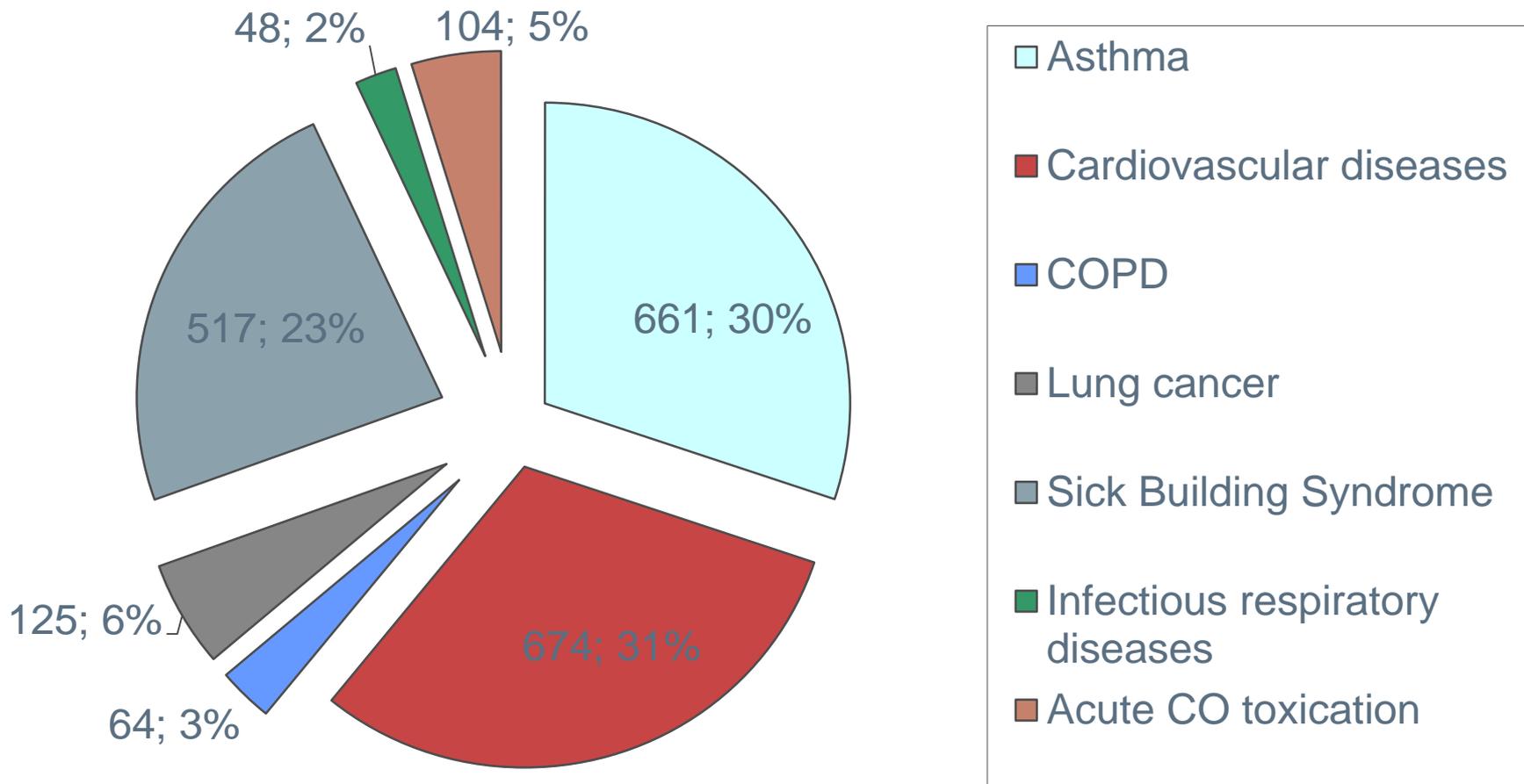
DALY: Disability-adjusted life years

Contribution of indoor air exposure to the European symptom- and disease burden (x 1000 DALY/year), not including environmental tobacco smoke

DALY: Disability-adjusted life years



Contribution of inadequate IAQ to the European symptom- and disease burden (x 1000 DALY/year, %), not including environmental tobacco smoke



Source: ENVIE Final Report, 2008
DALY: Disability-adjusted life years

Phases of epidemiological studies for assessing the effects of indoor pollutants

Sampling

- representative sample
- random sampling
- stratified sampling

Exposure assessment

- Survey
- Survey and on-site visit
- Measurements

Health outcomes

- Comfort survey
- Symptom survey
- Medical diagnosis (morbidity, absence from school)
- Measurements

Statistical analysis

- Correction factors



Human biomonitoring (HBM) in the assessment of indoor air quality

Collecting and analysing human tissue- and fluid samples in order to determine environmental exposure, certain diseases and/or disorders and (genetic) sensitivity and potential connections between them.

It is often combined with other monitoring processes (e.g. air, water, soil, food etc.), modelling or surveys about health and way of life.

(European Environment and Health Action Plan 2004-2010, European Commission on June 9th, 2004)

Its advantages:

- **integrated** attributes for the materials entering the body through different exposure pathways
- Consistent correlations can be shown with HEALTH effects

Its limits:

- **Temporal** processes (degradation, excretion) make their interpretation difficult
- Few materials have limit values, biomonitoring equivalent values or reference values



Biological monitoring of indoor pollutants

POLLUTANT	biological MARKER	biological MATERIAL
Formaldehyde	Formic acid	urine
Carbon monoxide	COHb	blood
Cigarette smoke	Cotinine	urine, saliva
Benzene	t,t (trans, trans) muconic acid, or s-phenyl mercapturic acid	urine
ethylbenzene	Mandelic acid	urine
xylenes	Methylhippuric acid	urine
toluene	o-cresol	urine
Trichloroethylene	trichloroacetic acid	urine
naphthalene	1-naphthol and 2-naphthol	urine
PAH compounds	1-Hydroxypyren	urine
Phthalates (measured with HPLC-MS/MS):		
DEHP	mono-ethyl-hexyl-phthalate (MEHP) - wall paint mono-(2-ethyl-5-hydroxyhexyl) phthalate (MEHHP) mono-(2-ethyl-5-oxohexyl) phthalate (MEOHP)	urine
BBzP	mono-benzene-phthalate (MBzP) - pvc flooring	urine
DEP	mono-ethyl-phthalate (MEP) - cosmetics	urine



The CLASSROOM environment

General cleanliness

regular cleaning, dusting, trash removal

Physical arrangement of the *classroom environment*

furniture

blackboard

personal work space - avoid overcrowding

Comfort environment

temperature (moderate temperature),
no sign of draughtiness,
children should not be seated in direct sunlight)

humidity (30-60%)

light

noise control

Emotional classroom environment

increases learners' performance.

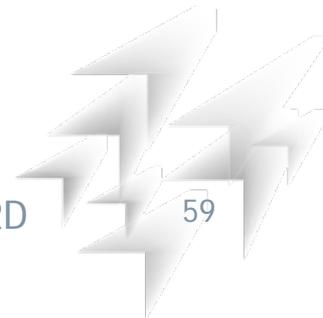
Cognitive classroom environment

makes learning an active and creative process.



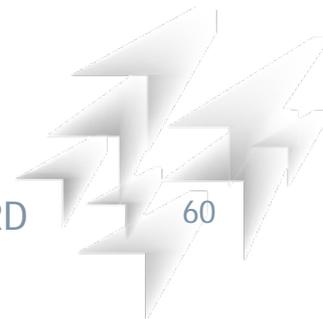
The role of overcrowding in indoor air quality

- Higher levels of chemical air pollutants (CO₂, PM, etc.)
- Increased risk of pathogen transmission (infection)
- Decreased attention
- Increased risk of accidents
- More frequent cases of fatigue and headache
- Higher noise level



Main points of healthy IAQ in school

1. Source control
2. Ventilation
3. Air cleaning



Main points of investigation of IAQ in school /1.

1. **Source control:** compliance to guideline concentration and reduction of source concentration
2. Ventilation
3. Air cleaning



WHO indoor air quality guidelines for selected pollutants (2010)

Pollutant	Guideline value	Reference time	Comments
Benzene	1.17 µg/m ³	Life time (1x 10 ⁻⁵ excess cancer risk)	No safe level of exposure can be recommended
Carbon monoxide	100 mg/m ³ 35 mg/m ³ 10 mg/m ³ 7 mg/m ³	15 minutes 1 hour 8 hours 24 hours	
Formaldehyde	0.1 mg/m ³	30 minute average	Valid for any 30 minute period
Naphthalene	0.01 mg/m ³	Annual average	
Nitrogen dioxide	200 µg/m ³ 40 µg/m ³	1 hour average Annual average	
Polycyclic aromatic hydrocarbons / B(a)P /	0.12 ng/m ³	Life time (1x 10 ⁻⁵ excess cancer risk)	B(a)P is taken as a marker of PAH mixture
Radon	167 Bq/m ³	Life time (1x 10 ⁻³ excess cancer risk for lifelong non-smokers)	
Trichloroethylene	23 µg/m ³	Life time (1x 10 ⁻⁵ excess cancer risk)	
Tetrachloroethylene	250 µg/m ³	Annual average	



Regulations and reference values

Ambient Air Quality regulations

- National Ambient Air Quality regulations (guideline values for contaminants)
aim: to protect the health of population 24 hours a day
- relevance for schools or office IAQ problems?



Focusing to source control of indoor air pollutants

- Ambient air contaminants transferred inside
- Heating sources
- Construction material emissions
- Furnishings (generally highest after manufacture and construction)
- Carpeting, curtains, blinds
- Paints, varnishes, adhesives, etc.
- Office equipment
- Cleaning products
- Human emission (sweat/perspiration; personal care products)
- Biocides
- Mould; biological agents
- Radon



1. Source control

2. Ventilation

~ 50% of all IAQ problems are due to inadequate ventilation!

3. Air cleaning



The role of air exchange in IAQ (ventilation)

- Providing fresh air
- Removing accumulated pollutants, diluting their concentration
- Reducing temperature

Hygienic aspects of ventilation:

- Air movement aids evaporation, and thus usually has a cooling effect on the body. A **lack of air movement** leads to damp problems and has a negative effect on metabolism and the thermal state of the body: can cause feelings of discomfort and exhaustion.
- The feeling of draught limits ventilation: **air velocity beyond 0.3-0.5 m/sec** is perceived as draught and could result in cooling of the body or parts of the body.
- The IAQ guidance values should not be reached primarily through ventilation, but by **reducing emission**



Fresh air demand / 1

- In the inhaled air: 21% oxygen, 0.03% carbon dioxide
(78% nitrogen, 0.97% inert gases)
- In the exhaled air: 16% oxygen, 3-5% carbon dioxide + water vapour
- Indicative importance of CO₂ concentration:
 - 0.1% CO₂ perception of stuffy air
 - 1% CO₂ discomfort/malaise,
 - 10% CO₂ life threatening

CO₂ concentration is generally used as an indication of the efficiency of ventilation

According to the CEN Report CR 1752 (1998 Dec):

CO₂ outdoor typically 350 ppm=700 µg/m³

category A: outdoor CO₂ + 460ppm (15% dissatisfied)

category B: outdoor CO₂ + 660 ppm (20% dissatisfied)

category C: outdoor CO₂ + 1190 ppm (30% dissatisfied)



Fresh air demand is influenced by

occupancy, activity (10-12x in case of physical work)
age, state of health, size and function of the premises

N.B.! There are other than just CO₂ producing/emitting pollution sources!

According to the CEN Report CR 1752 (1998 Dec):

Required ventilation in classrooms for comfort:

Category A: 6.0 litre/sec (l/s) per m² floor area

Category B: 4.3 l/s per m² floor area

Category C: 2.4 l/s per m² floor area



Person-related ventilation rate:

Standards on fresh air demand of building rooms according to fresh air need of persons:

fresh air demand \approx 15-36 m³/person/hour

Average classroom condition: 2m²/person \rightarrow 6m³/person



The total air should be exchanged min. 3-6 times /hour

Insufficient natural ventilation causes increased moisture/mold, enhanced concentration of bacteria/viruses/fungi and chemical pollutants, as well unpleasant odors.

Ventilation methods:

- Natural ventilation (windows or vent-holes)
- Mechanical ventilation (with fans)



Infiltration: random/ intentional flow of outdoor air through windows, cracks and different openings in the buildings.

Exfiltration: movement of air from indoor to outdoor.

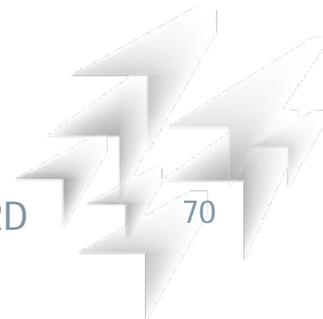
Natural Ventilation

Air Flow- occurs mainly due to two gradients:

- Pressure - difference between outdoor and indoor pressure
- Temperature - when the inside air temperature differs from outside one

Natural ventilation in general inefficient as it is not uniformly distributed. Air doesn't circulate evenly and stale air remains in some spaces.

It transfers pollen and other contaminants from ambient air.



Involves use of fans and / or air-conditioning equipment.

Main points of mechanical ventilation:

- pulling fresh air from outside to indoor
- transfer stale air to outside
- adjusting temperature and humidity inside.

Heating, Ventilation, Air Conditioning (HVAC) systems:

Functions:

- Heating - cooling
- Ventilation
- Filtration
- Humidification - dehumidification
- Air-flow

Parameters:

- Infiltration air
- Exfiltration air
- Air-recirculation



In naturally ventilated buildings

By Infiltration measurement. Infiltration is measured as air change per hour (ACH) - the average rate at which indoor air is replaced by fresh outdoor air.

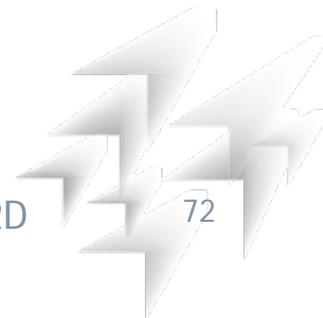
ACH is a rough index for different building conditions.

ACH is 0.1 to 0.2, in “leaky building”, ACH is 2.0 to 3.0 in normally ventilated buildings

Tracer gas technique is applied to measure infiltration. Non reactive gases are used with the assumption that the loss of tracking gas is only due to ventilation / exfiltration.

In mechanically ventilated buildings

ACH is measured by CO₂ concentration.



1. Source Control
2. Ventilation
3. Air Cleaning

As a rule air cleaning is recommended after careful source control and ventilation study are taken.



- In the usual way air cleaners are not effective for gaseous pollutants
- Efficient for collecting pollutants (> 0.3 micron particles)
- Pumping air through cleaning equipment
- Combination of source reduction and ventilation
- Air fresheners typically attempt to mask odours and add more air pollutants



Action plan for improving indoor air quality in schools

Steps

- assessment of the current state of the school environment
- identification of the problems
 - health symptoms or diseases
 - monitoring indicators of IAQ
- supportive conditions needed (legislation, experts, school management, intersectoral cooperation, financial background)



How to manage IAQ in schools?

Proactive operation

Preventive maintenance on buildings and equipment

Right, accurate cleaning procedures and practices

School Board and Staff Awareness Training

Reactive measures

Immediate provision and correction of building and equipment breakdowns.

Investigation of all IAQ concerns/complaints to resolve problems.

Compliance policy and action

Cooperation with stakeholders and keeping all local, state Regulations and standards relating to IAQ in schools



Action plans: tools for school

- adaptable to individual school needs
- no cost/ low cost
- no specialized training required
- voluntary
- common sense basis
- good IAQ is important for learning
- enhance the learners' and teachers' productivity
- accountability to school boards and other schools officials



Paying attention to:

Ventilation

Act immediately if any ventilation equipment break down (noises, odours, temperature control, air-flow problems, comfort)

Potential contaminants

Do not bring in or use air fresheners, candles, pesticides from home.
Minimize chemical exposure.

Find any water leaks, moisture on surfaces, mould, pest activity

Cleanliness

Cleaning

Store junks in containers.

Ensure that spills (especially on carpets) are cleaned promptly



Science teacher should take initiative to use Tools for schools and incorporate it into the science curriculum.

Higher grade learners should monitor IAQ in the school with teacher's guidance.

The teacher became the school's IAQ coordinator.

IAQ team:

- teachers, school board
- IAQ coordinator
- students and parents
- administrative staff
- school nurse/ physician
- school operators



Checklists for teachers and maintainers.

Inspect school, setting priorities.

Share IAQ information with parents and partners in health protection.



Classroom checklist

General cleanliness

Excess moisture

Thermal comfort

Ventilation

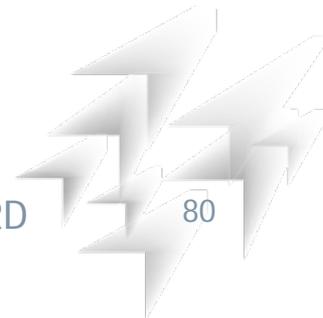
Odours

Materials, storage of materials

Pupils may unintentionally bring air contaminants into the classroom by recently dry-cleaned clothing, or clothing soiled with different chemicals (ETS) and biological agents

Laboratories, art rooms, etc.

Dressing rooms



Checklist for school maintaining staff

General cleanliness

Toilet

Store-room

Excess moisture

Thermal comfort

Ventilation

Check for unexplained odours

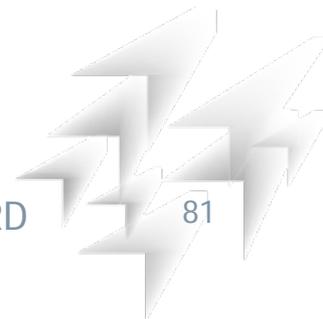
Combustion appliances -- Heating system

Printing equipment

Repairs and renovation

Pest control

Waste management



Checklist for Water, Sanitation and Hygiene (WASH) in Schools

Daily cleaning and maintenance of existing sanitation facilities

Assessment condition of toilets and hand wash facilities in schools

The pupils/toilet ratio (specified in WHO guidelines, 2009)

- hand washing facility requirements, provision of hygiene consumables

- the sanitation facilities should be in good condition (a large number of students does not make use of WASH facilities in their schools due to poorly maintained toilets)

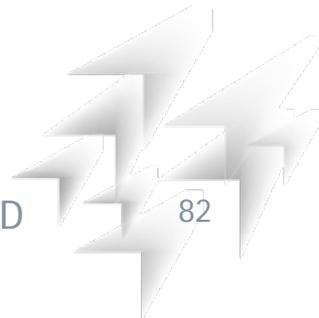
Recognition of health impacts and WASH educational outcomes

Mapping and description of water and sanitation system within the school and community

Control moisture in and around the school building

- repair leaks and drips

- move water from gutters away from building



Benefits from using the IAQ Tools for schools



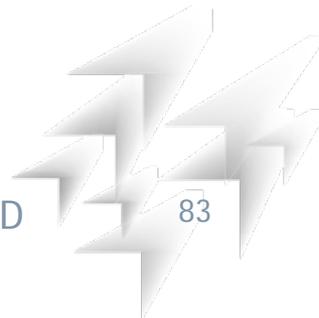
Better productivity of learners and teachers

Quicker and more cost-effective response to problems

Peaceful atmosphere for staff, learners and parents

Reduction of upkeep cost, expenses for repairs and avoidance of immediate technical intervention charge

Assists school in education of learners



Complementary environmental health initiatives

Healthy schools design and construction/reconstruction

Attractive programs

Active and safe routes to school, minimal vehicle transport to school

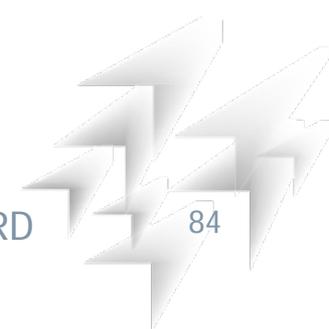
Recycling, greening of grounds, energy efficiency

Hazardous materials control

Identification, replacement and storage of hazardous materials

Movement around the school is regulated

Corridors and social areas as well as break and lunchtime are well supervised/monitored



Roles of school health nurses

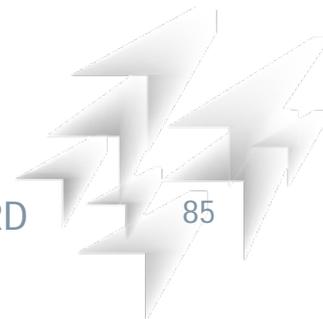
Liaison between school personnel, family and health care providers.

Provides screening for health conditions.

Provides direct healthcare to learners.

Promotes a healthy school environment.

Promotes health.



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



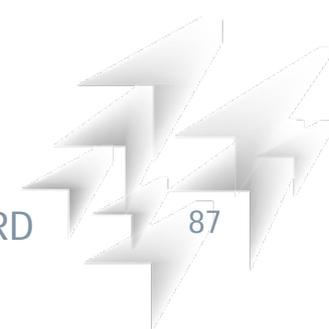
Proposed action plans to lower the concentration of FORMALDEHYDE

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.

Collect information about the furniture (date of productions, ventilation and other characteristics of the material of the furniture).

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 a 6-8 week ventilation.



Proposed action plans to lower the concentration of FORMALDEHYDE

- Plan the use of products containing formaldehyde concerning the proper ventilation during and after the use of them.
- Maintain the temperature and relative humidity of the school environments at the lowest comfort levels (formaldehyde emission and indoor concentrations increases by increasing temperature and humidity)
- Increase the knowledge about preventing exposure to formaldehyde (for example, when buying articles, always check the composition information, always wash all new clothes, do not use air fresheners).



Proposed action plans to lower the concentration of FORMALDEHYDE

Put special flowers in the classrooms which can absorb formaldehyde (Scindapsus /Golden Lotus,



Sansevieria, Dracena marginata, Filodendron, Peace lily, etc.). Besides formaldehyde, these plants can absorb several volatile organic compounds like benzene, xylene, toluene, etc.).



Proposed action plans to lower the concentration of BENZENE

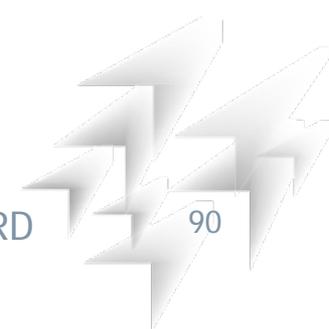
"Prevention" of the entry of benzene from the outside air (location of parking lots, cigarette smoke etc.).

Strict control of the smoking ban indoors.

Do not use benzene inside the building except in case you have an extraction chamber.

Ventilate the indoor areas during and after using products containing benzene (e.g. during painting/use of colours).

Handle as hazardous waste the rest of benzene containing colours by following the instructions for separating/handling hazardous waste).



Proposed action plans to lower the concentration of VOCs

Prevent the entry of VOCs from the outside air (e.g. parking lots).

Choose products that do not contain VOCs

Do not store products that are a source of VOCs in rooms where children stay.

When using products that are sources of VOCs (various cleaners, paints, varnishes ...), use them according to the manufacturer's instructions.



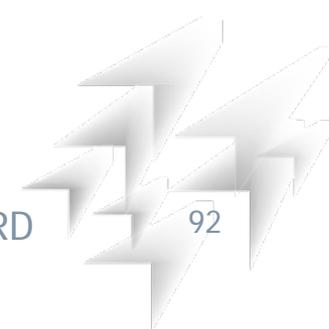
Proposed action plans to lower the concentration of VOCs

For the use of products that are the source of VOC, ensure sufficient amounts of fresh air.

Buy and stock the products that are the sources of VOCs in the quantities to be spent immediately. Discard the excess storage in unopened or open containers (note the instructions for separating waste).

Never mix products that are the source of organic volatile compounds, unless stated in the manufacturer's instructions.

Reduce the exposure to formaldehyde, benzene and tetrachlorethylene in a living environment at school.

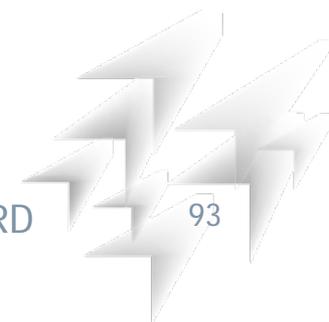


"Prevention" of the entry of particles from the outside air

Thoroughly ventilate the classrooms before and after lessons, as well 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.

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



General instructions on cleaning and maintaining the indoor environments

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.



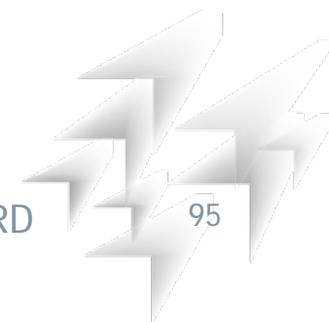
General instructions on maintaining the indoor environments

In case the school building is heated by stoves burning solid fuels, use dry hard wood. Keep the general instructions on fire.

Replace solid fuels with cleaner fuels and energies (e.g. solar energy, electricity, natural gas) as soon as possible considering the reduction of emissions from these stoves.

Regularly clean and maintain heating, smoke and ventilation devices. For furnaces for liquid and gaseous fuels, before the start of the heating season, ensure that the burners are correctly adjusted.

Install a CO monitoring device in the rooms.



Proposed action plans to lower the concentration of CO₂

If you do not have 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.

Install a CO₂ concentration monitor in the classroom.



Maintaining the indoor environments with respect to endocrine disrupting chemicals occurring in equipment, coverings and indoor air:



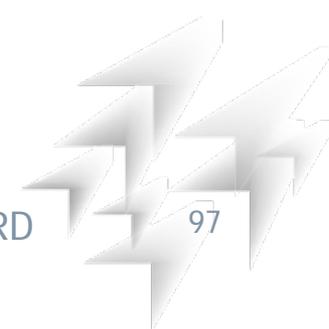
Avoid installing indoor PVC window blinds, which usually contain phthalates, bisphenols and flame retardants. Do not hang flame retarded curtains containing polybrominated flame retardants.

Avoid PVC floors on the same grounds. Use phthalate-free flooring.

If you have PVC floor, use wet cleaning practices frequently.

Do not use flame retarded upholstered furniture in the classroom.

If necessary to use carpets, use only woven carpets instead of manufactured carpets containing adhesives, phthalates, brominated flame retardants and fluorinated repellents.



Proposed action plans to maintain optimal temperature and humidity

Put a thermometer in the classroom. Ensure optimal temperature during winter, do not overheat the rooms.

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

Prepare for the insulation of the buildings and increase the heat resilience by installing outdoor shades. If you use indoor blinds or curtains, choose the ones not containing endocrine disrupting chemicals, and assure the proper cleaning.

Plant hypoallergenic trees and bushes around the school building.

Monitor the humidity in the classrooms, avoid dry air by placing plants and humidifiers in the classrooms.

Assure the right ventilation in classrooms of insulated buildings in the evenings for cooling the indoors.



Proposed action plans to combat climate change effects

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

Assure the right ventilation in classrooms of insulated buildings also at night by keeping the windows open in tilted position and propping them against possible stormy winds.

If you use indoor blinds or curtains, choose the ones not containing endocrine disrupting chemicals, and assure the proper cleaning.

Plant hypoallergenic trees and bushes around the school building.

During heat waves it is important to change the day schedule flexibly.

Drinking fountains in the corridor and in the yard can be realized at a relatively low cost.

Proper clothing of children both indoors and outdoors



Proposed action plans against mould

Avoid dampness.

Assure adequate ventilation.

Do not leave corners without air movement.

Assure adequate heating, prevent cold surfaces.

Take care of the soil of plants, use special material which hinders the growth of fungi.



Conclusions

Good IAQ is the guarantee of comfort, health and safety.

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, temperature, humidity and mould control all take part in improving indoor environment.

IAQ is an essential component of healthy school environment.

