



Guidelines for healthy environments within European schools

European Commission

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Abstract

This document describes the guidelines framework for healthy environments within European schools which was developed within SINPHONIE (Schools Indoor Pollution and Health – Observatory Network in Europe) project. Its objective is to provide a reference guide which links together both coherently and comprehensively the most up-to-date knowledge informed by the outcome of the SINPHONIE project. This includes key drivers and prevention, control, remediation and communication strategies for a healthy school environment in Europe. These guidelines for healthy environments within European schools are primarily directed at the relevant policy-makers at both European and national levels and at local authorities aiming to improve the indoor school environment in their countries while respecting the specificities (environmental, social, economic) of their national and local situations.

A second target group which is expected to benefit directly from these guidelines includes school-building designers and managers (responsible for the design, construction and renovation of school buildings), schoolchildren and their parents, teachers and other school staff. Users of this guidance should consult relevant national guidance in the first instance and use this publication to access supplementary information.



SINPHONIE

Schools Indoor Pollution and Health Observatory Network in Europe

Guidelines for healthy environments within European schools

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Guidelines for healthy environments within European schools

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FOREWORD

In Europe, more than 64 million students and almost 4.5 million teachers spend many hours each school day inside pre-primary, primary and secondary schools. Children spend more time in school than in any other place except home. There is much evidence regarding the potential effect on health of a variety of indoor pollutants that can be found in various types of building environments including schools, either originating from the ambient air or produced indoors from materials, products or activities. The presence of pollutants in schools may also affect children's growth, opportunities and learning performance, as well as their cultural and social development. An increase in the prevalence of bronchial asthma was documented in the last decades of the 20th century in the industrialised world, including Europe. Asthmatic children are known to be particularly sensitive to the effects of poor air quality and therefore the indoor and outdoor environment in schools has been increasingly receiving much of attention.

The European Commission, in the context of its Environment and Health Strategy supported a number of key projects for elaborating integrated approaches to address air quality and health issues (i.e. the chain from exposure to potential causes and sources, health-risk assessment, strategies and policy options) in various typologies of buildings including schools.

The funding for the SINPHONIE project was provided by the European Parliament to the European Commission in order to establish a scientific/technical network to act at European level with the long-term perspective of improving air quality in schools and kindergartens, thereby reducing the risk and burden of respiratory diseases among children and teachers potentially due to combined exposure to indoor and outdoor air pollution. SINPHONIE has been a milestone project which has provided standardised methodologies and tools for better characterising schools' indoor environments and assessing the health risks to schoolchildren and staff. At the same time, the project supported future policy actions by formulating guidelines, recommendations and risk management options for better air quality and associated health effects in schools.

SINPHONIE elaborated a framework and guidelines for healthy environments within European schools with the aim to link both coherently and comprehensively the most up-to-date knowledge (key drivers and prevention, control, remediation and communication strategies for a healthy school environment in Europe) and the specific outcome of the SINPHONIE project.

These guidelines for healthy environments within European schools are intended to enrich and reinforce existing national and local guidance and are primarily directed at the relevant policy-makers at the European and national levels as well as local authorities. They aim to improve the indoor school environment in the European countries while respecting the specificities (environmental, social, economic) of their national and local situations. A second target group which is expected to benefit directly from these guidelines includes school-building designers and managers (responsible for the design, construction and renovation of school buildings), schoolchildren and their parents, teachers and other school staff.

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1. Background and objectives of the guidelines for healthy environments within European schools

A healthy school environment is an important prerequisite to guaranteeing children's growth, learning opportunities and performance as well as their cultural and social development. The air quality of the school environment is of particular concern because of the time the schoolchildren spend at school and because their physiological characteristics make them a particularly susceptible group within the population. In Europe, more than 64 million students and almost 4.5 million teachers are exposed to indoor air in schools. They spend more of their time in indoor environments (pre-primary, primary and secondary schools and childcare settings) than in any other place, except at home.

There is substantial evidence of the potential detrimental impacts on health of a variety of air pollutants that can be found in indoor environments, including schools. Poor air quality affects our general well-being and comfort and has respiratory and other health-related effects such as cardiovascular disease and cancer, due to the presence of several specific pollutants causing health concerns. This has been reported abundantly in scientific literature (e.g. air quality guidelines (WHO, 2005, 2009, 2010), indoor air quality (IAQ) management strategies (EnVIE, 2008; SEARCH, 2010; etc.)) and also reflected in political declarations (Parma's World Health Organization (WHO) Ministerial Declaration, 2010).

An increase in the prevalence of bronchial asthma was documented in the final decades of the 20th century in the industrialised world, including Europe. Asthmatic children are known to be exceptionally sensitive to the effects of poor air quality. Therefore, schools constitute a particularly critical setting for this susceptible population group. A report by the European Federation of Asthma and Allergy Associations (EFA) in 2002 (EFA, 2002) identified various indoor air quality (IAQ) problems in schools in European countries. It underlined a lack of studies on their consequences for health and on standardised methodologies enabling the issues to be approached in a holistic way, as well as assessing the impact of different local policies regarding the indoor environment in school buildings.

In 2010, the Parma Declaration from WHO Europe, endorsed by 53 countries, called on member states of the WHO Europe region to implement measurable actions in order to reach the targets set. Its 'Regional Priority Goal 3 on preventing disease through improved outdoor and indoor air quality' states: "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 and, as guided by the Framework Convention on Tobacco Control, ensuring that these environments are tobacco smoke-free by 2015."

Following up on the Parma Declaration's objectives, the SINPHONIE project (Schools Indoor Pollution and Health – Observatory Network in Europe), funded by the European Parliament and supported by the European Commission, was the first Europe-wide pilot project to monitor the school environment and children's health in parallel in 23 European countries (SINPHONIE, 2013). This two-year project (2010-2012) brought together the multi-disciplinary expertise of 38 partners (plus one associated partner) from 25 countries.

SINPHONIE has been a milestone project which has provided standardised methodologies and tools for better characterising schools' indoor environments and assessing the health risks to schoolchildren and staff. It has also developed guidelines

and recommendations for healthy school environments covering a wide array of situations in Europe. Moreover, it represents a unique opportunity and an excellent vehicle for capacity building for several national institutions mainly in the Eastern and Southern European countries. In this sense, it has been a clear case of ‘technology transfer’ concerning indoor air quality and health-impact assessment methodologies in European countries. To reach the objective of healthy school environments in Europe, an integrated and holistic approach on prevention, control, remedial and communication strategies is needed to address air-quality and health issues (i.e. the chain from exposure to potential causes and sources, health-risk assessment, strategies and policy options) in schools, along with their location, design, construction, use, management and maintenance.

This document describes the guidelines framework for healthy environments within European schools which was developed within SINPHONIE as a basis to support the potential development of an EU coordinated programme for a healthy school environment.

Its objective is to provide a reference guide which links together both coherently and comprehensively the most up-to-date knowledge informed by the outcome of the SINPHONIE project. This includes key drivers and prevention, control, remediation and communication strategies for a healthy school environment in Europe. This guidance is intended to provide advice which could be considered generally applicable in most school environments in Europe. However, as each school environment is unique (in terms of design, climatic conditions, operational modes, etc.), the guidance needs to be adapted accordingly at national or local level. For this purpose, criteria for the uptake and implementation of the guidance into national policy measures and actions in the European countries are also provided. In this perspective, the guidance presented in this report is not intended to replace but rather to enrich and reinforce existing national and local guidance which will continue to be the first point of reference.

It should be emphasised that these guidelines aim to promote a preventive and cost-effective approach – in terms of the efforts and associated costs required to achieve good indoor air quality in a given school environment – as opposed to a problem-based approach that seeks to solve problems only after they have arisen.

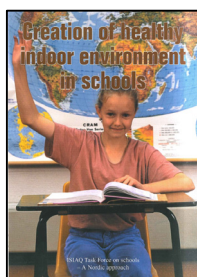
These guidelines for healthy environments within European schools are primarily directed at the relevant policy-makers at both European and national levels and at local authorities aiming to improve the indoor school environment in their countries while respecting the specificities (environmental, social, economic) of their national and local situations. A second target group which is expected to benefit directly from these guidelines includes school-building designers and managers (responsible for the design, construction and renovation of school buildings), schoolchildren and their parents, teachers and other school staff.

Users of this guidance should consult relevant national guidance in the first instance and use this publication to access supplementary information.

2. Overview and analysis of existing international initiatives for a healthy indoor environment in schools

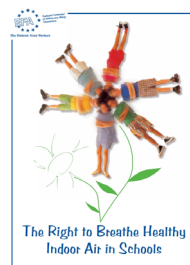
The development of this document was based on a review of the most up-to-date information collected from the literature and through the SINPHONIE partners on national initiatives (guidelines, programmes and regulations) aimed at improving the indoor environment in schools across Europe and internationally. The information collected was subsequently analysed, focusing on the situation in Europe; the main similarities and differences across European countries were identified and reported.

ISIAQ



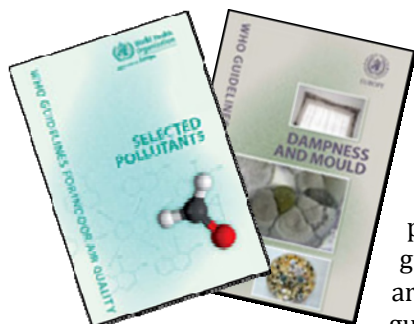
The International Society of Indoor Air Quality and Climate (ISIAQ) published the 2001 report 'Creation of a healthy indoor environment in schools', which includes requirements for a good indoor environment in schools, methods for surveying school buildings with indoor-climate problems, and for healthy renovation and management in schools, and remedial measures.

EFA



In 2001, in the context of the EU-funded project 'Indoor air pollution in schools', the European Federation of Asthma and Allergy Associations (EFA) prepared recommendations and proposals for a healthy school environment in Europe, which were outlined in the booklet "The right to breathe healthy indoor air in schools".

WHO



WHO published two documents presenting guidelines and recommendations on indoor air quality (although not specifically focusing on the school environment). In 2009, guidelines on dampness and mould were released (WHO, 2009) and in 2010 guidelines on indoor air and chemicals were published (WHO, 2010). Although both sets of guidelines focus on indoor air quality in dwellings, they are also applicable to school buildings. The WHO IAQ guidelines recommend targets for IAQ at which health risks, such as asthma exacerbation, hay fever, atopy, etc., can be significantly reduced, and they provide a scientific basis for legally enforceable standards in all regions of the world. The guidelines are targeted at public health professionals involved in preventing the health risks associated with environmental exposure, as well as at specialists and authorities involved in the design and use of buildings, indoor materials and products.

US EPA



For more than 10 years, the US Environmental Protection Agency (US EPA) has provided the 'IAQ Tools for Schools' action kit to school officials, staff members of various school facilities, teachers, health-care professionals, as well as students and their parents. This kit provides best practices, guidelines and a sample IAQ management plan to improve school air at low or no cost. All relevant materials are available on: <http://www.epa.gov/iaq/schools/>. The action kit is also used in Canada.

European countries



An overview of the information obtained for European countries is given in Annex A. It can be seen that policy measures differ among countries. In the case of countries that actually have policy measures in place, there are some commonalities in the objectives, although the scope and level of detail of these measures do differ. Several countries have adopted guidelines and recommendations by which they provide information to schools on how to create a healthy indoor environment in schools. However, many of these are not directly related to improving IAQ in school buildings specifically. Some of the measures are mandatory, while others are only recommendations. One country also prescribes mandatory IAQ measurements.

Annex A shows that several European countries have hygiene requirements in place. It seems that many of these requirements are not issued primarily to directly improve IAQ specifically, but rather to maintain basic hygiene in school buildings, thus preventing certain common infectious diseases. Hygiene requirements include taking care of such things as cleaning practices, personal hygiene, food safety and room conditions (lighting and ventilation). Annex A also shows that some countries have more technical requirements specifically aimed at improving IAQ in school buildings. These may include the design of school buildings, the placement of mechanical ventilation, or remediation programmes following the detection of problems.

The SINPHONIE review of national initiatives in EU Member States, accession and candidate countries noted that Germany and France have issued comprehensive guidelines and recommendations on hygiene and IAQ requirements for schools, measures to control specific indoor-air pollutants, structural and indoor climate requirements, and procedures in indoor-environment-related problem cases and their remediation.

The German Guidelines for Indoor Air Hygiene in School Buildings were issued by the Umweltbundesamt in 2008 (UBA, 2008).

In France, and in the context of the French environmental programme 'Grenelle Environnement' (France, 2010), mandatory requirements were developed for the regular monitoring and auditing of IAQ in schools on a periodic basis, and for establishing a labelling system for construction and decorating materials.

3. Guidelines for healthy environments within European schools

The complexity of indoor pollution sources and their relation to exposure and health effects presents major challenges for developing coherent approaches to the school environment. Likewise, the multitude of parties responsible for generating and controlling indoor air pollution, in buildings in general and in school buildings in particular, is significant.

It is clear, however, that in order to be effective, policies directed at improving indoor air quality must be part of a comprehensive, internally and externally consistent management strategy involving governments, institutions, professional bodies and individuals. Plans must be directed at both new and existing buildings and should involve action at local and national levels. Important considerations include: outdoor climate and air quality; building materials and styles; occupants' knowledge and behaviour patterns; energy and sustainability policies; and building-system technologies. Requirements for designing a successful strategy cover prior justification, goal setting, the appraisal of management options, and political willingness.

The aforementioned considerations stress the need to tackle and evaluate the school environment in a holistic and coherent way. This can be done by linking a shortlist of air-related health-exposure-source chains and evaluating the policy alternatives for minimising both unwanted health consequences, in terms of achievable public health benefits, and invasiveness. At the same time, the political, legal, technological, economic and social feasibility within European countries should also be taken into account.

The SINPHONIE project was the first Europe-wide project to monitor the school environment and children's health in parallel in 23 European countries, building upon the holistic concept developed by the EU-funded EnVIE project (EnVIE, 2008) (Figure 1). SINPHONIE assessed the air quality (indoor and outdoor) and associated children's health in schools throughout Europe using common and standardised methodologies and tools. It also developed risk-management options and guidelines for healthy air in school environments in Europe.

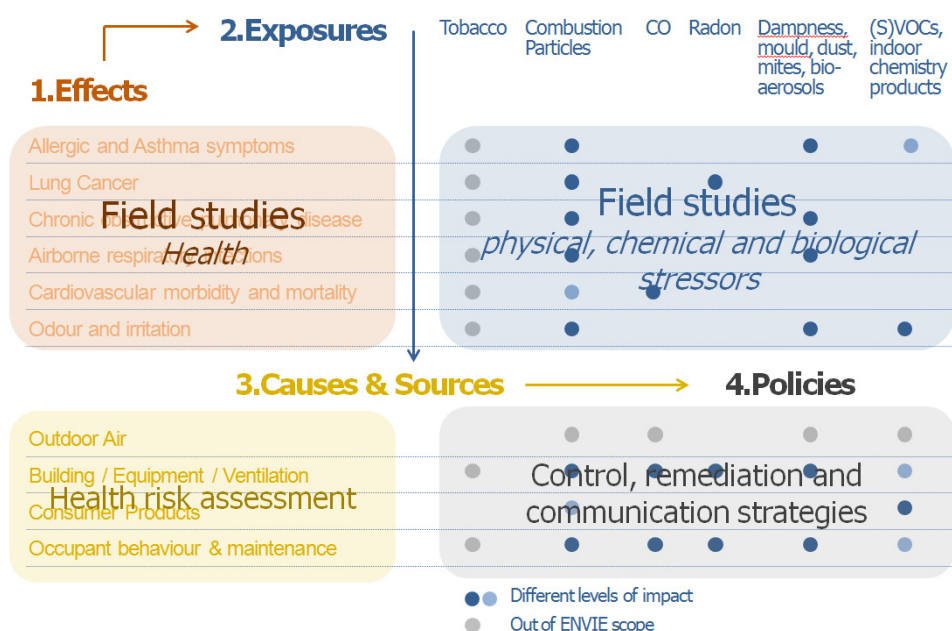


Figure 1. The SINPHONIE approach

These guidelines, which were developed bearing in mind the importance of ensuring the quality of the overall (indoor/outdoor) air in school buildings and the fact that many existing school buildings are quite old and need to be retrofitted to comply with the EU 2020 strategy's energy-performance requirements and to accommodate new educational approaches, are presented in this report. SINPHONIE formulated a guidelines framework for healthy environments within European schools, focusing on background materials, concepts and recommendations that have emerged from:

- The analysis of existing international initiatives on a healthy school environment (as described in Chapter 2 of the present report).
- The specific outcome of SINPHONIE and other related EU-funded projects.

The guidelines for healthy environments within European schools described in this report links, in a coherent and comprehensive way (Figure 2):

- Key drivers for a healthy indoor school environment.
- Health symptoms and problems and their potential stressors.
- Tips for a healthy school environment for specific school spaces.
- Prevention, control, remediation and communication strategies.
- Implementation criteria and recommendations for EU and national policies.



Figure 2. Conceptual framework of the guidelines for healthy environments within European schools

3.1 Key drivers for a healthy indoor environment in school

The indoor environment in a school building is a complex system involving many parameters which have an impact on the health and comfort of the occupants. A school building, like any other building, is a physical construction used, for among other purposes, to regulate or control environmental exposure. Several spaces may be defined within a school building that are used for different purposes (i.e. classrooms, dining halls, science workshops/labs, gyms, locker rooms, outside environment) and with different requirements according to the occupation density, type of ventilation (e.g. mechanical ventilation on/off, natural ventilation, etc.), heating and pollution load. The pollution load in a school building depends to a large extent on the interaction between the building and its outdoor environment, as well as on the way the building is constructed, furnished and used, the type of ventilation system, and the activities of its occupants. Major sources of air contaminants in a school building are:

- Outdoor air pollution due to traffic and urban and industrial activities, and from nearby and underground sources, which enter the school building through the ventilation system or by infiltration (permeability of the building envelope, such as the foundations, roof, walls, doors and windows).
- School building materials and furnishings (e.g. wall and floor coverings, use of paints and glues, insulation materials, etc.).
- The status of the school building construction (e.g. age, damage to walls and ceilings as a result of water infiltration, maintenance of building structure and equipment, etc.).
- Water and soil (e.g. air pollutants coming through the water supply, radon and contaminated soils, etc.).
- The processes that occur within school buildings (e.g. any combustion processes, heating, ventilation and air-conditioning systems, paper processing such as photocopying, etc.) and
- The school building occupants themselves and their activities (e.g. smoking tobacco, use of cleaning products, plants, pets, cooking, etc.).

Typical sources of indoor air pollutants in school buildings are shown in Table 1.

To properly assess and maintain a healthy school environment, it is important to: (a) acquire information about the school building's characteristics and operating conditions (e.g. occupant activities, maintenance routines, etc.; (b) identify, measure and monitor the evolution of the school building's indoor and outdoor pollutant sources and their strength; and (c) investigate the relationship between the pollution stressors (physical, chemical, biological) and the health problems of schoolchildren and staff.

As regards the potential health impact of those pollution sources relevant to the school environment, the influence of climate change should also be considered. The foreseen increase in ambient temperature and that of the heat-island phenomenon in specific urban zones, due to climate change, may induce changes in atmospheric conditions. In turn, these may affect indoor conditions, airflow through windows, and the pollution load in school buildings. Consequently, it is recommended to evaluate the impact of future potential climate changes on the IAQ of a given school environment then integrate the information retrieved on the sources and stressors affecting this school environment, as demonstrated in the SINPHONIE project.

Moreover, the implementation of energy-efficiency requirements in the EU (Energy Performance of Buildings Directive (EPBD), 2010), will result in the gradual movement towards a more energy-efficient building stock in Europe, as regards new and existing

buildings, including school buildings. When coping with school buildings' energy-efficiency requirements, it is recommended that attention should also be paid to preserving good IAQ, to avoid negatively affecting the health, comfort and productivity of the school building's occupants. In this context, passive and low-energy buildings are generally recommended. The challenge is to rationalise and optimise energy expenditure while adequately meeting the health and comfort requirements of school building occupants.

Table 1. Typical sources of indoor air pollutants in school buildings

(Source: US EPA Indoor Air Quality Tools for Schools – Reference Guide)

OUTDOOR SOURCES	BUILDING EQUIPMENT, COMPONENTS & FURNISHINGS	OTHER POTENTIAL INDOOR SOURCES
Outdoor air pollution <ul style="list-style-type: none"> • Pollen, dust, mould spores • Industrial emissions • Vehicle emissions • Outdoor machinery emissions 	HVAC equipment <ul style="list-style-type: none"> • Mould growth in drip pans, ductwork, coils and humidifiers • Improper venting of combustion products • Dust or debris in ductwork 	<ul style="list-style-type: none"> • Science laboratory supplies • Vocational art supplies • Food-preparation areas • Smoking lounges • Cleaning materials/air fresheners • Emissions from rubbish • Pesticides • Odours, PM (particulate matter) and VOCs from paint, caulk, adhesives, varnishes • Occupants with infectious diseases
	Other equipment <ul style="list-style-type: none"> • Emissions from office equipment (volatile organic compounds, ozone) • Emissions from shop, lab and cleaning equipment 	
	Components <ul style="list-style-type: none"> • Mould growth on or in soiled or water-damaged materials • Dry drain traps that allow the passage of sewer gas • Materials containing VOCs (volatile organic compounds), inorganic compounds or damaged asbestos • Materials that produce particles (dust) 	
Nearby sources <ul style="list-style-type: none"> • Loading docks • Odours from rubbish bins • Unsanitary debris or building exhausts near outdoor air intakes 		

Underground sources <ul style="list-style-type: none"> • Radon • Pesticides • Leakage from underground storage tanks 	Furnishings <ul style="list-style-type: none"> • Emissions from new furnishings and floorings • Mould growth on or in soiled or water-damaged furnishings 	<ul style="list-style-type: none"> • Dry-erase markers and similar pens • Insects and other pests • Personal care products • Stored petrol and lawn and garden equipment
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3.2 Health symptoms and problems versus potential stressors

3.2.1 Health symptoms in relation to physical, chemical and biological stressors

Exposure to the wide array of physical, chemical and biological stressors present in the school environment increases the potential for short- and long-term health problems among schoolchildren and staff, and for negative impacts on the quality of school buildings.

The outcome of the SINPHONIE project highlights important aspects of the complex pattern of interrelations between physical, chemical and biological factors, exposure, sources/causes and health impacts on schoolchildren.

Health problems affecting school building occupants range from lower attendance, comfort and performance and increased rates of absenteeism among schoolchildren and staff, to acute health effects (e.g. respiratory irritation), chronic diseases (e.g. asthma and allergies) and symptoms associated with the so-called 'sick building syndrome' (eye irritation, headaches, etc.). Allergic individuals and asthmatics face a higher risk.

The effects of IAQ problems on school building occupants 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; and headaches 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 (e.g. poor lighting, stress, noise, etc.). Due to varying sensitivities among school occupants, IAQ problems may affect a group of people or specific individuals and they may affect people in different ways. Individuals who may be particularly susceptible to the effects of indoor air pollution include, but are not limited to, people with: asthma, allergies, or chemical sensitivities; respiratory diseases; and suppressed immune systems (due to radiation, chemotherapy or disease).

One outcome of the SINPHONIE project indicates that asthma at school may affect 100 000 children in Europe.

As concerns the school building itself, inadequate IAQ could accelerate the deterioration of the building's envelope as a whole, reduce the efficiency of school facilities and

equipment, and increase the potential for school closures or the relocation of occupants within the same building or to other school buildings.

In terms of social impact, IAQ-related problems in the school environment may strain relationships among the school administration, the parents of schoolchildren and the school staff, have a negative impact on community trust, and ultimately even create liability problems.

3.2.2 How to recognise IAQ-related health problems in schools

Diagnosing IAQ-related symptoms in schools can be difficult, given that symptoms such as headaches, fatigue, shortness of breath, sinus congestion, coughing, sneezing, dizziness, nausea and irritation of the eyes, nose, throat and skin may also be caused by other factors (e.g. stress, noise, poor lighting, etc.). Below are some indications that may suggest which symptoms are linked to IAQ problems:

- Symptoms are widespread within a class or school.
- Symptoms disappear when the children or staff leave the school building at the end of the school day or for longer periods of time.
- Onset of symptoms is sudden after certain changes at school (such as the installation of new furniture, painting, or pesticide application).
- Reactions occur indoors but not outdoors.
- Symptoms have been identified by a doctor as being IAQ related.

However, it should be emphasised that it is not safe to assume that a lack of symptoms means that the IAQ in the school is acceptable. Health effects from long-term exposure (such as lung cancer due to radon) may not become evident for many years.

The only objective way to identify whether the observed symptoms or health effects are linked to an IAQ-related problem is to monitor the indicators that are known to relate to the most common health- or building-related IAQ problems in schools (see section 3.3 below). Such monitoring includes:

- A walk-through inspection of the school building environment.
- Measuring the physical, chemical and biological stressors suspected of causing the health problem.
- Associating the outcome of the investigations in steps 1 and 2 to information related to the school building's characteristics (design, building components, furnishings, equipment and climate), occupants' behaviour and potential indoor and outdoor pollutant sources, to be gathered from specific questionnaires, clinical tests and tools.

3.3 Indicators, tools, protocols and guidelines for monitoring IAQ and evaluating health in a school environment

During the last two decades, indicators, tools, protocols and guidelines for monitoring indoor pollution attributed to physical, chemical and biological stressors and for evaluating occupants' health in various indoor environments have been developed progressively by the European Commission, the WHO and some EU Member States.

As regards indoor air pollution due to chemicals, in 2010, the WHO issued health-based guidelines and recommendations for the following indoor-air-related chemicals (air pollutants): benzene, carbon monoxide, formaldehyde, naphthalene, nitrogen dioxide, polycyclic aromatic hydrocarbons (especially benzo[a]pyrene), radon, trichloroethylene and tetrachloroethylene. These chemicals have indoor sources, are known for their health hazards, and are often found in indoor environments, including school buildings, in concentrations causing concern to health.

The WHO guidelines for selected chemicals build on the critical appraisal of the setting and implementation of indoor exposure limits in the EU that was carried out by the European Commission (DG SANCO and DG JRC) in the context of the EU-INDEX project (Kotzias et al., 2005).

Another key aspect of indoor air pollution results from biological stressors. It is caused by hundreds of species of bacteria and fungi, in particular filamentous fungi (mould), which grow indoors when sufficient moisture is available. With reference to endotoxin, recent studies have shown that exposure levels in school classrooms are many times higher than in the home environment. In 2009, the WHO provided a comprehensive review of the scientific evidence on health problems associated with building moisture and biological agents. The review concluded that the most important effects include the increased prevalence of respiratory symptoms, allergies and asthma, as well as perturbation of the immunological system related to various microbiological stressors. Results from SINPHONIE showed multiple associations of selected microbial agents in indoor dust in schools with recent symptoms, past respiratory health symptoms and clinical measurements. This indicates the relevance of microbial agents to the respiratory health of pupils and teachers.

In line with the above-mentioned guidelines and recommendations, the SINPHONIE project used several indicators and put in place tools and protocols for IAQ and health monitoring in European schools, as shown in Tables 2 and 3. Their use is recommended when investigating the complex pattern of interrelations between physical, chemical and biological factors, exposure, sources/causes and health impacts on schoolchildren and staff. More detailed information about the physical, chemical and microbiological stressors most relevant to the indoor air environment in schools in relation to sources, health effects, risk-management options/control measures, standards/guidelines, and the SINPHONIE results for comparison, are presented in Annexes B and C.

A subset of the aforementioned indicators and protocols was adjusted to the objectives of WHO to monitor indoor air pollutants in schools in the WHO region and established in 2011 by the WHO in close collaboration with the European Commission's projects PILOT INDOOR AIR MONIT project (administrative arrangement no. SI2.582843 between DG SANCO and DG JRC) and SINPHONIE. The indicators and protocols to be used to monitor the implementation of time-bound commitments to reduce the health effects of environmental hazards among children, adopted by Member States at the Fifth WHO Ministerial Conference on Environment and Health in 2010, are:

- Mould and dampness
- Ventilation (calculated from CO₂ concentrations).
- Exposure to selected indoor-air pollutants in schools (NO₂ and formaldehyde as core pollutants, and benzene as an optional pollutant).



The mould/dampness indicator requires school inspections, while the indicators concerning ventilation and exposure to selected chemicals in indoor air necessitate air-quality monitoring in schools. Protocols

for IAQ monitoring in schools are described in the WHO-JRC (2011) report. A pilot survey was conducted in 2011–2012 in Albania and Croatia to test the feasibility of the suggested protocols and implementation on a larger scale in the WHO region, which started in 2013.

It should be emphasised that the aforementioned developments took advantage of parallel developments in the context of the European Commission's PILOT INDOOR AIR MONIT project (2010-2012). A harmonisation framework of criteria, protocols and techniques was developed for indoor air monitoring in various indoor settings and for different indoor air monitoring objectives. The resulting coherent and robust indicators, tools and protocols for IAQ and health monitoring of the school environment in Europe and the WHO region countries relied on strong cross-fertilisation and increased synergies between the European Commission (DG SANCO and JRC), the WHO, the 23 European countries involved in the SINPHONIE project, and ongoing IAQ monitoring programmes in Europe, such as the French Observatory on IAQ (OQAI, 2001) and the German Environmental Survey (GerES).

Table 2. SINPHONIE indicators for IAQ monitoring in European schools

Physical and chemical stressors	Micro-biological stressors
<ul style="list-style-type: none"> ➤ Benzene ➤ Trichloroethylene ➤ Tetrachloroethylene ➤ Formaldehyde ➤ Naphthalene ➤ Benzo(a)pyrene ➤ α-pinene ➤ d-limonene ➤ PM_{2.5} ➤ PM₁₀ ➤ NO₂ ➤ Ozone ➤ CO ➤ Radon 	<ul style="list-style-type: none"> ➤ Endotoxin ➤ Specific fungal and bacterial groups <ul style="list-style-type: none"> • <i>Penicillium/Aspergillus</i> group • <i>Cladosporium herbarum</i> • <i>Aspergillus versicolor</i>, • <i>Alternaria alternata</i> • <i>Trichoderma viride</i> • <i>Streptomyces</i> spp. • <i>Mycobacterium</i> spp. ➤ Allergens <ul style="list-style-type: none"> • House-dust mites • Horse, cat and dog allergens

Table 3. SINPHONIE tools and protocols for IAQ and health monitoring of the indoor school environment in the EU

SINPHONIE TOOLS AND PROTOCOLS FOR IAQ AND HEALTH MONITORING OF THE INDOOR SCHOOL ENVIRONMENT IN EU			
Type	Purpose	Actor/entity concerned/involved	Description
<i>Questionnaires</i>	Questionnaires for assessing children's and teachers' respiratory health and possible confounding factors related to their home environment.	Questionnaire for children	To collect information on children's respiratory/allergic symptoms/diseases, self-perceived air quality inside/outside the school, and self-perceived influence of poor air quality on school performance. In the case of kindergartens and elementary schools the questionnaire is filled in by the children's parents.
		Questionnaire for parents	To collect information on respiratory/allergic symptoms/diseases and dietary intake of their children, more common home risk factors (e.g. smoking habits, pet keeping, presence of moulds/dampness, cooking/heating system, gas appliances, cleaning products, etc.) and familiarity with respiratory/allergic diseases. This self-administered questionnaire was designed to investigate lifelong and recent symptoms, housing characteristics, and lifestyles.
		Questionnaire for teachers	To collect information on their respiratory/allergic symptoms/diseases and dietary intake, self-perceived air quality inside/outside the school, and self-perceived influence of poor air quality on school performance, more common home risk factors (e.g. smoking habits, pet

			keeping, presence of moulds/dampness, cooking/heating system, gas appliances, cleaning products, etc.), familiarity with respiratory/allergic diseases, and knowledge/management of school issues related to air quality and to children with asthma.
	Questionnaires for assessing the characteristics of the school building and classrooms.	Questionnaire about the school building	Concerning information on school-building characteristics (e.g. ventilation system), to be completed by the school principal.
		Questionnaire about the school classroom	One questionnaire for each monitored classroom to be completed, if possible with the co-operation of all teachers working in the classroom, concerning the physical characteristics of the classroom, cleaning procedures, furnishings and perception of IAQ.
<i>Attention/concentration test</i>	Test for assessing the attention/concentration capacity of schoolchildren in relation to various factors affecting their indoor school environment.	Children	The test comprises a series of mathematical and logical tests to be completed during the first lesson of the day and repeated during the last lesson of the same day and within a limited time.
<i>Absenteeism tool</i>	Tool for assessing illness-related absenteeism rates of schoolchildren.	Children	Absenteeism is assessed by filling in an attendance report to be completed by a teacher (or other instructed personnel) for each class, in order to record illness-related absence of the children for a defined time period. Respiratory illness was defined according to the health-related questionnaires.
<i>Protocols for clinical tests and measurement of non-invasive</i>	Tests and measurements for evaluating the response of the airway	Children	The clinical tests and measurements of non-invasive biomarkers include: - lung function test (spirometry)

biomarkers	mucosa to different indoor school environments and to assess the existence of allergic sensitisation in schoolchildren.		<ul style="list-style-type: none"> - exhaled nitric oxide (eNO) levels - exhaled carbon oxide (eCO) levels - acoustic rhinometry - nasal lavage - exhaled breath condensate - tear break-up-time test - skin prick tests
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3.4 Guidance on prevention, control, remediation and communication strategies

3.4.1 Guidance on general hygiene and specific IAQ requirements in school buildings

- ❖ General hygiene requirements concern the structure of the entire school building, its location and the recreational area conditions, and the provision of building materials which should be guaranteed throughout the building's life. In addition, there should be no thermal bridges as they can cause dampness and moulds. These hygiene requirements also apply to the school's individual rooms and areas in which regular and appropriate cleaning, ventilation, heating and provision and use of low-emission equipment should also be guaranteed.
- ❖ Specialised equipment, such as copiers and printers, which emit volatile organic compounds and particles during operation, should be housed in separate rooms of the school building with their autonomous ventilation system.
- ❖ Working or teaching in specialised areas within the school building should be carried out with all protective measures in place for pupils and staff (e.g. a sufficient number of appropriately operating and maintained fume cupboards in science workshops and labs; chemistry experiments and the handling of any carcinogenic, suspected carcinogenic, mutagenic or reprotoxic substances should be performed exclusively by specialised and well-trained teaching staff using the required protective equipment such as face masks, protective glasses and gloves, lab coats, etc.). For examples of protective measures in specialised areas see the German GUV 19.16¹.
- ❖ Type, procedures and frequency of cleaning should be tailored to the school areas and materials to be cleaned, with the aim of reducing exposure to chemical and microbiological contaminants and infectious diseases in the indoor school environment (e.g. proper cleaning at least once a day is essential for sanitary areas; the entrance area should be cleaned daily, while it is recommended that other corridors and staircases are cleaned at least every other day, at least three times a week; sports halls and similar areas require daily cleaning; classrooms and table tops have to be wet cleaned daily to reduce the concentration of particulate matter; and cleaning with disinfectant must be undertaken daily in sanitary areas and washrooms).
- ❖ Classrooms should be adequately ventilated. That means that the ventilation rate is health-based and is defined and expressed as litres/second per person and no longer simply as air changes per hour. The equivalence of the latter to l/s per person requires knowing the occupancy density of the school room. Use of mechanical ventilation will be justified on the quality of the outdoor air surrounding a given school area, i.e. when the outdoor air does not fulfil the WHO air-quality guidelines and therefore needs to be filtered into the various school rooms. Where a mechanical ventilation system is installed and in operation, attention must be paid to its regular inspection and maintenance to guarantee that the filtered air is always clean. Natural ventilation must be designed and operated to meet the required ventilation level. This implies a ventilation system that, for instance, in winter may require that CO₂ levels above

¹ German GUV 19.16 (<http://rzlpws50.hbk-bs.de/~vogt/bilder/guv1916.pdf>)

1500 ppm will not be reached. CO₂ alarms in classrooms are used in some EU countries as a practical way of giving warning when CO₂ reaches inappropriate levels in a classroom. This implies that nominal ventilation can only be fully operational during breaks, the duration of which should be planned accordingly. A good ventilation practice could be, at the very least, to ventilate classrooms before the school day starts then again for the duration for each break, in all seasons. During winter, it is recommended that the radiator vents are closed during ventilation to minimise energy loss, preferably by automatic vents with window contact switches. The method of ventilation in the classrooms (natural ventilation, cross ventilation, mechanical ventilation) depends on how airtight the building is, the climatic zone, the season, the quality of the outdoor air and noise levels surrounding the school building, and the reserve capacity of the heating system that should allow for the rapid reheating of the classrooms after ventilation.

3.4.2 Guidance on school building structural requirements

Selection of products and materials for school building construction and renovation work:

- ❖ Construction products and materials used in fixtures and fittings for indoor spaces during school construction or refurbishment should satisfy the health and environmental requirements of the EU Construction Products Regulation No. 305/2011 (CPR, 2011), and should be labelled with EU (preferred option) or national labels. An overview of private and voluntary labelling schemes and guidance on chemical emissions in the EU from building materials and products is given in Table 4 below.
- ❖ Due to increasing requirements for energy efficiency in EU buildings, it has become essential to use low-emission construction products and materials in school buildings. This makes it possible to control indoor air pollution and keep it at levels that minimise the associated risks to the health of schoolchildren and staff while rationalising the use of ventilation to dilute unacceptable levels of indoor air pollutants. This is recommended as part of a holistic approach concerning the design, operation and maintenance of sustainable school buildings in Europe. Significant effort is currently being put into advancing innovations towards sustainable buildings. This aims to: (a) reduce the overall impact of the built environment on human health and the natural environment by ensuring the efficient use of energy, water and other resources; (b) protect the health of occupants and improve employee productivity; and (c) reduce waste, pollution and environmental degradation. Some of the initiatives on sustainable and green buildings in Europe are shown in Table 5.

Table 4. Building materials, product labels and guidance on chemical emissions in EU

<i>Building materials and products labels and guidance on chemical emissions in EU</i>
<ul style="list-style-type: none"> • European Ecolabel (e.g. textile-covered flooring, wooden flooring, mattresses, indoor and outdoor paints and varnishes: Europe)² • EMICODE® (adhesives, sealants, parquet varnishes and other construction products: Germany/Europe)³ • GUT (carpets: Germany/Europe)⁴ • Blue Angel (Germany)⁵ • Nordic Swan (Scandinavia)⁶ • Umweltzeichen (Austria)⁷ • AgBB (Specifications for construction products: Germany)⁸ • M1 (construction products: Finland)⁹ • ANSES (formerly AFSSET) (construction products: France)¹⁰ • CertiPUR (PU foam for furniture industry: Europe)¹¹ • Ü mark (specifications in relation to CE marking: Germany)¹² • Danish Indoor Climate Label¹³ • Swedish 'byggvarudeklaration' (construction products: Sweden)¹⁴ • Natureplus (construction products: Germany/Europe)¹⁵

² European Ecolabel (<http://ec.europa.eu/environment/ecolabel/>)

³ EMICODE® (<http://www.emicode.com/index.php?id=1&L=1>)

⁴ The GUT label (<http://pro-dis.info/86.html?&L=0>)

⁵ Blue Angel (<http://www.blauer-engel.de/en/index.php>)

⁶ Nordic Swan (<http://www.svanen.se/en/Nordic-Ecolabel/>)

⁷ Umweltzeichen (<http://www.umweltzeichen.at/cms/home233/content.html>)

⁸ AgBB (<http://www.umweltbundesamt.de/themen/gesundheit/kommissionen-arbeitsgruppen/ausschuss-zur-gesundheitlichen-bewertung-von>)

⁹ M1

(<http://www.rakennustieto.fi/index/english/emissionclassificationofbuildingmaterials.html>)

¹⁰ ANSES

(http://www.anses.fr/fr/upload/bibliotheque/892980998778406505212938602998/COV_Avis_signe_2009_10.pdf)

¹¹ CertiPUR (<http://www.europur.com/index.php?page=certipur>)

¹² Ü mark (http://www.dibt.de/index_eng.html)

¹³ Danish Indoor Climate Label (<http://www.teknologisk.dk/ydelser/dansk-indeklima-maerkning/dim-omfatter/253.2>)

¹⁴ Swedish 'byggvarudeklaration'

(<http://www.byggvarubedomningen.se/sa/node.asp?node=455>)

¹⁵ Natureplus (<http://www.natureplus.org/>)

Table 5. Initiatives on sustainable and green buildings in EU

<i>Initiatives on sustainable and green buildings in EU</i>
<ul style="list-style-type: none">• BREEAM (promoting and certifying sustainable buildings: United Kingdom)¹⁶• Démarche HQE (promoting and certifying sustainable buildings: France)¹⁷• DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen, promoting and certifying sustainable buildings: Germany)¹⁸• VALIDEO (Voluntary Sustainable Construction certification system: Belgium)¹⁹

- ❖ The choice of floor covering (wood/wood-based products, flexible and ceramic floor coverings) will depend on the intended use of the area and the necessary standard required. For example, ceramic floor coverings should be used anywhere where coverings must prove durable given constant, heavy use and frequent cleaning (e. g. sanitary facilities). Only floor coverings that can be damp wiped should be used following the new construction or renovation of school buildings.
- ❖ Textile floor coverings are not recommended for use in school buildings because of the comparatively high cost of cleaning (in terms of time and money), and also their considerable contribution to the re-suspension of indoor PM.
- ❖ Solvent-free, low-emission floor covering adhesives are preferable for all types of floor coverings (flexible floor coverings, carpets, parquet).
- ❖ Only low-formaldehyde or formaldehyde-free eco-labelled furniture products should be used in school buildings.
- ❖ Before painting and varnishing, a check should be made as to whether the work requires the use of varnishes, or whether emulsion paints could be used instead. Emulsion and latex paints are suitable for mineral subsurfaces (walls and ceilings).
- ❖ Low-pollutant varnishes or wood glazes are the most suitable for protecting the surfaces of non-load-bearing timbers in indoor areas (classrooms, offices). Low-pollutant varnishes to protect the surfaces of wooden components or objects exposed to the weather are also available on the market.
- ❖ Surface-treating agents with a high solvent content should not be used for varnishing parquet. Water-based surface-treating agents (water seals) based on acrylic or polyurethane resin should be used instead.
- ❖ Emulsion paints are suitable for covering large areas of walls, ceilings and façades in school buildings. Only low-emission wall paints should be used in indoor areas of school buildings (e.g. matt emulsion paints, silk gloss and gloss latex paints and silicate emulsion paints).
- ❖ Preservatives included in the contents declaration on cans of water-based paints should be noted, to protect allergy sufferers.

¹⁶ BREEAM (<http://www.breeam.org/>)

¹⁷ Démarche HQE (<http://assohqe.org/hqe/spip.php?rubrique9>)

¹⁸ DGNB (<http://www.dgnb.de/en/>)

¹⁹ VALIDEO (http://www.valideo.org/Public/valideo_menu.php?ID=8641)

3.4.3 Guidance on the indoor climate, ventilation and acoustic requirements for school buildings

- ❖ As far as possible, physically comfortable operative temperatures in school classrooms should be maintained throughout the year according to the season and the external air temperature (between approximately 20°C and 26°C).
- ❖ Walls, floors and ceilings in a school building must be designed in such a way to prevent unpleasant thermal radiation exchange with cold surfaces.
- ❖ The risk of overheating in schools can be reduced if more exposed internal thermal mass is used with night-time cooling/purge ventilation, which helps absorb the heat generated inside classrooms even when the external temperature is higher than the thermal comfort limit.
- ❖ Insulating the school building fabric from outside will help improve the thermal resistance of the school building envelope to prevent external heat gains and maintain existing thermal mass to use night-time cooling.
- ❖ School buildings with a high window-to-wall ratio can be upgraded by using insulated glazing panels and external shading devices to prevent solar and conductive heat gains through windows. Low-E (low-emissivity) coatings on glazing can significantly reduce direct and indirect infra-red radiation, especially where external shading is difficult to provide.
- ❖ Reducing internal heat gains can also be a useful way of providing thermal comfort for schoolchildren. This can be achieved by using energy-efficient light fittings, lighting strategies and electrical equipment.
- ❖ There is significant scope for adaptive thermal comfort in school classrooms at present and it will increase in future. The need to adopt adaptive thermal comfort strategies in school buildings will increase, requiring schoolchildren to wear lighter clothes, and to increase indoor air movement either passively, by using the appropriate window design, or by using fans that help their bodies to dissipate heat quickly during the summer season.
- ❖ Low-energy comfort cooling is recommended for warm climatic zones if passive measures alone make it difficult to achieve thermal comfort. For example, direct/indirect passive down-draught evaporative cooling, earth air tubes, or using phase-change materials in air-handling units to store free night cooling are just some of the low-energy cooling technologies.
- ❖ The acoustic design of the entire school building, customised by department (general classrooms, music rooms, sports facilities, social areas, etc.), should be appropriate in order to achieve optimum working and learning conditions.

3.4.4 Guidance on indoor air pollution source management

The management of indoor air pollutant sources in school buildings includes:

- ❖ Source removal: eliminating pollutant sources or preventing them from entering the school building. Examples include discouraging buses to idle outside school buildings and replacing mouldy materials.
- ❖ Source substitution: replacing pollutant sources. Examples include selecting low-emission materials and products in school buildings.

- ❖ Source encapsulation: placing a barrier around the source so that it releases fewer pollutants into the indoor air in school buildings. Examples include covering pressed wood cabinets with sealed or laminated surfaces or using plastic sheeting to contain contaminants when renovating.
- ❖ Source control outdoors: controlling the quality of the outdoor air entering the indoor school environment by choosing 'pollution-free' zones in which to build schools, or by imposing stricter measures to improve traffic conditions in the close vicinity of school buildings (e.g. within a radius of 1 km).
- ❖ Source control indoors: avoiding excessive use of fragranced products such as cleaning agents and air fresheners at school.

3.4.5 Guidance on exposure control strategies

- ❖ Adjusting the time and location of pollutant exposure. An example of time control is scheduling floor stripping and waxing (with the ventilation system in operation), for example, over the weekend (provided that the school is not used during that period). This allows products to off-gas over the weekend while the school is unoccupied. Location control involves moving the pollutant source away from occupants or even relocating susceptible occupants.
- ❖ Temporarily increasing ventilation coupled with the proper use of the exhaust system while painting or applying pesticides, for example, can be useful in diluting the concentration of noxious fumes in the air.
- ❖ Ensuring adequate health-based ventilation (by natural or mechanical means) according to the HEALTHVENT (Health-based ventilation guidelines) project's ventilation approach (Carrer et al., 2013) is recommended in order to reduce the burden of pollutants of indoor origin and their associated health risks and to maintain good comfort conditions.
- ❖ Filtering particles and gaseous contaminants as air passes through ventilation equipment. In most cases, this type of system should be engineered on a case-by-case basis.
- ❖ Removing point sources of indoor pollutants (through exhaust-fume cupboards and local exhaust fans) to the outside before they disperse. Examples include exhaust systems for restrooms and kitchens, science labs, storage rooms, printing and duplicating rooms, and vocational/industrial areas (such as welding booths and firing kilns).

3.4.6 Guidance on education and communication

Teaching, training and raising the awareness of school occupants (teachers, pupils, other school-related staff) about IAQ issues is essential. This will help to reduce their exposure to several pollutants of concern in the indoor school environment by providing basic information and tips on how to prevent, remove, or control these pollutants during their daily activities at school. Some examples of recent initiatives in Europe are given below.

❖ *SINPHONIE project leaflets and brochures (in 20 European languages)*

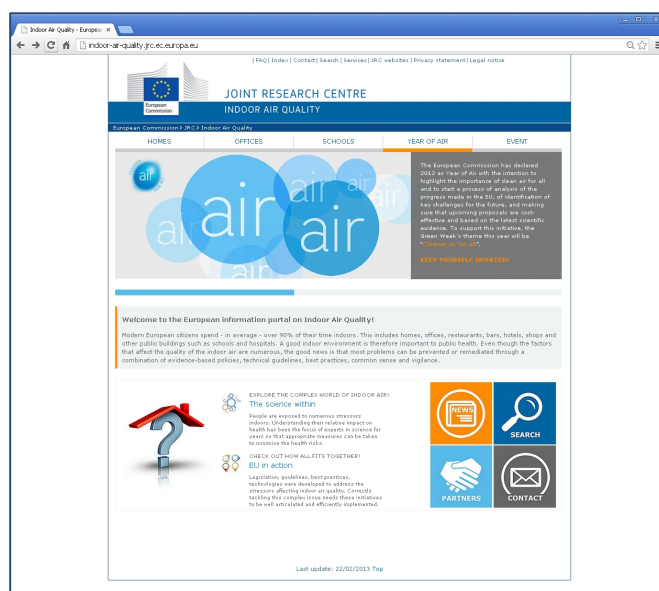
<http://sinphonie.rec.org/>

- “Clean air, healthy children, brighter future”
- “On the road to fitness and health at home and school”
- “Turning research into action”



❖ *EU information portal on IAQ (<http://indoor-air-quality.jrc.ec.europa.eu/Home>)*

This EU information portal contains tips for a healthy school environment by specific departments, as described in Chapter 3.5 of the present report.



❖ *Guidance documents and tools for local authorities and for school and day-care centre managers in France*

- Two **operational guides on IAQ management** were published in 2010 by the French Ministry of Health and the Institute for Public Health Surveillance:
 - A guide on IAQ management in buildings open to the public, aimed at the managers of these establishments and downloadable from the Health

Ministry's website www.sante.gouv.fr in the section "Les dossiers" (Features) – "La santé de A à Z" (Health from A to Z) – letter S – "Santé environnement" (environmental health):

<http://www.sante.gouv.fr/guide-de-gestion-de-la-qualite-de-l-air-interieur-dans-les-etablissements-recevant-du-public.html>

- A guide to diagnosing and treating unexplained collective syndromes, aimed at government departments responsible for managing these events, downloadable from the Institute for Public Health Surveillance website www.invs.sante.fr in the 'Publications' section – 'All publications':

http://www.invs.sante.fr/display/?doc=publications/2010/syndromes_collectifs_inexpliques/index.html

- The pack '*Ecol'air – Un établissement qui respire, c'est bon pour l'avenir - les outils pour une bonne gestion de la qualité de l'air dans les écoles*' ('An institution that breathes is good for the future – Tools for good air quality management in schools'). The pack contains **a series of tools for local authorities and school and day-care centre managers** on how to ensure better air quality in these buildings. It includes:
 - A simplified diagnostic guide to ventilation systems in schools.
 - A guide to purchasing and using cleaning products for better air quality.
 - A set of recommendations on how to take IAQ into account in school construction and renovation projects.
 - A poster: *Ecol'air – Better indoor air quality affects everyone!*
 - Four practical advice sheets.

The documents can be downloaded from the website of the Environment and Energy Management Agency (Agence de l'environnement et de la maîtrise de l'énergie, ADEME): www.ademe.fr 'Publications et documents' section – 'Air intérieur' (indoor air):

<http://www2.ademe.fr/servlet/getDoc?cid=96&m=3&id=79962&p1=00&p2=01&ref=17597>

- **A technical guide on mechanical ventilation systems in schools**, published by CETIAT ([Centre Technique des Industries Aérauliques et Thermiques](http://www.cetiat.fr)), the technical centre for heating, ventilation and air-conditioning (HVAC) systems 'Efficient Ventilation in Schools - Design Guide': conception, installation and maintenance. Downloadable from the website: <http://www.cetiat.fr/>.

3.5 Tips for a healthy school environment by specific school department

Classroom



Furniture

- Low-emission furniture is preferred.
- Only fully dried, emission-sealed, odourless products should be used.
- New furnishings should be stored in a clean, dry, well-ventilated area until VOC off-gassing has diminished.
- The installation of furniture and furnishings should be scheduled during periods of non-occupancy or holidays, well in advance of the beginning of term.

Blackboard

- Classrooms should be dusted, vacuumed with high-efficiency filter or wet-/steam-cleaned at the end of each school day.
- Blackboards should only be cleaned with a wet sponge.
- Cleaning and maintenance work should be done after classes and accompanied by abundant ventilation during and after cleaning; the cleaning agents used should be appropriate for the task and used according to the instructions, with reasonable frequency, and in reasonable quantities.
- Low-emission cleaning products are preferred.
- As far as possible, children should be prevented from running or playing sports in the classrooms.

Ventilation

- If no mechanical ventilation system is installed, natural ventilation should be used (i.e. open windows) as the first option for introducing fresh air; windows should be opened systematically before classes and during lesson breaks.

- If it is not possible, or permitted, to open the windows because of the weather, levels of outdoor air pollution, noise or for safety reasons, mechanical ventilation (with a controlled air supply) should be considered. Ventilation rates should be calculated according to the occupancy of the classrooms, their size and layout. European standards or national codes should be checked to ensure that the ventilation system is adapted to the school's specific situation.
- To prevent the infiltration of outdoor air and radon, it is important to ensure that mechanically ventilated buildings maintain a higher air pressure indoors than outdoors.
- Classrooms should be equipped with CO₂ monitor alarms that signal when the level of CO₂ becomes too high (e.g. over 700ppm) and therefore ventilation is required.
- Ventilation should be regularly adapted to maintain stable and comfortable temperature and humidity levels.
- Ventilation-control technologies, optimisation algorithms and practices that adapt to changing temperature, humidity and pollution levels, need to be further developed.
- Ventilation systems should be inspected regularly and a maintenance plan established that involves professional technical staff.
- Filters must be changed regularly and condensate pans checked to ensure that they are draining adequately.
- Teachers and students should be made aware that appropriate ventilation is essential, that ventilators need to be kept clear of books, papers and other items, and that mechanical ventilation should not be switched off.

Floor

- When a school is built, the designer should consider the use of the room when proposing a flooring type.
- Designers should explicitly consider cleaning and maintenance when specifying flooring finishes.
- The least hazardous flooring products with low emissions should be selected.
- Designers should also specify the use of entry-mat systems of adequate design and size to trap soil, pollutants, and moisture that would otherwise spread throughout the school building (and these should be enforced by school managers).
- Carpets should be cleaned with vacuum cleaners equipped with a HEPA (High Efficiency Particulate Air) filter.
- When it is time to replace carpeting, linoleum, hard wood or tiles are recommended as alternatives.

Science lab



Science tools

- Hazardous scientific equipment should not be left out or unattended.
- Rules for students should be drawn up with respect to the use and maintenance of scientific equipment.
- Students should be closely supervised while performing experiments.
- Safety devices should be installed in each lab, and inspected and maintained regularly.

Ventilation

- A ventilation system should be installed that is appropriate to the use of the room, its size and its occupancy rate.
- The ductwork should ensure that the air is extracted directly to the outside and not recirculated in the overall school ventilation system.
- The ventilation system should be regularly inspected, maintained and cleaned.
- Bottles containing off-gassing substances should not be left open on desks during breaks or for longer than necessary.
- Masks and other protective equipment should be used by students during specific experiments.
- Cookers and bunsen burners should not be left on when not in use.
- CO₂ detectors should be installed and the rate of ventilation increased if an alarm goes off.

Gym



Sports material

- Sports equipment should be dusted regularly during school periods (before or after classes).
- Disinfectants should only be used in exceptional cases for cleaning, such as in increased occurrences of infectious illnesses in the school.
- Cleaning agents should not be used, especially just before a sports class.
- Students should be instructed to wash/disinfect their hands after a sports class.
- Before the start of a new term, the gym should be thoroughly cleaned and disinfected. This should be done early enough to allow time for any off-gassing from the cleaning agents to be removed from the air.

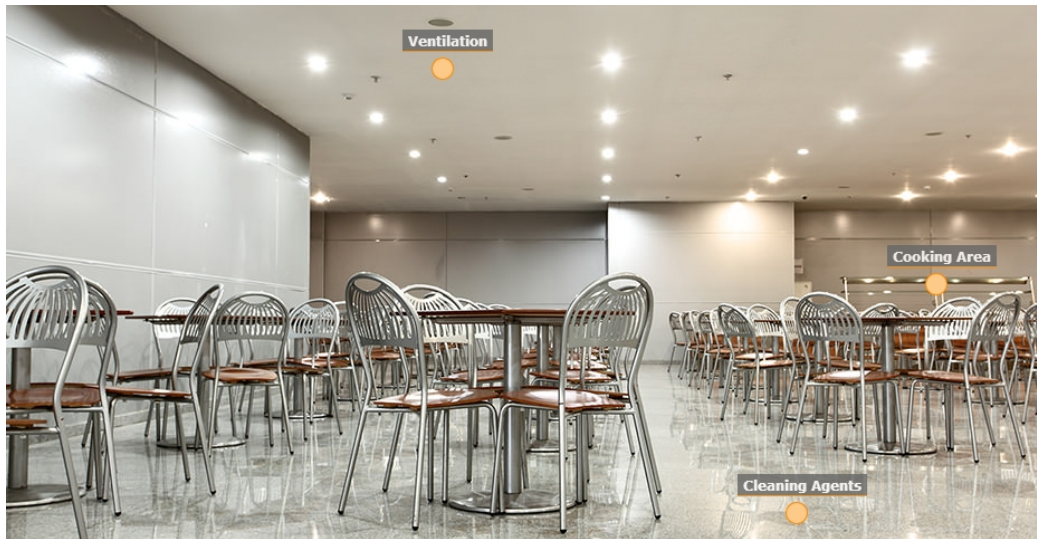
Cleaning agents

- Cleaning and maintenance requirements should be considered when specifying flooring finishes.
- Vacuuming and/or washing with water may not be sufficient in all cases, such as after intense exercise or games.
- Low-emission cleaning products are preferred.
- Cleaning products should be chosen according to the specific surfaces to be cleaned to avoid inappropriate mixing. They should be used according to the instructions on the label.
- Air fresheners should be avoided, or used in moderation.
- When required, stronger cleaning agents can be used, but only after classes and with increased ventilation rates.

Ventilation

- If the school building design permits, the gym should be located next to the school playground or in a green park. Where this is possible, natural ventilation (open windows) should be used as much and as often as possible, especially during sports classes.
- Natural ventilation is less advisable if the windows open on to the street, as particles from traffic and other airborne contaminants that are dangerous to health could enter the school building.
- If natural ventilation cannot be used, the design of the ventilation system, in terms of technology choice and ventilation rate, will depend on the air quality outdoors, the size and capacity of the gym, the seasonal conditions and the schedule of sports classes.
- The HVAC (Heating, Ventilation and Air Conditioning) system should be regularly checked, maintained, cleaned and repaired.
- Vents must not be blocked with furnishings, sports equipment or clothing.
- Air-supply openings must not be taped over to stop draughts. Appropriate adjustments or repairs should be carried out.
- Children should not be allowed to adjust or redirect the ventilation system themselves, as this can affect the air circulation throughout the school.

Dining hall



Cooking area

- Local exhaust fans (equipped with filters) should be installed, and air pressure in the food-preparation area controlled.
- The ductwork should be adapted so that exhaust fumes and odours from the food-preparation area are not fed into the main school ventilation system.
- As far as possible, the food-preparation area (i.e. kitchen) should be isolated from the dining hall.
- As far as possible, exposed food should be protected. Extraction hoods should be installed and regularly cleaned.

Cleaning agents

- Children should be taught to be as attentive as possible to food and liquid spills and to indicate them as quickly as possible.
- In large areas, low-emission cleaning agents should be used, following the instructions on the labels and in appropriate quantities. Rooms should be well ventilated during cleaning. When needed, stronger cleaning agents can be used after classes and with adequate ventilation.
- Resilient flooring should be used as liquid and food spills are likely; cleaning and maintenance needs should be considered explicitly when specifying flooring finishes for dining hall areas.
- Boxes should be disposed of immediately after delivery, and bags and packaging should not be stored. Waste bins should be removed as soon as possible to prevent cockroach infestation.
- Dishes, utensils and surfaces should be cleaned by the end of each day in order to create a habitat that is unfavourable to pests. If pesticides are necessary, spot treatments are preferred, and only after classes.

Ventilation

- The relative air pressure of the dining hall and its ventilation system should be designed so that air flow, humidity control, control of impurities and vapours are taken care of automatically and are appropriate to the specific needs of this area.
- In certain weather conditions, ventilation is ineffective for indoor humidity control as it becomes a source of moisture; mechanical ventilation systems are needed to remove moisture from the incoming outdoor air or from recirculated air.
- The ventilation system used in the dining room should be separate from that used in the classrooms.
- Research should be undertaken regularly to identify new technologies and advanced materials and coatings that prevent mould formation.
- Moisture damage should be treated as soon as it is noticed. In the event of a delay in addressing a moisture problem, it is still prudent to remove the mould.
- Material contaminated with fungus, including mould contaminants in settled dust, should be removed effectively and safely.

Locker rooms and Restrooms



Lockers

- A ventilation system should be installed that is appropriate to the size and location of the restroom and should be regularly inspected and maintained.
- Children should be instructed to close the doors, or an automatic door closing system should be installed to prevent damp air from circulating into other rooms in the school building.
- Water leaks or broken fans should be repaired as quickly as possible.
- Children should be instructed not to leave damp clothes or towels in the lockers.
- The locker room should be cleaned and vacuumed after school hours, and if possible the doors of the lockers should be left open overnight for ventilation.
- If mould appears, it should be removed immediately.
- If disinfectants or biocides are used to remove mould, it should always be done outside school hours. The restroom area should be ventilated and the air extracted outdoors. Chlorine bleach solution should never be mixed with other cleaning solutions or detergents that contain ammonia, as this can result in the production of toxic fumes.

Showers/Water closets

- Cleaning and maintenance should be explicitly considered when specifying flooring finishes for showers and water closets (WCs).
- Children should be instructed on hygiene rules: hands should be washed with soap/disinfectant; children should not drink from the taps (separate drinking water fountains should be installed), etc.
- Showers and WCs should be thoroughly cleaned at the end of each school day.
- Low-emission or plant-derived cleaning products are preferred.

- Cleaning products should be chosen according to the specific surfaces that need to be cleaned to avoid inappropriate mixing. They should be used according to the instructions on the label.
- If necessary, stronger cleaning agents can be used but only after classes and with increased ventilation.
- Hot-water installations should be set at a temperature higher than 50°C (which kills Legionella). Mixers or temperature-control devices should be installed so that children do not scald themselves.
- Water-duct systems should be regularly inspected, maintained and cleaned.
- Taps should be descaled and disinfected every six months.

Outside environment



- If possible, schools should be located away from heavily used streets and busy roads.
- Vehicles should be encouraged not to idle near school buildings, especially near outdoor air intakes.
- Natural ventilation (i.e. opening windows), while still the most advisable (especially in classrooms with high student numbers), should be used with care, taking into consideration the setting and time of day (e.g. close to heavy traffic or when parents are dropping off their children or picking them up while leaving the car engine running); weather conditions (e.g. smog, pollen count, humidity); and seasonal energy-efficiency requirements.
- If possible, ventilation should be achieved through 'street-side' windows.
- If possible, child pick-up areas should not be located close to school doors or windows.
- Mechanical ventilation should not be limited to extracting indoor air pollutants and replacing them with outdoor air, but should also filter and dilute contaminated outdoor air.

4. Criteria for implementing the guidelines for healthy environments within European schools into national legislation

Four criteria are proposed to help national and local authorities to judge which policy measures relating to the implementation of the guidelines for healthy school environments within European schools are most appropriate for their national or local situation.

The criteria are described below:

1) Effectiveness

Effectiveness refers to the estimation of the expected changes in terms of risks or impacts when a policy measure or action is implemented. In other words, it should be possible to indicate the expected effectiveness of a policy measure in terms of risk-reduction capacity. In the case of a school environment, it is important to distinguish between the impact at a general population level and at a sub-population level, such as a vulnerable group (e.g. asthmatics). Although it is strictly not possible to separate them, it is important to know whether a measure is aimed at improving the child's health, or his/her performance at school, or both (since a healthier child will most probably perform better at school, too).

2) Proportionality

Proportionality means acquiring an overview of costs versus benefits in terms of health gain. Awareness of the costs and benefits will help national and local authorities to evaluate measures and better judge their economic feasibility. Greater insight into the costs can be gathered by methods based on cost-benefit analyses, such as those described by Fisk et al. (2011). For this purpose, information about absenteeism due to sickness among teaching staff and pupils is typically used. Technical feasibility also plays a role, although this criterion is expected to be mainly school-building specific rather than country specific. One example would be the mechanical ventilation systems used to improve IAQ in school buildings. Many existing school buildings in Europe have been designed in such a way that subsequent modification of the building structure to accommodate mechanical ventilation systems is not cost-efficient. However, this also depends to a large extent on the ventilation options selected. Some options, such as a controlled exhaust with trickle ventilators, may be more technically feasible and therefore more cost-efficient.

3) Practicability

Practicability refers to assessment of the implementability, enforceability and manageability of the guidelines or recommendations. For example, mandatory monitoring of indoor school environments can be incorporated into national policies, but in the absence of appropriate enforcement strategies and instructions in the event that certain national regulations/standards are violated, it is neither very practical nor efficient.

4) Monitorability

Monitorability refers to the assessment of the direct (e.g. exposure levels, hygiene standards) and indirect (e.g. health symptoms like running nose, cough or longer-

term asthma prevalence rates) impacts of the policy measures that are undertaken, and generation of an overview of the costs of monitoring.

4.1 Relationship between cost of measures and health gains

As specifically mentioned with respect to the proportionality criterion, each measure undertaken involves costs. It is therefore advisable to assess in advance which measures are expected to result in a certain degree of health gain. It is important to bear in mind that health gain does not always go hand in hand with costs. Sometimes the cheapest solutions may result in the greatest health gain. This concept is illustrated in Figure 3 below.

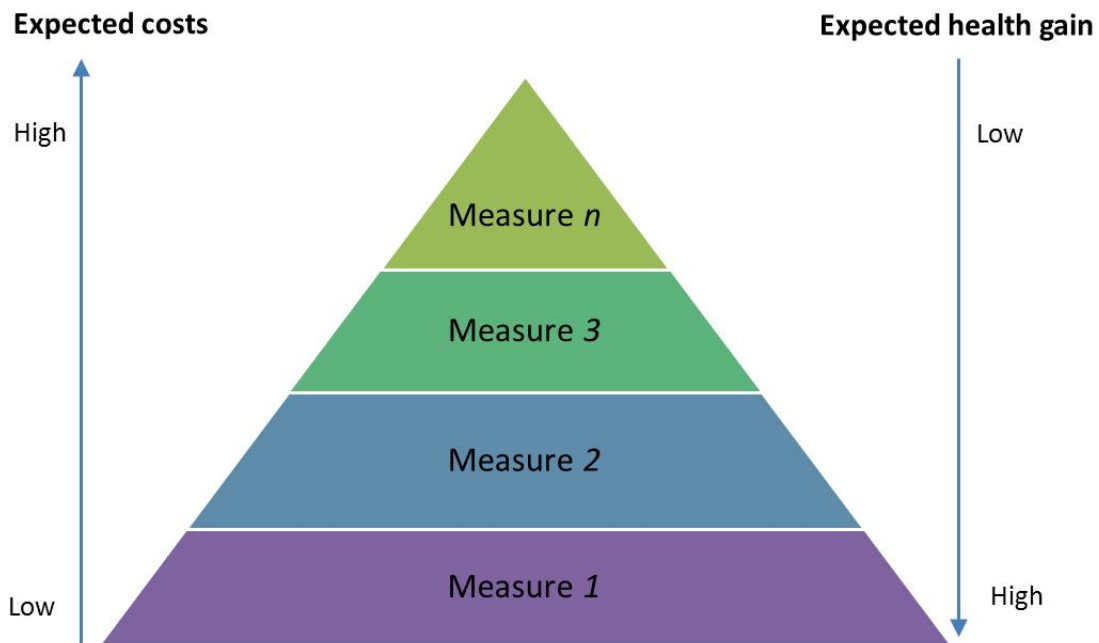


Figure 3. Diagram of the relationship between the expected costs and corresponding health gain of national measures

With reference to the concept presented in Figure 3, the underlying theory is that measure 1 is thought to involve a low-cost solution but leads to a relatively high health gain. If, however, the health gain does not reach the desired level, additional measures should be envisaged and undertaken that will continue to improve health but probably at an increased cost. This figure is a very simplistic theoretical illustration of the relationship between expected costs and corresponding health gains. In reality, this relationship is far more complex because the way in which health gains and costs are evaluated greatly influences their relationship. However, the purpose of this figure is to illustrate the relationship between measures, costs and health gains²⁰. It is also important to bear in mind which party or parties will have to pay/share the costs, such as national or local authorities, schools, parents, etc.

²⁰ More information on methods, and papers on cost-effectiveness related to health protection are available at <http://kosteneffectiviteit-preventie.rivm.nl/algemene-hta-literatuur/richtlijn-kea-onderzoek/>.

The relationship between the health gains of measures and the associated costs can be quantified using appropriate indicators, such as those shown in Table 6.

Table 6. Indicators for the relationship between health gains of measures and associated costs (*Source: US EPA voluntary guidelines for states' development and implementation of a school environmental health programme*)

Type of indicator	Example indicator
Health	<ul style="list-style-type: none"> - Percentage of reduction in the number of visits to school nurses in a year. - Percentage of decline in asthma incidents in a year. - Percentage of reduction of absenteeism. - Percentage decrease in number of reported cases of other respiratory-related illnesses.
Cost	<ul style="list-style-type: none"> - Fewer IAQ-related school staff compensation claims. - Reduced energy costs with well-maintained school buildings and equipment.
Social	<ul style="list-style-type: none"> - Positive feedback from school staff unions and parents' associations. - Positive media coverage. - Increased community trust.

Based on the review of existing national guidelines and recommendations for school environments, measures that can be taken are categorised in the following six groups:

Group 1: Hygienic requirements for cleaning procedures and frequency. It is expected that basic cleaning – with the reasonable use of cleaning products – will contribute most to the avoidance of infectious diseases.

Group 2: Awareness raising. It is thought that indoor hygiene can be greatly improved by structural awareness-raising, such as the education of (new) school staff, cleaning staff, parents and pupils/students. Structural implies here that awareness-raising is not just a one-off event but a mechanism that is routinely repeated over a certain time period. Education about cleaning, avoidance of tobacco smoking, the use of good hygiene practices, the characteristics of certain building products, etc., can positively influence behaviour and lead to improved health. Examples include the Dutch fact sheet 'Indoor Climate in Primary Schools' (<http://www.ggdkennisnet.nl/groep/7/documenten/1189>) and the Belgian educational material available for both primary schools (<http://www.lekkerfris.be>) and high schools (<http://www.airatschool.be>). In the Belgian experience, monitoring has shown improvements to IAQ following use of the educational materials.

Group 3: Good ventilation practice. It is known that good ventilation practice in classrooms (natural ventilation, such as opening windows in class; or mechanical ventilation) will lower CO₂ concentrations in the air, reducing concentrations of indoor-generated pollutants and positively influencing children's learning capacities.

Group 4: Use of products/materials. This measure is strongly related to measure 2. By knowing which building products, furnishings (based on composition) and products such as glues, paints, etc. contain and emit certain substances, knowledge-based decisions can be taken to avoid the use of certain products and to replace them with others that do not contribute to poor IAQ and therefore reduce the associated health risks. The use of low-emission building materials and consumer products, product labelling, and regulations on material emissions would be of considerable value in achieving this goal.

Group 5: Technical interventions, such as designing (new) school buildings or renovating (parts) of existing school buildings, paying special attention to indoor hygiene. This could, for example, involve the installation of mechanical ventilation and its technical specifications (design flow rates, noise nuisance prevention, etc.). Technical measures are generally expected to involve higher costs with health gains that are difficult to quantify. It is possible, however, that the costs of such technical measures are still relatively low compared to the total renovation costs. Thus, in the case of already planned renovations, the implementation of technical measures could still be cost-effective.

Group 6: IAQ monitoring. A shortlist of indicators can be chosen to regularly monitor IAQ in a limited number of randomly selected classrooms. These indicators must be defined on the basis of available IAQ guidelines (e.g. WHO), feasibility of assessment, and reasonable costs.

Table 7 provides examples of qualitative descriptions of possible measures aimed at improving IAQ in schools based on the criteria described in Chapter 4, and on the relationship between costs and health gain described in Section 4.1.1.

Table 7. Examples of qualitative descriptions of implementation criteria for specific measures

Measure		Criteria			
	Description	Effectiveness	Proportionality	Practicability	Monitorability
Hygiene	Cleaning of toilets	For young children higher when effectively compared to older students due to high body contact (hands) with toilets and hand-to-mouth behaviour.	Few additional costs are expected. (Re)education of cleaning staff and school staff.	Visual inspection of toilets is possible. Checklists where cleaning staff write down the time of last cleaning.	This measure can be monitored through a regular (e.g. annual) questionnaire on satisfaction distributed to (the oldest) pupils.
Awareness-raising	Opening of windows	In rooms without mechanical ventilation awareness-raising to maintain low CO ₂ and VOC levels in classrooms by	Educating school staff, parents and students will take time; likewise, changing behaviour will take time. Education materials need to	Awareness-raising programmes could be set up and coordinated via policy measures; they could become voluntary or even mandatory	The number of schools that consult/follow awareness programmes can be monitored.

		frequently opening windows. This increases pupils' concentration spans and learning capacities and is also beneficial for proper brain development.	be developed and set up in the local language. However, it is expected that costs can be limited because the same material can be used over multiple years.	for schools.	
<i>Use of products/ materials</i>	Avoidance of the use of solvent-containing paints and glues	Children will no longer be exposed to harmful solvents. Although the risk-reduction capacity is difficult to quantify, avoidance of frequent exposure to solvents remains beneficial.	Changing products is not expected to involve substantially increased costs.	The school can modify the way in which products are bought or change supplier. A visual inspection by school staff is optional.	n/a
	Avoidance of the use of building materials that are known to emit certain substances linked to asthma ²¹	If certain building materials are no longer used, building occupants will not be exposed to some substances that are linked to asthma. Depending on the alternative building material, a reduction in risk could be achieved.	The costs depend on the price of the alternative building materials. Compared to the societal costs of asthma treatment, the costs of alternative building materials are expected to be relatively low.	National policy could require the use of building materials for the renovation and construction of (new) school buildings that are not linked to asthma, and could enforce this measure via inspection.	In the long term, the effect of the prevalence of asthma could be monitored in buildings with alternative building materials. In the longer term, costs incurred for the monitoring of, e.g. the prevalence of asthma, are difficult to assess, but are still expected to be lower compared to the costs of asthma treatment.
<i>Technical measures</i>	Installation of a CO ₂	Maintaining a good CO ₂ level	The acquisition of a CO ₂ monitor	Practicability depends on how	Installation of a CO ₂ monitor in

²¹ 'Healthy Environments. A Compilation of Substances linked to Asthma' (2012). This recent report (8 August 2012) presents an overview of substances in building materials that may cause or aggravate asthma. This overview is intended to be a valuable resource for identifying asthma triggers and asthmagens and to support the development of measures to minimise their use in building materials and furnishings:
http://transparency.perkinswill.com/assets/whitepapers/NIH_AsthmaReport_2012.pdf.

	monitor in the classroom as an indicator of IAQ (e.g. CO ₂ traffic lights in the Netherlands or indicator lamps in Belgium).	leads to better concentration levels and higher learning capacities among children and is also beneficial for proper brain development.	is a low-cost solution.	it is decided to lower the CO ₂ concentration if the recommended level has been exceeded. The installation of mechanical ventilation is (considerably) more expensive than opening windows.	each classroom allows school staff and students to monitor CO ₂ concentrations. The costs are expected to be low.
<i>Monitoring IAQ</i>	Check compliance with existing IAQ guidelines.	Identification of critical situations (sources of indoor pollution, air stuffiness in class, etc.).	Costs involved in monitoring are still expected to be lower than the costs of treatment for asthma, and the loss of learning ability.	Use of passive samplers and CO ₂ monitor.	Percentage of schools or classrooms in which IAQ guideline levels are exceeded; evolution over the years.

5. Implementation challenges and recommendations

The guidelines framework for healthy environments within European schools presented in this report lays the groundwork for and promotes the development of sustainable school environmental health programmes in Europe. This can be achieved through a preventive and cost-effective approach to achieving a healthy school environment, as compared to a problem-based approach that seeks to solve problems after they have arisen. In this sense, the establishment of sustainable school environmental health programmes is encouraged as a holistic, comprehensive and implementable strategy integrating preventive measures and addressing environmental health issues by fostering well-maintained school buildings and grounds. Such programmes should promote a school environment that is conducive to learning and protects the health of schoolchildren and staff. In addition to improving the physical environment and minimising potential health risks, sustainable school environmental health programmes in Europe should also help to coordinate efforts at national and local authority levels to make healthy, safe and cost-effective choices that address each school's environmental health priorities. Some of the benefits include: improvements in schoolchildren's health; lower rates of absenteeism among children and teachers; stronger academic performance among pupils and greater participation in the classroom; greater teacher retention and job satisfaction; and cost savings through energy and water conservation and efficiency, and improved facility maintenance.

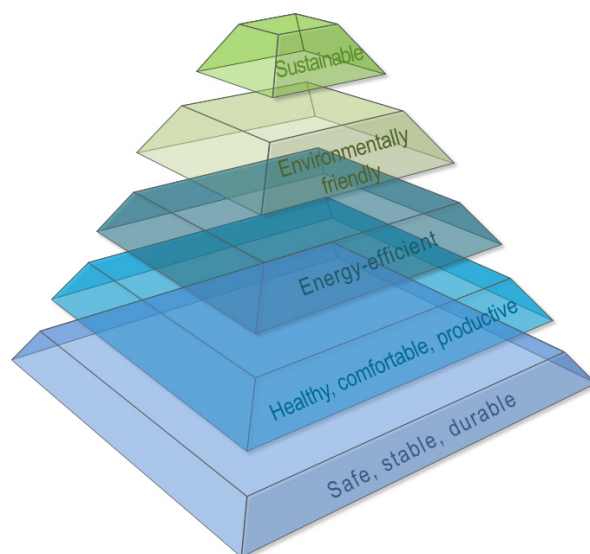


Figure 4. The holistic concept of an “Efficient Building”

An important prerequisite of a sustainable school environmental health programme is the design of sustainable school buildings harmonising advances in architecture and engineering with climatic and regional/local cultural values, as well as with the latest advances in decoupling heating/cooling functions and ventilation. Ventilation should no longer be seen as a panacea but as a solution to keeping the exposure to physical, chemical and biological stressors affecting the indoor school environment within safe levels. Therefore, every effort is advised to avoid outdoor air pollution in the school building area and to keep pollutants emitted or generated inside the building at low levels. For example, excess CO₂ emissions like those identified in the SINPHONIE survey due to inappropriate building design, construction, operation and maintenance and the

use of materials and products in classrooms and buildings, clearly represent one of the implementation challenges ahead. Similarly, levels of suspended particulate matter must be reduced and existing school buildings retrofitted to meet current energy efficiency requirements and standards.

In terms of ventilation, natural methods can no longer be recommended to achieve acceptable IAQ in school buildings. Thus, a paradigm shift towards favouring the practical implementation of the recently developed health-based ventilation guidelines, in the context of the EU-funded HEALTHVENT project (2010-2012) (Carrer et al., 2013), might prove crucial for developing sustainable healthy school environments in Europe. Within such programmes, technically adequate solutions and informed interventions based on state-of-the-art scientific evidence and technological capabilities should be sponsored, coordinated and carried out by relevant bodies at both national and local levels.

Sustainable school environmental health programmes in Europe may:

- *Promote initiatives*, including legislative initiatives, to regulate school buildings in terms of design, construction, materials used, cleaning and building maintenance procedures, as well as to enforce a ban on tobacco smoke, allergen avoidance and health-based ventilation at school.
- *Promote awareness-raising campaigns and training* on a healthy school environment aimed at school children and their families, school staff, professionals, policy-makers and the general public.
- *Promote research and innovation* to develop sustainable measures aimed at improving IAQ in the school environment and achieving associated public health gains through cost-effective and state-of-the-art scientific and technological approaches related to the built environment.

The following are recommended as a non-exhaustive list of actions, initiatives and developments that may be undertaken to help obtaining sustainable healthy school environments at national and local levels within a European perspective and dimension:

- ❖ Developing and implementing a tier-based tool kit for a healthy school environment in the EU (indicators, standardised questionnaires, tools, protocols and clinical tests for IAQ monitoring, the auditing of school buildings, assessing health in the school environment, and quantifying the health gains of measures against associated costs). In addition, requirements should be laid down for the periodical monitoring, auditing and assessment of IAQ and health-related parameters in schools in accordance with the PILOT INDOOR AIR MONIT harmonisation framework and the SINPHONIE standardised methods and tools.
- ❖ Establishing a European medical surveillance system for screening the health of schoolchildren and staff, including guidance on asthma management. Such a system may build on updating the SINPHONIE database by aggregating IAQ monitoring and health data from any future campaigns in European schools and making them available via the DG ENV's initiative on IPCheM (Information Platform for Chemical Monitoring) which is supported by DG JRC (<http://ies.jrc.ec.europa.eu/index.php?page=80>).

- ❖ Providing guidance on implementing a national programme for a sustainable school environment in European countries: (a) based on state-of-the-art construction technologies and IAQ strategies that promote the source control of construction products and materials, and the decoupling of heating/cooling functions in European schools according to the health-based ventilation approach developed by the EU-funded HEALTHVENT project; (b) giving due consideration to geographical, climate and cultural peculiarities and specificities across EU Member States; and (c) enabling the customising and adapting of existing national regulations, policies, guidance and economic capabilities in a resource-efficient way.
- ❖ Providing guidance on school environmental management that considers the health and safety of schoolchildren and staff in all practices related to the design, construction, renovation, operation and maintenance of school buildings and grounds, and using resources in a sustainable way (water, energy, educational materials, cleaning products and procedures, etc.).
- ❖ Setting up an EU-wide inventory of best school practices on IAQ and children's health in Europe.
- ❖ Developing and evaluating cost-effective mitigation measures for schools where problems have been identified, which could benefit from the outcome of the SINPHONIE survey and the experiences of existing national monitoring networks on IAQ and health in schools in European countries.
- ❖ Promoting the adequate management of outdoor air pollution (due to traffic and urban and industrial activities) and other sources near to or underneath the school building to meet the target values required by the relevant EU legislation and in line with the WHO guidelines and recommendations.
- ❖ Banning environmental tobacco smoke and requiring the use of low-emission and EU-labelled materials and products throughout the entire European school environment.
- ❖ Implementing adequate radon-prevention and mitigation strategies benefiting from the recommendations of the EU-funded RADPAR project (2009-2011) (<http://web.jrc.ec.europa.eu/radpar/documents.cfm>).
- ❖ Implementing measures to prevent dampness and mould in school buildings and reduce exposure to allergen sources, taking into consideration the related WHO guidelines and recommendations.
- ❖ Providing guidance on effective procedures for the cleaning and maintenance of the school building envelope, heating and ventilation systems and other equipment.
- ❖ Giving appropriate training to children, their parents and teachers on IAQ and health issues, and to school staff responsible for the management, maintenance and cleaning of school buildings.

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WHO-JRC (2011). Report on methods for monitoring indoor air quality in schools.
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7. ANNEXES

ANNEX A - Overview of information on policy initiatives (regulations, laws, guidelines, programmes) in European countries on healthy school environments

EU Member State	National policy measures (regulations, laws, guidelines, programmes)				
	Type	General description	Specification (parameter)	Stakeholder involvement/audience	Reference/ information source
<i>Albania</i>	No guidelines	-	-	-	-
<i>Austria</i>	Guidelines on hygiene requirements in schools	General guidelines describing hygiene measures in schools.	Contains recommendations on cleaning and personal hygiene, food hygiene, etc. A chapter on IAQ in schools is foreseen to be included in future updates.	School staff	http://www.bmukk.gv.at/schulen/unterricht/hygieneplan.xml
	Guidelines on indoor air in homes	Guidelines on the assessment of indoor air in homes. These guidelines also apply to schools.	Contains recommendations on the assessment of chemical and biological agents and requirements for ventilation (fungi, formaldehyde, CO ₂ , toluene, styrene, tetrachloroethylene, total VOCs) and describes health-based limit values.	-	http://www.innenraumanalytik.at/richtwerte.html
	German guidelines for indoor-air hygiene in school buildings	Detailed German guidelines for indoor health in school buildings; also frequently used in Austria.	See Germany below for a detailed description.	-	www.umweltdaten.de/publikationen/fpdf-l/3689.pdf
<i>Belgium</i>	Flemish regulations and	Guidelines and recommendations for a safe and	Contains requirements on temperature, humidity,	-	http://www.lekkerfris.be/

	decisions related to indoor climate (ARAB, KB (12 August 1993), KB (27 March 1998, 3 May 1999, 11 March 2002 and 17 July 2002), -Decision Flemish Government (8 December 2006, 11 June 2004, 19 November 2010 and 1 June 1985)	clean indoor environment, including the Flemish Indoor Environment Decree on IAQ.	ventilation, heating systems, the use and storage of cleaning agents, and IAQ in terms of guidance and intervention values for chemical, physical and biological agents. Belgium also provides educational programmes for primary and secondary schools, focused on education on classroom ventilation by opening windows. Its effectiveness has been proved by measurements of IAQ in the participating schools.		www.airatschool.be
<i>Cyprus</i>	No guidelines	-	-	-	-
<i>Czech Republic</i>	Laws on the protection and promotion of public health regarding the school environment (directed at public buildings, apart from flats (Edict Ministry of Health CR No. 6/2003 Ld. and Edict Ministry of Health CR No.410/2005 Ld.).	These laws describe hygiene requirements for the indoor environments in general (CR No. 6/2003 Ld.) and for areas designed as educational facilities for schoolchildren and young people (No.410/2005 Ld.).	Contains requirements on chemical, physical and biological agents in the indoor environment of habitable spaces (CR No. 6/2003 Ld.), and on ventilation, insulation, lighting, furniture, cleaning, etc. (No.410/2005 Ld.).	-	-
<i>Finland</i>	General	Binding recommendations on		-	-

	recommendations and guidelines on various IAQ aspects in all buildings	<p>the indoor climate and ventilation of buildings (Rakennusten sisäilmasto ja ilmanvaihto. Määräykset ja ohjeet (2012)).</p> <p>Recommendations on housing health (Asumisterveysopas Sosiaali- ja terveystieteiden ministeriö).</p> <p>Guidance on dampness and mould problems in school buildings. (Koulurakennusten kosteus- ja homevauriot. Opas ongelmien selvittämiseen (in Finnish)).</p>	Contains recommendations on physical conditions, such as temperature, noise and lighting, levels of chemical compounds and microbes (acceptable values given). The guidance refers to solving humidity problems.		
France	Law on mandatory IAQ monitoring in schools (décret nr. 2011-1728) and law providing more details about monitoring (décret 2012-14).	Both laws prescribe mandatory indoor-air monitoring strategies in primary and secondary schools and day-care centres. Benzene, formaldehyde and air stuffiness are the three targeted indicators. In addition, a ventilation audit is carried out.	All primary schools and day-care centres should perform IAQ monitoring before January 2018. This monitoring should then be repeated every seven years, except if guideline values are exceeded for the targeted indicators. In that case, measures should be repeated within two years.	Ministries, municipalities, schools, accredited companies	http://www.legifrance.gouv.fr/
	Decision on the execution of the laws on IAQ in schools	The decision describes the conditions for IAQ assessment and ventilation inspection.	Measurements and ventilation audit should be done by accredited bodies and laboratories. Accreditation will	Ministries, municipalities, schools, accredited companies	http://www.cofrac.fr/

	(DEVP1200916A).		be given by the Comité français d'accréditation (COFRAC).		
<i>Germany</i>	Guidelines for indoor-air hygiene in school buildings (2008)	Detailed guidance describing measures to be taken to create a healthy indoor climate in schools.	The guidelines contain detailed recommendations on: a) hygiene requirements in schools, including cleaning and ventilation, and minor building works and renovations; b) indoor pollutants and related health effects (chemical, physical and biological agents); c) building requirements, including certain building materials, furniture and acoustic requirements; d) procedures on how to deal with indoor problem cases; and e) overview of existing renovation/remediation guidelines.	Teachers, pupils, parents, school administrators, education authorities, planning departments, departments of health and environment, professional groups involved in planning, building, renovating or modernising school buildings	www.umweltdaten.de/publikationen/fpdf-l/4113.pdf
<i>Greece</i>	There are no specific regulations concerning IAQ or ventilation	Greece has two regulations concerning energy efficiency in buildings that take ventilation into consideration. Both regulations have energy as their primary concern. This may affect IAQ in school buildings (Greek Law 3661/2008 (KENAK, Ap. Φύλλου 407) and Technical Guides of the Technical Chamber of Greece (TOTE)).	Recommendations on the energy performance of buildings (calculation of the energy consumption of buildings, sets the minimum energy performance requirements and prescribes the issue of an energy performance certificate, the inspection of boilers and air-conditioning systems and the implementation of a national body of energy inspectors, in compliance with European	The regulations are mainly directed towards construction engineers and the inspectors issuing the energy performance certificates. Other stakeholders include: professional groups involved in planning, building or renovating school buildings and the Ministries for Environment, Energy &	http://www.epbd-ca.eu/ http://kenakteetdk.files.wordpress.com (in Greek) http://portal.tee.gr/portal/page/portal/tptee/totee/FEK%20407-B-2010%20-%20KENAK.pdf

			<p>Directive 2002/91/EC), thermo-physical characteristics of building structure materials and inspection of heat-insulation efficiency.</p> <p>Recommendations for ventilation in residential buildings (the application of natural ventilation is considered according to TOTE) and tertiary buildings with mechanical ventilation, ventilation according to the maximum number of people expected and the minimum volume of air per person to meet a minimum of fresh air.</p> <p>KENAK proposes air-change-rate regulations according to type of indoor use but does not include schools. Ventilation rate is calculated through a standard formula.</p>	Climate Change and for Health, Education and Occupation.	
<i>Hungary</i>	No guidelines specifically directed at IAQ. Standards exist for temperature regulation.	The standard contains a prescription for temperature in primary school buildings.	It contains a recommendation for the use of natural ventilation except for spaces where mass meetings are held. Here, a steady flow of ventilation should be produced without creating too much noise or draughts.	-	-
<i>Italy</i>	Gazzetta Ufficiale	Guidelines on hygiene measures	This contains recommendations	Various ministries, school	-

	Nr. 252. Guidelines for school-based prevention of risk factors for indoor allergies and asthma (2010)	in schools, including recommendations on building construction and maintenance.	on food safety, the design/construction and management of buildings, standard/values guidelines for indoor-air pollutants, remediation/renovation of buildings (removal of sources), hygiene (cleaning), air-conditioning (controls, maintenance), prevention of smoking/passive smoking, education children/family/school staff and promotion of healthy lifestyles.	staff, students and families	
<i>Lithuania</i>	Hygiene standard (HN21:2011)	The standard prescribes that school buildings must be designed and installed with heating, ventilation and (or) air-conditioning systems, supporting and regulating micro-climate and air-quality parameters.	This contains recommendations on temperature: the average temperature in classrooms must be 18 to 20°C; humidity: air humidity in school buildings must be 35 to 60%; ventilation: each classroom and training room must ensure natural ventilation by opening windows. Classrooms and training rooms not equipped with a mechanical ventilation system must be ventilated by opening windows after each lesson. Separate ventilation systems must be installed in classrooms, training rooms, workshops, sports halls, shops, food preparation rooms, toilets	-	-

			and showers. CO ₂ limits: the limit of average CO ₂ concentrations in classrooms during teaching hours is 1500 ppm; the limit for short-term concentrations is 5000 ppm.		
	Standard limit values of air pollutants in schools (HN34:2007)	This standard describes limit values for a series of air pollutants.	It contains limit values for levels of chemical and physical agents, among them NO ₂ , ozone, CO, formaldehyde, benzene, trichloroethylene, tetrachloroethylene, PM ₁₀ , PM _{2.5} . Air pollution tests are performed in schools only if the competent authority receives a complaint.	-	-
<i>Malta</i>	Waste Reduction Guidelines for Schools 2011	The aim of these guidelines is to offer teachers and students information on launching a waste-reduction campaign at their school.	This contains recommendations for the reduction of paper and other organic material. It also provides guidance for purchasing stationery and composting waste.	School staff and students	http://www.ekoskola.org.mt/uploads/2011/11/Printable-Version-of-Waste-reduction-Guidelines-for-a-Whole-School-Approach.pdf
<i>The Netherlands</i>	Guidelines and recommendations on a safe indoor environment	The guidelines describe hygiene measures and school building and planning.	It contains guidance values for ventilation (main indicator for overall air quality), acoustics, lighting, temperature, cleaning activities and remediation (asbestos). Also, guidance is provided for building new schools with a healthy indoor environment.	School staff	http://www.scsb.nl/images/stories/modellen/naslagwerk_definitief_binnenmilieu.pdf http://www.agentschap.nl.nl/content/brochure-eeen-nieuwe-frisse-school

					http://www.rivm.nl/bibliotheek/rapporten/609021044.pdf Advices for a healthy indoor environment for newly build schools Datasheets for improving of the ventilation in primary schools Directive of the Municipal Health Service on environmental medicine
<i>Portugal</i>	<p>Mandatory Portuguese regulation on IAQ and technical note providing more details about monitoring. Since January 2009, SCE has been mandatory for all buildings: new buildings, major</p>	<p>The regulation describes the conditions for IAQ assessment and ventilation inspection.</p> <ul style="list-style-type: none"> • Decree-Law no. 78/2006. (2006). National System for the Energy and IAQ Certification of Buildings (in Portuguese: Sistema Nacional de Certificação Energética e da Qualidade do Ar Interior nos Edifícios (SCE)). 	<p>This contains requirements for CO₂, PM₁₀, CO, HCOH, O₃, TVOC, radon, ventilation rate, bacteria, fungi and Legionella, and specifies the respective maximum concentrations.</p> <p>A measurements and ventilation audit should be done by accredited bodies and laboratories.</p>	<p>Municipalities, schools, certified labs and companies</p>	http://dre.pt/pdf1sdip/2006/04/067A00/24162468.pdf http://dre.pt/pdf1sdip/2006/04/067A00/24682513.PDF http://dre.pt/pdf1sdip/2006/04/067A00/24112415.PDF

	renovations of existing buildings, public buildings and all buildings being sold or rented.	<ul style="list-style-type: none"> • Decree-Law no. 79/2006. (2006). Regulation for energy and HVAC systems in buildings (in Portuguese: Regulamento dos Sistemas Energéticos de Climatização em Edifícios-RSECE). • Decree-Law no. 80/2006. (2006). Regulation for the characteristics of the thermal behaviour of buildings (in Portuguese: Regulamento das Características de Comportamento Térmico dos Edifícios-RCCTE). 			<u>Note</u> : Portugal is the only EU country which has made most progress in integrating IAQ control measures into energy-efficiency audits in buildings.
<i>Romania</i>	Guidelines on indoor air quality (Act No. 1955/1995)	The guidelines describe hygiene requirements as part of a school hygiene-regulation programme.	It contains recommendations on aspects such as sewage treatment, food requirements (intake of calories), heating requirements, lighting, ventilation, room conditions (temperature and humidity), norms for physical activity, (sanitary) cleaning requirements and furniture requirements.	County and local public health department, school Inspectorate/school staff	http://80.96.57.20/fisiere/Ordin_1955.pdf
<i>Serbia</i>	No guidelines	-	-	-	-
<i>Slovakia</i>	Laws on protection,	The policy measures prescribe requirements for micro-climate	This contains legal requirements and recommendations on	State administration authorities, communities,	http://jaspi.justice.gov.sk/jaspiw1/htm_zak/ja

	promotion and development of public health regarding indoor environment and indoor-air quality in public buildings (Act. No. 355/2007 and Decree No. 259/2008)	conditions, heating and ventilation, lighting and IAQ in public buildings, including schools.	hydrothermal micro-climate (temperature and humidity), heating, ventilation, lighting and cleaning. Air quality is covered by Decree No. 259/2008 providing requirements for chemical and physical agents, including odour (CO, PM ₁₀ , NO ₂ , O ₃ , SO ₂ , HCHO, NH ₃ , C ₇ H ₈ , C ₄ H ₄ (CH ₃) ₂ , C ₈ H ₈ , C ₂ Cl ₄ , CS ₂ , H ₂ S and asbestos).	other legal and physical persons: entrepreneurs, designers, school-building managers and users	spiw_mini_zak_vyber_h11.asp?clear=N http://www.zbierka.sk
	Decree of the Ministry of Health No. 259/2008 Coll. about requirements for the indoor environment of buildings	The policy describes specific mandatory requirements for the indoor environment, including educational facilities for children, schoolchildren and young people.	It contains target values for IAQ/indoor-air pollution: limit values for chemical, microbiological and biological indoor pollution and particulate matter/indoor climate requirements, requirements for heating, ventilation, insulation, lighting and air-conditioning. The presence of visible mould in the indoor environment is forbidden.	State administration authorities, communities, other legal and physical persons: entrepreneurs, designers, school-building managers and users	http://www.zbierka.sk
	Decree of the Ministry of Health No. 257/2007 Coll.	The policy describes specific mandatory requirements related to children and young people's health protection in facilities for children and the young (day-care centres, schools, etc.).	It contains regulations on the design of facilities for children and the young, e.g. number of m ² /child in rooms in day-care centres, in classrooms in primary and secondary schools according to their specialisation, number of	State administration authorities, communities, other legal and physical persons: entrepreneurs, designers, school-building managers and users.	http://www.zbierka.sk

			hygienic facilities, heating and ventilation requirements, and obligations of the school manager to establish a plan for cleaning and disinfection practices and their frequency, and ventilation practices (natural). Public health authorities in Slovakia supervise the fulfilment of the regulations of this policy and commonly binding legal regulations.		
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ANNEX B - *Physical and chemical stressors relevant to the indoor school environment in relation to sources, health effects, risk-management options/control measures, standards/guidelines/SINPHONIE results for comparison*

Stressor	Description	Sources	Health effects	Risk-management options and control measures	Standards/guidelines/ SINPHONIE results for comparison
INDOOR-AIR-RELATED PHYSICAL AND CHEMICAL STRESSORS					
Particulate matter (PM_{2.5} and PM₁₀)	<p>Airborne particulate matter is a composite of hundreds of different substances that exist as particles which are extraordinarily heterogeneous in terms of chemistry and size, with a high degree of spatial and temporal variability.</p> <p>An important component of fine particulate matter (PM_{2.5}) is soot. Soot</p>	<p>Indoor particulate matter concentrations depend on outdoor and indoor sources of PM. Outdoor combustion particles arise from industrial smokestack emissions, road vehicle exhausts (diesel/gasoline), non-road vehicles (e.g. marine, construction, agricultural and locomotive),</p>	<p>Epidemiological studies suggest that exposure to PM air pollution is associated with both short- and long-term health effects in humans. In particular, PM has been related to an increased risk of morbidity and mortality from cardiovascular diseases, lung disease, asthma, and other respiratory problems.</p> <p>Sub-populations, such as children, the elderly and people with respiratory diseases</p>	<ul style="list-style-type: none"> ❖ Minimise idling by transportation vehicles in the vicinity of school buildings. ❖ Use effective technologies to reduce traffic-related PM, such as filters and catalysts on transportation vehicles. ❖ Carefully consider potential PM sources (traffic and industry) in the surroundings of a new school construction area. ❖ Recommend putting in place health-based ventilation guidelines (HEALTHVENT project) to control exposure to NO₂ from indoor and outdoor 	<p>There are no standards for PM_{2.5} and PM₁₀ specifically for the school indoor air environment in the EU.</p> <p>The WHO 2005 ambient air guidelines for PM_{2.5} (25 µg/m³ as a 24-hour average, and 10 µg/m³ as an annual average to protect from short-term and</p>

	<p>is a component of diesel exhaust and is less than 2.5 microns in diameter.</p>	<p>heating exhausts (from coal or wood), forest fires, and other open fires or incineration (e.g. garden waste and burning rubbish).</p> <p>The extent to which these outdoor-sourced particles affect a school building's indoor air depends on the building's location, how close it is to the outdoor sources, the main wind direction relative to the sources, the type of ventilation system in use, the proportion of outdoor air in the indoor air mixture, and the location of the air intakes.</p> <p>Indoor combustion particulate sources include heating</p>	<p>(e.g. chronic obstructive pulmonary disease, acute bronchitis, asthma, pneumonia), are at increased risk of health effects from PM exposure.</p> <p>Children are especially sensitive to air pollution because they breathe 50 % more air per kg of body weight than adults.</p> <p>PM_{2.5} poses the greatest health risk and can aggravate existing respiratory conditions, such as asthma and bronchitis. It has been directly associated with increased hospital admissions and emergency room visits for heart and lung disease, decreased lung function, and premature death.</p> <p>Short-term exposure may cause shortness of breath, eye and lung</p>	<p>sources in school buildings.</p>	<p>long-term effects respectively) and PM₁₀ (50 µg/m³ as a 24-hour average and 20 µg/m³ as an annual average) are recommended for the indoor air in school environments.</p> <p>These guideline values may have to be reconsidered in the future in the light of recent evidence (Kephalopoulos et al., 2012), which shows some indications that indoor-generated particles may be more bioactive than ambient</p>
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		appliances, dry-process photocopying machines, cooking appliances and tobacco smoke.	irritation, nausea, light-headedness, and possible allergy aggravations.		<p>particles, often related to the presence of endotoxins and other pro-inflammatory components in particles of indoor origin.</p> <p><u>SINPHONIE schools:</u></p> <p>Note that SINPHONIE focused on teaching-hour average PM_{2.5} concentrations, instead of 24-hour averages, since children are only present during teaching hours and both levels may differ by 50 %.</p> <p>Overall, only 40 % of the schoolchildren were exposed</p>
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					to less than 10 $\mu\text{g}/\text{m}^3$, 47 % between 10 and 25 $\mu\text{g}/\text{m}^3$; and 13 % to more than 25 $\mu\text{g}/\text{m}^3$, thus presenting a risk for long-term effects on cardio-vascular-respiratory function and lung cancer mortality.
Benzene	<p>Benzene is a colourless liquid at room temperature and ambient pressure. It is volatile because of a low boiling point and a high vapour pressure, and highly flammable with a characteristic aromatic odour.</p> <p>Benzene is used as an industrial solvent in a wide variety of</p>	<p>Benzene in indoor air comes from outdoor air (exhaust fumes from mobile sources) and from indoor sources such as combustion (heating, cooking, incense burning, smoking, etc.), attached garages, building materials, vinyl, rubber and PVC floorings, nylon carpets,</p>	<p>Benzene causes central nervous system damage after acute exposure.</p> <p>Chronic benzene exposure may result in bone marrow depression.</p> <p>The major health risk associated with low-level exposure to benzene is leukaemia and the strongest link in humans is with acute non-lymphocytic leukaemia (ANLL). The</p>	<ul style="list-style-type: none"> ❖ Lower the permissible benzene content in any material and consumer product used in school buildings. ❖ Avoid building garages which are attached to schools. ❖ Ensure regular maintenance/inspection of all combustion devices used in school buildings. ❖ Smoking ban should be applied to all spaces in school buildings in EU Member States. ❖ It is recommended to put in place 	<p>Benzene is classified by the International Agency for Research on Cancer (IARC) as a known human carcinogen, hence no safe level of exposure can be recommended and its indoor-air</p>

	<p>applications, such as in paints, varnishes, lacquer, thinners and petrol (1 to 4 %). It can also be used as a raw material (chemical intermediate) in the synthesis of styrene, phenol, cyclohexane, aniline, alkyl benzenes in the manufacture of various plastics, resins and detergents, or for the syntheses of pesticides and pharmaceuticals. It can also be found as an impurity in chemical mixtures from the petroleum industry.</p>	<p>furniture and the storage of solvents.</p>	<p>lowest level of exposure at which an increased incidence of ANLL among occupationally exposed workers has been reliably detected appears to be in the range of 32 to 80 mg/m³.</p> <p>The estimated unit risk of leukaemia per 1 µg/m³ is 6×10^{-6}, and an excess lifetime risk of 1/10 000, 1/100 000 and 1/1000 000 are 17, 1.7 and 0.17 µg/m³, respectively.</p>	<p>health-based ventilation guidelines (HEALTHVENT project) to control exposure to NO₂ from indoor and outdoor sources in school buildings.</p>	<p>concentration should be kept as low as is reasonably achievable – in any case, it should not exceed outdoor concentrations.</p> <p>In the Air Quality Directive (2008/EC/50) (88), an EU limit value for ambient levels of benzene is set at 5 µg/m³ (yearly average).</p> <p><u>SINPHONIE schools</u>: about 25 % of schoolchildren are exposed to levels above 5 µg/m³ with higher percentages in Central-Eastern European</p>
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					countries.
NO₂	<p>Nitrogen dioxide (NO₂) is a reddish brown gas with a boiling point of 21.2°C and a molecular weight of 46.01 g/mol.</p> <p>It is emitted from combustion processes and produced by photochemical reactions.</p> <p>It is a strong oxidant with a characteristic pungent odour.</p>	<p>The most important indoor sources of NO₂ include gas appliances, kerosene heaters, woodstoves and fireplaces without flues.</p> <p>Ambient air (car exhausts) is a strong contributor to indoor concentrations of NO₂.</p> <p>The main ambient sources of nitrogen oxides (NO_x) include the intrusion of stratospheric NO_x, bacterial and volcanic action, and lightning. Fossil-fuel power stations, motor vehicles and domestic combustion appliances emit</p>	<p>NO₂ is an oxidising agent that is highly irritating to mucous membranes, and causes a wide variety of health effects. Most studies demonstrate substantial changes in pulmonary function in normal healthy adults at or above NO₂ concentrations of 2 ppm.</p> <p>Asthmatics appear to be responsive at about 0.5 ppm and subjective complaints have been reported at that level.</p> <p>NO₂ increases bronchial reactivity as measured by pharmacological bronchoconstrictor agents in normal and asthmatic subjects, even at levels that do not affect pulmonary function directly in the absence of a bronchoconstrictor.</p>	<ul style="list-style-type: none"> ❖ Control exposure of NO₂ in school kitchens by means of appropriate exhaust ventilation through vented hoods. ❖ It is recommended to put in place health-based ventilation guidelines (HEALTHVENT project) to control exposure to NO₂ from indoor and outdoor sources in school buildings. ❖ Ban (preferred option), or ensure sufficient local exhaust ventilation of any unvented gas stoves that may still be in use in European school buildings. ❖ Ensure regular maintenance/inspection of all combustion devices in school buildings. 	<p>The WHO 2010 and EU-INDEX 2005 and 2009 indoor air guidelines for NO₂ of 40 µg/m³ (annual and weekly average) and 200 µg/m³ (1-hour) are recommended for the indoor air in school environments.</p> <p><u>SINPHONIE schools:</u></p> <p>With the exception of a few classrooms where elevated NO₂ indoor levels were observed, schoolchildren were in general exposed to lower levels</p>

		nitric oxide (NO), which is a reactive compound that is oxidised to NO ₂ .	<p>Epidemiological studies suggest that children who are exposed to combustion contaminants from gas stoves have higher rates of respiratory symptoms and illness than other children.</p> <p>There have been concerns that infants may be at a higher risk of symptoms of high indoor NO₂ levels because of their high respiratory rates in relation to body size and because they spend a large proportion of their time indoors.</p>		than the guideline value of 40 µg/m ³ .
Formaldehyde	<p>Formaldehyde (HCHO) is a gas with a molecular weight of 30.03 and a boiling point at -21°C.</p> <p>It ranks among leading HPVCs (high production volume chemicals): in 2004,</p>	Formaldehyde is released from most wood-based materials, used extensively as a preservative, disinfectant and biocide, as a component of glues, varnishes, printing materials,	Formaldehyde has a pungent odour and has irritating properties which cause discomfort. The symptoms displayed after short-term exposure to formaldehyde are: irritation of the eyes, nose and throat, together with exposure-	<ul style="list-style-type: none"> ❖ Minimise emissions of formaldehyde from school-building materials, products and furnishings ❖ In schools, use building materials, products and furnishings labelled according to existing labelling schemes at national and EU level. ❖ It is recommended to ensure health-based ventilation for 	The WHO 2010 IAQ guidelines and the EU-INDEX 2009 update recommend guideline values of 120 µg/m ³ and 90 to 120 µg/m ³ (30-min

	<p>its production in the EU and Norway amounted to 10.7 million tonnes (FormaCare, 2008)</p>	<p>textile treatments, permanent markers, automotive equipment, and dozens of other products.</p> <p>It is also formed in combustion processes, tobacco smoking in particular, by the air chemistry of terpenes which are contained in fragrances and air fresheners, and in particular as a product of the hydrolysis of formaldehyde-based resins (mostly urea-formaldehyde, phenol-formaldehyde, and melamine-formaldehyde) resins.</p> <p>Because of its multitude of indoor</p>	<p>dependent discomfort, lachrymation, sneezing, coughing, nausea and dyspnoea. Children have been reported to be more sensitive to formaldehyde exposure.</p> <p>In December 2012, the European harmonised classification and labelling system classified formaldehyde as a Category 1B carcinogen</p> <p><u>Note:</u> A Category 1 substance is known or presumed to have carcinogenic/mutagenic potential for humans. For category 1A, the assessment is based primarily on human evidence; for category 1B, the assessment is based primarily on animal evidence.</p>	<p>indoor environments in schools according to the HEALTHVENT project's approach.</p>	<p>average) respectively to prevent sensory irritation in the general population.</p> <p>These guideline values are valid for any 30-minute period, and also prevent the effects of long-term exposure on lung function or the risk of nasopharyngeal cancer.</p> <p><u>SINPHONIE schools:</u></p> <p>It should be underlined that the aforementioned guideline values cannot be directly compared with</p>
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		<p>sources, formaldehyde is found ubiquitously in almost all indoor environments (hence in school buildings as well) at levels that exceed outdoor concentrations by an order of magnitude or more.</p> <p>Indoor concentrations of formaldehyde are influenced by temperature, humidity, ventilation rate, age of the building, product usage, presence of combustion sources, and the smoking habits of occupants.</p>			<p>the values measured in the SINPHONIE schools as the latter are related to a week-long period of sampling.</p> <p>The results of indoor formaldehyde measurements in the SINPHONIE schools range from 1.3 to 66.2 $\mu\text{g}/\text{m}^3$, with large differences between participating countries. The levels were significantly higher in Western and Central-Eastern countries than in Northern and Southern</p>
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					countries.
Naphthalene	<p>Naphthalene is a white crystalline powder with an aromatic odour. It is a two-ring hydrocarbon isolated from coal tar with a boiling point of 218°C and a molecular weight of 128.18 g/mol. Naphthalene has a half-life of three to eight hours in the atmosphere.</p>	<p>Naphthalene is an intermediate in the production of phthalate plasticisers, synthetic resins, phthaleins, dyes, pharmaceuticals, preservatives, celluloid, lampblack, smokeless powder, anthraquinone, indigo, perylene, and hydronaphthalenes.</p> <p>Crystalline naphthalene is used as a moth repellent and as a solid-block deodoriser for toilets. It is also used in the production of insecticides. Wood smoke, fuel oil and petrol also contain naphthalene.</p>	<p>The main health concerns of exposure to naphthalene are respiratory tract lesions, including tumours in the upper respiratory tract.</p> <p>Based on the IARC classification, naphthalene is possibly carcinogenic to humans (Group 2B).</p>	<ul style="list-style-type: none"> ❖ Restrict the use in school buildings of products containing naphthalene (e.g. solid-block deodorisers for toilets). ❖ Avoid using unvented kerosene heaters and ban tobacco smoking inside school buildings. ❖ It is recommended to ensure health-based ventilation for indoor environments in schools according to the HEALTHVENT project's approach. 	<p>A long-term guideline value of 10 µg/m³ has been established as an annual average to prevent the health risks associated with exposure to naphthalene (WHO, 2010). The same value was also recommended by the EU-INDEX in 2005 and 2009.</p> <p><u>SINPHONIE schools:</u></p> <p>Indoor concentrations of naphthalene in SINPHONIE schools varied</p>

		<p>Naphthalene emissions into the atmosphere mainly originate from fugitive emissions and motor vehicle exhausts. Spills into land and water during the storage, transport and disposal of fuel oil and coal tar are lost and released to the atmosphere due to volatilisation, photolysis, adsorption, and biodegradation.</p> <p>Usual indoor sources of naphthalene are unvented kerosene heaters and tobacco smoke.</p>			<p>from 0 to 30.8 $\mu\text{g}/\text{m}^3$. The Central-Eastern and Southern countries have significantly higher indoor naphthalene concentrations, although the mean values of all four EU regions were far below the WHO guideline value.</p> <p>About 5 % of schoolchildren were exposed to naphthalene at more than 10 $\mu\text{g}/\text{m}^3$.</p> <p>Most schoolchildren were exposed to very low levels of naphthalene (less than 1 $\mu\text{g}/\text{m}^3$).</p>
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Carbon monoxide	CO is a colourless, odourless and non-reactive gas and is a product of incomplete combustion, although some industrial and biological processes also produce it.	CO is widely generated indoors by unvented combustion appliances, particularly if they are operated in poorly ventilated rooms. Tobacco smoke is also an important source of indoor CO pollution.	Exposure to high levels of carbon monoxide is a frequent cause of fatal accidents. At lower levels, exposure leads to reduced exercise ability and increased risk of ischemic heart disease. Epidemiological studies involving large population groups, where exposures were generally at relatively low carbon monoxide levels, have demonstrated increased incidences of low birth weight, congenital defects, infant and adult mortality, cardiovascular admissions, congestive heart failure, stroke, asthma, tuberculosis and pneumonia (WHO 2010).	<ul style="list-style-type: none"> ❖ All indoor combustion equipment used in school buildings must expel gases into chimneys/hoods/vents leading outdoors. ❖ It is recommended to put in place in all European countries mandatory and certified inspections on a regular basis for indoor combustion equipment used in school buildings. ❖ It is highly recommended to install on a mandatory basis in all European countries CO-monitors/alarms in indoor spaces in school buildings that contain combustion equipment. ❖ It is recommended to ensure health-based ventilation in indoor environments in schools according to the HEALTHVENT project's approach. 	<p>A series of guideline values are recommended by WHO IAQ 2010 to prevent the effects of short peaks of exposure (the averaging times are in parentheses):</p> <ul style="list-style-type: none"> - 100 mg/m³ (15 mins) - 60 mg/m³ (30 mins) - 30 mg/m³ (1 h) - 10 mg/m³ (8 h) - 7 mg/m³ (24 h) <p><u>SINPHONIE schools:</u></p>
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					In all cases except one, the children in the SINPHONIE schools were exposed to less than the 7 mg/m ³ guideline value (24 h).
Ozone	Ozone (O ₃) is a gas naturally created in outdoor photo-oxidation reactions by sunlight, and artificially created as a by-product of human activities both outdoors and indoors.	Outdoors, particularly in urban settings near areas of high traffic, levels of ozone can become sufficiently elevated to cause health problems, particularly in sensitive individuals, such as elderly people or asthmatics. Since outdoor air is drawn into buildings through ventilation systems or open windows, elevated outdoor ozone levels can cause elevated	Being a strong oxidant, ozone can exert various physiological effects on pulmonary (lung) function, including reductions in lung function, air-exchange rates, and airway permeability. Ozone can also act as an irritant. The health impacts of exposure to elevated ozone levels include eye irritation, shortness of breath (dyspnoea), coughing, asthma, excessive mucous production, mucous membrane irritation,	<ul style="list-style-type: none"> ❖ Keep laser printers and photocopying machines away from classrooms and offices in appropriately and autonomously ventilated specific rooms in the school building. ❖ Avoid or reduce the physical activity of schoolchildren in outdoor spaces on days when ozone levels exceed the WHO guideline value. ❖ It is recommended to ensure health-based ventilation for indoor environments in schools according to the HEALTHVENT project's approach. 	<p>The WHO 2005 guideline value (aimed at reducing the risk of a broad range of respiratory symptoms associated with exposure to ozone) is:</p> <p>100 µg/m³ (8 h)</p> <p><u>SINPHONIE schools:</u></p> <p>In SINPHONIE schools, ozone values ranged</p>

		<p>levels indoors.</p> <p>A number of indoor sources can increase ozone levels even more. The major indoor sources of ozone are office machinery (particularly electrical equipment), computer terminals, laser printers, and photocopiers. High densities of such equipment and/or deficiencies in ventilation systems can lead to elevated ozone levels that may cause adverse health effects.</p>	<p>and chest pain upon inhalation.</p> <p>Subjects such as asthmatics and those with allergic rhinitis may be particularly susceptible to the effects of elevated ozone.</p>		from 0 to 141 $\mu\text{g}/\text{m}^3$.
d-Limonene		<p>There is widespread use of d-Limonene as a flavouring agent in numerous consumer products used in indoor</p>	<p>Potential hazards of exposure to d-Limonene are eye and airway irritation.</p> <p>Scientific findings suggest that reactions</p>	<ul style="list-style-type: none"> ❖ Limit the use of consumer products containing d-Limonene, such as air fresheners, in school buildings. ❖ Avoid excessive use of fragranced cleaning agents in school 	<p>An exposure limit of 450 $\mu\text{g}/\text{m}^3$ was recommended by the EU-INDEX project</p>

		environments.	<p>between unsaturated volatile compounds (e.g. limonene, α-pinene, styrene) and ozone or hydroxyl (OH) radicals produce chemically reactive products more likely to be responsible for eye and airway irritation than the chemically non-reactive VOCs usually measured indoors.</p> <p>It is therefore expected that an exacerbation of health effects will follow the concomitant presence of ozone in indoor environments.</p>	<p>buildings.</p> <ul style="list-style-type: none"> ❖ It is recommended to ensure health-based ventilation for indoor environments in school according to the HEALTHVENT project's approach. 	<p>in 2005.</p> <p>However, it was stated that it was not possible to recommend this long-term exposure value as a guideline value for d-Limonene due to the lack of sufficient toxicological data.</p> <p><u>SINPHONIE schools:</u></p> <p>The indoor concentrations of d-Limonene in the SINPHONIE schools ranged from 0 to 671 $\mu\text{g}/\text{m}^3$, with levels significantly higher in Eastern</p>
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					<p>countries than in Southern and Western countries and very low in Northern countries.</p> <p>The majority of schoolchildren were exposed to very low levels of d-Limonene (less than 100 µg/m³).</p>
Trichloroethylene	<p>Trichloroethylene (TCE) is a widely used industrial solvent. It is a volatile, colourless liquid with a sweet chloroform-like smell. It has a melting point of -84.8 °C, a boiling point of 86.7 °C, a Henry's Law constant of 1.03×10^{-2} atm·m³/mol at 20 °C, a</p>	<p>Consumers may be exposed to TCE by using wood stains, varnishes, finishes, lubricants, adhesives, typewriter correction fluid, paint removers and certain cleaners, where TCE is used as a solvent.</p> <p>Contaminated water or soil may also contribute to</p>	<p>Exposure to TCE increases the risks of liver, kidney and testicular cancer as well as non-Hodgkin's lymphoma. Since there is sufficient evidence that TCE is a genotoxic carcinogen, all exposures indoors are considered relevant and no threshold can be determined.</p> <p>IARC has classified TCE as probably</p>	<ul style="list-style-type: none"> ❖ Restrict the use of consumer products containing TCE in school buildings. ❖ Monitor TCE in water and soil in the school area to avoid potential indoor pollution in school buildings through TCE from contaminated water (bathing/showering) and soil. ❖ It is recommended to ensure health-based ventilation for indoor environments in school according to the HEALTHVENT project's approach. 	<p>Based on WHO guidelines for indoor air quality (2010) the estimated unit risk is 4.3×10^{-7} per µg/m³.</p> <p>The concentrations of airborne TCE associated with an excessive lifetime cancer risk of 1:10 000, 1:100 000</p>

	<p>vapour pressure of 7.8 kPa at 20 °C, a water solubility of 1.1 g/l at 20 °C and a log K_{ow} (octanol–water partition coefficient) of 2.29.</p> <p>TCE is mainly used for the vapour degreasing and cold cleaning of manufactured metal parts (80–95 % of consumption). Other applications include industrial dry-cleaning, printing, the production of printing ink, extraction processes, paint production and textile printing.</p>	indoor pollution through TCE.	carcinogenic to humans (Group 2A) based on sufficient evidence in animals and limited evidence in humans.		<p>and 1:1000 000 are respectively 230, 23 and 2.3 µg/m³.</p> <p><u>SINPHONIE schools:</u></p> <p>In the SINPHONIE schools a large range of values was observed (0 to 126 µg/m³) with significantly lower indoor TCE levels in the Western and Northern countries than in Southern and Eastern ones.</p> <p>Only 10 % of the children were exposed to TCE in schools at more than 5 µg/m³.</p>
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Tetrachloroethylene	<p>Tetrachloroethylene (TCA) (CAS Registry Number 127-18-4; C₂Cl₄; molecular weight 165.83) is a readily volatile, colourless liquid with an ether-like smell.</p> <p>Its main physical and chemical properties are as follows: molecular weight 165.83 g/mol; density (at 20°C) 1.6227 g/ml; melting point approximately - 22°C; boiling point 121°C; water solubility (at 25°C) 150 mg/litre; vapour pressure 18.47 mmHg at 25°C (2), 1.9 kPa at 20°C, 3.2 kPa at 30°C and 6.0 kPa at 40°C; Henry's Law constant 0.018 atm-m³/mol at 25 °C; log K_{ow} (octanol/water</p>	<p>Consumer products that may contain TCA include adhesives, fragrances, spot removers, stain removers, fabric finishes, water repellents, wood cleaners, motor vehicle cleaners and dry-cleaned fabrics.</p> <p>Consumer products described above are sources of indoor TCA exposure.</p> <p>Contaminated drinking water may be a source of indoor TCA exposure when taking a shower or washing dishes.</p>	<p>Exposure to TCA can affect the central nervous system, eyes, kidney, liver, lungs, mucous membranes and skin.</p> <p>Carcinogenicity is not used as an end-point, since there are no indications that TCA is genotoxic and there is some uncertainty about the epidemiological evidence as well as the relevance of the animal carcinogenicity data to humans. However, because of the remaining uncertainty about the carcinogenicity of TCA, it should be kept under review.</p> <p>IARC concluded that there is evidence for consistently positive associations between exposure to TCA and the risks for oesophageal and cervical cancer and</p>	<ul style="list-style-type: none"> ❖ Restrict the use of consumer products containing TCA in school buildings ❖ Monitor water supplies to school buildings to ensure they are not contaminated with TCA in order to avoid related exposure when taking a shower in the restrooms and washing dishes in the kitchens of the school buildings. ❖ It is recommended to ensure health-based ventilation for school indoor environments according to the HEALTHVENT project's approach. 	<p>The WHO IAQ 2010 recommends a TCA guideline value for year-long exposure of 250 µg/m³.</p> <p><u>SINPHONIE schools:</u></p> <p>None of the children were exposed to TCA at more than 250 µg/m³.</p> <p>Only 10% of the children were exposed to TCA in schools at more than 3.3 µg/m³.</p>
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	partition coefficient) 3.40 (measurement value) and 2.97 (estimated value); and log K_{oc} (octanol/carbon partition coefficient) 177~350 (measurement value).		non-Hodgkin's lymphoma. TCA is classified by IARC as a Group 2A carcinogen (probably carcinogenic to humans).		
Radon	<p>Radon (^{222}Rn) gas is an important source of ionising radiation of natural origin and a major contributor to the ionising radiation dose received by the general population in various indoor environments (homes, schools, workplaces).</p> <p>Excluding radiotherapy doses and radiation accidents, radon is the largest and most variable contributor</p>	The main source of indoor radon is the radon produced by the decay of radium in the soil subjacent to a building.	<p>The most important route of exposure to radon and its decay products is inhalation.</p> <p>IARC classified it as a Group 1 human carcinogen in 1988, while the WHO considers it to be the second cause of lung cancer after cigarette smoking.</p>	<ul style="list-style-type: none"> ❖ Radon levels in school buildings should be controlled by various building technology options, such as the installation of active radon sumps and radon-proof membranes in the foundations of school buildings. ❖ It is recommended to adopt in European countries building regulation strategies aimed at reducing the average radon levels in new buildings, including school buildings, to below the current national average levels. ❖ EU Member States are encouraged to consult the wide array of recommendations on radon-prevention and remediation 	<p>The excess lifetime risk of death from radon-induced lung cancer is 6×10^{-4} per Bq/m^3.</p> <p>In view of the latest scientific data on the health effects of indoor radon, WHO (2010) recommended a national residential reference level at 100 Bq/m^3.</p>

	to the average annual radiation dose received by the world population.			<p>strategies issued in 2012 in the context of the EU-funded RADPAR project (http://web.jrc.ec.europa.eu/radpar/)</p>	<p>Wherever this cannot be achieved the chosen reference level should not be higher than 300 Bq/m³.</p> <p>For children, a reference level of 167 Bq/m³ may be used associated with an excess lifetime risk of 1×10^{-3}.</p> <p><u>SINPHONIE schools:</u></p> <p>The results of indoor radon measurements in SINPHONIE schools show values from 0 to 9186 Bq/m³ (median value 100.9 Bq/m³) with significantly higher levels in</p>
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					Central-Eastern and Southern European countries than in Northern and Western countries. 50 % of the children were exposed to more than 100 Bq/m ³ .
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ANNEX C - Indoor air-related microbiological stressors (sources, health effects, risk-management options/control measures, standards/guidelines/SINPHONIE results for comparison)

Stressor	Description	Sources	Health effects	Risk-management options and control measures	Standards/guidelines/SINPHONIE results for comparison
INDOOR AIR-RELATED MICRO-BIOLOGICAL STRESSORS					
Endotoxin Fungal species/groups, for example: <ul style="list-style-type: none"> ❖ <i>Penicillium/Aspergillus/Paecilomyces</i> spp. Group ❖ <i>Aspergillus versicolor</i> ❖ <i>Alternaria alternata</i> 	<p><u>Endotoxins</u> are integral components of the outer membrane of gram-negative bacteria and are composed of proteins, lipids and lipopolysaccharides.</p> <p><u>Fungal species/groups</u> are ubiquitous in the environment, both indoors and outdoors. These are eukaryotic single- or multi-cell organisms comprising thousands of different species. Many fungi have the potential to</p>	<p>The main sources of bacteria and fungi in the indoor environment are outdoor air, people (directly and indirectly through tracking in outdoor material on clothes, such as soil) and microbial growth due to dampness on indoor surfaces and structures.</p> <p>Airborne endotoxins are usually associated with dust particles or aqueous aerosols.</p>	<p>The most important effects of exposure to these pollutants are the increased prevalence of respiratory symptoms, allergies and asthma, as well as disturbance of the immune system. However, research to prove causality between microbial exposure and respiratory health is still ongoing.</p> <p>The relationships between dampness, largely diverse</p>	<ul style="list-style-type: none"> ❖ Persistent dampness and microbial growth on interior surfaces and in school-building structures should be avoided or minimised. ❖ Periodical monitoring and thorough inspection of school buildings should be carried out to identify and remediate potential indoor moisture and microbial growth. ❖ Proper design, construction and maintenance of school 	<ul style="list-style-type: none"> - WHO guidelines on dampness and mould (2009) - WHO information brochure on damp and mould (Health risks, prevention and remedial actions) (2009) - WHO Interventions

<p>Bacterial groups, for example:</p> <ul style="list-style-type: none"> ❖ <i>Streptomyces</i> spp. ❖ <i>Mycobacterium</i> spp. 	<p>produce mycotoxins, which are low-relative-molecular-mass biomolecules, some of which are toxic to animals and human beings.</p> <p><u>Bacteria</u> are ubiquitous prokaryotic single-cell organisms, comprising an abundance of species. They can be found in the air and dust and on the surfaces of every building, including those with no damp problems. Also, these organisms produce a variety of bioactive compounds, some of them potentially hazardous to human health.</p>	<p>Particles have a broad size distribution, but endotoxin levels may be higher in the coarse fraction.</p> <p>Scientific literature shows that exposure to endotoxin in school classrooms clearly exceeds exposure in the home environment and similar trends can be expected for other microbial contaminants.</p>	<p>microbial exposure and health effects are difficult to quantify precisely. Therefore, no quantitative, health-based guideline values or thresholds can be recommended for acceptable levels of contamination by micro-organisms in indoor environments.</p> <p>Many fungal species produce type I allergens. Immunoglobulin (Ig)E sensitisation to the commonest outdoor and indoor fungal species, like <i>Alternaria</i>, <i>Penicillium</i>, <i>Aspergillus</i> and <i>Cladosporium</i> spp., is associated with allergic respiratory disease, especially asthma.</p>	<p>buildings and control of temperature and ventilation to avoid excess humidity, condensation on surfaces and excess moisture in school building materials.</p> <ul style="list-style-type: none"> ❖ Ventilation should be distributed effectively throughout all school building spaces, and stagnant air zones should be avoided. 	<p>and actions against damp and mould: review of selected case studies (2008)</p> <ul style="list-style-type: none"> - HEAL Directory of Agencies by EU country providing information on damp and mould to the public (2009) - Refer to the SINPHONIE state-of-the-art approach to sampling and analysing micro-biological agents in indoor environments in school (2013)
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					<p><u>SINPHONIE schools:</u></p> <p>The SINPHONIE dataset provides data on exposure distribution to microbiological stressors in the European school environment and shows significant adverse associations of elevated microbial agents with respiratory health symptoms in schoolchildren and teachers, and clinical measurements in the case of exhaled NO.</p>
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