European Commission

SINPHONIE

Schools Indoor Pollution & Health Observatory Network in Europe

Executive Summary of the Final Report

sinphonie
Schools Indoor Pollution and Health: Observatory Network in Europe

REGIONAL ENVIRONMENTAL CENTER

European Commission
Directorate General for Health and Consumers
Directorate General Joint Research Centre - Institute for Health and Consumer Protection

Contact information
Address: Via E. Fermi 2749, TP 281, I-21027 Ispra (VA), Italy
E-mail: JRC-IHCP-CAT@ec.europa.eu
Tel.: +39 0332 78 9871
Fax: +39 0332 78 5867

Further information on the Directorate-General for Health and Consumers is available at:
http://ec.europa.eu/dgs/health_consumer/index_en.htm
Further information on the Joint Research Centre is available at:
https://ec.europa.eu/jrc/

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Abstract
This report is the executive summary of the final report of the SINPHONIE (Schools Indoor Pollution and Health: Observatory Network in Europe) project. SINPHONIE was funded by the European Parliament and carried out under a contract with theEuropean Commission's Directorate-General for Health and Consumers (DG SANCO) (SANCO/2009/C4/04, contract SI2.570742).
The SINPHONIE project established a scientific/technical network to act at the EU 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 outdoor and indoor air pollution. At the same time, the project supports future policy actions by formulating guidelines, recommendations and risk management options for better air quality and associated health effects in schools.

SINPHONIE
Schools Indoor Pollution and Health
Observatory Network in Europe

Executive Summary of the Final Report

This report was prepared by:

Éva Csobod, Isabella Annesi-Maesano, Paolo Carrer, Stylianos Kephalopoulos, Joana Madureira, Peter Rudnai and Eduardo de Oliveira Fernandes

with contributions from:

Josefa Barrero-Moreno, Tímea Beregszászi, Anne Hyvärinen, Hans Moshammer, Dan Norback, Anna Páldy, Tamás Pándics, Piersante Sestini, Marianne Stranger, Martin Täubel, Mihály J. Varró, Eva Vaskovi, Gabriela Ventura and Giovanni Viegi

REGIONAL ENVIRONMENTAL CENTER

The Regional Environmental Center for Central and Eastern Europe
2000 Szentendre
Ady Endre ut 9-11, Hungary

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This report summarises the work performed by a consortium of 38 partners from 25 countries that involved around 300 people of specialised scientific and/or technical background.

The co-authors of this report wish to express their deep gratitude to all of their collaborators for their outstanding contribution to the execution of the SINPHONIE project. Names of all contributors can be found at the end of this report as well as on the SINPHONIE project's website (www.sinphonie.rec.org).

Special recognition goes to the teachers, pupils and parents who participated in the SINPHONIE project, for their enthusiasm and close cooperation.

1 Introduction

Poor indoor air quality (IAQ) has respiratory and other health-related effects. It affects general well-being due to the possible presence of several specific indoor pollutants with a variety of causes and sources. This has been reported on many occasions in the scientific literature and referred to in recent political declarations, air quality guidelines [1, 2] and overall (IAQ) management strategies [3], and by political and organisational bodies dealing with public health and related environmental issues. The Parma Declaration of the World Health Organization (WHO) Europe [4], endorsed by 53 countries in 2010, called on member states of the WHO Europe region to implement measurable actions in order to reach the targets set in the declaration The WHO Guidelines for IAQ [5] specifically state that clean air is a basic requirement for life. It is also emphasised that the primary aims of the WHO guidelines are to provide a uniform basis for the protection of public health from the adverse effects of exposure to indoor air pollution, and to eliminate or reduce to a minimum exposure to those pollutants that are known or likely to be hazardous. The guidelines are targeted at public health professionals involved in preventing health risks from environmental exposure, as well as at specialists and authorities involved in the design and use of buildings and the materials and products used inside them.

The European Commission adopted the European Union (EU) Environment and Health Action Plan 2004–2010 [6] in June 2004 as the first cycle in the implementation of the European Environment and Health Strategy. The action plan was an operational document that set out 13 key actions for the period until 2010. Among these key actions, Action 12 concerned the "improvement of indoor air quality". In the context of the implementation of Action 12, the EU-funded project EnVIE [7] elaborated a priority strategy for IAQ management through source control, which, in the case of schools, meant addressing the IAQ issue from a number of perspectives, including school location, design and construction, occupation density and the management of ventilation.

The 7th Environment Action Programme and the Clean Air Policy Package of the EC were developed and came into force in late 2013. These documents provide the policy framework for potential follow up activities of the SINPHONIE project.

The indoor environment in schools constitutes a particular cause of concern, since schoolchildren are a particularly vulnerable group of the population. 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 detrimental effect on health of a variety of indoor pollutants that can be found in school environments, 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 [8]. Asthmatic children are known to be particularly sensitive to the effects of poor air quality.

School buildings should be regarded as part of the urban infrastructure, which is influenced by local conditions including geography, climate, energy use, available materials, economic development and urban strategies. School buildings also reflect technological progress in terms of construction and comfort, as well as the influence of architectural models, construction experience and practices imported from other regions, even within Europe, which are not always appropriately integrated in such a way as to make them coherent with local values and practice.

The SINPHONIE project established a scientific/technical network to act at the EU 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 outdoor and indoor air pollution. At the same time, the project supports future policy actions by formulating guidelines, recommendations and risk management options for better air quality and associated health effects in schools.

SINPHONIE was initiated and funded by the European Parliament. It was carried out under a contract with the European Commission's Directorate-General for Health and Consumers (DG SANCO). The project was conceived as a challenging pilot research project in the fields of health and environment, targeting mainly indoor air in schools but also outdoor air in the school vicinity, including consideration of the impacts of traffic and climate change. The multidisciplinary project was designed to run for two years (2010–2012). It covered most European countries, including some EU accession countries, and aimed to survey schools and establish an observatory network in Europe on school indoor pollution and health. Besides the ultimate objective of improving air quality in schools and kindergartens in the long term, the project also paid special attention to improving overall IAQ assessment in European schools and to elaborating methods and procedures for undertaking wide-scale surveys and auditing, which are essential tools in IAQ monitoring and building assessments. Gaining an understanding of children's exposure to particular indoor air pollutants and evaluating the associated potential health outcomes are prerequisites for providing appropriate support to policy making and action.

The SINPHONIE consortium involved 38 partners from 25 countries, and one associated partner from Belgium. The partners contributed broad expertise in the fields of health, exposure, sources and IAQ-related policies, as well as some of the comfort parameters associated with the management of building envelopes and ventilation. Overall, 114 primary schools in 23 European countries participated in the environment and health monitoring and assessment. Exposure levels among 5,175 schoolchildren (including 264 children at pre-schools) were assessed[1].

By capitalising on existing knowledge and sources, the SINPHONIE project attempted to extend the range of available information covering old and new EU member states and some accession countries using a comprehensive procedure. This procedure was put into operation after a process of training involving over 80 people in order to ensure overall quality and

[1] It should be noted that throughout this report these numbers may differ slightly taking into account the specific involvement of each partner/country in a given action of the fieldwork (environment and/or health).

reliable results. Because of the multidisciplinary nature of the project, this was the only way to obtain results; guarantee the compilation of recommendations, guidelines and good practices for better indoor air within European school environments; and generate information relevant to existing and future policies.

An analysis of the SINPHONIE results confirms that IAQ in schools is a very important issue and has an impact on children's health, including respiratory problems such as asthma and allergies, as well as attendance and performance. The SINPHONIE results show that indoor air pollution in schools is complex and variable, that it can have different origins (outdoor, indoor) and nature (physical, chemical and biological), and that it can be caused by a variety of sources (such as combustion processes, building materials or components and consumer products). Air pollutants were found in classrooms in concentrations that in several cases exceeded WHO guideline values and that were thus harmful to schoolchildren's health.

The overall SINPHONIE results, supported by studies on the effectiveness of certain remedial measures, confirm that schools frequently have IAQ problems caused by poor building location, construction and maintenance, high occupation density, poor cleaning and insufficient ventilation.

2 Objectives

The overall objectives of SINPHONIE were to: (a) contribute to the better characterisation of IAQ in schools in the EU; (b) produce recommendations and guidelines on remedial measures in the school environment to cover a wide range of situations in Europe; and (c) disseminate these guidelines to policy makers and other stakeholders who are able to take action in European countries.

In order to achieve these overall SINPHONIE objectives, the project's technical objectives were to:

- *critically review and collate European (and non-European) research on the health effects most relevant to indoor air and the respective contaminants in the indoor air in schools; assess the policy relevance of the objectives and conclusions of this research; and identify epidemiological and toxicological research needs that are critical for knowledge-based policy development;*
- *assess building characteristics and patterns of everyday use in the selected classrooms that influence their IAQ;*
- *measure physical and comfort parameters (temperature, relative humidity and ventilation rate) and chemical and biological pollutants in the indoor (and related outdoor) air in schools and childcare settings throughout Europe in order to produce new exposure data for an array of pollutants: formaldehyde, benzene, α-pinene and limonene, naphthalene, NO_2, CO, CO_2, radon, trichloroethylene, tetrachloroethylene, PAH and BaP, particulate matter (PM_{10} and $PM_{2.5}$), allergens in dust and mould, and bacteria in dust and air;*
- *evaluate the impact of the outdoor air surrounding the school environment, including the effects of transportation, traffic and climate change;*

- *assess the influence of building characteristics, cleaning products and ventilation systems on the exposure data obtained;*
- *assess the impacts of outdoor air pollution abatement measures, including measures taken in the short term, on IAQ in schools and on the exposure of children in school environments;*
- *make a systematic source apportionment of indoor air pollutants in school environments in quantitative terms;*
- *assess the influence of mixtures of pollutants in the indoor air and the emergence of new pollutants caused by chemical and biochemical interactions;*
- *obtain data on the health status of children via questionnaire surveys and clinical tests, focusing on asthma, respiratory infections, upper respiratory tract symptoms, coughing, wheezing, dyspnea, allergic rhinitis, bronchitis and school performance;*
- *evaluate the impact of the indoor air in classrooms on children's health and performance in order to define priorities for policy development;*
- *evaluate the effectiveness of appropriate ventilation in reducing ambient air pollution in schools;*
- *produce recommendations and guidelines on remedial measures in school environments to cover a wider array of situations in Europe; and*
- *disseminate the SINPHONIE outputs and recommendations to stakeholders able to undertake actions on the issues highlighted by the project.*

3 Methodology

As most indoor air comes directly from the ambient air [8] (the latter contributing a large proportion of the indoor pollution load), the SINPHONIE methodology first took into consideration geographical and climatic aspects and the correlated parameters regarding the location of school buildings and their environment (e.g. traffic levels, urbanisation, construction practices and building typologies). Air quality in the outdoor/indoor school environment and the associated health implications therefore had to be evaluated taking into account interregional variability in the countries participating in SINPHONIE. Four geographical clusters were defined within the project as a tool for organising the presentation and discussion of most of the SINPHONIE results (see Figure 1).

While school buildings in many European regions rely on natural ventilation, there is a trend towards the installation of mechanical ventilation and correlated systems for heating and cooling. Such systems are often presented or proposed as essential and as a general requirement for every school building, although they are meaningful only if justified by the climate and ambient conditions. It should also be underlined that an appropriately implemented holistic approach to the school building issue and consequent appropriate design and study methodology may even require the decoupling of functions such as heating or cooling and ventilation, leaving the ventilation rate to be controlled according to health-based criteria, [10]. In accordance with the criteria laid down in the call for tenders by DG SANCO, the schools were selected in order to address relevant factors in the participating countries and therefore included urban and rural sites; different levels of outdoor air pollution

(green zones, areas with heavy traffic and industrial areas); different locations within the country (north, south, east, west), and different ventilation practices and climatic conditions. No restrictions were imposed in relation to construction features. The partners were required to choose schools that were representative of the building stock of the country in terms of typology, construction techniques and age.

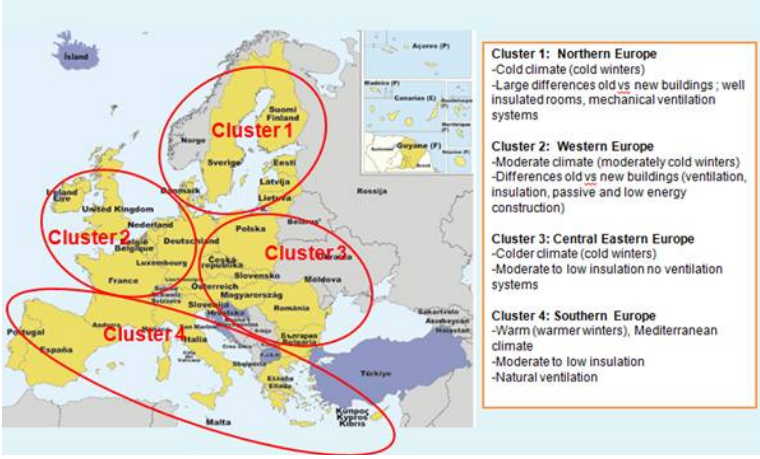

Figure 1. The four geographical clusters in the SINPHONIE project

Following the selection and definition of appropriate tools, methods and procedures to be used in SINPHONIE, field studies were carried out in the selected schools in each country (≤6), including their vicinity, focusing specifically on three classrooms per school (including kindergartens). Overall, 114 schools were selected from the 23 countries for the field activities based on the criteria described above. In order to decide on the methodological approach for air monitoring in school buildings and the identification of the associated health effects, relevant past and concurrent projects funded by the EU and WHO were considered and analysed, including AIRMEX (European Indoor Air Monitoring and Exposure Assessment) [11]; THADE (Towards Healthy Air in Dwellings in Europe) [12]; EU-INDEX (Critical Appraisal of the Setting and Implementation of Indoor Exposure Limits in the EU)[13]; SEARCH (School Environment and Respiratory Health of Children) [14]; and PILOT INDOOR AIR MONIT [15]; as well as the WHO Guidelines for IAQ [16].

SINPHONIE was more ambitious than earlier projects due to its integrated approach to health and environment issues related to the school environment, and due to the large number of parameters assessed. This justified the special efforts dedicated to the preparation of the field studies and campaigns in the 23 participating countries, which were preceded by well-prepared environment and health training for over 80 scientific and technical staff at the European Commission's Joint Research Centre (JRC) in Ispra, Italy. An important element in the SINPHONIE methodological framework was the setting up and population of the SINPHONIE database. The database supported the creation of the observatory network for Europe on school indoor pollution and health by generating significant amounts of high-

quality data in line with the SINPHONIE objectives, while also feeding into future similar projects and actions to be undertaken in European countries.

The SINPHONIE field studies started with walkthrough inspections of the selected school buildings, which were followed by the collection of data on school building characteristics. Data were collected via a school building and classroom "checklist", which made possible the comprehensive description of both the school indoor environment and the school building itself (e.g. school building shape and orientation, distance from the main outdoor pollution sources, and type of construction, materials and ventilation systems used). The characterisation of the school environment (operation, occupants' patterns of activity etc.), and of the health-related symptoms/diseases of building occupants, was obtained through specific questionnaires distributed to teachers, pupils and parents during the field activities in each of the schools examined.

The environmental characterisation of the school buildings involved monitoring chemical, physical, biological and comfort parameters, while the health characterisation included health information reported via the questionnaires, accompanied by specific clinical tests. Health risk assessments were carried out focusing on inhalation exposure and health effects such as irritation symptoms and respiratory diseases (i.e. airway allergic reactions), and on the most vulnerable subjects (i.e. children).

For the measurement campaigns, a set of methodologies and equipment was selected according to the relevant standards of the International Organization for Standardization (ISO) and the European Committee for Standardization (CEN). Equipment was acquired and managed taking into consideration accuracy targets, quality control requirements, and the reasonableness of the investments.

The analysis of 16 chemical, physical and comfort parameters (including key priority compounds recognised by WHO and the European Commission) and 13 biological contaminants, including endotoxins (one analyte), fungal and bacterial DNA (seven analytes) and allergens (five analytes), made it possible to obtain an overview of IAQ in schools across Europe.

In the main study, 30 different laboratories from the 23 countries were involved in the field campaign and the chemical analysis. Each laboratory delegated national monitoring experts for the JRC training in May 2011 to learn about harmonised sampling sites, sample collection, sample preparation and analysis. In order to obtain a SINPHONIE dataset reporting comparable data, the data were collected in a uniform way, with measurement uncertainty reduced to a minimum. SINPHONIE fieldwork and analysis guidelines were formulated and field and lab workers were trained.

The protocol on the sampling of biological contaminants in schools guided the study centres in the actual sampling. The biological sampling was coordinated by the leaders of the biological study (Finland and Hungary) in cooperation with the project coordinator. Sample analysis was centralised at three laboratories in Finland, Hungary and Sweden.

4 Results

SINPHONIE results were mainly obtained from the analysis of collected data, especially concerning the causal relationship between exposure and health effects. In parallel, additional information was obtained regarding environmental conditions and the use and management of the school buildings. The SINPHONIE results are described comprehensively in the Final Report.

A. Exposure levels

- The WHO-recommended guideline values for $PM_{2.5}$ and radon were not respected in a significant proportion of the monitored classrooms.
- 13% of all schoolchildren were exposed to $PM_{2.5}$ at concentrations higher than 25 $\mu g/m^3$ (WHO ambient 24-hour mean guideline), and more than 85% at concentrations above 10 $\mu g/m^3$ (WHO guideline value as annual mean), which are the recommended guideline values to limit the risk of long-term effects on cardio-vascular-respiratory function and lung cancer mortality.
- 50% of schoolchildren were exposed to radon at a higher level than 100 Bq/m^3 (i.e., the national residential reference proposed by WHO in 2010 in order to manage excess lifetime risk of radon-induced lung cancer), with the highest median levels in Central and Eastern Europe and Southern Europe.
- About 25% of all schoolchildren were exposed to benzene at school at concentrations above 5 $\mu g /m^3$ (Air Quality Directive 2008/50/EC), the guideline value for managing excess lifetime risk of leukaemia. Based on the unit risk estimations contained in the WHO guidelines, the benzene median exposure level is linked to a risk level of 1.3×10^{-5}, with an excess lifetime leukaemia risk of 1:76,923 in the total population studied, and a risk level of 2.0×10^{-5}, corresponding to an excess lifetime leukaemia risk of 1:50,000, in schoolchildren in Central and Eastern Europe.
- More than 60% of all children were exposed to formaldehyde at school at concentrations above 10 $\mu g/m^3$ (the value proposed by the French Agency for Environmental and Occupational Health Safety, AFSSET, as a long-term indoor air guideline value to protect from long-term effects on lung function and excess lifetime cancer cases from formaldehyde), with highest median levels in countries in Central and Eastern Europe and Western Europe.
- Exposure to environmental tobacco smoke can still be found in a few schools (5%).
- The highest median levels of bio-contaminants in SINPHONIE schools and kindergartens were found for the larger fungal group *Penicillium spp./Aspergillum spp./Paecilomyces spp*., followed by two bacterial genera, *Mycobacterium spp*. and *Streptomyces spp*. Although median values were low in some cases, 50% of children and teachers were exposed to high levels of endotoxins and microbes. These results indicate that fungi common in damp buildings are more abundant than those typically found outdoors. There are no EC limit values or WHO guidance to compare against the bio-contaminant level measured in SINPHONIE schools, and national guidance exists in only a few countries. The real value of the study is the innovative method of

microbe sampling and analysis, which can be used in future microbial exposure assessments.

- Levels of CO_2 (mean and median) were higher than 1,000 ppm in both primary schools and kindergartens. Cluster 1 (Northern Europe) and Cluster 2 (Western Europe) presented the highest percentage of classrooms with low levels of CO_2 (<1,000 ppm), whereas Cluster 3 (Central and Eastern Europe) and Cluster 4 (Southern Europe) had higher percentages of classrooms with CO_2 levels higher than 1,500 ppm, may reduce the quality of the learning performance of children in these regions.
- The majority (86%) of values for ventilation rates were lower than the desirable value of 4 l/s.child, due to two factors: the high occupation density in classrooms in some European countries; and the inappropriate way in which ventilation rates are expressed (i.e. in terms of air changes per hour rather than litres per second per person [child]).
- The indoor/outdoor (I/O) ratio for NO_2 and ozone is <1, in contrast to most of the other pollutants, for which the I/O ratio is > 1 (e.g. formaldehyde and limonene). This highlights the importance of both the outdoor pollution surrounding the school building and the indoor sources inside the school building.
- The levels of chemical air pollutants assessed in the vicinity of the schools were elevated due to the presence of the traffic-related air pollutants $PM_{2.5}$, NO_2 and ozone. The level of these pollutants were significantly higher in Central and Eastern and Southern European countries.
- 58% of the schools were exposed to noise from busy roads.

B. Health outcomes

Several air pollutants were significantly related to the considered health outcomes in children and teachers Recent (<3 months) symptoms were more often related than symptoms in the past year or ever.

The following health outcomes and their association with environmental exposure were identified:

- Up to 1.5% of the schoolchildren had an asthma attacks in school, which represents nearly 100,000 cases among schoolchildren in Europe. Among them, about a third had asthma attacks in classrooms corresponding to 30000 cases among schoolchildren in Europe.
- The prevalence of diagnosed asthma, nasal allergies and eczema among schoolchildren was 8%, 9% and 17% respectively.
- Among all children, the most common recent (<3 months) health event was a blocked nose (47%) followed by a runny nose, feeling cold or feverish, having a headache, feeling tired and having a sore throat (36%).
- Children in schools with elevated levels of chemical air pollutants are at higher risk of suffering from recent symptoms related to several respiratory illnesses.

- Multiple associations were shown in SINPHONIE between selected microbial agents in the indoor dust in schools and recent symptoms, past respiratory health symptoms and clinical measurements, indicating the relevance of microbial agents to the respiratory health of pupils and teachers.
- Children with an allergic background are particularly vulnerable, meaning that exposure to air pollutants can trigger symptoms and diseases.
- Tetrachloroethylene ($p=0.036$) and ozone ($p=0.021$) were significantly associated with a decrease in the forced expiratory volume in one second.
- Many of the teachers had respiratory problems and almost 17% suffered from coughing or phlegm, 27% had suffered from a nasal allergy in their life and 9% had asthma diagnosed by a doctor.

C. Outcome of case studies

- A formaldehyde abatement measure was found to reduce levels of indoor formaldehyde with an efficiency of 79% in test chamber simulations. The simulation of classroom ceiling coverage with sorptive boards in a test house established an indoor formaldehyde reduction of 60%.
- Emissions testing of a selection of typical classroom products underlined the varying degree to which these products affect IAQ in classrooms. The tested liquid paints were the major contributors (although temporarily) to indoor concentrations of volatile organic compounds. Varnished and glued chairs contributed to indoor concentrations of volatile organic compounds and aldehyde during the six days of emissions testing.
- Both natural and mechanical ventilation may provide effective classroom ventilation, provided that proper occupation densities are respected in the classroom, that the work periods and breaks are organised appropriately, and that ventilation is well planned and managed.

D. The most striking results overall

The most striking results overall are those that: (a) underline the relevance of IAQ in schools as a societal problem with clear impacts on the health, quality of life and learning performance of European schoolchildren; and (b) clearly indicate that a number of values and rules are still not fully implemented in our society in relation to IAQ and health in schools.

The SINPHONIE project provided evidence of the following:

- There is a high prevalence (3.6%) of children who ever had an asthma attack at school which represents about 250,000 cases among schoolchildren in Europe and a high prevalence of asthma attacks in the classrooms (up to 1.4%), which represents nearly 100,000 cases among schoolchildren in Europe.
- IAQ in classrooms varies significantly among the schools and cities in the 23 European countries that participated in the SINPHONIE survey depending on the

type, location (neighbourhood environment), age and management (including cleaning practices) of the school buildings.

- Children attending schools with elevated levels of air pollutants are at greater risk of suffering from health symptoms affecting their respiratory system.
- In 5% of schools, smoking is still permitted indoors, even if within a specific smoking area.
- In terms of occupation density, 8% of the classrooms provide less than 1.5 m^2/child, and 20% provide less than 2 m^2/child, which represents a high potential for quite low ventilation rates per capita (i.e. CO_2 concentrations well above 1,500 ppm) for the same commonly used air changes per hour, affecting children's health and learning performance.
- With respect to monitored indoor bio-contaminants, 50% of children and teachers were exposed to high levels of endotoxins and microbes in the current study.
- Almost 17% of teachers suffered from coughing or phlegm, 27% had suffered from a nasal allergy in their life and 9% had asthma diagnosed by a doctor.

Harmonised methodologies and protocols were also developed and implemented during the fieldwork to monitor IAQ and the health of children and teachers in schools in the large number of countries involved in SINPHONIE.

E. Causes and sources of health effects

During the monitoring of school building characteristics, certain parameters emerged as potentially relevant to IAQ-related health effects among schoolchildren. Potential causes and sources are highlighted below:

- *Outdoor sources*: 67% of the SINPHONIE schools were located near to traffic routes and 45% near to industrial areas. In these schools, there was higher exposure to particulate matter, NO_2 and benzene, according to the current study.
- *Soil*: 73% of the schools were located in low-radon zones and 4% in a radon risk zone. However, relevant information is missing for 23% of schools.
- *Construction and building management*: 61% of the SINPHONIE schools lacked wall insulation, 42% lacked roof insulation, 25% had air leakages and 7% presented visible mould growth with a certain level of biological contaminants.
- *Consumer products*: 63% of the SINPHONIE classrooms had blackboards and 46% contained one or more computer, printer or photocopier; 69% of the furniture in the classrooms was wood based; and a very low percentage of classrooms had been constructed using certified low-emission building materials. These products can increase the level of exposure in the classroom and affect the respiratory health of children and teachers.
- *Occupants' behaviour*: 5% of the SINPHONIE schools had a room set aside for smokers. Classroom ventilation conditions (operating mainly during breaks) were poor, resulting in high levels of CO_2 (in 20% of the classrooms the floor space per child was less than 2 m^2 and 86% of the schools used natural ventilation).

F. Guidelines for healthy school environments in Europe

SINPHONIE has produced guidelines for healthy school environments, which are published separately from this report. The translations of the guidelines are available on the SINPHONIE project's website: www.sinphonie.rec.org.

The guidelines are intended to be 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 at national or local level. Criteria for the uptake and implementation of the guidance into national policy measures and actions in European countries are also provided. The SINPHONIE guidelines are intended not to replace but rather to enrich and reinforce existing national and local guidance, which should continue to be the first point of reference.

The SINPHONIE guidelines promote a cost-effective preventive approach to achieving good IAQ in a given school environment, as opposed to a problem-based approach that seeks to solve problems after they have emerged.

The guidelines for healthy school environments in Europe are primarily directed to relevant policy makers at both European and national levels and to 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 that is expected to benefit directly from these guidelines includes school building designers and managers (responsible for the design, construction and renovation of school buildings). A third target group comprises schoolchildren and their parents, teachers and other school staff.

Overall, and in the context of a pragmatic centripetal approach (from outdoors to indoors, from the environment to the people and from sources and causes to health effects), the SINPHONIE guidelines for healthy school environments in Europe underline that, in future strategies and policies relating to the school environment, priority should be given to pollution source control that takes into consideration the aspects outlined below.

Location

- The proper management of urban pollution, particularly from the outdoor air and its major sources (e.g. transportation, traffic).
- Better control over the quality of the outdoor air that enters the school indoor environment by choosing "pollution-free" zones for new schools, by promoting compliance with the WHO guidelines for ambient air near existing schools, and by introducing stricter measures to improve traffic conditions in the vicinity of schools (e.g. within a radius of 1 km).
- Adequate radon prevention and mitigation strategies.

Building design, construction (including retrofitting) and maintenance

- The proper design and construction of school buildings, the selection of clean materials for new and retrofitted schools and the integration of features related to

energy, indoor air and comfort requirements into a holistic assessment at both the school building design and post-occupational phases.

- The elimination of moisture/mould and allergen sources in the school building.
- An appropriate strategy for heating and, where necessary, cooling, to ensure satisfactory temperature, relative humidity and ventilation in classrooms.
- An appropriate strategy for ventilation in classrooms by either natural or mechanical means.
- The decoupling, as far as possible, of heating/cooling functions from the ventilation function.
- The establishment of ventilation levels based on health criteria measurable in litres per second per person (l/s.person).

Management and use

- The definition and enforcement of maximum permitted occupation densities in classrooms to ensure appropriate levels of CO_2 with acceptable and affordable ventilation rates.
- The periodical monitoring of IAQ and health parameters in schools.
- The establishment of a manual of procedures for the proper use and management of the school indoor environment, in particular IAQ.
- The appropriate cleaning and maintenance of school buildings.
- The selection of low-emission products for cleaning and low-emission materials for school activities and teaching.
- The appropriate training of students, their parents and teachers, and the school staff responsible for the management, maintenance and cleaning of school buildings.
- The development and implementation of harmonised methodologies and protocols for IAQ assessment at different levels of complexity and/or exigency in European countries.
- A ban on environmental tobacco smoke in all school spaces.

G. Communication and dissemination

In the context of SINPHONIE, and taking advantage of the involvement of so many schools throughout Europe, a number of leaflets (translated into all EU languages) were produced containing recommendations and instructions aimed at schoolchildren, staff and parents on the main issues related to the operation and management of school buildings in order to achieve good IAQ. These were made available via the SINPHONIE project's website (www.sinphonie.rec.org).

5 Conclusions

It should be underlined that SINPHONIE, as a multidisciplinary study involving a wide array of parameters and actors, could not generate sufficient evidence in relation to some of its specific objectives to allow firm conclusions to be reached on complex topics such as the impacts of traffic on the indoor air or the impacts of climate change on IAQ in relation to health and comfort in school buildings 30 to 50 years from now.

Nevertheless, despite the diverse fields of application and the rich variety of cultural, technological, climatic and social aspects, SINPHONIE achieved important results and elaborated harmonised and standardised methodologies, which, if fully explored and implemented, can be expected to contribute to a healthier school environment in Europe in the years to come.

SINPHONIE favoured a holistic approach to IAQ in school environments, systematically linking health endpoints and environmental factors such as air pollution sources and causes, including consideration of the actual status of school buildings and their management. This helped to identify the full dimension of the issues to be addressed in order to find efficient solutions for improving overall air quality and health in European school environments.

The SINPHONIE findings clearly show that Indoor Air Quality is a real problem in schools in many European countries. There is evidence that many schools have high levels of air pollutants (above the recommended guideline values in the case of $PM_{2.5}$, formaldehyde, benzene and radon). In addition, 67% of the selected schools were located in the vicinity of a transportation axis; 20% of the schools were operating with occupation densities of less than 2 m^2/child; and smoking was still permitted in 5% of the monitored schools.

Schools are critical locations as children represent a particularly susceptible segment of the population to certain health determinants, including those related to IAQ. However, some of the findings that emerged during the SINPHONIE project underline the relevance of schools as buildings, most of which were constructed in the 1990s or earlier. Although 60% of the school buildings in Europe have been retrofitted to some extent since then, they are typically far from healthy, and this remains a priority challenge for future policies at both EU and national levels. This sometimes leads to an overemphasis on the need for ventilation, heating or cooling, and even a failure to consider the potential impacts of climate change.

The results of the SINPHONIE field studies indicate that, despite some significant differences in indoor temperatures depending on the geographical location of the school and on the existence of more or less adequate heating/cooling systems, the mean temperature values observed during the heating period were quite similar (around 20ºC), regardless of the region in which the buildings were located. That supports the hypothesis that in terms of the impact on the indoor environmental parameters of the foreseeable global warming and climate change, the values of those parameters may not be significantly conditioned by future trends of the outdoor climatic values.

Concerning the impacts of transportation and traffic, it is clear that related pollutants such as $PM_{2.5}$, NO_2, ozone and noise influence the indoor air quality in schools, especially those located in the proximity of busy roads. Here, there seems to be an interplay between two

factors. One is related to the age and location of the school buildings in European countries, many of which were planned and built when the roads were less busy and promised the benefits of easy accessibility without taking into account potential future trends in the pollution burden. The second is related to urban pollution itself, which is doubtless mainly, but not exclusively, due to transportation and traffic. Since the issue of IAQ in school buildings cannot be properly addressed without taking into account the quality of the ambient air, it is essential that the local/national authorities managing ambient air quality in their urban environments maximise their efforts to ensure that the ambient air respects WHO air quality guidelines.

In order to ensure the appropriate and efficient implementation of the guidelines and recommendations elaborated within the SINPHONIE project and aimed at healthy school environments in Europe, particular attention should be given to the following points:

- Good IAQ in schools is very much dependent on the school location, as the outdoor air is a major source of indoor pollution. In line with other policy trends at EU and WHO Europe level, it is therefore necessary to emphasise how important it is for cities to meet WHO ambient air quality guidelines. This is the only way to ensure suitable IAQ in buildings, including schools.
- School buildings should be designed taking into account advances in construction technologies and IAQ strategies, starting with source control through clean materials and construction products to the decoupling of heating/cooling functions from health-based ventilation. Due consideration must be given to climate and geography, materials and culture, ensuring a holistic approach to sustainability and prioritising efficiency whenever time and the management of resources is at stake.
- Priority should be given to simple but sound rules, free from technical buzzwords, social prejudices and cultural conditions, leading to appropriate school building management procedures that take into account the adequate knowledge and specificity of the actual building in its actual location and the proper use of resources (water, energy, educational materials, cleaning products, cleaning procedures) by approaching each school building as an actual children's "second skin" for many hours during a vulnerable period of their lives.
- Awareness-raising campaigns and trainings should be organised, aimed at children and their families, school staff, professionals, policy makers and the general public.

Decision making based on technically inadequate solutions, naïve interpretations and interventions that are weakly linked to scientific merit and foundations is the main cause of poor IAQ in European schools, as highlighted by SINPHONIE. The excellent cooperation between the EU and WHO Europe and the follow-up to promising political declarations (such as Parma 2010) will only be meaningful if the consistent steps, developments and recommendations set out in this report are taken on board.

References:

1. World Health Organization. *Air Quality Guidelines for Europe*. 2nd ed. Copenhagen: WHO Regional Office for Europe. 2000.
2. World Health Organization. *Air Quality Guidelines Global Update 2005: Particulate matter, ozone, nitrogen dioxide and sulfur dioxide*. 2005.
3. De Oliveira Fernandes, E., Jantunen, M., Carrer, P., Seppänen, O., Harrison, P., Kephalopoulos, S. EnVIE Co-ordination Action on Indoor Air Quality and Health Effects: Final Activity report. Project no. SSPE-CT-2004-502671, IDMEC, Porto, Portugal 2008.
4. World Health Organization. *Parma Declaration on Environment and Health*. 2010.
5. World Health Organization. *Development of WHO Guidelines for Indoor Air Quality*. Bonn, Germany: WHO Regional Office for Europe. 2006.
6. European Commission. *The European Union Environment and Health Action Plan 2004–2012*. 2004.
7. De Oliveira Fernandes, E., Gustafsson,H., Seppanen, O., Crump, D., Ventura, G., Madureira. J. et al. WP3 Final Report on the Characterization of Spaces and Sources. EnVIE Project. Brussels: European Commission 6th Framework Programme of Research. 2008.
8. ISAAC, The Global Asthma report, 2011, Paris, France
9. Jantunen, M., De Oliveira Fernandes, E., Carrer, P. and Kephalopoulos, S.. *Promoting actions for healthy indoor air (IAIAQ)*. Luxembourg: European Commission Directorate-General for Health and Consumer Protection. 2011.
10. Carrer, P., Wargocki, P., De Oliveira Fernandes, E., Kephalopoulos, S., Allard, F. Asikainen, A., Asimakopoulos, D., Asimakopoulou, M., Bischoff, W., Braubach, M., Brelik, N., Fanetti, A., Hänninen, O., Heroux, M-E., Jantunen, M., Hartmann, T., Leal, V., Malvik, B., Mustakov, T., Palkonnen, S., Popov, T., Salari, M., Salvi, R., Santamouris, M., Santos, H., Seppänen, O. - Framework for health-based ventilation guidelines in Europe. ECA report no. 30. European Commission DG Joint Research Centre, Luxembourg: Office for Official Publications of the European Communities. 2014 (in print).
11. AIRMEX: European Indoor Air Monitoring and Exposure Assessment. Available from: http://ihcp.jrc.ec.europa.eu/our_databases/airmex.
12. Franchi, M., Carrer, P. Kotzias, D., Rameckers, E.M.A.L., Seppänen, O., Bronswijk J.E.M.V., et al. *Towards Healthy Air in Dwellings in Europe*. The THADE Report: European Federation of Allergy and Airways Diseases Patients Associations. 2004.
13. Kotzias, D., Koistinen, K., Kephalopoulos, S., Schlitt, C., Carrer, P., Maroni, M. et al. *The INDEX project. Critical Appraisal of the Setting and Implementation of Indoor Exposure Limits in the EU*. Final Report. EUR 21590 EN: European Commission, Directorate-General, Joint Research Centre. 2005.
14. Csobod, E., Rudnai, P. and Vaskovi, E. *School Environment and Respiratory Health of Children (SEARCH)*. Szentendre. 2010.
15. Kephalopoulos S., Barrero-Moreno, J. Larsen, B., Geiss, O., Tirendi, S. and Reina, V. "PILOT INDOOR AIR MONIT AA final report". DG SANCO – DG JRC administrative arrangement PILOT INDOOR AIR MONIT (conract no. SI 2582843). March 2013.
16. World Health Organization. *WHO guidelines for indoor air quality: selected pollutants*. Copenhagen: WHO Regional Office for Europe. 2010.

SINPHONIE Partners: Institutions and Staff

1. REC, Regional Environmental Center for Central and Eastern Europe, HQ Hungary (coordinator)

Éva Csobod (Coordination Committee member), Péter Szuppinger, Réka Prokai, Petur Farkas, Cecilia Fuzi

REC Albania: Eduart Cani

REC Bosnia and Herzegovina: Jasna Draganic

REC Serbia: Eszter Réka Mogyorosy, Zorica Korac

2. IDMEC-FEUP, Instituto de Engenharia Mecânica – Faculdade de Engenharia da Universidade do Porto, Portugal

Eduardo de Oliveira Fernandes (Coordination Committee member), Gabriela Ventura, Joana Madureira, Inês Paciência, Anabela Martins, Ricardo Pereira, Elisabete Ramos

3. NIEH, National Institute of Environmental Health, Hungary

Peter Rudnai (Coordination Committee member), Anna Páldy, Gyula Dura, Tímea Beregszászi, Éva Vaskövi, Donát Magyar, Tamás Pándics, Zsuzsanna Remény-Nagy, Renáta Szentmihályi, Orsolya Udvardy, Mihály J. Varró

4. JRC, Joint Research Centre – Institute for Health and Consumer Protection, European Commission

Stylianos Kephalopoulos (Coordination Committee member), Dimitrios Kotzias, Josefa Barrero-Moreno

5. IPH-ALB, Institute for Public Health, Albania

Rahmije Mehmeti

6. IPH-BH, Institute of Public Health, Bosnia and Herzegovina

Aida Vilic, Daniel Maestro

7. IEH, Institute of Environmental Health, Medical University, Austria

Hanns Moshammer, Gabriela Strasser, Piegler Brigitte

8. UBA-A, Planning & Coordination Substances & Analysis, Umweltbundesamt GmbH, Austria

Philipp Hohenblum

9. VITO, Flemish Institute for Technological Research, Belgium

Eddy Goelen, Marianne Stranger, Maarten Spruy

10. National Centre for Public Health and Analysis, Bulgaria

Momchil Sidjimov

11. LGH, Larnaca General Hospital, Cyprus

Adamos Hadjipanayis

12. CSGL, State General Laboratory, Cyprus

Andromachi Katsonouri-Sazeides, Eleni Demetriou

13. NPHI-CZ, National Public Health Institute, Czech Republic

Ruzana Kubinova, Helena Kazmarová, Beatricia Dlouha, Bohumil Kotlík

14. HPI, Health Board, Estonia

Helen Vabar, Juri Ruut, Meelis Metus, Kristiina Rand, Antonina Järviste

15. THL, National Institute for Health and Welfare, Finland

Aino Nevalainen, Anne Hyvarinen, Martin Täubel, Kati Järvi

16. UPMC Paris 06, Université Pierre et Marie Curie Paris 06, France

Isabella Annesi-Maesano, Rive Solene, Soutrik Banerjee

17. CSTB, Centre Scientifique et Technique du Bâtiment, France

Corinne Mandin, Bruno Berthineau

18. UBA, Umweltbundesamt (Federal Environment Agency) – Indoor Hygiene Section, Germany

Heinz-Joern Moriske, Marcia Giacomini, Anett Neumann

19. UOWM, University of Western Macedonia, Greece

John Bartzis, Krystallia Kalimeri, Dikaia Saraga

20. NKUA, National Kapodistrian University of Athens, Greece

Mattheos Santamouris, Margarita Niki Assimakopoulos, Vasiliki Asimakopoulos

21. UMIL, Universitá degli Studio di Milano, Italy

Paolo Carrer, Andrea Cattaneo, Salvatore Pulvirenti, Franco Vercelli, Fabio Strangi, Elida Omeri, Silvia Piazza, Andrea D'Alcamo, Anna Clara Fanetti

22. USiena, Università degli Studi di Siena, Italy

Piersante Sestini, Magdalini Kouri

23. CNR Palermo, National Research Council (CNR) – Institute of Biomedicine and Molecular Immunology (IBIM), Palermo, Italy

Giovanni Viegi, Giuseppe Sarno, Sandra Baldacci, Sara Maio, Sonia Cerrai, Vincenzo Franzitta, Salvatore Bucchieri, Fabio Cibella, Sara Maio

24. FSM, Fondazione Salvatore Maugeri, Italy

Margherita Neri

25. KTU, Kaunas University of Technology, Lithuania

Dainius Martuzevičius, Edvinas Krugly

26. University of Malta, Malta

Stephen Montefort, Peter Fsadni

27. IOMEH, Institute of Occupational Medicine and Environmental Health, Poland

Piotr Z. Brewczyński, Ewa Krakowiak, Jolanta Kurek, Elżbieta Kubarek, Agnieszka Wlazło

28. UAVR CESAM, University of Aveiro – Centre for Environmental and Marine Studies Portugal

Carlos Borrego, Célia Alves, Joana Valente

29. UBB, Babes-Bolyai University, Romania

Eugen Gurzau, Cristina Rosu, Gabriela Popita, Iulia Neamtiu, Cristina Neagu

30. UU, Uppsala University, Sweden

Dan Norback

31. TNO, Netherlands Organisation for Applied Scientific Research, The Netherlands

Phylomena Bluyssen, Michel Bohms

32. HVDGM, Public Health Service Gelderland Midden, The Netherlands

Peter Van Den Hazel

33. RIVM, Rijksinstituut voor Volksgezondheid en Milieu (National Institute for Public Health and the Environment), The Netherlands

Flemming Cassee, Yuri Bruinen de Bruin

34. NILU, Norsk Institutt for Luftforskning (Norwegian Institute for Air Research), Norway

Alena Bartonova, Aileen Yang

35. PHA-SK, Public Health Authority, Slovakia

Katarína Halzlová, Michal Jajcaj, Milada Kániková, Olga Miklankova, Marianna Vítkivá

36. IV, Institute Vinca, Serbia

Milena Jovsevic-Stojanovic, Marija Zivkovic, Zarko Stevanovic, Ivan Lazovic, Zana Stevanovic

37. MC, Dr Dragisa Misovic Medical Centre, Serbia

Zorica Zivkovic, Sofija Cerovic, Jasmina Jocic-Stojanovic

38. UCL, University College London, UK

Dejan Mumovic, Paula Tarttelin, Lia Chatzidiakou, Evangelia Chatzidiakou

Associated Partner

39. Hainaut Public Health Institute, Belgium

Marie-Christine Dewolf

Advisory Committee

ISPRA, Institute for Environmental Protection and Research, Italy

Luciana Sinisi

REHVA, Federation of European HVAC Associations, Belgium

Oli Seppanen

ERS, European Respiratory Society

Nadia Kamel

HEAL, Health & Environment Alliance

Genon K. Jensen, Anne Stauffer

King's College E&H, UK

Frank Kelly

EFA, European Alliance of Asthma and Allergy Associations

Susanna Palkonen

Ministry for Rural Development, Hungary

Zsuzsanna Pocsai

Consulting Tank Experts

ITF, Italian Trust Fund, Ministry for the Environment, Land and Sea, Italy

Stefania Romano

MoH-CY, Ministry of Health, Cyprus

Stella Michaelidou-Canna

DTU, Technical University of Denmark

Pawel Wargocki

Aarhus University, Denmark

Torben Sigsgaard

European Commission
EUR 26730 EN – Joint Research Centre – Institute for Health and Consumer Protection

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Author(s): Éva Csobod, Isabella Annesi-Maesano, Paolo Carrer, Stylianos Kephalopoulos, Joana Madureira, Peter Rudnai, Eduardo de Oliveira Fernandes, Josefa Barrero-Moreno, Tímea Beregszászi, Anne Hyvärinen, Hans Moshammer, Dan Norback, Anna Páldy, Tamás Pándics, Piersante Sestini, Marianne Stranger, Martin Täubel, Mihály J. Varró, Eva Vaskovi, Gabriela Ventura and Giovanni Viegi

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