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On the Contribution of Schools to Children's Overall Indoor Air Exposure

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by

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To Mãe,

and Pai,

with my love.

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List of Publications

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2. Joana Madureira, Inês Paciência, Eduardo de Oliveira Fernandes. 2012. Levels and indoor-outdoor relationships of size-specific particulate matter in naturally ventilated Portuguese schools. Journal of Toxicology and Environmental Health, Part A, 75:1423–1436.

Publications in Scientific Meetings with complete paper

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2. Joana Madureira, Milton Severo, Joana Teixeira, Inês Paciência, Elisabete Ramos, Gabriela Ventura, Henrique Barros, Eduardo de Oliveira Fernandes. 2014. Indoor air quality in public primary schools in Porto and its dependence on building characteristics. In: Proceedings of 13rd International Conference on Indoor Air Quality and Climate. July 7-12. Hong Kong. *Accepted*.
3. Joana Madureira, Inês Paciência, Gabriela Ventura, E. Oliveira Fernandes. Exposure of children to VOCs in European schools and homes environments: a systematic review. 2013. Occupational Safety and Hygiene. CRC Press. ISBN 978-1-138-00047-6. Pages 457-462. http://www.crcpress.com/product/isbn/9781138000476.
4. Joana Madureira, Inês Paciência, Marianne Stranger, Gabriela Ventura, Eduardo de Oliveira Fernandes. 2012. Field study on schoolchildren's exposure to indoor air in Porto, Portugal - Preliminary results. In: Proceedings of 10th International Conference HB2012. July 8-12, 2012, Brisbane, Australia. Paper ID: 4C4.

5. Joana Madureira, Inês Paciência, Elisabete Ramos, Henriques Barros, Eduardo de Oliveira Fernandes. 2012. A Cross-sectional Study of the Effect of Indoor Environment on Health Problems among Schoolchildren - Preliminary Results. In: Proceedings of 10th International Conference HB2012. July 8-12, 2012. Brisbane, Australia. Paper ID: 4C7.

6. Joana Madureira, Inês Paciência, Ricardo Pereira, Eduardo de Oliveira Fernandes. 2012. Particulate matter concentrations in naturally ventilated classrooms - results from Portuguese schools. In: Proceedings of International Congress on Environmental Health (ICEH 2012). May 29th-June 1st 2012. Lisboa. p. 167-8.

7. Joana Madureira, Inês Paciência, Elisabete Ramos, Henrique Barros, Eduardo de Oliveira Fernandes. 2012. Indoor Air Quality in Primary Schools and in Homes and its Impact on Children's Health - Study Design in João Santos Baptista, A. S. Miguel, Gonçalo Perestrelo, Nelson Costa, Mónica Barroso, Pedro Arezes, P. Carneiro, P. Cordeiro, Rui Melo. SHO 2012: International Symposium on Occupational Safety and Hygiene. ISBN 978-972-99504-9-0: 344-349.

8. Joana Madureira and Eduardo de Oliveira Fernandes. 2011. Human Exposure to Indoor Air: the Portuguese Case. In: Arezes, P; Baptista, JS; Barroso, MP; Carneiro, P; Cordeiro, P; Costa, N; Melo, R; Miguel, AS; Perestrelo, GP. SHO2011: International Symposium on Occupational Safety and hygiene. ISBN: 978-972-99504-7-6: 373-377.

Publications in Scientific Meetings with abstract

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2. Joana Madureira, Inês Paciência, Elisabete Ramos, Henrique Barros, Eduardo de Oliveira Fernandes. 2012. Association between indoor environment characteristics of homes and respiratory symptoms in schoolchildren. Eur J Epidemiol. 27:S1-S197. DOI 10.1007/s10654-012-9722-6.

Other Publications

1. WHO/Europe. 2011. Methods for monitoring indoor air quality in schools. Report from the meeting 4-5 April 2011. Bonn, Germany. Scherfigsvej 8 DK-2100 Copenhagen, Denmark.

Abstract

The effects of exposure to pollution on asthma, allergies and other respiratory symptoms in children have been of growing concern over the recent decades. Although a number of environmental and epidemiological studies have been carried out in the field, the results are somehow conflicting and data regarding indoor air exposure are still scarce. The main objective of this thesis is to further the study of indoor air quality (IAQ) in schools and at homes towards the understanding of its impact on children's health targeting asthma, allergy and respiratory symptoms.

A cross-sectional study including a total of 1134 children (participation rate of 69.2%), with a mean age of 8.6 years (standard deviation=0.7), from 73 classrooms of 20 public primary schools located in the city of Porto, Portugal; and a case-control study in 68 homes of asthmatic (case) and non-asthmatic children (control) were carried out in the heating season of the years between 2011 and 2013. The child health information was obtained using a self-administered questionnaire completed by the parents based on the ISAAC (International Study of Asthma and Allergies in Childhood) questionnaire; and by spirometry, exhaled nitric oxide (eNO) and tear film stability tests performed at school by trained health professionals. Measurements of volatile organic compounds (VOC), formaldehyde, acetaldehyde, carbon monoxide, $PM_{2.5}$, PM_{10}, CO_2, temperature, relative humidity, bacteria and fungi were conducted both indoors and outdoors. School building and classrooms characteristics were collected via a walkthrough inspection and checklist fulfillment. In the case-control study, parameters, methods and procedures were the same used in the IAQ assessment at schools.

The results suggest that at school children exposed to total VOC at levels above 189.84 $\mu g/m^3$ had a twofold increased risk of having asthma-related symptoms. Those findings are supported by the results of spirometry and eNO. In addition, higher $PM_{2.5}$ and PM_{10} levels increase the odds of asthma-like symptoms; the association being stronger for PM_{10}. Thus, the present study supports the pro-inflammatory role of particulate matter, especially among the most susceptible children. In addition, no significant association was found between the indoor air parameters at home and asthma; however the effect of lack of statistical power or a reverse causality cannot be excluded.

In general, in spite of the most indoor air parameters in the schools evaluated as part of this study are in accordance with IAQ guidelines/recommendations; exposure to indoor air could increase respiratory complaints among children.

The results are in general consistent with the existing literature and, although limited to the field of asthma, allergies and respiratory symptoms in childhood, contribute with new information on school and home environments in Portugal and their relationship with children health.

Resumo

A manifestação da asma, alergias e outros problemas respiratórios nas crianças associados à exposição à poluição do ar tem justificado o crescente número de estudos. Apesar da existência de estudos epidemiológicos nesta área, estes revelam inconsistências e são ainda escassos no que diz respeito à exposição ao ar interior. O objetivo desta tese é contribuir para o melhor conhecimento da asma, alergias e outros sintomas do foro respiratório nas crianças através do aprofundamento do estudo da sua interação com a QAI.

Esta tese compreende um estudo transversal que envolveu um total de 1134 crianças (taxa de participação de 69.2%), com uma média de idades de 8.6 anos (desvio padrão=0.7), de 73 salas de aula de 20 escolas públicas do 1º ciclo do ensino básico situadas na cidade do Porto-Portugal; e um estudo caso-controlo que incluiu 68 casas de crianças asmáticas (caso) e de crianças não-asmáticas (controlo), ambos efetuados em período de aquecimento entre 2011-2013. No estudo transversal, a informação relativa ao estado de saúde das crianças e do ambiente das suas habitações foi recolhida através de um questionário preenchido em casa pelos pais, baseado no questionário do ISAAC (International Study of Asthma and Allergies in Childhood), e através da realização de espirometria, da quantificação do óxido nítrico no ar exalado (eNO) e da estabilidade do filme lacrimal. Na componente ambiental foram efetuadas medições de compostos orgânicos voláteis (COV), formaldeído, acetaldeído, monóxido de carbono, $PM_{2.5}$, PM_{10}, CO_2, temperatura, humidade relativa, bactérias e fungos. As caraterísticas do edifício e espaços individuais foram obtidas através de visitas aos locais e preenchimento de uma *checklist* validada. No estudo caso-controlo foram avaliados os mesmos parâmetros, usados os mesmos métodos e procedimentos de medição da QAI utilizados nas escolas.

Os resultados, suportados pela espirometria e níveis de eNO, apontam para que crianças expostas a concentrações de COV totais superiores ou iguais a 189.84 $\mu g/m^3$ apresentem o dobro do risco de exibirem sintomas de asma. Da mesma forma, um aumento da concentração de $PM_{2.5}$ e PM_{10} corresponde a uma maior probabilidade de ocorrência de sintomas de asma, sendo a associação mais forte para as PM_{10}. Assim, o presente estudo suporta o papel pró-inflamatório das partículas, nomeadamente nas crianças mais sensibilizadas. No presente estudo não foi observada associação estatisticamente significativa entre os parâmetros da QAI medidos no quarto das crianças e a presença de asma. No entanto, não deverá ser excluído o efeito de falta de poder estatístico ou de causalidade inversa.

Em geral, apesar de a maioria dos parâmetros do ar interior nas escolas avaliadas cumprirem as recomendações da QAI; a exposição ao ar interior pode aumentar as queixas respiratórias entre as crianças.

Embora restringidos à asma, alergias e sintomas respiratórios nas crianças, os resultados são, de uma maneira geral, consistentes com a literatura existente e, fornecem nova informação sobre a QAI em escolas e residências de Portugal e da sua relação com a saúde das crianças.

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List of Acronyms and Abbreviations

AIRMEX	European Indoor Air Monitoring and Exposure Assessment
ATS	American Thoracic Society
ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineers
aOR	Adjusted Odds Ratio
BiBa	Indoor Air in Primary Schools
BMI	Body Mass Index
SBUT	Self-reported Break-Up-Time
CFU/m^3	Colony forming units per cubic metre
CI	Confidence Interval
CO	Carbon monoxide
CO_2	Carbon dioxide
CPD	Construction Product Directive
DALY	Disability-Adjusted Life Year
DL	Detection Limit
2,4-DNPH	2,4-dinitrophenylhydrazine
EC	European Commission
ECRHS	European Community Respiratory Health Survey
EFA	European Federation of Allergy and Airways Diseases Patients Association
eNO	Exhaled nitric oxide
EnVIE	Co-ordination Action on Indoor Air Quality and Health Effects
EPBD	Energy Performance of Buildings Directive
EPHECT	Emissions, Exposure Patterns and Health Effects of Consumer Products in the EU
ERS	European Respiratory Society
ETS	Environmental Tobacco Smoke
EU	European Union
$FEF_{25-75\%}$	Forced expiratory flow 25-75%
FEV_1	Forced Expiratory Volume in 1 second
FEV_1/FVC	FEV_1/FVC ratio
FVC	Forced Vital Capacity
GINA	Global Initiative for Asthma
GPSD	General Product Safety Directive
HealthVent	Health-Based Ventilation Guidelines for Europe
HESE	Health Effects of Schools Environment
HITEA	Health Effects of Indoor Pollutants: Integrating Microbial, Toxicological and Epidemiological Approaches
IARC	International Agency for Research Cancer
IAQ	Indoor Air Quality
ICC	Intra-class Correlation Coefficient
IDMEC-FEUP	Institute of Mechanical Engineering / Faculty of Engineering of University of Porto

IgE	Immunoglobulin E
EU-INDEX	Critical Appraisal of the Setting and Implementation of Indoor Exposure Limits
I/O ratio	Indoor/outdoor ratio
ISAAC	International Study of Asthma and Allergies in Childhood
JRC	Joint Research Centre
LARES	Large Analysis and Review of European Housing and Health Status
MEA	Malt extract agar
NO_2	Nitrogen dioxide
OR	Odds Ratio
P25	25^{th} Percentile
P75	75^{th} Percentile
PAH	Polycyclic Aromatic Hydrocarbons
PCA	Principal Component Analysis
$PM_{2.5}$	Particulate matter with aerodynamic diameter smaller than or equal to 2.5 µm
PM_{10}	Particulate matter with aerodynamic diameter smaller than or equal to 10 µm
Porto-MA	Porto Metropolitan Area
ppm	Parts per million
PVC	Polyvinyl chloride
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals Regulation
REHVA	Federation of European Heating, Ventilation and Air-conditioning Associations
SaudAR	Health and The Air We Breathe
SD	Standard Deviation
SEARCH	School Environment and Respiratory Health of Children
SINPHONIE	Schools Indoor Pollution and Health: Observatory Network in Europe
T3CE	Trichloroethylene
T4CE	Tetrachloroethylene
THADE	Towards Health Air in Dwellings in Europe
TSA	Tryptic soy agar
TVOC	Total Volatile Organic Compounds
VOC	Volatile Organic Compounds
WHO	World Health Organization

1. Introduction

1.1 Scope and Rationale

The research that supports this thesis was carried out from 2011 to 2013 in the context of the Doctoral Program in Occupational Safety and Health of the University of Porto and was developed at the Unit of Advanced Studies on Energy in the Built Environment of the Institute of Mechanical Engineering / Faculty of Engineering of the University of Porto (IDMEC-FEUP). This thesis, entitled "On the Contribution of Schools to Children's Overall Indoor Air Exposure" is focused on the association between children's health and exposure to indoor air pollutants in the school and at home, with a special focus on asthma, allergy and respiratory symptoms.

Human exposure occurs when a person comes into contact with a pollutant at a certain concentration during a certain period of time (Nieuwenhuijsen, 2003; Ott, 1995; Ott, 1982). This means that exposure requires both a pollutant and an exposed subject. People can be exposed to pollutants through inhalation, ingestion and dermal contact, but for most pollutants breathing is the most common pathway to exposure (ECA 22, 2000). Exposure to airborne pollutants occurs both outdoors and indoors, but the present study will focus exclusively on a subset of indoor environments, namely, school buildings and residential. There are many other indoor environments such as aircraft and automobiles which this study will not address. Occupational environments are also not considered in the present study.

The risk of exposure to indoor air follows a "chain of events" starting at a pollutant source emitting at a given rate and ending with a dose at the subject's body capable of causing a certain health effect. The dose and dose-response are outcomes of an exposure to a particular pollutant (Ott, 1982).

A given environment usually contains several substances which may interact among themselves originating new substances *in loco* or which may have additive and synergistic effects within the human body (Billionnet *et al.*, 2011). This type of interaction, added to the diversity of indoor microenvironment to which a person is routinely exposed, may in some cases make for a difficult identification of the causal relationships and of the paths between source and bodily impact.

People today live mostly indoors, with indoor environments accounting for 90% of the lifetime of European populations. Each indoor microenvironment has unique characteristics and constitutes a basic breathing and dermal exposure background. As people come into contact with many different microenvironments and their time of residence in each environment is variable, the total indoor exposure will be determined by the concentration of the specific pollutant in each indoor microenvironments to which the person is exposed and by the time spent in each microenvironment (Annesi-Maesano *et al.*, 2012; Stranger *et al.*, 2007).

A model to approach the indoor air pollution from causes and sources to exposures and health effects has been proposed by the European research project EnVIE (Co-ordination Action of Indoor Air Quality and Health Effects) (Oliveira Fernandes *et al.*, 2008) sponsored by DG Research. This model aims to provide an effective and holistic strategy for risk assessment and risk management regarding indoor air quality (IAQ) in the built environment. EnVIE addresses the aforementioned "chain of events" in the inverse order starting with the "health effects" and proceeding through "exposures" to "causes and sources" considering the latter as the actual targets of all policy and strategy for the risk management of the indoor air pollution problem.

In keeping with EnVIE's rationale, this thesis dedicates its chapters addressing health effects in the first place, focusing in the particular case of asthma, allergy and respiratory symptoms attributed or attributable to exposure to indoor air pollution.

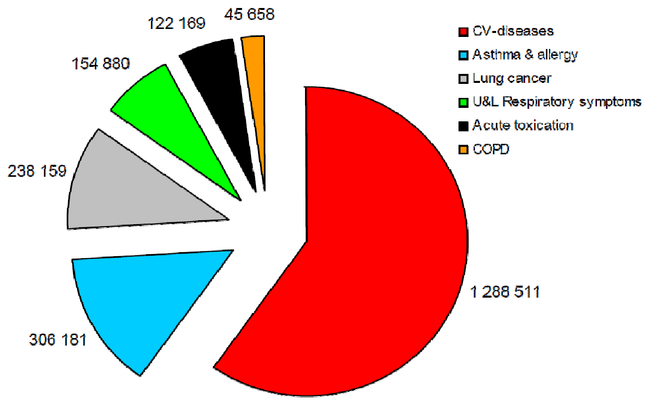
1.2 Health Effects of Indoor Air

The assessment of the health impacts of indoor air pollution usually entailing epidemiological studies occasionally complemented by toxicological studies led to a scientific basis for proposing acceptable concentration or exposure thresholds for specific pollutants (ECA 22, 2000). The state-of-the-art in pollutants risk assessment is currently represented by the World Health Organization (WHO) (indoor) air quality guidelines. These guidelines take the form of limiting values for a pollutant-set of concentrations or exposures, derived from the best and most universally representative data currently available at the world scale.

The IAIAQ (Promoting Actions for Healthy Indoor Air) report has recently estimated the burden of disease attributable to major indoor air exposures in 26 European countries at 2 million Disability-Adjusted Life Year (DALY)[1], i.e. two million years of healthy life are lost annually (Jantunen *et al.*, 2011). The same report identifies the most important diseases caused or aggravated by indoor air exposures: cardiovascular diseases; asthma and allergy; lung cancer; (upper and lower) respiratory infections/symptoms; acute toxication and chronic obstructive pulmonary disease (Figure 1).

The magnitude of IAQ health effects and of their expression in terms of DALY makes clear that IAQ management needs particular attention. Besides better knowledge at all levels, there is a need for better strategies and policies and better assessment and monitoring methods.

[1] DALY for a disease or health condition are calculated as the sum of the years of life lost due to premature mortality in the population and the years lost due to disability for people living with the health condition or its consequences (WHO [online]).

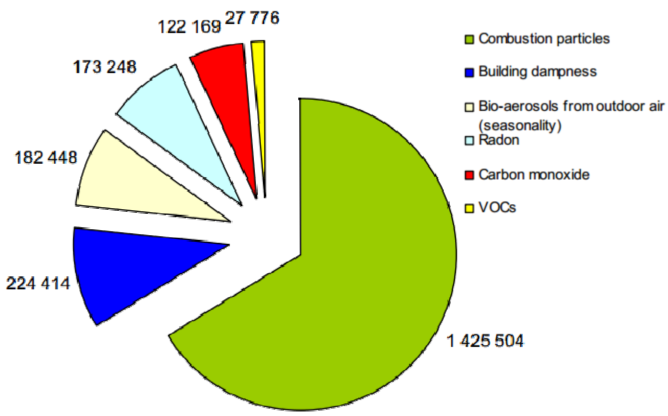


CV-diseases: cardiovascular diseases; U&L respiratory symptoms: (upper and lower) respiratory infections/symptoms; COPD: Chronic obstructive pulmonary disease.

Figure 1 Burden of disease associated with indoor air quality, discriminated by key health outcomes

1.3 Exposure Agents, Causes and Sources of Indoor Air

Having identified the health effects, the following step is the investigation of exposures, causes and sources of indoor air pollution. The aforementioned IAIAQ report paints a portrait of the current burden of disease associated with IAQ in terms of key exposure agents (Figure 2) and key sources of exposure, allowing for an explicit ranking of source typology by relevance (Figure 3) (Jantunen *et al.*, 2011).



VOC: Volatile organic compounds.

Figure 2 Burden of disease associated with indoor air quality, discriminated by key exposure agents

Figure 2 and Figure 3 reveal that ambient (or outdoor) air generally contains critical pollutants in significant concentrations (Jantunen *et al.*, 2011). The air that is breathed indoors is in most cases drawn from the outdoor environment; therefore when outdoor air is not clean it becomes a particularly critical source of indoor pollution.

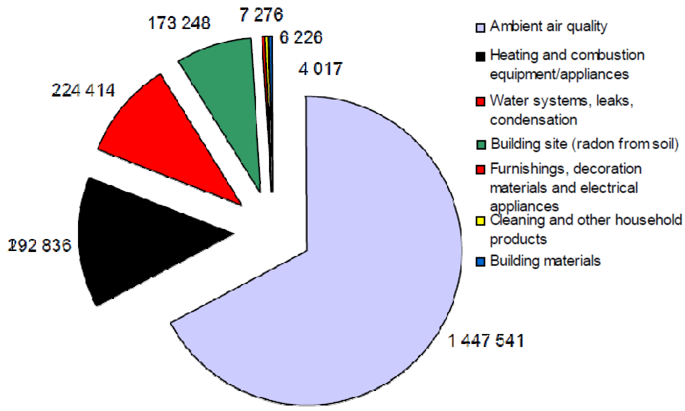


Figure 3 Burden of disease associated with indoor air quality, discriminated by key sources of exposure

Outdoor air pollution has long been a cause for concern in industrialized countries, mainly due to the fossil fuels which fed the industrialization boom, aggravated since the middle of the past century by accelerated urbanization and generalized motorization. There are many unfortunate historical events, being associated with particulate matter from industrial emissions and vehicle fuels and leading to premature death of hundreds of people. An example is the 4000 excess deaths due to respiratory (mainly bronchitis and emphysema) and cardiovascular diseases registered in the Great Fog of London in 1952, attributed to the reliance on coal for domestic heating combined with specific meteorological conditions (Mayor of London, 2002).

Many research and political actions were undertaken in the last 50 or 60 years and many are still ongoing with the aim of ensuring the proper management of ambient air quality and control pollutants such as airborne particulate matter, nitrogen dioxide (NO_2), etc. Despite the great progress made, there are still many cities in the world that cannot claim to have proper ambient air quality and are indeed far from satisfying the WHO air quality guidelines. The European Commission (EC) launched on the 18th of December of 2013 a comprehensive and judiciously scaled clean air policy package to promote clean urban air (EC IP/13/1274, 2013). The main components of the package are: 1) a “Clean Air Programme for Europe”, which sets out new interim objectives for reducing health and environmental impacts up to 2030; it also defines the emission reduction requirements for key pollutants and the policy agenda needed to achieve the objectives; 2) a revised “National Emission Ceilings Directive” containing updated national ceilings for six key air pollutants (particulate matter, sulphur dioxide, nitrogen oxides, volatile organic compounds, ammonia and methane) for 2020 and 2030; and 3) a new directive for medium-sized combustion plants between 1 and 50 MW (thermal).

Safeguarding clean ambient air falls within the remit of public authorities. It becomes an indoor pollution problem when outdoor pollutants are carried into building through supposedly controlled openings (windows, doors, specific inlets and outlets), unintended and uncontrolled openings (leaks, cracks, etc.) and, even, through mechanical systems that fail to block the pollutants.

Mechanical systems equipped with filtering and, less commonly, washing capabilities have been proposed as the answer to polluted outdoor air and have even been made mandatory in some countries. This need not become a generalized solution if all actors including national and municipal public authorities work towards ensuring clean ambient air and adopt appropriate measures for the location, design and management of buildings, keeping in mind the characteristics of the geography and consequent climate conditions, present and foreseen according to climate change projections. This is particularly true for the Southern European belt where climate and cultural traditions going back for millennia allow for an effective continuity between indoor and outdoor environments which are in more or less permanent contact through open doors and windows throughout most of the year.

New and more demanding requirements for thermal comfort and energy efficiency have also affected IAQ. Starting in 1973, the successive worldwide energy shocks have induced advances in energy efficiency and in correlated building construction technologies such over-insulation and air tightness that have not been without negative impact on the IAQ. In an effort to reduce energy demand in commercial and residential buildings, there has been a trend towards better sealed buildings and to lower ventilation rates. Non-openable windows also became more common, firstly in commercial buildings with central air conditioning and later in other building types (Clausen *et al.*, 2011; Larsson, 2010). Low ventilation rates may cause increased concentrations of indoor-generated pollutants and have been associated with increased indoor air humidity and, therefore, higher risk of dampness in dwellings as well as mould and dust mite infestations (Emenius *et al.*, 1998; Sundell *et al.*, 1995). While it is true that lower ventilation rates are a factor in the increase in humidity-related building pathologies and indoor pollution, it does not follow that a return to higher ventilation rates is the right answer. Reducing the concentration of indoor pollutants through dilution must remain as a second-tier action that may even be dispensed with after first-tier actions have been taken to reduce the pollution sources. Ventilation rates are part of the *menu* of technical options available to solve specific problems but are not a general panacea.

Along with the trend toward such constructions, and besides the penetration of the (polluted) air from outdoors, the last 50 years have seen a marked increase in chemical contaminants in the built environment due to new building materials, interior furnishings and consumer products such as cleaning agents and other household products (Weschler, 2009). In the last decade the focus of research and policy has also started to shift from primary emissions towards secondary emission phenomena such as the products of ozone-initiated indoor chemistry (Bornehag *et al.*, 2004a; Bornehag *et al.*, 2004b; Weschler, 2004) and the chemicals and biological particles arising from the growth of microorganisms on interior surfaces (Fisk *et al.*, 2007; Adan, 1994).

In practice, each indoor environment has unique characteristics determined by: a) the local outdoor air, the type of activity in the surroundings and the environment quality; b) the specific building characteristics (e.g. construction and cladding materials, furniture and decorations, occupant behaviour and maintenance procedures); and c) the air system in itself, i.e. the means of ventilation (Figure 4).

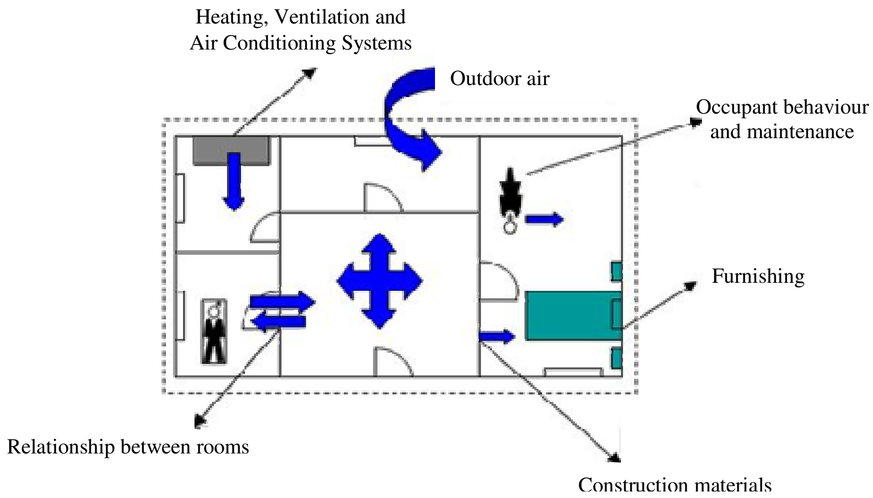


Figure 4 The indoor environment as a result of complex interactions

Thus, indoor air pollution contains a wide range of pollutants which can be of biological origin (e.g. moulds), physical (e.g. particulate matter) and chemical (e.g. aldehydes). Extensive characterization of the pollution sources has taken place in the last 20 years through on site audits and laboratory emissions tests. Some knowledge regarding IAQ audits has been acquired at the EU level following the 1992-1994 audit of IAQ in offices conducted in nine EU countries under the auspices of the Joule Program (CEC-DGXII) (Bluyssen *et al.*, 1996) and others significant epidemiological and public health studies at EU level such as the THADE (Towards Health Air in Dwellings in Europe) project (Franchi *et al.*, 2004) and the AIRMEX (European Indoor Air Monitoring and Exposure Assessment) project (Kotzias *et al.*, 2009). Each of these projects had specific purposes but in overall aimed to increase the knowledge regarding the IAQ situation in Europe. Among the more recent projects, SINPHONIE (Schools Indoor Pollution and Health: Observatory Network in Europe) (2010-2012) merits a special mention, having covered over 6000 children and 1000 teachers in 25 countries (http://sinphonie.eu/). In addition, the study of the potential indoor pollution from consumer and household products languished for years but recent advances have led to the development of guidelines to promote the control of some consumer products (https://esites.vito.be/sites/ephect/Pages/home.aspx).

Indoor air quality has whole-building implications but is most properly a space-specific issue, as the spaces defined by the partitions often have quite specific and disparate requisites. Yet, it is well known that the practical intervention in the building stock in what regards IAQ is not indifferent to the typology of the buildings or spaces. Buildings such as offices, schools or homes are so different in their scope and use that it makes full sense to refer in this case to schools as a special case in the context of IAQ polices; primarily, of course, because children are a particularly susceptible group of the population (Simoni *et al.*, 2010; Geller *et al.*, 2007; Salvi, 2007; Heath and Mendell, 2004).

1.4 Health-Based Guidelines

There is no dedicated European legislation for IAQ except in what regards the ban on tobacco smoke in public buildings and commercial establishments (EU, 2004). In addition, there is a number of ventilation standards in different Member States for residential and non-residential buildings and a wide spectrum of initiatives in several EU Member States have been promoted regarding the labelling of materials and products and the survey of some specific environments such as schools. Very recently the Federation of European Heating, Ventilation and Air-conditioning Associations (REHVA) called for an EC initiative to coordinate the different policies dealing with the built environment and harmonize methods and procedures regarding building construction, ventilation and energy systems, etc (REHVA, 2013). Great progress is therefore ongoing on IAQ management, based on initiatives by Member States, some EC Directorates-General and other institutions. There is a widely recognized need for a horizontal policy framework which spans safety, health, energy efficiency and sustainability aspects across existing legislative instruments and standardization activities related to the built environment.

Meanwhile DG SANCO undertook a relevant breakthrough promoting a number of high-grade projects such as IAIAQ, HealthVent (Health-Based Ventilation Guidelines for Europe), EPHECT (Emissions, Exposure Patterns and Health Effects of Consumer Products in the EU), SINPHONIE, etc., while from the EC side, Joint Research Centre (JRC) has been for the last 25 years a true leader in what regards IAQ through the “European Collaborative Action on Urban Air, Indoor Environment and Human Exposure” (http://ihcp.jrc.ec.europa.eu/our_activities/public-health/indoor_air_quality/eca/eca-publications).

At this stage it is particularly relevant to underline also the leadership of the WHO in developing air quality guidelines since 1987 (WHO, 1987). These guidelines are addressed to the whole world in an attempt to produce a set of reference values grounded on epidemiological studies and toxicological information. These guidelines were originally intended to apply to the outdoor air, although this was only implicit in the guidelines (WHO, 2005; 2000).

In general, the prerequisites of WHO in what regards ambient air quality may seem unrealistic or unattainable for urban locations as the ambient air in many cities is far from meeting WHO air quality guidelines. It must be recognized that outdoor and indoor air are basically the “same air”, i.e. the indoor air inherits characteristics of the outdoor air but entails much higher exposure durations. It should also be recognized how important and strategic the WHO prerequisites are as it puts pressure on public authorities who have the obligation to provide a healthy environment to their citizens, including good air quality that does not increase health risks. If the ambient or urban air in some cities is not clean, the political question is to know if it makes more sense to place more emphasis on improving outdoor air quality, which entails certain types of measures and delegation of responsibilities, in particular if the city should be considered as "smart city", "sustainable city" or "intelligent city", or if the emphasis should be on IAQ where the measures and responsibilities fall on the building level and may entail ventilation systems that include air filtering and washing air capabilities, further isolating the buildings from the influence of their surroundings. In this context mechanical ventilation should not be considered as imperative only because it is easier to filter ambient air than to make it less polluted. Whichever solution is entertained, the air entering the building for ventilation should always meet WHO guidelines.

Recently, WHO produced specific guidelines for indoor air (WHO, 2010c; 2009b). The primary aim of the WHO IAQ guidelines is "to provide a uniform basis for the protection of public health from adverse effects of indoor exposure to air pollution, and to eliminate or reduce to a minimum exposure to those pollutants that are known or are likely to be hazardous". These guidelines are not intended as a model for legislation in any country, EU Member State or not. The guidelines are "targeted at public health professionals involved in preventing health risks from environmental exposures as well as specialists and authorities involved in the design and use of buildings, indoor materials and products". The guidelines are a reference for risk assessment and risk management as they "are based on the accumulated scientific knowledge available at the time of their development". They have the character of recommendations. Nevertheless, countries may wish to reference the guidelines as a scientific basis for legally enforceable standards or legislation (WHO, 2010c).

The air quality guidelines and the guidelines addressing IAQ differ only in the specific criteria for particulate matter which are not specifically mentioned in the IAQ guidelines although they considerably contribute to the pollution indoors, and the biological pollutants which are only mentioned in the IAQ guidelines.

The "WHO Guidelines for Indoor Air Quality: Selected pollutants" (WHO, 2010c) recommend targets for nine air pollutants playing a specific role in indoor air. The nine selected substances considered in these guidelines are: *benzene*, *carbon monoxide*, *formaldehyde*, *naphthalene*, NO_2, *polycyclic aromatic hydrocarbons* (especially benzo[*a*]pyrene), *radon*, *trichloroethylene* and *tetrachloroethylene*.

The selection of substances has been done considering information on the existence of indoor sources, on the availability of epidemiological and some toxicological data and on exposure levels causing health concerns. Based on the accumulated evidence, the experts formulated health risk evaluations and agreed on the guidelines presented in Table 1 for each of the pollutants.

In support of the development of health-based policies concerning the exposure of populations to chemical substances, the Institute for Health and Consumer Protection of the European Commission's JRC has launched a series of projects. At first, within the frame of the EU-INDEX project (Critical Appraisal of the Setting and Implementation of Indoor Exposure Limits), a priority list of chemical substances present in indoor air was set up on the basis of health impact criteria (Kotzias *et al.*, 2005). Highest priority was given to five chemical substances that were found to be present in elevated concentrations in indoor environments: *formaldehyde*, NO_2, *carbon monoxide*, *benzene* and *naphthalene*. The second group of priority chemicals which are not considered as requiring urgent regulatory risk management actions specific to indoor air included: *acetaldehyde; o-, p- and m-xylene; toluene and styrene*. Finally, the third group of additional chemicals of interest which are considered to require further research with regard to human exposure or dose response before recommendations can be made included *d-limonene* and *α-pinene* (Kotzias *et al.*, 2005). EU-INDEX guideline values were suggested for each selected compound as reported in Table 1.

The "WHO guidelines on dampness and mould" (WHO, 2009b) concluded that "persistent dampness and microbial growth on interior surfaces and in building structures should be avoided or minimized, as they may lead to adverse health effects. As the relationships between dampness, microbial exposure and health effects cannot be quantified precisely, no quantitative, health-based guideline values or thresholds can be recommended for acceptable levels of contamination by microorganisms. Instead, it is recommended that dampness and mould-related problems be prevented. When they occur, they should be remediated because they increase the risk of hazardous exposure to microbes and chemicals".

The WHO also points out that "building standards and regulations with regard to comfort and health do not sufficiently emphasize requirements for preventing and controlling excess moisture and dampness"; this needs to be carefully taken into account in the context of energy-efficiency measures in buildings (WHO, 2009b).

Table 1 Indoor air quality guidelines defined by WHO and EU-INDEX

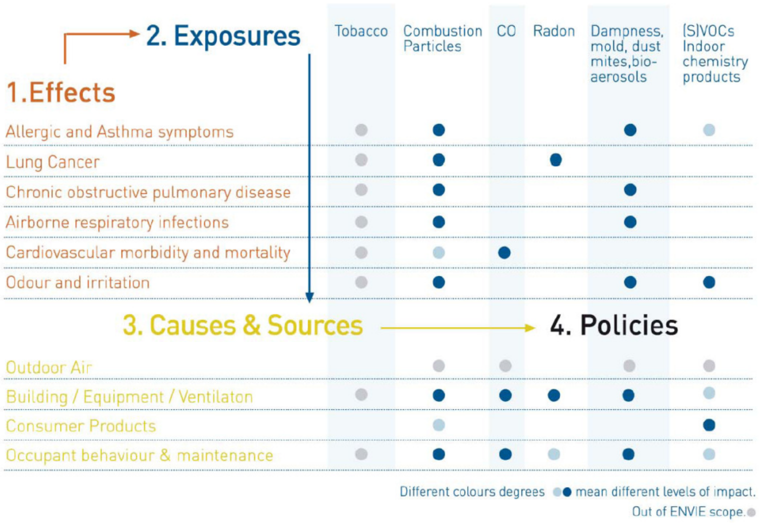
Pollutant	WHO IAQ Guidelines	EU-INDEX
Benzene	No safe level	10 µg/m^3
Toluene	260 µg/m^3 (1 week)***	--
α-pinene	--	450 µg/m^3
d-limonene	--	450 µg/m^3
Xylenes	--	200 µg/m^3
Trichloroethylene	No safe level	--
Tetrachloroethylene	250 µg/m^3 (annual)	--
Naphthalene	10 µg/m^3 (annual)	10 µg/m^3 (annual)
Styrene	260 µg/m^{3***}	200 µg/m^3
Formaldehyde	100 µg/m^3 (30 minutes)	30 µg.m^{-3} (30 minutes)
Acetaldehyde	--	--
Carbon monoxide	7 mg/m^3 (24 hours)	--
	10 mg/m^3 (8 hours)	10 mg/m^3 (8 hours)
	35 mg/m^3 (1 hour)	30 mg/m^3 (1 hour)
	100 mg/m^3 (15 minutes)	--
Nitrogen dioxide	200 µg/m^3 (1 hour)	200 µg/m^3 (1 hour)
	40 µg/m^3 (annual)	40 µg/m^3 (annual)
Polycyclic aromatic hydrocarbons†	No threshold can be determined	--
Radon	100 Bq/m^3	--
$PM_{2.5}{}^{*}$	25 µg/m^3 (24 hours)***	--
	10 µg/m^3 (annual)***	--
$PM_{10}{}^{**}$	50 µg/m^3 (24 hours)***	--
	20 µg/m^3 (annual)***	--

† Benzo[a]pyrene is often used as a marker for total carcinogenic polycyclic aromatic hydrocarbons (WHO, 2010c).
* Particulate matter with an aerodynamic size ≤ 2.5 µm; **Particulate matter with an aerodynamic size ≤ 10 µm; ***WHO air quality guidelines.

1.5 Strategy for Good Indoor Air Quality

The issue is to assure good IAQ by undertaking effective measures upstream of the point of use of the air in order to avoid or reduce the exposures. The need to establish a rationale and a framework to structure the approach to such a complex and diversified issue, in particular for the indoor air, has been identified in the context of the EU Action Plan. The EnVIE project defined a model that starts from the health effects attributable to indoor air and goes backwards searching successively for the exposures and causes/sources to end up with a “concept” or “strategy” that gives first priority to source control and attributes a specific topping duty to ventilation either to complement the required air quality level or just to assure the needs associated with the metabolism of the occupants or both

(Figure 5) (Oliveira Fernandes *et al.*, 2008). Another EC project, in the wake of EnVIE but this time under the sponsorship of the EC DG SANCO, HealthVent (2008-2013) aimed to establish a sound background to the definition of proper ventilation rates (ECA 30, 2012). That led to the definition of a reference health-based ventilation rate expressed in l/s per person, moving away from ventilation requirements founded on sensory perceptions and often expressed in parameters lacking rigor such as air changes per hour, which is not focused on the occupants and do not take into account neither the density of occupation of the space under consideration nor the volume of the space.



Explanatory note: Different degrees of colours mean different levels of impact and/or out exclusion from the scope of EnVIE. Tobacco smoke was not addressed in the EnVIE model due to being recent banned from these environments and, even more importantly because it would hide all the other impacts if included. Outdoor air is not addressed by EnVIE because it is covered by current WHO air quality guidelines that address urban outdoor air concentrations.

Figure 5 The EnVIE model

The strategy for IAQ risk management is to prevent and/or reduce pollution negative impacts on health and has been stated in the EnVIE project by pointing to source control as the first priority since preventing exposure is the most effective way of protecting human health from environmental threats. This is in line with the public health strategies for avoiding or attenuating the impact of diseases through prevention measures. Ventilation shall then act at the level of exposure: the non-removed pollutants emitted from the source, ventilation will disperse and diffuse them and so reduce the concentration of those contaminants in the space.

Pollutant control is also often most effective and easier to implement at the source level. In many cases, source control is the most cost-efficient approach to protecting IAQ, for example, cavities containing asbestos can be sealed or enclosed; gas stoves can be adjusted to decrease the amount of emissions; the latter can be swiftly removed through stacks or exhausters at the source; good hygiene practices can minimize biological contaminants (including the control of moisture and occasional cleaning and disinfection of wet or moist surfaces); and good housekeeping practices can control particulate matter. The selection of materials and consumer products with “clean” or “ecological” labels is another example of source control (ECA 29, 2013b; ECA 27, 2012). Source control is expected to take place in the future increasingly at the design stage with a pre-evaluation of pollution load as proposed by the HealthVent project and illustrated in Figure 6 (ECA 30, 2012).

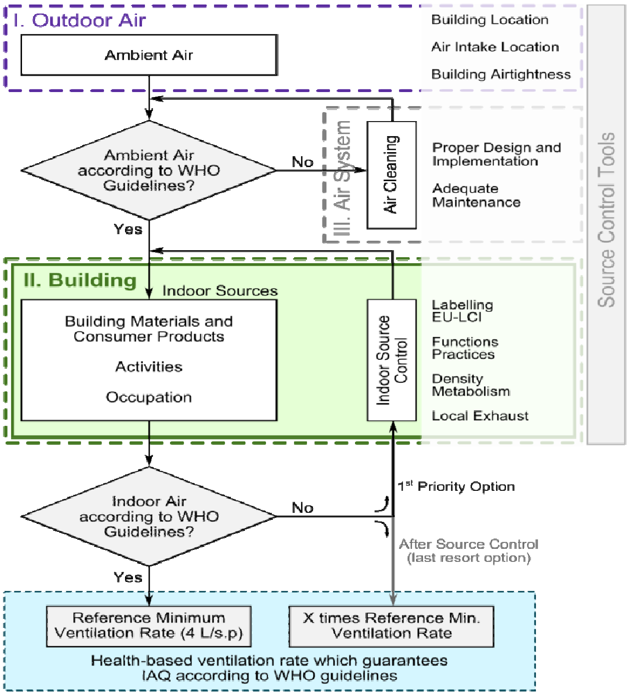


Figure 6 Source control and health-based ventilation flowchart

A more upstream and foundational strategy for good IAQ is to increase the awareness of all actors - including public authorities, that have long undervalued indoor air pollution - in particular through public education. Public education is a key step in reducing exposures to many indoor air pollutants. The choices made by owners, renters, users and managers of buildings have a major impact on exposures to air pollution. Thus the whole universe of decisions leading to an operational building stating with the choice of location and proceeding through design, construction, management and maintenance properly belong in an IAQ strategy for the future (Oliveira Fernandes *et al.*, 2008).

Current EU ventilation standards have been mostly based on the sensory evaluation of the perception of thermal comfort following the theory proposed by Ole Fanger. This theory provides only general guidance regarding exposure control by providing recommended indoor carbon dioxide (CO_2) and humidity levels. It does not adequately address the health-related quality of outdoor air and obscures the distinct requirements for health and comfort by proposing comfort categories as the main decision criteria for designing ventilation requirements [EN 15251 (CEN, 2007) and EN 13779 (CEN, 2003)].

The EU standards concerning ventilation and the national regulations of Member States all fail to use health criteria in setting ventilation requirements. The EnVIE project has recommended that health-based ventilation guidelines should be developed as a strategic priority for controlling exposure to pollutants and for reducing the burden of disease associated with exposure to air pollution.

EnVIE proposed a Green Paper on IAQ defending a comprehensive approach of all materials, products and actions implicated in building construction as potential contributory sources of indoor pollutants and dangerous indoor air exposures, in the wake of the EU Construction Products Regulation No. 305/2011 (CPR, 2011). A comprehensive policy should contribute to clarify and help to coordinate the application of overlapping Directives including the Regulation on the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) (EC 1907/2006) (EC, 2006), the Energy Performance of Buildings Directive (EPBD) (2010/31/EU) (EC, 2010) and the General Product Safety Directive (GPSD) (2001/95/EC) (EC, 2001), further harmonize the labeling procedures for building materials and components, as already is the case in a few Member States including Finland, Denmark, Germany and France and also introduce and harmonize the procedures for auditing and reporting IAQ in the context of energy certification of buildings, as legally required in Portugal from 2006 (DL 79/2006) and recently updated (DL 118/2013).

More recently PILOT INDOOR-MONIT (Kephalopoulos *et al.*, 2013a), a pilot project sponsored by DG SANCO, tackled the harmonization of monitoring requirements concerning indoor air pollutants, setting five alternative indoor air audit methodologies including the 'survey' typology which is adopted in this thesis.

Ventilation should be avoided as a solution for indoor air pollution problems. For more than a century and a half ventilation was misrepresented as a panacea to cope with all such problems, a practice originating in the field of occupational health, were it has a long history, and creeping into other fields with the dissemination of HVAC systems in buildings.

Mechanical ventilation is needed to filter the outdoor air where it does not meet air quality guidelines but this cannot justify making mechanical systems mandatory for every building and every location in Europe. On the contrary, any intervention at the EC level must strive to incorporate regional and local specificities including climatic differences and their influence on past and current architectural and building practice; this necessarily leads to the consideration of many different ventilation practices. For example, there is a long tradition in Southern countries of quasi-permanent interchange between indoors and outdoors through open windows and doors throughout the year.

Difficulties in quantifying and measuring natural ventilation rates should not be an excuse for preferring mechanical ventilation. These difficulties must be set against the shortcomings of current ventilation metrics which often lack clarity, rigor and even meaning, of which the widespread use of air changes per hour in lieu of proper ventilation criteria is perhaps the most glaring example. Any meaningful ventilation metric in the context of health-based ventilation outcomes will necessarily be expressed in terms of an air volume flow per person and per unit of time e.g. (l/s per person) or (m^3/h per person).

1.6 Exposure Guidelines

All activities and buildings can potentially cause environmental disturbance. In the 1960s the focus was on the physical impact of new objects or activities upon the outdoor environment. With the growing awareness regarding IAQ indoor environments have also become a primary concern. This has led to the introduction of Exposure Guidelines addressing procedures for limiting putative indoor pollutants.

World Health Organization Europe’s Parma Declaration (2010), endorsed by 53 countries, and invited Member States of the WHO Europe region to implement tangible actions in order to reach a set of IAQ targets. Its Regional Priority Goal 3 on preventing disease through improved outdoor and IAQ 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 was the first Europe-wide pilot project to monitor the school environment and children’s health in parallel in 25 European countries (http://sinphonie.eu/).

The attainment of healthy school environments in Europe requires an integrated and holistic approach to prevention, control, remedial and communication strategies for air quality and health, i.e. the chain from exposures to potential causes and sources, health-risk assessment, strategies and policy options. These strategies must address school location, design, construction, use, management and maintenance.

The guidelines framework for healthy environments within European schools has been documented in a publication soon to be released to the public. Its objective is to provide a reference guide which coherently and comprehensively contains the most up to-date knowledge supported by the findings of the SINPHONIE project. This guidance is intended to be generally applicable in most school environments in Europe and therefore safeguards the necessary scope for adaptation at the national and local level as each school environment is unique (in terms of design, climatic conditions, operational modes, etc.). For this purpose, criteria for incorporating the guidance into national policy measures and actions in the European countries are also provided. The aim of the guidelines is not to replace but rather to enrich and reinforce existing national and local policies which should continue to be the primary references.

These guidelines for healthy environments within European schools are primarily directed at the relevant policy-makers at both the European and the national level and at local authorities wishing to improve the indoor school environment in their countries while safeguarding the specificities (environmental, social, economic) of each country and location. A second target group for these guidelines is the designers and managers whose decisions directly affect the design, construction and renovation of school buildings. A third target group comprises schoolchildren, parents, teachers and other school staff.

2. Relevance, Objectives and Thesis Outline

2.1 Relevance of the Theme and Motivation

The student population of the European Union in the 2010/2011 academic year comprised more than 64 million students enrolled in pre-primary, primary and secondary schools (EUROSTAT, 2013). As children spend more time in schools than in any other environment except home, the levels of indoor air pollution in schools will significantly impact a child's total exposure to pollutants. The school environment is compulsory. Children and parents often have no freedom of choice concerning the school environment because allocation policy is often rigidly set as a function of administrative or residential subdivisions. This places an additional duty on school authorities to provide an indoor environment appropriate for children.

There is strong evidence that poor IAQ may have respiratory and other health related outcomes and affects general well-being (Jantunen *et al.*, 2011). Asthmatic children are known to be exceptionally sensitive to poor IAQ. Asthma and allergic diseases are actually the most prevalent chronic diseases among children and it has been reported that more than one third of children in Europe have asthma or allergy (Oliveira Fernandes *et al.*, 2008; Zhao *et al.*, 2008). Asthma affects around 300 million people worldwide corresponding to 15 million DALY per year, and it is estimated that there will be an additional 100 million persons with asthma by 2025 (Masoli *et al.*, 2004). The occurrence of pollutant-related disturbances at school may also affect children's growth and learning performance as well as reduce their opportunities for cultural and social development.

The prevalence of asthma and allergy among children has increased in recent decades (Sun *et al.*, 2009) at a rate that, according to several authors including Masoli *et al.* (2004) and Etzel (2007), cannot be explained by genetic changes and it is more likely to be due to changes in environmental exposures. Many explanations have been offered, including indoor air pollution.

Indoor air quality is affected by chemical, physical and biological agents and is determined by a combination of pollution sources, all of them having local specificities; climate and culture; local ambient air be it urban or rural; building characteristics, in particular the materials used; and indoor activities (Oliveira Fernandes *et al.*, 2008).

In the context described in Chapter 1 the target for this research is the exposure of children to the indoor air at school complemented with a close check of the indoor air/environment at their homes. Children tend to have greater exposure to airborne pollutants than adults because they generally breathe at a faster rate and more often through the mouth, bypassing the filtering action of the nose.

They are often also more susceptible to illness caused by air pollution because their immune system and organs are still developing and immature.

This thesis is based on specific work extending procedures and criteria for the assessment of IAQ in buildings to a fuller evaluation of children's exposure including both school and home environments. Taking the EnVIE model and selecting respiratory diseases as a particular case of health outcomes, the ambition, beyond the characterization of the situation in a particular set of schools of a given country or city, was to be able to develop an appreciation of the relative relevance of indoor air at school and at home for the health of schoolchildren.

In addition, the experience gained in other audits and studies also suggested that it was possible to improve and fine tune the procedures of the "IAQ survey typology" for schools to attain a full correspondence with the integrated set of policies and practices for IAQ in the light of the most recent advances in the field.

This thesis opted to study the school environment because it is well known that in practice the range of possible interventions in the building stock in what regards IAQ is strongly dependent on building typology. Now that tobacco smoke has been banned in most public spaces, schools stand out among one of the most urgent and problematic cases remaining, especially as they concern children, a particular susceptible group of the population.

The EC through its Environment and Health Strategy and Action Plan (2004-2010) set out thirteen key actions, among which Action 12 "on the improvement of indoor air quality" with a particular focus on the reduction of the adverse effects of indoor air pollution on children's health, namely on the occurrence of respiratory diseases. The latter was one of the four regional priority goals of the Children's Environment and Health Action Plan for Europe, agreed upon at the Fourth Ministerial Conference on Environment and Health in Budapest in 2004. In fact, among the findings of the "Indoor Air Pollution in Schools" project of the European Federation of Allergy and Airways Diseases Patients Association (EFA) there was evidence that the right to breathe clean air in schools had not yet achieved wide recognition throughout Europe and that there was a need for further research to evaluate the impact of air pollutants in schools on children's well-being and to provide a sound basis to promote European regulations and campaigns directed to the improvement of the school environment (EFA, 2000).

Another study on IAQ in European schools conducted in 2004-2005 by the HESE (Health Effects of Schools Environment) project uncovered a number of common indoor air problems in several schools, particularly due to poor ventilation and a diffuse lack of awareness and preparedness to cope with environmental problems and care for more susceptible children such as those suffering from asthma (Simoni *et al.*, 2010; Ciarleglio *et al.*, 2006; Norbäck *et al.*, 2006).

In 2003-2008, the AIRMEX project on exposure to indoor air chemicals and possible health risks associated mainly to volatile organic compounds (VOC) funded and coordinated by the European Commission's JRC, targeted schools and kindergartens in cities across selected EU Member States in addition to other building types. The key findings from the AIRMEX project highlighted the need for further research to address the burden of indoor air pollution on public health in the EU, in particular in regard to indoor environments where children frequently stay, i.e. schools and homes (Geiss *et al.*, 2011).

Other important studies, in the European context or at Member States level, e.g., "Binnenlucht in Basisscholen" (BiBa – "Indoor Air in Primary Schools") in Belgium, the "Observatory of Indoor Air Quality" and the 6 Cities study in metropolitan France, highlighted the state of maintenance of school buildings and respective ventilation levels as one of the major problems in schools (Annesi-Maesano *et al.*, 2012; Stranger *et al.*, 2010; Kirchner *et al.*, 2006).

Several other studies have demonstrated a strong association between the exposure to poor indoor air and short and/or long-term health problems including asthma, allergic reactions and respiratory symptoms, even more significant in asthmatic children [e.g. (Jantunen *et al.*, 2011; Arvanitis *et al.*, 2010)]. For example, Clausen *et al.* (2009) reported strong associations between dampness, ventilation rate, concentrations of specific chemicals and the prevalence of asthma/allergy among schoolchildren.

The literature review found that the few studies conducted in Portuguese schools aimed to: 1) evaluate the association between the IAQ in nine secondary schools in the Porto area and the prevalence of allergic and respiratory symptoms in adolescents (Fraga *et al.*, 2008); 2) characterize the IAQ in eleven secondary schools located in the Porto area and to evaluate the health symptoms among teachers (Madureira *et al.*, 2009); 3) evaluate the relation between outdoor and IAQ and children's health in the city of Viseu (SaudAR - Health and The Air We Breathe) (Borrego *et al.*, 2008); 4) study the impact of ozone on the prevalence of childhood asthma involving two primary schools in Torre de Moncorvo and two primary schools in Mogadouro (Sousa, 2009); and 5) obtain information about indoor pollutant concentrations in sixteen elementary schools in Lisboa and Aveiro and to estimate the actual occurrence of asthma/rhinitis in the Lisboa primary school population (Pegas, 2012). Additionally, under SaudAR project, Martins *et al.* (2012) suggests a relation between indoor air pollution (namely VOC), airways inflammation and oxidative stress.

Among these studies, few systematically evaluated the building characteristics, IAQ parameters and health related outcomes in a large sample of children attending primary schools; while the literature related to schools' environment and adverse respiratory effects is generally coherent in showing increased risks of asthma, allergies and respiratory health. Very recently the Portuguese government introduced an upper limit of 26 children per class (Despacho n.º 5048-B/2013) without taking into account the IAQ and physical and social conditions of each class and of each school.

The available evidence on the relationship between housing and health is still insufficient to adequately describe the impact of housing upon health. Children spend more time than adults indoors at home. Large studies of home environments conducted in the United States and Europe have shown that physical, chemical and biological factors can influence children's well being [e.g. (Bornehag *et al.*, 2004b; Spengler *et al.*, 1994)]. The LARES (Large Analysis and Review of European Housing and Health Status) survey that evaluated the relationship between housing conditions and health focusing on the effect of cold homes and dampness, noise effects and domestic accidents, provided new evidence of links between the health of inhabitants and their housing conditions (WHO, 2007a).

The complexity of exposure patterns, the changes in the vulnerability of children at various stages of their development and the practical limitations of the different researches resulted in an incomplete understanding of the impact of the exposure to indoor air on children's health.

Thus, although there has been considerable interest in the health effects of indoor air pollution, many questions still remain unanswered or require further explanation in particular in what regards the contribution of exposure to indoor air pollution at home and in school environments to the health of children. This thesis aims to undertake a multidisciplinary study through a comprehensive evaluation of the impact on children's health of IAQ at home and in schools.

2.2 Research Question and Objectives

This thesis addresses the following research question:

"What are the health effects of IAQ in schools on children of ages 8-9 taking into account the effect of the exposure to indoor air at home?"

The main objective is, then, to further the study IAQ in schools and at homes towards the understanding of its impact on children's health targeting asthma, allergy, and respiratory symptoms. This was accomplished by considering the following aspects:

1. Regarding the school environment

- To assess the IAQ by measuring a set of indoor air parameters.
- To investigate whether indoor air pollution is associated with building characteristics and occupant behaviour.

- To evaluate the association between indoor air exposure and children's health outcomes focused on asthma, allergies and respiratory symptoms.

2. Regarding the home environment

- To assess the IAQ by measuring a set of indoor air parameters.
- To examine the relationship between IAQ and the occurrence of asthma.

2.3 Research Plan Structure and Thesis Outline

This research study is multidisciplinary in nature and involved collaborations with several institutions. The participatory institutions were the Laboratory of Indoor Air Quality of IDMEC-FEUP, the Public Health Institute of University of Porto, the Department of Clinical Epidemiology, Predictive Medicine and Public Health from University of Porto Medical School, and the Department of Environment Health of the National Institute of Health (Porto). Figure 7 shows the structure of the work plan used in this research.

Chapter 1 contextualizes the issue of IAQ and introduces the holistic approach that shall be followed in undertaking the risk management of indoor air pollution-derived problems. The EnVIE model is introduced, followed by a brief overview of the whole issue of IAQ health effects, sources and exposures, health guidelines and exposure guidelines.

In Chapter 2 the relevance of and motivation for the work is described as well as the objectives and research plan structure.

Chapter 3 gives an overview of the state-of-the-art regarding asthma, allergies and respiratory symptoms and indoor air exposure, following the approach of the EnVIE model.

Chapter 4 provides the description of the participants, materials and methods used in the field survey of this work. It describes the details of the study design, study population, clinical health examination, sampling sites and sampling procedures for collection of indoor and outdoor chemical, physical and comfort parameters and microbiological agents. The analytical methods used to determine the selected parameters are also described, as well as the statistical methods used.

Chapter 5 and Chapter 6 present the results and their discussion, respectively. The first part of each chapter deals with the cross-sectional study carried out in 20 schools dealing with specific indoor parameters and clinical measurements; the second part is related to the case-control study at 68 homes. Chapter 5 also explores the links between children's health and indoor exposure at school and at home.

Finally, Chapter 7 summarises the main findings, makes contributions towards some recommendations on IAQ risk management and underlines possible lines of work to complement and further develop the studies undertaken for this thesis.

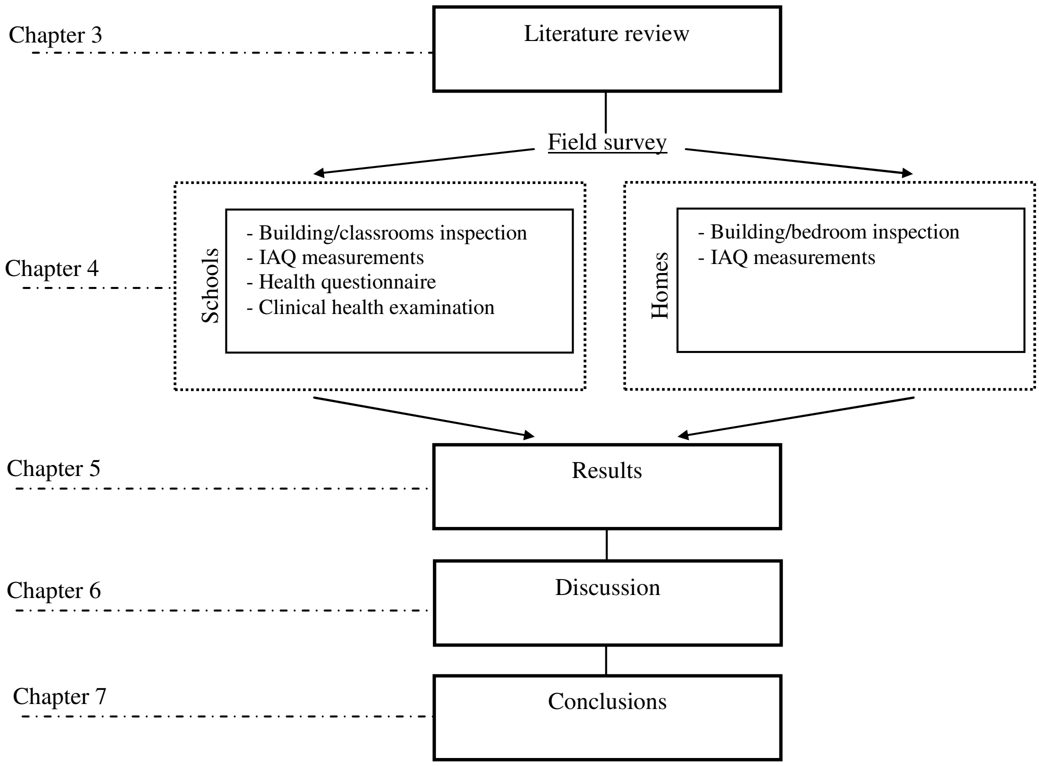


Figure 7 Research plan structure

3. Literature Review

The literature review, based on several multidisciplinary state-of-the-art reviews of the related scientific literature and reports from the most recent WHO and EU research projects, is structured following the EnVIE model, which goes from "health effects" through "exposures" and "causes and sources", finally leading to a set of proposals on "strategies and policies" to tackle the comprehensive issue of IAQ in the built environment.

In line with IAIAQ report the most important diseases which have been associated with (caused or aggravated by) indoor air exposures (Jantunen *et al.*, 2011) are allergic and asthma symptoms; lung cancer; cardiovascular diseases; chronic obstructive lung disease; (upper and lower) respiratory infections/symptoms, and acute toxication. Particularly, this thesis is focused on the most important and common chronic health problems among children: asthma, allergy and respiratory symptoms.

3.1 Asthma, Allergies and Respiratory Symptoms

3.1.1 Introduction

The respiratory tract is the preferred route for airborne pollutants to enter the body. During breathing, each human organism needs a daily 10-20 m^3 of breathable air (Almeida *et al.*, 2010). The ancient Greeks were found to be the first to use the word asthma defined as short drawn breath, hard breath or panting (Zuraimi, 2008). Asthma is a disorder defined by its clinical, physiological, and pathological characteristics. The predominant feature of the clinical history is episodic shortness of breath, particularly at night, often accompanied by cough. Wheezing appreciated on auscultation of the chest is the most common clinical finding. The main physiological feature of asthma is episodic airway obstruction characterized by expiratory airflow limitation. The dominant pathological feature is airway inflammation, sometimes associated with airway structural changes. The clinical, physiological and pathological characteristics of asthma have been combined by the Global Initiative Program for Asthma (GINA) in the definition:

> "*Asthma is a chronic inflammatory disorder of the airways in which many cells and cellular elements play a role. The chronic inflammation is associated with airway hyperresponsiveness that leads to recurrent episodes of wheezing, breathlessness, chest tightness, and coughing, particularly at night or in the early morning. These episodes are usually associated with widespread, but variable, airflow obstruction within the lung that is often reversible either spontaneously or with treatment*" (Masoli *et al.*, 2004).

According to the report "Global strategy for asthma management and prevention" asthma symptoms in schoolchildren are less specific than in older children and adults; and the onset of asthma has reported to be the highest in the first years of life with the disease occurring more frequently in boys than girls (GINA, 2012).

The word allergy derives from the Greek words *allos* et *ergon* (Zuraimi, 2008). Allergy can be defined as an inappropriate body's response to an innocuous foreign substance (Janeway and Travers, 1994). Allergic rhinitis is clinically defined as a symptomatic disorder affecting the upper airways and defined as nose symptoms including sneezing, itching, blockage or increased secretion due to immunological mechanisms which are reversible spontaneously or after treatment (Todo-Bom *et al.*, 2007). Allergic rhinitis normally appear during mid-childhood and adolescence, may disappear only in at most 20% of the cases (Zuraimi, 2008; EFA, 2000). The clinical definition of rhinitis is difficult to use in the epidemiological settings of large populations where it is impossible to examine everybody or to obtain the laboratory evidence of an immune response. So far there has been no standardization of the definition of rhinitis in epidemiological studies, and thus comparison of prevalence between studies is difficult (Bousquet *et al.*, 2008).

Eczema was defined as a genetically determined skin barrier defect combined with typical clinical skin manifestations, such as dry skin and itchy rash in the folds of the elbows, behind the knees, in front of the ankles, under the buttocks or around the ears, eyes or neck (Broms, 2010). Usually begins in infancy with the most of individuals having their initial onset before the age of five (Zuraimi, 2008).

Asthma, rhinitis and eczema can either be allergic or non-allergic depending on whether specific immunologic mechanisms are initiating the reaction. An immunological reaction means that a person becomes sensitized with a production of Immunoglobulin E (IgE)-antibodies after contact with certain allergens (Johansson *et al.*, 2004). For young children asthma is mainly allergic. Allergens are proteins that can cause sensitization and allergic or asthmatic symptoms among sensitized individuals. Examples of common indoor related sources of allergens are from furred pets, birds, house dust mites and mould. Other indoor air exposures that are associated with either sensitization or symptoms of asthma and allergies are e.g. tobacco smoke, combustion particles and chemical compounds in consumer products and building materials (Bornehag *et al.*, 2004a). These compounds are not allergens themselves but so-called adjuvant factors which enhance or modify the immune response to an antigen (Larsen *et al.*, 2007).

Earlier epidemiological studies have shown a tendency towards co-morbidity or co-occurrence of asthma and allergy manifestations so that children who have one of the diseases tend to have one or more of the others as well (Burgess *et al.*, 2009; Illi *et al.*, 2004; Sheldon, 2001). More than half of the population in United States suffering from allergic rhinitis also has asthma (Sheldon, 2001). Comorbidity of asthma with eczema was diagnosed in one third of children in a recent study (Yuksel *et al.*, 2008).

Children who have an allergic predisposition, also known as atopy, are frequently seen to get eczema in early childhood. Children with eczema are frequently diagnosed with asthma within a few years of age (Kapoor *et al.*, 2007). Later in their childhoods, vulnerable school age children may experience allergic problems that involve symptoms from the nose and eyes, called rhinitis. This process is called “the atopic march” or “the allergic march” (WHO, 2007a) and is described in Figure 8 (Spergel, 2010). Therefore, early diagnosis and adequate control is crucial.

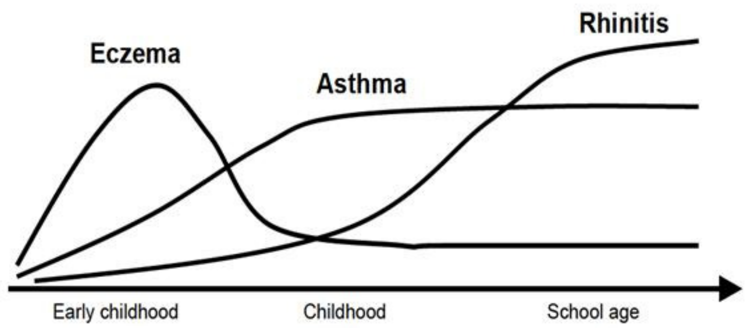


Figure 8 Overall picture of allergic disease development in children that most often starts with eczema and followed by asthma and rhinitis later on in life

3.1.2 Burden of disease

Asthma and allergic diseases are common chronic diseases in the world among children and are, therefore, a global public health issue (WHO, 2010b). The WHO has estimated that asthma affects around 300 million people worldwide corresponding to 15 million DALY per year, similar to diabetes (Bousquet *et al.*, 2009; Masoli *et al.*, 2004). With the projected increase in the proportion of the world’s population that will be urban from 45% to 59% in 2025, there is likely to be a marked increase in the number of asthmatics worldwide over the next decade. It is estimated that there may be an additional 100 million persons with asthma by 2025 (Masoli *et al.*, 2004).

Asthma and allergies affect quality of life, school/work performance and family/social life (Carroll *et al.*, 2005). Physical capabilities are further impaired by co-morbidities, mainly allergic rhinitis (Sram *et al.*, 2013; Bahadori *et al.*, 2009). Asthma and allergies have both individual and social impact and their costs are mainly associated with emergency room use, hospitalizations and medication (direct costs) and time off work or school and early retirement (indirect costs) (Barnes *et al.*, 1996). The costs of asthma are higher in severe or uncontrolled asthma (Godard *et al.*, 2002) and are likely to rise as its prevalence increases (Barnes *et al.*, 1996). Hospitalization for asthma is one measure of asthma severity and burden. Hospitalization rates decreased in countries where asthma managements programs have been implemented (Bousquet *et al.*, 2007; WHO, 2007a; Haahtela *et al.*, 2006).

In Portugal, over 24000 people were hospitalized between 2000 and 2007 because of asthma with a total cost of around €27 billion (Bugalho *et al.*, 2009; Bugalho, 2008). Despite the implementation of a national program for asthma management, among the health regions - Alentejo, Algarve, Centre, Lisboa and Tagus Valley and North, only two main health regions (North and the Lisboa and Tagus Valley regions) achieved the goals reducing at least 20% of asthma hospitalizations over a 8 year period (Bugalho *et al.*, 2009; Bugalho, 2008). Nunes and Ladeira (2004) points for an overall yearly cost of asthma per patient of €200, which is 3.8 times the cost of the non-asthmatic.

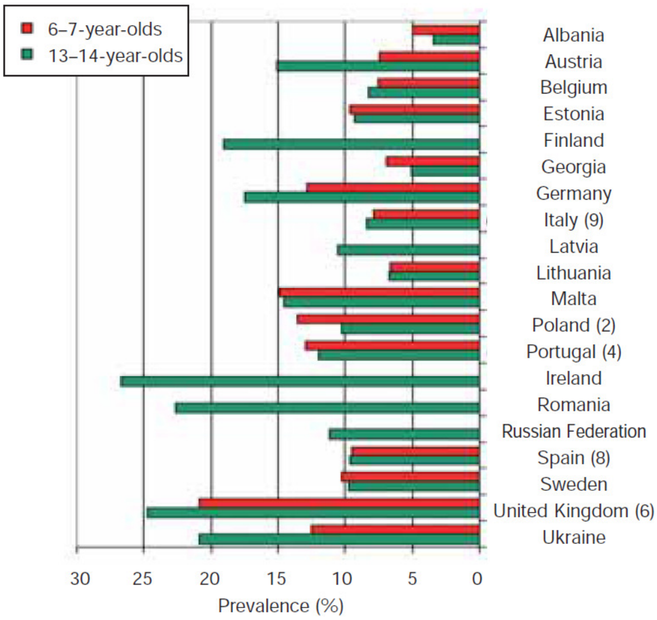
3.1.3 Prevalence in epidemiological surveys

Globally the prevalence of asthma and allergies has increased over the last few decades (WHO, 2007b). Asthma has become the commonest chronic disease in children and is one of the major causes of hospitalization for those aged under 15 years. Studies have shown that approximately 50% of childhood eczema heals before adolescence (Sandstrom and Faergemann, 2006; Illi *et al.*, 2004). Beyond this, in the Western world, eczema affects 15-20% of pre-school children (Eller *et al.*, 2010). The increasing prevalence of allergic diseases in children throughout Europe is no longer restricted to specific seasons or environments (WHO, 2007b). The greatest increases are generally seen in urban areas (WHO, 2007b). The WHO recommends the assessment of population needs related to asthma and other chronic respiratory diseases in order to define adequate health policies (Bousquet *et al.*, 2007).

Examples of nationwide prevalence studies are the National Asthma Survey in the United States (O'connor *et al.*, 2008), the National Health and Nutrition Examination Survey in the United States (Mchugh *et al.*, 2009); and the National Population Health Survey in Canada (Ghosh *et al.*, 2008). Among all multinational studies on prevalence of asthma two large studies stand out in the 1990's: the "International Study of Asthma and Allergies in Childhood" (ISAAC) in children (Asher *et al.*, 1995) and the "European Community Respiratory Health Survey" (ECRHS) in adults (Burney *et al.*, 1994). The ISAAC aimed to describe the prevalence and severity of asthma, rhinitis and eczema in children with 6-7 years old and 13-14 years old living in different centres, and to make comparisons within and between countries (Asher *et al.*, 1995); while the ECHRS, which was performed on adults between 20-44 years old, aimed to estimate the variation in the prevalence of asthma, asthma-like symptoms and bronchial responsiveness in Europe; to estimate variation in exposure to known or suspected risk factors for asthma and to estimate the variation in treatment practice for asthma in the European community (Burney *et al.*, 1994). Both studies collected data with standardized methods.

In 1998, the results of the Phase I of ISAAC showed geographical differences in the prevalence of asthma and wheezing. According to the countries studies the ISAAC results demonstrated that the frequency of asthma varied from 2.1-4.4% in Albania, Greece and Russia, to almost 32% in Australia, New Zealand, Ireland and United Kingdom (Asher *et al.*, 1998). Kasznia-Kocot *et al*. (2010) reported that the observed variability could be partially explained by different ways of defining wheezing and asthma. According to the same authors, it might also be explained by differences in socio-economic status and in lifestyle (e.g. exposure to active and passive smoking).

Between 1999 and 2004, asthma prevalence rates in Europe ranged from approximately 5% to 20% in children aged 6-7 years and from approximately 5% to 25% in children aged 13-14 years (Figure 9) (WHO, 2007b).



Note. As the data were collected from specific centres only, prevalence figures are not country-representative. When data were collected from more than one centre, the number of centres is given in brackets (WHO, ENHIS, 2007b).

Figure 9 Prevalence of asthma symptoms in children aged 6-7 years and 13-14 years, ISAAC Phase III, 1999-2004

There is a worldwide variation in the prevalence of asthma. For the past 40 years the prevalence of asthma and allergies has increased worldwide mainly among children and young adults (Anthracopoulos *et al.*, 2009; Lai *et al.*, 2009; Bateman and Jithoo, 2007; WHO, 2007a; Eder *et al.*, 2006; Pearce and Douwes, 2006; Russell, 2006; Plácido, 2004; Bach, 2002; Pearce *et al.*, 2000). The increasing trends and geographical variations are also similar to rhinitis and eczema symptoms. Asthma affects people of all ages and all ethnic backgrounds (Bousquet *et al.*, 2009). According to Masoli *et al*. (2004) asthma and allergies are still increasing as communities adopt modern lifestyles and become urbanized. However, in some countries with high asthma and allergies prevalence, it seems that rising trends have reached a plateau or are even decreasing (Lotvall *et al.*, 2009; WHO, 2007a; Asher *et al.*, 2006; Zollner *et al.*, 2005). This may be due to an increased awareness of the disease, to the fact that asthma may have become milder or to the implementation of national and global asthma prevention and management guidelines and consequent earlier detection and improved treatment of asthmatics (Von Hertzen and Haahtela, 2005).

In Portugal, the ISAAC Phase I and Phase III assessed the prevalence of asthma in Funchal, Lisboa, Portimão and Porto (Phase I); and Funchal, Lisboa, Portimão, Porto and Coimbra (Phase III). The results obtained for group of 6-7 years old are presented in Table 2. From the ISAAC survey for children aged 6-7 years old the prevalence of wheeze ever was 20.9 in 2002 in Porto; while the prevalence in wheeze in the last 12 months for the same age group was 10.0%. In what regards “asthma ever” and “eczema ever” the values obtained in Porto in 1995 were 10.0% and 10.9%, respectively (Table 2). Data from Phase I and Phase III of ISAAC study among 13-14 years old group by participating centres are presented in Table 3.

Portugal was one of the first countries to set up a national program on asthma. However, few data on asthma prevalence is available and, as most of the studies use non-standardized methods, the definition of asthma varies between studies and prevalence estimates are difficult to compare. Moreover, most of asthma studies in Portugal were performed on teenagers and adults from selected cities or regions. Furthermore, only a few studies present age and sex-specific prevalence. Table 4 summarizes the prevalence of asthma among Portuguese children and adolescents.

These data pointed to significant regional differences in terms of prevalence of respiratory symptoms, recommending further studies to define evolutionary trends and identify risk factors.

Table 2 Results of Phase I and Phase III of ISAAC study among 6-7 years old group by participating Portuguese centres

	Funchal		Lisboa		Portimão		Porto		Coimbra	
Variable / ISAAC Phase	I	III	I	III	I	III	I	III	I	III
Wheeze ever	33.4	25.3	27.3	30.2	22.0	28.4	NA	20.9	NA	NA
Wheeze in the past 12 months	14.7	11.0	13.1	14.2	11.0	13.2	NA	10.0	NA	NA
Four or more attacks of wheeze in the past 12 months	5.2	2.1	3.5	3.4	2.1	2.5	NA	2.3	NA	NA
Sleep disturbance from wheeze, 1 or more nights a week in the past 12 months	5.0	4.1	2.9	3.4	1.8	3.6	NA	2.7	NA	NA
Speech limited by wheeze in the past 12 months	7.2	3.3	3.1	2.9	3.1	2.1	NA	2.5	NA	NA
Asthma ever	17.5	14.2	8.3	7.8	6.2	4.9	NA	10.0	NA	NA
Wheeze during or after exercise in the past 12 months	11.4	7.0	6.7	7.1	4.6	5.5	NA	5.7	NA	NA
Night cough in the past 12 months	34.9	32.9	26.3	32.7	22.0	29.4	NA	30.8	NA	NA
Nose symptoms ever	23.9	27.0	26.9	31.2	18.0	28.0	NA	26.1	NA	NA
Nose symptoms in the past 12 months	20.6	21.6	23.4	26.3	14.7	23.1	NA	22.1	NA	NA
Nose and eye symptoms in the past 12 months	11.8	9.4	9.0	10.1	5.2	8.2	NA	7.5	NA	NA
Nose symptoms affecting activities a lot in the past 12 months	1.7	1.5	1.0	1.0	1.8	0.9	NA	0.7	NA	NA
Symptoms of rhinoconjunctivitis in the past 12 months	11.2	9.2	8.6	10.0	5.0	7.9	NA	7.4	NA	NA
Rash ever	26.2	24.9	20.0	20.5	4.8	15.8	NA	16.8	NA	NA
Rash in the past 12 months	18.6	18.1	16.8	15.3	3.8	12.2	NA	13.5	NA	NA
Eczema ever	13.3	11.5	11.2	15.6	7.7	15.2	NA	10.9	NA	NA
Symptoms of eczema in the past 12 months	12.4	10.0	11.1	10.2	2.6	8.0	NA	8.5	NA	NA
Number of participants	1797	1819	2143	2477	1189	1069	NA	2464	NA	NA

NA: Not applicable

Table 3 Results of Phase I and Phase III of ISAAC study among 13-14 years old group by participating Portuguese centres

	Funchal		Lisboa		Portimão		Porto		Coimbra	
Variable / ISAAC Phase	I	III	I	III	I	III	I	III	I	III
Wheeze ever	19.4	19.4	21.6	25.9	18.1	18.2	14.1	22.1	NA	20.6
Wheeze in the past 12 months	10.6	9.0	11.1	14.6	8.1	9.7	7.4	13.1	NA	10.7
Four or more attacks of wheeze in the past 12 months	2.7	1.9	2.8	3.5	2.0	2.2	1.7	2.6	NA	2.6
Sleep disturbance from wheeze, 1 or more nights a week in the past 12 months	1.8	1.5	1.3	2.1	1.4	1.8	1.0	1.5	NA	1.0
Speech limited by wheeze in the past 12 months	2.7	2.7	2.4	3.5	1.9	2.1	1.6	2.8	NA	2.2
Asthma ever	13.1	15.2	12.3	15.6	10.3	12.4	11.3	15.1	NA	12.2
Wheeze during or after exercise in the past 12 months	16.6	21.2	14.1	24.8	14.8	18.2	10.5	21.0	NA	19.5
Night cough in the past 12 months	19.8	34.1	17.5	35.4	18.1	31.4	13.1	32.9	NA	30.5
Nose symptoms ever	29.8	32.6	31.4	39.7	28.5	34.4	29.8	41.8	NA	31.8
Nose symptoms in the past 12 months	21.1	21.4	20.7	29.0	19.7	21.7	22.7	31.7	NA	23.9
Nose and eye symptoms in the past 12 months	8.5	8.9	7.0	10.6	8.9	7.2	6.6	10.3	NA	6.5
Nose symptoms affecting activities a lot in the past 12 months	0.5	1.1	0.3	0.6	0.1	0.2	0.5	0.5	NA	0.3
Symptoms of rhinoconjunctivitis in the past 12 months	7.7	8.7	6.5	10.5	8.8	7.1	6.2	10.3	NA	6.5
Rash ever	15.3	13.4	10.6	13.5	5.9	11.3	13.8	13.1	NA	15.4
Rash in the past 12 months	9.1	8.1	6.5	9.4	3.3	7.7	8.9	8.6	NA	10.2
Eczema ever	15.0	13.6	10.3	12.9	9.4	11.0	9.2	10.9	NA	16.7
Symptoms of eczema in the past 12 months	5.4	4.5	4.0	5.6	1.8	4.9	4.4	5.3	NA	6.0
Number of participants	3532	3161	3030	3024	1058	1109	3131	3336	NA	1177

NA: Not applicable

Table 4 Prevalence of asthma among children and adolescents in Portuguese studies

Survey	Sample	Method	Asthma prevalence
Nunes *et al*. (1987)	5500 patients aged 7 to 17 years from Portimão	Questionnaire (using a symptom score) and spirometry	3.4%
Prata *et al.* (1994)	927 children between the ages 6-12 in Faial Island, Açores	Parents' self-administered questionnaire *Lifetime asthma*: asthma diagnosed by a doctor *or* had consulted their physicians for dispnea accompanied by wheezing *and* had received asthma medication in last 12 months or in their lifetime	8.0%
Vicente *et al*. (1995)	17200 participants aged 12-19 years living in 8 major cities of Portugal	*Lifetime asthma*: positive to wheeze *and* wheeze with breathlessness *and* negative to wheeze with a cold in lifetime	4.4%
		Current asthma: positive to wheeze *and* wheeze with breathlessness *and* negative to wheeze with a cold in last 12 months	Bragança: 1.1% Braga: 1.9% Porto: 3.7% Aveiro: 3.9% Coimbra: 5.4% Lisboa: 6.0% Évora: 3.1% Faro: 4.8%
Morais Almeida *et al*. (1996)	1061 children between the ages 6-10 in the Madeira Island	Investigator-applied a standard questionnaire *Lifetime asthma:* cumulative lifetime diagnosis (asthma ever), symptoms during the previous year and current asthma (bronchial challenge test)	14.6% *(symptoms during the previous year)*
Leiria Pinto P. *et al*. (1998)	1879 adolescents aged 12-16 years living in metropolitan area of Lisboa	Self-administered questionnaire (cumulative and current asthma)	Cumulative asthma: 17.0% Current asthma: 10.0%
Barros *et al*. (1999)	In Porto, among the 62 public primary schools 24 were selected by simple randomization and 21 schools agreed to participate in the study. In Viseu were included all 9 eligible schools. It were considered 3022 children aged 6-9 years from Porto (72.6%) and Viseu (27.4%)	Parents' self-administered questionnaire *Lifetime asthma*: presence of dyspnoea and wheezing ever and in last 12 months and absence of upper respiratory infections	Ever: Porto: 13.2% Viseu: 9.8% Last 12 months: Porto: 7.7% Viseu: 5.4%
Branco *et al*. (2005)	2820 subjects (Northern and central region, Lisboa and Vale do Tejo, Alentejo and Algarve) aged between 0 and >75 years (0-4; 5-9; 10-14; 15-24; 25-34; 35-44; 45-54; 55-64; 65-74; and ≥75 years)	Telephone interview Lifetime asthma: "*Have you ever had asthma*?"	8.6%* *(n=239)* 0-4 years: 5.5%* *(n=66)* 5-9 years: 3.5%* *(n=118)* 10-14 years: 3.8%* *(n=126)* 15-24 years: 9.1%* *(n=347)*

* Weighted percentage

Table 4 Prevalence of asthma among children and adolescents in Portuguese studies (cont.)

Survey	Sample	Method	Asthma prevalence
Falcão *et al*. (2008)	2161 adolescents aged 13 years old from Porto (part of Epiteen cohort)	Parents' self-administered questionnaire *Lifetime asthma:* "*Has your child ever had asthma*?" and physician diagnosed asthma ("*Has your child been diagnosed by a physician as having asthma*?")	Ever: 12.9% *(84.4% with physician diagnosis)* Diagnosis ever: 11.9%
Correia-de-Sousa *et al*. (2010)	A stratified random sample by age (0-7 years; 8-19 years; 20-64 years: and ≥65 years) and gender was obtained from the practice general database of 13568 registered patients in Horizonte Family Health Unit (Matosinhos). It was considered 576 patients (279 males) aged 33.2 (±28.1) years	Physician's questionnaire based on GINA criteria ("*Does this patient have asthma?*") and patient's questionnaire based on the ISAAC questionnaire ("*Have you ever had asthma?*")	10.2% *(from 576 subjects)* 0-7 years: 9.6% 8-19 years: 13.1%
Couto and Almeida (2010)	1253 participants aged 15 or older (>65) of mainland Portugal	Questionnaire by direct and personal interview *Lifetime asthma:* "*Have you ever been diagnosed with any of the following allergies / allergic diseases*? *Including asthma*"	6.0% *(from 1253 subjects)* 15-24 years: 4.2%
Pegas *et al*. (2011a)	342 children between the ages 5-12 from Lisboa	Parents' self-administered questionnaire based on ISAAC questionnaire *Lifetime asthma:* "*Has your child ever had asthma*?"	5.6%

3.1.4 Environmental risk factors

Despite its high prevalence, the cause of childhood asthma and allergies still remains unclear. Epidemiological studies have suggested that there are important host-specific factors and environmental factors (GINA, 2009), the first including genetic disposition. Multiple studies have found that genetic factors, often expressed as asthma and allergic problems in the family, are the strongest individual risk factor for the development of asthma and allergies in children (Jaakkola *et al.*, 2004). It has been estimated that the odds of having a child with asthma was three times higher in families with one asthmatic parent and six times higher in families with two parents with allergic symptoms, compared to those families without allergic symptoms (Uddenfeldt, 2010). Although a family history of asthma is a strong risk factor it is neither a sufficient nor a necessary cause for the development of asthma. In early childhood boys suffer more often from asthma than girls while in the teenage years the gender ratio is reversed (Broms, 2010). The increased risk for males in childhood is hypothesized to be caused by narrower airways, to increased airway tone and, possibly, higher IgE in boys (Bjornson and Mitchell, 2000).

The environmental factors may play an important role in the development of asthma and include chemical, physical and biological exposures in indoor and outdoor environments (Jacquemin *et al.*, 2011; Bateman *et al.*, 2008; Masoli *et al.*, 2004). Currently, there is an on-going effort to identify the causative environmental factors responsible for the worldwide increase in prevalence. However, for many environmental factors it is still uncertain whether they are involved in the development of asthma or they are only triggers of asthma symptoms or both (WHO, 2010b). Studies on environmental factors associated with asthma have shown conflicting results. Environmental exposures identified as risks in some studies appeared to be protective in others and in further studies showed no effect (Heinrich, 2011). Some of these differences may be due to the effect of dose, but the timing of environmental exposures may also be important.

According to several studies, the rapid increase of the prevalence of asthma and allergic diseases in recent decades may suggest that the potential risk factors can be focused on environmental changes rather than genetic factors (Etzel, 2007; Masoli *et al.*, 2004). Large number of epidemiological studies, including ISAAC and ECRHS, besides showing the clear pattern of increasing prevalence of asthma and allergic diseases in many parts of the world, they show that there are marked variations of asthma and allergies between countries (Asher *et al.*, 2006; Sennhauser *et al.*, 2005; Von Mutius, 2000; Asher *et al.*, 1998; ECRHS, 1996). This indicates that the risk factors for asthma and allergy may be more related with the "environment" than with the "genes". Besides, there are obvious associations between age, exposure and disease penetration, hinting at different vulnerability for the same exposure depending on the actual living conditions when child is exposed. As reported by the

Institute of Medicine of the United States, indoor air exposure of both indoor and outdoor pollutants could play a more significant part in the etiology of asthma and allergies (IOM, 2000).

To be noticed that this thesis does not focus on host-specific factors. This thesis will focus on the exposure to main indoor air parameters that have been assumed to be related to health outcomes which are described in more detail in following sub-chapters.

3.2 Indoor Air Quality and Health in School

There is increasing evidence that exposure to indoor air pollutants can cause or contribute to short-term and long-term health problems, including nasal congestion, eye and skin irritations, coughing, sneezing, respiratory tract infection, allergic reactions, asthma, headaches, fatigue, dizziness and nausea (Bernstein *et al.*, 2008; Geller *et al.*, 2007; Viegi *et al.*, 2004). Moreover, from the educational standpoint, the occurrence of pollutant-related disturbances at school may also affect children's growth, and learning performance as well as their cultural and social development (Mendell and Heath, 2005).

The need to address IAQ has been abundantly recognized by the European Environment and Health Action Plan 2004-2010 of the Commission of the European Communities (CEC, 2004), the WHO ministerial declaration (WHO, 2010a), the Strategic Research Agenda of the European Construction Technology Platform (ECTP, 2005), the air quality guidelines developed by WHO (WHO, 2010c; 2009b) and recent proposals on overall management strategies (Oliveira Fernandes *et al.*, 2008).

The EC adopted on June 9, 2004, the EU Environment and Health Action Plan 2004-2010 (CEC, 2004) as the first cycle of the implementation of the European Environment and Health Strategy. The EU Action Plan is an operational document setting out thirteen key actions for the period until 2010, grouped around three broad vectors: information, research and response. Among those key actions, Action 12 concerned the "improvement of indoor air quality".

The Parma Declaration of WHO Europe, endorsed by 53 countries in 2010, called on Member States of the WHO Europe region to implement measurable actions in order to reach the target set included in the Declaration. Its regional priority goal III "aim to prevent and reduce respiratory disease due to outdoor and indoor air pollution" states: "We aim to provide each child with a healthy indoor environment in childcare facilities, kindergartens, schools and public recreational settings, implementing WHO's IAQ guidelines and, as guided by the Framework Convention on Tobacco Control, ensuring that these environments are tobacco smoke-free by 2015" (WHO, 2010a).

The indoor environment of schools is cause for concern because schoolchildren represent a particularly susceptible group of the population (Geller *et al.*, 2007). Children are frail during their growth and because of their physical constitution and breathing pattern are more susceptible to the health effects of air pollution than adults (Annesi-Maesano *et al.*, 2003). Based on the EUROSTAT demographic database (2013), for the 2010/2011 academic year more than 64 million students spend part of their lifetime in schools: pre-primary, primary and secondary schools. Primary schools accommodate children for about 8 hours daily, which makes them the second most time-spent indoor environment after homes.

There is strong evidence of the potential detrimental role to health of a variety of indoor pollutants commonly found in school environments, originating in the outdoor air or associated with indoor materials, products or activities with indoor air pollutant levels two to five times higher than outdoor levels (Annesi-Maesano *et al.*, 2012). Asthmatic children are known to be exceptionally sensitive to effects of poor air quality. Schools are a particularly critical setting for this susceptible population group.

A report by EFA in 2002 identified various IAQ problems in schools in Europe and found a lack of studies on the consequences to health as well as on standardized methodologies to approach the issue and to assess the impact of different local policies regarding indoor environment in school buildings (EFA, 2002).

DG SANCO funded the HESE project to provide data on IAQ in European schools. The HESE study, performed in 2004-2005, involved six operational units in five European countries (Siena and Udine, Italy; Reims, France; Oslo, Norway; Uppsala, Sweden; Aarhus, Denmark). Twenty-one schools (46 classrooms) were evaluated and respiratory/allergic health information was collected for more than 600 children. Besides promoting awareness of the importance of school environmental air quality on the health of children and providing practical tools for evaluating, improving, and maintaining good air quality in schools, the aims of the HESE included the evaluation of IAQ in schools and the impact of pollutants in the school environment on the respiratory health of European children, in particular on the aggravation of symptoms among asthmatic children. The study revealed a number of IAQ problems in schools, attributed particularly to poor ventilation, and a diffuse lack of awareness and preparedness to cope with environmental problems in general and with the care of more vulnerable children in particular, such as those suffering from asthma (Ciarleglio *et al.*, 2006). Moreover, health effects were found in the HESE children exposed to higher indoor pollution at school, in terms of respiratory disturbances and declined nasal patency (Norbäck *et al.*, 2006).

In 2003-2008, the AIRMEX project on exposure to indoor air chemicals and possible health risks associated mainly to VOC, which was funded and co-ordinated by the European Commission’s JRC, included schools and kindergartens in cities across selected EU Member States in addition to other building types. The results indicated that indoor air pollution levels are higher than the respective outdoor ones. In most cases, indoor pollutant concentrations were higher at homes than in public buildings and schools/kindergartens, probably due to stronger indoor sources at dwellings (Geiss *et al.*, 2011; Kotzias *et al.*, 2009). Key findings highlighted the need for further research to address the burden of indoor air pollution on public health in the EU, in particular, in indoor environments where children frequently stay.

The SEARCH (School Environment and Respiratory Health of Children) project (2006-2009) was developed to build up an Italian-Hungarian IAQ project and implement a new cooperation on air quality in schools, between eight countries: Albania, Austria, Bosnia Herzegovina, Hungary, Italy, Norway, Serbia and Slovakia. Ten schools per country were involved, totalling 35 to 40 classrooms, except for Italy with 13 schools and 55 classrooms. The main aims of the SEARCH project included the assessment of the links between school environment and child respiratory health, and the proposal of recommendations to improve the quality of the school environment. Outdoor and indoor monitoring assessed temperature, relative humidity, carbon monoxide (CO), CO_2, NO_2, benzene, toluene, xylenes, formaldehyde and particulate matter with aerodynamic diameter smaller than or equal to 10 µm (PM_{10}) (Csobod *et al.*, 2010). The project concluded that classrooms painted with water-resistant paints presented great levels of benzene, xylenes and ethylbenzene and the occupants of these classrooms showed more prevalence of allergies. The presence of new furniture was related to high ethylbenzene and xylene concentrations; while classrooms with carpets on the floor showed increased VOC levels which were related to students awoken by wheezing at night. Schools located near heavy traffic and/or industry areas had an adverse effect on children exposure. Higher number of students in a classroom was associated with higher CO_2 and PM_{10} levels. In addition, insufficient ventilation rate during the class period was related to increased levels of CO_2 and formaldehyde and a high number of chronic bronchitis and asthma cases (Csobod *et al.*, 2010).

The BiBa project, in 2009, evaluated IAQ in classrooms of thirty Flemish primary schools. The study included classroom inspections, evaluation of ventilation rate, relative humidity, temperature; and measurement of exposure to chemical pollutants: benzene, toluene, tetrachloroethylene (T4CE), ethylbenzene, xylenes, 1,2,4-triethylbenzene, total VOC (TVOC), formaldehyde and acetaldehyde. Particulate matter with aerodynamic diameter smaller than or equal to 2.5 µm ($PM_{2.5}$) was also evaluated. A very high variability in concentrations among classrooms was observed. BiBa project concluded that concentrations of many chemicals were much higher indoors than outdoors (Stranger *et al.*, 2010).

The HITEA (Health Effects of Indoor Pollutants: Integrating Microbial, Toxicological and Epidemiological Approaches) project (2008-2013) studied the relationship between the role of biological agents present in indoor air and long-term respiratory, inflammatory and allergic health impacts among children and adults. HITEA focused on many indoor exposures and factors, like allergens, cleaning agents, traffic exhaust and poor ventilation, but the main objective focused on microbial exposures due to dampness and moisture problems of buildings. Other important objective of this project was to propose new approaches to characterize indoor biological exposures, by using novel methods to measure airborne exposure and by characterizing the house dust for its in vitro toxicity, inflammatory properties and microbial toxin content. Under this project, Bakolis *et al*. (2012) found endotoxin levels varying from 0.1 to 402.6 EU/mg. However, there was no evidence of cause-effect of endotoxin exposure and lung function problems.

Recently, the SINPHONIE project, involving 38 partners from 25 countries, aimed to contribute to a better understanding of the situation of IAQ in primary schools and kindergartens, to produce recommendations and guidelines on remedial measures in school environments covering a wide array of situations in Europe and to disseminate these guidelines to relevant stakeholders able to take action. The overall results confirmed that schools frequently have IAQ problems caused by poor building location, construction and maintenance, excessive density of occupation, poor cleaning and insufficient ventilation; many schools with high levels of air pollutants that might cause a higher risk to have symptoms and complaints related to IAQ and to suffer from allergic and respiratory symptoms and other diseases in the past year and ever.

Some other projects related with IAQ in schools in the European context or at national level (e.g., Observatory of Indoor Air Quality and the 6 Cities study in metropolitan France) highlighted that the status of the school buildings and irrespective ventilation levels are two of the major problems in schools (Annesi-Maesano *et al.*, 2012; Stranger *et al.*, 2010; Kirchner *et al.*, 2006). These findings were supported by a recent literature review on school environment and IAQ in particular (Annesi-Maesano *et al.*, 2013).

Other studies in schools have been performed in Northern Europe (Kim *et al.*, 2007), Central Europe (Fromme *et al.*, 2007); United States (Godwin and Batterman, 2007; Shaughnessy *et al.*, 2006) and China (Kim *et al.*, 2007; Mi *et al.*, 2006; Zhao *et al.*, 2006). Significant differences among indoor environments from different regions have been found.

From the literature review, it was found that only few studies were conducted to evaluate the associations of school characteristics and asthma, allergies and respiratory symptoms among the attending students or teachers (Nafstad *et al.*, 2005; 1997; Li *et al.*, 1997; Rylander, 1997; Koskinen *et al.*, 1995; Ruotsalainen *et al.*, 1995). The most commonly studied school characteristic was the presence of moisture and mould with inconsistent evidence found: Koskinen *et al*. (1997; 1995) reported associations of some endpoints with the presence of moulds in schools while Nafstad *et al*. (2005) did not find any association with asthma, allergies and respiratory problems. Inference based on findings from reviewed studies in dwellings and offices suggest that dampness, ventilation types, building materials, cleaning and maintenance and outdoor pollution sources related to the school environments could be associated with asthma, allergies and respiratory symptoms among attending children. It is to be noted that climate and ways of built in different regions around the world could vary substantially between schools and non-schools environments.

Other studies focused on the relation between indoor air pollution and health outcomes. Meininghaus *et al*. (2003) organized a study aimed at identifying compounds (such as aldehydes and VOC) which could be responsible for the reported adverse health effects, but no cause could be identified. Janssen *et al*. (2003) identified an association between truck traffic and its related air pollutants with chronic respiratory symptoms in Dutch schoolchildren living close to motorways. Also in the Netherlands it was found in a study of 54 children from four different schools that the personal exposure of children attending schools located within 100 m from a major road had a 30% increase of soot exposure, and a 37% increase of nitrogen oxides exposure. The differences appeared to be smaller and insignificant for $PM_{2.5}$ and NO_2 (Van Roosbroeck *et al.*, 2007).

However, data on air quality found in classrooms and its health effects are scant and inconsistent. Furthermore, few studies have used objective assessments of IAQ and health indicators (Viegi *et al.*, 2004). More objective lung function measurements or allergy tests were only performed in a few longitudinal or time series studies, which focused on the evolution of the health situation of a limited number of participants, due to the fact that these measurements are more time consuming and require more effort and financial support.

In spite of the various studies performed worldwide to assess the IAQ in school environments, the information on IAQ and health for Portugal is very limited. Fraga *et al*. (2008) evaluated the association between the IAQ in nine Porto secondary schools and the prevalence of allergic and respiratory symptoms in adolescents. Carbon dioxide concentrations higher than 2100 ppm were associated with greater respiratory symptoms. In 2004-2005, Madureira *et al*. (2009) characterised the IAQ in eleven secondary schools located in Porto; evaluated health symptoms reported by teachers and investigated the impact of pollutants on the prevalence of those symptoms. The results pointed out for CO_2 concentrations exceeding the reference values (1000 ppm) and the increase of breathable particulate matter concentrations associated with the use of chalk. Later, the SaudAR project studied the relation between outdoor and indoor air and human health in primary schools of Viseu city. Two different populations of children with wheezing symptoms were compared, but no differences were found concerning the prevalence of wheezing (Neuparth *et al.*, 2006). Furthermore, the SaudAR project pointed out that the state of buildings and ventilation are one of the major problems in schools. In the frame of SaudAR study, Valente (2010) evaluated IAQ at four primary schools during the summer and winter of 2006 and 2007. The particulate matter concentrations ranged according to the season; higher values were observed in summer. Particulate matter concentrations were higher indoors than outdoors. The low levels observed during weekends suggested that higher particulate matter concentration during week days are related to human activities. Additionally, under SaudAR project (Martins *et al.*, 2012) suggests a relation between indoor air pollution (namely VOC), airways inflammation and oxidative stress. More recently, Pegas (2012) showed that IAQ in elementary schools located in Aveiro and Lisboa was worse than outdoor air. In addition, the author reported that the CO_2 and bioaerosol levels were higher than 1000 ppm for CO_2 and 500 CFU/m^3 for bacteria and fungi concentrations; and underlined the contribution from indoor sources to indoor levels of VOC, carbonyls and PM_{10}.

The available but limited information shows that national studies have usually involved either a relatively small number of schools, or assessed a small set of parameters (e.g. CO_2, TVOC and formaldehyde). No studies were conducted to evaluate building characteristics, IAQ parameters and health related outcomes in a large sample of schoolchildren. Consequently, the understanding of exposures and the association with health effects remain incomplete. By the way, in Portugal, schools should be periodically monitored in terms of IAQ since 2006 according to the *Regulamento dos Sistemas Energéticos de Climatização em Edifícios* (DL 79/2006). This decree-law was recently revised and substituted by the DL 118/2013 of August 20 (DL 118/2013).

To bridge the knowledge gap on the health effects, there is a need for a comprehensive investigation of children exposure in primary schools using a standardized protocol to measure a wide range of health-relevant parameters. While the literature related to schools environment and adverse respiratory effects is generally coherent showing increased risks of asthma, allergies and respiratory illnesses, current Portuguese data has not revealed that schools characteristics and indoor air exposures play an important role in IAQ in classrooms and consequently on the adverse health. Current information has not revealed, however, what characteristics of the schools and occupant behaviours are associated with poor IAQ.

This current survey will provide useful data on IAQ and health for school staff as well as to guide regulatory decision-making and public health protection efforts in order to prevent diseases or symptoms in schoolchildren. In addition, information deriving from this study will be very useful for school users and operators by implementing measures to avoid characteristics and behaviours that are associated with poor IAQ.

3.3 Indoor Air Quality and Health at Home

Human beings live 90% of their lifetime indoors. Most of their time is spent at home with residence times in the United States, Canada and Germany reported to be strikingly similar; 15.5 to 15.7 hours per day (Brasche and Bischof, 2005). In the industrialized countries, children spend more time at home compared to adults and within homes they can be exposed to a multitude of pollution sources which suggests that significant exposures may occur at home. Until recently, little attention has been paid to the potential health impact related to home indoor exposures.

Relatively fewer studies have been performed on associations of home characteristics and indoor factors and asthma and allergies in schoolchildren (Mcconnell *et al.*, 2006; Mendell, 2006; Gauderman *et al.*, 2005; Zmirou *et al.*, 2004; Nicolai *et al.*, 2003). For asthma and wheeze, only associations with dampness and wall paper were more consistent in the schoolchildren. For rhinitis and eczema, studies among schoolchildren were too sparse to draw any conclusion.

Emissions of pollutants from cooking and heating with gas or solid fuels have been found to affect respiratory illnesses in children. Observed effects were an increase in respiratory diseases (Burr *et al.*, 1999) and in the susceptibility to asthma and changes in lung function (Corbo *et al.*, 2001). Owing to specific sources (cleaning materials, solvents, etc.) the concentration of VOC measured in the indoor air is often significantly higher than outdoors. Some VOC are known to cause harmful effects to health: several are known carcinogens. The LARES survey provided additional evidence that adequate IAQ is not common in many European homes, and that it is still affected by a variety of pollutants and problems such as a claimed insufficient ventilation, leading to the above-mentioned health effects (WHO, 2011). In addition, a cross-sectional study carried out in 557 Portuguese homes, distributed throughout the mainland, the authors concluded that the majority of the homes studied had reasonable air quality and thermal comfort, but revealed that in 60% of the homes, at least one of the measured parameters (CO_2, CO, PM_{10}, VOC or formaldehyde) was above the defined limit: 7.6% of the CO_2 measurements were above 1000 ppm; 50% of the houses had VOC concentrations above 600 $\mu g/m^3$; 2.3% of the PM_{10} measurements were above 150 $\mu g/m^3$; only three measurements of formaldehyde and two of CO were above the maximum values of 100 $\mu g/m^3$ and 12.5 mg/m^3, respectively (Almeida *et al.*, 2010). In addition, no significant associations were found with the health parameters evaluated (Almeida *et al.*, 2010).

There is increasing evidence that mould growth in damp buildings is an important risk factor for respiratory illness. Mould-related symptoms are likely a result of irritation, allergy, or infection (WHO, 2012; Chapman *et al.*, 2003). Mould spores are present in all kinds of indoor environment. Common building materials and furnishings provide ample nutrition for many species of moulds, but they can grow and amplify indoors only when there is an adequate supply of moisture. Older houses with recent water damage are frequently the favourite sites for mould growth. Poor social conditions (state rental housing, and financial difficulty with housing costs) were also found to be significant predictors of damp, mouldy homes (Butler *et al.*, 2003).

Though in most cases a dose-response relationship cannot be derived between the measured concentration of fungi and the registered health problems (Moriske *et al.*, 2003), irritations of the throat and eyes, allergies (most frequently allergic rhinitis), lower respiratory symptoms (dry cough, wheeze) and asthma have been repeatedly observed. Apart from respiratory symptoms, depression and the presence of general symptoms like fatigue, headache, dizziness, and difficulties in concentration were also reported (Moriske *et al.*, 2003; Rylander and Etzel, 1999). The LARES survey showed that there is a considerable amount of European homes affected with mould growth and dampness. Substantial mould growth was detected in 32% of all surveyed homes associated with health effects such as asthma (WHO, 2011).

In summary, relatively little but valuable information about associations of home indoor exposures with asthma and allergies among children has been generated by several studies in the United States (Burr *et al.*, 1999; Spengler *et al.*, 1994; Strachan, 1989), Europe (Behrens *et al.*, 2005; Fischer *et al.*, 1998), Russia (Jaakkola *et al.*, 2004; Spengler *et al.*, 2004) and Taiwan (1998; Yang *et al.*, 1997; Li and Hsu, 1996). It should be noted that the mentioned studies do not provide information about IAQ in schools attended by the children.

In Portugal schoolchildren spend most of their time in their homes. Indeed, the home indoor environment can have a significant impact on children's health. Many residential buildings are located close to main roads. Home building materials and construction finishes and consumer products are different from those used in other countries which may have implications in the indoor exposure. In addition, smoking is prohibited in most of public spaces due to specific law, such as the Portugal case (Lei 37/2007), which could have implications on smoking at home in private. The above factors together with other features such as socio-economic conditions, climatic condition, occupants' behaviour, make a case for the need to evaluate associations of indoor exposure at homes with children's health. Despite of asthma and allergies exhibits a high prevalence in children and constitutes an important public health concern, little is known about the home factors that may influence this prevalence from our own environment. Indeed, children's exposure to risk factors at home and schools has not been studied concurrently.

3.4 Indoor Air: Exposures and Risk Factors

Associations have been reported between some important indoor exposures and asthma and allergic symptoms among children. However, the causes behind the increase in asthma and allergies among children are largely unknown and very little is known regarding indoor air risk factors to these diseases. With the exception of pets, ETS (environmental tobacco smoke) and other combustion sources, the indoor risk factors could be present in either homes or schools or both. However, children spend more time at home than at school and it is worth highlighting that specific motivations, operations, building designs and aspects of home and primary school environments are different and effect measures linking these potential harmful exposures could vary substantially.

The following text will present the knowledge regarding the relationships between indoor exposure to chemicals and physical parameters and asthma, allergy and respiratory symptoms. The section will also discuss the problems of microbiological agents and these health outcomes.

3.4.1 Chemical and physical exposure

Humans are exposed to a wide and increasing range of chemicals. During the last decades in Europe more than 100000 new chemicals have been introduced to the entire environments (CEC, 2001). Sources for chemical contamination in indoor environments include namely outdoor emissions, building materials and finishes (Bornehag *et al.*, 2005), consumer products such as paints, cleaning agents (Choi *et al.*, 2010), personal care products (Sathyanarayana *et al.*, 2008), occupant behaviour and maintenance. Some of these chemicals may persist from several months in the indoor environment (Weschler and Nazaroff, 2008). Some chemicals have been shown to be toxic in animal studies and an increasing body of evidence suggests that they are also impacting human health (Weschler and Nazaroff, 2008).

Nowadays, legal obligations under the GPSD (EC, 2001) and the EU regulatory framework for the REACH (EC, 2006) which entered into force in June 2007, require detailed understanding of where and how chemicals are used throughout their life-cycle. This information enables a better characterization of emissions and exposure to these chemical substances, which is essential to be able to control emissions from sources aiming at reducing adverse health effects (Bruinen *et al.*, 2008). These policies require scientifically sound human risk assessment procedures incorporating acceptable qualitative and quantitative human exposure information. Whilst policy action is taken to assess and mitigate impacts on human health, large knowledge gaps still exist. The effects of long-term and low-dose exposure to mixtures of chemicals, particularly in young children, are poorly understood. Possible combined effects of exposure to a mixture of chemicals found at low levels in the environment or in consumer goods, especially of young children, are receiving particular attention (EEA and JRC, 2013).

<u>Outdoor emissions</u>

Air pollution remains one of the major environmental problems in Europe, affecting health and well-being of European citizens. Some of outdoor pollutants originate from traffic, car-parks, construction and industrial sites. Outdoor air pollution includes both gaseous and particulate pollution. Primary pollutants are emitted directly out of exhaust pipes and stacks (nitrogen oxides, particulate matter, etc.). Secondary pollutants are formed from the primary pollutants in the co-presence of sunlight, moisture, or both (ozone and secondary particles, like sulphate) (EEA and JRC, 2013). A recent report of European Environment Agency has confirmed that traffic emissions (i.e. emissions from road transport), a significant source of outdoor pollution in many countries, has remained the main source of health damaging pollutants, being the most significant source of nitrogen oxides, CO, and the second most important source of PM_{10} and $PM_{2.5}$ (EFA, 2008; Heinrich *et al.*, 2005; Holgate *et al.*, 1999). The impacts of the two widespread pollutants evaluated here, particulate matter and ozone, are the best known but other pollutants should also be considered for policy action.

Large amounts of particulate matter are generated by various human activities. Since particles can travel hundreds and thousands of kilometres in the air, and are partly created from gaseous pollutants in the atmosphere, their effects can be seen far from the source. Particulate matter is a mixture of solid or solid/liquid particles suspended in air (WHO, 2000). These particles vary considerably in origin, size, shape and in chemical properties. Upon inhalation PM_{10} and $PM_{2.5}$ are deposited on the wall of airways and lungs; the smaller the particles the deeper the penetration within the system (Kaiser, 2000). While larger particles deposit mainly in the nose and throat, particles of $PM_{2.5}$ penetrate in the deeper parts of the lungs, being able to reach the alveoli. Therefore, the attention has been recently focused on $PM_{2.5}$ (WHO, 2006) and consequently it was concluded (Pope *et al.*, 2002) that especially this fraction of PM_{10} is associated with some of the more serious health effects (mortality, lung cancer). Nevertheless, other particulate matter properties such as chemical composition also significantly contribute to adverse health effects (Harrison and Yin, 2000), suggesting that they are the result of a complex (eventually synergic) interaction of multiple particles properties with the respiratory tract. Obviously, further understanding of particulate matter is necessary to design effective air pollution strategies, for appropriate reduction of risks associated with air particulate pollution.

In 2010, an estimated 21% of the urban population was exposed to PM_{10} concentration levels exceeding the daily EU limit value designed to safeguard health. Up to 30% of the urban population was exposed to $PM_{2.5}$ concentration levels above the indicative annual EU limit value (to be met by 2020). Referring to more stringent WHO health-based air quality guidelines, respectively up to 81% and 95% of urban dwellers were exposed to particulate matter concentrations above the values set for the protection of human health in the period 2008-2010 (EEA and JRC, 2013). Out of 27 EU Member States, Portugal is, respectively, the 12-14th and the 8-11th largest contributor of traffic PM_{10} and $PM_{2.5}$. It is especially alarming though that contrary to the other EU countries where traffic particulate matter decreased during last two decades, in Portugal PM_{10} and $PM_{2.5}$ from traffic emissions increased by 18% between 1990 and 2006 (EFA, 2008). This information indicates that traffic particulate matter in Portugal is a matter of great concern and the reduction of these emissions, mainly related to the $PM_{2.5}$, is fundamental in order to protect public health.

Epidemiological research on asthma and allergies prevalence among children associated with traffic exposure has been shown in most (Jantunen *et al.*, 2011; Clark *et al.*, 2010; Gehring *et al.*, 2010;

Mcconnell *et al.*, 2006; D' Amato *et al.*, 2005; Gauderman *et al.*, 2005) but not all surveys (Hirsch *et al.*, 1999; Dockery *et al.*, 1996). Traffic-related pollutants have also been revealed to have an indirect effect on allergic response by influencing quantitatively and qualitatively allergens (Brunekreef *et al.*, 1997; Knox *et al.*, 1997; Weiland *et al.*, 1994). Annesi-Maesano *et al*. (2007) supports that a complex pollution mixture associated with fine particulate matter might in part contribute to the enhancement of allergic sensitization through interactions with allergens. Long-term average exposure to particulate matter is associated with both the risks of chronic effects on children's health, such as impaired development of lung function, and the frequency of acute effects, such as the aggravation of asthma or incidence of respiratory symptoms (WHO, 2009c).

To be noticed that for different studies, investigations to link asthma and allergies with traffic exposures have been demonstrated using different traffic indicators which include self-reported traffic-density (Duhme *et al.*, 1996), proximity to roads (Mcconnell *et al.*, 2006; Ryan *et al.*, 2005), traffic intensities (Brauer *et al.*, 2002; Venn *et al.*, 2001) and measurements of pollutants putative to be surrogate exposures of traffic pollution (Brunekreef *et al.*, 1997).

Ozone is another outdoor air pollutant that causes substantial deaths and illness. Ozone in lower levels of the atmosphere originates largely from human activity and is not only harmful to humans but has adverse effects on materials and vegetation. It is also a greenhouse gas when in the upper troposphere (WHO, 2010b). Short-term exposure to ozone can increase respiratory deaths and the incidence of respiratory symptoms. The consequences of long-term exposure are less well established but suggestive evidence points to further negative effects (WHO, 2008). Current policies are only expected to reduce ozone-related mortality by about 1000 deaths or fewer (WHO, 2008). Reductions in illness are expected to be greater, with particular benefits in the reduction of cough and lower respiratory symptoms in children (by an estimated 40%). Implementation of all technically feasible pollution reduction measures would, however, halve the current mortality by 2020 (WHO, 2008).

Recently, the WHO in Europe coordinated the REVIHAAP (Review of evidence on health aspects of air pollution) project which aimed to provide the EC and its stakeholders with evidence-based advice on the health aspects of air pollution (WHO, 2013). The review concludes that a considerable amount of new scientific information on the adverse effects on health of particulate matter, ozone and nitrogen dioxide, observed at levels commonly present in Europe, has been published in recent years. This new evidence supports the scientific conclusions of the WHO air quality guidelines, last updated in 2005, and indicates that the effects in some cases occur at air pollution concentrations lower than those serving to establish these guidelines. It also provides scientific arguments for taking decisive actions to improve air quality and reduce the burden of disease associated with air pollution in Europe (WHO, 2013).

Building materials and finishes and consumer products

A growing body of research from Europe and Australia suggests that chemical emissions from common building materials and finishes such as carpet (Jaakkola *et al.*, 2004), polyvinyl chloride (PVC) flooring (Jaakkola *et al.*, 2004; Jaakkola *et al.*, 2000; Jaakkola *et al.*, 1999; Oie *et al.*, 1999), painting (Emenius *et al.*, 2004; Jaakkola *et al.*, 2004), wall paper (Jaakkola *et al.*, 2000; Jaakkola *et al.*, 1999) and activities related to these materials (Emenius *et al.*, 2004; Jaakkola *et al.*, 2004) have a variety of adverse effects on respiratory and immune health (Bornehag *et al.*, 2004a; 2000; Jaakkola *et al.*, 1999; Oie *et al.*, 1999). The identified risk factors include specific organic compounds such as VOC and formaldehyde (Garrett *et al.*, 1999).

Volatile organic compounds are ubiquitous in the indoor environment and the number of VOC detected in indoor air is usually higher than in outdoor air. According to Samet (1990) levels of most VOC can be 5-10 timed higher indoors than outdoors. Among all VOC benzene are of particular interest due to their known carcinogenic effects. Chlorinated compounds such as trichloroethylene (T3CE) and T4CE have received increasing attention. Trichloroethylene as a solvent or as a component of solvent blends it is used in adhesives, paints, varnishes, paint strippers, and water proofing agents. Consumers may be exposed to T3CE through the use of wood stains, varnishes, finishes, lubricants, adhesives, typewriter correction fluid, paint removers and certain cleaners, where T3CE is used as a solvent (WHO, 2010c). Use of these products may result in elevated indoor air concentrations over background, although, as they are expected to be used intermittently rather than constantly, both short-term and long-term average concentrations are likely to be variable. Its main health effects are neurotoxic and carcinogenic. Immunotoxic, hepatic and developmental effects are also reported. International Agency for Cancer Research (IARC) has classified T3CE as a probable human carcinogen based on sufficient evidence in animals and limited evidence in humans. Tetrachloroethylene is used in the finishing and processing of textiles, the production of paint removers and printing inks, and the formulation of adhesives and specialized cleaning fluids. Consumer products that may contain T4CE include adhesives, fragrances, spot removers, stain removers, fabric finishes, water repellents, wood cleaners, motor vehicle cleaners and dry-cleaned fabrics (WHO, 2010c). The respective main health effects of concern are local irritation (eyes, mucous membranes, respiratory tract and skin), effects on the central nervous system and cancer. According to WHO (2010c), T4CE was classified as a probable human carcinogen by IARC.

Formaldehyde is classified as a human carcinogen (Group 1) by the IARC. Formaldehyde sources in indoor environments include: furniture and wooden products containing formaldehyde-based resins such as particleboard, plywood and medium-density fibreboard; insulating materials (in the early 1980s, urea formaldehyde foam insulation was a major source of indoor pollution); textiles; do-it-yourself products such as paints, wallpapers, glues, adhesives, varnishes and lacquers; household cleaning products such as detergents, disinfectants, softeners, carpet cleaners and shoe products;

cosmetics such as liquid soaps, shampoos, nail varnishes and nail hardeners; electronic equipment, including computers and photocopiers; and other consumer items such as insecticides and paper products (Salthammer *et al.*, 2010; WHO, 2010c; Dassonville *et al.*, 2009). Secondary formation of formaldehyde occurs indoors through chemical reactions between, for example, ozone and terpenes (WHO, 2010c; Nicolas *et al.*, 2007; Destaillats *et al.*, 2006; Weschler, 2006). In what regards the formaldehyde often associated with wood products; the EU has established testing standards for the classification of end products of wood glued (laminated flooring, laminated wood, etc) according to their formaldehyde emission (EC conformity marking). This classification has been taken for other products such as ceiling tiles and flooring. Effects of formaldehyde in indoor air include sensory irritation to the eyes and upper airways, lung effects (asthma and allergy) and eczema. Associations were reported with increases in asthmatic symptoms (Garrett *et al.*, 1999). Formaldehyde has been related to nocturnal attack of breathlessness and cumulative asthma (Zhao *et al.*, 2008). Higher concentration of this pollutant was associated to decrease nasal patency (Norback, 2000) and new asthma diagnosis among children without history of atopy (Smedje and Norbäck, 2001). In the French school, formaldehyde was related to an increased risk of rhinitis (Annesi-Maesano *et al.*, 2012). Exposure to aldehydes was found to be associated to airway inflammation in schoolchildren of the 6 Cities study. These associations occurred even in children with no history of airway damage and seem to be enhanced in atopic subjects.

Textile materials are potential sources of biologic and non-biologic particles, as well as chemical emissions (Wallace, 2000), which may cause inflammation of airways through allergic or irritative mechanisms. Besides the actual materials used in the production of textiles, particles attached to the surface may be re-suspended and the chemicals adsorbed may be emitted into indoor air. In addition, dust mites can also find suitable microenvironments in carpets that are optimal for their proliferation (Zhang *et al.*, 1997; IOM, 1993). Katsoyiannis *et al.* (2008) measured the emissions of VOC and carbonyls from carpets (wool, synthetic, mixed) in small experimental rooms (from 0.28 to 0.45 m^3). In this study emissions from aromatic hydrocarbons are low and the maximum levels of benzene and toluene observed are respectively 4.6 $\mu g/m^3$ and 8.6 $\mu g/m^3$. The ethylbenzene, xylenes and styrene are detected in a few cases and at low levels; while the levels of styrene are 11 $\mu g/m^3$. For carbonyl compounds, maximum levels are obtained for formaldehyde (24 $\mu g/m^3$). The issuance of this aldehyde is due to the glues that bind the fibres together and support. Acetaldehyde can also be issued; the maximum level obtained was 14 $\mu g/m^3$ (Katsoyiannis *et al.*, 2008). Studies of associations between carpets and asthma in children have been conflicting; Behrens *et al.* (2005) found significantly reduced risk of asthma symptoms among German children with carpets in the bedroom, but Jaakkola *et al.* (2004) reported significantly higher odds of wheezing in Russian children with presence of carpets. In Taiwan, the presence of carpets was found to be unrelated with asthma, cough, wheeze, bronchitis and allergic rhinitis (Yang *et al.*, 1997). Jaakkola *et al.* (1999) reported that carpeting in one or more rooms was not associated with bronchial obstruction.

Polyvinyl chloride materials are potential emission sources of the chemicals used for example, plasticizers, adhesives, solvents and stabilizers in production (Kavlock *et al.*, 2002). Such emissions usually take place over a long time. There is a growing body of literatures showing an association between phthalates (commonly used as plasticizers in PVC materials such as flooring materials) and symptoms in the airways (wheezing, asthma) and in the skin (eczema) that can be of allergic (IgE-mediated) or non-allergic origin in children, but most of the epidemiological studies are of a cross-sectional design (Bornehag and Nanberg, 2010; Jaakkola and Knight, 2008). Another previous report on a 5-year questionnaire follow-up study showed a relationship between PVC-flooring in childhood and the development of asthma in children (Larsson *et al.*, 2010). Epidemiologic studies carried out among pre-school children in Scandinavia (Bornehag *et al.*, 2004a; 2000; Jaakkola *et al.*, 1999; Oie *et al.*, 1999) have shown relations between the amount of textile wall material and plasticized PVC materials at home and asthma, bronchial obstruction, and lower respiratory symptoms.

Renovation measures, such as painting, varnishing and installations of built-in wooden furniture's, result in an increase in chemical emissions, which will then decline rather sharply over time. In a recent study of 5951 Russian schoolchildren 8-12 years of age in nine cities, the risks of asthma, wheezing, and allergies were related to the installation of new linoleum flooring, synthetic carpet, wall covering, and particle board, as well as recent painting and the presence of new furniture (Jaakkola *et al.*, 2004). Emenius *et al.* (2004) had shown that recurrent wheezing for 2 years olds Swedish children were significantly associated with repainting, particularly in the child's bedroom (OR: 1.7; 95% CI: 1.1-2.6).

Naphthalene has been classified by IARC in Group 2B as "possibly carcinogenic to humans" on the basis of sufficient evidence of its carcinogenicity in experimental animals and inadequate evidence of carcinogenicity in humans. The highest indoor concentrations, however, usually orders of magnitude above the outdoor air levels, come from consumer products such as multipurpose solvents, lubricants, herbicides, charcoal lighters and hair sprays, rubber materials and, most importantly, naphthalene insect repellents (mothballs) used to protect textiles stored indoors in closets (although this use has decreased, mainly in western Europe). Wood smoke, fuel oil and gasoline also contain naphthalene. (WHO, 2010c). Exposure to naphthalene has been linked to a number of adverse health effects. The major non cancer end-points is metaplasia in respiratory epithelium, and the cancer end point of concern are nasal tumours (Jia and Batterman, 2010).

Moreover, candles, home fragrances and incense traditionally used in everyday life are significant sources of chemical compounds and particulate matter.

Occupant behaviour and building maintenance

Children and adolescents (as well as adults) can be exposed to tobacco smoke indirectly through ETS (Fontham *et al.*, 2009; WHO, 2009d). Passive smokers are exposed to tobacco smoke which contains many potent respiratory irritants, agents of inflammation and respiratory toxins (IARC, 2009). It is also well established that exposure to ETS creates a huge burden to health. There is strong evidence among published studies that exposure to ETS is causally associated with an increased prevalence of asthma and wheeze in children and that exposure to ETS aggravates asthma in childhood (Uddenfeldt, 2010; WHO, 2009d). In western Europe, various studies from the late 1990s indicated that the proportion of children aged 0-4 years exposed to ETS at home lay between 20% (Netherlands) and 35% (England), with higher levels often seen in older children (WHO, 2009d). Strachan and Cook (1998) conducted a meta-analysis on ETS studies to assess the effects of parental smoking on the prevalence of asthma and wheeze. Dose-dependent relationships between the prevalence of asthma and wheeze and parental smoking were found. They also found that while maternal smoking had a greater effect than paternal smoking, the effect of paternal smoking alone was clearly significant suggesting that the postnatal effect is important. Asthmatic children with mothers who smoke were found to have more severe asthma when compared with those whose mothers did not smoke (IOM, 2000). According to Bernstein *et al*. (2008) young children, in particular, who spend most of their time at home, are at increased risk for even greater exposures to tobacco smoke if their mothers smoke; it was estimated that ETS exposure in home increases the risk of developing asthma by 40-200%. While most of the works relating ETS exposures had focused on asthma and wheeze in children, there have been very few studies performed on the associations with rhinitis and eczema symptoms. Literature review studies showed conflicting results with no associations in some (Raherison *et al.*, 2007), and both significant increased (Ekerljung *et al.*, 2008; Trude and Skorge, 2007; Biagini *et al.*, 2006) or reduced risk of symptoms in others (Kurosaka *et al.*, 2006; Magnusson *et al.*, 2005). Unlike some other public health hazards, exposure to ETS is easily preventable. A number of countries worldwide have implemented various forms of smoke-free policies, and research shows that these policies are successful. In Portugal, the legislation was set in force by January 2008 by Lei 37/2007 (2007). However, the home remains an unregulated source of ETS exposure and is probably the most important source of exposure for children. According to WHO (2010b) in many countries, over 80% of children are regularly exposed to ETS in the home and even more outside the home.

Domestic combustion of fuels, in particular, the use of gas appliances in a poorly ventilated kitchen and heating appliances, is a major source of indoor air pollution. Combustion emits a number of different pollutants but the smallest particles, with a diameter of 2.5 µm or less, appear to have the greatest health-damaging potential as well as NO_2 (WHO, 2010b; IOM, 2000). There is consistent evidence that exposure to indoor air pollution from indoor combustion increases the risk of pneumonia, chronic respiratory disease and lung cancer. There is also some evidence for associations with asthma, tuberculosis, adverse pregnancy outcomes, ischemic heart disease and cancers of the nose and throat (WHO, 2009a). In a study performed among Russian children, Spengler *et al*. (2004) recorded higher odds of current doctor diagnosed asthma with gas cooking fuel. This was different from the earlier study performed in the United States showing no relation of asthmatic symptoms among 15523 children with gas cooking. No association of gas cooking appliances use with asthma, wheeze or allergic rhinitis was reported in Taiwanese children (Yang *et al.*, 1997). Burr *et al*. (1999) reported no associations of gas cooking with asthma and allergies among British children but documented that heating using main gas, bottle paraffin and other means significantly increased the odds of wheeze and rhinoconjunctivitis. No associations were also observed for both gas cooking and heating with asthma symptoms among children in Prague, Poznan, Huddersfield and Amsterdam (Fischer *et al.*, 1998). Three studies relating gas heating and cooking with asthma and allergies among pre-school children were found. Volkmer *et al*. (1995) showed that cooking using natural gas was associated with higher odds of asthma (OR: 1.15; 95% CI: 1.02-1.30) and current wheeze (OR: 1.13; 95% CI: 1.01-1.26) in South Australian schoolchildren. Similar odds were observed for these symptoms among Adelaide pre-school children exposed to cooking with natural gas. In Hong Kong, Wong *et al*. (2006) reported that gas cooking in the homes was associated with higher odds of pre-school children having one or more respiratory illnesses (allergic rhinitis, asthma, bronchitis, sinusitis and pneumonia). The authors reported that there was a dose-response relation between the frequency of gas cooking and the prevalence of respiratory illnesses in one of the studied estates that recorded lower outdoor air pollution.

Carbon dioxide is not a pollutant itself. Indoor CO_2 levels are usually an indicator of the adequacy of ventilation. Only few studies investigated the associations between CO_2 and health. However, in some studies CO_2 levels have been positively associated with asthma attack, asthma medication, current asthma (Mi *et al.*, 2006) as well as with dry cough at night and rhinitis (Simoni *et al.*, 2010). Protective effects have also been found for nocturnal and daytime breathlessness (Mi *et al.*, 2006; Kim, 2005). Kvisgaard *et al.* (1990) and Iwashita *et al.* (1997) reported that occupant behaviour may account for as much as 63-87% of the total ventilation rate.

Different studies investigated the association between indoor particulate matter and asthma (Raaschou-Nielsen *et al.*, 2010; Diette *et al.*, 2007; Tavernier *et al.*, 2006); while Raaschou-Nielsen *et al.* (2010) looked at the effect of indoor particulate matter exposure on wheeze. Despite Kim *et al.* (2005) and Chen *et al*. (1997) did not find any association between PM_{10} and children's health; high PM_{10} concentrations were associated with regular day and night cough (Csobod *et al.*, 2010). This pollutant was also linked with decrease in children lung function (Castro *et al.*, 2009) and a small reduction in ventilatory capacity (Scarlett *et al.*, 1996). In addition, increasing exposure to PM_{10} was associated with acidity of exhaled breath condensate in a study carried out by Martins *et al*. (2012).

Links between health and $PM_{2.5}$ concentrations were given in Annesi-Maesano *et al*. study in the schoolyards (Annesi-Maesano *et al.*, 2007) and in classrooms (Annesi-Maesano *et al.*, 2012). After adjustment for confounders and NO_2 as a potential modifier, the odds of suffering from exercise induced asthma and flexural dermatitis at the period of the survey, past year atopic asthma and skin prick test positivity to indoor allergens were significantly increased in schoolchildren whose schoolyards presented $PM_{2.5}$ concentrations exceeding 10 $\mu g/m^3$. Similar values of odds ratio were found when considering the concentrations of $PM_{2.5}$ in the classrooms (Annesi-Maesano *et al.*, 2012).

3.4.2 Microbiological exposure

Microbiological pollution is a key element of indoor air pollution. Microbiological agents of relevance to health are widely heterogeneous, ranging from pollen and spores of plants (mainly from outdoors), to bacteria, fungi, algae and some protozoa emitted outdoors or indoors (Le Cann *et al.*, 2011; Hersoug, 2005; Nevalainen and Seuri, 2005; IOM, 2004).

There is strong evidence regarding the hazards posed by several microbiological agents that pollute indoor air; however, the WHO working group convened in October 2006 concluded that the individual species of microbes and other biological agents that are responsible for health effects cannot be identified. This is due to people often being exposed to multiple agents simultaneously, to complexities in accurate estimation of exposure and to the large numbers of symptoms and health outcomes due to exposure. The exceptions include some common allergies, which can be attributed to specific agents, such as house-dust mites and pets (WHO, 2009b).

The presence of many biological agents in the indoor environment is mainly attributable to dampness and inadequate ventilation (WHO, 2009b). Excess moisture on almost all indoor materials leads to growth of microbes, such as mould, fungi and bacteria. Moreover, dampness initiates chemical or biological degradation of materials, which also pollutes indoor air (Zock *et al.*, 2006; Nevalainen and Seuri, 2005; IOM, 2004). Dampness has therefore been suggested to be a strong, consistent indicator of risk of asthma and respiratory symptoms (e.g. cough and wheeze).

Dampness can be a concern, particularly in areas with a temperate damp climate, like Europe. There prevalence of indoor damp is estimated to be in the order of 10-50% (WHO, 2009b). Fungi producing allergens such as *Cladosporium*, *Alternaria*, *Penicillium* and *Aspergillus* are known to develop in the presence of moisture (Bloom *et al.*, 2009) and are strongly associated with allergic respiratory diseases, especially asthma (WHO, 2009b). Sufficient epidemiological evidence is available from studies conducted in different countries and under different climatic conditions to show that the occupants of damp or mouldy buildings, both houses and public buildings, are at increased risk of respiratory symptoms, respiratory infections and exacerbation of asthma (Sahakian *et al.*, 2008; Zock *et al.*, 2002; Brunekreef *et al.*, 1989). Jaakkola *et al*. (1993) documented higher odds of nasal congestion (OR: 2.4; 95% CI: 1.2-5.0) for children exposed to dampness. In addition, the PATY (Pollution and the Young) project (Antova *et al.*, 2008) compiled data on exposure and health status for 57161 children aged from 6 to 12 years in 12 countries and reported that indoor mould exposure was consistently associated with adverse respiratory health outcomes (wheeze, nocturnal cough, sensitivity to inhaled allergens and hay fever). However, these results were based on data from a self-reported questionnaire on exposure and health outcomes.

A number of studies have suggested an association between house dust mite and atopic eczema. House dust mites thrive in damp conditions, and housing dampness may therefore be an indicator of house dust mite. In a study from Nottingham, a statistically significant association was shown between atopic eczema symptoms and dampness in the child's home (Mcnally *et al.*, 2001). The population attributable risk was estimated to be 4% for housing dampness. The suggested explanation was an indirect effect of dampness through house dust mite.

Toxicological evidence obtained in vivo and in vitro has been shown the occurrence of diverse inflammatory and toxic responses after exposure to microorganisms isolated from damp buildings, including their spores, metabolites and components (WHO, 2009b).

While the evidence is strong enough for an association between indoor dampness and mould and a wide range of respiratory and allergic diseases, the evidence does not yet support the causal role. In addition, the specific dampness related agents underlying these diseases and the mechanisms of their action remain unknown (Mendell *et al.*, 2011). Quantitatively determined concentrations of microbial agents do not show a consistent association with respiratory health outcomes; in some cases, exposure to microbial factors is protective against asthma-related symptoms and wheezing, particularly for those who are exposed very early in life (Mendell *et al.*, 2011; IOM, 2004). Several other studies have reported similar absence of association between quantified microbiological agents and asthma or allergic disease (Holme *et al.*, 2010; Wickman *et al.*, 1992). Other studies have found an association between microbiological agents and adverse health outcomes (Reponen *et al.*, 2012). The inconsistent association between microbiological exposure and health outcomes in different studies could in part be due to variations in study design and the lack of standard methodology for environmental assessments (Mendell *et al.*, 2011; WHO, 2009b).

Although approaches to reduce and eliminate damp and mould from buildings exist, relevant public policies need to be strengthened (WHO, 2010b). Persistent dampness and microbial growth on interior surfaces and in building structures should be avoided or minimized, as they may lead to adverse health effects. Thus, good design and proper construction can help to prevent problems from occurring (WHO, 2012). Maintenance and use of buildings can also be considered key factors to preserve healthy housing; for example, a speedy response to water damage will help to keep the building/space in sound condition (WHO, 2012).

As the relations between dampness, microbial exposure and health effects cannot be quantified precisely, no quantitative health-based guideline values or thresholds can be recommended for acceptable levels of contamination with microorganisms. Instead, it is recommended that dampness and mould-related problems be prevented. When they occur, they should be remediated because they increase the risk of hazardous exposure to microbes and chemicals (WHO, 2009b).

4. Participants and Methods

4.1 Study Design

In order to fulfil the objectives of this thesis a cross-sectional study to investigate the association between the IAQ in school and children's health and a case-control study to better understand the role of the home environment in this association were carried out.

The study was conducted according to the guidelines laid down in the Declaration of Helsinki and was approved by the Ethics Committee of the University of Porto (22/CEUP/2011). Written informed consent was obtained from the parents or the legal guardians of the children.

The access to the schools was allowed by *Direção Geral dos Estabelecimentos Escolares*, the official entity that assures regional policies for all schools in the Northern Region of Portugal and, therefore, of Porto.

4.2 Characterization of the Study Region

Porto is the second largest Portuguese city, located in the North at a latitude and longitude of 41°10' N and 8°40' W, respectively. The city heads the Porto Metropolitan Area (Porto-MA), one of the two Metropolitan regions in the country, which includes 16 municipalities with about 1.2 million inhabitants and a population density of 540 inhabitants per square kilometre.

The Metropolitan Area region is limited in the West by the Atlantic Ocean with 50 km of coastline and crossed by the Douro River. This area is designated in climatic terms by North maritime (Ribeiro *et al.*, 1988), characterized by warm and dry summers and mild and wet winters with two net transition seasons: spring and autumn. The annual average air temperature is around 15 °C and the difference between warmer and colder monthly averages is less than 10 °C. Annual air humidity is between 75 and 80% and the total annual average precipitation varies between 1000 mm and 1200 mm, with about 40% in the winter season, and with more than 100 days per year with precipitation equal or higher than 1.0 mm. Prevailing winds blow from West and North-West in summer and from East and Southeast in winter (Santos *et al.*, 2002; Monteiro, 1997). In the North of Portugal, Porto-MA is the region with the highest power consumption per capita and per industry, which is related to a relatively high industrial density. In Porto-MA the most important stationary sources of atmospheric pollutants are one oil refinery, one petrochemical plant, one thermoelectric plant working on natural gas, one waste incineration unit and one international shipping port. Nevertheless, motor traffic is responsible for a significant amount of the pollutants emitted to the atmosphere (Pereira *et al.*, 2002).

4.3 Cross-Sectional Study of Children's Indoor Exposure in Schools

The cross-sectional survey was designed to investigate the association between IAQ and children's health. The study addresses two components of evaluation: 1) children's health characteristics by standardized questionnaires and clinical health examination; and 2) indoor air at schools including a set of physical, chemical and biological measurements.

In Portugal the scholar education is compulsory by law until 18 years old. The public primary schools are run by the local municipality administration. At the beginning of the study (2011/12 academic year) Porto municipality had 53 public primary schools with about 9680 children. Figure 10 shows geographical distribution of public primary schools in the Porto city.

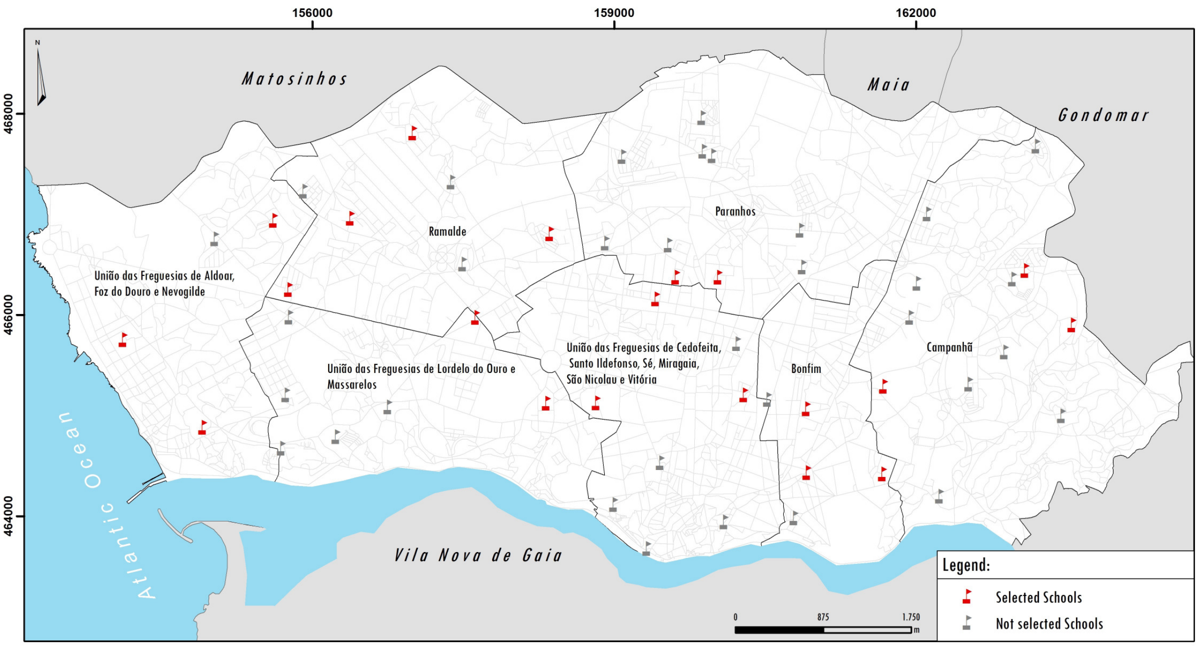


Figure 10 Location of the 53 public primary schools at Porto according to the participation on this study

4.3.1 Sample size and selection procedure

The number of schools was defined based on the estimated sample size of children to study the relation between IAQ and asthma, allergy and respiratory symptoms. In regard to the figures obtained in recent studies in Portugal, the prevalence of asthma in children is approximately 10% (Falcão *et al.*, 2008), while it is estimated that 10% of non-asthmatic children have symptoms and that the exposure to poor indoor air leads to a two times higher risk of having symptoms. Within these premises, a sample of 1600 children was established. Thus, assuming 20 children per room and 4 classrooms per school, a sample size of 20 schools was used to give sufficient confidence.

Thus, the 20 (38%) schools with the highest number of students were selected from a total of 53 public primary schools. A letter of introduction was sent to the executive board of each school, followed by a phone contact to organize a first meeting where all the details were explained in order to obtain their consent and involvement. All the 20 schools agreed to participate in the study.

In each school, four classrooms of 3rd and/or 4th grades were selected among the classrooms with similar conditions and judged to be representative of the school building. The preference is a classroom with high density of occupation and full weekly occupation time by the same class; and, if possible, at different floor levels. If there are fewer than four classrooms per school fulfilling the criteria above, all were selected. Five schools had only three classrooms designated to the 3rd and 4th grade, and one school just two classrooms. So, a total of 73 classrooms were included in the current study.

4.3.2 Data collection

<u>Health questionnaire survey</u>

The health of the children was assessed by two standardized self-administrated questionnaires: one was completed by the children at school (Children’s questionnaire, Annex 1) and the other was filled in at home by their parents/legal guardians (Parents’ questionnaire, Annex 2).

Children’s questionnaire

At school, children occupying the investigated classrooms answered a self-administered questionnaire largely based on validated ISAAC questionnaire (Asher *et al.*, 1995). The questionnaire covered information on respiratory/allergic health, current symptoms/diagnosis, exposure to ETS and perception of school environment. The data collected from the children’s questionnaires were not used in this thesis.

Parents’ questionnaire

Approximately two weeks before the planed date for the IAQ measurements in the school, elements of the research team went to school and presented the study to the children of each one of the selected classrooms. During this presentation the parents’ questionnaire, the informed consent and an informative letter were distributed to the children. The informative letter explained the purpose and the design of the study and included the contacts of the research team to allow the clarification of any doubts by the parents. The answered questionnaires and signed informed consents were collected by teachers after up to three reminders.

The parents' questionnaire were based on the Portuguese version (Rosado Pinto, 2011) of the questionnaire used in ISAAC (Asher *et al.*, 1995), in the ECRHS (Janson *et al.*, 2001) and in the HESE study (2006). One set of questions was about respiratory/allergic health of the child; current symptoms/diagnosis (during the past 3 months); socio-economic characteristics, building characteristics of the home (e.g. outdoor traffic pollution, dampness, floor and wall coverings, cooking fuel types; air conditioning), in particular the child's bedroom, ETS exposure, perinatal information and dietary habits. Supplementary questions on availability to modify their daily behaviour at home in order to improve IAQ at their homes were added.

Health variables definition

To answer the objectives of this thesis, all the data were extracted from the parental questionnaire. Table 5 shows the list of the ever, past year, past month symptoms/diseases as well as a question on wheezing in the past 30 days as assessed in children using the questions of the ISAAC. Symptoms and diseases were grouped by typology: asthma-like, rhinitis-like, skin diseases, and other respiratory diseases apart from cold.

Table 5 Ever, past year and past month symptoms/diseases in children

Symptom/disease	*ISAAC question*
Asthma-like	
Ever wheeze	Has your child ever had wheezing or whistling in the chest at any time in the past?
Wheeze (<12 months)	If "yes", then: in the past 12 months, has your child had wheezing or whistling in the chest?
Wheeze (<30 days)	If "yes", then: in the past 30 days, has your child had wheezing or whistling in the chest?
Doctor-diagnosed asthma	Has your child ever had asthma diagnosed by a doctor?
Asthma in school	If "yes", then: has your child ever had an asthma attack while at school?
Rhinitis-like	
Ever runny / blocked nose†	Has your child ever had a problem with sneezing, or a runny, or blocked nose when he/she DID NOT have a cold or the flu?
Nasal allergy (<12 months)†	If "yes", then: in the past 12 months, has your child had a problem with sneezing, or a runny, or blocked nose when he/she DID NOT have a cold or the flu?
Eye irritation (<12 months)†	If "yes", then: in the past 12 months, has this nose problem been accompanied by itchy-watery eyes?
Ever nasal allergy	Has your child ever had nasal allergies, including hay fever?
Doctor-diagnosed nasal allergy	If "yes" then: was it confirmed by a physician?
Skin diseases	
Ever itchy rash (for 6 months)	Has your child ever had an itchy rash which was coming and going for at least 6 months?
Ever eczema	Has your child ever had eczema?
Other respiratory diseases apart from cold	
Dry cough at night (<12 months)	In the past 12 months, has your child had a dry cough at night, apart from a cough associated with a cold or chest infection?
Cough episodes	Does your child have a cough on most days (four or more days per week) apart from common colds?
Phlegm episodes	Does your child have phlegm on most days (four or more days per week) apart from common colds?

† Not occurring due to cold.

Table 6 shows the list of recent (<3 months) symptoms by organ in children as assessed through the parents' questionnaires and the original question "*During the past three months, has your child had any of the following symptoms*?". The possible replies were: (1) No, never; (2) Yes, sometimes (1-3 times/month); (3) Yes, often (1-4 times/week); and (4) Yes, daily. All the three kinds of "yes" replies were coalesced into a single "yes" response.

Table 6 Recent symptoms (<3 months) by organ considered in children

Symptom	*Question*: "*During the past three months, has your child had any of the following symptoms*?"
Skin	
Hand rash	Skin rash on hands or forearms
Face rash	Skin rash on the face or neck
Eczema	Eczema (if "yes", where?)
Eye	
Eye irritation	Eye irritation (redness, dryness, itch)
Swollen eye	Swollen eyes
Nose	
Runny nose	Runny nose/nasal phlegm
Blocked nose	Nasal obstruction/blocked nose
Lower Airways	
Dry throat	Dry throat
Sore throat	Sore throat
Irritating cough	Irritating cough
Shortness of breath	Breathing difficulties
Systemic	
Headache	Headache
Nausea	Nausea
Symptom(s) improve on returning home	Do any of these symptoms improve when your child is away from school ("yes", "no", "do not know")

Clinical health examination

The clinical tests were performed at school during a normal school period by a team of experienced researchers following standardised procedures, in one day of the week of the IAQ measurements in the classrooms. All children were invited to measure weight, height and lung function (obtained by spirometry tests). Exhaled nitric oxide (eNO) and tear film stability were performed in a sub-sample of five children from each classroom. These children were randomly selected from the participant children.

Weight and height

Body weight was measured using a digital scale - Tanita (Tanita® TBF-300, Tanita Corporation of America, Inc., Illinois, USA) (in kilograms, to the nearest tenth), and height was measured (in centimetres, to the nearest tenth) using a portable stadiometre (SECA® 214). Both were measured with the child upright and standing without shoes. Then, the body mass index (BMI) was calculated [weight (kg)/m^2].

Lung function

Lung function was measured using a portable spirometer (ML3500, MicroLab®) by a well-trained technician. All spirometry tests were performed according to American Thoracic Society (ATS) / European Respiratory Society (ERS) (ATS/ERS, 1995) guidelines. In brief, immediately following a full inhalation, the children seals his/her lips around the mouthpiece and blasts the air out as fast as possible until the lungs are absolutely empty. Demonstration to the children of the procedure and the maximal effort required was performed before starting, and the best of three technically acceptable tests was considered the final result. Values for forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), FEV_1/FVC ratio and forced expiratory flow 25-75% ($FEF_{25\text{-}75\%}$) were expressed as percentages of the predicted value for statistical analysis.

Exhaled nitric oxide

The levels of eNO were measured according to the ATS/ERS guidelines (2005) with the handheld device NIOX MINO system (Aerocrine, Stockholm, Sweden) with a detection limit of 5 ppb. The analyzer provides online continuous measurement of nitric oxide. After children exhaled residual volume, they inserted the mouthpiece, inhaled-nitric-oxide free air from the apparatus to the total lung capacity and then exhaled for 10 seconds at a constant flow rate of 50 ml/s. The end point of measurement occurred when a plateau for at least 2 seconds was observed. A visual feedback helped the children achieve the desired expiratory flow of 50 ml/s (± 10%).

Tear film stability

Tear film stability was estimated by a standardized method, assessing self-reported break-up-time (SBUT) recording the time (in seconds) the child could keep his or her eyes open without blinking, when watching a fixed point at the wall. This method has been used previously (Wieslander *et al.*, 1999) and has a good correlation with the fluoresceine method for detection of tear film BUT (Kjaergaard, 1992; Wyon, 1992). The child was sitting, looking at a fixed point on the wall at about 5 m (a flower painted with a felt pen). The child was instructed to blink on command, when a stopwatch is started, and to fix the point on the wall until the child feels the need to blink again. The time between the blinks is recorded three times. The average of the two most concordant tests per children was used for the statistical analyses.

4.3.3 Participants

All children enrolled in the selected classrooms were eligible. In the 73 selected classrooms 1639 eligible children were identified. Although 1134 parents consented to the participation of their child in at least one of the components of the study, health questionnaire and/or clinical health examination, (participation rate of 69.2%), only data on 1099 (out of 1639) children was collected using the parents' questionnaire study. One hundred and eighty one (11.0%) parents refused to participate and 324 (19.8%) did not return the signed informed consent form and parents' questionnaire and, therefore, were considered as refusals. Table 7 summarizes the number of participants in each component of health evaluation.

Table 7 Number of participants in each component of the health evaluation

	n
Participants in at least one component	1134
Children's questionnaire	1060
Parents' questionnaire	1099
Weight and height	1027
Lung function test	
FVC	842
FEV_1	842
FEV_1/FVC	842
$FEF_{25-75\%}$	829
Exhaled nitric oxide	359
Tear film stability	363

FVC: Forced vital capacity; FEV_1: Forced expiratory volume in 1 second; $FEF_{25-75\%}$: Forced expiratory flow 25-75%.

Out of 1099 children who participated in the parents' questionnaire, 121 children with missing information on at least one of the following outcomes (ISAAC questions) as previously defined were excluded for the detailed analyses:

- Wheeze (<12 months),
- Wheeze (<30 days),
- Ever nasal allergy,
- Cough episodes,
- Phlegm episodes.

As a result, analyses with these health outcomes were conducted with 978 children. Lastly, for analyses concerning recent symptoms (<3 months) a sub-sample of 846 participants was obtained, after exclusion of 132 children with missing information for the variables analyzed:

- Skin symptoms (hand rash or face rash symptoms) assessed by the questions "*During the past three months, has your child had a skin rash on hands or forearms*?" or "*During the past three months, has your child had a skin rash on the face or neck*?",
- Eczema,
- Eye irritation,
- Nose symptoms (runny nose or blocked nose symptoms) assessed by the replies "yes, daily" and "yes, often" in the questions "*During the past three months, has your child had a runny nose/nasal phlegm*?" or "*During the past three months, has your child had a nasal obstruction/blocked nose*?",
- Irritating cough.

Regarding headache in the last previous three months among the 978 participants, 139 children had missing information for this symptom, leading to a total of 839 participants.

Among these 846 participants, 378 children who had a positive answer to the specific question "*During the past three months, has your child felt they were getting a cold*?" were further excluded. Thus, the analysis was based on the information of 468 participants (245 girls).

From the 978 children, 761 children underwent pulmonary function tests. In addition, 318 and 321 children performed eNO and SBUT, respectively.

4.3.4 Indoor air quality measurements in schools

The study included walkthrough inspection of school buildings and selected classrooms, as well as of air sampling. The walkthrough inspection and air sampling was performed concurrently in two heating season periods: November 2011 to March 2012 and November 2012 to December 2012. Thirteen schools were evaluated in the first heating season period and 7 schools in the second period campaign. The measurements were made during normal activities and under representative conditions of occupancy and use of the classrooms. Outdoor measurements were also performed, as well as a detailed outdoor characterization through information obtained from the checklist.

<u>Walkthrough inspection and checklist (outdoor environment, building and classrooms characteristics)</u>

A walkthrough inspection was completed for each school by a trained researcher to gather information related to school building characteristics and characteristics of the selected classrooms involved in study. In the walkthrough inspection a standardized checklist was used (Annex 3) that has been previously field-tested in SINPHONIE project and was completed with the assistance of principals and teachers. The checklist includes a large set of questions related to the following main topics: outdoor characterization, building construction characteristics, ventilation and heating systems, past occurrences or visible problems and building use and potential indoor sources. A specific checklist form was filled in for each classroom (Annex 3) identifying all relevant information such as the area, finishing materials and their conditions concerning floor, walls, and ceiling; windows; past occurrences and visible problems, heating and ventilation system, scholar activity products (paintings, glues, etc.) maintenance routines and cleaning procedures. The type of classroom furniture, the presence of chalkboards, copiers and plants were also noted, as well as information about environmental modifiers including air fresheners and insecticides.

Environmental monitoring

For each school, four classrooms (when applicable) and one outdoor representative location were identified and simultaneously studied. At each of these locations a set of key parameters were sampled (Table 8). Chemical, physical and comfort parameters and microbiological agents were measured with a specific sampling strategy for each pollutant (e.g. equipment, protocols, sample collection and analysis). These parameters included 10 VOC (including 6 aromatic, 2 terpenes and 2 halogenated hydrocarbons), 2 aldehydes, CO, $PM_{2.5}$ and PM_{10}, as well as the temperature, relative humidity, CO_2, ventilation rate, bacteria and fungi levels. Although the constituents of particulate matter can be physical, biological or chemical (Arvanitis *et al.*, 2010), in this study, the particulate matter is classified as physical parameter based on the principles of its measurements.

In addition to the scientific relevance, cost effectiveness and time limitations were take into consideration during the selection of the parameters and for these reasons NO_2, polycyclic aromatic hydrocarbons (PAH), radon and allergens were not evaluated.

Table 8 Chemical, physical and comfort parameters and microbiological agents studied

Chemical parameters	Physical and comfort parameters	Microbiological agents
Benzene[1] Toluene[1] m/p-xylene[1], o-xylene[1] d-limonene[2] α-pinene[2] Trichloroethylene[3] Tetrachloroethylene[3] Naphthalene[1] Styrene[1], Formaldehyde[4] Acetaldehyde[4] CO	$PM_{2.5}^{*}$, PM_{10}^{**} Temperature Relative humidity CO_2 Ventilation rate	Bacteria and fungi

[*] Particulate matter with an aerodynamic size ≤ 2.5 µm; [**]Particulate matter with an aerodynamic size ≤ 10 µm.
[1]Aromatic hydrocarbons; [2]Terpenes; [3]Halogenated hydrocarbons; [4]Aldehydes.

The air sampling covered a 5-day period (school week, from Monday morning until Friday afternoon), in order to assess exposure to the substances that are known to cause mainly chronic health effects. Safe and childproof sampling sites were ensured and complied with the rules as prescribed by ISO 16000-1 (2004). Indoor samples were collected at a height of about 1-1.5 m above the floor, which is the breathing zone. The selected place was not allowed to be closer than 1 m to a wall, a door or an active heating system. Furthermore, the indoor sampling site was selected as far away as possible from the blackboard (when applicable).

Parallel outdoor samples were taken at places which provided electricity and a tamper-free environment. Outdoor samples were collected at heights of 1-2 m above the ground. All the samplers and equipments were mounted in a shelter protecting from direct sunlight and precipitation.

Each day teachers completed a specific diary reporting the number of children and adults present in the classroom, ventilation practices (e.g. periods of window opened), type of activities developed in the classroom (e.g., reading/writing, painting, pasting, felt-tip pen drawings) and cleaning routines (Annex 4). The research team asked the school staff to maintain the same cleaning practices during the study.

Chemical parameters

Volatile organic compounds were collected using a stainless-steel sampling tubes containing Tenax® TA (60/80 mesh). Concentrations of target VOC that included benzene, toluene, m/p-xylene, o-xylene, d-limonene, α-pinene, trichloroethylene (T3CE), tetrachloroethylene (T4CE), naphthalene, styrene were investigated. The passive air sampling (2 samples per room) was conducted during a scholar week, from Monday morning to Friday afternoon. After sampling, Tenax tubes were thermally desorbed (Dani STD 33.50) and quantified using a non-polar column by gas chromatography (Agilent Technologies 6890N) coupled to a mass spectrometry detector (Agilent Technologies 5973), according to ISO 16000, part 6 (2011). Total VOC (TVOC) concentration was quantified using the toluene response factor, and concentrations were calculated as the sum of volatile organic compounds eluting between hexane and hexadecane (included), expressed as toluene. To control contamination during transport and sampling, a field blank was employed in every school. All samples were taken in duplicate to test the reproducibility of measurements. The limits of detection were 1.3 $\mu g/m^3$ for toluene, 1.8 $\mu g/m^3$ for p-xylene, 2.8 $\mu g/m^3$ for d-limonene, 2.5 $\mu g/m^3$ for T4CE and 4.4 $\mu g/m^3$ for naphthalene.

Aldehydes (formaldehyde and acetaldehyde) were sampled by passive devices Radiello® (RAD 165, Sigma Aldrich), consisting of a cartridge filled with 2,4-dinitrophenylhydrazine (2,4-DNPH). By reaction with 2,4-DNPH, aldehydes give the corresponding 2,4-dinitrophenyllhydrazones, which was desorbed in 2 ml of acetonitrile (Sigma-Aldrich) and manually stirred for 30 minutes. Then, the solution was passed through a polyvinyl difluoride 0.45 mm-syringe filter (13 mm Syringe Filter, Specanalítica) and determined using isocratic reverse phase High Performance Liquid Chromatography (HPLC) (Agilent Technologies, 1220 Infinity LC) with a UV detector operated at 360 nm according to ISO 16000-4 (2011). Aldehydes were identified and quantified by comparison of their retention times and peak areas with those of standard solutions. Samplers were placed in each classroom on Monday morning and collected on Friday afternoon. Each cartridge was sealed after sampling and then brought back to laboratory where it was stored in the refrigerator (<4 °C). As an internal quality, control duplicate samplings were collected in 1 school per set of 3 schools. Field blanks were collected and analyzed to assess possible contamination through the sample collection and analysis process. The detection limits were 0.075 $\mu g/m^3$ for formaldehyde, and 0.178 $\mu g/m^3$ for acetaldehyde.

Carbon monoxide concentrations were measured continuously using an IAQ-CALC monitor (model 7545, TSI, Inc.). The instrument includes an electrochemical sensor for CO in a range from 0 to 500 ppm (0 to 572.8 mg/m^3) with accuracy of ±3% of reading or ±3 ppm (3.4 mg/m^3). Data were downloaded onto LogDat2™ downloading software and then exported for data management. Measurements were conducted over five consecutive days (from Monday to Friday) with a time step of 5 minutes. The instrument was calibrated annually at the factory.

Physical and comfort parameters

Two TSI DustTrak DRX photometers (model 8533; TSI Inc.), which measure particles with a laser photometer based on light scattering technology, were used to continuously monitor the $PM_{2.5}$ and PM_{10} concentration. The measuring range of the equipment is 0.001 to 150 mg/m^3 (1 to 150×10^3 $\mu g/m^3$) with accuracy of ± 0.1% of reading of 0.001 mg/m^3 (1 $\mu g/m^3$). Powered by an internal battery, the DustTrak DRX operated with a flow rate of 3.0 l/min using a built-in diaphragm pump. The 2 available photometers were calibrated annually at the factory. The measurements were conducted 24 hours in each location (indoor and outdoor) at 1 minute intervals. As a consequence of the limited number of sampling units, indoor and outdoor particulate matter could not be sampled in parallel.

Carbon dioxide concentrations were measured continuously using an IAQ-CALC monitor (model 7545, TSI, Inc.). The instrument includes an infrared non-dispersive sensor in a range from 0 to 5000 ppm with accuracy of ±3% of reading or ±50 ppm. Data was downloaded onto LogDat2™ downloading software and then exported for data management. Measurements were conducted over five consecutive days (from Monday to Friday) with a time step of 5 minutes. The instrument was calibrated annually at the factory.

The ventilation rate (l/s per person) was estimated based on decay of the indoor CO_2 concentration (emitted by the occupants during the class periods) where the room was precisely documented as non-occupied. On average, only the most trustworthy fractions of the 12-hours period (typically time period matched between 8.00 p.m. and 8.00 a.m.) of CO_2 data extracted for each day was used for further data treatment. The estimated final ventilation rate in the classroom is the time-weighted average of the ventilation rates obtained during the school week. The ventilation rate values were estimated using the average outdoor CO_2 concentration over the week measurements period. The air change per hour (ach) was calculated based on the ASTM E 741-00 (2006) and ASTM D 6245-98 (2002) standards according the following equation:

$$ach = -\frac{1}{t - t_0} ln\left(\frac{C_t - C_{out}}{C_0 - C_{out}}\right) \tag{1}$$

where "t" is time and "C_t" and "C_o" are the concentrations of the gas at time t and t=0, respectively. The above equation can be rearranged in the following way:

$$ln\, C_{t=} \ln C_0 - \ ach \times t \tag{2}$$

Thus, ln C_t, has a linear relationship with t, and the slope of the scatter of ln C_t, *vs.* t is the ach value (h^{-1}). In order to obtain ventilation rate in l/s per person it was take into consideration the volume (m^3) and the number of occupants:

$$Ventilation\ rate = \frac{volume \ \times ach}{3.6 \times nº\ occupants} \tag{3}$$

Temperature and relative humidity levels were measured continuously using an IAQ-CALC monitor (model 7545, TSI, Inc.). The equipment includes a thermistor for measuring temperature in a range from 0 to 60 ºC with an accuracy of ±0.6 °C, and a thin-film capacitive sensor for relative humidity (range of 5 to 95% relative humidity; accuracy ±3.0% relative humidity). Data were downloaded onto LogDat2™ downloading software and then exported for data management. Measurements were conducted for five consecutive days (from Monday to Friday) with a time step of 5 minutes. The instrument was calibrated annually at the factory.

Microbiological agents

Air samples were obtained using a single-stage microbiological air impactor (AirIdeal™, bioMérieux SA) according to the NIOSH Method 0800 (NIOSH, 1998). This is a handheld, battery-operated instrument that consists of a holder for a 90 mm-diameter nutrient agar plate and a sieve plate containing 220 holes. A fan draws air through the sieve plate causing airborne particles to impact on the agar plate, and air is exhausted through the side of the sampler. Tryptic soy agar (TSA) and malt extract agar (MEA) supplemented with 1% of chloramphenicol were used as culture media for bacteria and fungi, respectively. Air was drawn through the sampler at 100 l/min, and sequential duplicate air samples (duplicates of 100 and 250 litres) were collected indoors and outdoors between 9.30 a.m. and 12.00 a.m. For each sampling day, agar media blanks per culture were taken into the field but were not opened. The impactor was calibrated before use. After each sampling, the impactor was cleaned with cotton swabs wetted with isopropyl alcohol. After sampling, the agar media plates were sealed, marked, and transported to the laboratory in a thermal bag for incubation.

Incubation conditions for bacteria were 37±1 ºC for 48±3 hours. For fungi samples, the incubation period was 25±3 ºC for 72±3 hours. The bacteria and fungi colonies were then enumerated and concentrations evaluated in colony-forming units per cubic meter of air (CFU/m^3), taking into account a positive hole correlation factor that is used to correct for the possibility that more than one particle containing a cultivable microorganism, passes through the same hole (Andersen, 1958). The quantification limit is 10 CFU/plate.

4.3.5 Statistical analysis

A descriptive statistics analysis was performed to characterize the children participants and the IAQ measurements. Shapiro-Wilk test was used for normality testing. The distribution of all indoor air parameters were skewed; thus they were described by median, 25th percentile (P25) and 75th percentile (P75). In addition, mean, standard deviation (SD), minimum and maximum were also presented.

Volatile organic compounds data were explored to determine the proportion of samples above the detection limit. Concentrations of VOC below the detection limits were excluded from the statistical analyses. To be noticed that CO, $PM_{2.5}$, PM_{10}, CO_2, temperature and relative humidity levels were calculated from the data collected during teaching periods to ensure that the sample is representative of the exposure time of the children; while data of individual VOC, TVOC, formaldehyde and acetaldehyde, measured in parallel and continuously (24 hours for five consecutive days), are reported for the school week under observation. It is noteworthy that in order to correctly explore the relationship between indoor and outdoor, the data used for the I/O ratios analysis were those collected during the same period from indoor data.

Kruskal-Wallis test was used to compare continuous variables and the Qui-square ($\chi2$) test for comparison of categorical variables.

Statistical analyses were performed using SPSS Statistics version 19 (SPSS Inc., Released 2009, USA). A *p*-value below 0.05 was considered statistically significant.

Associations between indoor air parameters and health outcomes

The association between the indoor exposure parameters and the symptoms/diseases in the children were estimated by odds ratios (OR) and respective 95% confidence intervals (95% CI) using logistic regression models. Adjustments have been made for age (continuous variable in years), sex, mother's education level (categorical variable measured as the number of successfully completed years of formal schooling: 0-6 years; 7-9 years; 10-12 years and ≥13 years), BMI (continuous variable), relative humidity and temperature (both as continuous variable).

In the aforementioned analysis, a model was created for each indoor parameter variable. All indoor parameters were considered, except benzene, T3CE, T4CE, styrene and naphthalene levels which were below the limits of detection in more than 75% of classrooms, and were considered as categorical (based on the respective tertile or taking into account the limit of detection).

The binary health outcomes considered, based on ISAAC questions, were:

- Wheeze (<12 months),
- Wheeze (<30 days),
- Ever nasal allergy,
- Cough episodes,
- Phlegm episodes.

Regarding the recent symptoms (<3 months), the binary health outcomes considered were:

- Skin symptoms (hand rash or face rash symptoms),
- Eczema,
- Eye irritation,
- Nose symptoms (runny nose or blocked nose symptoms),
- Irritating cough,
- Headache.

Statistical analyses were performed using SPSS Statistics version 19 (SPSS Inc., Released 2009, USA). A *p*-value below 0.05 was considered statistically significant.

Relationship between building/classroom characteristics, occupant behaviour and indoor air parameters

As a first approach, we applied the principal components analysis (PCA) with varimax rotation to understand how the indoor air parameters were aggregated. The Scree Plot criterion was used to determine the number of components retained. If the factor loading was 0.40 or higher (in absolute value) an item was considered in the indicator. Considering the asymmetry of the input variables distribution we applied the logarithm to each of the parameters of IAQ with the purpose of normalizing them.

After choosing the indicators that represented each factor, multiple linear regression was used to assess the factor associated with each variable. For this, we used the stepwise forward method to assess which factors were associated with each input variable (data not shown).

In a second approach, a multilevel linear regression with two levels: classroom and school (random effect) was used to determine what factors explained each input variables and to evaluate the aggregation within schools. The aggregation was estimated using Intraclass Correlation Coefficient (ICC).

We considered four models of multilevel analysis, the first of which is with the characteristics of the classroom; the second is represented by the characteristics of the school and the third model is the junction of the characteristics of the classroom and school for each indicator. Finally, the fourth and final model is represented by the totality of the classroom and school characteristics that have a significant effect on each of the IAQ parameter.

Statistical analysis was performed using the statistical software R and multilevel analysis was implemented using the function lme (linear mixed effects) in the nlme library.

4.4 Case-Control Study of Indoor Air Quality at Home

The second step of the thesis was a case-control study in order to investigate the relationships between home indoor exposure to air pollutants and asthma. Therefore, inspection and measurements of IAQ in a sub-sample of children homes were conducted. Due to time and logistic limitations a total of 68 homes were evaluated.

4.4.1 Selection procedures of cases and controls

Asthmatic cases were identified among children who took part in the cross-sectional study. Asthma cases were defined on the basis of an affirmative response to one of the following standardized questions in the parents' questionnaire:

- "*Has your child ever had asthma diagnosed by a doctor*?",
- "*In the past 12 months, has your child had wheezing or whistling in the chest?"*.

Controls were selected among those children whose parents/legal guardians had answered "no" to both questions. For both groups they were not included if:

- Rebuilt/refurbished their homes (<6 months), and
- Changed residence since completing the parents' questionnaire.

The recruitment of participants was performed in two steps. In a first approach, at the end of the first field work campaign (March 2012), all parents who had participated up to that time were invited to allow air measurements at their homes (n=667). This invitation was sent by letter to the parents describing the study in general and more specifically the environmental assessment that would be performed at their home. A pre-paid and pre-addressed return envelope was enclosed to the letter in order to be returned with the informed consent. Forty-one families agreed to participate (4 homes from asthmatic children). Three weeks after receiving the parents consent, research staff attempted to contact the parents by telephone, but despite their previous written consent, 9 parents refused to participate. Thus, we obtained authorization to evaluate 32 homes: 4 from asthmatic (cases) and 28 from non-asthmatic children (controls).

On a second approach, based on the parents' questionnaire from the second period campaign on schools, randomly recruitment contact was made by telephone in order to invite and schedule the home visit/assessment. If the telephone was disconnected, and after several unsuccessful attempts the child/family was designated as a non-responder (passive refusal). Parents of 34 participants (out of 40) that fulfilled the criteria to be a case and 2 controls (out of 350) agreed to participate. The final sample participating in the case-control study comprised 68 children divided in two groups, 38 asthmatics and 30 non-asthmatics.

4.4.2 Indoor air quality measurements at home

Walkthrough inspection in individual rooms, as well as air sampling in 68 homes took place from November 2012 to March 2013. Because of the limited number of instruments available, a maximum of 5 homes were simultaneously monitored each week depending also on the availability of parents. Concurrent outdoor measurements were also taken, as well as a detailed outdoor characterization through information obtained from the checklist.

Walkthrough inspection and checklist (outdoor environment, building and indoor characteristics)

A well-trained technician completed a standardized walkthrough inspection and filled in a detailed checklist to collect information about outdoor characteristics, building characteristics and observations on the dwelling's interior and its possible moisture damage, mould problems, presence of pets and carpeting throughout the home, cleaning practices and characteristics of ventilation and heating, cooking devices, indoor smoking habits, emission sources such as candles, incense and room deodorizers, etc. (Annex 5).

Environmental monitoring

In each investigated home the child's bedroom and an outdoor sampling location (if possible) were selected for air sampling. The children's bedroom was chosen since it represents the room with the longest exposure time in their homes. In 3 of the inspected homes, researchers were not allowed to perform the air sampling in the child's room due to privacy reasons; thus in these cases air sampling was made in the living room. At each of these locations the same parameters that were assessed in the classrooms were simultaneously sampled.

Indoor samples were collected from the rear of the bedroom, 1-1.5 m above the floor (breathing zone) and not closer than 1 m from a wall, a door or an active heating system under normal conditions regarding heating and airing of the home as well as the use of rooms. Outdoor sampling sites were constrained by access to electricity and whenever possible not closer than 1 m from the building at heights of 1-2 m above the ground. All the samplers and equipments were mounted in a shelter protected from direct sunlight and precipitation.

The parents were requested to fill in a weekly time activity diary reporting their personal activities, which included smoking, cooking and cleaning activities, ventilation habits, number of occupants, etc. (Annex 6). Moreover the families were asked to maintain their regular routine during the environmental monitoring.

Chemical parameters

Indoor and outdoor samples of VOC were collected and analysed using an identical process as the one described in section 4.3.4. The passive air sampling was conducted over a total of 7 consecutive 24-hours periods, from Saturday to Friday. To control contamination during transport and sampling, for every set (week) of homes a field blank was employed. All samples were taken in duplicate to test the reproducibility of measurements. The limits of detection were 1.3 $\mu g/m^3$ for toluene, 1.8 $\mu g/m^3$ for p-xylene, 2.8 $\mu g/m^3$ for d-limonene, 2.5 $\mu g/m^3$ for T4CE and 4.4 $\mu g/m^3$ for naphthalene.

Aldehydes (formaldehyde and acetaldehyde) were sampled and analysed using the procedure described in section 4.3.4. At the homes the passive samplers were placed in the bedrooms from Saturday until Friday. As an internal quality control duplicate samplings were collected in 1 bedroom per set of 3 homes. A blank sample was deployed in each set of 3-5 homes (i.e. per week campaign). The limits of detection were 0.0778 $\mu g/m^3$ for formaldehyde and 0.1653 $\mu g/m^3$ for acetaldehyde.

Carbon monoxide concentrations in the child's bedroom were continuously measured during a period of 7 days, at 5 minutes intervals, using the same equipment IAQ-CALC (TSI 7545, TSI, Inc.) that was installed by the researchers during the school visits. Data were downloaded onto LogDat2™ downloading software and then exported for data management. The equipment was calibrated annually according to manufacturer specifications.

Physical and comfort parameters

Methodologies used to determine $PM_{2.5}$ and PM_{10} were identical to those described in section 4.3.4. Besides the 3 homes that due to privacy reasons samplers were placed into living room, in another one home- due to the noise associated with sampling of particulate matter - also the living room was chosen.

Carbon dioxide concentrations in the child's bedroom were continuously measured during a period of 7 days, at 5 minutes intervals, using the same equipment IAQ-CALC (TSI 7545, TSI, Inc.) that was installed by the researchers during the school visits. Data were downloaded onto LogDat2™ downloading software and then exported for data management. The equipment was calibrated annually at the factory.

Ventilation rates were calculated based on decays of the indoor CO_2 concentration, after occupancy periods, as reported in section 4.3.4. Carbon dioxide data corresponding to an average of 9 hours of measurement per bedroom (time period between 9.00 a.m. and 6.00 p.m.) from each day were used for further data treatment. The final estimated ventilation rate in the bedroom was the time-weighted average of the ventilation rates obtained during the measurement week period using the correspondent outdoor CO_2 mean value.

Temperature and relative humidity levels in the child's bedroom were continuously measured during a period of 7 days, at 5 minutes intervals, using the same equipment IAQ-CALC (TSI 7545, TSI, Inc.) installed by the researchers during the schools visits. Data were downloaded onto LogDat2™ downloading software and then exported for data management. The equipment was calibrated according to manufacturer specifications.

Microbiological agents

The collection and respective laboratory analysis were performed using the procedures described in section 4.3.4.

4.4.3 Statistical analysis

A descriptive statistics analysis was performed to characterize the sub-sample of participants and the IAQ at homes. Shapiro-Wilk test was used for normality testing. The distribution of all indoor air parameters was skewed; thus they were described by median, 25^{th} percentile (P25) and 75^{th} percentile (P75). In addition, mean, standard deviation (SD), minimum and maximum was also presented.

Volatile organic compounds data were explored to determine the proportion of samples above the detection limit. Concentrations of VOC below the detection limits were excluded from the statistical analyses. The 7-day means of all chemical, physical and comfort parameters levels were used in the analyses. The data used for the I/O ratios analysis were those collected during the same period from indoor data.

Kruskal-Wallis test was used to compare continuous variables and the Qui-square ($\chi 2$) test for comparison of categorical variables.

Statistical analysis was performed using SPSS Statistics version 19 (SPSS Inc., Released 2009, USA). A *p*-value below 0.05 was considered statistically significant.

Associations between indoor air parameters and asthma

The association between the indoor air parameters and asthma status among the children were estimated by odds ratios (OR) and respective 95% confidence intervals (95% CI) using logistic regression models. Adjustments have been made for age (continuous variable in years), sex, mother's education level (categorical variable measured as the number of successfully completed years of formal schooling: 0-6 years; 7-9 years; 10-12 years and ≥13 years) and indoor exposure (as categorical variable) in classroom. In the aforementioned analysis a model was created for each indoor parameter variable. All exposure variables were considered, except benzene, T3CE, T4CE, styrene and naphthalene levels which were below the limits of detection in more than 75% of classrooms, and were considered as categorical based on the respective tertile.

5. Results

The results are organized in accordance with the research objectives described in Chapter 2. The first part refers to the cross-sectional study carried out in 73 classrooms from 20 schools dealing with specific assessment of indoor parameters, questionnaire survey and clinical health examination in participating children; while the second part is related to the case-control study at 68 homes.

5.1 Cross-Sectional Study of Children's Indoor Exposure in Schools

5.1.1 Participants' characteristics

For this analysis data 121 children were excluded since they had missing information on the health outcomes studied. Our final sample was 978 children (508 girls).

The characteristics of children included in this analysis were compared with those excluded (Table 9). No significant differences were found by sex, BMI, doctor-diagnosed asthma and family history of any allergic disorders between included and excluded participants. However, those excluded were significantly older, had more siblings and had parents with lower level of education.

Among the participants, 51.9% of the children were female with a mean (standard deviation) age of 8.6 (0.7) years. Moreover, a high proportion of children had a family history of allergic disease (45.3%) and most of them had one or more siblings. In terms of educational level, among the participants more than 30% of the mothers had higher education.

Table 9 Characteristics of the included and excluded participants

	Included, *n*=978		Excluded, *n*=121		
	n	%	*n*	%	*p*-value
Sex					0.884
Girls	508	51.9	62	51.2	
Boys	470	48.1	59	48.8	
Age (years)[* †]	8.6 (0.7)		8.8 (0.9)		0.018
Body mass index (kg/m^2)[* †]	18.3 (3.15)		18.6 (3.77)		0.739
Doctor-diagnosed asthma[†]					0.073
No	880	90.8	87	85.3	
Yes	89	9.2	15	14.7	
Family history of any allergic disorders					0.240
No	535	54.7	73	60.3	
Yes	443	45.3	48	39.7	
Number of siblings[†]					0.018
None	178	19.5	13	13.3	
1	454	49.8	44	44.9	
2 or more	279	30.6	41	41.8	
Mothers' education level[†]					<0.001
0-6 years	188	20.0	34	32.7	
7-9 years	181	19.2	27	26.0	
10-12 years	245	26.0	25	24.0	
≥ 13 years	238	34.8	18	17.3	
Fathers' education level[†]					<0.001
0-6 years	188	20.9	39	42.4	
7-9 years	218	24.2	24	26.1	
10-12 years	227	25.2	13	14.1	
≥ 13 years	267	29.7	16	17.4	

[†] Denominator for each variable may vary due to missing data.
[*] Mean (standard deviation).

The housing characteristics of the participants are shown in Table 10. About three quarters of the children lived in apartments and the mean (standard deviation) building age was 27.0 (23.0) years. Approximately 77% of the children lived in dwellings exposed to traffic of which 34.2% were highly exposed to traffic. Slightly more than 11% of dwellings were close to cultivation areas where pesticides were being used. Only 7.4% had air conditioning and 23.5% had a fireplace. In addition, 28.3% of the dwellings were decorated in the past 12 months. Twenty-four percent of the families reported dampness in their dwelling during the last 5 years; while 14.5% and 13.0% of the parents reported signals of visible mould growth and water leakage or water damage indoors, respectively. In the child's bedroom no more than 10% of the parents reported dampness or visible mould and 65.0% the presence of carpets.

Table 10 Building characteristics of the dwelling among study population (n=978)

Building characteristics	Girls		Boys		Total	
	n	%	*n*	%	*n*	%
Type of building†						
Single-family house	37	7.6	36	8.1	73	7.8
Semi-detached house	38	7.8	53	11.9	91	9.7
Apartment	382	78.4	322	72.0	704	75.4
Other (including farm)	30	6.2	36	8.1	66	7.1
Building age*†	27.4 (22.7)		26.6 (23.4)		27.0 (23.0)	
Location from traffic†						
Far away from busy traffic	104	21.7	105	23.6	209	22.6
With small (reasonable) traffic	209	43.5	190	42.8	399	43.2
Near to busy traffic	167	34.8	149	33.6	316	34.2
Street with heavy traffic (<200 m)†						
No	202	43.3	202	46.7	404	44.9
Yes	248	53.2	214	49.4	462	51.4
Don´t know	16	3.4	17	3.9	33	3.7
Dwelling decorated (<12 months)†						
No	354	72.2	318	71.1	672	71.7
Yes	136	27.8	129	28.9	265	28.3
Dampness during the past 5 years†						
No	373	76.3	341	76.1	714	76.2
Yes	116	23.7	107	23.9	223	23.8
Water leakage/damage indoors (<12 months)†						
No	439	88.3	386	85.6	825	87.0
Yes	58	11.7	65	14.4	123	13.0
Visible mould growth (<12 months)†						
No	420	85.5	380	85.4	800	85.5
Yes	71	14.5	65	14.6	136	14.5
Bubbles or yellow discoloration (<12 months)†						
No	466	95.3	430	95.8	896	95.5
Yes	23	4.7	19	4.2	42	4.5
Smell of mould in one or more rooms (not the basement, <12 months)†						
No	446	91.0	400	90.1	946	90.6
Yes	44	9.0	44	9.9	88	9.4
Dampness/condensation on the lower part of the windows (during winter)†						
No	273	55.4	275	61.1	548	58.1
Yes	220	44.6	175	38.9	395	41.9
Child's bedroom characteristics						
Type of floor material†						
Plastic (PVC/Vinyl)	3	0.6	2	0.4	5	0.5
Linoleum	2	0.4	0	0	2	0.2
Wood/Parquet	428	0.4	368	82.0	796	84.4
Wall-to-wall-carpet	9	1.8	4	0.9	13	1.4
Tiles	37	7.5	60	13.4	97	10.3
Other	15	3.0	15	3.3	30	3.2
Presence of carpets†						
No	154	30.9	179	39.6	333	35.0
Yes	345	69.1	273	60.4	618	65.0
Dampness or visible mould growth†						
No	450	90.2	407	89.8	857	90.0
Yes	49	9.8	46	10.2	95	10.0

† Denominator for each variable may vary due to missing data.
* Mean (standard deviation).

Approximately 40% of families had pets with fur at home. Around 25% of the children were exposed to ETS at home. Moreover, 30.5% of the caregivers reported at least one tobacco smoker in the household. The use (frequently/often) of air fresheners and incense stick were reported by 34.6% and 37.3%, respectively. These percentages were reduced when the presence of these consumer products in the child's bedroom was taking into account (Table 11).

Table 11 Living conditions at home among study population (*n*=978)

Building	Girls		Boys		Total	
	n	%	*n*	%	*n*	%
Domestic pets (with fur)†						
No	297	58.9	297	64.1	594	61.4
Yes	207	41.1	166	35.9	373	38.6
Exposure to tobacco smoke at home†						
Yes, daily or almost	37	7.5	35	7.6	72	7.5
Yes, often (1-4 times/week)	15	3.0	15	3.3	30	3.1
Yes, sometimes (1-3 times/month)	75	75.1	58	12.7	133	13.9
No, never	369	74.4	350	76.4	719	75.4
Number of smokers at home†						
None	258	52.0	238	52.2	496	52.1
One	153	30.8	139	30.5	292	30.7
Two or more	85	17.1	79	17.3	164	17.2
Number of cigarettes smoked in the home (inside spaces)†						
None	311	65.8	296	66.8	607	66.3
1 or 2	34	7.2	29	6.5	63	6.9
3 to 4	42	8.9	42	9.5	84	9.2
5 to 10	56	11.8	55	12.4	111	12.1
11 to 20	21	4.4	18	4.1	39	4.3
More than 20	9	1.9	3	0.7	12	1.3
Use of air fresheners (frequently/often)†						
No	322	64.7	302	66.2	624	65.4
Yes	176	35.3	154	33.8	330	34.6
Use of incense sticks (frequently/often)†						
No	310	62.5	284	62.8	594	62.7
Yes	186	37.5	168	37.2	354	37.3
Use of products anti-moth/naphthalene†						
No	444	89.2	417	91.6	861	90.3
Yes	54	10.8	38	8.4	92	9.7
Child´s bedroom						
Presence of air freshener†						
No	459	95.8	421	94.8	880	95.3
Yes	20	4.2	23	5.2	43	4.7
Presence of air cleaners†						
No	468	96.9	432	96.4	900	96.7
Yes	15	3.1	16	3.6	31	3.3
Presence of products anti-moth/naphthalene†						
No	462	95.3	422	94.8	884	95.1
Yes	23	4.7	23	5.2	46	4.9
Presence of humidifier†						
No	479	99.0	441	99.1	920	99.0
Yes	5	1.0	4	0.9	9	1.0

† Denominator for each variable may vary due to missing data.

Prevalence of health outcomes reported by parents' questionnaire

Table 12 presents the prevalence of ever, past month and year symptoms/diseases regarding the 978 children. In the lifetime, ever wheezing (30.3%) and ever runny/blocked nose not occurring due to cold (28.7%) were the most frequent symptoms; itchy rash and eczema were reported by around 20.0% of children. In the past year the most frequent reported symptom was dry cough at night time (30.8%), nasal allergy (24.6%) and eye irritation (12.3%), which was followed-up closely by wheeze (11.1%). The prevalence of diagnosed asthma and diagnosed nasal allergy was 9.2% and 12.7%, respectively.

Table 12 Prevalence of ever, past month and year symptoms/diseases in children (*n*=978)

Symptom/disease	Girls		Boys			Total	
	n	%	*n*	%	*p*-value	*n*	%
Asthma-like							
Ever wheeze†	123	24.2	173	36.9	<0.001	296	30.3
Wheeze (<12 months)	42	8.3	67	14.3	0.003	109	11.1
Wheeze (<30 days)	21	4.1	28	6.0	0.192	49	5.0
Doctor-diagnosed asthma†	29	5.8	60	12.9	<0.001	89	9.2
Asthma in school†	11	2.2	12	2.6	0.684	23	2.4
Rhinitis-like							
Ever runny / blocked nose† *	139	27.5	140	30.0	0.387	279	28.7
Nasal allergy (<12 months)† *	119	23.5	120	25.7	0.430	239	24.6
Eye irritation (<12 months)† *	60	11.9	60	12.8	0.639	120	12.3
Ever nasal allergy	64	12.6	99	21.1	<0.001	163	16.7
Doctor-diagnosed nasal allergy	50	9.8	74	15.7	0.006	124	12.7
Skin diseases							
Ever itchy rash (for 6 months)†	89	17.9	90	19.5	0.532	179	18.7
Ever eczema†	97	19.8	86	18.9	0.740	183	19.3
Other respiratory diseases apart from cold							
Dry cough at night (<12 months)†	158	31.5	138	30.1	0.622	296	30.8
Cough episodes	62	12.2	43	9.1	0.123	105	10.7
Phlegm episodes	54	10.6	44	9.4	0.509	98	10.0

† Denominator for each variable may vary due to missing data.
* Not occurring due to cold.

Of those 978 children, recent symptoms (<3 months) analysis included only 846 children (450 girls) after exclusion of participants with related missing information. Thus, as summarized in Table 13, eye irritation (83.2%) was the most reported condition followed by blocked nose (54.1%), runny nose (43.7%), sore throat (38.2%) and headache (34.0%). Face rash, eczema and hand rash symptoms were the less common (5.7% and 7.2%, respectively). Moreover, 14.7% of the children felt better when returning home (Table 13).

Table 13 Prevalence of recent symptoms (<3 months) among children (*n*=846)

Symptom	Girls		Boys			Total	
	n	%	*n*	%	*p*-value	*n*	%
Skin							
Hand rash†	32	7.1	28	7.2	0.977	60	7.2
Face rash†	27	6.0	21	5.3	0.668	48	5.7
Eczema	33	7.3	28	7.1	0.883	61	7.2
Eye							
Eye irritation	70	15.6	72	18.2	0.308	704	83.2
Swollen eye†	32	7.2	33	8.4	0.521	65	7.8
Nose							
Runny nose†	201	44.7	168	42.5	0.532	369	43.7
Blocked nose	246	54.7	212	53.5	0.742	458	54.1
Lower airways							
Dry throat†	101	22.5	82	21.2	0.651	183	21.9
Sore throat†	187	41.6	135	34.4	0.030	322	38.2
Irritating cough	136	30.2	127	32.1	0.562	263	31.1
Shortness of breath†	50	11.2	64	16.4	0.030	114	13.6
Systemic							
Headache†	160	35.9	125	31.8	0.214	285	34.0
Nausea†	60	13.6	38	9.7	0.085	98	11.8
Symptom(s) improve on returning home†	45	14.6	39	14.8	0.944	84	14.7

† Denominator for each variable may vary due to missing data.

To avoid misclassification regarding the presence of cold those that reported "feeling like getting a cold" during the last 3 months were excluded. The prevalence of each symptoms decrease, although the relation remains similar, except for runny nose, blocked nose symptom and eye irritation (Table 14).

Table 14 Prevalence of recent symptoms (<3 months) among children excluding those with the symptom of "feeling like getting a cold" (*n*=468)

Symptom	Girls		Boys			Total	
	n	%	*n*	%	*p*-value	*n*	%
Skin							
Hand rash†	12	4.9	11	5.0	0.977	23	4.9
Face rash	13	5.3	3	1.3	0.019	16	3.4
Eczema	18	7.3	11	4.9	0.280	29	6.2
Eye							
Eye irritation	25	10.2	26	11.7	0.614	51	10.9
Swollen eye†	8	3.3	10	4.5	0.493	18	3.9
Nose							
Runny nose	46	18.8	40	17.9	0.815	86	18.4
Blocked nose	73	29.8	73	32.7	0.493	146	31.2
Lower airways							
Dry throat†	24	9.8	17	7.7	0.424	41	8.8
Sore throat†	49	20.1	43	19.4	0.847	92	19.7
Irritating cough	35	14.3	38	17.0	0.413	73	15.6
Shortness of breath†	13	5.3	16	7.3	0.382	29	6.2
Systemic							
Headache†	58	23.9	52	23.5	0.932	110	23.7
Nausea†	23	9.4	10	4.5	0.043	33	7.1
Symptom(s) improve on returning home†	13	9.0	19	14.5	0.158	32	11.6

† Denominator for each variable may vary due to missing data.

5.1.2 School buildings and classrooms characteristics based on walkthrough inspection

Information concerning the school building and classroom characteristics that potentially affect IAQ was gathered via walkthrough inspection. A total of 13 (65%) schools were situated close to a heavily trafficked road, 5 (25%) schools were close to a car park and 2 (10%) schools were close to gasoline dispensing facilities. Mean building age of the schools was 51 years (range: 22-73 years). The oldest primary school was built in 1940. One-quarter of the school buildings were refurbished before 2004; while 75% between 2004 and 2008. All buildings suffered at least one refurbishment since their construction. School buildings were constructed of brick and concrete block and none had mechanical ventilation system. Most schools had ridge roof (89.5%) and the remaining 10.5% had flat roof. Most of the schools consisted in general classrooms, library and offices; only 2 schools had a science/laboratory room. At present, the primary schools as well as most public buildings in Portugal were covered by smoke-free law (Lei n.º 37/2007).

Table 15 shows the main characteristics of the 73 studied classrooms. The classrooms size and ceiling height ranged between 43 m^2 and 70 m^2 (mean=51±6 m^2) and 2.9 m and 3.6 m (mean=3.4±0.2 m), respectively. None of the classrooms had any mechanical ventilation system, and opening windows was the only way to ventilate. On average the windows area was 13.2±4.8 m^2. During the winter time, the windows were usually closed due to outdoor weather conditions, outdoor noise and/or due to heating systems being turned on. Most floors consisted of synthetic smooth floor covering (PVC/vinyl, linoleum) (65.8%), and not a single case of wall-to-wall carpeting was present. Each classroom was equipped with standard school furniture, almost all made of plywood. It was observed that about 30% of the classrooms had a closet or shelves with gouaches and inks and glues for graphic arts. Whiteboards (for marker pens) and interactive boards were found in 67.1% of classrooms; while blackboard and chalk were observed in 24 (32.9%) classrooms. All the classrooms had heating systems, being the electrical radiators the most frequent type. Approximately 20% of the classrooms had interior damp stains and around 30% presented visible mould in the walls, ceiling and corners of the ceiling. In addition, approximately half of the classrooms (49.3%) had a tendency to form condensation on the windows. All classrooms were cleaned daily (floors and desks) with a broom or vacuum cleaner (less common).

The classrooms were occupied from Monday through Friday, from 9.00 a.m. to 5.30 p.m., with a morning and an afternoon break irrespectively between 10.30-11.00 a.m. and 3.30-4.00 p.m. The lunch break was from 12.00 a.m. until 1.15 p.m.

Table 15 Classrooms characteristics collected by checklist

Characteristic	*n* (%)	Mean	SD	Median	Min	Max
Floor area (m^2)	--	51	6	49	43	70
Volume (m^3)	--	171	23	166	147	254
Occupants per classroom (no.)	--	21	3	21	16	27
Density of occupation (m^2/occupant)	--	2.4	0.4	2.4	1.8	3.5
Type of floor						
Synthetic smooth (PVC/vinyl, linoleum)	48 (65.8)	--	--	--	--	--
Wooden	25 (34.2)	--	--	--	--	--
Wall surface						
Water based paint	73 (100.0)	--	--	--	--	--
Ceiling surface						
Wooden	7 (9.6)	--	--	--	--	--
Painted	66 (90.4)	--	--	--	--	--
Type of board						
Blackboard and chalk	24 (32.9)	--	--	--	--	--
Whiteboard with pen	49 (67.1)	--	--	--	--	--
Interactive board						
No	26 (35.6)	--	--	--	--	--
Yes	47 (67.1)	--	--	--	--	--
Heating system						
Hot water radiators/convectors	9 (12.3)	--	--	--	--	--
Electrical radiators/convectors	60 (82.2)	--	--	--	--	--
Heating floor	4 (5.5)	--	--	--	--	--
Damp stains						
No	59 (80.8)	--	--	--	--	--
Yes	14 (19.2)	--	--	--	--	--
Visible mould						
No	53 (72.6)	--	--	--	--	--
Yes	20 (27.4)	--	--	--	--	--

n: Number of classrooms; SD: Standard deviation; Min: Minimum; Max: Maximum.

5.1.3 Distribution of chemical, physical and comfort parameters and microbiological agents in classrooms

Table 16 provides descriptive data for the indoor parameters measured in the classrooms. It was observed that four individual VOC (benzene, T4CE, naphthalene, styrene) were detected in less than 18 (25%) classrooms, while T3CE was not detected in any sample. So, particular attention was devoted to those VOC detected in more than 75% of the samples. The VOC with highest median concentration was d-limonene (23.1 µg/m^3) followed by toluene (6.37 µg/m^3); most of individual VOC had median levels lower than 5 µg/m^3. The median TVOC concentration was 140.3 µg/m^3 (P25-P75=85.5-198.4 µg/m^3). The median values of VOC, formaldehyde and CO levels were lower than the guidelines values established by WHO (2010c) and EU-INDEX project (Kotzias *et al.*, 2005).

Regarding particulate matter, in all classrooms, the indoor median concentration of $PM_{2.5}$ and PM_{10} exceed the 25 µg/m^3 and 50 µg/m^3 guideline value suggested by WHO air quality guidelines for a sampling period of 24 hours (Table 16). The mean CO_2 concentration in the classrooms during school hours had a median of 1469 ppm, ranging from 829 ppm to 3111 ppm. Among the 73 classrooms surveyed, 86% of the classrooms (*n*=63) had median CO_2 concentrations exceeding 1000 ppm. Higher values were measured in classrooms with higher occupant density.

Concerning microbiological agents, the classrooms had a median concentration of bacteria higher than 1000 CFU/m^3 and, in some cases, indoor levels were 6 times higher than the reference value established by Portuguese legislation (500 CFU/m^3). On the other hand, fungi concentrations ranged from 61-1322 CFU/m^3 indoors (median=240 CFU/m^3) (Table 16).

Table 16 Distribution of indoor chemical, physical and comfort parameters and microbiological agents in classrooms (*n*=73 classrooms)

Chemical	*n*>DL§	Mean	SD	Median	P25	P75	Min	Max
Benzene, µg/m^3	7	2.16	0.49	2.47	1.58	2.60	1.48	2.67
Toluene, µg/m^3	72	15.1	34.5	6.37	4.49	10.4	1.84	202.5
m/p-xylene, µg/m^3	71	17.7	59.0	4.97	3.31	6.82	1.21	365.2
o-xylene, µg/m^3	68	3.93	6.92	2.30	1.83	3.37	1.09	52.4
d-limonene, µg/m^3	71	38.1	44.5	23.1	11.5	48.6	2.77	215.3
α-pinene, µg/m^3	63	3.40	5.50	1.75	1.32	2.75	1.01	32.0
T3CE, µg/m^3	0	--	--	--	--	--	--	--
T4CE, µg/m^3	18	2.90	1.53	2.90	1.77	3.39	1.07	8.25
Naphthalene, µg/m^3	6	1.40	0.21	1.33	1.24	1.60	1.15	1.68
Styrene, µg/m^3	13	1.41	0.46	1.19	1.17	1.35	1.02	2.66
TVOC, µg/m^3	73	172.2	145.2	140.3	85.5	198.4	8.88	820.2
Formaldehyde, µg/m^3	73	19.8	10.9	17.5	13.8	23.1	8.24	126.9
Acetaldehyde, µg/m^3	73	9.31	7.82	7.65	4.96	10.4	1.92	64.6
CO, mg/m^3	--	0.48	0.44	0.38	0.07	0.68	0.01	1.70
Physical and comfort								
$PM_{2.5}$, µg/m^3	--	94	40	82	67	106	39	244
PM_{10}, µg/m^3	--	139	49	127	109	167	56	320
CO_2, ppm	--	1669	601	1469	1195	2104	829	3111
Ventilation rate, l/s per person	--	0.87	1.38	0.33	0.21	0.78	0.11	7.21
Temperature, ºC	--	20.5	2.06	20.8	19.2	21.7	14.3	24.6
Relative humidity, %	--	55	10	54	50	65	34	74
Microbiological								
Bacteria, CFU/m^3	--	3626	2269	3224	1784	5430	168	8372
Fungi, CFU/m^3	--	323	235	240	169	400	61	1322

DL: Detection limit; SD: Standard deviation; P25: 25^{th} percentile; P75: 75^{th} percentile; Min: Minimum; Max: Maximum; T3CE: Trichloroethylene; T4CE: Tetrachloroethylene; TVOC: Total Volatile Organic Compounds.
§ Number of classrooms with values above the detection limit.

Descriptive data on outdoor concentrations are given in Table 17. Data on outdoor levels of formaldehyde and acetaldehyde was missing in one school due to weather issues. Similar to the indoor environments benzene, T3CE, T4CE, naphthalene and styrene were observed in less than 25% of the outdoor schools. Unlike of indoor samples, d-limonene and α-pinene were detected in only 5 and 3 outdoor samples, respectively. Median outdoor concentrations of VOC were low (generally

<5 µg/m^3 for individual compounds). In general, outdoor concentrations tend to be lower than the corresponding indoor levels.

Table 17 Distribution of outdoor chemical, physical and comfort parameters and microbiological agents in playgrounds (*n*=20 schools)

Chemical	*n*>DL§	Mean	SD	Median	P25	P75	Min	Max
Benzene, µg/m^3	2	2.22	0.86	2.22	1.61	2.82	1.61	2.82
Toluene, µg/m^3	20	4.99	2.95	4.11	2.83	7.21	1.17	10.4
m/p-xylene, µg/m^3	18	4.81	5.74	3.29	1.81	6.35	1.14	26.3
o-xylene, µg/m^3	15	2.72	2.32	2.17	1.93	2.71	1.14	10.9
d-limonene, µg/m^3	5	2.11	0.49	2.05	1.70	2.55	1.37	2.62
α-pinene, µg/m^3	3	2.57	1.38	2.25	1.38	4.09	1.38	4.09
T3CE, µg/m^3	0	--	--	--	--	--	--	--
T4CE, µg/m^3	5	3.37	1.99	2.98	2.03	4.90	1.74	6.80
Naphthalene, µg/m^3	0	--	--	--	--	--	--	--
Styrene, µg/m^3	1	1.02	--	1.02	--	--	--	--
TVOC, µg/m^3	20	54.5	42.2	48.2	35.4	62.9	12.1	216
Formaldehyde, µg/m^3	19‡	2.90	0.74	2.74	2.27	3.60	1.82	4.17
Acetaldehyde, µg/m^3	14‡	0.96	0.58	0.84	0.82	1.36	0.19	2.09
CO, mg/m^3	--	0.39	0.45	0.22	0.04	0.55	0.01	1.30
Physical and comfort								
$PM_{2.5}$, µg/m^3	--	81	61	71	40	100	27	270
PM_{10}, µg/m^3	--	88	64	75	45	112	30	276
CO_2, ppm	--	449	90	442	364	504	349	636
Temperature, ºC	--	14.6	3.25	14.5	11.7	16.9	10.0	20.6
Relative humidity, %	--	59	10	59	53	68	40	75
Microbiological								
Bacteria, CFU/m^3	--	624	863	213	79	853	20	3684
Fungi, CFU/m^3	--	224	127	200	112	302	53	590

DL: Detection limit; SD: Standard deviation; P25: 25th percentile; P75: 75th percentile; Min: Minimum; Max: Maximum; T3CE: Trichloroethylene; T4CE: Tetrachloroethylene; TVOC: Total Volatile Organic Compounds.
§ Number of schools with values above the detection limit.
‡ Total of 19 out of 20 schools was assessed.

In order to allow the comparison between indoor and outdoor levels, the summary data of each environment, as well as the information on I/O ratios, are given in Table 18. Indoor/outdoor ratio (I/O ratio) was calculated taking into account the average of all classrooms of each school. The indoor concentrations usually exceed outdoor levels, leading to an I/O ratio higher than the unit, in particular for d-limonene, acetaldehyde, formaldehyde, CO_2 and bacteria.

Table 18 Indoor/outdoor ratio for chemical, physical and comfort parameters and microbiological agents

Chemical	*n*[§]	Indoor median	Outdoor median	I/O ratio median[‡]
Benzene, µg/m^3	1	2.38	2.84	0.84
Toluene, µg/m^3	20	5.57	4.11	1.70
m/p-xylene, µg/m^3	18	5.23	3.29	1.68
o-xylene, µg/m^3	15	2.42	2.17	1.25
d-limonene, µg/m^3	5	13.9	2.05	10.11
α-pinene, µg/m^3	3	2.38	2.25	1.55
T3CE, µg/m^3	0	--	--	--
T4CE, µg/m^3	2	2.27	2.36	1.01
Naphthalene, µg/m^3	0	--	--	--
Styrene, µg/m^3	0	--	--	--
TVOC, µg/m^3	20	149.5	48.2	2.88
Formaldehyde, µg/m^3	19	17.02	2.74	6.30
Acetaldehyde, µg/m^3	14	7.90	0.84	9.94
CO, mg/m^3	14	0.41	0.22	1.35
Physical and comfort				
$PM_{2.5}$, µg/m^3	16	86	71	1.45
PM_{10}, µg/m^3	16	130	75	1.82
CO_2, ppm	15	1611	442	3.40
Temperature, ºC	19	20.7	14.5	1.40
Relative humidity, %	19	54	59	0.88
Microbiological				
Bacteria, CFU/m^3	20	2977	272	8.82
Fungi, CFU/m^3	20	264	202	1.26

[§] Correspond to the number of indoor measurements matched with the correspondent outdoor measurements.
DL: Detection limit; SD: Standard deviation; P25: 25th percentile; P75: 75th percentile; Min: Minimum; Max: Maximum; T3CE: Trichloroethylene; T4CE: Tetrachloroethylene; TVOC: Total Volatile Organic Compounds.
[‡] The median of I/O ratios.

5.1.4 Associations between indoor air parameters and children's health

The associations between children's health outcomes and indoor air parameters were studied. Indoor air parameters were categorized into 3 classes according to the approximation of the tertiles of exposure, except for α-pinene which was categorized into 2 categories according to detection limit. The five VOC (benzene, T3CE, T4CE, naphthalene and styrene) with more than 75% of values below the detection limit were not considered in the analysis.

Table 19 shows data regarding the association of the chemical parameters and wheeze, nasal allergy, cough episodes and phlegm. After adjustment, higher values of toluene and xylene isomers were associated with the occurrence of wheeze; no significant association was found with other VOC, but the increase concentration of TVOC showed increased odds of wheeze in the previous month. Formaldehyde and acetaldehyde also showed a positive association with the occurrence of wheeze, but only concerning the previous year.

Regarding ever nasal allergy, a significant association was found only for TVOC. Children in classrooms with levels between 101.87 µg/m^3 and 189.93 µg/m^3 presented significant higher odds to have nasal allergy than those in classrooms with lower levels [OR=1.65 (95% CI: 1.05-2.62)] (Table 19). The odds for cough and phlegm episodes were significant higher among children in classrooms with d-limonene levels between 12.19 µg/m^3 and 30.49 µg/m^3 (Table 19).

Table 19 Associations between indoor chemical parameters and wheeze, nasal allergy, cough episodes and phlegm episodes (*n*=978)

	Wheeze (<12 months)		Wheeze (<30 days)		Ever nasal allergy		Cough episodes		Phlegm episodes	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
Toluene, μg/m^3										
<4.64	1	1	1	1	1	1	1	1	1	1
4.64-8.06	1.29 (0.78-2.16)	1.32 (0.74-2.35)	0.84 (0.38-1.85)	0.91 (0.38-2.14)	1.03 (0.68-1.55)	0.95 (0.60-1.51)	0.83 (0.52-1.33)	0.76 (0.44-1.31)	0.82 (0.50-1.34)	0.70 (0.40-1.21)
≥8.07	1.55 (0.94-2.57)	**1.82 (1.01-3.30)**	1.65 (0.83-3.29)	**2.44 (1.11-5.40)**	0.98 (0.65-1.49)	1.07 (0.66-1.72)	0.62 (0.38-1.04)	0.73 (0.40-1.33)	0.65 (0.39-1.10)	0.63 (0.34-1.16)
m/p-xylene, μg/m^3										
<4.02	1	1	1	1	1	1	1	1	1	1
4.02-5.89	**2.03 (1.23-3.36)**	**2.35 (1.32-4.21)**	1.77 (0.83-3.77)	2.13 (0.92-4.97)	1.36 (0.91-2.03)	1.37 (0.88-2.14)	0.83 (0.52-1.35)	0.87 (0.49-1.52)	0.75 (0.46-1.23)	0.78 (0.45-1.37)
≥5.90	1.36 (0.79-2.33)	1.84 (0.96-3.52)	1.75 (0.81-3.76)	2.32 (0.94-5.73)	0.84 (0.54-1.30)	0.88 (0.52-1.46)	0.71 (0.43-1.17)	0.94 (0.51-1.74)	0.68 (0.40-1.13)	0.70 (0.38-1.30)
o-xylene, μg/m^3										
<1.89	1	1	1	1	1	1	1	1	1	1
1.89-2.61	1.49 (0.88-2.42)	1.62 (0.89-2.98)	1.02 (0.48-2.17)	1.55 (0.63-3.79)	0.94 (0.62-1.41)	0.84 (0.52-1.37)	1.19 (0.73-1.92)	1.27 (0.70-2.30)	1.05 (0.64-1.72)	1.02 (0.57-1.84)
≥2.62	1.44 (0.86-2.39)	1.66 (0.92-2.99)	1.50 (0.74-3.02)	**2.27 (1.01-5.11)**	0.99 (0.66-1.49)	0.95 (0.60-1.52)	0.87 (0.52-1.45)	0.92 (0.50-1.70)	0.77 (0.46-1.31)	0.76 (0.41-1.39)
d-limonene, μg/m^3										
<12.19	1	1	1	1	1	1	1	1	1	1
12.19-30.49	0.98 (0.60-1.59)	1.04 (0.59-1.84)	1.04 (0.52-2.10)	1.04 (0.48-2.28)	1.23 (0.82-1.84)	1.31 (0.82-2.10)	**1.66 (1.02-2.70)**	**2.49 (1.35-4.59)**	1.42 (0.87-2.34)	**1.92 (1.06-3.47)**
≥30.50	1.05 (0.64-1.71)	1.01 (0.52-1.95)	0.98 (0.47-2.01)	0.98 (0.38-2.49)	0.93 (0.61-1.43)	1.03 (0.59-1.81)	0.93 (0.54-1.61)	1.62 (0.76-3.44)	0.89 (0.52-1.55)	1.10 (0.53-2.28)
α-pinene, μg/m^3										
<1.00	1	1	1	1	1	1	1	1	1	1
≥1.00	1.55 (0.84-2.84)	1.82 (0.92-3.57)	1.79 (0.70-4.58)	2.63 (0.91-7.58)	0.87 (0.56-1.35)	1.00 (0.61-1.62)	0.98 (0.57-1.68)	0.92 (0.51-1.67)	1.14 (0.64-2.03)	1.17 (0.62-2.21)
TVOC, μg/m^3										
<101.87	1	1	1	1	1	1	1	1	1	1
101.87-189.93	1.58 (0.96-2.61)	1.67 (0.93-3.00)	1.95 (0.89-4.26)	**2.56 (1.05-6.25)**	**1.50 (1.00-2.25)**	**1.65 (1.05-2.62)**	0.84 (0.51-1.38)	0.73 (0.40-1.32)	0.75 (0.47-1.27)	0.71 (0.39-1.29)
≥189.94	1.42 (0.86-2.32)	1.64 (0.94-2.85)	**2.22 (1.05-4.67)**	**2.67 (1.15-6.18)**	0.97 (0.64-1.48)	1.06 (0.67-1.68)	0.80 (0.49-1.29)	0.88 (0.52-1.49)	0.81 (0.50-1.32)	0.85 (0.50-1.45)
Formaldehyde, μg/m^3										
<14.92	1	1	1	1	1	1	1	1	1	1
14.92-20.13	**1.65 (1.02-2.67)**	**2.11 (1.20-3.68)**	1.51 (0.79-2.91)	2.02 (0.95-4.29)	1.02 (0.68-1.54)	1.08 (0.68-1.74)	0.95 (0.58-1.56)	0.95 (0.54-1.70)	0.92 (0.56-1.52)	0.90 (0.51-1.61)
≥20.14	0.98 (0.58-1.68)	1.12 (0.56-2.24)	0.58 (0.25-1.34)	0.83 (0.30-2.31)	0.97 (0.64-1.48)	0.98 (0.57-1.68)	1.00 (0.61-1.64)	0.95 (0.48-1.86)	0.89 (0.53-1.49)	0.66 (0.33-1.32)
Acetaldehyde, μg/m^3										
<5.80	1	1	1	1	1	1	1	1	1	1
5.80-9.82	1.34 (0.80-2.23)	1.59 (0.90-2.81)	1.59 (0.76-3.31)	1.60 (0.73-3.52)	0.88 (0.59-1.32)	1.07 (0.68-1.68)	0.92 (0.56-1.52)	0.89 (0.51-1.56)	0.83 (0.50-1.40)	0.80 (0.45-1.42)
≥9.83	1.60 (0.97-2.66)	**1.83 (1.01-3.33)**	1.46 (0.69-3.12)	1.92 (0.82-4.48)	0.89 (0.59-1.35)	0.98 (0.61-1.59)	1.02 (0.62-1.67)	1.14 (0.62-2.07)	1.09 (0.66-1.80)	1.12 (0.62-2.02)
CO, mg/m^3										
<0.16	1	1	1	1	1	1	1	1	1	1
0.16-0.60	0.68 (0.41-1.14)	0.91 (0.51-1.61)	0.81 (0.40-1.66)	0.88 (0.41-1.92)	0.80 (0.52-1.21)	0.75 (0.47-1.18)	0.76 (0.46-1.26)	1.05 (0.59-1.88)	0.88 (0.51-1.50)	1.09 (0.60-2.00)
≥0.61	0.84 (0.53-1.35)	1.09 (0.64-1.85)	0.82 (0.42-1.63)	0.94 (0.45-1.98)	0.69 (0.46-1.04)	0.76 (0.48-1.18)	0.72 (0.44-1.18)	1.02 (0.58-1.78)	0.99 (0.60-1.64)	1.35 (0.77-2.37)

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother's education, body mass index, relative humidity and temperature; CI: confidence interval.

Higher levels of particulate matter, both $PM_{2.5}$ and PM_{10}, increase the odds of wheeze, but the association was strong for PM_{10}. In contrast, the odds of wheeze were lower with increasing levels of relative humidity (Table 20). Regarding cough and phlegm episodes, only CO_2 levels showed a significant association with children exposed to levels between 1299.87 ppm and 1913.07 ppm, presenting 50% less odds to have cough and phlegm episodes than those in schools with lower levels (Table 20).

Regarding the exposure to microbiological agents and after adjustment (Table 21), lower odds of wheeze in the previous year were found among those in schools with higher levels of bacteria (OR=0.51, 95% CI: 0.28-0.92) and of wheeze in the previous month among those in schools with higher levels of fungi (OR=0.38, 95% CI: 0.16-0.91). By contrast, higher levels of bacteria were significantly associated with higher odds of cough episodes (OR=1.88, 95% CI: 1.03-3.43).

Table 20 Associations between indoor physical and comfort parameters and wheeze, nasal allergy, cough episodes and phlegm episodes (*n*=978)

	Wheeze (<12 months)		Wheeze (<30 days)		Ever nasal allergy		Cough episodes		Phlegm episodes	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
$PM_{2.5}$, μg/m^3										
<72.53	1	1	1	1	1	1	1	1	1	1
72.53-97.92	1.35 (0.81-2.26)	1.72 (0.96-3.08)	1.44 (0.64-3.22)	1.44 (0.62-3.39)	1.15 (0.77-1.71)	1.25 (0.81-1.92)	0.94 (0.56-1.56)	1.18 (0.66-2.09)	0.97 (0.58-1.62)	1.11 (0.63-1.96)
≥97.93	1.48 (0.88-2.48)	**1.90 (1.04-3.45)**	**2.20 (1.02-4.74)**	**2.28 (1.00-5.18)**	0.79 (0.51-1.22)	0.73 (0.45-1.19)	1.26 (0.77-2.07)	1.44 (0.81-2.56)	1.08 (0.64-1.81)	1.25 (0.70-2.23)
PM_{10}, μg/m^3										
<116.77	1	1	1	1	1	1	1	1	1	1
116.77-137.88	1.07 (0.64-1.80)	1.23 (0.66-2.27)	1.85 (0.78-4.39)	1.58 (0.61-4.09)	1.09 (0.73-1.63)	1.24 (0.79-1.95)	1.18 (0.70-1.96)	1.19 (0.65-2.18)	0.90 (0.54-1.50)	0.89 (0.49-1.61)
≥137.89	1.48 (0.90-2.45)	**1.93 (1.07-3.49)**	**2.96 (1.30-6.73)**	**3.00 (1.23-7.33)**	0.79 (0.51-1.21)	0.73 (0.44-1.19)	1.36 (0.82-2.27)	1.36 (0.75-2.47)	1.05 (0.63-1.74)	1.11 (0.62-1.98)
CO_2, ppm										
<1299.87	1	1	1	1	1	1	1	1	1	1
1299.87-1913.07	0.62 (0.37-1.06)	0.68 (0.36-1.25)	1.15 (0.54-2.47)	1.49 (0.64-3.46)	0.97 (0.64-1.48)	1.25 (0.76-2.06)	**0.53 (0.31-0.88)**	**0.51 (0.28-0.95)**	**0.56 (0.33-0.96)**	**0.50 (0.27-0.94)**
≥1913.08	1.08 (0.67-1.72)	1.19 (0.63-2.26)	1.47 (0.71-3.03)	2.07 (0.81-5.27)	0.98 (0.65-1.50)	1.30 (0.75-2.26)	0.66 (0.41-1.08)	0.85 (0.43-1.68)	0.74 (0.45-1.22)	0.70 (0.36-1.37)
Temperature, ºC										
<19.62	1	1	1	1	1	1	1	1	1	1
19.62-21.30	0.86 (0.53-1.41)	0.76 (0.44-1.31)	0.93 (0.46-1.88)	0.86 (0.40-1.82)	1.07 (0.70-1.63)	0.90 (0.57-1.42)	1.00 (0.61-1.64)	0.84 (0.48-1.46)	0.93 (0.56-1.55)	0.94 (0.53-1.65)
≥21.31	0.84 (0.52-1.37)	0.72 (0.39-1.32)	0.94 (0.47-1.89)	0.77 (0.33-1.81)	1.10 (0.73-1.66)	0.97 (0.59-1.61)	0.88 (0.53-1.46)	0.64 (0.34-1.20)	0.84 (0.50-1.41)	0.82 (0.44-1.53)
Relative humidity, %										
<50.56	1	1	1	1	1	1	1	1	1	1
50.56-57.64	0.85 (0.52-1.40)	0.60 (0.32-1.10)	0.55 (0.27-1.10)	**0.41 (0.18-0.94)**	1.38 (0.92-2.08)	0.96 (0.58-1.59)	1.00 (0.62-1.61)	1.12 (0.61-2.07)	1.11 (0.66-1.85)	1.21 (0.64-2.27)
≥57.65	0.94 (0.58-1.54)	0.66 (0.33-1.30)	0.56 (0.28-1.14)	0.40 (0.15-1.07)	0.99 (0.64-1.52)	0.78 (0.43-1.40)	0.65 (0.38-1.11)	0.72 (0.35-1.46)	1.00 (0.59-1.69)	0.98 (0.48-2.01)

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother's education, body mass index, relative humidity and temperature; CI: confidence interval.

Table 21 Associations between indoor microbiological agents and wheeze, nasal allergy, cough episodes and phlegm episodes (*n*=978)

	Wheeze (<12 months)		Wheeze (<30 days)		Ever nasal allergy		Cough episodes		Phlegm episodes	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
Bacteria, CFU/m^3										
<2058.00	1	1	1	1	1	1	1	1	1	1
2058.00-3856.00	0.76 (0.48-1.22)	0.83 (0.48-1.41)	0.94 (0.49-1.81)	0.88 (0.43-1.83)	1.08 (0.72-1.62)	1.29 (0.82-2.04)	1.05 (0.61-1.79)	1.33 (0.72-2.46)	1.28 (0.74-2.23)	1.44 (0.78-2.64)
≥3857.00	0.61 (0.37-1.01)	**0.51 (0.28-0.92)**	0.54 (0.25-1.15)	0.52 (0.22-1.19)	0.73 (0.47-1.12)	0.72 (0.44-1.19)	1.59 (0.96-2.62)	**1.88 (1.03-3.43)**	**1.73 (1.02-2.94)**	1.65 (0.90-3.02)
Fungi, CFU/m^3										
<199.67	1	1	1	1	1	1	1	1	1	1
199.67-320.00	0.99 (0.62-1.60)	0.87 (0.50-1.51)	0.79 (0.41-1.53)	0.89 (0.42-1.89)	1.39 (0.92-2.18)	1.54 (0.96-2.47)	1.32 (0.80-2.17)	1.39 (0.78-2.47)	1.34 (0.81-2.24)	1.20 (0.68-2.14)
≥321.00	0.63 (0.37-1.06)	0.57 (0.32-1.01)	**0.36 (0.16-0.83)**	**0.38 (0.16-0.91)**	1.14 (0.74-1.75)	1.20 (0.75-1.93)	0.99 (0.58-1.66)	0.87 (0.48-1.58)	0.95 (0.55-1.64)	0.78 (0.42-1.41)

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother's education, body mass index, relative humidity and temperature; CI: confidence interval.

As a next step, associations between the exposure variables and skin symptoms, eczema, eye irritation, nose symptoms and irritating cough present in the past 3 months were analysed. No association was found between chemical parameters and eczema, eye irritation and nose symptoms (Table 22). Regarding skin symptoms, only d-limonene showed a significant association with children in classrooms with levels between 12.19 $\mu g/m^3$ and 30.49 $\mu g/m^3$ presenting a odds 2.15 (95% CI: 1.11-4.18) higher than those in classrooms with lower levels. o-xylene, formaldehyde, acetaldehyde and CO were associated with the occurrence of irritating cough (Table 22).

Table 22 Associations between indoor chemical parameters and skin symptoms, eczema, eye irritation, nose symptoms and irritating cough present in the past 3 months (*n*=846)

	Skin symptoms		Eczema		Eye irritation		Nose symptoms		Irritating cough	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
Toluene, µg/m^3										
<4.64	1	1	1	1	1	1	1	1	1	1
4.64-8.06	0.85 (0.47-1.53)	0.98 (0.50-1.91)	1.03 (0.54-1.94)	1.24 (0.61-2.49)	0.97 (0.63-1.51)	1.14 (0.70-1.85)	1.08 (0.64-1.83)	1.45 (0.78-2.70)	0.87 (0.61-1.25)	0.94 (0.63-1.39)
≥8.07	1.45 (0.85-2.48)	1.50 (0.79-2.85)	0.92 (0.48-1.79)	1.14 (0.54-2.42)	0.96 (0.62-1.50)	0.97 (0.58-1.63)	0.74 (0.41-1.31)	1.04 (0.52-2.06)	0.83 (0.58-1.19)	1.00 (0.66-1.52)
m/p-xylene, µg/m^3										
<4.02	1	1	1	1	1	1	1	1	1	1
4.02-5.89	1.32 (0.74-2.37)	1.36 (0.69-2.69)	0.87 (0.47-1.63)	1.04 (0.52-2.08)	1.18 (0.76-1.82)	1.19 (0.73-1.94)	0.98 (0.57-1.68)	0.84 (0.44-1.61)	0.96 (0.67-1.36)	1.03 (0.69-1.53)
≥5.90	1.73 (0.98-3.04)	1.81 (0.90-3.65)	0.72 (0.37-1.40)	0.81 (0.37-1.78)	0.99 (0.63-1.56)	1.06 (0.62-1.82)	0.91 (0.52-1.58)	1.02 (0.51-2.02)	0.92 (0.64-1.32)	1.18 (0.77-1.82)
o-xylene, µg/m^3										
<1.89	1	1	1	1	1	1	1	1	1	1
1.89-2.61	1.32 (0.75-2.34)	1.75 (0.87-3.52)	0.71 (0.37-1.37)	1.06 (0.49-2.29)	0.74 (0.47-1.16)	0.89 (0.52-1.51)	1.24 (0.72-2.12)	1.76 (0.88-3.49)	1.22 (0.85-1.74)	**1.55 (1.01-2.36)**
≥2.62	1.42 (0.80-2.50)	1.77 (0.90-3.50)	0.83 (0.44-1.56)	1.19 (0.57-2.51)	1.00 (0.65-1.54)	1.12 (0.68-1.85)	0.94 (0.53-1.66)	1.41 (0.71-2.82)	0.97 (0.68-1.40)	1.24 (0.81-1.89)
d-limonene, µg/m^3										
<12.19	1	1	1	1	1	1	1	1	1	1
12.19-30.49	1.59 (0.91-2.77)	**2.15 (1.11-4.18)**	0.89 (0.47-1.70)	0.92 (0.44-1.90)	1.13 (0.73-1.75)	0.92 (0.56-1.52)	1.48 (0.87-2.52)	1.33 (0.71-2.48)	1.15 (0.81-1.65)	1.25 (0.83-1.87)
≥30.50	1.20 (0.67-2.16)	1.28 (0.57-2.84)	0.94 (0.49-1.79)	1.10 (0.45-2.70)	1.00 (0.64-1.57)	0.66 (0.36-1.20)	0.87 (0.48-1.58)	0.77 (0.34-1.73)	1.03 (0.72-1.48)	1.12 (0.69-1.83)
α-pinene, µg/m^3										
<1.00	1	1	1	1	1	1	1	1	1	1
≥1.00	1.26 (0.66-2.38)	1.56 (0.74-3.29)	1.33 (0.62-2.87)	1.90 (0.82-4.39)	0.94 (0.58-1.51)	0.97 (0.58-1.64)	1.28 (0.67-2.42)	1.32 (0.66-2.64)	1.28 (0.86-1.92)	1.36 (0.88-2.11)
TVOC, µg/m^3										
<101.87	1	1	1	1	1	1	1	1	1	1
101.87-189.93	0.70 (0.38-1.27)	0.70 (0.35-1.42)	1.28 (0.66-2.45)	1.51 (0.73-3.13)	1.30 (0.83-2.02)	1.16 (0.70-1.91)	0.96 (0.55-1.66)	0.76 (0.39-1.50)	1.01 (0.70-1.45)	1.01 (0.67-1.52)
≥189.94	1.16 (0.70-1.93)	1.26 (0.70-2.23)	1.15 (0.61-2.19)	1.33 (0.66-2.68)	1.08 (0.70-1.68)	1.04 (0.64-1.68)	0.96 (0.57-1.64)	0.99 (0.56-1.77)	1.05 (0.74-1.49)	1.12 (0.77-1.64)
Formaldehyde, µg/m^3										
<14.92	1	1	1	1	1	1	1	1	1	1
14.92-20.13	1.43 (0.83-2.46)	1.42 (0.75-2.69)	0.79 (0.43-1.45)	1.04 (0.50-2.15)	0.94 (0.62-1.43)	1.02 (0.63-1.67)	0.87 (0.51-1.49)	0.78 (0.41-1.47)	1.23 (0.87-1.76)	**1.59 (1.05-2.40)**
≥20.14	1.08 (0.60-1.94)	1.05 (0.48-2.30)	0.64 (0.33-1.24)	1.05 (0.44-2.46)	0.64 (0.40-1.02)	0.72 (0.39-1.30)	0.82 (0.47-1.41)	0.95 (0.45-2.03)	0.97 (0.67-1.40)	1.43 (0.88-2.30)
Acetaldehyde, µg/m^3										
<5.80	1	1	1	1	1	1	1	1	1	1
5.80-9.82	1.13 (0.65-1.96)	1.13 (0.61-2.11)	0.93 (0.50-1.73)	1.12 (0.57-2.18)	1.00 (0.65-1.53)	1.13 (0.70-1.82)	1.34 (0.79-2.29)	1.30 (0.71-2.36)	1.28 (0.89-1.84)	1.32 (0.89-1.96)
≥9.83	1.13 (0.65-1.97)	1.07 (0.54-2.10)	0.76 (0.39-1.46)	0.90 (0.42-1.93)	0.81 (0.51-1.27)	0.67 (0.39-1.14)	0.96 (0.54-1.70)	0.99 (0.48-2.00)	1.36 (0.95-1.96)	**1.58 (1.04-2.41)**
CO, mg/m^3										
<0.16	1	1	1	1	1	1	1	1	1	1
0.16-0.60	0.99 (0.58-1.70)	1.17 (0.63-2.17)	0.98 (0.53-1.81)	0.98 (0.51-1.90)	1.28 (0.81-2.03)	1.41 (0.85-2.33)	1.11 (0.65-1.90)	1.32 (0.71-2.45)	0.98 (0.68-1.43)	1.13 (0.75-1.70)
≥0.61	0.68 (0.39-1.20)	0.88 (0.46-1.69)	0.51 (0.26-1.02)	0.57 (0.27-1.20)	1.18 (0.75-1.84)	1.25 (0.76-2.07)	0.74 (0.42-1.30)	0.99 (0.52-1.90)	1.23 (0.86-1.75)	**1.48 (1.00-2.20)**

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother's education, body mass index, relative humidity and temperature; CI: confidence interval.

Regarding physical and comfort parameters, after adjustment, increasing odds of irritating cough with increasing levels of $PM_{2.5}$ and PM_{10} were found on the other hand, lower odds of eye irritation was found among children in classrooms with high temperature (Table 23).

No significant association was found regarding the exposure to microbiological agents (Table 24).

Table 23 Associations between indoor physical and comfort parameters and skin symptoms, eczema, eye irritation, nose symptoms and irritating cough present in the past 3 months (n=846)

	Skin symptoms		Eczema		Eye irritation		Nose symptoms		Irritating cough	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
$PM_{2.5}$, µg/m^3										
<72.53	1	1	1	1	1	1	1	1	1	1
72.53-97.92	1.08 (0.61-1.90)	1.61 (0.84-3.07)	1.24 (0.65-2.35)	1.32 (0.66-2.60)	1.49 (0.96-2.33)	1.61 (0.99-2.63)	1.14 (0.63-2.03)	1.05 (0.55-2.00)	**1.50 (1.04-2.14)**	**1.54 (1.04-2.28)**
≥97.93	1.42 (0.82-2.47)	1.70 (0.89-3.24)	1.21 (0.62-2.34)	1.06 (0.52-2.20)	1.32 (0.83-2.10)	1.52 (0.91-2.52)	**1.78 (1.03-3.10)**	1.52 (0.82-2.82)	**1.49 (1.03-2.16)**	**1.54 (1.03-2.31)**
PM_{10}, µg/m^3										
<116.77	1	1	1	1	1	1	1	1	1	1
116.77-137.88	1.03 (0.58-1.84)	1.26 (0.64-2.50)	1.31 (0.68-2.50)	0.99 (0.49-2.00)	1.22 (0.78-1.91)	1.33 (0.80-2.21)	1.56 (0.85-2.83)	1.01 (0.51-2.01)	**1.44 (1.00-2.08)**	**1.52 (1.01-2.30)**
≥137.89	1.56 (0.90-2.71)	1.85 (0.97-3.52)	1.28 (0.66-2.49)	1.04 (0.51-2.14)	1.30 (0.83-2.04)	1.54 (0.93-2.57)	**2.15 (1.20-3.84)**	1.66 (0.88-3.15)	**1.52 (1.05-2.19)**	**1.64 (1.08-2.47)**
CO_2, ppm										
<1299.87	1	1	1	1	1	1	1	1	1	1
1299.87-1913.07	1.25 (0.70-2.24)	1.34 (0.68-2.65)	1.29 (0.69-2.40)	1.52 (0.74-3.12)	0.95 (0.60-1.50)	0.98 (0.58-1.67)	0.79 (0.47-1.36)	0.76 (0.40-1.44)	0.85 (0.59-1.23)	0.96 (0.63-1.47)
≥1913.08	1.49 (0.84-2.64)	1.51 (0.69-3.31)	0.76 (0.38-1.54)	0.92 (0.38-2.23)	1.20 (0.77-1.87)	1.07 (0.59-1.93)	0.66 (0.38-1.15)	0.70 (0.32-1.53)	1.16 (0.81-1.66)	1.57 (0.97-2.56)
Temperature, ºC										
<19.62	1	1	1	1	1	1	1	1	1	1
19.62-21.30	0.70 (0.40-1.23)	0.75 (0.40-1.41)	1.06 (0.56-1.99)	0.94 (0.46-1.91)	**0.60 (0.38-0.93)**	**0.57 (0.34-0.93)**	1.00 (0.58-1.75)	0.76 (0.40-1.44)	1.09 (0.77-1.56)	0.99 (0.67-1.46)
≥21.31	0.78 (0.46-1.34)	0.81 (0.41-1.59)	0.83 (0.43-1.59)	0.77 (0.34-1.74)	**0.62 (0.40-0.96)**	0.62 (0.36-1.04)	1.05 (0.61-1.80)	0.77 (0.38-1.53)	0.82 (0.57-1.17)	0.67 (0.43-1.04)
Relative humidity, %										
<50.56	1	1	1	1	1	1	1	1	1	1
50.56-57.64	0.78 (0.44-1.38)	0.72 (0.36-1.46)	1.30 (0.70-2.42)	0.89 (0.42-1.89)	1.13 (0.72-1.79)	0.84 (0.48-1.46)	1.00 (0.59-1.69)	1.00 (0.51-1.97)	0.86 (0.60-1.24)	0.80 (0.52-1.25)
≥57.65	1.01 (0.59-1.73)	0.88 (0.42-1.86)	0.75 (0.38-1.52)	0.52 (0.21-1.34)	1.28 (0.82-2.01)	0.84 (0.45-1.55)	0.66 (0.37-1.18)	0.80 (0.37-1.72)	0.91 (0.64-1.30)	0.82 (0.51-1.34)

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother's education, body mass index, relative humidity and temperature; CI: confidence interval.

Table 24 Associations between indoor microbiological agents and skin symptoms, eczema, eye irritation, nose symptoms and irritating cough present in the past 3 months (n=846)

	Skin symptoms		Eczema		Eye irritation		Nose symptoms		Irritating cough	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
Bacteria, CFU/m^3										
<2058.00	1	1	1	1	1	1	1	1	1	1
2058.00-3856.00	1.19 (0.67-2.13)	1.14 (0.58-2.24)	1.01 (0.54-1.92)	1.14 (0.56-2.33)	1.15 (0.73-1.81)	1.13 (0.68-1.86)	0.92 (0.53-1.61)	0.89 (0.47-1.70)	0.95 (0.66-1.37)	0.96 (0.64-1.43)
≥3857.00	1.37 (0.78-2.40)	1.49 (0.77-2.90)	0.87 (0.45-1.67)	1.01 (0.48-2.13)	1.01 (0.64-1.60)	0.91 (0.55-1.53)	1.06 (0.62-1.82)	1.17 (0.62-2.22)	1.05 (0.74-1.50)	1.03 (0.69-1.54)
Fungi, CFU/m^3										
<199.67	1	1	1	1	1	1	1	1	1	1
199.67-320.00	1.38 (0.79-2.39)	1.80 (0.94-3.42)	1.16 (0.61-2.22)	1.81 (0.88-3.72)	1.06 (0.68-1.66)	1.23 (0.74-2.05)	0.86 (0.49-1.51)	1.08 (0.55-2.11)	0.99 (0.69-1.42)	1.16 (0.78-1.74)
≥321.00	0.99 (0.55-1.79)	1.06 (0.54-2.05)	1.12 (0.58-2.16)	1.31 (0.64-2.68)	1.10 (0.71-1.73)	1.25 (0.77-2.04)	1.10 (0.64-1.88)	1.43 (0.77-2.64)	0.78 (0.54-1.13)	0.81 (0.54-1.20)

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother's education, body mass index, relative humidity and temperature; CI: confidence interval.

Finally, further analyses for reports concerning the headache symptom were made (Table 25). Compared with children of classrooms with lower levels, the odds of headache were higher among children in classrooms with higher levels of $PM_{2.5}$ (OR=1.48, 95% CI: 1.00-2.19), PM_{10} (OR=2.06, 95% CI: 1.06-4.02) and relative humidity (OR=1.62, 95% CI: 1.00-2.61) (Table 26).

Table 25 Associations between indoor chemical parameters and headache symptom in the past 3 months (*n*=839)

	OR (95% CI)	aOR (95% CI)
Toluene, µg/m³		
<4.64	1	1
4.64-8.06	1.10 (0.77-1.57)	1.23 (0.82-1.85)
≥8.07	1.35 (0.95-1.93)	1.33 (0.88-2.02)
m/p-xylene, µg/m³		
<4.02	1	1
4.02-5.89	1.00 (0.70-1.42)	0.82 (0.55-1.23)
≥5.90	1.07 (0.75-1.52)	0.86 (0.56-1.32)
o-xylene, µg/m³		
<1.89	1	1
1.89-2.61	0.86 (0.60-1.23)	0.94 (0.61-1.44)
≥2.62	1.24 (0.87-1.76)	1.20 (0.80-1.81)
d-limonene, µg/m³		
<12.19	1	1
12.19-30.49	1.26 (0.88-1.80)	1.39 (0.92-2.09)
≥30.50	1.15 (0.80-1.64)	0.93 (0.58-1.51)
α-pinene, µg/m³		
<1.00	1	1
≥1.00	1.46 (0.97-2.18)	1.22 (0.78-1.90)
TVOC, µg/m³		
<101.87	1	1
101.87-189.93	0.94 (0.65-1.34)	0.82 (0.54-1.24)
≥189.94	1.16 (0.82-1.63)	1.07 (0.73-1.56)
Formaldehyde, µg/m³		
<14.92	1	1
14.92-20.13	1.38 (0.80-2.39)	1.34 (0.70-2.54)
≥20.14	1.04 (0.58-1.87)	0.95 (0.43-2.10)
Acetaldehyde, µg/m³		
<5.80	1	1
5.80-9.82	**1.61 (1.13-2.28)**	1.41 (0.95-2.08)
≥9.83	1.28 (0.89-1.84)	1.18 (0.78-1.81)
CO, mg/m³		
<0.16	1	1
0.16-0.60	0.99 (0.69-1.42)	0.98 (0.66-1.46)
≥0.61	1.02 (0.72-1.44)	1.02 (0.69-1.50)

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother's education, body mass index, relative humidity and temperature; CI: confidence interval.

Table 26 Associations between indoor physical and comfort parameters and headache symptom in the past 3 months (*n*=839)

	OR (95% CI)	aOR (95% CI)
$PM_{2.5}$, µg/m^3		
<72.53	1	1
72.53-97.92	1.02 (0.71-1.45)	1.09 (0.74-1.61)
≥97.93	**1.60 (1.12-2.27)**	**1.48 (1.00-2.19)**
PM_{10}, µg/m^3		
<116.77	1	1
116.77-137.88	1.11 (0.61-2.01)	1.44 (0.71-2.92)
≥137.89	1.68 (0.96-2.94)	**2.06 (1.06-4.02)**
CO_2, ppm		
<1299.87	1	1
1299.87-1913.07	1.27 (0.70-2.31)	1.41 (0.70-2.84)
≥1913.08	1.56 (0.88-2.79)	1.73 (0.78-3.86)
Temperature, ºC		
<19.62	1	1
19.62-21.30	0.95 (0.67-1.35)	1.13 (0.76-1.68)
≥21.31	1.00 (0.71-1.42)	1.23 (0.80-1.89)
Relative humidity, %		
<50.56	1	1
50.56-57.64	0.78 (0.54-1.11)	1.02 (0.65-1.58)
≥57.65	1.17 (0.82-1.66)	**1.62 (1.00-2.61)**

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother's education, body mass index, relative humidity and temperature; CI: confidence interval.

No associations were observed between microbiological agents and the headaches symptom (Table 27).

Table 27 Associations between indoor microbiological agents and headache symptom in the past 3 months (*n*=839)

	OR (95% CI)	aOR (95%CI)
Bacteria, CFU/m^3		
<2058.00	1	1
2058.00-3856.00	1.19 (0.66-2.15)	1.17 (0.59-2.34)
≥3857.00	1.44 (0.81-2.53)	1.64 (0.84-3.23)
Fungi, CFU/m^3		
<199.67	1	1
199.67-320.00	1.34 (0.77-2.33)	1.69 (0.88-3.23)
≥321.00	0.95 (0.52-1.72)	0.99 (0.50-1.93)

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother's education, body mass index, relative humidity and temperature; CI: confidence interval.

In order not to bias the investigation of the relationship between air pollution and recent symptoms, children with an affirmative answer to "*During the past 3 months, has your child felt like they were getting a cold*?" were not included in these analyses. The OR was adjusted for age, sex, mother's education, BMI and also for the effects of relative humidity and temperature.

Higher levels of acetaldehyde were associated with lower odds of eye irritation (OR=0.49, 95% CI: 0.24-1.00). Similar, a decrease in the odds of eczema was observed with increasing CO concentrations

(OR=0.18, 95% CI: 0.05-0.63). For the remaining indoor air pollutants, it was no found a significant effect on recent symptoms (Table 28).

Then, only the effect of o-xylene on irritating cough remained statistically significant (OR=1.79, 95% CI: 1.02-3.14). In addition, higher levels of o-xylene become associated with an increasing odds ratio for skin symptoms (OR=3.26, 95% CI: 1.03-10.36). Similar results were observed for higher levels of PM_{10} and the odds of irritating cough (OR=4.00, 95% CI: 1.21-13.22) (Table 29).

Regarding microbiological agents no association was found (Table 30).

Table 28 Associations between indoor chemical parameters and skin symptoms, eczema, eye irritation, nose symptoms and irritating cough, not including children reporting “feeling like getting a cold” (*n*=468)

	Skin symptoms		Eczema		Eye irritation		Nose symptoms		Irritating cough	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
Toluene, μg/m^3										
<4.64	1	1	1	1	1	1	1	1	1	1
4.64-8.06	0.56 (0.22-1.47)	0.75 (0.24-2.29)	1.23 (0.50-3.04)	1.32 (0.45-3.84)	1.11 (0.58-2.14)	1.23 (0.60-2.54)	0.99 (0.42-2.35)	1.65 (0.49-3.70)	0.73 (0.46-1.16)	0.78 (0.46-1.29)
≥8.07	1.57 (0.72-3.43)	2.18 (0.79-5.98)	0.75 (0.26-2.15)	1.26 (0.34-4.62)	0.70 (0.33-1.48)	0.60 (0.24-1.49)	0.71 (0.27-1.88)	0.68 (0.20-2.28)	0.79 (0.49-1.28)	0.90 (0.53-1.55)
m/p-xylene, μg/m^3										
<4.02	1	1	1	1	1	1	1	1	1	1
4.02-5.89	1.01 (0.39-2.61)	1.12 (0.33-3.82)	0.90 (0.36-2.28)	1.33 (0.44-4.00)	1.13 (0.59-2.18)	1.16 (0.56-2.42)	1.12 (0.46-2.70)	0.73 (0.24-2.20)	1.07 (0.68-1.70)	1.24 (0.74-2.08)
≥5.90	2.15 (0.93-4.97)	3.62 (1.16-11.34)	0.75 (0.28-2.00)	1.42 (0.40-5.08)	0.66 (0.31-1.40)	0.71 (0.29-1.74)	0.86 (0.33-2.23)	0.68 (0.20-2.30)	0.84 (0.52-1.37)	1.01 (0.57-1.80)
o-xylene, μg/m^3										
<1.89	1	1	1	1	1	1	1	1	1	1
1.89-2.61	1.04 (0.43-2.50)	2.20 (0.64-7.58)	1.04 (0.42-2.63)	1.87 (0.55-6.40)	0.52 (0.26-1.07)	0.54 (0.23-1.27)	1.38 (0.58-3.31)	1.91 (0.60-6.10)	1.35 (0.85-2.15)	**1.79 (1.02-3.14)**
≥2.62	1.58 (0.68-3.66)	**3.26 (1.03-10.36)**	0.84 (0.31-2.32)	1.57 (0.42-5.87)	0.83 (0.42-1.62)	0.93 (0.42-2.05)	0.84 (0.31-2.32)	0.89 (0.26-3.01)	1.02 (0.62-1.68)	1.30 (0.73-2.30)
d-limonene, μg/m^3										
<12.19	1	1	1	1	1	1	1	1	1	1
12.19-30.49	1.55 (0.67-3.59)	2.50 (0.86-7.29)	0.86 (0.33-2.22)	0.95 (0.30-3.04)	0.68 (0.34-1.34)	0.46 (0.20-1.05)	1.20 (0.50-2.89)	0.87 (0.30-2.57)	1.05 (0.66-1.66)	1.27 (0.75-2.17)
≥30.50	1.22 (0.50-2.95)	1.81 (0.49-6.65)	0.87 (0.34-2.26)	2.90 (0.66-12.70)	0.64 (0.32-1.28)	0.42 (0.15-1.13)	0.87 (0.34-2.26)	0.87 (0.24-3.22)	0.89 (0.55-1.44)	1.05 (0.55-2.01)
α-pinene, μg/m^3										
<1.00	1	1	1	1	1	1	1	1	1	1
≥1.00	1.40 (0.53-3.70)	1.99 (0.57-6.99)	0.75 (0.29-1.92)	1.18 (0.41-3.45)	0.66 (0.34-1.28)	0.73 (0.34-1.58)	1.10 (0.41-2.96)	1.05 (0.33-3.34)	1.10 (0.67-1.83)	1.03 (0.59-1.78)
TVOC, μg/m^3										
<101.87	1	1	1	1	1	1	1	1	1	1
101.87-189.93	0.97 (0.40-2.36)	0.98 (0.31-3.09)	1.48 (0.56-3.94)	2.53 (0.78-8.24)	1.12 (0.58-2.19)	1.07 (0.50-2.28)	1.09 (0.46-2.58)	0.66 (0.23-1.95)	1.16 (0.73-1.86)	1.23 (0.73-2.07)
≥189.94	1.43 (0.64-3.17)	1.94 (0.74-5.08)	1.36 (0.51-3.60)	2.04 (0.63-6.58)	0.72 (0.35-1.48)	0.68 (0.30-1.52)	0.68 (0.26-1.78)	0.57 (0.20-1.60)	0.98 (0.61-1.56)	0.97 (0.58-1.62)
Formaldehyde, μg/m^3										
<14.92	1	1	1	1	1	1	1	1	1	1
14.92-20.13	1.38 (0.63-3.00)	1.90 (0.70-5.14)	0.68 (0.28-1.64)	1.12 (0.35-3.57)	0.59 (0.30-1.13)	0.60 (0.27-1.32)	0.75 (0.31-1.81)	0.49 (0.16-1.50)	1.04 (0.66-1.56)	1.32 (0.77-2.28)
≥20.14	0.68 (0.27-1.71)	0.82 (0.22-3.03)	0.38 (0.13-1.10)	0.52 (0.13-2.14)	0.41 (0.19-0.85)	0.44 (0.18-1.13)	0.77 (0.32-1.88)	0.73 (0.21-2.53)	0.97 (0.60-1.56)	1.36 (0.74-2.50)
Acetaldehyde, μg/m^3										
<5.80	1	1	1	1	1	1	1	1	1	1
5.80-9.82	1.10 (0.48-2.51)	1.40 (0.53-3.71)	1.20 (0.52-2.80)	1.89 (0.70-5.10)	0.67 (0.34-1.30)	0.82 (0.39-1.69)	1.10 (0.44-2.70)	0.99 (0.36-2.77)	0.19 (0.74-1.91)	1.12 (0.67-1.86)
≥9.83	1.10 (0.48-2.49)	1.32 (0.44-3.94)	0.38 (0.12-1.22)	0.60 (0.15-2.43)	**0.49 (0.24-1.00)**	0.43 (0.18-1.02)	1.09 (0.44-2.68)	0.99 (0.30-3.21)	1.28 (0.80-2.05)	1.38 (0.80-2.37)
CO, mg/m^3										
<0.16	1	1	1	1	1	1	1	1	1	1
0.16-0.60	0.79 (0.35-1.79)	1.22 (0.45-3.29)	0.64 (0.27-1.52)	0.70 (0.26-1.88)	0.79 (0.39-1.61)	0.96 (0.43-2.14)	0.93 (0.38-2.24)	1.00 (0.36-2.82)	0.88 (0.54-1.44)	0.94 (0.55-1.60)
≥0.61	0.62 (0.27-1.42)	1.01 (0.35-2.86)	**0.18 (0.05-0.63)**	**0.18 (0.04-0.86)**	0.88 (0.45-1.72)	1.13 (0.52-2.43)	0.63 (0.25-1.61)	0.75 (0.25-2.20)	1.10 (0.69-1.74)	1.11 (0.66-1.88)

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother’s education, body mass index, relative humidity and temperature; CI: confidence interval.

Table 29 Associations between indoor physical and comfort parameters and skin symptoms, eczema, eye irritation, nose symptoms and irritating cough, not including children reporting "feeling like getting a cold" (n=468)

	Skin symptoms		Eczema		Eye irritation		Nose symptoms		Irritating cough	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
$PM_{2.5}$, µg/m^3										
<72.53	1	1	1	1	1	1	1	1	1	1
72.53-97.92	0.78 (0.33-1.85)	1.66 (0.58-4.79)	1.28 (0.53-3.12)	1.42 (0.52-3.85)	1.30 (0.68-2.49)	1.58 (0.75-3.31)	1.17 (0.48-2.89)	1.51 (0.52-4.34)	1.10 (0.70-1.73)	1.06 (0.65-1.74)
≥97.93	1.38 (0.61-3.12)	2.14 (0.74-6.21)	0.82 (0.29-2.36)	0.67 (0.18-2.44)	0.74 (0.34-1.62)	1.05 (0.45-2.47)	1.26 (0.49-3.26)	1.26 (0.41-3.88)	0.97 (0.59-1.60)	0.91 (0.53-1.56)
PM_{10}, µg/m^3										
<116.77	1	1	1	1	1	1	1	1	1	1
116.77-137.88	1.16 (0.47-2.86)	1.91 (0.56-6.53)	1.95 (0.77-4.93)	1.42 (0.50-4.08)	1.17 (0.60-2.25)	1.17 (0.55-2.51)	1.50 (0.57-3.97)	1.07 (0.34-3.31)	1.06 (0.67-1.68)	0.99 (0.59-1.66)
≥137.89	1.98 (0.84-4.65)	**4.00 (1.21-13.22)**	0.97 (0.32-2.95)	0.79 (0.22-2.78)	0.80 (0.38-1.69)	1.08 (0.46-2.49)	1.84 (0.70-4.85)	1.43 (0.47-4.37)	1.08 (0.66-1.75)	1.00 (0.58-1.72)
CO_2, ppm										
<1299.87	1	1	1	1	1	1	1	1	1	1
1299.87-1913.07	1.34 (0.55-3.27)	1.95 (0.65-5.82)	0.80 (0.32-1.98)	1.48 (0.48-4.52)	0.64 (0.32-1.29)	0.67 (0.30-1.50)	0.64 (0.26-1.61)	0.61 (0.21-1.77)	0.90 (0.55-1.46)	0.93 (0.54-1.62)
≥1913.08	1.39 (0.58-3.33)	2.26 (0.61-8.36)	0.50 (0.18-1.37)	1.53 (0.39-6.00)	0.65 (0.33-1.29)	0.55 (0.21-1.41)	0.69 (0.28-1.68)	0.63 (0.17-2.31)	1.00 (0.63-1.61)	1.25 (0.66-2.38)
Temperature, ºC										
<19.62	1	1	1	1	1	1	1	1	1	1
19.62-21.30	0.74 (0.32-1.69)	0.69 (0.36-1.87)	1.14 (0.44-2.93)	0.82 (0.27-2.45)	0.71 (0.36-1.41)	0.54 (0.25-1.20)	1.14 (0.48-2.69)	0.83 (0.30-2.28)	1.18 (0.73-1.88)	1.15 (0.69-1.94)
≥21.31	0.70 (0.31-1.60)	0.62 (0.20-1.94)	0.96 (0.36-2.53)	0.44 (0.12-1.62)	0.68 (0.34-1.34)	0.55 (0.23-1.30)	0.67 (0.26-1.78)	0.49 (0.14-1.67)	1.04 (0.65-1.67)	0.99 (0.55-1.78)
Relative humidity, %										
<50.56	1	1	1	1	1	1	1	1	1	1
50.56-57.64	0.82 (0.36-1.84)	0.55 (0.18-1.63)	1.43 (0.60-3.39)	0.71 (0.22-2.31)	1.12 (0.57-2.20)	0.72 (0.30-1.68)	1.62 (0.66-3.95)	2.01 (0.64-6.37)	0.78 (0.49-1.23)	0.85 (0.48-1.52)
≥57.65	0.79 (0.34-1.86)	0.44 (0.11-1.70)	0.34 (0.09-1.27)	0.16 (0.02-1.10)	0.92 (0.44-1.90)	0.46 (0.16-1.37)	0.91 (0.32-2.57)	1.35 (0.34-5.32)	0.79 (0.49-1.28)	0.89 (0.45-1.77)

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother's education, body mass index, relative humidity and temperature; CI: confidence interval.

Table 30 Associations between indoor microbiological agents and skin symptoms, eczema, eye irritation, nose symptoms and irritating cough, not including children reporting "feeling like getting a cold" (n=468)

	Skin symptoms		Eczema		Eye irritation		Nose symptoms		Irritating cough	
	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)	OR (95% CI)	aOR (95% CI)
Bacteria, CFU/m^3										
<2058.00	1	1	1	1	1	1	1	1	1	1
2058.00-3856.00	0.89 (0.37-2.11)	0.95 (0.32-2.81)	0.61 (0.24-1.59)	0.88 (0.28-2.69)	0.81 (0.42-1.58)	0.97 (0.47-2.02)	0.52 (0.20-1.31)	0.53 (0.18-1.52)	0.74 (0.47-1.19)	0.77 (0.46-1.28)
≥3857.00	1.18 (0.52-2.67)	1.92 (0.69-5.39)	0.62 (0.24-1.60)	1.00 (0.30-3.30)	0.51 (0.24-1.08)	0.44 (0.18-1.07)	0.68 (0.29-1.61)	0.83 (0.28-2.45)	0.66 (0.41-1.06)	0.66 (0.38-1.13)
Fungi, CFU/m^3										
<199.67	1	1	1	1	1	1	1	1	1	1
199.67-320.00	1.13 (0.51-2.48)	1.52 (0.56-4.14)	1.24 (0.49-3.16)	1.60 (0.51-5.06)	1.08 (0.53-2.21)	1.06 (0.46-2.46)	0.72 (0.29-1.78)	0.73 (0.23-2.28)	1.10 (0.70-1.74)	1.30 (0.77-2.21)
≥321.00	0.68 (0.27-1.70)	0.78 (0.26-2.39)	1.04 (0.38-2.84)	1.07 (0.32-3.56)	1.44 (0.71-2.91)	1.61 (0.75-3.48)	0.94 (0.39-2.28)	0.91 (0.32-2.56)	0.82 (0.50-1.34)	0.81 (0.47-1.41)

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother's education, body mass index, relative humidity and temperature; CI: confidence interval.

5.1.5 Respiratory function and tear film stability according to indoor air parameters

From the 978 children considered in this analysis, 761 children (392 girls) underwent pulmonary function tests, 318 children (165 girls) performed the eNO test and 321 children (167 girls) the SBUT.

Table 31 presents the results of lung function tests (percentage predicted of FVC, FEV_1, FEV_1/FVC ratio and $FEF_{25\text{-}75\%}$) according to the categories of indoor air parameters. Generally, children present normal pulmonary function and although some statistical differences were found, no relevant differences were detected.

Table 31 Spirometry parameters values according to indoor chemical, physical and comfort parameters and microbiological agents (*n*=761)

	FVC (% of the predicted value) (*n*=761)			FEV_1 (% of the predicted value) (*n*=761)			FEV_1/FVC (*n*=761)			FEF_{25-75} (% of the predicted value) (*n*=749)		
	n	Mean (SD)	*p*-value	*n*	Mean (SD)	*p*-value	*n*	Mean (SD)	*p*-value	*n*	Mean (SD)	*p*-value
Toluene, µg/m³			0.689			0.377			0.293			0.103
<4.64	257	103.9 (12.0)		257	107.2 (11.1)		257	103.5 (5.15)		254	108.9 (18.2)	
4.64-8.06	253	103.8 (11.6)		253	108.5 (11.9)		253	104.7 (5.35)		250	114.9 (22.6)	
≥8.07	243	102.4 (12.4)		243	106.0 (13.2)		243	103.6 (6.61)		237	109.1 (22.6)	
m/p-xylene, µg/m³			0.075			0.205			0.414			0.939
<4.02	249	104.4 (11.6)		249	107.8 (10.7)		249	103.5 (5.46)		247	110.4 (19.2)	
4.02-5.89	261	104.6 (11.7)		261	108.4 (12.3)		261	103.8 (5.77)		257	111.0 (22.4)	
≥5.90	243	100.9 (14.4)		243	105.3 (12.8)		243	104.6 (5.82)		237	111.6 (21.8)	
o-xylene, µg/m³			0.728			0.808			0.125			0.221
<1.89	250	104.2 (11.8)		250	107.6 (10.8)		250	103.5 (5.51)		249	109.4 (18.4)	
1.89-2.61	247	102.8 (12.2)		247	107.7 (12.6)		247	104.9 (5.17)		245	114.2 (22.4)	
≥2.62	256	103.3 (12.0)		256	106.6 (12.6)		256	103.4 (6.27)		247	109.3 (22.3)	
d-limonene, µg/m³			0.268			0.426			0.753			0.886
<12.19	254	104.8 (12.8)		254	108.3 (12.2)		254	103.6 (5.52)		250	111.9 (21.3)	
12.19-30.49	257	103.3 (11.7)		257	107.4 (12.0)		257	104.1 (4.89)		253	110.5 (19.4)	
≥30.50	242	107.8 (11.0)		242	105.9 (11.7)		242	104.2 (6.78)		238	110.6 (23.4)	
α-pinene, µg/m³			0.459			0.601			0.640			0.903
<1.00	129	104.7 (10.0)		129	108.2 (9.80)		129	103.6 (5.73)		128	111.4 (19.5)	
≥1.00	624	103.2 (12.3)		624	107.1 (12.4)		624	104.0 (5.70)		613	111.0 (21.6)	
TVOC, µg/m³			0.060			**0.013**			0.534			0.158
<101.87	286	103.9 (12.9)		286	108.1 (12.3)		286	104.3 (5.49)		283	112.8 (20.7)	
101.87-189.93	214	105.1 (11.2)		214	109.2 (11.7)		214	104.0 (4.94)		210	112.4 (22.2)	
≥189.94	253	100.8 (11.1)		253	103.9 (11.5)		253	103.3 (6.73)		248	107.0 (20.6)	
Formaldehyde, µg/m³			0.855			0.370			0.213			0.281
<14.92	267	102.9 (18.9)		267	106.2 (10.8)		267	103.4 (5.08)		266	108.6 (20.7)	
14.92-20.13	256	103.6 (11.9)		256	107.1 (11.7)		256	103.7 (6.75)		253	111.4 (21.0)	
≥20.14	238	103.9 (13.2)		238	108.7 (13.5)		238	104.8 (5.11)		230	113.7 (21.8)	
Acetaldehyde, µg/m³			0.061			**0.029**			0.471			0.432
<5.80	253	103.9 (12.1)		253	107.1 (11.3)		253	103.3 (5.41)		251	109.3 (19.4)	
5.80-9.82	279	101.4 (11.3)		279	105.3 (11.9)		279	104.0 (6.39)		273	110.7 (22.3)	
≥9.83	229	105.5 (12.2)		229	110.0 (12.4)		229	104.4 (4.99)		225	113.6 (21.5)	
CO, mg/m³			0.672			0.853			0.859			0.895
<0.16	236	102.9 (12.8)		236	106.9 (12.9)		236	104.1 (5.30)		233	111.0 (23.0)	
0.16-0.60	253	104.3 (11.6)		253	107.9 (10.7)		253	103.7 (5.75)		245	110.6 (18.8)	
≥0.61	259	103.0 (11.3)		259	107.1 (12.4)		259	104.1 (6.08)		258	112.1 (21.4)	
$PM_{2.5}$, µg/m³			0.451			0.603			0.644			0.443
<72.53	224	102.2 (13.5)		224	106.5 (13.6)		224	104.4 (5.31)		217	111.0 (20.7)	
72.53-97.92	269	104.5 (11.2)		269	108.3 (10.9)		269	103.9 (5.80)		266	113.3 (22.5)	
≥97.93	262	103.5 (11.4)		262	107.1 (11.7)		262	103.6 (5.91)		260	109.3 (20.4)	
PM_{10}, µg/m³			0.733			0.974			0.264			0.588
<116.77	230	102.5 (13.9)		230	107.2 (13.8)		230	104.8 (5.24)		222	112.0 (21.9)	
116.77-137.88	255	103.8 (11.0)		255	107.6 (10.7)		255	103.8 (5.64)		254	112.3 (21.1)	
≥137.89	270	103.8 (11.4)		270	107.2 (11.8)		270	103.4 (6.06)		267	109.4 (21.0)	
CO_2, ppm			0.745			0.801			0.692			0.717
<1299.87	242	104.0 (10.4)		242	108.2 (9.79)		242	104.3 (4.69)		242	112.7 (17.5)	
1299.87-1913.07	243	102.0 (14.0)		243	106.2 (14.3)		243	104.3 (6.08)		236	111.3 (24.8)	
≥1913.08	249	103.9 (11.0)		249	107.4 (11.6)		249	103.5 (6.16)		245	109.6 (20.8)	
Temperature, ºC			0.950			0.901			0.967			0.253
<19.62	272	103.0 (10.5)		272	106.8 (10.8)		272	103.9 (6.32)		268	110.8 (22.0)	
19.62-21.30	233	103.5 (10.9)		233	107.5 (11.6)		233	104.0 (5.00)		231	108.7 (19.3)	
≥21.31	243	103.6 (14.3)		243	107.5 (13.8)		243	104.1 (5.64)		237	114.1 (22.1)	
Relative humidity, %			0.230			0.173			0.144			0.305
<50.56	248	102.5 (11.9)		248	105.6 (11.4)		248	103.2 (5.43)		246	108.6 (19.1)	
50.56-57.64	264	105.0 (10.3)		264	108.9 (10.0)		264	103.9 (5.21)		262	111.9 (20.7)	
≥57.65	236	102.2 (13.9)		236	107.1 (14.9)		236	105.0 (6.46)		228	113.7 (24.4)	
Bacteria, CFU/m³			0.229			**0.026**			**0.032**			**0.002**
<2058.00	233	101.8 (10.4)		233	104.2 (10.4)		233	102.6 (5.36)		232	104.1 (18.0)	
2058.00-3856.00	260	104.9 (12.7)		260	109.1 (12.4)		260	104.3 (6.34)		252	114.8 (22.3)	
≥3857.00	252	103.0 (12.4)		252	107.8 (12.5)		252	104.8 (5.01)		249	113.4 (21.3)	
Fungi, CFU/m³			0.200			0.268			0.762			0.747
<199.67	253	103.0 (12.3)		253	106.6 (12.5)		253	103.7 (5.36)		251	109.6 (22.2)	
199.67-320.00	226	101.8 (12.6)		226	106.0 (13.0)		226	104.3 (6.20)		224	111.6 (22.7)	
≥321.00	270	105.0 (11.0)		270	108.8 (10.5)		270	103.8 (5.61)		262	111.7 (18.8)	

FVC: Forced vital capacity; FEV1: Forced expiratory volume in 1 second; FEF25-75%: Forced expiratory flow 25-75%; SD: Standard deviation.

Furthermore, the present study investigated the association between indoor air parameters and airway inflammation, using the values measured by eNO among children. In our study, eNO was assessed in 318 children [*n*=165 girls (51.9%)] from all classrooms. Almost 23.3% of schoolchildren (16.4% of girls) had an eNO value over 20 ppb and a greater percentage of values above 35 ppb (10.7% of children) were observed in boys (13.1%).

As eNO could be influenced by the presence of respiratory and allergic symptoms, we stratified our sample. Children with symptoms (*n*=156) were defined based on an affirmative response to one of the following questions: "*Has your child ever had wheezing or whistling in the chest at any time in the past*?", "*In the past 12 months, has your child had wheezing or whistling in the chest?*", "*In the past 30 days, has your child had wheezing or whistling in the chest?*", "*Has your child ever had asthma diagnosed by a doctor?*", "*Has your child ever had a problem with sneezing, or a runny, or blocked nose when he/she did not have a cold or the flu?*", "*In the past 12 months, has your child had a problem with sneezing, or a runny, or blocked nose when he/she did not have a cold or the flu?*", "*Has your child ever had nasal allergies, including hay fever?" and "If yes, was it confirmed by a physician?*".

The global median (P25-P75) of eNO was 13.0 ppb (9.00-18.0 ppb), being significantly lower among children without symptoms [12.0 ppb (9.00-17.0 ppb)] than in those with symptoms [13.5 ppb (10.0-23.0 ppb)], p=0.021.

In general, non-significant differences of eNO values were found according to indoor exposure. However, we found high values of eNO among those in classrooms in the medium level of TVOC that reached statistical significance among those with respiratory and allergic symptoms (Table 32).

Table 32 Exhaled nitric oxide values according to indoor measured parameters

	eNO, ppb					
	Children without symptoms (*n*=159)			Children with symptoms (*n*=156)		
	n	Mean (SD)	*p*-value	*n*	Mean (SD)	*p*-value
Toluene, µg/m^3			0.626			0.474
<4.64	53	15.7 (19.8)		56	19.5 (18.4)	
4.64-8.06	60	13.4 (5.93)		50	23.4 (20.5)	
≥8.07	43	14.6 (7.69)		48	23.8 (21.7)	
m/p-xylene, µg/m^3			0.144			0.202
<4.02	53	12.9 (5.97)		48	21.1 (18.9)	
4.02-5.89	59	17.1 (19.2)		59	25.6 (22.8)	
≥5.90	44	12.9 (5.49)		47	18.7 (20.1)	
o-xylene, µg/m^3			0.507			0.725
<1.89	56	14.1 (6.39)		48	23.7 (21.3)	
1.89-2.61	56	13.4 (6.78)		50	22.3 (21.5)	
≥2.62	44	16.3 (21.6)		56	20.5 (17.9)	
d-limonene, µg/m^3			0.926			0.841
<12.19	63	14.7 (18.6)		49	21.6 (18.4)	
12.19-30.49	51	14.8 (6.03)		57	23.3 (21.5)	
≥30.50	42	13.8 (6.90)		48	21.1 (20.4)	
α-pinene, µg/m^3			0.731			0.622
<1.00	24	13.7 (5.61)		26	20.3 (16.8)	
≥1.00	132	14.6 (13.6)		128	22.4 (20.8)	
TVOC, µg/m^3			0.158			**0.012**
<101.87	64	13.5 (6.82)		56	18.8 (16.7)	
101.87-189.93	45	17.6 (21.5)		52	28.8 (24.8)	
≥189.94	47	13.0 (5.21)		46	18.6 (16.3)	
Formaldehyde, µg/m^3			0.193			0.061
<14.92	58	13.4 (4.99)		56	24.8 (22.7)	
14.92-20.13	48	17.4 (20.8)		55	24.4 (20.2)	
≥20.14	53	13.4 (7.56)		45	16.2 (15.0)	
Acetaldehyde, µg/m^3			0.354			0.358
<5.80	53	12.9 (4.73)		52	25.4 (22.4)	
5.80-9.82	55	16.40 (19.4)		57	20.3 (17.9)	
≥9.83	51	14.4 (8.32)		47	20.8 (19.8)	
CO, mg/m^3			0.467			0.514
<0.16	61	13.3 (4.98)		56	24.3 (20.5)	
0.16-0.60	41	16.5 (22.2)		46	19.8 (19.5)	
≥0.61	54	14.4 (7.78)		53	21.7 (20.3)	
$PM_{2.5}$, µg/m^3			0.212			0.210
<72.53	51	17.0 (20.6)		46	19.6 (16.9)	
72.53-97.92	53	12.7 (4.74)		58	20.8 (19.3)	
≥97.93	53	14.1 (6.78)		50	26.4 (23.5)	
PM_{10}, µg/m^3			0.430			0.165
<116.77	51	16.5 (20.7)		48	18.9 (18.3)	
116.77-137.88	53	13.4 (4.72)		55	21.4 (18.4)	
≥137.89	53	14.0 (6.92)		51	26.4 (23.2)	
CO_2, ppm			0.466			0.369
<1299.87	55	13.4 (5.34)		51	25.1 (20.1)	
1299.87-1913.07	55	16.2 (19.5)		53	19.5 (18.6)	
≥1913.08	43	14.0 (7.40)		50	21.9 (21.7)	
Temperature, ºC			0.261			0.706
<19.62	49	14.1 (6.42)		58	23.3 (21.6)	
19.62-21.30	51	16.8 (20.2)		49	20.1 (17.9)	
≥21.31	53	12.8 (5.80)		48	22.6 (20.6)	
Relative humidity, %			0.679			0.769
<50.56	58	14.1 (6.02)		54	23.3 (21.5)	
50.56-57.64	51	15.8 (20.0)		58	22.2 (18.1)	
≥57.65	47	13.6 (7.40)		43	20.3 (21.2)	
Bacteria, CFU/m^3			0.432			0.060
<2058.00	49	12.8 (5.49)		49	27.6 (23.0)	
2058.00-3856.00	54	16.1 (19.6)		55	21.1 (19.0)	
≥3857.00	54	14.9 (7.81)		49	18.1 (17.7)	
Fungi, CFU/m^3			0.881			0.645
<199.67	51	14.2 (5.58)		52	24.3 (22.1)	
199.67-320.00	49	14.2 (7.36)		51	22.1 (21.0)	
≥321.00	58	15.2 (19.2)		50	20.6 (17.5)	

SD: Standard deviation

As mentioned previously, the study of tear film stability includes 321 children. The median (P25-P75) SBUT was 12.5 seconds (8.02-21.8 seconds). Girls had a similar median (P25-P75) SBUT value than boys: 12.5 seconds (8.03-20.0 seconds) *vs*. 11.5 seconds (7.53-22.6 seconds), p=0.749. Tear film break-up time was significantly lower at medium levels of formaldehyde and PM_{10}. This suggests that children are exposed to compounds that could cause impaired tear film stability (Table 33).

Table 33 Tear film stability according to indoor measured parameters

	SBUT, seconds		
	n	Mean (SD)	*p*-value
Toluene, µg/m³			0.253
<4.64	112	19.6 (21.2)	
4.64-8.06	112	18.2 (22.3)	
≥8.07	91	23.9 (31.1)	
m/p-xylene, µg/m³			0.175
<4.02	102	19.8 (20.1)	
4.02-5.89	122	17.9 (22.6)	
≥5.90	92	24.2 (31.5)	
o-xylene, µg/m³			0.402
<1.89	106	19.8 (22.1)	
1.89-2.61	108	18.4 (24.8)	
≥2.62	102	23.0 (27.6)	
d-limonene, µg/m³			0.441
<12.19	114	19.8 (20.5)	
12.19-30.49	111	22.6 (31.4)	
≥30.50	91	18.2 (20.6)	
α-pinene, µg/m³			0.207
<1.00	50	24.4 (31.8)	
≥1.00	266	19.6 (23.4)	
TVOC, µg/m³			0.170
<101.87	121	18.9 (20.9)	
101.87-189.93	100	18.2 (21.9)	
≥189.94	95	24.3 (31.4)	
Formaldehyde, µg/m³			**0.049**
<14.92	116	18.6 (19.4)	
14.92-20.13	105	17.1 (19.0)	
≥20.14	100	25.1 (33.6)	
Acetaldehyde, µg/m³			0.134
<5.80	106	21.0 (24.5)	
5.80-9.82	114	16.6 (18.8)	
≥9.83	101	23.2 (30.1)	
CO, mg/m³			0.572
<0.16	120	18.1 (18.6)	
0.16-0.60	88	21.1 (27.0)	
≥0.61	109	21.3 (28.3)	
$PM_{2.5}$, µg/m³			0.114
<72.53	98	19.2 (22.4)	
72.53-97.92	113	17.4 (17.4)	
≥97.93	106	24.2 (32.4)	
PM_{10}, µg/m³			**0.027**
<116.77	100	19.6 (22.3)	
116.77-137.88	110	16.1 (16.9)	
≥137.89	107	25.1 (32.3)	
CO_2, ppm			0.075
<1299.87	114	17.2 (16.2)	
1299.87-1913.07	112	19.4 (23.8)	
≥1913.08	91	24.4 (32.8)	
Temperature, ºC			0.857
<19.62	109	19.0 (22.5)	
19.62-21.30	109	16.9 (15.9)	
≥21.31	95	24.6 (33.6)	
Relative humidity, %			0.108
<50.56	107	20.6 (23.4)	
50.56-57.64	104	20.6 (29.3)	
≥57.65	106	18.9 (20.8)	
Bacteria, CFU/m³			0.208
<2058.00	101	17.4 (20.8)	
2058.00-3856.00	111	19.7 (21.1)	
≥3857.00	104	23.5 (31.3)	
Fungi, CFU/m³			0.433
<199.67	106	20.0 (23.6)	
199.67-320.00	102	17.8 (21.5)	
≥321.00	109	22.2 (28.3)	

SD: Standard deviation.

5.1.6 Associations between schools/classrooms characteristics and occupant behaviour with indoor air parameters

The purpose of this sub-chapter was to examine the role of the schools/classrooms characteristics and occupant behaviour on the IAQ. The aforementioned characteristics were collected from the checklist. The Scree Plot suggested the existence of three components. Table 34 displays each variable's loading of the first three components, the item in bold was the parameter selected to represent each component. The first component explains 19.3% of variance and was characterized by the variables: TVOC, toluene, m/p-xylene and o-xylene; the second factor has 15.9% of variance explained and CO_2, relative humidity, $PM_{2.5}$, PM_{10}, T4CE and bacteria characterized this component. Finally, the third factor explains 9.5% of variance and was characterized by six parameters of IAQ: CO_2, CO, temperature, benzene, styrene and limonene. As a result, three of these indicators (TVOC, PM_{10} and CO_2) were selected for the analysis.

Table 34 Rotated component matrix with *varimax* rotation obtained of the principal components analysis method

	Component		
	1	2	3
CO_2, ppm	0.277	0.549	**0.487**
CO, mg/m^3	0.000	-0.116	0.486
Temperature, ºC	-0.008	-0.353	-0.707
Relative humidity, %	-0.023	0.567	0.482
$PM_{2.5}$, µg/m^3	-0.020	-0.794	0.052
PM_{10}, µg/m^3	0.062	**-0.766**	0.042
TVOC, µg/m^3	**0.927**	0.072	0.075
Benzene, µg/m^3	-0.081	0.135	0.574
Toluene, µg/m^3	0.975	0.012	-0.044
T4CE, µg/m^3	-0.050	-0.447	0.099
m/p-xylene, µg/m^3	0.964	-0.030	-0.080
Styrene, µg/m^3	-0.178	-0.161	0.509
o-xylene, µg/m^3	0.975	-0.002	-0.074
α-pinene, µg/m^3	0.226	0.249	0.087
d-limonene, µg/m^3	0.029	0.181	0.671
Naphthalene, µg/m^3	0.169	0.352	0.155
Formaldehyde, µg/m^3	-0.038	0.365	-0.280
Acetaldehyde, µg/m^3	0.000	0.180	0.068
Ventilation rate, l/s per person	-0.150	0.098	-0.328
Fungi, CFU/m^3	-0.132	-0.220	-0.145
Bacteria, CFU/m^3	-0.212	0.437	-0.096
Variance explained (%)	**19.3**	**15.9**	**9.5**

TVOC: Total volatile organic compounds; T4CE: Tetrachloroethylene.
Note: The item in bold was the parameter selected to represent each component.

The results of multilevel analysis are presented by the estimated linear regression coefficients of the classroom and school features and the respective 95% CI as well as intra-class correlation coefficient (ICC). In this study, when the ICC value is null or approaching zero, means that schools are homogeneous among themselves and there are no differences in the input variables of IAQ evaluated at different schools.

Ceiling height, windows area and number of windows usually open in the cooling season were the characteristics that showed effect on the classroom CO_2 levels, explaining 16.4% of the differences between schools (Table 35). None of the school characteristics represent a significant effect for this parameter.

Table 35 Estimated linear regression coefficients of the classroom features and respective 95% confidence intervals for the parameter CO_2, assuming a multilevel model with “school” as a random effect

$\ln(CO_2)$	Classroom Estimates (95% CI)
Ceiling height (m)	0.724 (0.26; 1.19)
Windows area (m^2)	-0.022 (-0.04; -0.01)
No. of windows usually open in the cooling season	0.048 (-0.03; 0.12)
Variance of school (%)	**1.5**
ICC (%)	**16.4**

ICC: Intra-class correlation coefficient.

Concerning the PM_{10}, the characteristics that showed a significant effect in the room were the number of windows usually open in the heating season; visible damp spots on walls, ceiling or floor; main ceiling surface material; visible mould growth in the room and the presence of a closet or shelves with gouaches, inks etc. for graphic arts, explaining 28.4% of the differences between schools; while gasoline dispensing facilities nearby, car park source of outdoor air pollution and the existence of a laboratory were the characteristics that have excelled on school levels of PM_{10}, explained 33.1% of differences between schools (Table 36).

Table 36 Estimated linear regression coefficients of the classroom/school features and respective 95% confidence intervals for the parameter PM_{10}, assuming a multilevel model with "school" as a random effect

$\ln(PM_{10})$	Classroom Estimates (95% CI)	School Estimates (95% CI)	Total Estimates (95% CI)
No. of windows usually open in the heating season	0.176 (0.05; 0.31)	--	0.106 (-0.03; 0.24)
Visible damp spots on walls, ceiling or floor	0.357 (0.12; 0.60)	--	0.281 (0.06; 0.51)
Main ceiling surface material	-0.345 (-0.67; -0.03)	--	-0.306 (-0.59; -0.02)
Visible mould growth in the room	-0.247 (-0.47; -0.03)	--	-0.145 (-0.37; 0.07)
Existence of a closet or shelves with gouaches, inks etc. for graphic arts	-0.147 (-0.40; 0.10)	--	-0.054 (-0.28; 0.17)
Gasoline dispensing facilities nearby	--	-0.485 (-0.85; -0.12)	-0.385 (-0.71; -0.06)
Proximity of a car park	--	-0.319 (-0.57; -0.07)	-0.173 (-0.40; 0.06)
Existence of a laboratory room	--	0.366 (0.01; 0.72)	0.264 (-0.05; 0.57)
Variance of school (%)	**2.6**	**3.2**	**1.6**
ICC	**28.4**	**33.1**	**17.3**

ICC: Intra-class correlation coefficient.

When the TVOC parameter was analysed we found that the characteristics of the school had no significant effect on it. The number of windows usually open in the cooling season, the main floor surface material, the number of windows usually open before classes and the presence of a closet or shelves with gouaches, inks etc. for graphic arts are the variables that explain 21.3% of the differences between the schools evaluated (Table 37).

Table 37 Estimated linear regression coefficients of the classroom features and respective 95% confidence intervals for the parameter TVOC, assuming a multilevel model with "school" as a random effect

ln(TVOC)	Classroom Estimates (95% CI)
No. of windows usually open in the cooling season	-0.186 (-0.35; -0.03)
Main floor surface material	0.601 (0.13; 1.08)
Windows usually open before classes	-0.698 (-1.31; -0.08)
Existence of a closet or shelves with gouaches, inks etc. for graphic arts	0.438 (-0.06; 0.93)
Variance of school (%)	**8.3**
ICC	**21.3**

ICC: Intra-class correlation coefficient.

To summarize the effect of all variables resulting from each of parameters analyzed individually, we performed a multilevel regression analysis using the same model for each of the parameters studied. We found that there is an increase in the value of the ICC for the parameter CO_2 to 19.6% and parameter PM_{10} reaching the ICC of 40.0%. On the other hand, we perceived a decrease, assuming a value of 15.5% of this coefficient, when we analyze the parameter TVOC (Table 38).

Table 38 Estimated linear regression coefficients of the classroom/school features and respective 95% confidence intervals for the three parameters of indoor air quality, assuming a multilevel model with "school" as a random effect

	$\ln(CO_2)$ Estimates (95% CI)	$\ln(PM_{10})$ Estimates (95% CI)	ln(TVOC) Estimates (95% CI)
Ceiling height (m)	0.657 (0.15; 1.16)	-0.290 (-0.84; 0.26)	0.057 (-0.94; 1.05)
Windows area (m^2)	-0.024 (-0.05; 0.01)	0.003 (-0.03; 0.03)	-0.006 (-0.06; 0.04)
No. of windows usually open in the cooling season	0.067 (-0.02; 0.16)	0.045 (-0.05; 0.14)	-0.113 (-0.29; 0.06)
No. of windows usually open in the heating season	-0.123 (-0.28; 0.03)	0.127 (-0.02; 0.28)	-0.227 (-0.53; 0.08)
Visible damp spots on walls, ceiling or floor	-0.012 (-0.26; 0.24)	0.371 (0.10; 0.64)	0.340 (-0.15; 0.83)
Main ceiling surface material	-0.025 (-0.38; 0.33)	-0.312 (-0.70; 0.08)	-0.009 (-0.72; 0.70)
Visible mould growth in room	0.066 (-0.18; 0.31)	-0.245 (-0.50; 0.01)	0.046 (-0.43; 0.52)
Existence of a closet or shelves with gouache, inks etc. for graphic arts	0.082 (-0.22; 0.39)	-0.106 (-0.46; 0.25)	0.555 (-0.05; 1.16)
Windows usually open before classes	-0.034 (-0.36; 0.29)	0.160 (-0.20; 0.52)	-0.661 (-1.30; -0.02)
Main floor surface material	0.035 (-0.28; 0.35)	-0.001 (-0.37; 0.37)	0.557 (-0.05; 1.17)
Variance of school (%)	**1.88**	**4.24**	**6.02**
ICC	**19.6**	**40.0**	**15.5**

ICC: Intra-class correlation coefficient.

5.2 Case-Control Study of Indoor Air Risk Factors at Home

5.2.1 Characteristics of the study population

Table 39 presents the socio-demographic and personal characteristics between cases (n=38) and controls (n=30). The proportion of boys is significantly higher in the case group than in control group, however the remaining characteristics (age, BMI, family history of allergic disorders, number of siblings and parental education level) showed no significant differences. In data not shown, 26 (70.3%) cases had been diagnosed with asthma by a physician.

Table 39 Characteristics among case and control group

	Case, *n*=38		Control, *n*=30		
	n	%	*n*	%	*p*-value
Sex					0.006
Girls	9	23.7	17	56.7	
Boys	29	76.3	13	43.3	
Age (years)[*†]	8.5 (0.7)		8.6 (0.7)		0.782
Body mass index (kg/m^2)[*†]	17.7 (2.01)		18.1 (2.20)		0.422
Family history of allergic disorders					0.280
No	14	36.8	15	50.0	
Yes	24	63.2	15	50.0	
More than 3 siblings[†]					0.305
None	6	17.6	6	24.0	
1	14	41.2	12	48.0	
2 or more	14	41.2	7	28.0	
Mothers' education level					0.827
0-6 years	3	7.9	3	10.0	
7-9 years	7	18.4	3	10.0	
10-12 years	7	18.4	7	23.3	
≥ 13 years	21	55.3	17	56.7	0.777
Fathers' education level[†]					
0-6 years	5	13.5	4	14.3	
7-9 years	7	18.9	6	21.4	
10-12 years	12	32.4	9	32.1	
≥ 13 years	13	35.1	9	32.1	

[†] Denominator for each variable may vary due to missing data.
[*] Mean (standard deviation).

As expected, the prevalence of symptoms of rhinitis and other respiratory diseases apart from cold were higher among cases, but no significant differences were found regarding skin diseases (Table 40).

Table 40 Prevalence of ever, past month and year symptoms/diseases among case and control group

Symptom/disease	Case, *n*=38		Control, *n*=30		
	n	%	*n*	%	*p*-value
Asthma-like					
Ever wheeze	33	89.2	5	17.2	<0.001
Wheeze (<30 days)	12	31.6	0	0	0.001
Asthma in school	7	18.9	0	0	0.009
Rhinitis-like					
Ever runny/blocked nose[*]	26	68.4	9	30.0	0.001
Nasal allergy (<12 months)[*]	26	68.4	8	26.7	0.002
Eye irritation (<12 months)[*]	21	55.3	2	6.7	<0.001
Ever nasal allergy	17	47.2	5	16.7	0.023
Doctor-diagnosed nasal allergy[†]	13	36.1	4	13.3	0.025
Skin diseases					
Ever itchy rash (for 6 months)	12	32.4	10	33.3	0.926
Ever eczema	10	30.3	8	26.7	0.633
Other respiratory diseases apart from cold[†]					
Dry cough at night (<12 months)	30	83.3	7	23.3	<0.001
Cough episodes	9	25.0	2	6.7	0.036
Phlegm episodes	9	24.3	1	3.3	0.013

[*] Not occurring due to cold.
[†] Denominator for each variable may vary due to missing data.

Table 41 presents the prevalence of recent symptoms and diseases (<3 months) by case and control groups. In general, prevalence of skin and systemic symptoms was similar in both groups. Moreover, the reported frequency of swollen eye, runny and blocked nose, irritating cough and shortness of breath was significantly higher in the case group.

Table 41 Prevalence of recent (<3 months) symptoms and disease among case and control group

Symptom/disease	Case, *n*=38		Control, *n*=30		
	n	%	*n*	%	*p*-value
Skin†					
Hand rash	7	19.4	4	13.8	0.549
Face rash	7	18.9	4	13.8	0.582
Eczema	1	3.1	4	14.3	0.122
Eye†					
Eye irritation	16	44.4	7	24.1	0.091
Swollen eye	12	33.3	1	3.6	0.004
Nose†					
Runny nose	28	73.7	13	44.8	0.017
Blocked nose	32	88.9	13	43.3	<0.001
Lower airways					
Dry throat†	16	44.4	9	30.0	0.232
Sore throat†	21	60.0	14	46.7	0.286
Irritating cough	29	76.3	9	30.0	<0.001
Shortness of breath†	21	56.8	2	6.7	<0.001
Systemic†					
Headache	16	44.4	10	33.3	0.361
Symptom(s) improve on returning home†	3	10.3	5	22.7	0.233

† Denominator for each variable may vary due to missing data.

5.2.2 Homes characteristics based on walkthrough inspection and checklist

Table 42 presents housing characteristics for the study participants by case and control group. There were no significant differences in potential sources of pollutants measured by either caregiver report or home inspection, except for few characteristics. Studied dwellings were mainly apartments (>80.0%) located in Porto-MA. The number of inhabitants varied between 2 and 7. In general, case group children lived in older houses; whilst controls often lived in more recent houses.

There were no significant differences in the proximity of potential outdoor air pollution sources (e.g. attached garage, highway, power plant for the building, industry) in the homes of asthmatic children when compared with control children, except for gasoline dispense facilities (p=0.020). However, more than three-quarters of the homes were near streets with busy traffic at least one part of the day (rush hours) (77.8% of asthmatic children' homes and 76.7% of non-asthmatic children' homes; p=0.915); 88.9% of case homes and 80.0% of control homes were in front of a car park.

Only 13.2% of the case families had air conditioning. The most common home heating sources were gas and electricity, with some homes having multiple heating sources. Other potential sources of indoor air pollution identified were fireplaces (3 dwellings from case group and 3 dwellings from control group) and attached garage (63.9% and 53.3% in case and control homes, respectively).

Research team experienced more commonly visible signs of dampness (such as visible mould growth, damp spots) than mouldy odours; but bubbles or yellow discoloration were not observed in any of the homes. Signs of indoor mould growth were observed mostly in the case group homes (47.2% *vs.* 20.0%, $p<0.022$). Signs of high humidity (dampness/condensation on windows) were more common in case homes (51.4% in case homes *vs*. 36.7% in control homes, $p=0.233$).

Likewise, the characteristics were similar in the bedrooms of asthmatic and control children.

Table 42 Building characteristics of the dwelling among case and control group

Building characteristics	Case, *n*=38	Control, *n*=30	
	n (%)	*n* (%)	*p*-value
Type of building			0.655
Single-family house	4 (10.5)	4 (13.3)	
Semi-detached house	2 (5.3)	2 (6.7)	
Apartment	32 (84.2)	24 (80.0)	
Building age*†	34.0 (40.7)‡	23.8 (14.4)‡	0.799
Building location	25 (65.8)	23 (76.7)	
Urban area	12 (31.6)	7 (23.3)	
Sub-urban area	1 (2.6)	0	
Rural area			
Street with heavy traffic (<200 m)†			1.00
No	6 (16.7)	5 (16.7)	
Yes	30 (83.3)	25 (83.3)	
Near of source of outdoor air pollution†			
Car park	32 (88.9)	24 (80.0)	0.320
Busy road (at least part of the day)	28 (77.8)	23 (76.7)	0.915
Highway	5 (13.9)	5 (16.7)	0.756
Power plant for the building	1 (2.8)	0	0.361
Other power plant (up to 1 km)	6 (16.7)	1 (3.3)	0.082
Gasoline dispense facilities	6 (16.7)	0	**0.020**
Industry (up to 10 km)	35 (97.2)	30 (100)	0.361
Agricultural sources (up to 3 km)	2 (5.6)	2 (6.7)	0.852
Attached garage	23 (63.9)	16 (53.3)	0.389
Air conditioner*			**0.040**
No	33 (86.8)	30 (100.0)	
Yes	5 (13.2)	0	
Water leakage/damage indoors (<12 months)†			**0.025**
No	36 (100)	26 (86.7)	
Yes	0	4 (13.3)	
Visible mould growth†			**0.022**
No	19 (52.8)	24 (80.0)	
Yes	17 (47.2)	6 (20.0)	
Bubbles or yellow discoloration†			1.00
No	36 (100)	30 (100)	
Yes	0	0	
Dampness/condensation on the lower part of the windows (during winter)*†			0.233
No	18 (48.6)	19 (63.3)	
Yes	19 (51.4)	11 (36.7)	
Noticeable mould odour†			0.400
No	33 (91.7)	29 (96.7)	
Yes	3 (8.3)	1 (3.3)	

* Data provided from parents' questionnaire.
† Denominator for each variable may vary due to missing data.
‡ Mean (standard deviation).

Table 42 Building characteristics of the dwelling among case and control group (cont.)

Child´s bedroom characteristics	Case, *n*=38	Control, *n*=30	
	n (%)	*n* (%)	*p*-value
Bedroom area (m^2) ‡	11.5 (2.67)	12.0 (3.33)	0.193
Heating system†			0.287
No	26 (72.2)	25 (83.3)	
Yes	10 (27.8)	5 (16.7)	
Type of floor material†			0.933
Synthetic smooth (PVC/Vinyl, linoleum)	1 (2.8)	1 (3.3)	
Laminate parquetry	29 (80.6)	24 (80.0)	
Stone/ceramic tiles	4 (11.1)	1 (3.3)	
Wood/cork	2 (5.6)	4 (13.3)	
Carpet	0	0	
Furniture materials†			
Wood	27 (77.1)	25 (83.3)	0.537
Plywood	21 (60.0)	8 (26.7)	**0.007**
Textiles	0	1 (3.3)	0.280
Metal	2 (5.7)	2 (6.7)	0.874
Plastic laminate or composite	1 (2.9)	0	0.355
Water leakage/damage indoors (<12 months) †			0.277
No	34 (94.4)	26 (86.7)	
Yes	2 (5.6)	4 (13.3)	
Visible mould growth†			0.239
No	27 (75.0)	26 (86.7)	
Yes	9 (25.0)	4 (13.3)	
Visible damp spots on walls, ceiling or floor†			0.466
No	26 (72.2)	24 (80.0)	
Yes	10 (27.8)	6 (20.0)	
Bubbles or yellow discoloration†			0.273
No	36 (100.0)	29 (96.7)	
Yes	0	1 (3.3)	
Noticeable mould odour†			0.668
No	34 (94.4)	29 (96.7)	
Yes	2 (5.6)	1 (3.3)	
Presence of carpets†			0.134
No	13 (38.2)	6 (20.7)	
Yes	21 (61.8)	23 (79.3)	
Stuffed toys†			0.062
No	15 (42.9)	6 (20.7)	
Yes	20 (57.1)	23 (79.3)	

‡ Mean (standard deviation).
† Denominator for each variable may vary due to missing data.

Living conditions of families were summarized in Table 43. In the present study no significant differences were found in the living conditions such as reported smoking habits at home, pets, use of air fresheners, incense sticks and humidifiers between the case and control groups.

Table 43 Living conditions at home among case and control group

Building	Case, *n*=38	Control, *n*=30	
	n (%)	*n* (%)	*p*-value
Domestic pets (with fur)			0.502
No	27 (71.1)	19 (63.3)	
Yes	11 (28.9)	11 (36.7)	
Exposure to tobacco smoke at home†	16 (44.4)	11 (39.3)	0.681
Number of smokers at home*†			0.245
None	22 (59.5)	15 (50.0)	
One	12 (32.4)	8 (26.7)	
Two or more	3 (8.1)	7 (23.3)	
Number of cigarettes smoked at home (inside spaces)*†			0.257
None	27 (73.0)	17 (58.6)	
1 or 2	4 (10.8)	3 (10.3)	
3 to 4	1 (2.7)	5 (17.2)	
5 to 10	3 (8.1)	3 (10.3)	
11 to 20	1 (2.7)	1 (3.4)	
More than 20	1 (2.7)	0	
Use of air fresheners (frequently/often)			0.401
No	27 (71.1)	24 (80.0)	
Yes	11 (28.9)	6 (20.0)	
Use of incense sticks (frequently/often)*†			0.066
No	22 (57.9)	23 (79.3)	
Yes	16 (42.1)	6 (20.7)	
Presence/use of humidifier*			0.158
No	34 (89.5)	23 (76.7)	
Yes	4 (10.5)	7 (23.3)	

* Data provided from parents' questionnaire.
† Denominator for each variable may vary due to missing data.

5.2.3 Distribution of chemical, physical and comfort parameters and microbiological agents at home

Table 44 provides descriptive data for the indoor measured parameters among case and control homes. As occurred in classrooms, four specific VOC were observed in less than 25% of samples (benzene, T4CE, naphthalene and styrene); while T3CE was not detected in any sample. For both groups, the highest indoor median concentration was measured for toluene, d-limonene, formaldehyde and acetaldehyde. Overall, there were no significant differences in indoor air parameters in the homes of asthmatic children compared to those homes of non-asthmatic children, except for d-limonene levels (median=10.6 µg/m^3 in case homes *vs*. median=15.6 µg/m^3 in control homes, p=0.013).

The median concentration of TVOC was 97.4 µg/m^3 with a maximum of 793.6 µg/m^3 measured in a case home; while in control homes the median TVOC levels were 125.0 µg/m^3. Aldehydes were detected in all samples. Levels of formaldehyde were below the current indoor exposure guidelines of 100 µg/m^3 (WHO, 2010c). No significant difference was observed between case and control homes.

Data on $PM_{2.5}$ and PM_{10} was missing in 26 homes from case group and 12 homes from control group due to technical problems in the measurement equipment during field campaign. Median concentrations of $PM_{2.5}$ and PM_{10} were lower in the homes of children with asthma (54 µg/m^3 *vs*. 67 µg/m^3, p=0.966 for $PM_{2.5}$; and 56 µg/m^3 *vs*. 71 µg/m^3, p=0.966 for PM_{10}).

Furthermore, around 61% of the measured bedrooms had median CO_2 concentration above 1000 ppm; approximately 4% of the rooms had an average CO_2 concentration exceeding 2000 ppm although none of the rooms exceeded 3000 ppm. These numbers could be higher if we took into account that 59.3% of case family dwellings and 62.5% of control family homes did not comply the 1000 ppm as a reference value. The aforementioned results may imply that the median ventilation rate was lower in the control family houses than in case homes (2.08 l/s per person *vs.* 2.60 l/s per person; p=0.126). Almost seventy percent (69.8%) of all dwellings had a ventilation rate below 4 l/s per person.

The median indoor temperature was significantly lower in the bedroom of asthmatic than in non-asthmatic children (16.7 ºC *vs.* 17.7 ºC; p=0.045). Approximately 93% of houses (35 case and 28 control homes) had at least one average temperature and/or relative humidity which fell outside the recommended range. The recommended temperature should be between 20 ºC and 24 ºC in winter. In around 93% of the measurements, temperature was under 20 ºC and no values were observed over 26 ºC. The indoor relative humidity should be between 30% and 70%. Regarding to relative humidity of the indoor air, none of the values was below 30%. However, it was observed that in 32.4% of the homes the relative humidity value was over 70%. There were a significant number of homes (97.1%) with relative humidity over 50%.

Regarding the microbiological agents, bacteria concentrations in the homes of asthmatic children varied widely from 98 to 6528 CFU/m^3 (median=774 CFU/m^3); while in the control homes it varied from 188 to 6528 CFU/m^3 (median=652 CFU/m^3); however there were no statistically significant differences (p=0.608). Concerning fungi levels, higher indoor levels were observed in the control group (case group *vs*. control group: 170 CFU/m^3 *vs*. 301 CFU/m^3; p=0.253).

Table 44 Distribution of indoor chemical, physical and comfort parameters and microbiological agents in case and control homes

	Case, *n*=38							Control, *n*=30						
Chemical	*n*	*n*>DL[§]	Mean	SD	Median	P25-P75	Min-Max	*n*	*n*>DL[§]	Mean	SD	Median	P25-P75	Min-Max
Benzene, µg/m^3	37	5	1.12	0.12	1.06	1.02-1.25	1.01-1.28	25	3	4.72	3.33	4.97	1.27-7.92	1.27-7.92
Toluene, µg/m^3	37	36	25.9	69.0	5.92	3.99-12.8	1.01-398.5	25	25	19.6	34.0	8.03	4.96-17.1	1.64-167.4
m/p-xylene, µg/m^3	37	36	8.70	15.8	3.34	2.05-7.66	1.03-86.3	25	22	11.6	21.3	4.90	2.66-9.37	1.01-89.8
o-xylene, µg/m^3	37	31	4.18	5.54	2.30	1.80-3.75	1.06-29.2	25	21	5.44	8.19	2.51	2.00-4.48	1.23-30.4
d-limonene, µg/m^3	37	34	22.6	38.2	10.6	4.58-23.6	1.11-177.0	25	25	49.0	67.6	15.6	8.26-67.9	1.46-278.2
α-pinene, µg/m^3	37	29	6.59	10.4	3.05	2.02-5.55	1.15-54.1	25	19	3.65	2.96	2.65	1.77-4.50	1.04-14.2
T3CE, µg/m^3	37	0	--	--	--	--	--	25	0	--	--	--	--	--
T4CE, µg/m^3	37	5	1.77	0.34	1.92	1.43-2.04	1.25-2.11	25	4	6.71	8.08	3.40	1.52-15.2	1.47-18.6
Naphthalene, µg/m^3	37	6	3.69	5.74	1.47	1.09-5.08	1.09-15.4	25	7	17.9	33.1	1.69	1.17-27.2	1.06-89.7
Styrene, µg/m^3	37	6	1.78	0.73	1.41	1.25-2.57	1.24-2.96	25	2	1.24	0.10	1.24	1.17-1.30	1.17-1.30
TVOC, µg/m^3	37	37	146.7	157.9	97.4	55.1-149.5	24.1-793.6	25	25	203.5	210.4	125.0	63.8-260.0	18.0-895.2
Formaldehyde, µg/m^3	38	38	14.6	10.4	11.4	6.90-17.5	3.68-50.7	30	30	16.6	9.49	14.8	8.53-22.2	5.22-43.3
Acetaldehyde, µg/m^3	38	38	11.5	8.94	8.69	6.43-14.6	2.15-52.1	30	30	15.0	17.4	10.9	6.62-14.5	2.87-85.2
CO, mg/m^3	36	--	0.49	1.14	0.25	0.11-0.42	0.01-6.74	29	--	0.69	1.25	0.39	0.18-0.69	0.01-6.71
Physical and comfort														
$PM_{2.5}$, µg/m^3	12	--	89	76	54	42-123	36-287	18	--	79	64	67	46-87	19-307
PM_{10}, µg/m^3	12	--	92	78	56	46-131	38-296	18	--	82	64	71	48-90	20-308
CO_2, ppm	27	--	1176	361	1121	828-1463	697-1913	24	--	1260	514	1157	810-1594	671-2641
Ventilation rate, l/s per person	35	--	4.05	4.04	2.60	1.66-5.02	0-18.2	28	--	3.35	4.28	2.08	1.17-4.20	0-20.5
Temperature, ºC	38	--	16.7	2.28	16.7	15.2-18.1	10.7-22.3	30	--	17.6	1.71	17.7	16.2-18.5	14.6-23.0
Relative humidity, %	38	--	64	10	65	57-71	36-84	30	--	66	8	66	60-72	43-82
Microbiological														
Bacteria, CFU/m^3	38	--	1542	1904	774	369-1723	98-6528	30	--	1413	1878	652	336-1585	188-6528
Fungi, CFU/m^3	38	--	1038	1837	170	96-1006	34-6528	30	--	524	869	301	181-513	66-4805

DL: Detection limit; SD: Standard deviation; P25: 25th percentile; P75: 75th percentile; Min: Minimum; Max: Maximum; T3CE: Trichloroethylene; T4CE: Tetrachloroethylene; TVOC: Total Volatile Organic Compounds.

[§] Number of homes with values above the detection limit.

Descriptive data on outdoor measurements are given in Table 45. The number of outdoor measurements was less than indoors mainly due to weather conditions and to the lack of an appropriate location. In general, outdoor concentrations were lower than indoor levels.

In order to allow the comparison between indoor and outdoor levels, information on I/O ratios is shown in Table 46. In the present study, the I/O ratios obtained in particular for formaldehyde, acetaldehyde and bacteria in both groups indicated a notable contribution of internal sources. The I/O ratio for d-limonene, observed in case homes, was calculated based on a very low number of homes with corresponding indoor and outdoor measurements.

Table 45 Distribution of outdoor chemical, physical and comfort parameters and microbiological agents in case and control homes

	Case, n=38							Control, n=30						
Chemical	n	n>DL§	Mean	SD	Median	P25-P75	Min-Max	n	n>DL§	Mean	SD	Median	P25-P75	Min-Max
Benzene, µg/m^3	31	4	1.34	0.19	1.32	1.17-1.54	1.14-1.59	21	0	--	--	--	--	--
Toluene, µg/m^3	31	28	3.69	2.07	2.98	2.27-4.08	1.99-11.0	21	20	3.28	2.60	2.58	1.54-3.78	1.19-12.4
m/p-xylene, µg/m^3	31	27	3.75	5.03	2.42	1.92-3.42	1.37-28.1	21	17	3.22	2.42	2.65	1.91-3.46	1.19-11.3
o-xylene, µg/m^3	31	27	2.04	1.80	1.46	1.15-2.26	1.01-10.4	21	13	1.88	0.84	1.57	1.40-2.28	1.04-4.21
d-limonene, µg/m^3	31	6	12.1	13.2	8.64	2.95-18.6	2.23-38.0	21	8	10.3	23.3	2.06	1.29-3.45	1.09-68.1
α-pinene, µg/m^3	31	11	1.98	1.08	1.61	1.29-2.30	1.24-4.75	21	3	1.45	0.36	1.61	1.03-1.70	1.03-1.70
T3CE, µg/m^3	31	0	--	--	--	--	--	21	0	--	--	--	--	--
T4CE, µg/m^3	31	1	1.73	--	1.73	--	--	21	2	6.76	6.47	6.76	2.18-11.3	2.18-11.3
Naphthalene, µg/m^3	31	1	1.20	--	1.20	--	--	21	0	--	--	--	--	--
Styrene, µg/m^3	31	3	1.12	0.06	1.13	1.06-1.18	1.06-1.18	21	0	--	--	--	--	--
TVOC, µg/m^3	31	31	60.4	43.8	44.8	25.0-90.8	14.6-168.7	21	21	43.8	32.2	40.1	23.4-50.7	5.49-158.9
Formaldehyde, µg/m^3	31	31	2.20	1.78	1.90	1.47-2.12	1.15-11.2	25	25	2.98	2.71	2.21	1.49-3.60	0.90-14.3
Acetaldehyde, µg/m^3	31	29	1.48	1.09	1.27	0.89-1.62	0.32-5.73	25	23	1.89	2.26	1.23	0.85-2.00	0.17-11.3
CO, mg/m^3	22	--	0.62	1.79	0.06	0.009-0.14	0.001-6.27	15	--	0.51	1.59	0.07	0.02-0.22	0.01-6.25
Physical and comfort														
$PM_{2.5}$, µg/m^3	5	--	55	14	52	42-69	42-74	11	--	68	33	62	44-80	37-156
PM_{10}, µg/m^3	5	--	57	16	52	42-74	42-78	11	--	71	33	64	46-83	40-156
CO_2, ppm	18	--	548	169	503	418-720	360-853	10	--	516	140	506	432-546	318-843
Temperature, ºC	22	--	12.3	1.75	12.7	11.6-13.4	8.10-15.4	15	--	14.0	2.44	13.6	12.5-15.2	9.60-19.2
Relative humidity, %	22	--	71	9	71	64-78	54-89	14	--	70	12	72	64-79	40-92
Microbiological														
Bacteria, CFU/m^3	38	--	66	65	47	28-74	10-325	30	--	70	59	59	33-92	10-317
Fungi, CFU/m^3	38	--	146	165	116	62-156	26-873	30	--	271	250	147	94-458	18-985

DL: Detection limit; SD: Standard deviation; P25: 25th percentile; P75: 75th percentile; Min: Minimum; Max: Maximum; T3CE: Trichloroethylene; T4CE: Tetrachloroethylene; TVOC: Total Volatile Organic Compounds.

§ Number of outdoor homes with values above the detection limit.

Table 46 Indoor/outdoor ratio for chemical, physical and comfort parameters and microbiological agents

	Case, *n*=38				Control, *n*=30			
Chemical	*n*[§]	Indoor median	Outdoor median	I/O median[‡]	*n*[§]	Indoor Median	Outdoor median	I/O median[‡]
Benzene, µg/m^3	2	1.14	1.20	0.95	0	--	--	--
Toluene, µg/m^3	27	6.40	2.94	1.88	19	8.03	2.62	2.54
m/p-xylene, µg/m^3	26	3.34	2.41	1.32	16	5.71	2.72	2.27
o-xylene, µg/m^3	23	2.23	1.46	1.47	13	3.28	1.57	2.24
d-limonene, µg/m^3	3	1.82	7.92	0.23	8	36.8	2.06	19.8
α-pinene, µg/m^3	8	4.28	1.42	2.43	3	6.32	1.61	3.72
T3CE, µg/m^3	0	--	--	--	0	--	--	--
T4CE, µg/m^3	1	1.25	1.73	0.72	2	3.30	6.76	0.56
Naphthalene, µg/m^3	0	--	--	--	0	--	--	--
Styrene, µg/m^3	0	--	--	--	0	--	--	--
TVOC, µg/m^3	30	100.7	44.8	2.61	20	117.5	40.1	3.36
Formaldehyde, µg/m^3	31	11.8	1.90	5.90	25	16.9	2.21	6.97
Acetaldehyde, µg/m^3	29	9.30	1.27	7.33	23	10.9	1.23	9.26
CO, mg/m^3	20	0.27	0.06	4.79	14	0.46	0.08	5.27
Physical and comfort								
$PM_{2.5}$, µg/m^3	5	47	52	0.96	11	66	62	0.92
PM_{10}, µg/m^3	5	50	52	0.94	11	69	64	0.90
CO_2, ppm	12	1206	468	2.16	7	1031	505	2.04
Temperature, ºC	22	16.4	12.7	1.31	15	18.2	13.6	1.24
Relative humidity, %	22	66	71	0.90	14	64	72	0.91
Microbiological								
Bacteria, CFU/m^3	38	774	47	14.2	30	652	59	14.0
Fungi, CFU/m^3	38	170	116	2.29	30	301	147	1.69

T3CE: Trichloroethylene; T4CE: Tetrachloroethylene; TVOC: Total Volatile Organic Compounds.
[§] Correspond to the number of indoor measurements matched with the correspondent outdoor measurements.
[‡]The median of I/O ratios.

5.2.4 Associations between indoor air parameters with asthma

Associations between case status and indoor parameters were examined using multiple logistic regression models (Table 47). Concentrations of target VOC below the detection limit in more than 25% of the samples were excluded from the statistical analysis. After adjustment for age, sex, mother's education level and for indoor exposure in classroom no association was observed between any indoor air parameter and asthma status among children.

Table 47 Association between exposure to indoor parameters levels and case status

Parameter	OR (95% CI)	aOR (95% CI)
Toluene, µg/m^3		
<4.87	1	1
4.87-11.31	0.34 (0.09-1.89)	0.18 (0.03-1.12)
≥11.32	0.31 (0.08-1.18)	0.19 (0.03-1.21)
m/p-xylene, µg/m^3		
<2.48	1	1
2.48-5.42	0.57 (0.16-2.07)	0.75 (0.15-3.61)
≥5.43	0.47 (0.13-1.70)	0.37 (0.08-1.82)
o-xylene, µg/m^3		
<1.80	1	1
≥1.80-3.03	0.81 (0.23-2.88)	0.80 (0.16-4.12)
≥3.04	0.50 (0.14-1.76)	0.25 (0.04-1.45)
d-limonene, µg/m^3		
<6.63	1	1
6.63-18.05	0.44 (0.12-1.68)	1.20 (0.03-1.13)
≥18.06	0.30 (0.08-1.14)	0.18 (0.03-1.08)
α-pinene, µg/m^3		
<1.44	1	1
1.44-3.40	0.96 (0.28-3.31)	1.46 (0.31-6.98)
≥3.41	1.00 (0.28-3.54)	0.59 (0.12-2.91)
TVOC, µg/m^3		
<72.09	1	1
72.09-145.52	1.08 (0.30-3.92)	0.52 (0.10-2.62)
≥145.53	0.49 (0.14-1.72)	0.25 (0.04-1.37)
Formaldehyde, µg/m^3		
<8.94	1	1
8.94-17.39	0.89 (0.27-2.97)	0.49 (0.12-2.01)
≥17.40	0.44 (0.13-1.46)	0.32 (0.07-1.43)
Acetaldehyde, µg/m^3		
<7.90	1	1
7.90-13.07	0.77 (0.24-2.52)	0.41 (0.09-1.90)
≥13.08	0.70 (0.22-2.26)	0.38 (0.08-1.87)
CO, mg/m^3		
<0.18	1	1
0.18-0.41	0.52 (0.15-1.82)	0.86 (0.20-3.71)
≥0.42	**0.25 (0.07-0.90)**	0.26 (0.06-1.16)
$PM_{2.5}$, µg/m^3		
<48.58	1	1
48.58-83.20	1.00 (0.17-5.98)	2.07 (0.15-29.0)
≥83.21	1.00 (0.17-5.98)	0.98 (0.10-9.44)
PM_{10}, µg/m^3		
<50.56	1	1
50.56-84.95	1.00 (0.17-5.98)	1.56 (0.11-22.0)
≥84.96	1.00 (0.17-5.98)	0.94 (0.10-8.84)
CO_2, ppm		
<924.30	1	1
924.30-1386.75	1.27 (0.33-4.93)	4.01 (0.54-29.8)
≥1386.76	0.79 (0.20-3.04)	0.41 (0.06-2.80)
Temperature, ºC		
<16.26	1	1
16.26-18.32	0.53 (0.17-1.68)	0.55 (0.13-2.34)
≥18.33	0.36 (0.10-1.38)	0.44 (0.08-2.37)
Relative humidity, %		
<62.29	1	1
62.29-69.69	0.77 (0.24-2.52)	1.22 (0.28-5.22)
≥69.70	0.70 (0.22-2.26)	0.57 (0.14-2.27)
Bacteria, CFU/m^3		
<530.0	1	1
530.0-1024.0	0.91 (0.28-2.94)	2.43 (0.52-11.3)
≥1025.0	1.30 (0.40-4.24)	2.41 (0.52-11.1)
Fungi, CFU/m^3		
<152.0	1	1
152.0-407.0	0.16 (0.04-0.58)	0.27 (0.06-1.16)
≥408.0	0.38 (0.10-1.39)	0.35 (0.08-1.65)

OR: unadjusted odds ratio; aOR: adjusted odds ratio for age, sex, mother´s education and indoor exposure in classroom; CI: Confidence interval.

6. Discussion

This study explored the associations between indoor air parameters and children health outcomes focusing on asthma, allergies and other respiratory symptoms. Most of the investigations on health effects of air pollution have been conducted for outdoor air pollutants such as particulate matter, ozone and NO_2 (Heinrich *et al.*, 2005; Holgate *et al.*, 1999). Evidence suggests that city-dwellers spend most of their time in buildings and are by far more exposed to pollution indoors than outdoors. To our knowledge this is the first study conducted in a large sample of both schools and homes.

In this survey the prevalence of wheeze ever and wheeze in the preceding 12 months is higher than that found in the national ISAAC evaluation (Porto ISAAC-Phase III, 6 to 7 years old children) (http://isaac.auckland.ac.nz/). Regarding Epiteen cohort studies, carried out in Porto and which included adolescents with 13 years old, the prevalence of the above symptoms is lower than the values obtained in the current study (wheeze ever=18.3% and wheeze last year=9.3%) (Falcão *et al.*, 2008). In addition, Epiteen results showed a higher prevalence of asthma diagnosis (11.9%) than those obtained in the present study (9.2%). In this survey doctor-diagnosed nasal allergy was reported by 12.7%, but a higher percentage of children had runny nose symptoms (43.7%) and blocked nose symptoms (54.1%). The prevalence of ever nasal allergy in the current study is lower than the prevalence of nose symptoms ever reported in the Porto ISAAC-Phase III data (16.7% *vs.* 26.1%). The values are more similar for the prevalence of nasal allergy in the past 12 months reported in our study (24.6%) and the prevalence of nose symptoms in the last year according to Porto ISAAC results (22.1%).

Concerning the associations between children's health and indoor air parameters, the present study revealed a significant association between indoor air pollutants of the VOC family and asthma-related symptoms among children. Effects of toluene and xylene on asthma are more and more suggested, even if results are still scarce (Hulin *et al.*, 2010). In a population of children aged between 6 months and 3 years, the risk of asthma increased almost two times for every 10 $\mu g/m^3$ increase in the indoor concentration of toluene (Rumchev *et al.*, 2004). Similar OR was found for xylenes (OR=1.61; 95% CI: 1.10-2.35 for m-xylene and OR=1.49; 95% CI: 0.99-2.23 for p-xylene, respectively). A case-control study carried out in France also showed a significant association between exposure to toluene and xylene isomers and a higher risk of asthma in children even at low concentrations (Hulin *et al.*, (2010). Median concentrations of toluene and xylenes reported by Hulin *et al.* (2010) and Rumchev *et al.* (2004) are similar to the ones found in the present study. In our population, toluene and xylene isomers, the most abundant aromatic compounds found in the studied classrooms, were associated with an increased prevalence of wheeze among children in spite of the fact that indoor concentrations of such pollutants were below the respective WHO IAQ guidelines and EU-INDEX recommendations. These results are in agreement with previous studies which showed that exposure to toluene and xylene had a harmful effect on wheeze symptoms (Martins *et al.*, 2012; Guieysse *et al.*, 2008; Rumchev *et al.*, 2004). However, the relationship of toluene, xylene and asthma, particularly in children, remains still controversial. A study in the United Kingdom found that toluene and xylene exposure was not associated with an increased risk of wheezing illness (Venn *et al.*, 2003). Several factors could account for inconsistencies, including confounding factors, small effect levels, or chronicity of exposure (Dales and Raizenne, 2004).

Aldehydes (formaldehyde and acetaldehyde) have rarely been measured in schools (Annesi-Maesano *et al.*, 2013). Formaldehyde is one of the most studied pollutants when focusing on the effect on indoor air pollution on respiratory health. According to Mendell *et al.* (2007), recent epidemiological studies confirm the allergic potential of formaldehyde in the development of asthma and other allergic symptoms. A recent meta-analysis focusing on formaldehyde exposure and asthma in children calculated a pooled OR of 1.03 (95% CI: 1.02-1.04) for an increase of 10 $\mu g/m^3$ (Mcgwin *et al.*, 2010). Two studies focused on respiratory effects of indoor formaldehyde exposure revealed an increased risk of asthma associated with elevated indoor concentrations (Rumchev *et al.*, 2002; Smedje and Norbäck, 2001). Concentrations obtained in the French and Swedish studies are close to those found in the present study (Hulin *et al.*, 2010; Smedje and Norbäck, 2001). Moreover, Rumchev *et al.* (2002) showed an elevated risk of asthma only in children exposed to formaldehyde levels above 60 $\mu g/m^3$ at home. In the present study, it was found that indoor exposure to formaldehyde was related to asthma-like symptoms, namely, wheeze in the past year and irritating cough reported during the previous 3 months. However, Ezratty *et al.* (2007) and Billionnet *et al.* (2011) questioned the effect of formaldehyde on asthma. As suggested by Wolkoff and Nielsen (2010) complex co-exposures with other compounds, exposure levels and socio-economic factors could encumber the interpretation of the association with formaldehyde, explaining different findings among studies. Acetaldehyde, another aldehyde, was also found to be associated with asthma-like symptoms in our population. In agreement with our findings, exposure to acetaldehyde at home, in a subsample of the 6 Cities study, was associated with a higher risk of asthma (Hulin *et al.*, 2010). However, further research is needed to better understand the potential implication of aldehydes levels on asthma.

This research also investigated the influence of VOC and aldehydes indoor concentrations on the respiratory function among children by objective clinical examination. So far, few studies have assessed the effects of school indoor air parameters on children health using clinical objective measurements (Martins *et al.*, 2012; Le Cann *et al.*, 2011; Zhao *et al.*, 2008; Kim *et al.*, 2007). Spirometry is used to measure the limitation of the airflow in the airways and to study its reversibility. The bronchial obstruction is variable over time meaning that many asthmatics will not present spirometry abnormalities and so a battery of tests is necessary until signs of obstruction or reversibility are found (GINA, 2012). In the current study it was observed that, in general, children present normal pulmonary function. Wallner *et al*. (2012) found a correlation between xylene (m/p-xylene and o-xylene) concentrations and a decrease of FVC and FEV_1. Moreover, eNO assessment was performed because it is faster and easier to obtain than other measurements of inflammation of airways such as sputum eosinophils count (Franklin and Stick, 2008). Up to date, research on the effects of exposure to VOC and aldehydes on eNO is scarce. Nevertheless, some variations exist among the data from eNO assessments (La Grutta *et al.*, 2012). Such variations could be mainly related to the population studied (i.e., genetic variation, atopic *vs*. non-atopic, and asthmatic *vs*. non asthmatic), including the treatment effects (i.e., inhaled steroid in asthmatics), and to the variable pollutants exposure (i.e., personal *vs*. ambient, level of exposure and short term *vs*. long term) (La Grutta *et al.*, 2012). In the specific case of the present study none associations were obtained between specific VOC, aldehydes and the inflammatory indicator eNO. Therefore, in light of the evidence that the variations in eNO measurements show some inconsistencies in children exposed to environmental pollutants, further research appears to be needed.

According to Kotzias *et al*. (2005) toluene has been used as a solvent in a variety of household products such as paints, thinners, cleaning agents, coatings, rubber, adhesives, resin and printing products. Results for toluene levels in this study are far below the weekly average concentrations in libraries, offices, newspaper stands and copy centres in Bari, Italy (Bruno *et al.*, 2008); but are similar to those reported by Stranger *et al*. (2007) in primary schools of Antwerp, Belgium and by Martins *et al.* (2012) in Portuguese schools. Xylenes are widely used in the chemical industry as solvents for products such as paints, inks, dyes, adhesives and detergents (Sarigiannis *et al.*, 2011). Xylenes are usually reported in literature together with benzene and toluene, but their concentration might be reported in three different ways. In fact it is possible to find values for all three individual isomer xylenes, for the sum of all these three without any information on the most abundant; and finally, o-xylene on its own and (m- and p-) xylenes together, because of their close gas chromatographic retention times and insufficient separation (Sarigiannis *et al.*, 2011). In the current study indoor xylene concentrations are higher than those registered in previous studies involving 14 elementary schools of the Portuguese capital, Lisboa (m/p-xylene comprises values from 0.6-40 $\mu g/m^3$) (Pegas *et al.*, 2011b); while the mean values are lower than those reported in Turkey (o-xylene, indoor concentration: 11.2 $\mu g/m^3$ (Pekey and Arslanbas, 2008). But, few studies have quantified specific VOC as the present study did, referring only to the TVOC levels.

Regarding aldehydes results, indoor concentrations of formaldehyde and acetaldehyde are higher than those outdoors which suggests that indoor sources are more important contributors to the indoor levels. Indoor formaldehyde concentrations may be related to the insulating materials, parquet, particle board or plywood furniture containing formaldehyde-based resins, paints, cleaning and other consumer products used either in the didactic work or in the cleaning processes of the classrooms (Gilbert *et al.*, 2008; Mendell, 2007). Additionally, formaldehyde and acetaldehyde can occur in the indoor environment as secondary emissions, therefore as products of the reaction of a primarily emitted pollutant with ozone (Nazaroff and Weschler, 2004). The formaldehyde concentrations measured in this study are higher than those reported for schools in other countries: Sweden, (Smedje *et al.*, 1997; Norbäck *et al.*, 1990) and Australia, (Zhang *et al.*, 2006), but lower than the median concentration reported in France by Annesi-Maesano *et al.* (2012). Thus, taking into consideration that each classroom was equipped with standard school furniture basically made of plywood and that currently no special care is taken regarding the household products used in the classrooms, a reflection could be made at this stage regarding the selection of new furniture, cleaning, consumer and didactic products. Formaldehyde was the most abundant aldehyde. However, acetaldehyde was also present indoors and their indoor concentrations were higher than those outdoors. There is a lack of European population based data on acetaldehyde levels. In Helsinki average indoor air concentrations of acetaldehyde are clearly higher than ambient concentrations, 18.2 $\mu g/m^3$ and 2.7 $\mu g/m^3$ respectively, suggesting also the presence of considerably strong indoor sources (Kotzias *et al.*, 2005). Lower values were observed in the present study comparing with the previous one; while similar findings were obtained by Annesi-Maesano *et al.* (2013).

Concerning other respiratory symptoms apart from cold, the odds to have cough episodes and phlegm episodes were significantly higher among children in classrooms with d-limonene levels with the 2nd tertile. For concentrations of d-limonene higher than 3rd tertile the odds to have cough episodes and phlegm episodes remained but without statistically significance. According to Kotzias *et al.* (2005) d-limonene is generally recognized as safe and the most important health effects associated with d-limonene are irritation of the eyes, nose, throat and skin. In addition, it has been proposed that reactions between d-limonene and ozone or hydroxyl radicals produce chemically reactive products more likely to be responsible for eye and airway irritation, such as formaldehyde which may cause irritation at low concentrations, than the chemically non-reactive VOC usually measured indoors (WHO, 2010c; Nicolas *et al.*, 2007; Destaillats *et al.*, 2006; Singer *et al.*, 2006a; Weschler, 2006; Kotzias *et al.*, 2005; Nazaroff and Weschler, 2004). The presence of d-limonene was identified in both indoor and outdoor samples, but with higher concentrations in the indoor environment, suggesting additional indoor sources or inadequate ventilation ratios. Terpenes, including d-limonene, are well known as substances emitted from cleaning products and room fresheners (Singer *et al.*, 2006b). Although in the current study the high proportion of d-limonene indoors agrees with other observations made of the increasing ubiquity of this compound in the indoor environments (Weschler, 2004); the observed d-limonene concentration range is much lower than the recommended value proposed by EU-INDEX project (450 $\mu g/m^3$).

The observed associations of VOC and aldehydes and asthma-related symptoms seem to suggest the need to be further investigated as these indoor air pollutants were found in low concentrations in the current survey taking into account the values in WHO IAQ guidelines (WHO, 2010c) and EU-INDEX recommendations (Kotzias *et al.*, 2005) in order to assure that the results were not response errors, or an effect of chance.

In the present study, TVOC levels were significantly associated with wheeze in the preceding month and were also related with increases in reported ever nasal allergy. Therefore, it can be supposed that TVOC may be associated with the presence of asthma or allergic rhinitis, although for the latter no nose symptoms were reported and the 3rd tertile of TVOC concentrations may reject the hypothesis of allergic rhinitis. Total VOC concentration was related to chronic airway and chronic eye symptoms by Hulin *et al*. (2010) and Norbäck *et al*. (1990). Concerning spirometry, all parameters in the volume of exhaled air were lower where TVOC had higher concentrations (highest tertile), being statistically significant for FEV_1. The eNO results support the potential existence of chronic airway inflammation in children under medium TVOC concentration. In addition, eNO concentrations are significantly higher in children with symptoms of respiratory and allergic diseases when exposed to same TVOC concentrations as occurred with the remaining indoor air parameters.

The potential mechanism of allergic sensitization could be the irritation properties of VOC. Volatile organic compounds could facilitate the penetration of allergens in the target organs by irritation of the respiratory mucosa and impaired muco-ciliary clearance (D' Amato *et al.*, 2005). Experimental studies, in which humans have been exposed to known levels of VOC under carefully controlled conditions, have shown that even moderate concentrations of VOC may cause inflammation and obstructive reactions in the airways as well as inflammatory response in the nose (Koren *et al.*, 1992). One of the molecular mechanisms that may explain the effects of indoor pollutants on inflammation is oxidative stress (Baeza and Marano, 2007; Bonay and Aubier, 2007), in which VOC may play a key role (Baulig *et al.*, 2003). Another potential mechanism is a synergistic effect of sensitization and exposure to such pollutants on airway reactivity, lowering the dose of antigen exposition needed to provoke bronchial or nasal constriction (Leikauf, 2002; Roux *et al.*, 1999).

Given the potential impact of exposure to VOC on children health, it is important to increase the understanding of the factors that affect their indoor concentration. According to Mendell (2007) and Zhang *et al.* (2006) indoor TVOC levels might be due to the furnishing, floor covering, insulating materials, adhesives, paints and glues as well as other solvents and cleaning products. In addition to these indoor sources, the insufficient ventilation is likely to favour the increase of TVOC levels (Zhang *et al.*, 2006). In the present study, indoor concentrations of TVOC were higher when compared to the outdoor; indicating indoor main sources. Moreover, this study showed an increase in TVOC levels when floor surface material is PVC/vinyl, linoleum. Unlike, decreases in TVOC levels were associated with the increase of ventilation measured by the number of windows usually open in the cooling season and if the windows are usually open before classes. These findings underlined the importance of occupant behaviours in the control and guarantee of good IAQ.

The mean indoor TVOC concentrations measured in this study are higher than in the studies performed in schools elsewhere: in Sweden [mean TVOC of 6 $\mu g/m^3$ by Smedje *et al.*, (1997)], in Minnesota, United States [median TVOC of 14 $\mu g/m^3$ by Adgate *et al.*, (2004)], in Australia [maximum TVOC of 94 $\mu g/m^3$ by Zhang *et al.*, (2006)], in Michigan, United States [mean TVOC of 58 $\mu g/m^3$ by Godwin and Batterman (2007)], but lower than those measured in South Korea [mean TVOC of 374 $\mu g/m^3$ by Yang *et al.* (2009)]. However, comparisons of TVOC levels across studies can be problematic owing to differences in definition, sampling times, measurement and analysis (Zhang *et al.*, 2006).

Concerning particulate matter, PM_{10} and, more recently, $PM_{2.5}$ have been assessed in schools indoors and outdoors. In the present study both median $PM_{2.5}$ and PM_{10} levels exceed the recommended WHO air quality guidelines. An increasing number of data has shown that increased levels should result in the increased prevalence of acute and chronic health effects, including asthma, among children (Mendell and Heath, 2005; Daisey *et al.*, 2003). Links between health and $PM_{2.5}$ concentrations were published for schoolyards (Annesi-Maesano *et al.*, 2007) and for classrooms (Annesi-Maesano *et al.*, 2012). The present study showed that higher levels of $PM_{2.5}$ and PM_{10} increase the odds of asthma-like symptoms (wheeze and irritating cough) among children; nevertheless the association was strong for PM_{10}. However, for the irritating cough this relationship disappears when the children with "feeling like getting a cold" are excluded. Annesi-Maesano *et al.* (2012) reported that high prevalence of asthma in the past year was found in children attending classrooms with "high" (>17.5 $\mu g/m^3$) pollution levels of $PM_{2.5}$. It was also reported that increased PM_{10} concentrations had significant pertinence on lung disorders (such as wheeze and shortness of breath) and on reduction of lung functions; while $PM_{2.5}$ were strongly associated with cardiopulmonary diseases and lung cancer (Gemenetzis *et al.*, 2006). In addition, spirometry did not reveal an obstructive pattern. Nevertheless, given the association between wheeze symptoms, $PM_{2.5}$ and PM_{10} levels, as well as the eNO results that, although not significant, were higher in the 3rd tertile among the children with symptoms, it is possible to suppose that particulate matter is associated with an increase in airways inflammation.

Most studies of particulate matter have been focused on ambient (outdoor) exposures and their relationship to hospital admissions and mortality. Although the mechanisms are not well understood, it has been shown that particulate matter may enhance airway inflammatory reactions and sensitization (Jaakkola *et al.*, 2000). It has been suggested that this could be due to the intervention of the PAH contained in particulate matter or strongly related to it. However, it cannot be excluded that particulate matter might also influence non-immunological properties of the allergens, such as their enzymatic activity, thus contributing to their increased penetration in the target organs (Steerenberg *et al.*, 2003).

Exposure to $PM_{2.5}$ has been measured in few studies (Annesi-Maesano *et al.*, 2013). Since the classrooms do not contain any specific $PM_{2.5}$ source (such as smoking, cooking), the indoor $PM_{2.5}$ concentrations were more likely to be due to outdoor penetration rather than indoor sources related to the presence of children and the intensity of their indoor activities as reported by (Polidori *et al.*, 2007); as well as resulted from reactions between ozone and terpenes (Sarwar *et al.*, 2003; Weschler and Shields, 2003). This is consistent with the observations from other studies (Oeder *et al.*, 2012; Almeida *et al.*, 2011; Guo *et al.*, 2010; Fromme *et al.*, 2007). As previously referred, European Environment Agency has confirmed that emissions from road transport are the second most important source of $PM_{2.5}$ and PM_{10} (EFA, 2008; Heinrich *et al.*, 2005; Holgate *et al.*, 1999). Additionally, some studies on source apportionment performed in Porto have shown that the main source of fine particulate matter is the outdoor air such as the urban traffic (Slezáková, 2009). As in the present study 13 (65%) of the schools were situated close to a heavily trafficked road and 5 (25%) were close to a car park it is expected that ambient air contribute to the indoor concentrations of particulate matter in the classrooms. This illustrates the issue of the impact of the location of schools suggesting that when new schools are built, outdoor risks factors should be considered. These findings appear consistent with the obtained I/O ratio for $PM_{2.5}$.

The direct comparison of indoor PM_{10} concentrations with previous studies is difficult. Differences between sampling periods, collection methods and measurement strategies could explain some disparities among studies. For example gravimetric methods (Martins *et al.*, 2012; Madureira *et al.*, 2009) or dust track in classrooms (Simoni *et al.*, 2010; Kim, 2005) were used. In an investigation in the United States, after the modification of the sampling procedure from 24 to 8 hours measurements, the mean PM_{10} values were twice as high as before (Yip *et al.*, 2004). Furthermore, Stranger *et al.* (2008) showed, in a pilot study made in Belgium classrooms, that 12 hours $PM_{2.5}$ concentrations exceeded those of 24 hours by 40%.

In general, the indoor PM_{10} concentrations obtained in the present study are consistent with data reported in other studies that dealt with PM_{10} sampled during teaching hours (157 $\mu g/m^3$) (Fromme *et al.*, 2008), (118 $\mu g/m^3$) (Simoni *et al.*, 2010), (112 $\mu g/m^3$) (Janssen *et al.*, 1997); but higher than those reported by Stranger *et al.* (2007) in 27 Belgian schools.

The indoor PM_{10} concentrations might either originate from particle generation by occupants themselves, resulting from school occupants' activities or re-suspension of deposited particles (Arvanitis *et al.*, 2010). Several studies concluded that the introduction of new particulate matter including soil material brought in with shoes, blackboard dust, skin flakes, and cloth and furniture fragments seems to be the main reason for high indoor PM_{10} concentrations (Oeder *et al.*, 2012; Almeida *et al.*, 2011; Guo *et al.*, 2010). Fromme *et al.* (2007) reported that high PM_{10} levels in schools were correlated with less frequent cleaning and inefficient removal of deposited particles that thus became re-suspended. According to the same authors, occupancy strongly influences the indoor concentration level of PM_{10} through re-suspension. However that effect decreases with particulate matter size.

Specific characteristics from both the classrooms and the school such as the number of open windows in the heating season, the visible damp spots on the wall or ceiling, and the presence of a laboratory room were associated with significantly higher PM_{10} concentrations. On the contrary, the values are significantly lower if the main ceiling surface material is painted (instead of wooden) and if exist gasoline dispensing facilities and car park on the proximities of the school. These relationships pointed out for conditions that could cause introduction from outdoors and re-suspension of coarse particles indoors resulted from occupant activities, as well as for the presence of other potential indoor sources of coarse particles such as the degradation/peeling of coating materials in the wall, ceiling (e.g. paint) resulted from dampness problems. The inverse association regarding the proximity of gasoline dispensing facilities or car park may reflect that in these schools there is a tendency to avoid opening the windows which prevents the entrance to the indoor environment of particulate matter from outside.

The findings above appear to be consistent with the obtained I/O ratio higher than the unit. Moreover, in what regards the I/O ratios, the largest the particles, the highest the ratios when the classroom was occupied. In particular, the PM_{10} indoor concentration profiles show peaks within the time slots when the studied classrooms were occupied (Madureira *et al.*, 2012).

Carbon dioxide, while not being a pollutant itself, becomes a proxy for the indoor pollution and a tracer of the level of air renewal. Only few studies investigated the associations between CO_2 and health (Annesi-Maesano *et al.*, 2013). In the present study it was found an inverse association between CO_2 and respiratory symptoms in particular cough and phlegm episodes for children exposed to levels between 1299.87 ppm and 1913.07 ppm, presenting 50% less odds to have cough episodes and phlegm episodes than those in schools with lower CO_2 levels. Despite the fact that for 86% of the classrooms the CO_2 mean levels in the classrooms exceed 1000 ppm no effects were found for other asthma-related symptoms as reported in earlier studies (Simoni *et al.*, 2010; Mi *et al.*, 2006; Norbäck *et al.*, 1995) or other health problems, e.g. headache. A probable explanation for the lack of association is the low levels of chemical indoor pollutants which were below IAQ WHO guidelines and EU-INDEX recommendations.

Inadequate ventilation, as indicated by CO_2 levels, appears to be a common IAQ problem encountered in schools (Pegas *et al.*, 2011b; Madureira *et al.*, 2009; Mumovic *et al.*, 2009; Geelen *et al.*, 2008). The classroom that presented the greatest CO_2 concentrations was one that had the heating system turned on and windows and doors always closed. Carbon dioxide spikes were even more pronounced when students started activities inside the classrooms and exits to the playground (data not shown). In this study, none of the classrooms had a density of occupation lower than 1.5 m^2/occupant. However, if the ASHRAE criterion is take into account (2.0 m^2/occupant) the number of classrooms below the recommendable value rises to 13.7%.

Multiple regression models were performed to assess the associations between the schools/classrooms characteristics, occupant behaviour and the CO_2 levels. The present study showed higher CO_2 concentrations in classrooms with higher ceiling height and an inverse association with the windows area in the classroom. Although almost all classrooms have the same ceiling height (range=2.9-3.6 m), the classroom area/volume and the density of occupation varied between classrooms. Moreover, the difficulty associated to heat a high space volume might also explain and determine the occupant behaviour reflected in a reduced number of times that the windows are open (introduction of "fresh" air) and thus suggesting a potential stagnation of the indoor air. Thus, as a surrogate for ventilation in classrooms, the results of the present study underlined the relevance of the use strategies or occupant behaviour in the indoor CO_2 concentrations taking into account that the school staff reported that opening windows was not so frequent due to noise problems and/or weather conditions. Kvisgaard *et al.* (1990) and Iwashita *et al.* (1997) reported that occupant behaviour may account for as much as 63-87% of the total ventilation rate.

Ventilation is a critical issue both for health and for performance (Mendell and Heath, 2005). The point is that before considering the need of mechanical ventilation there are a number of actions that can be accounted for. If clean materials and consumer products are used and the air outside respect the WHO air quality guidelines, the ventilation rate can be established just to control CO_2 produced by the occupants. If the ambient air fulfils the WHO air quality guidelines the basic option shall be natural ventilation. Therefore, there is the possibility of creating conditions of "mechanical assisted" ventilation with mechanical auxiliary systems to intensify the air renewal under meteorological conditions adverse to the use of natural ventilation. When economically justifiable the "mechanical assisted" ventilation can include a heat exchanger to recover some "heating energy" transferred to the incoming air. A parameter that cannot be left aside this discussion is the duration time of both "teaching periods" and "breaks". The implementation of more breaks and recesses between classes, and decreasing the occupancy per classroom might help to reduce the indoor pollutant levels.

Besides chemicals, biological contamination is also a contributor to indoor air pollution and until now has been poorly documented in schools (WHO, 2009b). Bacteria concentrations at school varied widely according to studies. Reported maximum mean concentration value was 17000 CFU/m^3 (Kim *et al.*, 2007) and minimum was 250 CFU/m^3 (Taskinen *et al.*, 1999). That, probably, representing the degree of occupancy of the building and the efficiency of its ventilation. No comparisons can be made on the levels of microbial contaminants observed in classrooms in relation to WHO guidance and EU limit values. Even on national level, only in very few countries guidance is provided with respect to indoor microbial levels and those cases refer to levels of viable fungi and/or bacteria such as in Portugal. In the present study mean levels of bacteria higher than 500 CFU/m^3, value recommended by Portuguese legislation, were observed in 63 (86%) classrooms. These findings are similar to those obtained in 11 schools in Porto in winter season (Madureira *et al.*, 2009), but lower than those reported in a study covering 14 schools in Lisboa in spring (Pegas *et al.*, 2011b).

In the present study bacteria concentrations were associated with lower odds of asthma-related symptoms but with an increase in cough episodes. This is in contrast with a previous school study reporting positive associations between indoor viable bacteria measured in spring and current asthma (wheeze in the past 12 months) (Smedje *et al.*, 1997) as well as with exacerbation of asthma (Douwes *et al.*, 2003). Similarly, the findings of most epidemiological studies on bacterial components (such as endotoxin) have been contradictory (Radon, 2006). Some demonstrated protective effects, while others showed associations with increased asthma symptoms in children (Michel, 2000; Michel *et al.*, 1996). In addition, despite the fact that spirometry parameters in general showed little variation, it was still possible to verify a significant difference in $FEF_{25\text{-}75\%}$ which was lower with higher levels of bacteria. The association between the concentrations of bacteria and the eNO results was more pronounced in children with symptoms of respiratory and allergic disease than in asymptomatic children, although the difference was not significant.

In the current research indoor bacteria concentrations are higher when compared with outdoor levels, indicating significant indoor sources and insufficient ventilation. According to WHO (2009b), the main sources of bacteria in the indoor environment are people, indoor bacterial growth and outdoor air. Higher indoor bacteria concentrations are probably due to inadequate ventilation rates, movement causing particle suspension and food products derived from lunch breaks (Mentese *et al.*, 2009; Lee *et al.*, 2002). Other potential source of indoor bacteria may be human oral and respiratory fluid emitted via coughing, sneezing, talking, and breathing (Xie *et al.*, 2009) or the direct shedding of skin-associated microbiota (Fox *et al.*, 2010) taking into account that all indoor samplings were performed during occupied periods. In the present study, approximately 20% of the classrooms had interior damp stains and 49.3% of classrooms had a tendency to form condensation on the windows. This excess of moisture could be associated with higher levels of bacteria as reported by (Meklin *et al.*, 2002). Moreover, the environmental conditions surrounding the classrooms, as plants and soil in the school playgrounds can offer the important sources of microorganisms (Moschandreas *et al.*, 2003; Goh *et al.*, 2000).

In the present work fungi concentrations were determined using the same method employed for bacteria. For both the indoor and outdoor air samples, the concentrations of fungi are lower than the concentrations of the bacteria, which are consistent with other studies (Godwin and Batterman, 2007). As the measurements were taken between November 2011 and March 2012; and between November and December 2012, the weather conditions such as low temperatures and precipitation levels could explain lower outdoor concentrations. However, during heating season occupants spend more time in indoor environments, windows are closed more often and ventilation might be insufficient, thus indoor temperature and relative humidity become suitable for fungal growth indoors. Indoors fungal growth is mainly affected by their outdoor concentration and indoor factors such as temperature, humidity and building/furnishing materials (Meng *et al.*, 2012; Chao *et al.*, 2002). The amount of water on or in materials is the most important trigger of the growth of bacteria but also fungi (WHO, 2010c). Thus, although approaches to reduce and eliminate damp and mould from buildings exist, relevant public policies need to be strengthened (WHO, 2010c). Good design and proper construction can help to prevent problems from occurring (WHO, 2012). Maintenance and use of buildings can also be considered key factors to preserve healthy building; for example, a speedy response to water damage will help to keep the building/space in sound condition (WHO, 2012).

Concentrations found in schools were variable. When we compared our indoor fungi levels with the 500 CFU/m^3 established by the Portuguese legislation, the median level is lower than the reference value but higher than those values reported in other studies conducted in similar places (Grisoli *et al.*, 2012; Roda *et al.*, 2011; Mentese *et al.*, 2009; Kim *et al.*, 2007). A study carried out in elementary schools in Lisboa, Portugal (Pegas *et al.*, 2011b) reported much higher levels of indoor fungi concentration (mean values above 1802 CFU/m^3) but in the latter, fungi levels were monitored in spring.

Quantitatively determined concentrations of microbiological agents do not show a consistent association with respiratory health outcomes; in some cases, exposure to microbial factors is protective against asthma-related symptoms and wheezing, particularly for those who are exposed very early in life (Mendell *et al.*, 2011). The inconsistent association between exposure to bacteria/fungi and health outcomes in different studies could in part be due to variations in study design, sampling and analyzing method, season of the year for the measurements, region where the measurements have been made, climate and indoor activities, etc. (Chew *et al.*, 2003; Hyvarinen *et al.*, 2001; Ren *et al.*, 2001). Additionally, the culture method has been criticised because of the short-term nature of the measurement, which could not be representative of long-term exposure (Pasanen, 2001). This problem could be overcome by increasing the sampling time and the number of samples; but these were considered to be impractical due to cost and time limitations. Furthermore, the non-identification of the species-specific may contribute to the lack of association between microbiological agents' exposure and health outcomes. Several fungi produce allergens known to be associated with allergies and asthma; many fungi also produce toxins and irritants with suspected effects on respiratory health (Mentese *et al.*, 2009; WHO, 2009b). Stark *et al.* (2005) noted that total fungi concentrations would group diverse genera into a single exposure variable that may not accurately predict risk. In addition, Holme *et al.* (2010) found no significant association between fungi concentrations and health outcomes despite the significant associations with specific genera. Fungi species of *Penicillium*, *Aspergillus* and *Cladosporium* have been the most frequently associated with allergy and exist both in indoor and outdoor environments (Jo and Seo, 2005; Daisey *et al.*, 2003). This could imply that measurements of specific genera predict health outcomes better than viable fungi concentrations. Thus, developing a fundamental understanding of the origins and character of microbiological agents is therefore a research priority for reducing human exposure to microbiological agents in the indoor environment.

During the week of the study, temperature and relative humidity levels were recorded. Beyond meteorological specificities during the sampling campaign in each school, the difference between indoor temperatures may be related to the heating system as well as associated with building characteristics (probable better insulation of the more recent buildings, less exposed façades, sharing internal walls, etc.). The ASHRAE standard 55-2004 (2004) describes the temperature and relative humidity ranges that are comfortable for 80% of people engaged in chiefly sedentary activities. These values were conceived for adults in office environments and presume “normal indoor clothing”. The recommended indoor temperature ranges for comfort are 20-23 ºC in winter; while the suggested indoor relative humidity values for comfort are in the range 30-60%. Across the 73 classrooms median temperature was 20.8 ºC, being 47.2% of the classrooms within 20-23 ºC. More than two thirds (70.8%) of the classrooms had a relative humidity between 30% and 60%. Control of relative humidity helps to limit the growth of microorganisms. If relative humidity levels fall below 25%, building occupants can experience respiratory irritation and possibly dry, itchy eyes and skin.

On the other hand, eye complaints, such as burning, dryness, grittiness, itchiness, and a stinging feeling, scratchiness, soreness, blurry vision, strain, etc. (‘‘eye irritation’’), are commonly reported symptoms in epidemiological studies of the indoor environment (Wolkoff *et al.*, 2005). In our study, eye irritation (in the previous 3 months) was one of the most frequent symptoms reported by the parents (83.2%). The cause(s) of eye irritation in the indoor environment is (are) unknown, although several suspected factors have been studied (Wolkoff *et al.*, 2003). A clinical test to evaluate the tear film stability is the SBUT. While some different studies have shown possible effects of outdoor air pollution on the tear film (Gupta *et al.*, 2002), some studies investigate the relationship between indoor air parameters and tear film stability in adults in occupational or non-occupational settings (Wieslander and Norbäck, 2010; Wolkoff *et al.*, 2005). According to present knowledge, exposure to indoor VOC may alter the tear film at industrial concentration levels. However, in office environment VOC concentrations are generally 3-4 orders of magnitude lower than industrial levels or occupational exposure limits (Wolkoff *et al.*, 2005). Further, there is no convincing evidence that either VOC or particles at typical indoor levels result in an altered tear film, and are able to cause eye complaints (Wolkoff *et al.*, 2003). At present, it appears that oxidation products from the reaction between certain VOC that are used in household products as solvents or fragrances (for example, in air fresheners) and ozone may contribute to eye irritation, in addition to the well known eye irritants, for example, formaldehyde (Wolkoff *et al.*, 2008). Thus, although our results suggest that children can be exposed to formaldehyde and PM_{10} levels that could cause impaired tear film stability, our results should be interpreted with some caution. Moreover, break-up time tests in schools were not performed blindly introducing the possibility of bias. In addition, many other risk factors as lighting (glare and poor contrast), gaze position, impairment of the visual nervous system (Murata *et al.*, 1991) and stress (Thomson, 1998; Apter *et al.*, 1994) could play an important role. Thus, our results might be an effect of chance. Further research is need in the relationship between symptoms and clinical signs from the ocular mucosa.

Several aspects of this study are noteworthy as strengths. This study provides an IAQ investigation in a larger number of classrooms of public primary schools located in Porto and collected detailed information on health of a susceptible population. Our study had a large sample size in particular when compared with earlier studies carried out in Portugal (Pegas *et al.*, 2011a; Valente, 2010; Madureira *et al.*, 2009; Sousa, 2009; Neuparth *et al.*, 2006). In addition, measurements were performed using standardized procedures and the objective measurement of a broad spectrum of chemical, physical and comfort parameters and biological agents in classrooms allowed a better appraisal of individual exposure compared to indirect methods such as the use of questionnaires or checklists (Viegi *et al.*, 2004). Moreover, detailed health data on a large number of children (participation rate of about 70%) were collected in the questionnaire study, which makes the estimated prevalence of asthma, allergic and respiratory symptoms relatively unbiased. Additionally, the use of different objective clinical outcomes is also a point that should be emphasised.

Some limitations were present in our study. Because of the cross-sectional design of the study, our data do not allow causal relationships between indoor air parameters and health outcomes. Although indoor air pollution were avoided during vacations or weekends and the school staff and teachers were asked not to modify their activities and behaviour during the survey to reduce misclassification, the measurement conducted for a single week may be a poor surrogate for past months/year exposure. Furthermore, one problem is selection bias, when i.e. parents of allergic children might be more willing to respond to questionnaires focusing on asthma and allergy compared with parents of non-allergic children (Bornehag *et al.*, 2012). Furthermore, parents of children with allergies may also answer systematically differently compared with parents of children without allergy i.e. reporting bias. Minimizing all these potential biases as well as increasing the response rates are known ways to obtain good data quality in questionnaire studies (Morton *et al.*, 2006). Although the participation rate of 69.2% was reasonably high, the possibility of selection bias should still be considered. But this is likely to be minimal taking also into account that the prevalence of asthma obtained in the present study is in line with the previous studies. Indeed, there is a general trend that the response rates in questionnaire studies are declining and such a decreasing response rate can be seen in many parts of the world (Koshy and Brabin, 2012; Morton *et al.*, 2006). One possible reason for lower response rates could be that the number of studies (both scientifically based and those more commercially focused) have increased dramatically during the recent decade which might make people exhausted for answering surveys (Barclay *et al.*, 2002).

Since answers to parental-reported symptoms relied partly on the memory of the individuals, further information bias may also occur. Furthermore, they tend to respond erratically as they seem to identify themselves with the problem of the study.

For the current work, homes of 68 children (38 asthmatics and 30 controls) were also evaluated in order to investigate the relationships between exposure to indoor air parameters and asthma.

Residential IAQ is not regulated, and the levels of indoor pollution are not widely known. Some sources of indoor air pollution in homes are outdoor air, dampness, allergens, cleaning and consumer products, building materials, smoking, carpets, and biomass burning for fuel or cooking (Oliveira Fernandes *et al.*, 2008). Rive *et al*. (2013) showed that the dwellings of the asthmatics were more polluted by benzene than those of the non-asthmatics. The findings of the present research contrast with previous data as in the present study indoor air concentrations are in general similar for homes of children with and without asthma. Only a statistically significance was found for d-limonene and temperature. Similar to the present study, a previous case-control study including 150 asthmatic and 150 non-asthmatic children showed no differences in housing characteristics as well as in indoor air pollution among the two groups (Diette *et al.*, 2007). The results from the present study suggest that differences in lifestyle could influence IAQ, while it is possible that individuals with asthma and their families may selectively adapt their behaviour to avoid certain environmental triggers as part of a multifaceted approach to control asthma. Other possible explanation might be that the homes of asthmatic children have higher flow rates of outdoor air than control homes. Furthermore, it must be underlined that in the present study no statistically significant differences were found in the living conditions between case and control groups such as the presence of pets, use of air fresheners, incense sticks and humidifiers, the presence of stuffed toys and smoking habits at home.

As observed in classrooms, benzene, T3CE, T4CE, naphthalene and styrene were detected in less than 25% of the samples. On the contrary, many VOC were found in nearly every home in both groups, including toluene and other aromatics, which are present in household products, paints adhesives, synthetic fragrances, vehicle emissions and many others; and d-limonene, which is a constituent of cleaning products, air fresheners and fragrances (Steinemann *et al.*, 2011). In both groups toluene, d-limonene, formaldehyde and acetaldehyde have the highest median concentrations indoors; as it was observed for the classrooms.

In general, VOC concentrations are lower than levels reported in other studies for homes of individuals with asthma (or with asthma-like symptoms). For instance, in Sweden toluene averaged 120 $\mu g/m^3$ (range of 1 to 2330 $\mu g/m^3$) in living rooms and bedrooms sampled in 1991 and 1992

(Norback *et al.*, 1995); and in Korea, toluene, p/m-xylene had mean concentrations of 31 µg/m^3, in homes of children sampled in 2008 (Hwang *et al.*, 2011).

It would be reasonable to expect that families with asthmatic children clean their homes more frequently than control families, fact that could lead to an increase the indoor levels of terpenes such as d-limonene in case homes. In this study no significant statistical differences was found in what regards cleaning frequency in both case and control homes. That suggests that, although families from both groups clean their homes with similar frequency, the case families probably use low-emitting consumer products. This fact might explain the statistically significant differences found in indoor d-limonene concentrations between case and control group; with higher levels of d-limonene found in the control groups.

In the present study the median concentrations of TVOC are lower than 200 µg/m^3, with a total of 4 homes (2 homes for each group) exceeding 600 µg/m^3. These results are higher than those exposure level reported by Rumchev *et al.* (2004) (median of 78.5 µg/m^3 in case homes and 36.2 µg/m^3 in control homes), who also reported that children exposed to TVOC at levels higher than 60 µg/m^3 are 4 times more likely to have asthma than those who were not exposed to such levels. In addition to the VOC indoor sources, the proximity of heavy traffic roads as well as of gasoline dispensing facilities and the existence of attached garages could also contribute to the indoor TVOC concentrations, although there were no significant differences among those variables in the homes of asthmatic children when compared with control children, except for gasoline dispense facilities (p=0.020).

Aldehydes (formaldehyde and acetaldehyde) were detected in every indoor samples. Measured levels of indoor formaldehyde are not strictly comparable with IAQ WHO guidelines (2010c), because of differing average exposure times; however, it is reasonable to assume that they did not exceed WHO neither for the case nor for the control homes. In the present study, in both groups, the concentration of formaldehyde is somewhat lower compared with previous studies. Indoor levels of formaldehyde in dwellings in various nations generally range between 7.3 and 50.4 µg/m^3, although concentrations exceeding 120 µg/m^3 have also been observed (Lovreglio *et al.*, 2009). A recent study measured the formaldehyde concentrations using passive samplers in residential environments in 12 European cities, finding a mean level of 23.8 µg/m^3 across Europe (Bruinen *et al.*, 2008), which is higher than those in the present study. Dassonville *et al.* (2009) measured five aldehydes on several occasions over the course of one year in the bedrooms of 196 Parisian infants randomly selected from a birth cohort study and reported mean concentration of 19.4 µg/m^3. It is likely that indoor formaldehyde concentrations are derived from indoor sources such as gas appliances, building materials including new coverings, smoking and the use of air fresheners and, ultimately influenced by ventilation rates. Acetaldehyde, another aldehyde emitted from building materials or combustion sources such as cigarette smoke, was also found, even at low levels, higher for control than for cases homes; however the differences were not statistically significant.

Concerning particulate matter, the number of samples from home does not equal 68 in total due to equipment problems. Thus, as a result of the smaller number of measurements, both indoors and outdoors, the results on particulate matter have to be carefully analysed. WHO air quality guidelines 24 hours values for $PM_{2.5}$ were exceeded in the majority of homes (100% in case group and 89% in control group) (WHO, 2005); while 20 homes (8 cases and 12 control homes) exceeded the corresponding value PM_{10} guidelines value (50 µg/m^3). As been reported elsewhere, smoking is a major determinant of indoor particulate matter concentrations (Fontham *et al.*, 2009; WHO, 2009d). Previous studies have consistently reported increased particulate matter concentrations in homes with smokers, indicating that smoking contribution to indoor $PM_{2.5}$ ranges from 25 to 45 µg/m^3. Nonetheless, as the sampling of $PM_{2.5}$ and PM_{10} was performed in the children bedroom, the results might be not so influenced by tobacco smoke, although more than 25% of the parents in both groups referred exposure to tobacco smoke at home. In addition, some specifically identified sources of particulate matter (e.g., traffic emissions, fuel combustion for heating and/or cooking), human-related activities (e.g. burning candles, incense, cleaning, walking) can contribute to the increase of indoor particulate matter levels (Chao *et al.*, 2002) in both groups. To be noticed that the potential influence of ambient particulate concentrations on indoor levels cannot be carefully evaluated as measurements were incomplete due to missing values.

In the present study, indoor $PM_{2.5}$ levels are generally higher than those found in northern Europe and the United States (Rodes *et al.*, 2010; Brown *et al.*, 2008; Meng *et al.*, 2005; Hanninen *et al.*, 2004; Lai *et al.*, 2004; Adgate *et al.*, 2003).

ASHRAE guideline value for CO_2 (1000 ppm) is exceeded in most dwellings (in 59.3% of cases *vs.* 62.5% of controls, p=0.815). Its median values in case and control homes were recorded as 1121 ppm and 1157 ppm, respectively. These values were lower than those obtained during teaching hours in the schools. Higher CO_2 values were obtained during the night when the bedroom door, in most of situations, is closed (data not shown). Low ventilation rates could result in higher gas phase concentrations of volatile pollutants generated indoors and prolongs the persistence of VOC. Finally, low ventilation rates mean also longer residence times for airborne pollutants and more time for chemical reactions among these pollutants. In the present survey, control homes, which are inserted in more recent constructions, have lower ventilation rate.

There are also many other potential indoor exposures including bacteria and fungi agents. The main factors affecting atmospheric dispersion and survival of microorganisms are the relative humidity, temperature, oxygen, wind and air turbulence, air pollutants and water and nutrient availability (WHO, 2009b). Regarding the bacteria levels, it was found higher concentrations indoors than outdoors; while the similarity of indoor and outdoor airborne fungal concentrations suggests limited indoor sources of fungi, i.e. that indoor concentrations may be impacted by outdoor levels. Although without significant statistical differences, higher concentrations of fungi in control group than in case group were observed. Only median bacteria concentration in asthmatic and non-asthmatic homes exceeded the value recommended by Portuguese legislation (500 CFU/m^3).

The high amounts of bacteria in both indoor and outdoor may derive from several factors, including levels in outdoor air, from the human self-activities, such as breathing, sweating and movement causing particle re-suspension (WHO, 2009b).

Concentrations of total bacteria assessed in a study among 6 elderly care centres are close to that of our study (Mendes *et al.*, 2013). The results from this study show lower concentrations of bacteria and fungi at bedrooms than those obtained in classrooms. In accordance with these findings, previous studies have found higher levels in children day care centres than in homes (Oldfield *et al.*, 2007; Wan and Li, 1999). The similar trends of bacteria and CO_2 concentrations by classroom in our study indicate possible human source of the bacteria. Low ventilation rates and crowded conditions increase CO_2 levels, and bioeffluent concentrations, including bacteria and fungi. In addition, building characteristics and activities more specific to schools might reflect the respective higher levels compared to those in homes.

Previously, large concentrations of fungi and bacteria in association with visible mould growth have been reported, but some studies have found no difference in indoor concentrations between houses with mould problems and "reference" houses (WHO, 2009b). Suggested reasons for a lack of an association in some studies have included the variability of indoor sources including occupant behaviour, cleaning activities, etc. (WHO, 2009b). In the present study, during the house surveys signs of indoor mould growth were mostly observed in the case group homes (47.2% *vs.* 20.0%, $p<0.022$); and signs of high humidity was observed in 51.4% of the case homes and 36.7% in control homes ($p=0.233$). In addition, all microbiological samples were collected with bedroom windows closed. Supporting these results are the more common signs of high humidity (dampness/condensation on windows) in case homes (51.4% of case homes).

It should be noticed that microbiological agents were determined using short-term indoor measurements and thus require careful and cautions interpretation given the influence of outdoor concentrations and the great variation that can occur very rapidly (Chew *et al.*, 2003; Cho *et al.*, 2000). Although there is an agreement on the harmful effects of microbiological agents on human health, there are no threshold values available for indoor bioaerosol concentrations. Thus, according to (WHO, 2009b) the most important means for avoiding adverse health effects is the prevention (or minimization) of persistent dampness and microbial growth on interior surfaces and in building structures. In addition, the culture-base method has some limitations as stated above. Furthermore, the non-identification of the species-specific may contribute to the lack of association between microbiological agents' exposure and health outcomes. Species level identification and molecular quantification methods may alleviate some of the inconsistencies.

Air temperature in the dwellings of asthmatic children ranged from 10.7 °C to 22.3 °C (median=16.7 °C), whereas relative humidity ranged from 36% to 84% (median=65%). Air temperature in the dwellings of control group ranged from 14.6 ºC to 23.0 °C (median=17.7 °C), whereas relative humidity ranged from 43 to 82% (median=66%). In what regards the temperature, the differences may be associated with building characteristics (e.g. less exposed façades, sharing internal walls in case of apartments) but also with occupant behaviour (e.g., different strategies for heating systems/apparatus on/off and for ventilation).

An increasing number of investigations have been carried out to assess the health effects associated with a poor IAQ, especially in populations with asthma and asthma-related symptoms (Mendell, 2007; Viegi *et al.*, 2004). Additionally, other studies have related indoor air pollution to respiratory symptoms aggravation (Martins *et al.*, 2012; Viegi *et al.*, 2004). In the present study, the multiple regression models, adjusted for age, sex, mother's education level and indoor exposure in classrooms, showed that there was no significant association between IAQ and asthma. Conversely, studies done in homes of asthmatic children have suggested that higher indoor benzene (Rive *et al.*, 2013), toluene concentrations (Rumchev *et al.*, 2004) as well as formaldehyde levels led to increased asthma-related symptoms in young children (Rumchev *et al.*, 2002). In a subsample of the 6 Cities study, exposure to acetaldehyde, toluene and formaldehyde at home was also significantly associated with a higher risk of asthma (Hulin *et al.*, 2010). To be noticed that, for the above studies only the exposure at home was taken into account.

Several hypotheses could explain these inconsistencies. A possible explanation might be to the lower levels of indoor air pollutants in the present study when compared to those results obtained in the previous one and due to little variation in levels of indoor air parameters which are remarkably similar at homes of children with or without asthma. In addition, the small sample size resulted in a study with lower statistical power and reverse causality cannot be excluded. Therefore, further research on exposure to indoor air relating to asthma should focus more into a large sample size of homes. Furthermore, the results of this study should not dissuade clinicians and policy makers from continuing to work toward improvement in certain aspects of the home environment for the sake of children with existing asthma.

A particular strength of the current study is the wide range of the indoor air measured parameters that enhanced the understanding of the indoor air environment in which children, in particular those with asthma, live. These data were obtained using the same procedures, methods and laboratory analyses of those data collected in schools. These results provide some of the first measurements of IAQ at children's home, and are also valuable given the paucity of existing data. Indoor air quality assessments were based on objective assessments thus limiting misclassification. Such assessments are more reliable than source classifications through home characteristics collected only by questionnaire or checklist. Although in the present study indoor monitoring was limited to seven consecutive days in each home, the occurrence of some stability is expected because indoor source activities patterns tend to be consistent from day to day. In the present study residents were asked not to modify their usual habits and activities. For this reason, data collection was avoided during vacations and a "classic" week was chosen. In addition, the sample was drawn from the participants in cross-sectional study in schools; and data collection took place in real life conditions. Therefore we can assume that measure exposure is representative of usual exposure at least in a recent period.

On the limitations, first of all, this study was based on a small sample size and therefore resulted in a study with a lower statistical power. We conducted a case-control study which is known to have a potential problem with selection bias. Briefly, it is more likely that the people who were most interested participated in the study. Moreover, as the recruitment of cases and controls was based on volunteer householders, this could have attracted volunteers who were aware of indoor pollution and this may lead to an underestimation of indoor air pollution levels at homes and may have contributed to the lower concentrations observed. A further source of selection bias in this study may have arisen from refusals. Even if the parents gave reasons for their refusals to participate ("too busy"), the refusal of having a survey in a home may be associated with a particular lifestyle, which may affect the concentrations of indoor pollutants. Study children in this investigation may therefore represent a group with relatively lower exposure to indoor air pollutants.

Moreover, recall bias may have been introduced because parents who live with asthmatic/allergic children may be more prone to reporting their exposure although information has been collected in a uniform manner. For instance, parents of children with asthma often have some knowledge of environmental triggers and appropriate environmental modifications; they might be eager to give the "right" answer rather than the true answer, especially to sensitive questions about smoking, and having pets. On the other hand, underreporting may also occur among the asthmatic cases because of parental avoidance of reporting illness of their children. Such reporting bias does not occur to the same extent in longitudinal studies, which made results less subject to recall bias and allowed assessment of temporal relationships (Morton *et al.*, 2006).

7. Conclusions

This chapter presents the main conclusions of this thesis bearing in mind the objectives set in Chapter 2, highlighting some subsidies for potential recommendations for risk management of indoor air exposure and concluding with a few proposals for further research.

7.1 Main Findings

Although restricted to the field of children asthma and allergies, the results of this thesis are in general consistent with the existing literature and contribute with new information on school and home IAQ condition in Portugal and their relationship with children health.

In general, despite the fact that the concentration for the most indoor air parameters in the schools evaluated in this study are in accordance with IAQ guidelines/recommendations, exposure to indoor air could increase respiratory complaints among children.

Some of the related specific results pointed out:

- Data from health outcomes collected with a standardized questionnaire submitted to parents are consistent with previous national findings:
    - The prevalence of wheeze ever was 30.3% and 11.1% in preceding 12 months; while the diagnosis for asthma had a prevalence of 9.2%.
    - In what regards rhinitis, doctor-diagnosed nasal allergy was reported at 12.7%, but a higher percentage of children reported runny nose symptoms (43.7%) and blocked nose symptoms (54.1%). In addition, the prevalence of ever nasal allergy and nasal allergy in the past 12 months was 16.7% and 24.6%, respectively.
- Indoor exposure to VOC, $PM_{2.5}$ and PM_{10} in classrooms even some at low levels may be associated with asthma-related symptoms.
    - Children exposed to TVOC at levels of $\geq$189.84 $\mu g/m^3$ had a twofold increased risk of having asthma-related symptoms. These findings were supported by the results of spirometry and eNO tests which suggested for the existence of chronic airway inflammation.
    - Higher $PM_{2.5}$ and PM_{10} levels increase the odds of asthma-like symptoms; the association was stronger for PM_{10}. Spirometry did not reveal an obstructive pattern. It would be possible to suppose that $PM_{2.5}$ and PM_{10} may be associated with airway inflammation if it is taken into account that, although not significant, eNO levels were higher in the 3rd tertile

among the children with symptoms. Thus, the present study supports the pro-inflammatory role of $PM_{2.5}$ and PM_{10}, especially among the most susceptible children.

- There was no significant association between indoor air parameters at home and asthma; however we could not exclude the effect of lack of statistical power or a reverse of causality.

The results generally support the findings of previous studies. Furthermore, some progress seems to have been achieved in the interpretation of data obtained from IAQ measurements for the purpose of risk assessment that will allow designing preventive strategies and presenting information regarding risk management in a format accessible to the general public. The related specific results are:

- Most classrooms presented indoor concentrations below the values established by WHO IAQ guidelines or by EU-INDEX recommendations, while particular concentrations of certain parameters could indicate an opportunity or need for the implementation of programs to further improve IAQ by, firstly, controlling pollutant sources.
    - Most of individual VOC had median levels lower than 5 µg/m^3.
    - d-limonene followed by aromatic compounds toluene and xylene were usually the most abundant classes of VOC indoors.
    - Median $PM_{2.5}$ and PM_{10} levels exceeded the recommended WHO air quality guidelines in all classrooms.
    - In 86% of the classrooms the mean CO_2 concentrations exceeded 1000 ppm indicating inadequate ventilation during teaching period.
    - Mean levels of bacteria (>500 CFU/m^3 – maximum concentration value established by Portuguese legislation) were observed in 63 (86%) classrooms.
- Indoor air pollution in classrooms differs from outdoor pollution chiefly in some parameters whose indoor values are markedly higher. Namely,
    - The median I/O ratios for most VOC were greater than 1; confirming that for this class of pollutant indoor sources could be more important than outdoor sources.
    - In general, the indoor concentrations of formaldehyde, CO_2 and bacteria were higher than those observed outdoors.
- Although features of school/classrooms buildings (for instance the type of flooring) can influence IAQ parameters, the behaviour and activities of the occupants such as opening windows, seem to have a more important role in the IAQ.
- The indoor environment of the homes of children with or without asthma is remarkably similar.
    - No significant difference was observed between IAQ in the case and control homes, except for d-limonene and temperature.
- Additionally, indoor levels at home generally accomplished the WHO IAQ guidelines and EU-INDEX recommendations; what can explain the lack of association between IAQ and asthma in

the present study. However, as a result of the small number of indoor and outdoor measurements, caution should be applied in interpreting data for particulate matter.

- The median concentrations of most of the single VOC measured in this study were below 5 $\mu g/m^3$, excepting toluene and d-limonene compounds.
- WHO air quality guidelines 24 hours values for $PM_{2.5}$ were exceeded in most homes (100% for the case group and 89% for the control group); while 20 homes (8 case homes and 12 control homes) exceeded the corresponding value PM_{10} guidelines value (50 $\mu g/m^3$).
- More than half of the case and control homes investigated had mean CO_2 concentrations above 1000 ppm (59.3% *vs*. 62.5%, respectively).

7.2 Subsidies for some Recommendations

The complexity of the relationships between indoor air exposures and health effects, which are furthermore embedded in the larger set of all exposures and all health risks, inspires a prudent attitude that may be expressed in three basic tenets: 1) caution in deriving judgments from personal experience and original research unless it is consistent with previous research results, which unfortunately are quite sparse in the field of IAQ and health; 2) to bear in mind that different climates inspire different practices in designing, building and managing domestic and school buildings, so that some caution must be adopted when attempting to compare results from different places around the world; and, 3) to take to heart the lessons arising from the two most recent models for IAQ management, namely EnVIE that stresses the priority to source control, awarding a subsidiary role to ventilation, and HealthVent that preconizes decoupling ventilation from the heating and cooling functions and establishing ventilation levels based solely on health criteria.

Nonetheless, a set of general recommendations can be derived from this thesis bearing in mind the specificity of the experience and results obtained for the schools and homes in the light of the models mentioned above.

A. Starting by source control, it could be recommended:

- To express a word of caution regarding the quality of the air in the urban environment in general.
- To carefully study the location of future buildings, in particular when dealing with susceptible populations (children, elderly people, and families in general).
- To take IAQ and health related issues in due consideration from the building design stage bearing in mind its:

- Location and relationship with the outdoor environment: noise and air pollution in the surrounding environment; organization of the surrounding spaces and traffic lines and air circulation around the building in connection with the openings in the building envelope.
- Proper level of continuous thermal insulation of the envelope avoiding solutions of continuity that may cause condensations and dampness indoors.
- Organization of indoor spaces considering indoor air flows, specification of clean building materials and components, claddings and furniture and selection of equipment and of its location indoors.
- Proper location of spaces with specific uses (classes, labs, copying, drawing and painting activities, etc.) in order to facilitate the source control.
- Functions and schedules of use (for instance, in schools, density of occupation, duration of classes and breaks, routines of cleaning and maintenance operations).

B. Regarding ventilation, it could be recommended:

- To decouple heating and cooling functions from ventilation proper allowing for a better fit of the ventilation level with the actual health needs.
- To pre-set the density of occupation per room and explore the opportunities for the admission of outside air.
- To assess the opportunities for natural ventilation *vs*. the need for mechanical ventilation.

A pragmatic set of guidelines has been recently produced within the SINPHONIE project, and will be published soon by the JRC as an autonomous report. This document will include a detailed coverage of the requirements for healthy school buildings.

At this stage it is particularly relevant to stress that:

1. Exposure control regarding indoor air is not, from the strategic point of view, an issue to be left for a later stage and be undertaken by over sizing ventilation, and eventually mechanizing it, a naïve approach that unfortunately overwhelms other essential aspects to be tackled upstream, such design, construction and functional strategies.
2. There is a need to consider the built environment as a whole, namely looking at “outdoor” and “indoor” air as a continuum and approaching the individual building from the early stage of its design, the neighborhood and the whole city accordingly.

7.3 Further Studies

Exposure assessment is one of the main challenges. Given the complex exposure patterns, uncertainties and time lags in health impacts, there is a need for new ways of appraising health risk evidence, drawing from a range of sources and methods.

Further research would enrich the limited literature available on the study of asthma, allergies and respiratory problems and their relationships to indoor air exposure. Therefore, in the particular case of the theme of this thesis, further work is needed to assess the indoor environment in a larger sample of schools and homes and its long-term health effects.

Further research would enrich the limited literature available on the study of asthma, allergies and respiratory problems and their relationships to indoor air exposure. Therefore, in the particular case of the theme of this thesis, further work is needed to assess long-term health effects of the indoor environment.

Findings from this study should be tested using, namely a birth cohort; aiming to investigate the importance of early life exposure to environmental agents as well as the risk factors for different chronic diseases/disorders in children later in life. In particular such studies should be based on the concept of the “exposome”, referred to as “the totality environmental exposures from conception onwards”.

Indeed, as part of a large European study HEALS (Health and Environment-wide Associations based on Large population Surveys) in which IDMEC-FEUP is participating, an “exposome study” is currently being carried out and could give an impulse towards broader and better sized studies that will be necessary to fully elucidate the complex links between health and environment.

References

2006. *Health Effects of School Environment (HESE) - Final Scientific Report* [Online]. Available: http://ec.europa.eu/health/ph_projects/2002/pollution/fp_pollution_2002_frep_04.pdf [Accessed].

Adan, O. C. G. 1994. On the fungal defacement of interior finishes'. Technical University of Eindhoven.

Adgate, J. L., Church, T. R., Ryan, A. D., Ramachandran, G., Fredrickson, A. L., Stock, T. H., Morandi, M. T. & Sexton, K. 2004. Outdoor, indoor, and personal exposure to VOCs in children. *Environ. Health Perspect.,* 112**,** 1386-1392.

Adgate, J. L., Ramachandran, G., Pratt, G. C., Waller, L. A. & Sexton, K. 2003. Longitudinal variability in outdoor, indoor, and personal PM2.5 exposure in healthy non-smoking adults. *Atmospheric Environment,* 37**,** 993-1002.

Almeida, M., Lopes, I. & Nunes, C. 2010. Caracterização da qualidade do ar interior em Portugal – estudo HabitAr. *Ver Port Imunoalergologia,* 18**,** 21-38.

Almeida, S. M., Canha, N., Silva, A., Freitas, M. d. C., Pegas, P., Alves, C., Evtyugina, M. & Pio, C. A. 2011. Children exposure to atmospheric particles in indoor of Lisbon primary schools. *Atmospheric Environment,* 45**,** 7594-7599.

American Society for Testing and Materials International Standards Worldwide 2002. ASTM D 6245-98 (2002) Standard guide for using indoor carbon dioxide concentrations to evaluate indoor air quality and ventilation.

American Society for Testing and Materials International Standards Worldwide 2006. ASTM E 741-00 (2006) Standard test method for determining air change in a single zone by means of a tracer gas dilution.

American Thoracic Society 1995. Standardization of Spirometry - 1994 Update. *American Journal of Respiratory and Critical Care Medicine,* 152**,** 1107-1136.

American Thoracic Society; European Respiratory Society 2005. ATS/ERS recommendations for standardized procedures for the online and offline measurement of exhaled lower respiratory nitric oxide and nasal nitric oxide, 2005. *American Journal of Respiratory and Critical Care Medicine,* 171**,** 912-930.

Andersen, A. 1958. New sampler for the collection, sizing, and enumeration of viable airborne particles. *J Bacteriol,* 76**,** 471-84.

Annesi-Maesano, I., Agabiti, N., Pistelli, R., Couilliot, M. F. & Forastiere, F. 2003. Subpopulations at increased risk of adverse health outcomes from air pollution. *European Respiratory Journal,* 21**,** 57s-63s.

Annesi-Maesano, I., Baiz, N., Banerjee, S., Rudnai, P., Rive, S. & The Sinphonie, G. 2013. Indoor air quality and sources in schools and related health effects. *J Toxicol Environ Health B Crit Rev,* 16**,** 491-550.

Annesi-Maesano, I., Lavaud, F., Raherison, C., Kopferschmitt, C., Blay, F. d., Charpin, D. & Caillaud, D. 2012. Poor air quality in classrooms related to asthma and rhinitis in primary schoolchildren of the French 6 Cities Study. *Thorax,* 67**,** 682-8.

Annesi-Maesano, I., Moreau, D., Caillaud, D., Lavaud, F., Le Moullec, Y., Taytard, A., Pauli, G. & Charpin, D. 2007. Residential proximity fine particles related to allergic sensitisation and asthma in primary school children. *Respir Med,* 101**,** 1721-9.

Anthracopoulos, M. B., Antonogeorgos, G., Liolios, E., Triga, M., Panagiotopoulou, E. & Priftis, K. N. 2009. Increase in chronic or recurrent rhinitis, rhinoconjunctivitis and eczema among schoolchildren in Greece: Three surveys during 1991-2003. *Pediatric Allergy and Immunology,* 20**,** 180-186.

Antova, T., Pattenden, S., Brunekreef, B., Heinrich, J., Rudnai, P., Forastiere, F., Luttmann-Gibson, H., Grize, L., Katsnelson, B., Moshammer, H., et al. 2008. Exposure to indoor mould and children's respiratory health in the PATY study. *J. Epidemiol. Com. Health* 62**,** 708-714.

Apter, A., Bracker, A., Hodgson, M., Sidman, J. & Leung, W. Y. 1994. Epidemiology of the Sick Building Syndrome. *Journal of Allergy and Clinical Immunology,* 94**,** 277-288.

Arvanitis, A., Kotzias, D., Kephalopoulos, S., Carrer, P., Cavallo, D., Cesaroni, G., De Brouwere, K., de Oliveira-Fernandes, E., Forastiere, F., Fossati, S., et al. 2010. The Index-Pm Project: Health Risks from Exposure to Indoor Particulate Matter. *Fresenius Environmental Bulletin,* 19**,** 2458-2471.

Asher, M. I., Anderson, H. R., Stewart, A. W., Crane, J., Ait-Khaled, N., Anabwani, G., Anderson, H. R., Beasley, R., Bjorksten, B., Burr, M. L., et al. 1998. Worldwide variations in the prevalence of asthma symptoms: the International Study of Asthma and Allergies in Childhood (ISAAC). *European Respiratory Journal,* 12**,** 315-335.

Asher, M. I., Keil, U., Anderson, H. R., Beasley, R., Crane, J., Martinez, F., Mitchell, E. A., Pearce, N., Sibbald, B., Stewart, A. W., et al. 1995. International Study of Asthma and Allergies in Childhood (ISAAC) - Rationale and Methods. *European Respiratory Journal,* 8**,** 483-491.

Asher, M. I., Montefort, S., Bjorksten, B., Lai, C. K. W., Strachan, D. P., Weiland, S. K. & Williams, H. 2006. Worldwide time trends in the prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and eczema in childhood: ISAAC Phases One and Three repeat multicountry cross-sectional surveys. *Lancet,* 368**,** 733-743.

ASRHAE 2004. ASHRAE Standard 55-2004 Thermal Environmental Conditions for Human Occupancy.

Assembleia da República 2007. Lei n.º 37/2007 de 14 de Agosto. Normas para a protecção dos cidadãos da exposição involuntária ao fumo do tabaco e medidas de redução da procura relacionadas com a dependência e a cessação do seu consumo. Imprensa Nacional Casa da Moeda, Portugal.

Bach, J. F. 2002. The effect of infections on susceptibility to autoimmune and allergic diseases. *N Engl J Med,* 347**,** 911-20.

Baeza, A. & Marano, F. 2007. [Air pollution and respiratory diseases: a central role for oxidative stress]. *Med Sci (Paris),* 23**,** 497-501.

Bahadori, K., Doyle-Waters, M. M., Marra, C., Lynd, L., Alasaly, K., Swiston, J. & Fitzgerald, J. M. 2009. Economic burden of asthma: a systematic review. *BMC Pulm Med,* 9**,** 24.

Bakolis, I., Doekes, G., Heinrich, J., Zock, J. P., Heederik, D., Kogevinas, M., Guerra, S., Norbäck, D., Ramasamy, A., Nevalainen, A., et al. 2012. Respiratory health and endotoxin: associations and modification by CD14/-260 genotype. *European Respiratory Journal,* 39**,** 573-581.

Barclay, S., Todd, C., Finlay, I., Grande, G. & Wyatt, P. 2002. Not another questionnaire! Maximizing 8 the response rate, predicting non-response and assessing non-response bias in postal questionnaire 9 studies of GPs. *Family practice* 19**,** 105-111.

Barnes, P. J., Jonsson, B. & Klim, J. B. 1996. The costs of asthma. *European Respiratory Journal,* 9**,** 636-42.

Barros, H., Pereira, C. & Mateus, P. 1999. Asma em crianças dos 6 aos 9 anos. Um estudo populacional em duas cidades portuguesas (Porto e Viseu). *Rev Port Imunoalergologia*.

Bateman, E., Hurd, S., Barnes, P., Bousquet, J., Drazen, J. & FitzGerald, M. 2008. Global strategy for asthma management and prevention: GINA executive summary. *Eur Respir J* 31**,** 143-78.

Bateman, E. D. & Jithoo, A. 2007. Asthma and allergy - a global perspective. *Allergy,* 62**,** 213-5.

Baulig, A., Garlatti, M., Bonvallot, V., Marchand, A., Barouki, R., Marano, F. & Baeza-Squiban, A. 2003. Involvement of reactive oxygen species in the metabolic pathways triggered by diesel exhaust particles in human airway epithelial cells. *Am J Physiol Lung Cell Mol Physiol,* 285**,** L671-9.

Behrens, T., Maziak, W., Weiland, S., Rzehak, P., Siebert, E. & Keil, U. 2005. Symptoms of asthma and the home environment. The ISAAC I and III cross-sectional surveys in Munster, Germany. *Int Arch Allergy Immunol* 137**,** 53-6.

Bernstein, J. A., Alexis, N., Bacchus, H., Bernstein, I. L., Fritz, P., Horner, E., Li, N., Mason, S., Nel, A., Oullette, J., et al. 2008. The health effects of non-industrial indoor air pollution. *J Allergy Clin Immunol,* 121**,** 585-91.

Biagini, J., LeMasters, G. & Ryan, P. 2006. Environmental risk factors of rhinitis in early infancy. *Pediat Allergy and Immunol* 17**,** 278-84.

Billionnet, C., Gay, E., Kirchner, S., Leynaert, B. & Annesi-Maesano, I. 2011. Quantitative assessments of indoor air pollution and respiratory health in a population-based sample of French dwellings. *Environmental Research,* 111**,** 425-434.

Bjornson, C. & Mitchell, I. 2000. Gender differences in asthma in childhood and adolescence. *J Gend Specif Med,* 3**,** 57-61.

Bloom, E., Nyman, E., Must, A., Pehrson, C. & Larsson, L. 2009. Molds and Mycotoxins in Indoor Environments - A Survey in Water-Damaged Buildings. *Journal of Occupational and Environmental Hygiene,* 6**,** 671-678.

Bluyssen, P. M., De Oliveira Fernandes, E., Groes, L., Clausen, G., Fanger, P. O., Valbjørn, O., Bernhard, C. A. & Roulet, C. A. 1996. European Indoor Air Quality Audit Project in 56 Office Buildings.

Bonay, M. & Aubier, M. 2007. [Air pollution and allergic airway diseases]. *Med Sci (Paris),* 23**,** 187-92.

Bornehag, C., Sundell, J., Weschler, C., Sigsgaard, T., Lundgren, B., Hasselgren, M. & Hägerhed-Engman, L. 2004a. The association between asthma and allergic symptoms in children and phthalates in house dust: a nested case-control study. *Environ Health Perspect,* 112**,** 1393-1397.

Bornehag, C. G., Lundgren, B., Weschler, C. J., Sigsgaard, T., Hagerhed-Engman, L. & Sundell, J. 2005. Phthalates in indoor dust and their association with building characteristics. *Environmental Health Perspectives,* 113**,** 1399-1404.

Bornehag, C. G., Moniruzzaman, S., Larsson, M., Lindstrom, C. B., Hasselgren, M., Bodin, A., von Kobyletzkic, L. B., Carlstedt, F., Lundin, F., Nanberg, E., et al. 2012. The SELMA study: a birth cohort study in Sweden following more than 2000 mother-13 child pairs. *Paediatr Perinat Epidemiol* 26**,** 456-467.

Bornehag, C. G. & Nanberg, E. 2010. Phthalate exposure and asthma in children. *Int J Androl,* 33**,** 333-45.

Bornehag, C. G., Sundell, J., Bonini, S., Custovic, A., Malmberg, P., Skerfving, S., Sigsgaard, T. & Verhoeff, A. 2004b. Dampness in buildings as a risk factor for health effects, EUROEXPO: a multidisciplinary review of the literature (1998-2000) on dampness and mite exposure in buildings and health effects. *Indoor Air,* 14**,** 243-257.

Borrego, C., Neuparth, N., Carvalho, A. C., Carvalho, A., Miranda, A. I., Costa, A. M., Monteiro, A., Martins, H., Correia, I., Ferreira, J., et al. 2008. A Saúde e o Ar que Respiramos um caso de estudo em Portugal, Fundação Calouste Gulbenkian.

Bousquet, J., Burney, P., Zuberbier, T., Cauwenberge, P., Akdis, C. & Bindslev-Jensen, C. 2009. GA2LEN (Global Allergy and Asthma European Network) addresses the allergy and asthma 'epidemic'. *Allergy,* 64**,** 969-77.

Bousquet, J., Dahl, R. & Khaltaev, N. 2007. Global alliance against chronic respiratory diseases. *Allergy,* 62**,** 216-223.

Bousquet, J., Khaltaev, N., Cruz, A. A., Denburg, J., Fokkens, W. J., Togias, A., Zuberbier, T., Baena-Cagnani, C. E., Canonica, G. W., van Weel, C., et al. 2008. Allergic rhinitis and its impact on asthma (ARIA) 2008 update (in collaboration with the World Health Organization, GA(2)LEN and AllerGen). *Allergy,* 63**,** 8-+.

Branco, M., Nogueira, P. & Contreiras, T. 2005. Report on prevalence estimates of some chronic diseases in mainland Portugal. Lisboa: Observatório Nacional de Saúde.

Brasche, S. & Bischof, W. 2005. Daily time spent indoors in German homes - Baseline data for the assessment of indoor exposure of German occupants. *International Journal of Hygiene and Environmental Health,* 208**,** 247-253.

Brauer, M., Hoek, G., Van Vliet, P., Meliefste, K., Fischer, P., Wijga, A., Koopman, L., Neijens, H., Gerritsen, J., Kerkhof, M., et al. 2002. Air pollution from traffic and the development of respiratory infections and asthmatic and allergic symptoms in children. *Am J Respir Crit Care Med,* 166**,** 1092-8.

Broms, K. 2010. A nationwide study of asthma and allergy in Swedish preschool children. Uppsala University.

Brown, K. W., Sarnat, J. A., Suh, H. H., Coull, B. A., Spengler, J. D. & Koutrakis, P. 2008. Ambient site, home outdoor and home indoor particulate concentrations as proxies of personal exposures. *Journal of Environmental Monitoring,* 10**,** 1041-1051.

Bruinen, d. B. Y., Koistinen, K., Kephalopoulos, S., Geiss, O., Tirendi, S. & Kotzias, D. 2008. Characterisation of urban inhalation exposures to benzene, formaldehyde and acetaldehyde in the European Union: comparison of measured and modelled exposure data. *Environ Sci Pollut Res Int* 15**,** 417-30.

Brunekreef, B., Dockery, D. & Speizer, F. 1989. Home dampness and respiratory morbidity in children. *Am Rev Respir Dis* 140**,** 1363-7.

Brunekreef, B., Janssen, N., de Hartog, J., Harssema, H., Knape, M. & van Vliet, P. 1997. Air pollution from truck traffic and lung function in children living near motorways. *Epidemiology,* 8**,** 298-303.

Bruno, P., Caselli, M., de Gennaro, G., Iacobellis, S. & Tutino, M. 2008. Monitoring of volatile organic compounds in non-residential indoor environments. *Indoor Air,* 18**,** 250-256.

Bugalho, d. A. A. 2008. Plano Nacional de Controlo da Asma - Plano de actividades. Lisboa: Centro Hospitalar Lisboa Norte.

Bugalho, d. A. A., Covas, A., Prates, L. & Fragoso, E. 2009. Asthma hospital admission and mortality in mainland Portugal 2000-2007. *Rev Port Pneumol* 15**,** 367-83.

Burgess, J. A., Lowe, A. J., Matheson, M. C., Varigos, G., Abramson, M. J. & Dharmage, S. C. 2009. Does Eczema Lead to Asthma? *Journal of Asthma,* 46**,** 429-436.

Burney, P., Luczynska, C., Chinn, S. & Jarvis, D. 1994. The European Community Respiratory Health Survey. *Eur Respir J* 7**,** 954-60.

Burr, M., Anderson, H., Austin, J., Harkins, L., Kaur, B., Strachan, D. & Warner, J. 1999. Respiratory symptoms and home environment in children: a national survey. *Thorax,* 54**,** 27-32.

Butler, S., Williams, M., Tukuitonga, C. & Paterson, J. 2003. Problems with damp and cold housing among Pacific families in New Zealand. *New Zealand Medical Journal,* 116.

Carrer, P., Bruinen, d. B. Y., Franchi, M. & Valovirta, E. Year. The EFA Project: Indoor air quality in European schools. In: Ninth International Conference on Indoor Air Quality and Climate 2002, 2002 Monterey, California. 794-799.

Carroll, C. L., Balkrishnan, R., Feldman, S. R., Fleischer, A. B., Jr. & Manuel, J. C. 2005. The burden of atopic dermatitis: impact on the patient, family, and society. *Pediatr Dermatol,* 22**,** 192-9.

Castro, D., Slezakova, K., Oliva-Teles, M. T., Delerue-Matos, C., Alvim-Ferraz, M. C., Morais, S. & Pereira, M. C. 2009. Analysis of polycyclic aromatic hydrocarbons in atmospheric particulate samples by microwave-assisted extraction and liquid chromatography. *Journal of Separation Science* 32**,** 501-510.

Chao, H. J., Schwartz, J., Milton, D. K. & Burge, H. A. 2002. Populations and determinants of airborne fungi in large office buildings. *Environ Health Perspect,* 110**,** 777-82.

Chapman, J. A., Terr, A. I., Jacobs, R. L., Charlesworth, E. N. & Bardana, E. J. 2003. Toxic mold: phantom risk vs. science. *Annals of Allergy, Asthma and Immunology,* 91**,** 222-232.

Chen, S.-J., Liao, S.-H., Jian, W.-J. & Lin, C.-C. 1997. Particle size distribution of aerossol carbons in ambient air. *Environment International* 23**,** 475-488.

Chew, G. L., Rogers, C., Burge, H. A., Muilenberg, M. L. & Gold, D. R. 2003. Dustborne and airborne fungal propagules represent a different spectrum of fungi with differing relations to home characteristics. *ALLERGY,* 58**,** 13-20.

Cho, P., Sheng, C., Chan, C., Lee, R. & Tam, J. 2000. Baseline blink rates and the effect of visual task difficulty and position of gaze. *Curr Eye Res,* 20**,** 64-70.

Choi, H., Schmidbauer, N., Sundell, J., Hasselgren, M., Spengler, J. & Bornehag, C. G. 2010. Common household chemicals and the allergy risks in pre-school age children. *PLoS One,* 5**,** e13423.

Ciarleglio, G., Norbäck, D., Wieslander, G., Sigsgaard, T., Bønløkke, J., Annesi-Maesano, I., Canciani, M., Cossettini, M., Nystad, W., Nafstad, P., et al. 2006. Subjective and objective measurement of air quality in European schools. *Eur Respir J* 28**,** 696s.

Clark, N. A., Demers, P. A., Karr, C. J., Koehoorn, M., Lencar, C., Tamburic, L. & Brauer, M. 2010. Effect of Early Life Exposure to Air Pollution on Development of Childhood Asthma. *Environmental Health Perspectives,* 118**,** 284-290.

Clausen, G., Beko, G., Corsi, R. L., Gunnarsen, L., Nazaroff, W. W., Olesen, B. W., Sigsgaard, T., Sundell, J., Toftum, J. & Weschler, C. J. 2011. Reflections on the state of research: indoor environmental quality. *Indoor Air,* 21**,** 219-30.

Clausen, G., Toftum, J. & Bekö, G. Year. Indoor Environment and Children's Health (IECH) – An ongoing epidemiological investigation on the association between indoor environmental factors in homes and kindergartens and children's health and wellbeing. In: 9th International Healthy Building 2009 Syracuse, NY.

Commission of the European Communities 2001. White Paper (2001) Strategy for a Future Chemical Policy. Brussels.

Commission of the European Communities 2004. The European Environment & Health Action Plan 2004-2010, COM(2004) 416 final. Brussels.

Corbo, G. M., Forastiere, F., Agabiti, N., Dell'Orco, V., Pistelli, R., Aebischer, M. L., Valente, S. & Perucci, C. A. 2001. Effect of gas cooking on lung function in adolescents: modifying role of sex and immunoglobulin E. *Thorax,* 6**,** 536-540.

Couto, M. & Almeida, M. M. 2010. Diagnóstico da doença alérgica em Portugal: Um estudo exploratório [*Allergic disease diagnosis in Portugal: An exploratory study*]. *Rev Port Imunoalergologia,* 19**,** 23-32.

Csobod, E., Rudnai, P. & Vaskovi, E. 2010. School Environment and Respiratory Health of Children (SEARCH) - International research project report within the programme "Indoor air quality in European schools: Preventing and reducing respiratory diseases". Hungary: Regional Environmental Center for Central and Eastern Europe Country Office Hungary.

D' Amato, G., Liccardi, G., D' Amato, M. & Holgate, S. 2005. Environmental risk factors and allergic bronchial asthma. *Clin Exp Allergy,* 35**,** 1113-1124.

Daisey, J. M., Angell, W. J. & Apte, M. G. 2003. Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information. *Indoor Air,* 13**,** 53-64.

Dales, R. & Raizenne, M. 2004. Residential exposure to volatile organic compounds and asthma. *J Asthma,* 41**,** 259-70.

Dassonville, C., Demattei, C., Laurent, A., Le Moullec, Y., Seta, N. & Momas, I. 2009. Assessment and predictor determination of indoor aldehyde levels in Paris newborn babies' homes. *Indoor Air* 19**,** 314-23.

de Sousa, J. C., Silva, M. L., Lobo, F. A. & Yaphe, J. 2010. Asthma incidence and accuracy of diagnosis in the Portuguese sentinel practice network. *Primary Care Respiratory Journal,* 19**,** 352-357.

Destaillats, H., Lunden, M. M., Singer, B. C., Coleman, B. K., Hodgson, A. T., Weschler, C. J. & Nazaroff, W. W. 2006. Indoor secondary pollutants from household product emissions in the presence of ozone: A bench-scale chamber study. *Environ Sci Technol,* 40**,** 4421-8.

Diette, G. B., Hansel, N. N., Buckley, T. J., Curtin-Brosnan, J., Eggleston, P. A., Matsui, E. C., McCormack, M. C., Williams, D. L. & Breysse, P. N. 2007. Home indoor pollutant exposures among inner-city children with and without asthma. *Environmental Health Perspectives,* 115**,** 1665-1669.

Dockery, D., Cunningham, J., Damokosh, A., Neas, L., Spengler, D. & Koutrakis, P. 1996. Health effects of acid aerosols on North American children: respiratory symptoms. *Environ Health Perspect* 104.

Douwes, J., Thorne, P., Pearce, N. & Heederik, D. 2003. Bioaerosol health effects and exposure assessment: Progress and prospects. *Annals of Occupational Hygiene,* 47**,** 187-200.

Duhme, H., Weiland, S., Keil, U., Kraemer, B., Schmid, M., Stender, M. & Chambless, L. 1996. The association between self-reported symptoms of asthma and allergic rhinitis and self-reported traffic density on street of residence in adolescents. *Epidemiology,* 7**,** 578-82.

ECA 27 2012. Report nr 27 of European Collaborative Action (ECA), Harmonisation framework for indoor products labelling schemes in the EU. Ispra, Italy: Environment and Quality of Life, EC Joint Research Centre.

Eder, W., Ege, M. J. & von Mutius, E. 2006. The asthma epidemic. *N Engl J Med,* 355**,** 2226-35.
Ekerljung, L., Ronmark, E., Larsson, K., Sundblad, B. M., Bjerg, A., Ahlstedt, S., Dahlen, S. E. & Lundback, B. 2008. No further increase of incidence of asthma: Incidence, remission and relapse of adult asthma in Sweden. *Respir Med,* 102**,** 1730-1736.
Eller, E., Kjaer, H. F., Host, A., Andersen, K. E. & Bindslev-Jensen, C. 2010. Development of atopic dermatitis in the DARC birth cohort. *Pediatric Allergy and Immunology,* 21**,** 307-314.
Emenius, C., Egmar, A. C. & Wickman, M. 1998. Mechanical ventilation protects one-storey single-dwelling houses against increased air humidity, domestic mite allergens and indoor pollutants in a cold climatic region. *Clinical and Experimental Allergy,* 28**,** 1389-1396.
Emenius, G., Svartengren, M., Korsgaard, J., Nordvall, L., Pershagen, G. & Wickman, M. 2004. Indoor exposures and recurrent wheezing in infants: a study in the BAMSE cohort. *Acta Paediatr* 93.
EPHECT project. 2010. Available: https://esites.vito.be/sites/ephect/Pages/home.aspx [Accessed March, 2013].
Etzel, R. A. 2007. Indoor and outdoor air pollution: Tobacco smoke, moulds and diseases in infants and children. *International Journal of Hygiene and Environmental Health,* 210**,** 611-616.
European Comission 2011. Construction Products Regulation (EU) No 305/2011.
European Comission 2013. Environment: New policy package to clean up Europe´s air. In: Ip/13/1274 (ed.).
European Comission & Joint Research Centre 2000. ECA Report No. 22: Risk Assessment in Relation to Indoor Air Quality. In: 195829/En, E. (ed.).
European Commission 2001. Directive 2001/95/EC on general product safety.
European Commission 2006. EC 1907/2006 Registration, Evaluation, Authorisation and Restriction of Chemical substances.
European Commission 2010. Directive 2010/31/EU on the energy performance of buildings
European Commission. 2013. *EUROSTAT Education and Training* [Online]. Available: http://epp.eurostat.ec.europa.eu/portal/page/portal/education/introduction [Accessed].
European Committee for Standardization 2003. EN 13779 Ventilation for non-residential buildings - Performance requirements for ventilation and room-conditioning systems.
European Committee for Standardization 2007. EN 15251 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics.
European Community Respiratory Health Survey 1996. Variations in the prevalence of respiratory symptoms, self-reported asthma attacks, and use of asthma medication in the European Community Health Survey (ECRHS). *Eur Respir J,* 9**,** 687-95.
European Construction Technology Platform 2005. Strategic Research Agenda for the European Construction Sector.
European Environment Agency & European Commission´s Joint Research Centre 2013. Environment and human health. Copenhagen, Denmark.
European Environmental Agency 2008. Annual European Community LRTAP Convention Emissions Inventory Report 1990-2006. EEA Technical Report No. 7. Copenhagen, Denmark.
European Federation of Asthma and Allergy Associations 2000. Indoor air pollution in schools. European Commission.
European Federation of Asthma and Allergy Associations 2008. Respiratory Allergies Raise Awareness, Relieve the Burden. In: Valovirta, E. (ed.).
Ezratty, V., Bonay, M., Neukirch, C., Orset-Guillossou, G., Dehoux, M., Koscielny, S., Cabanes, P. A., Lambrozo, J. & Aubier, M. 2007. Effect of formaldehyde on asthmatic response to inhaled allergen challenge. *Environ. Health Perspect,* 115**,** 210-214.
Falcão, H., Ramos, E., Marques, A. & Barros, H. 2008. Prevalence of asthma and rhinitis in 13 year old adolescents in Porto, Portugal. *Rev Port Pneumol,* 14**,** 747-768.
Federation of European Heating Ventilation and Air Conditioning Associations 2013. Experts are concerned about unhealthy indoor air in European buildings REHVA position paper on indoor air quality. Brussels, Belgium.
Fischer, P., Kriz, B., Martuzzi, M., Wojtyniak, B., Lebret, E., Reeuwijk, H., Pikhart, H., Briggs, D., Gorynski, P. & Elliott, P. 1998. Risk Factors Indoors and Prevalences of Childhood Respiratory Health in Four Countries in Western and Central Europe. *Indoor Air* 8**,** 244-254.
Fisk, W. J., Lei-Gomez, Q. & Mendell, M. J. 2007. Meta-analysis of the associations of respiratory health effects with dampness and mold in homes. *Indoor Air,* 17**,** 284-296.
Fontham, E., Thun, M., Ward, E., Balch, A., Delancey, J. & Samet, J. 2009. American Cancer Society perspectives on environmental factors and cancer. *CA: A Cancer Journal for Clinicians,* 59**,** 343-351.
Fox, K., Fox, A., Elssner, T., Feigley, C. & Salzberg, D. 2010. MALDI-TOF mass spectrometry speciation of staphylococci and their discrimination from micrococci isolated from indoor air of schoolrooms. *Journal of Environmental Monitoring,* 12**,** 917-923.

Fraga, S., Ramos, E., Martins, A., Samudio, M. J., Silva, G., Guedes, J., Oliveira Fernandes, E. & Barros, H. 2008. Indoor air quality and respiratory symptoms in Porto schools. *Rev Port Pneumol,* 14**,** 487-507.

Franchi, M., Carrer, P., Kotzias, D., Rameckers, E. M. A. L., Sppanen, O., Bronswijk, J. E. M. H. v. & Viegi, G. 2004. Towards Healthy Air in Dwellings in Europe. The THADE Report. European Federation of Allergy and Airways Diseases Partients Associations.

Franklin, P. J. & Stick, S. M. 2008. The value of FeNO measurement in asthma management: the motion against FeNO to help manage childhood asthma--reality bites. *Paediatr Respir Rev,* 9**,** 122-6.

Fromme, H., Diemer, J., Dietrich, S., Cyrys, J., Heinrich, J., Lang, W., Kiranoglu, M. & Twardella, D. 2008. Chemical and morphological properties of particulate matter (PM10, PM2.5) in school classrooms and outdoor air. *Atmos. Environ,* 42**,** 6597-6605.

Fromme, H., Twardella, D., Dietrich, S., Heitmann, D., Schierl, R., Liebl, B. & Ruden, H. 2007. Particulate matter in the indoor air of classrooms - exploratory results from Munich and surrounding area. *Atmospheric Environment,* 41**,** 854-866.

Garrett, M., Hooper, M., Hooper, B., Rayment, P. & Abramson, M. 1999. Increased risk of allergy in children due to formaldehyde exposure in homes. *Allergy,* 54**,** 330-7.

Gauderman, W., Avol, E., Lurmann, F., Kuenzli, N., Gilliland, F. & Peters, J. 2005. Childhood asthma and exposure to traffic and nitrogen dioxide. *Epidemiology,* 16**,** 737-43.

Geelen, L. M., Huijbregts, M. A., Ragas, A. M., Bretveld, R. W., Jans, H. W., van Doorn, W. J., Evertz, S. J. & van der Zijden, A. 2008. Comparing the effectiveness of interventions to improve ventilation behavior in primary schools. *Indoor Air,* 18**,** 416-24.

Gehring, U., Wijga, A., Brauer, M., Fischer, P., de Jongste, J., Kerkhof, M. & et al. 2010. Traffic-related Air Pollution and the Development of Asthma and Allergies during the First 8 Years of Life. *Am J Respir Crit Care Med* 181**,** 596-603.

Geiss, O., Giannopoulos, G., Tirendi, S., Barrero-Moreno, J., R. Larsen, B. & Kotzias, D. 2011. The AIRMEX study - VOC measurements in public buildings and schools/kindergartens in eleven European cities: Statistical analysis of the data. *Atmospheric Environment,* 45**,** 3676-3684.

Geller, R. J., Rubin, I. L., Nodvin, J. T., Teague, W. G. & Frumkin, H. 2007. Safe and healthy school environments. *Pediatr Clin North Am,* 54**,** 351-373.

Gemenetzis, P., Moussas, P., Arditsoglou, A. & Samara, C. 2006. Mass concentration and elemental composition of indoor PM2.5 and PM10 in university rooms in Thessaloniki, northern Greece. *Atmospheric Environment,* 40**,** 3195-3206.

Ghosh, S., Pahwa, P., Rennie, D. & McDuffie, H. 2008. Opposing trends in the prevalence of health professional-diagnosed asthma by sex: a Canadian National Population Health Survey study. *Can Respir J,* 15**,** 146-52.

Gilbert, N. L., Guay, M., Gauvin, D., Dietz, R. N., Chan, C. C. & Levesque, B. 2008. Air change rate and concentration of formaldehyde in residential indoor air. *Atmospheric Environment,* 42**,** 2424-2428.

Global Initiative for Asthma. 2009. *Global strategy for the diagnosis and management of asthma in children 5 years and younger* [Online]. Available: http://www.ginasthma.org/local/uploads/files/GINA_Under5_2009_CorxAug11_1.pdf [Accessed].

Global Initiative for Asthma. 2012. *Global strategy for asthma management and prevention* [Online]. Available: http://www.ginasthma.org/local/uploads/files/GINA_Report_2012Feb13.pdf [Accessed].

Godard, P., Chanez, P., Siraudin, L., Nicoloyannis, N. & Duru, G. 2002. Costs of asthma are correlated with severity: a 1-yr prospective study. *Eur Respir J* 19**,** 61-7.

Godwin, C. & Batterman, S. 2007. Indoor air quality in Michigan schools. *Indoor Air,* 17**,** 109-121.

Goh, I., Obbard, J. P., Viswanathan, S. & Huang, Y. 2000. Airborne bacteria and fungal spores in the indoor environment - A case study in Singapore. *Acta Biotechnologica,* 20**,** 67-73.

Grisoli, P., Rodolfi, M., Chiara, T., Zonta, L. A. & Dacarro, C. 2012. Evaluation of microbiological air quality and of microclimate in university classrooms. *Environ Monit Assess,* 184**,** 4171-80.

Guieysse, B., Hort, C., Platel, V., Munoz, R., Ondarts, M. & Revah, S. 2008. Biological treatment of indoor air for VOC removal: Potential and challenges. *Biotechnology Advance,* 26**,** 398-410.

Guo, H., Morawska, L., He, C., Zhang, Y. L., Ayoko, G. & Cao, M. 2010. Characterization of particle number concentrations and PM2.5 in a school: influence of outdoor air pollution on indoor air. *Environ. Sci. Pollut. Res. Int., ,* 17**,** 1268-1278.

Gupta, S., Gupta, V., Joshi, S. & Tandon, R. 2002. Subclinically dry eyes in urban Delhi: an impact of air pollution? *Ophthalmologica,* 216**,** 368-71.

Haahtela, T., Tuomisto, L., Pietinalho, A., Klaukka, T., Erhola, M. & Kaila, M. 2006. A 10 year asthma programme in Finland: major change for the better. *Thorax,* 61**,** 663-70.

Hanninen, O. O., Alm, S., Katsouyanni, K., Kunzli, N., Maroni, M., Nieuwenhuijsen, M. J., Saarela, K., Sram, R. J., Zmirou, D. & Jantunen, M. J. 2004. The EXPOLIS study: implications for exposure research and

environmental policy in Europe. *Journal of Exposure Analysis and Environmental Epidemiology,* 14**,** 440-456.
Harrison, R. M. & Yin, J. X. 2000. Particulate matter in the atmosphere: which particle properties are important for its effects on health? *Science of the Total Environment,* 249**,** 85-101.
Heath, M. J. & Mendell, G. A. 2004. Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature. *Indoor Air,* 10**,** 1-26.
Heinrich, J. 2011. Influence of indoor factors in dwellings on the development of childhood asthma. *International Journal of Hygiene and Environmental Health* 214**,** 1-25.
Heinrich, J., Topp, R., Gehring, U. & Thefeld, W. 2005. Traffic at residential address, respiratory health, and atopy in adults: the national German health Survey 1998. *Environmental Research* 98**,** 240-249.
Hersoug, L. G. 2005. Viruses as the causative agent related to 'dampness' and the missing link between allergen exposure and onset of allergic disease. *Indoor Air,* 15**,** 363-366.
Hirsch, T., Weiland, S. & von Mutius, E. 1999. Inner city air pollution and respiratory health and atopy in children. *Eur Respir J* 14**,** 669-77.
Holgate, S. T., Samet, J. M., Koren, H. S. & Maynard, R. L. 1999. Sources of Air Pollution. Air Pollution and Health. London, United Kingdom, : Academic Press.
Holme, J., Hägerhed-Engman, L., Mattsson, J., Sundell, J. & Bornehag, C. 2010. Culturable mold in indoor air and its association with moisture-related problems and asthma and allergy among Swedish children. *Indoor Air* 20**,** 329-40.
Hulin, M., Caillaud, D. & Annesi-Maesano, I. 2010. Indoor air pollution and childhood asthma: variations between urban and rural areas. *Indoor Air,* 20**,** 502-514.
Hwang, G., Yoon, C. & Choi, J. 2011. A Case-Control Study: Exposure Assessment of VOCs and Formaldehyde for Asthma in Children. *Aerosol and Air Quality Research,* 11**,** 908-914.
Hyvarinen, A., Reponen, T., Husman, T. & Nevalainen, A. 2001. Comparison of the indoor air quality in mould damaged and reference buildings in a subarctic climate. *Cent Eur J Public Health,* 9**,** 133-9.
Illi, S., von Mutius, E., Lau, S., Nickel, R., Gruber, C., Niggemann, B., Wahn, U. & Group, M. A. S. 2004. The natural course of atopic dermatitis from birth to age 7 years and the association with asthma. *Journal of Allergy and Clinical Immunology,* 113**,** 925-931.
Institute of Medicine 1993. Indoor allergens: Assessing and controlling adverse health effects, Washington D.C, USA., National Academy Press.
Institute of Medicine 2000. Clearing the air: Asthma and indoor air exposures, Washington D.C, USA, National Academy Press.
Institute of Medicine 2004. Damp indoor spaces and health, Washington D.C, USA, National Academy Press.
International Agency for Research on Cancer 2009. Evaluating the effectiveness of smoke-free policies, Lyon.
ISO 16000-1:2004 2004. Indoor air - Part 1: General aspects of sampling strategy.
ISO 16000-4:2011 2011. Determination of formaldehyde -- Diffusive sampling method. In: Organization, I. S. (ed.).
ISO 16000-6:2011 2011. Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS or MS-FID. In: Organization, I. S. (ed.).
Iwashita, G. & Akasaka, H. 1997. The effects of human behavior on natural ventilation rate and indoor air environment in summer - A field study in southern Japan. *Energy and Buildings,* 25**,** 195-205.
Jaakkola, J., Jaakkola, N. & Ruotsalainen, R. 1993. Home dampness and molds as determinants of respiratory symptoms and asthma in pre-school children. *J Expo Anal Environ Epidemiol,* 3**,** 129-42.
Jaakkola, J., Oie, L., Nafstad, P., Botten, G., Samuelsen, S. & Magnus, P. 1999. Interior surface materials in the home and the development of bronchial obstruction in young children in Oslo, Norway. *Am J Public Health,* 89**,** 188-92.
Jaakkola, J., Parise, H., Kislitsin, V., Lebedeva, N. & Spengler, J. 2004. Asthma, wheezing, and allergies in Russian schoolchildren in relation to new surface materials in the home. *Am J Public Health,* 94**,** 560-2.
Jaakkola, J., Verkasalo, P. & Jaakkola, N. 2000. Plastic wall materials in the home and respiratory health in young children. *Am J Public Health,* 90**,** 797-9.
Jaakkola, J. J. K. & Knight, T. L. 2008. The Role of Exposure to Phthalates from Polyvinyl Chloride Products in the Development of Asthma and Allergies: A Systematic Review and Meta-Analysis. *Epidemiology,* 19**,** S128-S128.
Jacquemin, B., Kauffmann, F., Pin, I., Le Moual, N., Bousquet, J. & Gormand, F. 2011. Air pollution and asthma control in the Epidemiological study on the Genetics and Environment of Asthma. J Epidemiol Community Health
Janeway, C. & Travers, P. 1994. Immunobiology. The immune system in health and disease, London, New York, Current Biology Publications and Garland Publishing.

Janson, C., Anto, J., Burney, P., Chinn, S., De MR & Heinrich, J. 2001. The European Community Respiratory Health Survey: what are the main results so far? European Community Respiratory Health Survey II. *Eur Respir J* 18**,** 598-611.
Janssen, N., Brunekreef, B., van Vliet, P., Aarts, F., Meliefste, K., Harssema, H. & Fischer, P. 2003. The relationship between air pollution from heavy traffic and allergic sensitization, bronchial hyperresponsiveness, and respiratory symptoms in Dutch schoolchildren. *Environ Health Perspect. ,* 111**,** 1512-8.
Janssen, N. A., Hoek, G., Harssema, H. & Brunekreef, B. 1997. Childhood exposure to PM10: relation between personal, classroom, and outdoor concentrations. *Occup. Environ. Med.,* 54**,** 888-894.
Jantunen, M., Oliveira Fernandes, E., Carrer, P. & Kephalopoulos, S. 2011. Promoting actions for healthy indoor air (IAIAQ). Luxembourg: European Commission Directorate General for Health and Consumers.
Jia, C. & Batterman, S. 2010. A critical review of naphthalene sources and exposures relevant to indoor and outdoor air. *Int J Environ Res Public Health,* 7**,** 2903-39.
Jo, W. K. & Seo, Y. J. 2005. Indoor and outdoor bioaerosol levels at recreation facilities, elementary schools, and homes. *Chemosphere,* 61**,** 1570-1579.
Johansson, S. G. O., Bieber, T., Dahl, R., Friedmann, P. S., Lanier, B. Q., Lockey, R. F., Motala, C., Martell, J. A. O., Platts-Mills, T. A. E., Ring, J., et al. 2004. Revised nomenclature for allergy for global use: Report of the Nomenclature Review Committee of the World Allergy Organization, October 2003. *Journal of Allergy and Clinical Immunology,* 113**,** 832-836.
Joint Research Centre. *ECA Publications* [Online]. Available: http://ihcp.jrc.ec.europa.eu/our_activities/public-health/indoor_air_quality/eca/eca-publications [Accessed October, 2013].
Kaiser, J. 2000. Air pollution - Evidence mounts that tiny particles can kill. *Science,* 289**,** 22-23.
Kapoor, R., Menon, C., Hoffstad, O., Bilker, W., Leclerc, P. & Margolis, D. 2007. The prevalence and age of onset of asthma and seasonal allergy among patients with atopic dermatitis. *Journal of Investigative Dermatology,* 127**,** S62-S62.
Kasznia-Kocot, J., Kowalska, M., Gorny, R. L., Niesler, A. & Wypych-Slusarska, A. 2010. Environmental Risk Factors for Respiratory Symptoms and Childhood Asthma. *Annals of Agricultural and Environmental Medicine,* 17**,** 221-229.
Katsoyiannis, A., Leva, P. & Kotzias, D. 2008. VOC and carbonyl emissions from carpets: A comparative study using four types of environmental chambers. *Journal of Hazardous Materials,* 152**,** 669-676.
Kavlock, R., Boekelheide, K., Chapin, R., Cunningham, M., Faustman, E., Foster, P., Golub, M., Henderson, R., Hinberg, I., Little, R., et al. 2002. NTP Center for the Evaluation of Risks to Human Reproduction: phthalates expert panel report on the reproductive and developmental toxicity of di(2-ethylhexyl) phthalate. *Reprod Toxicol,* 16**,** 529-653.
Kephalopoulos, S., Barrero-Moreno, J., Larsen, B., Geiss, O., Tirendi, S. & Reina, V. 2013a. PILOT INDOOR AIR MONIT AA final report. DG SANCO – DG JRC administrative arrangement PILOT INDOOR AIR MONIT (contract no. SI 2582843).
Kephalopoulos, S., Carrer, P., Crump, D. & Däumling, C. 2013b. ECA report no. 29 on Harmonisation framework for health based evaluation of indoor emissions from building products in Europe based on the EU-LCI concept. Luxembourg: European Union.
Kim, J. L., Elfman, L., Mi, Y., Wieslander, G., Smedje, G. & Norbäck, D. 2007. Indoor molds, bacteria, microbial volatile organic compounds and plasticizers in schools--associations with asthma and respiratory symptoms in pupils. *Indoor Air,* 17**,** 153-63.
Kim, J. L. E., L.Mi, Y.Johansson, M.Smedje, G.Norback, D. 2005. Current asthma and respiratory symptoms among pupils in relation to dietary factors and allergens in the school environment. *Indoor air,* 15**,** 170-82.
Kirchner, S., Arenes, J.-F., Cochet, C., Derbez, M., Duboudin, C., Elias, P., Gregoire, A., Jédor, B., Lucas, J.-P., Pasquier, N., et al. 2006. National Dwellings survey: report on air quality in French National survey. Final report. Indoor Air Quality Observatory. .
Kjaergaard, S. 1992. Assessment of Eye Irritation in Humans. *Annals of the New York Academy of Sciences,* 641**,** 187-198.
Knox, R., Suphioglu, C. & Taylor, P. 1997. Major grass pollen allergen Lol p 1 binds to diesel exhaust particles: implications for asthma and air pollution. *Clin Exp Allergy* 27**,** 246-51.
Koren, H. S., Graham, D. E. & Devlin, R. B. 1992. Exposure of humans to a volatile organic mixture. III. Inflammatory response. *Arch Environ Health,* 47**,** 39-44.
Koshy, G. & Brabin, B. J. 2012. Parental compliance--an emerging problem in Liverpool community child 4 health surveys 1991-2006. *BMC medical research methodology* 12**,** 53.
Koskinen, O., Husman, T., Hyvärinen, A., Reponen, T. & Nevalainen, A. 1995. Respiratory Symptoms and Infections among Children in a Day-Care Center with Mold Problems. *Indoor Air,* 5**,** 3-9.

Koskinen, O. M., Husman, T. M., Hyvarinen, A. M., Reponen, T. A. & Nevalainen, A. I. 1997. Two moldy day-care centers: a follow-up study of respiratory symptoms and infections. *Indoor Air-International Journal of Indoor Air Quality and Climate,* 7**,** 262-268.

Kotzias, D., Geiss, O., Tirendi, S., Barrero, J., Reina, V., Gotti, A., Cimino reale, G., Marafante, E., Sarigiannis, D. & Casatti, B. 2009. Exposure to Multiple Air Contaminants in Public Buildings, Schools and Kindergartens - The European Indoor Air Monitoring and Exposure Assessment (AIRMEX) Study. *Frenesius Enviornmental Bulletin,* 18**,** 670-681.

Kotzias, D., Koistinen, K., Kephalopoulos, S., Schlitt, C., Carrer, P., Maroni, M., Jantunen, M., Cochet, C., Kirchner, S., Lindvall, T., et al. 2005. The INDEX project. Critical Appraisal of the Setting and Implementation of Indoor Exposure Limits in the EU. Final Report. EUR 21590 EN. European Comission, Directorate General, Joint Research Centre.

Kurosaka, F., Nakatani, Y., Terada, T., Tanaka, A., Ikeuchi, H., Hayakawa, A., Konohana, A., Oota, K. & Nishio, H. 2006. Current cat ownership may be associated with the lower prevalence of atopic dermatitis, allergic rhinitis, and Japanese cedar pollinosis in schoolchildren in Himeji, Japan. *Pediatr Allergy Immunol,* 17**,** 22-8.

Kvisgaard, B. & Collet, P. 1990. The user's influence on air change. In: Sherman, H. (ed.) Air change rate and air tightness in buildings. Philadelphia: American Society forTesting and Materials.

La Grutta, S., Ferrante, G., Malizia, V., Cibella, F. & Viegi, G. 2012. Environmental effects on fractional exhaled nitric oxide in allergic children. *J Allergy (Cairo),* 2012**,** 916926.

Lai, C. K. W., Beasley, R., Crane, J., Foliaki, S., Shah, J., Weiland, S. & Group, I. P. T. S. 2009. Global variation in the prevalence and severity of asthma symptoms: Phase Three of the International Study of Asthma and Allergies in Childhood (ISAAC). *Thorax,* 64**,** 476-483.

Lai, H. K., Kendall, M., Ferrier, H., Lindup, I., Alm, S., Hanninen, O., Jantunen, M., Mathys, P., Colvile, R., Ashmore, M. R., et al. 2004. Personal exposures and microenvironment concentrations of PM2.5, VOC, NO2 and CO in Oxford, UK. *Atmospheric Environment,* 38**,** 6399-6410.

Larsen, S. T., Hansen, J. S., Hansen, E. W., Clausen, P. A. & Nielsen, G. D. 2007. Airway inflammation and adjuvant effect after repeated airborne exposures to di-(2-ethylhexyl)phthalate and ovalbumin in BALB/c mice. *Toxicology,* 235**,** 119-129.

Larsson, M. 2010. Indoor Environmental Factors and Chronic Diseases in Swedish Pre-School Children: Risk factors and methodological issues investigated in a longitudinal study on airway diseases and autism spectrum disorders. Karlstad University.

Larsson, M., Hägerhed-Engman, L., Kolarik, B., James, P., Lundin, F. & Janson, S. 2010. PVC – as flooring material – and its association with incident asthma in a swedish child cohort study. *Indoor air* 20**,** 494-501.

Le Cann, P., Bonvallot, N., Glorennec, P., Deguen, S., Goeury, C. & Le Bot, B. 2011. Indoor environment and children's health: Recent developments in chemical, biological, physical and social aspects. *International Journal of Hygiene and Environmental Health* 215**,** 1-18.

Lee, S. C., Guo, H., Li, W. M. & Chan, L. Y. 2002. Inter-Comparison of air pollutant concentrations in different indoor environments in Hong Kong. *Atmos. Environ,* 36**,** 1929-1940.

Leikauf, G. D. 2002. Hazardous air pollutants and asthma. *Environ Health Perspect,* 110 Suppl 4**,** 505-26.

Leiria Pinto, P. 1998. Asma brônquica e o adolescente. Conhecimentos e atitudes. Dissertação de mestrado em Patologia do Aparelho Respiratório. Faculdade de Ciências Médicas da Universidade Nova de Lisboa.

Li, C. & Hsu, L. 1996. Home dampness and childhood respiratory symptoms in a subtropical climate. *Arch Env Health,* 51**,** 42-6.

Li, C. S., Hsu, C. W. & Tai, M. L. 1997. Indoor pollution and sick building syndrome symptoms among workers in day-care centers. *Archives of Environmental Health,* 52**,** 200-207.

Lotvall, J., Ekerljung, L., Ronmark, E., Wennergren, G., Linden, A. & Ronmark, E. 2009. West Sweden Asthma Study: prevalence trends over the last 18 years argues no recent increase in asthma. *Respir Res,* 10**,** 94.

Lovreglio, P., Carrus, A., Iavicoli, S., Drago, I., Persechino, B. & Soleo, L. 2009. Indoor formaldehyde and acetaldehyde levels in the province of Bari, South Italy, and estimated health risk. *J Environ Monit* 11**,** 955-61.

Madureira, J., Alvim-Ferraz, M. C. M., Rodrigues, S., Goncalves, C., Azevedo, M. C., Pinto, E. & Mayan, O. 2009. Indoor Air Quality in Schools and Health Symptoms among Portuguese Teachers. *Human and Ecological Risk Assessment,* 15**,** 159-169.

Madureira, J., Paciencia, I. & Fernandes Ede, O. 2012. Levels and indoor-outdoor relationships of size-specific particulate matter in naturally ventilated Portuguese schools. *J Toxicol Environ Health A,* 75**,** 1423-36.

Magnusson, L., Olesen, A., Wennborg, H. & Olsen, J. 2005. Wheezing, asthma, hayfever, and atopic eczema in childhood following exposure to tobacco smoke in fetal life. *Clin Exp Allergy,* 35**,** 1550-6.

Martins, P. C., Valente, J., Papoila, A. L., Caires, I., Araujo-Martins, J., Mata, P., Lopes, M., Torres, S., Rosado-Pinto, J., Borrego, C., et al. 2012. Airways changes related to air pollution exposure in wheezing children. *European Respiratory Journal,* 39**,** 246-253.

Masoli, M., Fabian, D., Holt, S. & Beasley, R. 2004. The global burden of asthma: executive summary of the GINA Dissemination Committee report. *Allergy* 59**,** 469-78.

Mayor of London 2002. Fifty Years On - The Struggle for Air Quality in London since the Great Smog of December 1952. In: Authority, G. L. (ed.). London, United Kingdom.

McConnell, R., Berhane, K., Yao, L., Jerrett, M., Lurmann, F., Gilliland, F., Kunzli, N., Gauderman, J., Avol, E., Thomas, D., et al. 2006. Traffic, susceptibility, and childhood asthma. *Environ Health Perspect,* 114**,** 766-72.

McGwin, G., Lienert, J. & Kennedy, J. I. 2010. Formaldehyde exposure and asthma in children: a systematic review. *Environ Health Perspect,* 118**,** 313-7.

McHugh, M., Symanski, E., Pompeii, L. & Delclos, G. 2009. Prevalence of asthma among adult females and males in the United States: results from the National Health and Nutrition Examination Survey (NHANES), 2001-2004. *J Asthma* 46**,** 759-66.

McNally, N. J., Williams, H. C. & Phillips, D. R. 2001. Atopic eczema and the home environment. *British Journal of Dermatology,* 145**,** 730-736.

Meininghaus, R., Kouniali, A., Mandin, C. & Cicolella, A. 2003. Risk assessment of sensory irritants in indoor air - a case study in a French school. *Environ Int,* 28**,** 553-7.

Meklin, T., Reponen, T., Toivola, M., Koponen, V., Husman, T., Hyvarinen, A. & Nevalainen, A. 2002. Size distributions of airborne microbes in moisture-damaged and reference school buildings of two construction types. *Atmospheric Environment,* 36**,** 6031-6039.

Mendell, M. 2006. Indoor residential chemical exposures as risk factors for asthma and allergy in infants and children: a review. *Proceedings of Healthy Buildings* 1**,** 151-6.

Mendell, M., Mirer, A. & Cheung, K. 2011. Respiratory and allergic health effects of dampness, mold, and dampness-related agents: a review of the epidemiologic evidence. *Environ Health Perspect,* 119**,** 748-756.

Mendell, M. J. 2007. Indoor residential chemical emissions as risk factors for-respiratory and allergic effects in children: a review. *Indoor Air,* 17**,** 259-277.

Mendell, M. J. & Heath, G. A. 2005. Do indoor pollutants and thermal conditions in schools influence student performance? A critical review of the literature. *Indoor Air,* 15**,** 27-52.

Mendes, A., Pereira, C., Mendes, D., Aguiar, L., Neves, P., Silva, S., Batterman, S. & Teixeira, J. P. 2013. Indoor air quality and thermal comfort-results of a pilot study in elderly care centers in Portugal. *J Toxicol Environ Health A,* 76**,** 333-44.

Meng, J., Barnes, C. S. & Rosenwasser, L. J. 2012. Identity of the fungal species present in the homes of asthmatic children. *Clin Exp Allergy,* 42**,** 1448-58.

Meng, Q. Y., Turpin, B. J., Polidori, A., Lee, J. H., Weisel, C., Morandi, M., Colome, S., Stock, T., Winer, A. & Zhang, J. 2005. PM2.5 of ambient origin: estimates and exposure errors relevant to PM epidemiology. *Environ Sci Technol,* 39**,** 5105-12.

Mentese, S., Arisoy, M., Rad, A. Y. & Gullu, G. 2009. Bacteria and fungi levels in various indoor and outdoor environments in Ankara, Turkey. *Clean-Soil, Air Water,* 37**,** 487-493.

Mi, Y. H., Norbäck, D., Tao, J., Mi, Y. L. & Ferm, M. 2006. Current asthma and respiratory symptoms among pupils in Shanghai, China: influence of building ventilation, nitrogen dioxide, ozone, and formaldehyde in classrooms. *Indoor Air,* 16**,** 454-464.

Michel, O. 2000. Systemic and local airways inflammatory response to endotoxin. *Toxicology,* 152**,** 25-30.

Michel, O., Kips, J., Duchateau, J., Vertongen, F., Robert, L., Collet, H., Pauwels, R. & Sergysels, R. 1996. Severity of asthma is related to endotoxin in house dust. *American Journal of Respiratory and Critical Care Medicine,* 154**,** 1641-1646.

Ministério da Economia e do Emprego 2013. Decreto-Lei n.º 118/2013 Regulamento dos Sistemas Energéticos e de Climatização em edifícios.

Ministério da Educação e Ciência 2013. Despacho n.º 5048-B/2013 Artigo 19.º.

Ministério das Obras Públicas Transportes e Comunicações 2006. Decreto-Lei n.º 79/2006 Regulamento dos Sistemas Energéticos e de Climatização em edifícios.

Monteiro, A. 1997. O Clima Urbano do Porto: Contribuição para a definição das estratégias de planeamento e ordenamento do território, Lisbon, Fundação Calouste Gulbenkian.

Morais Almeida, M., Câmara, R. & Ornelas, P. 1996. Prevalência de asma brônquica e de atopia em crianças da Ilha da Madeira [Prevalence of bronchial asthma and atopy in children from Madeira Island]. *Rev Epidemiol* 2**,** 39-40.

Moriske, H.-J., Szewzyk, R. & Leonidas, M. 2003. Mould Guide - Guide for the Prevention, Investigation, Evaluation and Remediation of Indoor Mould Growth. WHO Collaborating Centre for Air Quality Management and Air Pollution Control.

Morton, L. M., Cahill, J. & Hartge, P. 2006. Reporting participation in epidemiologic studies: a survey of practice. *Am J Epidemiol,* 163**,** 197-203.

Moschandreas, D. J., Pagilla, K. R. & Storino, L. V. 2003. Time and space uniformity of indoor bacteria concentrations in Chicago area residences. *Aerosol Science and Technology,* 37**,** 899-906.

Mumovic, D., Palmer, J., Davies, M., Orme, M., Ridley, I., Oreszczyn, T., Judd, C., Critchlow, R., Medina, H. A., Pilmoor, G., et al. 2009. Winter indoor air quality, thermal comfort and acoustic performance of newly built secondary schools in England. *Building and Environment,* 44**,** 1466-1477.

Murata, K., Araki, S., Kawakami, N., Saito, Y. & Hino, E. 1991. Central-Nervous-System Effects and Visual Fatigue in Vdt Workers. *International Archives of Occupational and Environmental Health,* 63**,** 109-113.

Nafstad, P., Jaakkola, J. J. K., Skrondal, A. & Magnus, P. 2005. Day care center characteristics and children's respiratory health. *Indoor Air,* 15**,** 69-75.

Nazaroff, W. W. & Weschler, C. J. 2004. Cleaning products and air fresheners: exposure to primary and secondary air pollutants. *Atmospheric Environment,* 38**,** 2841-2865.

Neuparth, N., Martins, P., Lopes da Mata, P., Rosado Pinto, J., Valente, J. & Borrego, C. 2006. Air pollution and the lung - Health and the air we breathe (SaudAr project) -epidemiology European Respiratory Society.

Nevalainen, A. & Seuri, M. 2005. Of microbes and men. *Indoor Air,* 15**,** 58-64.

Nicolai, T., Carr, D., Weiland, S., Duhme, H., von Ehrenstein, O., Wagner, C. & von Mutius, E. 2003. Urban traffic and pollutant exposure related to respiratory outcomes and atopy in a large sample of children. *Eur Respir J* 21**,** 956-63.

Nicolas, M., Ramalho, O. & Maupetit, F. 2007. Reactions between ozone and building products: Impact on primary and secondary emissions. *Atmospheric Environment,* 41**,** 3129-3138.

Nieuwenhuijsen, M. J. 2003. Exposure assessment in occupational and environmental epidemiology, New York, USA, London: Oxford University Press.

NIOSH 1998. NIOSH Manual of Analytical Methods.

Norbäck, D., Bjornsson, E. & Janson, C. 1995. Asthmatic symptoms and volatile organic compounds, formaldehyde, and carbon dioxide in dwellings. *Occup Environ Med,* 52**,** 388-95.

Norbäck, D., Sestini, P., Elfman, L., Wieslander, G., Sigsgaard, T., Canciani, M., Ciarliegio, G., Annesi-Maesano, I., Nystad, W. & Viegi, G. 2006. Health effects of the school environment (HESE): Indoor environment in primary schools in Italy, France, Denmark, Norway and Sweden. Lisboa: Healthy Buildings HB.

Norbäck, D., Torgen, M. & Edling, C. 1990. Volatile organic compounds, respirable dust, and personal factors related to prevalence and incidence of sick building syndrome in primary schools. *Br. J. Ind. Med.,* 47**,** 733-741.

Norback, D. W., R.Wieslander, G.Smedje, G.Erwall, C.Venge, P. 2000. Indoor air pollutants in schools: nasal patency and biomarkers in nasal lavage. *Allergy,* 55**,** 163-70.

Nunes, C. & Ladeira, S. 1987. Epidemiologic study of asthma in schoolchildren. *The lung environment*.

Nunes, C. & Ladeira, S. 2004. The economic impact of asthma in continuous evaluation. *Revista Portuguesa de Imunoalergologia,* XII**,** 114-128.

O'Connor, K., Osborn, L., Olson, L., Blumberg, S., Frankel, M. & Srinath, K. 2008. Design and operation of the National Asthma Survey. National Center for Health Statistics. *Vital Health Stat,* 1**,** 1-122.

Oeder, S., Dietrich, S., Weichenmeier, I., Schober, W., Pusch, G., Jorres, R. A., Schierl, R., Nowak, D., Fromme, H., Behrendt, H., et al. 2012. Toxicity and elemental composition of particulate matter from outdoor and indoor air of elementary schools in Munich, Germany. *Indoor Air,* 22**,** 148-58.

Oie, L., Nafstad, P., Botten, G., Magnus, P. & Jaakkola, J. K. 1999. Ventilation in homes and bronchial obstruction in young children. *Epidemiology,* 10**,** 294-9.

Oldfield, K., Siebers, R. & Crane, J. 2007. Endotoxin and indoor allergen levels in kindergartens and daycare centres in Wellington, New Zealand. *N Z Med J,* 120**,** U2400.

Oliveira Fernandes, E., Gustafsson, H., Seppänen, O., Crump, D. & Ventura Silva, G. 2008. WP3 Final Report on Characterization of Spaces and Sources. EnVIE Project. Brussels: European Commission 6th Framework Programme of Research.

Ott, W. R. 1982. Concepts of human exposure to air pollution. *Environ Int. ,* 7**,** 179-196.

Ott, W. R. 1995. Human exposure assessment: The birth of a new science. *J Exposure Anal Environ Epid. ,* 5**,** 449-472.

Pasanen, A. L. 2001. A review: Fungal exposure assessment in indoor environments. *Indoor Air,* 11**,** 87-98.

Pearce, N. & Douwes, J. 2006. The global epidemiology of asthma in children. *International Journal of Tuberculosis and Lung Disease,* 10**,** 125-132.
Pearce, N., Douwes, J. & Beasley, R. 2000. The rise and rise of asthma: a new paradigm for the new millennium? *J Epidemiol Biostat,* 5**,** 5-16.
Pegas, P., Alves, C., Scotto, M., Evtyugina, M., Pio, C. A. & Freitas, M. 2011a. Risk factors and prevalence of asthma and rhinitis among primary school children in Lisbon *Rev Port Pneumol,* 17**,** 109-116.
Pegas, P. N. 2012. Qualidade do ar interior em escolas do 1º ciclo de Lisboa e Aveiro. Doutoramento em Ciências e Engenharia do Ambiente, Universidade de Aveiro.
Pegas, P. N., Alves, C. A., Evtyugina, M. G., Nunes, T., Cerqueira, M., Franchi, M., Pio, C. A., Almeida, S. M. & Freitas, M. C. 2011b. Indoor air quality in elementary schools of Lisbon in spring. *Environ Geochem Health,* 33**,** 455-468.
Pekey, H. & Arslanbas, D. 2008. The relationship between indoor, outdoor and personal VOC concentrations in homes, offices and schools in the metropolitan Rregion of Kocaeli, Turkey. *Water Air Soil Pollutant,* 191**,** 113-129.
Pereira, M., Alvim-Ferraz, M. & Santos, R. 2002. Air quality evaluation on a Portuguese urban area according to the new European legislation. *Environmental Science and Pollution Research***,** 40.
Plácido, J. 2004. A asma a nível nacional e mundial: perspectivas actuais e tendências futuras. *Rev Port Clin Geral,* 20**,** 583-7.
Polidori, A., Arhami, M., Sioutas, C., Delfino, R. J. & Allen, R. 2007. Indoor/outdoor relationships, trends, and carbonaceous content of fine particulate matter in retirement homes of the Los Angeles basin. *Journal of the Air & Waste Management Association,* 57**,** 366-379.
Pope, I. C., Burnett, R., Thun, M., Calle, E., Krewski, D., Ito, K. & Thurston, G. 2002. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *Journal of the American Medical Association,* 287**,** 1132-1141.
Prata, C., Marto, J., Mouzinho, I., Menezes, I. & Susano, R. 1994. Estudo epidemiológico sobre asma brônquica numa população escolar dos Açores (Faial) [Epidemiological study on bronchial asthma in a school age population from Faial, Azores]. *Acta Med Port* 7**,** 541-4.
Raaschou-Nielsen, O., Hermansen, M. N., Loland, L., Buchvald, F., Pipper, C. B., Sorensen, M., Loft, S. & Bisgaard, H. 2010. Long-term exposure to indoor air pollution and wheezing symptoms in infants. *Indoor Air,* 20**,** 159-67.
Radon, K. 2006. The two sides of the "endotoxin coin". *Occupational and Environmental Medicine,* 63**,** 73-8, 10.
Raherison, C., Penard-Morand, C., Moreau, D., Caillaud, D., Charpin, D., Kopfersmitt, C., Lavaud, F., Taytard, A. & Annesi-Maesano, I. 2007. In utero and childhood exposure to parental tobacco smoke, and allergies in schoolchildren. *Respir Med,* 101**,** 107-117.
Ren, P., Jankun, T. M., Belanger, K., Bracken, M. B. & Leaderer, B. P. 2001. The relation between fungal propagules in indoor air and home characteristics. *ALLERGY,* 56**,** 419-24.
Reponen, T., Lockey, J., Bernstein, D. I., Vesper, S. J., Levin, L., Khurana Hershey, G. K., Zheng, S., Ryan, P., Grinshpun, S. A., Villareal, M., et al. 2012. Infant origins of childhood asthma associated with specific molds. *J Allergy Clin Immunol,* 130**,** 639-644 e5.
Ribeiro, O., Lautensach, H. & Daveau, S. 1988. Geografia de Portugal II: O Ritmo Climático e a Paisagem, Lisbon.
Rive, S., Hulin, M., Baiz, N., Hassani, Y., Kigninlman, H., Toloba, Y., Caillaud, D. & Annesi-Maesano, I. 2013. Urinary S-PMA related to indoor benzene and asthma in children. *Inhal Toxicol,* 25**,** 373-82.
Roda, C., Barral, S., Ravelomanantsoa, H., Dusseaux, M., Tribout, M., Le Moullec, Y. & Momas, I. 2011. Assessment of indoor environment in Paris child day care centers. *Environmental Research,* 111**,** 1010-1017.
Rodes, C. E., Lawless, P. A., Thornburg, J. W., Williams, R. W. & Croghan, C. W. 2010. DEARS particulate matter relationships for personal, indoor, outdoor, and central site settings for a general population. *Atmospheric Environment,* 44**,** 1386-1399.
Rosado Pinto, J. 2011. ISAAC (International Study of Asthma and Allergies in Childhood) 20 anos em Portugal. *Acta Pediátrica Portuguesa,* 42.
Roux, E., Hyvelin, J. M., Savineau, J. P. & Marthan, R. 1999. Human isolated airway contraction: interaction between air pollutants and passive sensitization. *Am J Respir Crit Care Med,* 160**,** 439-45.
Rumchev, K., Spickett, J., Bulsara, M., Phillips, M. & Stick, S. 2004. Association of domestic exposure to volatile organic compounds with asthma in young children. *Thorax,* 59**,** 746-751.
Rumchev, K. B., Spickett, J. T., Bulsara, M. K., Phillips, M. R. & Stick, S. M. 2002. Domestic exposure to formaldehyde significantly increases the risk of asthma in young children. *European Respiratory Journal,* 20**,** 403-408.

Ruotsalainen, R., Jaakkola, N. & Jaakkola, J. J. K. 1995. Dampness and Molds in Day-Care-Centers as an Occupational-Health Problem. *International Archives of Occupational and Environmental Health,* 66**,** 369-374.

Russell, G. 2006. The childhood asthma epidemic. *Thorax,* 61**,** 276-8.

Ryan, P., LeMasters, G., Biagini, J., Bernstein, D., Grinshpun, S., Shukla, R. & al., e. 2005. Is it traffic type, volume, or distance? Wheezing in infants living near truck and bus traffic. *J Allergy Clin Immunol* 116**,** 279-84.

Rylander, R. 1997. Airborne (1->3)-beta-D-glucan and airway disease in a day-care center before and after renovation. *Archives of Environmental Health,* 52**,** 281-285.

Rylander, R. & Etzel, R. 1999. Introduction and summary: workshop on children's health and indoor mold exposure. *Environ Health Perspect,* 107 Suppl 3**,** 465-8.

Sahakian, N., Park, J. & Cox-Ganser, J. 2008. Dampness and mold in the indoor environment: implications for asthma. *Immunol Allergy Clin North Am* 28**,** 485-505.

Salthammer, T., Mentese, S. & Marutzky, R. 2010. Formaldehyde in the indoor environment. *Chem Rev,* 110**,** 2536-72.

Salvi, S. 2007. Health effects of ambient air pollution in children. *Paediatr. Respir. Rev,* 8**,** 275-280.

Samet, J. 1990. Environmental controls and lung disease. *Am Rev Respir Dis* 142**,** 915-39.

Sandstrom, F. M. & Faergemann, J. 2006. Atopic dermatitis in adults: does it disappear with age? . *Acta Derm Venereol,* 86**,** 135-139.

Santos, F., Forbes, K. & Moita, R. 2002. Climate Change in Portugal: Scenarios, Impacts and Adaptation Measures Lisboa, Gradiva.

Sarigiannis, D. A., Karakitsios, S. P., Gotti, A., Liakos, I. L. & Katsoyiannis, A. 2011. Exposure to major volatile organic compounds and carbonyls in European indoor environments and associated health risk. *Environment International,* 37**,** 743-765.

Sarwar, G., Corsi, R., Allen, D. & Weschler, C. 2003. The significance of secondary organic aerosol formation and growth in buildings: experimental and computational evidence. *Atmospheric Environment,* 37**,** 1365-1381.

Sathyanarayana, S., Karr, C. J., Lozano, P., Brown, E., Calafat, A. M., Liu, F. & Swan, S. H. 2008. Baby care products: possible sources of infant phthalate exposure. *Pediatrics,* 121**,** e260-8.

Scarlett, J. F., Abbott, K. J., Peacock, J. L., Strachan, D. P. & Anderson, H. R. 1996. Acute effects of summer air pollution on respiratory function in primary school children in southern England. *Thorax,* 51**,** 1109-14.

Sennhauser, F. H., Braun-Fahrlander, C. & Wildhaber, J. H. 2005. The burden of asthma in children: a European perspective. *Paediatric respiratory reviews,* 6**,** 2-7.

Shaughnessy, R. J., Haverinen-Shaughnessy U., Nevalainen, A. & Moschandreas, D. 2006. A preliminary study on the association between ventilation rates in classrooms and student performance. *Indoor Air,* 16**,** 465-468.

Sheldon, S. 2001. The linkage between rhinitis, sinusitis, and asthma. *Clinical and Applied Immunology Reviews,* 1**,** 229-234.

Simoni, M., Annesi-Maesano, I., Sigsgaard, T., Norbäck, D., Wieslander, G., Nystad, W., Canciani, M., Sestini, P. & Viegi, G. 2010. School air quality related to dry cough, rhinitis and nasal patency in children. *European Respiratory Journal,* 35**,** 742-749.

Singer, B. C., Coleman, B. K., Destaillats, H., Hodgson, A. T., Lunden, M. M., Weschler, C. J. & Nazaroff, W. W. 2006a. Indoor secondary pollutants from cleaning product and air freshener use in the presence of ozone. *Atmospheric Environment,* 40**,** 6696-6710.

Singer, B. C., Destaillats, H., Hodgson, A. T. & Nazaroff, W. W. 2006b. Cleaning products and air fresheners: emissions and resulting concentrations of glycol ethers and terpenoids. *Indoor Air,* 16**,** 179-191.

SINPHONIE project. *Schools Indoor Pollution and Health: Observatory Network in Europe* [Online]. Available: http://www.sinphonie.eu/ [Accessed January, 2012].

Slezáková, K. 2009. Suspended particles in outdoor and indoor air: characterization to support epidemiological studies. Faculdade de Engenharia. Universidade do Porto.

Smedje, G. & Norbäck, D. 2001. Incidence of asthma diagnosis and selfreported allergy in relation to the school environment–a four-year follow-up study in schoolchildren. *Int. J. Tuberc. Lung Dis.,* 5**,** 1059-1066.

Smedje, G., Norbäck, D. & Edling, C. 1997. Subjective indoor air quality in schools in relation to exposure. *Indoor Air* 7**,** 143-150.

Sousa, S. I. V. d. 2009. Impact of Ozone on the Prevalence of Childhood Asthma. Faculty of Engineering, University of Porto.

Spengler, J., Jaakkola, J., Parise, H., Katsnelson, A., Privalova, L. & Kosheleva, A. 2004. Housing characteristics and children's respiratory health in the Russian Federation. *Am J Public Health* 94**,** 657-62.

Spengler, J., Neas, L., Nakai, S., Dockery, D., Speizer, F., Ware, J. & Raizenne, M. 1994. Respiratory symptoms and housing characteristics. *Indoor air,* 4**,** 72-82.

Spergel, J. M. 2010. From atopic dermatitis to asthma: the atopic march. *Ann Allergy Asthma Immunol,* 105**,** 99-106; quiz 107-9, 117.

SPSS Inc. Released 2009. PASW Statistics for Windows, Version 17.0. Chicago: SPSS Inc.

Sram, R. J., Binkova, B., Dostal, M., Merkerova-Dostalova, M., Libalova, H., Milcova, A., Rossner, P., Jr., Rossnerova, A., Schmuczerova, J., Svecova, V., et al. 2013. Health impact of air pollution to children. *Int J Hyg Environ Health*.

Stark, P. C., Celedon, J. C., Chew, G. L., Ryan, L. M., Burge, H. A., Muilenberg, M. L. & Gold, D. R. 2005. Fungal levels in the home and allergic rhinitis by 5 years of age. *Environ Health Perspect,* 113**,** 1405-9.

Steerenberg, P. A., Withagen, C. E. T., Dormans, J. A. M. A., van Dalen, W. J., van Loveren, H. & Casee, F. R. 2003. Adjuvant activity of various diesel exhaust and ambient particles in two allergic models. *Journal of Toxicology and Environmental Health-Part A,* 66**,** 1421-1439.

Steinemann, A. C., MacGregor, I. C., Gordon, S. M., Gallagher, L. G., Davis, A. L., Ribeiro, D. S. & Wallace, L. A. 2011. Fragranced consumer products: Chemicals emitted, ingredients unlisted. *Environmental Impact Assessment Review,* 31**,** 328-333.

Strachan, D. 1989. Hay fever, hygiene, and household size. *British Medical Journal,* 299**,** 1259-60.

Strachan, D. & Cook, D. 1998. Health effects of passive smoking. 6. Parental smoking and childhood asthma: longitudinal and case-control studies. *Thorax,* 53**,** 204-12.

Stranger, M., Debrouwere, K., Goelen, E., Koppen, G., Torfs, R., Desager, K., Tilborghs, G., Mampaey, M. & Constandt, K. Year. BiBa, on the indoor air quality in primary school classrooms. In: Proceedings of Indoor Air Quality in different living settings, 2010 Brussels, Belgium.

Stranger, M., Potgieter-Vermaak, S. S. & Van Grieken, R. 2007. Comparative overview of indoor air quality in Antwerp, Belgium. *Environ Int,* 33**,** 789-97.

Stranger, M., Potgieter-Vermaak, S. S. & Van Grieken, R. 2008. Characterization of indoor air quality in primary schools in Antwerp, Belgium. *Indoor Air,* 18**,** 454-463.

Sun, Y., Varnel, G. & Sundell, J. 2009. An on-going study on home environment and asthma and allergy among children in North East Texas, USA. Syracuse, NY USA: 9th International Conference Healthy Buildings 2009.

Sundell, J., Wickman, M., Pershagen, G. & Nordvall, S. L. 1995. Ventilation in homes infested by house-dust mites. *Allergy,* 50**,** 106-12.

Taskinen, T., Hyvarinen, A., Meklin, T., Husman, T., Nevalainen, A. & Korppi, M. 1999. Asthma and respiratory infections in school children with special reference to moisture and mold problems in the school. *Acta Paediatrica,* 88**,** 1373-1379.

Tavernier, G., Fletcher, G., Gee, I., Watson, A., Blacklock, G., Francis, H., Fletcher, A., Frank, T., Frank, P., Pickering, C. A., et al. 2006. IPEADAM study: Indoor endotoxin exposure, family status, and some housing characteristics in English children. *Journal of Allergy and Clinical Immunology,* 117**,** 656-662.

The International Study of Asthma and Allergies in Childhood. Available: http://isaac.auckland.ac.nz/# [Accessed April, 2013].

Thomson, W. D. 1998. Eye problems and visual display terminals - the facts and the fallacies. *Ophthalmic and Physiological Optics,* 18**,** 111-119.

Todo-Bom, A., Loureiro, C., Almeida, M. M., Nunes, C., Delgado, L., Castel-Branco, G. & Bousquet, J. 2007. Epidemiology of rhinitis in Portugal: evaluation of the intermittent and the persistent types. *Allergy,* 62**,** 1038-1043.

Trude, D. & Skorge, M. D. 2007. Environmental tobacco smoke (ETS) in childhood and incidence of respiratory symptoms in adulthood. *Respiratory Medicine* 3**,** 125.

Uddenfeldt, M. 2010. A longitudinal study of asthma.

Valente, J. 2010. Modelação da qualidade do ar e da saúde humana: da mesoescala à dose. PhD, University of Aveiro.

Van Roosbroeck, S., Jacobs, J., Janssen, N. A. H., Oldenwening, M., Hoek, G. & Brunekreef, B. 2007. Long-term personal exposure to PM2.5, soot and NOx in children attending schools located near busy roads, a validation study. *Atmospheric Environment,* 41**,** 3381-3394.

Venn, A., Lewis, S., Cooper, M., Hubbard, R. & Britton, J. 2001. Living Near a Main Road and the Risk of Wheezing Illness in Children. *Am J Respir Crit Care Med* 164**,** 2177-80.

Venn, A. J., Cooper, M., Antoniak, M., Laughlin, C., Britton, J. & Lewis, S. A. 2003. Effects of volatile organic compounds, damp, and other environmental exposures in the home on wheezing illness in children. *Thorax,* 58**,** 955-60.

Vicente, P., Rodrigues, T., Silva, A., Tzer, T. & Barros, H. 1995. Prevalência de asma em estudantes das escolas secundárias portuguesas [Prevalence of asthma in students from Portuguese secondary schools]. *Arq Med,* 9**,** 90-2.

Viegi, G., Simoni, M., Scognamiglio, A., Baldacci, S., Pistelli, F., Carrozzi, L. & Annesi-Maesano, I. 2004. Indoor air pollution and airway disease. *International Journal of Tuberculosis and Lung Disease,* 8**,** 1401-1415.

Volkmer, R., Ruffin, R., Wigg, N. & Davies, N. 1995. The prevalence of respiratory symptoms in South Australian preschool children. II. Factors associated with indoor air quality. *J Paediatr Child Health,* 31**,** 116-20.

von Hertzen, L. & Haahtela, T. 2005. Signs of reversing trends in prevalence of asthma. *Allergy,* 60**,** 283-92.

von Mutius, E. 2000. The burden of childhood asthma. *Archives of disease in childhood,* 82 Suppl 2**,** II2-5.

Wallace, L. 2000. Assessing Human Exposure to Volatile Organic Compounds, New York, USA, McGraw-Hill.

Wallner, P., Kundi, M., Moshammer, H., Piegler, K., Hohenblum, P., Scharf, S., Frohlich, M., Damberger, B., Tappler, P. & Hutter, H. P. 2012. Indoor air in schools and lung function of Austrian school children. *J Environ Monit,* 14**,** 1976-82.

Wan, G. H. & Li, C. S. 1999. Indoor endotoxin and glucan in association with airway inflammation and systemic symptoms. *Archives of Environmental Health,* 54**,** 172-9.

Weiland, S., Mundt, K., Ruckmann, A. & Keil, U. 1994. Self-reported wheezing and allergic rhinitis in children and traffic density on street of residence. *Ann Epidemiol* 4**,** 243-7.

Weschler, C. 2006. Ozone's impact on public health: contributions from indoor exposures to ozone and products of ozone-initiated chemistry. *Environ Health Perspect* 114**,** 1489-96.

Weschler, C. J. 2004. Chemical reactions among indoor pollutants: what we've learned in the new millennium. *Indoor Air,* 14**,** 184-194.

Weschler, C. J. 2009. Changes in indoor pollutants since the 1950s. *Atmospheric Environment* 43**,** 153-169.

Weschler, C. J. & Nazaroff, W. W. 2008. Semivolatile organic compounds in indoor environments. *Atmospheric Environment,* 42**,** 9018-9040.

Weschler, C. J. & Shields, H. C. 2003. Experiments probing the influence of air exchange rates on secondary organic aerosols derived from indoor chemistry. *Atmospheric Environment,* 37**,** 5621-5631.

Wickman, M., Gravesen, S., Nordvall, S. L., Pershagen, G. & Sundell, J. 1992. Indoor viable dust-bound microfungi in relation to residential characteristics, living habits, and symptoms in atopic and control children. *J Allergy Clin Immunol,* 89**,** 752-9.

Wieslander, G. & Norbäck, D. 2010. Ocular symptoms, tear film stability, nasal patency, and biomarkers in nasal lavage in indoor painters in relation to emissions from water-based paint. *International Archives of Occupational & Environmental Health,* 83**,** 733-741.

Wieslander, G., Norbäck, D., Nordstrom, K., Walinder, R. & Venge, P. 1999. Nasal and ocular symptoms, tear film stability and biomarkers in nasal lavage, in relation to building-dampness and building design in hospitals. *International Archives of Occupational and Environmental Health,* 72**,** 451-461.

Wolkoff, P., Clausen, P. A., Larsen, K., Hammer, M., Larsen, S. T. & Nielsen, G. D. 2008. Acute airway effects of ozone-initiated d-limonene chemistry: importance of gaseous products. *Toxicology Letters,* 181**,** 171-6.

Wolkoff, P. & Nielsen, G. D. 2010. Non-cancer effects of formaldehyde and relevance for setting an indoor air guideline. *Environ Int,* 36**,** 788-99.

Wolkoff, P., Nojgaard, J. K., Troiano, P. & Piccoli, B. 2005. Eye complaints in the office environment: precorneal tear film integrity influenced by eye blinking efficiency. *Occupational and Environmental Medicine,* 62**,** 4-12.

Wolkoff, P., Skov, P., Franck, C. & Petersen, L. N. 2003. Eye irritation and environmental factors in the office environment - hypotheses, causes and a physiological model. *Scandinavian Journal of Work Environment & Health,* 29**,** 411-430.

Wong, T., Yu, T., Liu, H. & Wong, A. 2006. Household gas cooking: a risk factor for respiratory illnesses in preschool children. *Arch Dis Child,* 89**,** 631-6.

World Health Organization 2000. Air Quality Guidelines, Second Edition. European Series No. 91. Copenhagen, Denmark: World Health Organization Regional Publications.

World Health Organization 2005. Air Quality Guidelines Global Update 2005 Particulate matter, ozone, nitrogen dioxide and sulfur dioxide.

World Health Organization. 2006. *WHO Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulfur Dioxide: Global Update 2005 (Summary of Risk Assessment)* [Online]. Genova, Switzerland. Available: http://whqlibdoc.who.int/hq/2006/WHO_SDE_PHE_OEH_ [Accessed].

World Health Organization 2007a. Global surveillance, prevention and control of chronic respiratory diseases - A comprehensive approach. Geneva.

World Health Organization 2007b. Prevalence of asthma and allergies in children.

World Health Organization 2008. Health risks of ozone from long-range transboundary air pollution. In: World Health Organization Regional Office for Europe (ed.). Copenhagen, Denmark.

World Health Organization 2009a. Children living in homes with problems of damp.

World Health Organization 2009b. Dampness and mould. WHO guidelines for indoor air quality.
World Health Organization 2009c. Exposure of children to air pollution (particulate matter) in outdoor air. In: World Health Organization Regional Office for Europe (ed.). Copenhagen, Denmark.
World Health Organization 2009d. Exposure of children to second-hand tobacco smoke. In: World Health Organization Regional Office for Europe (ed.). Copenhagen, Denmark.
World Health Organization 2010a. The Fifth Ministerial Conference on Environment and Health Parma.
World Health Organization 2010b. Health and Environment in Europe: Progress Assessment. In: World Health Organization Regional Office for Europe (ed.). Copenhagen, Denmark.
World Health Organization 2010c. WHO Guidelines for Indoor Air Quality: Selected pollutants. In: World Health Organization Regional Office for Europe (ed.). Copenhagen.
World Health Organization 2011. Environmental burden of disease associated with inadequate housing - A method guide to the quantification of health effects of selected housing risks in the WHO European Region. In: World Health Organization Regional Office for Europe (ed.). Copenhagen.
World Health Organization 2012. Environmental Health Inequalities in Europe. In: World Health Organization Regional Office for Europe (ed.). Copenhagen, Denmark.
World Health Organization 2013. Review of evidence on health aspects of air pollution - REVIHAAP Project - Technical Report. Copenhagen, Denmark: World Health Organization Regional Office for Europe.
World Helath Organization. *Health statistics and health information systems* [Online]. Available: http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/ [Accessed].
World Helath Organization 1987. Air quality guidelines for Europe. Copenhagen: World Health Organization Regional Office for Europe.
Wyon, D. P. 1992. Sick Buildings and the Experimental Approach. *Environmental Technology,* 13**,** 313-322.
Xie, X. J., Li, Y. G., Sun, H. Q. & Liu, L. 2009. Exhaled droplets due to talking and coughing. *Journal of the Royal Society Interface,* 6**,** S703-S714.
Yang, C., Chiu, J., Cheng, M. & Lin, M. 1997. Effects of indoor environmental factors on respiratory health of children in a subtropical climate. *Environ Res* 75**,** 49-55.
Yang, C., Lin, M. & Hwang, K. 1998. Childhood asthma and the indoor environment in a subtropical area. *Chest,* 114**,** 393-7.
Yang, W., Sohn, J., Kim, J., Son, B. & Park, J. 2009. Indoor air quality investigation according to age of the school buildings in Korea. *Journal of Environmental Management,* 90**,** 348-354.
Yip, F. Y., Keeler, G. J., Dvonch, J. T., Robins, T. G., Parker, E. A., Israel, B. A. & Brakefield-Caldwell, W. 2004. Personal exposures to particulate matter among children with asthma in Detroit, Michigan. *Atmospheric Environment,* 38**,** 5227-5236.
Yuksel, H., Dinc, G., Sakar, A., Yilmaz, O., Yorgancioglu, A., Celik, P. & Ozcan, C. 2008. Prevalence and comorbidity of allergic eczema, rhinitis, and asthma in a city in western Turkey. *J Investig Allergol Clin Immunol,* 18**,** 31-5.
Zhang, G., Spickett, J., Rumchev, K., Lee, A. H. & Stick, S. 2006. Indoor environmental quality in a ‘low allergen’ school and three standard primary schools in Western Australia. *Indoor Air,* 16**,** 74-80.
Zhang, L., Chew, F., Soh, S., Yi, F., Law, S., Goh, D. & Lee, B. 1997. Prevalence and distribution of indoor allergens in Singapore. *Clin. Exp.,* 27**,** 876-85.
Zhao, Z. H., Elfman, L., Wang, Z. H., Zhang, Z. & Norbäck, D. 2006. A comparative study of asthma, pollen, cat and dog allergy among pupils and allergen levels in schools in Taiyuan city, China, and Uppsala, Sweden. *Indoor Air,* 16**,** 404-413.
Zhao, Z. H., Zhang, Z., Wang, Z. H., Ferm, M., Liang, Y. L. & Norbäck, D. 2008. Asthmatic symptoms among pupils in relation to winter indoor and outdoor air pollution in schools in Taiyuan, China. *Environmental Health Perspectives,* 116**,** 90-97.
Zmirou, D., Gauvin, S., Pin, I., Momas, I., Sahraoui, F., Just, J., Le Moullec, Y., Bremont, F., Cassadou, S., Reungoat, P., et al. 2004. Traffic related air pollution and incidence of childhood asthma: results of the Vesta case-control study. *J Epidemiol Community Health,* 58**,** 18-23.
Zock, J.-P., Jarvis, D., Luczynska, C., Sunyer, J. & Burney, P. 2002. Housing characteristics, reported mold exposure, and asthma in the European Community Respiratory Health Survey. *J Allergy Clin Immunol* 110**,** 285-92.
Zock, J. P., Heinrich, J., Jarvis, D., Verlato, G., Norbäck, D., Plana, E., Sunyer, J., Chinn, S., Olivieri, M., Soon, A., et al. 2006. Distribution and determinants of house dust mite allergens in Europe: the European Community Respiratory Health Survey II. *J Allergy Clin Immunol,* 118**,** 682-90.
Zollner, I., Weiland, S., Piechotowski, I., Gabrio, T., von Mutius, E. & Link, B. 2005. No increase in the prevalence of asthma, allergies, and atopic sensitisation among children in Germany: 1992-2001. *Thorax,* 60**,** 545-8.
Zuraimi, B. M. S. 2008. Child care centre and home exposures among preschool children in Singapore and their associations with asthma, allergies and respiratory symptoms.

Annexes

Annex 1. Children's questionnaire

QUESTIONÁRIO SOBRE ALERGIAS E DOENÇAS RESPIRATÓRIAS NAS CRIANÇAS

(A preencher pelos alunos na sala de aula na presença de um profissional envolvido no estudo)

Projecto financiado pela

Comissão Europeia

Direcção Geral para a Saúde e Defesa dos Consumidores

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Instruções para o preenchimento do questionário

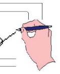
- Quando te for pedido para escrever um texto (por exemplo, nome da escola/país, o teu nome, outras especificações, ...), escreve de forma clara, se possível, em letras maiúsculas e no espaço indicado.
- Por favor, assinala a caixa correspondente à tua opção de resposta. Por exemplo:

Este questionário vai ser submetido a **leitura óptica**. Por favor use **tinta preta ou azul** evitando tocar nos cantos das caixas.

1	2	3	4	5	6	7	8	9	0
A	B	C	D	E	F	G	H		

Preencha assim ●

Não preencha assim ☒ ✓



Instruções para o preenchimento do questionário para os profissionais que prestam assistência às crianças durante o preenchimento do questionário:

O termo "ataque de asma" é definido como qualquer alteração aguda nos sintomas da asma, que ocorre de repente, e que interrompe a rotina normal da criança e requer medicação extra ou intervenção que melhore os sintomas, para que a criança possa respirar normalmente de novo. Os sintomas são tosse, pieira ou ambos com dificuldade em respirar. A pieira pode ser suficientemente grave para limitar a conversa a apenas uma ou duas palavras, entre duas respirações.

Se a criança não conhecer o termo "eczema", provavelmente é porque nunca teve eczema. Neste caso diga à criança para responder "Não" à questão C7.

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*E para escola primária e J para jardim-de-infância

ID da criança: ___

QC1. Data: (Dia/Mês/Ano) __ - __ - ____

IDENTIFICAÇÃO DA TUA ESCOLA:

QC2. Nome da escola: ______

QC3. Cidade: ______ **QC4.** País: ______

QC5. Turma: ______

IDENTIFICAÇÃO DO ALUNO:

Nome (primeiro e último): ______

Nota: O teu nome não vai constar na base de dados. Serás identificado por um código

QC6. Data de nascimento: (Dia/Mês/Ano) __ - __ - ____

QC7. Idade: __ (anos) e __ (meses)

QC8. Género: O Masculino O Feminino

33753

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*E para escola primária e J para jardim-de-infância

ID da criança: ___

C1. Já alguma vez tiveste um ataque de asma (ou pieira ou assobios (silvos) no peito) na escola?
O Não O Sim Se "Não", passa à questão **C5.**

C2. Onde ocorreu esse ataque de asma na escola? (Assinala as opções que se apliquem)

- O Na sala de aula
- O No ginásio
- O Na casa de banho
- O No exterior
- O Noutro local ______

C3. O ataque ocorreu durante a prática de alguma das seguintes actividades? (Assinala as opções que se apliquem)

- O Durante as aulas
- O Durante a prática de exercício físico
- O Durante as actividades artísticas (pintura, colagem, etc.)
- O Durante o intervalo
- O Durante outra actividade ______

C4. Como foi gerido o ataque de asma? (Assinala as opções que se apliquem)

- O Não foi efectuado nada
- O A medicação para a asma foi administrada pelo próprio
- O Os professores/funcionários sugeriram que a medicação para a asma fosse tomada
- O Os professores/funcionários forneceram a medicação
- O Os pais foram chamados à escola
- O Fui consultado por um enfermeiro(a) ou médico(a) que estivesse presente na escola
- O Foi chamado o serviço de emergência médica, ou fui levado para o hospital/centro de saúde

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C) SINTOMAS/DIAGNÓSTICO

Na semana passada, tiveste algum dos seguintes sintomas? (Se necessário assinala mais que uma opção)

	Sim, em casa	Sim, na escola	Sim, noutros locais	Não, nunca
C5. Alterações na pele com comichão nas mãos ou antebraços	O	O	O	O
C6. Alterações na pele com comichão na face ou pescoço	O	O	O	O
C7. Eczema	O	O	O	O
C7.1. Onde?				
C8. Comichão nas mãos ou nos antebraços	O	O	O	O
C9. Comichão na face ou no pescoço	O	O	O	O
C10. Irritação nos olhos	O	O	O	O
C11. Comichão nos olhos	O	O	O	O
C12. Olhos secos	O	O	O	O
C13. Sensação de "areia" nos olhos	O	O	O	O
C14. Olhos vermelhos	O	O	O	O
C15. Olhos inchados	O	O	O	O
C16. Pingo no nariz	O	O	O	O
C17. Comichão/irritação no nariz	O	O	O	O
C18. Espirros	O	O	O	O
C19. Nariz entupido/obstrução nasal	O	O	O	O
C20. Correr sangue do nariz	O	O	O	O
C21. Garganta seca	O	O	O	O
C22. Dor de garganta	O	O	O	O
C23. Tosse seca	O	O	O	O
C24. Dificuldade em respirar	O	O	O	O
C25. Sensação de constipação	O	O	O	O
C26. Dor de cabeça/enxaqueca	O	O	O	O
C27. Mal-estar/indisposição	O	O	O	O
C28. Fadiga/cansaço	O	O	O	O
C29. Constipação	O	O	O	O
C30. Gripe ou febre	O	O	O	O
C31. Pieira no peito	O	O	O	O
C32. Dificuldade em respirar com pieira no peito	O	O	O	O
C33. Dores musculares	O	O	O	O

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C34. Se algum dos sintomas/diagnósticos referidos na página anterior ocorreram na escola (coluna 2) na última semana, assinala o local onde ocorreram/tiveram início

O Na sala de aula Qual(ais) o(s) sintoma(s)?

O No ginásio Qual(ais) o(s) sintoma(s)?

O Na casa de banho Qual(ais) o(s) sintoma(s)?

O No exterior Qual(ais) o(s) sintoma(s)?

O Noutro local Qual(ais) o(s) sintoma(s)?

Por favor, especifica

Relativamente à tua exposição ao fumo do tabaco nos últimos 7 dias, por favor assinala apenas uma das opções.

EXPOSIÇÃO AO FUMO PASSIVO

NOS ÚLTIMOS 7 DIAS:

C35. Estiveste exposto ao fumo do tabaco (cigarros, charutos, cachimbo, ...)?

O Não O Sim Se "Não", passa à questão **C39.**

C36. Onde ocorreu essa exposição?

O Em casa

O Na escola

O Noutro local

C37. Onde ocorreu essa exposição?

	1 hora ou menos	2-5 horas	6 ou mais horas
Em casa	O	O	O
Na escola	O	O	O
Noutro local	O	O	O

C38. Como julgas a tua exposição ao fumo do tabaco nos seguintes locais?

	Leve	Moderada	Excessiva
Em casa	O	O	O
Na escola	O	O	O
Noutro local	O	O	O

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Gostaríamos de saber qual é a tua opinião sobre o ambiente escolar, por favor assinala apenas uma das opções.

PERCEPÇÃO DO AMBIENTE ESCOLAR

ASSINALA UM NÚMERO DE 0 A 6

C39. Qual é a tua percepção relativamente à iluminação da escola? (se a iluminação for variável tenta dar uma média da classificação)

O 0 O 1 O 2 O 3 O 4 O 5 O 6

Extremamente má — Extremamente boa

C40. Durante as actividades escolares qual é a tua percepção relativamente ao barulho/ruído? (se o baralho/ruído for variável tenta dar uma média da classificação)

O 0 O 1 O 2 O 3 O 4 O 5 O 6

Extremamente má — Extremamente boa

C41. Qual é a tua percepção relativamente à qualidade do ar interior na escola? (se a qualidade do ar interior na escola for variável tenta dar uma média da classificação)

O 0 O 1 O 2 O 3 O 4 O 5 O 6

Extremamente má — Extremamente boa

C41.1. Se achas que a qualidade do ar interior não é boa, por favor, tenta explicar as razões.

C42. Qual é a tua percepção à qualidade do ar exterior na escola? (se a qualidade do ar exterior na escola for variável tenta dar uma média da classificação)

O 0 O 1 O 2 O 3 O 4 O 5 O 6

Extremamente má — Extremamente boa

C43. Sentes que a tua capacidade para realizar as tarefas escolares é reduzida devido a uma deficiente qualidade do ar interior na escola?

O Não O Sim O Não sei

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ASSINALA UM NÚMERO DE 0 A 10

C44. Qual é a tua satisfação relativamente à escola?

O 0 O 1 O 2 O 3 O 4 O 5 O 6 O 7 O 8 O 9 O 10

Totalmente insatisfeito — Totalmente satisfeito

C45. Consideradas as tuas actividades escolares stressantes?

O 0 O 1 O 2 O 3 O 4 O 5 O 6 O 7 O 8 O 9 O 10

Nada stressantes — Extremamente stressantes

C46. Quanto agradável/amigável é a tua escola?

O 0 O 1 O 2 O 3 O 4 O 5 O 6 O 7 O 8 O 9 O 10

Nada agradável/amigável — Muito agradável/amigável

FIM

OBRIGADA PELA TUA COLABORAÇÃO

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Annex 2. Parents' questionnaire

QUESTIONÁRIO SOBRE ALERGIAS E DOENÇAS RESPIRATÓRIAS NAS CRIANÇAS E HABITAÇÃO

(A PREENCHER PELOS PAIS/ENCARREGADOS DE EDUCAÇÃO)

Projecto financiado pela

Comissão Europeia

Direcção Geral para a Saúde e Defesa dos Consumidores

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Caros Pais/Encarregados de Educação,

Convidamos o seu filho a participar num importante estudo Europeu, designado SINPHONIE (financiado pela Direcção Geral para a Saúde e Defesa dos Consumidores da Comissão Europeia, que envolve 38 instituições de 25 países), cujo objectivo é avaliar a qualidade do ar interior em edifícios escolares (escolas primárias e jardins-de- infância) e o seu efeito na saúde das crianças.

Ao concordar com a participação do seu filho no presente estudo, ficávamos gratos que preenchesse o questionário em anexo. Toda a informação é absolutamente confidencial e será utilizada apenas para fins de investigação. De acordo com as regras nacionais de protecção de dados, toda a informação recolhida pode ser consultada pelo próprio.

Instruções para o preenchimento do questionário

Se possível, o preenchimento do questionário deverá ser efectuado por ambos os pais/encarregados de educação.

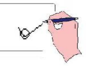
- Quando lhe for pedido para escrever um texto (por exemplo, nome da escola/país, outras especificações, ...), escreva de forma clara, se possível, em letras maiúsculas e no espaço indicado.
- Por favor, assinale o número ou caixa correspondente à sua opção de resposta. Assinale apenas uma opção, salvo indicação em contrário. Por exemplo:

Este questionário vai ser submetido a **leitura óptica**. Por favor use **tinta preta ou azul** evitando tocar nos cantos das caixas.

1	2	3	4	5	6	7	8	9	0
A	B	C	D	E	F	G	H		

Preencha assim ●

Não preencha assim ⊗



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Código: P T E _ _ _ E _ S _
País Escola E/J* Edifício Sala
*E para escola primária e J para jardim-de-infância

ID da criança:

QP1. Data: (Dia/Mês/Ano) __ - __ - ____

QP2. Questionário preenchido por:

O Mãe O Pai O Ambos O Outro

IDENTIFICAÇÃO DA ESCOLA DO SEU FILHO:

QP3. Nome da escola:

QP4. Morada da escola:

QP5. Cidade: **QP6.** Código postal: ____ - ___

QP7. País: **QP8.** Turma:

O SEU FILHO:

Nome (completo):

Nota: O nome da criança não vai constar na base de dados. A criança será identificada por um código

QP9. Data de nascimento: (Dia/Mês/Ano) __ - __ - ____

QP10. Idade: __ (anos) e __ (meses)

QP11. Peso: __ Kg **QP12.** Altura: ___ cm

QP13. Género: O Masculino O Feminino

Idade dos pais:

QP14. Idade da mãe: __ anos **QP15.** Idade do pai: __ anos

QP16. Telefone de casa:

QP17. Telemóvel do Pai:

QP18. Telemóvel da Mãe:

QP19. Outro Contacto: Qual?

62099

Código: P T E _ _ _ E _ S _
País Escola E/J* Edifício Sala
*E para escola primária e J para jardim-de-infância

ID da criança:

Para começar, gostaríamos que respondesse a algumas questões sobre a gestação e o período perinatal do seu filho.
Por favor assinale apenas uma opção.

A) INFORMAÇÃO PERINATAL

PA1. A gravidez foi: O Singular O Múltipla O Não sabe

PA2. O seu filho nasceu dentro das três semanas para a data prevista?

- O Sim
- O Não, nasceu mais de 3 semanas antes da data prevista
- O Não, nasceu mais de 3 semanas depois da data prevista
- O Não sabe

PA3. Qual o peso ao nascer do seu filho? ____ g O Não sabe

PA4. O seu filho foi amamentado ao peito?

- O Não
- O Sim, exclusivamente (nem água bebia)
- O Sim, mas com ingestão de água
- O Não sabe

PA4.1. até aos __ meses de idade

PA5. A mãe fumou durante a gravidez?

- O Não
- O Sim → **PA5.1.** em média fumou __ cigarros por dia
- O Não sabe

PA6. O pai ou outro familiar fumaram na presença da mãe durante a gravidez?

O Não O Sim O Não sabe

PA7. Durante o primeiro ano de vida, o seu filho foi exposto ao fumo do tabaco?

O Não O Sim O Não sabe

PA8. Durante os dois primeiros anos de vida, o seu filho sofreu de alguma destas infecções:

PA8.1. Pneumonia	O Não	O Sim	O Não sabe
PA8.2. Bronquite	O Não	O Sim	O Não sabe
PA8.3. Bronquite asmática	O Não	O Sim	O Não sabe
PA8.4. Bronquiolite	O Não	O Sim	O Não sabe

PA9. Quantos irmãos/irmãs mais novos tem o seu filho?

PA10. Quantos irmãos/irmãs mais velhos tem o seu filho?

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Gostaríamos que respondesse a algumas questões sobre a saúde do seu filho. Por favor assinale apenas uma opção.

B) ALERGIAS/DOENÇAS RESPIRATÓRIAS

O SEU FILHO:

PB1. Alguma vez teve pieira ou assobios (silvos) no peito?
O Não O Sim Se "Não", passe à questão **PB10.**

PB2. Se sim, teve pieira ou assobios (silvos) no peito durante os últimos 12 meses?
O Não O Sim Se "Não", passe à questão **PB10.**

PB3. Quantos ataques de pieira teve nos últimos 12 meses?
O Nenhum O De 1 a 3 O De 4 a 12 O Mais de 12

PB4. Nos últimos 12 meses, quantas vezes em média, dormiu mal devido à pieira?
- O Nunca
- O Menos de 3 noites nos últimos 12 meses
- O Menos de 1 noite por mês
- O Entre 1 e 3 noites por mês
- O 1 ou mais noites por semana

PB5. Nos últimos 12 meses, a pieira foi suficientemente forte para limitar a conversa a apenas uma ou duas palavras, entre duas respirações?
O Não O Sim

PB6. Nos últimos 12 meses, teve pieira no peito associada à constipação ou infecção respiratória?
- O Apenas durante os períodos de constipação ou gripe
- O Além de constipação ou gripe
- O Tanto durante como além de constipação ou gripe

PB7. Nos últimos 12 meses, a pieira no peito teve influência na qualidade de vida do seu filho, relativamente a:

	Muito pouco	Pouco	Relativa mente	Muito
PB7.1. Actividades físicas/desportivas	O	O	O	O
PB7.2. Duração/qualidade do sono	O	O	O	O
PB7.3. Prática de actividades	O	O	O	O
PB7.4. Assiduidade escolar	O	O	O	O
PB7.5. Relacionamento com outras pessoas	O	O	O	O

PB8. Teve pieira ou assobios (silvos) no peito durante os últimos 30 dias?
O Não O Sim

PB9. Nos últimos 12 meses, alguma vez sentiu pieira no peito durante ou depois de efectuar exercício físico?
O Não O Sim

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PB10. Nos últimos 12 meses, teve tosse seca à noite além da tosse associada à constipação ou infecção respiratória?
O Não O Sim

PB11. Alguma vez um médico diagnosticou asma ao seu filho?
O Não O Sim Se "Não", passe à questão **PB21.**

PB12. Com que a idade ocorreu o primeiro ataque de asma*? [ ][ ] anos

*Um ataque de asma é uma alteração aguda nos sintomas da asma, que ocorre de repente, e que interrompe a rotina normal da criança e requer medicação extra ou intervenção que melhore os sintomas, para que a criança possa respirar normalmente de novo. Os sintomas são tosse, pieira ou ambos com dificuldade em respirar. A pieira pode ser suficientemente grave para limitar a conversa a apenas uma ou duas palavras, entre duas respirações.

PB13. Com que a idade ocorreu o último ataque de asma? [ ][ ] anos

PB14. Nos últimos 12 meses, tomou algum medicamento para a asma (comprimidos, sprays, nebulizadores, ou outro)?
- O Nunca
- O Sim, ocasionalmente, quando necessário
- O Sim, regularmente, pelo menos durante 2 meses

PB15. Toma actualmente (nos últimos 3 meses) algum medicamento para a asma (comprimidos, sprays, nebulizadores, ou outro)?
O Não O Sim

PB16. Já alguma vez teve um ataque de asma na escola?
O Não O Sim Se "Não", passe à questão **PB21.**

PB17. Onde ocorreu esse ataque de asma na escola? (Assinale as opções que se apliquem)
- O Na sala de aula
- O No ginásio
- O Na casa de banho
- O No exterior
- O Noutro local [ ]

PB18. O ataque ocorreu durante a prática de alguma das seguintes actividades? (Assinale as opções que se apliquem)
- O Durante as aulas
- O Durante a prática de exercício físico
- O Durante as actividades artísticas (pintura, colagem, etc.)
- O Durante o intervalo
- O Durante outra actividade [ ]

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PB19. Como foi gerido o ataque de asma? (Assinale as opções que se apliquem)

- O Não foi efectuado nada
- O A medicação para a asma foi administrada pelo próprio
- O Os professores/funcionários sugeriram que a medicação para a asma fosse tomada
- O Os professores/funcionários forneceram a medicação
- O Os pais foram chamados à escola
- O Foi consultado por um enfermeiro(a) ou médico(a) que estivesse presente na escola
- O Foi chamado o serviço de emergência médica, ou foi levado para o hospital/centro de saúde

PB20. O seu filho está autorizado a tomar a medicação para a asma na escola?

- O Não
- O Sim, mas apenas quando o(a) professor(a) reconhece que é necessário
- O Sim, quando necessário

PB21. Tem tosse na maioria dos dias (4 ou mais dias por semana) além da tosse associada à constipação?

- O Não
- O Sim, durante menos de um mês por ano
- O Sim, durante 1-2 meses por ano
- O Sim, durante 3 ou mais meses por ano

→ **PB21.1.** Há quantos anos tem essa tosse? ☐☐

PB22. Tem tosse seca na maioria dos dias (4 ou mais dias por semana) além da tosse seca associada à constipação?

- O Não
- O Sim, durante menos de um mês por ano
- O Sim, durante 1-2 meses por ano
- O Sim, durante 3 ou mais meses por ano

→ **PB22.1.** Há quantos anos tem essa tosse? ☐☐

O SEU FILHO:

PB23. Já alguma vez teve crises de espirros, corrimento nasal ou nariz entupido quando não estava constipado ou com gripe?

O Não O Sim Se "Não", passe à questão **PB28.**

PB24. Nos últimos 12 meses, teve crises de espirros, corrimento nasal ou nariz entupido quando não estava constipado ou com gripe?

O Não O Sim Se "Não", passe à questão **PB28.**

PB25. Nos últimos 12 meses, esse problema do nariz foi acompanhado por olhos lacrimejantes e com comichão?

O Não O Sim

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PB26. Em qual ou quais dos últimos 12 meses ocorreu esse problema no nariz? (Assinale as opções que se apliquem)

O Janeiro	O Abril	O Julho	O Outubro
O Fevereiro	O Maio	O Agosto	O Novembro
O Março	O Junho	O Setembro	O Dezembro

PB27. Nos últimos 12 meses, esse problema no nariz afectou as actividades diárias do seu filho?

O Muito pouco O Pouco O Muito O Excessivamente

PB28. Já alguma vez teve alergias, incluindo febre dos fenos?

O Não O Sim → **PB28.1.** Foi diagnosticada pelo médico? O Não O Sim

PB29. Já alguma vez teve rinite alérgica, excluindo febre do feno (poeira, animais, etc.)?

O Não O Sim → **PB29.1.** Foi diagnosticada pelo médico? O Não O Sim

PB30. Alguma vez teve alergia/hipersensibilidade a gatos?

O Não O Sim → **PB30.1.** Foi diagnosticada pelo médico? O Não O Sim

PB31. Alguma vez teve alergia/hipersensibilidade a cães?

O Não O Sim → **PB31.1.** Foi diagnosticada pelo médico? O Não O Sim

PB32. Alguma vez teve alergia/hipersensibilidade ao pólen?

O Não O Sim → **PB32.1.** Foi diagnosticada pelo médico? O Não O Sim

PB33. Alguma vez teve alergia a algum alimento?

O Não O Sim Se "Não", passe à questão **PB36.**

PB34. Se sim, a que alimento(s)? (Assinale todas as opções que se apliquem)

- O Não foi/foram identificado(s)
- O Leite
- O Ovos
- O Amendoins
- O Fruta
- O Peixe
- O Outro(s) alimento(s) ☐

PB35. A alergia foi diagnosticada por um médico? O Não O Sim

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PB36. Tem algum familiar que sofre de alguma doença alérgica?

- ○ Não
- ○ Sim → Por favor indique quem
- ○ Não sabe

	Pai	Mãe	Irmãos
Asma	○	○	○
Sintomas nasais relacionados com a alergia (pingo, espirros, comichão e nariz tapado)	○	○	○
Eczema	○	○	○

O SEU FILHO:

PB37. Já alguma vez teve alterações na pele com comichão que apareciam e desapareciam, durante pelo menos 6 meses?
○ Não ○ Sim Se "Não", passe à questão **PB43.**

PB38. Com que a idade ocorreram essas alterações na pele pela primeira vez?
○ Com idade inferior a 2 anos ○ Entre os 2-4 anos ○ Com idade igual ou superior a 5 anos

PB39. Nos últimos 12 meses, alguma vez teve essas alterações na pele?
○ Não ○ Sim Se "Não", passe à questão **PB43.**

PB40. Essas alterações na pele afectaram-lhe alguma vez qualquer uma destas partes: as dobras dos cotovelos, atrás dos joelhos, frente dos tornozelos, entre as nádegas ou à volta do pescoço, orelhas ou olhos?
○ Não ○ Sim

PB41. Alguma vez durante os últimos 12 meses esta comichão passou completamente?
○ Não ○ Sim

PB42. Nos últimos 12 meses, quantas vezes, em média, acordou a meio da noite por causa da comichão?
- ○ Nunca
- ○ Menos de 1 noite por semana
- ○ 1 ou mais noites por semana

PB43. Já alguma vez teve eczema?
○ Não ○ Sim

PB44. Já teve dor de ouvidos ou otites (inflamação dos ouvidos)?
○ Não ○ Sim Se "Não", passe à questão **PB46.**

PB45. Nos últimos 12 meses, teve dor de ouvidos ou otites?
○ Não ○ Sim

PB46. Tem problemas de saúde importantes (incluindo outros que não os problemas respiratórios)?
○ Não ○ Sim

PB46.1. Por favor especifique:

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Gostaríamos que respondesse a mais algumas questões sobre a saúde do seu filho. Por favor assinale apenas uma opção em cada pergunta.

C) SINTOMAS/DIAGNÓSTICO

O SEU FILHO:

Nos últimos 3 meses, teve algum dos seguintes sintomas?

	Sim, diariamente ou quase (5-7 vezes por semana)	Sim, muitas vezes (1-4 vezes por semana)	Sim, às vezes (1-3 vezes por mês)	Não, nunca
PC1. Alterações na pele com comichão nas mãos ou antebraços	○	○	○	○
PC2. Alterações na pele com comichão na face ou pescoço	○	○	○	○
PC3. Eczema	○	○	○	○
PC3.1. Onde?				
PC4. Comichão nas mãos ou nos antebraços	○	○	○	○
PC5. Comichão na face ou no pescoço	○	○	○	○
PC6. Irritação nos olhos (prurido, olhos vermelhos ou secos)	○	○	○	○
PC7. Olhos inchados	○	○	○	○
PC8. Dor de cabeça/enxaqueca	○	○	○	○
PC9. Náuseas	○	○	○	○
PC10. Pingo no nariz	○	○	○	○
PC11. Nariz entupido/obstrução nasal	○	○	○	○
PC12. Garganta seca	○	○	○	○
PC13. Sensação de constipação	○	○	○	○
PC14. Dor de garganta	○	○	○	○
PC15. Tosse irritativa	○	○	○	○
PC16. Dificuldade em respirar	○	○	○	○
PC17. Sensação de cansaço/fadiga	○	○	○	○

PC18. Os sintomas apresentados melhoram quando o seu filho não está na escola?
- ○ Não
- ○ Sim → **PC18.1.** Qual(ais) dele(s)? (Escreva o(s) código(s) correspondente(s) ao(s) sintoma(s), por exemplo, PC1, PC2,...)
- ○ Não sabe

PC19. Os sintomas apresentados melhoram quando o seu filho não está em casa?
- ○ Não
- ○ Sim → **PC19.1.** Qual(ais) dele(s)? (Escreva o(s) código(s) correspondente(s) ao(s) sintoma(s), por exemplo, PC1, PC2,...)
- ○ Não sabe

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Gostaríamos que respondesse a algumas questões relacionadas com a alimentação do seu filho. Por favor assinale apenas uma das opções.

D) INFORMAÇÃO SOBRE HÁBITOS ALIMENTARES

O SEU FILHO:

Nos últimos 6 meses, quantas vezes comeu cada um dos alimentos referidos:

	Nunca	Raramente	1 vez por semana	Mais de 1 vez por semana	Diariamente
PD1. Peixe	O	O	O	O	O
PD2. Carne	O	O	O	O	O
PD3. Fruta	O	O	O	O	O
PD4. Vegetais frescos	O	O	O	O	O
PD5. Leite	O	O	O	O	O
PD6. Iogurte (ou outros produtos lácteos fermentados)	O	O	O	O	O
PD7. *Fast-food* (hamburgues, pizza, cachorro quente, etc.)	O	O	O	O	O

Em casa, qual o tipo de gorduras/óleos utilizado na confecção dos alimentos?

	Nunca	Raramente	1 vez por semana	Mais de 1 vez por semana
PD8. Manteiga	O	O	O	O
PD9. Margarina	O	O	O	O
PD10. Azeite	O	O	O	O
PD11. Óleos: girassol, soja	O	O	O	O
PD12. Banha	O	O	O	O
PD13. Outros óleos	O	O	O	O

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Gostaríamos que respondesse a algumas questões relacionadas com a casa e ambiente interior onde vive o seu filho. Sempre que o questionarmos sobre a casa estamos a referir-nos à casa onde o seu filho habita durante mais tempo. Por favor assinale apenas uma opção.

E) INFORMAÇÃO SOBRE A CASA

PE1. Qual o tipo de edifício onde habita o seu filho?

- O Vivenda
- O Casa geminada
- O Apartamento
- O Quinta
- O Outras

PE2. Em que piso se localiza a sua habitação? Indique "0" se for rés-do-chão ou "77" no caso da questão não se aplicar à sua situação

PE3. Número de compartimentos: (não conte com a cozinha, despensa, casas de banho, corredor, garagem, salas sem janela)

PE4. Indique a área total da sua casa (em m²) m²

e a média do pé-direito da sua casa (tendo em conta todos os compartimentos, em metros) m

PE5. Quantas pessoas habitam na casa? pessoas

PE6. Em que ano (aproximadamente) foi a casa construída? (ano)

PE7. Em que ano o seu filho foi viver para a casa onde vive actualmente? (ano)

PE8. Qual a localização da casa?

- O Local com ar limpo e afastado de áreas de tráfego intenso
- O Local com pouco tráfego
- O Local próximo de áreas de tráfego intenso

PE9. O seu filho vive na proximidade de uma rua com tráfego intenso (a menos de 200 metros)?

O Não O Sim O Não sabe

PE9.1. Qual o tipo de rua? O Auto-estrada O Estrada O Avenida O Outras

PE9.2. Qual a distância da casa à rua com tráfego intenso? (escolha a opção que melhor se aplica)

- O Aproximadamente igual a 20m ou menos
- O Aproximadamente igual a 50m ou menos
- O Aproximadamente igual a 100m ou menos
- O Aproximadamente igual a 200m ou menos

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PE10. Existe na vizinhança alguma fonte de poluição do ar exterior que possa influenciar o ambiente interior?

- O Não
- O Sim (se "Sim", por favor, especifique) ________

PE11. A casa encontra-se próxima de uma área de cultivo (horta, pomar, vinha,...) que seja pulverizada com pesticidas?

O Não O Sim

PE12. Existe(m) lareira(s) para aquecimento na casa?

O Não O Sim

PE13. Existe ar condicionado na casa?

O Não O Sim

PE14. Existe ar condicionado no quarto do seu filho?

O Não O Sim

PE15. Existe sistema de ventilação mecânica na casa?

O Não O Sim

PE16. Existe um desumidificador na casa, incluindo qualquer desumidificador integrado no sistema de aquecimento da casa?

O Não O Sim

PE17. Qual é o tipo de fogão que é utilizado na confecção de alimentos?

- O Fogão eléctrico
- O Fogão a gás (mesmo que combinado com forno eléctrico)
- O Fogão a carvão ou a lenha

PE18. Existe algum exaustor em funcionamento sobre o fogão?

- O Não
- O Sim, e encontra-se ligado ao exterior
- O Sim, mas não se encontra ligado ao exterior

PE19. Existe algum esquentador a gás na casa de banho?

- O Não
- O Sim, e os produtos de combustão são libertados para o exterior
- O Sim, e os produtos de combustão não são libertados para o exterior

PE20. A casa de banho tem ventilação de exaustão com ventilador próprio ou outros meios?

O Não O Sim O Não sabe

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PE21. Existe algum aquecedor a gás na casa?

- O Não
- O Sim, e os produtos de combustão são libertados para o exterior
- O Sim, e os produtos de combustão não são libertados para o exterior
- O Não sabe

PE22. Na casa, o seu filho está exposto ao fumo do tabaco?

- O Sim, diariamente ou quase (5-7 vezes por semana)
- O Sim, muitas vezes (1-4 vezes por semana)
- O Sim, às vezes (1-3 vezes por mês)
- O Não, nunca

PE23. Quantos fumadores habitam a mesma casa que o seu filho?

O Nenhum O Um O Dois O Três ou mais

PE24. Por dia, em média, quantos cigarros são fumados, na casa onde vive o seu filho?

O Nenhum O Entre 1 a 2 O De 3 a 4 O De 5 a 10 O De 11 a 20 O Mais de 20

PE25. Nos últimos 12 meses, o interior da casa foi decorado (pinturas, colocação de revestimentos)?

O Não O Sim

PE26. Quando foi realizada a última decoração? Mês: ☐☐ Ano: ☐☐☐☐

PE27. O que foi decorado? (Assinale as opções que se apliquem)

- O Tecto
- O Parede
- O Mobiliário
- O Pavimento
- O Radiadores
- O Outro(s) ________

PE28. Qual o tipo de material utilizado na decoração? (Assinale as opções que se apliquem)

- O Papel de parede
- O Cal
- O Tinta solúvel em água
- O Tinta resistente à água (sintética)
- O Painéis de madeira
- O Outro(s) ________

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PE29. Qual o tipo de material do pavimento do quarto do seu filho?

- O Plástico (Vinil/PVC)
- O Linóleo
- O Madeira/Parquet
- O Carpete a cobrir toda a superfície
- O Tijoleira
- O Outro(s)

PE30. Existem carpetes/tapetes no quarto do seu filho?

O Não O Sim

PE31. Qual é o tipo de aquecimento existente no quarto do seu filho? (Assinale as opções que se apliquem)

- O Aquecimento eléctrico
- O Aquecimento central (utilizando radiadores)
- O Aquecedor a gás
- O Piso radiante
- O Aquecimento das paredes
- O Outro

PE32. Na casa onde reside o seu filho, existe algum animal de estimação?

- O Não
- O Sim → **PE32.1.** Qual/Quais o(s) animal/animais (Por favor especifique e indique o número de animais)

PE33. Nos últimos 12 meses, algum dos seguintes itens foi observado na casa?

PE33.1. Fuga de água ou danos devido à fuga de água/infiltrações nas paredes, pavimento ou tecto

O Não O Sim

PE33.2. Descoloração ou manchas amarelas no pavimento em PVC ou descoloração ou manchas pretas no pavimento

O Não O Sim

PE33.3. Crescimento visível de bolores nas paredes, pavimento ou tecto

O Não O Sim

PE33.4. Cheiro a mofo num ou mais compartimentos (excluindo a cave)

O Não O Sim

PE34. No Inverno, é comum observar humidade/condensação na parte inferior das janelas?

O Não O Sim

PE35. No quarto do seu filho existe humidade ou crescimento visível de bolores?

O Não O Sim

PE36. Nos últimos 5 anos, ocorreu na casa algum problema de humidade, danos causados pela água, crescimento visível de bolores ou cheiro a mofo?

O Não O Sim

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PE37. No interior da casa, alguma vez viu baratas?

- O Nunca
- O Raramente
- O Às vezes
- O Muitas vezes

PE38. Na casa costuma utilizar frequentemente/muitas vezes ambientadores?

O Não O Sim

PE39. Na casa costuma utilizar frequentemente/muitas vezes incenso, velas de cheiro?

O Não O Sim

PE40. Na casa costuma utilizar frequentemente/muitas vezes produtos anti-traça/naftalina?

O Não O Sim

PE41. Na casa costuma utilizar frequentemente/muitas vezes colas, solventes, produtos industriais, quando o seu filho está presente?

O Não O Sim

PE42. Existe alguma garagem com comunicação directa com a casa?

O Não O Sim

NO QUARTO DO SEU FILHO:

PE43. Indique o número total de janelas:

PE43.1. Indique o valor aproximado da área total envidraçada (em metros²): m²

PE43.2. Qual a localização das janelas?

O Numa das paredes O Em mais de 1 parede

PE43.3. Qual a orientação das janelas? (Por favor, assinale as opções que se apliquem)

O Norte O Sul O Este O Oeste

PE43.4. Indique com que frequência as janelas são abertas:

	Nunca	Ocasionalmente	Frequentemente	Indique o número de janelas que são abertas, em média, por dia
PE43.4.1. Durante o dia	O	O	O	
PE43.4.2. Durante a noite	O	O	O	

PE44. Qual o tipo de material dos caixilhos das janelas do quarto do seu filho?

PE44.1. Aço	O Não	O Sim	O Não sabe	**PE44.3.** PVC	O Não	O Sim	O Não sabe
PE44.2. Madeira	O Não	O Sim	O Não sabe	**PE44.2.** Alumínio	O Não	O Sim	O Não sabe

PE44.5. Outra

PE45. São utilizados dispositivos de protecção solar, como cortinas, persianas, ou outros?

- O Não
- O Sim → **PE45.1.** Qual o tipo de material (por exemplo tecido)

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PE46. Indique se no quarto do seu filho existe/existem:

PE46.1. Esterilizador/purificador de ar
O Não O Sim

PE46.2. Desumidificador
O Não O Sim

PE46.3. Humidificador
O Não O Sim

PE46.4. Peluches
O Não O Sim

PE46.5. Computador
O Não O Sim

PE46.6. Fotocopiadoras
O Não O Sim

PE46.7. Impressoras
O Não O Sim

PE46.8. Plantas
O Não O Sim

PE46.9. Ambientadores
O Não O Sim

PE46.10. Produtos anti-traça/naftalina
O Não O Sim

PE47. Utiliza capas protectoras/forras anti-ácaros (ou equivalente) apropriados para colchões e almofadas?

O Não
O Sim → **PE47.1.** Com que frequência são mudadas

PE48. Com que frequência é limpo o quarto do seu filho (superfícies, mobiliário)?

O Diariamente
O Mais que uma vez por semana
O Uma vez por semana
O Outra

PE49. Qual/Quais são os utensílios utilizados para a limpeza do quarto do seu filho? (Assinale as opções que se apliquem)

O Vassoura
O Aspirador
O Pano húmido
O Pano seco

PE50. Indique quais os produtos utilizados para a limpeza do quarto do seu filho (por exemplo, lixívia, produto para madeiras, ...):

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Gostaríamos que respondesse a algumas questões relacionadas com o estatuto sócio-económico dos pais. Por favor assinale apenas uma opção.

F) ESTATUTO SÓCIO-ECONÓMICO

PF1. Educação:

	Mãe	Pai
1. Ensino primário incompleto (<4.º ano)	O	O
2. Ensino primário completo (4.º ano)	O	O
3. 5.º e 6.º anos completos	O	O
4. 7.º, 8.º e 9.º anos completos	O	O
5. 10.º e 11.º anos completos	O	O
6. 12.º ano completo	O	O
7. Grau de ensino superior ao 12.º ano	O	O

PF2. Emprego:

	Mãe	Pai
1. Empregado a tempo inteiro	O	O
2. Empregado a *part-time*	O	O
3. Desempregado	O	O
4. Pensionista	O	O
5. Incapacitado	O	O
6. Especifique qual a profissão/ocupação		

PF3. Ocupação mais recente (actual/passada):

	Mãe	Pai
1. Empresário(a)	O	O
2. Supervisor ou responsável	O	O
3. Professor(a) ou secretário(a)	O	O
4. Doméstica/o (ocupa-se das tarefas do lar)	O	O
5. Empregado por conta de outrem	O	O
6. Trabalhador por conta própria	O	O
7. Outro (por favor especifique)		

PF3.1. Se trabalha por conta própria ou é empresário indique o número de funcionários:
O <= 10 funcionários O >= 11 funcionários

PF4. A sua família recebe benefícios do estado (por exemplo, benefícios fiscais, apoio financeiro para equilibrar a vida familiar, ...)?
O Sim, regularmente O Sim, às vezes O Não

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Gostaríamos que respondesse a algumas questões sobre a percepção do seu filho sobre o ambiente na escola. Por favor assinale apenas uma opção, quando pedido assinale aquelas que se apliquem.

G) PERCEPÇÃO DO SEU FILHO RELATIVAMENTE AO AMBIENTE ESCOLAR

ASSINALE UM NÚMERO DE 0 A 6

PG1. Qual é a percepção do seu filho relativamente à iluminação da escola? (se a iluminação for variável, tente dar uma média da classificação)

O 0 O 1 O 2 O 3 O 4 O 5 O 6

Extremamente má — Extremamente boa

PG2. Durante as actividades escolares qual é a percepção do seu filho relativamente ao barulho/ruído? (se o baralho/ruído for variável, tente dar uma média da classificação)

O 0 O 1 O 2 O 3 O 4 O 5 O 6

Extremamente mau — Extremamente bom

PG3. Qual é a percepção do seu filho relativamente à qualidade do ar interior na escola? (se a qualidade do ar interior na escola for variável, tente dar uma média da classificação)

O 0 O 1 O 2 O 3 O 4 O 5 O 6

Extremamente má — Extremamente boa

PG3.1. Se o seu filho acha que a qualidade do ar interior da sua escola não é boa, por favor, tente explicar porquê.

PG4. Qual é a percepção do seu filho relativamente à qualidade do ar exterior na escola? (se a qualidade do ar exterior na escola for variável, tente dar uma média da classificação)

O 0 O 1 O 2 O 3 O 4 O 5 O 6

Extremamente má — Extremamente boa

PG5. O seu filho sente que a sua capacidade para realizar as tarefas escolares é reduzida devido a uma deficiente qualidade do ar interior na escola?

O Não O Sim O Não sabe

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ASSINALE UM NÚMERO DE 0 A 10

PG6. Qual é a satisfação do seu filho relativamente à escola?

O 0 O 1 O 2 O 3 O 4 O 5 O 6 O 7 O 8 O 9 O 10

Totalmente insatisfeito — Totalmente satisfeito

PG7. Quão stressantes são as actividades escolares para o seu filho?

O 0 O 1 O 2 O 3 O 4 O 5 O 6 O 7 O 8 O 9 O 10

Nada stressantes — Extremamente stressantes

PG8. Como é que o seu filho percepciona o clima de cooperação na escola?

O 0 O 1 O 2 O 3 O 4 O 5 O 6 O 7 O 8 O 9 O 10

Muito mau — Muito bom

PG9. Nos últimos 12 meses, o seu filho faltou às aulas devido a problemas alérgicos, sintomas/doenças respiratórias não associadas a constipações ou infecções no peito?

O Não

O Sim → **PG9.1.** Quantos dias? [ ][ ]

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ESTUDO DE INTERVENÇÃO

Gostaríamos de saber se estaria disponível a modificar alguns dos seus comportamentos/hábitos no sentido de melhorar a qualidade do ar interior da sua casa. Por favor assinale apenas uma opção.

	Indisponível	Pouco disponível	Disponível	Muito disponível	Não se aplica
Retirar ou substituir materiais e objectos que acumulam pó:					
como as cortinas	o	o	o	o	o
como as carpetes e alcatifas	o	o	o	o	o
Remover do quarto tudo aquilo que seja susceptível de acumular pó, incluindo:					
os livros e revistas	o	o	o	o	o
bonecos tipo peluche	o	o	o	o	o
Guardar os brinquedos em caixas ou arcas	o	o	o	o	o
Usar capas anti ácaros nos colchões e almofadas	o	o	o	o	o
Lavar e secar semanalmente os brinquedos	o	o	o	o	o
Abrir as janelas diariamente e deixar correr o ar pela casa incluindo pelas casas de banho:					
durante a manhã/tarde	o	o	o	o	o
durante a noite	o	o	o	o	o
Não deixar que ninguém fume dentro da sua casa	o	o	o	o	o
Deixar de usar em toda a sua casa:					
velas perfumadas	o	o	o	o	o
incenso	o	o	o	o	o
ambientadores	o	o	o	o	o
Evitar o uso de produtos de limpeza com substâncias e cheiros muito activos e agressivos	o	o	o	o	o
Deixar de usar humidificadores	o	o	o	o	o
Evitar ou não deixar circular os animais domésticos (exemplo cão e o gato) no interior da casa	o	o	o	o	o

Quais as principais **motivações** que contribuem para a modificação do(s) seu(s) comportamento(s)/hábito(s):

Quais as principais **barreiras** que contribuem para a não modificação do(s) seu(s) comportamento(s)/hábito(s):

FIM

OBRIGADA PELA SUA COLABORAÇÃO

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Annex 3. School and classroom checklist

sinphonie

Schools Indoor Pollution and Health: Observatory Network in Europe

Checklists

Project funded by

European Commission

Health and Consumers Directorate-General

Instructions

The checklists presented next should be fulfilled by the research team of the Institution Partner of SINPHONIE Project. Some parts of the checklist can be completed by the research team in advance (either from documentation already existent about the building school* or by site visit), and some need to be completed with the help of a building manager or equivalent.

* Some buildings may have a book of maintenance, service and operation that will save time and effort. A list of documentation is proposed to be asked to the school that can be an important source of information:

List of Documentation	Notes
Building Energy performance certification	If exists may provide info for the rest of the section
As-built file, if as-built file does not exist, project for execution	If exists may provide info for the rest of the section
Book of operation, service and maintenance	If exists may provide info for the rest of the section
Complaints	
Report of the last regular inspection of the HVAC system	

Concerning the questions, please try to obtain answers to all. If this is not possible, please write in the column "additional comments" that you could not reach information about that question.

You can tick all the options you think are applicable to the specific school. If you detect in the visit some important aspect that can help in the interpretation of the results, please write it in additional information section in the final of the checklist.

The observations during the measurements should not be recorded in this checklist form: a short questionnaire will be filled during the campaign days.

Checklist codes, example

Building checklist code p t s 0 1 - k b 1 (a: p t; b: s 0 1; c: k; d: b 1)

Room checklist code p t s 0 1 r 1 - k b 1 (e: r 1)

Refers to

a	Country	pt	code for the country (for example pt for Portugal)
b	School	01	from 01 till maximum of schools studied
c	School 'level'	k	k for kindergarten or s for Primary School
d	Building	1	some schools could have more than 1 building; in this case if the classrooms to be studied are located in different buildings a check list has to be fulfilled for each building
e	Room	1	from 1 to 3

Concerning building location please check the category that best characterize the building surrounding area:

- Industrial: Product oriented establishments, such as manufacturing and utilities;
- Commercial: Service oriented establishments, such as retail establishments, restaurants and shopping centers;
- Residential: Area with absence of a dominating industrial or commercial influence.
- Suburban: Essentially an area that is close enough to a major urban center as to be affected by the urban area.

Instructions Page 2 of 2

Building checklist code ☐☐☐☐☐ - ☐☐☐

A. Building

Identification

School ☐

Kindergarten ☐

Total number of occupants: __________ Total Area: __________ m²

Address: ______________________________

____

____

GPS coordinates: ______________________________

Contact person: ______________________________

(phone) ______________________________

(e-mail) ______________________________

Building shape, orientation of the building and shading by nearby buildings:

(a sketch of the basic plan of the building and surrounding; an air photo, Google maps picture,...)

Investigator ______________________________ Date ______________

1. Outdoor Characterization

1.1. Geographical location

		Additional comments
Interior		
Seacoast		
North of the country		
South of the country		
East of the country		
West of the country		

1.2. Building location

		Additional comments
Industrial area		
Mixed industrial/residential area		
Commercial area		
Mixed commercial/residential area		
City centre, densely packed housing		
Town, with or without small gardens		
Suburban, with larger gardens		
Village in a rural area		
Rural area with no or few other homes nearby		

1.3. Nearby potential sources of outdoor air pollution that might influence the indoor environment

		Additional comments
None		
Car parking		
Attached garage		
Direct access from basement or roof car park		
Busy road (at least part of the day)		
Highway		
Power plant for the building		
Other power plant **(up to 1 km)**		
Gasoline dispensing facilities		
Industry **(up to 10 km)**		
Cooling towers		
Built on a landfill site		
Waste management site (tip or garbage dumpsters) **(up to 3 km)**		
Agricultural sources **(up to 3 km)**		
Other (specify) ___________________________		

1.4. Nearby* noise sources outside the building that might influence the indoor environment

		Additional comments
None		
Car parking close to the building		
Busy road (at least part of the day)		
Highway		
Railway or station		
Subway		
Air traffic **(up to 3 km)**		
Sea, river or canal traffic		
Building, construction etc		
Sports events		
Other entertainment or leisure		
Factories or works		
Commercial premises		
Forestry, farming etc		
Community buildings (halls, churches, etc)		
Other (specify) ___________________________		

*up to 1km

Building checklist Page **1** of **8**

2. Construction Characterization

2.1. Year of construction ______________

2.2. Was the school building built originally for being a school?

		Additional comments
No		
Yes		

2.3. Year of conversion and/or refurbishment ______________

2.4. Number of storeys

		Additional comments
Occupied above ground		
Unoccupied above ground		
Occupied below ground		
Unoccupied below ground		

2.5. Total number of rooms

		Additional comments
Classrooms		
Dining rooms		
Gymnasiums/Sport hall		
Teachers' rooms/Offices		
Kitchen		
Library		
Bathrooms/Toilets		
Garages		
Other ______________________		

2.6. External walls construction (massive means made of solid bricks; lightweight means made of wood)

		Additional comments
Single wall		
Double wall		
Mixture of single and double		
Massive structure (high thermal inertia)		
Lightweight structure (low thermal inertia)		
Mixture of massive and lightweight		
Without insulation		
With insulation		
External insulation thickness (mm) __________		
All walls		
Some walls		
Cavity insulation thickness (mm) __________		
All walls		
Some walls		
Internal insulation thickness (mm) __________		
All walls		
Some walls		
Type of insulation		
Mineral wool		
Glass wool		
Fiber glass		
Polystyrene		
Polyurethane		
Cork		
Other (specify) ____________________		

Building checklist Page **2** of **8**

2.7. Structure of the roof

		Additional comments
Flat roof		
Ridge roof		
Massive structure		
Lightweight structure		
Mixture of massive and lightweight		
Without insulation		
With insulation		
External insulation thickness (mm) ___________		
Cavity insulation thickness (mm) ___________		
Internal insulation thickness (mm) ___________		
Type of insulation		
Mineral wool		
Glass wool		
Fiber glass		
Polystyrene		
Polyurethane		
Cork		
Other (specify) ___________________		

2.8. Type of foundation/ground floor

		Additional comments
Basement		
Slab on grade		
Crawl space		
Other (specify) ______________________		

2.9. Has the school got a yard?

		Additional comments
No		
Yes		

2.10. If in a radon-affected zone*, is there proper construction of foundation and ventilation (control of pressure difference), or other measures to control migration of radon?

		Additional comments
Not in a radon affected zone		
Radon zone		
Migration controlled		
Migration not controlled		
Unknown		

* Please contact National Authorities in natural radiation to inquire this

2.11. Who is the maintainer of the building?

		Additional comments
Municipality		
Foundation/Institution		
Church		
Private		
Other (specify) ______________________		

2.12. Has the building been certified by any program*?

		Additional comments
No		
Yes		
Which ________________________________		

* Legislation, Regulation (Energy Performance, IAQ, Sustainability)...

Building checklist Page 3 of 8

3. Ventilation

3.1. Type of general ventilation strategy

		Additional comments
Natural		
Natural assisted (exhaustion)		
Mechanical		

If you answered "Natural" please jump to section 4

3.2. Type of mechanical ventilation

		Additional comments
Supply system only		
Both exhaust and supply		
Exhaust system only		
Toilets/other polluted rooms only		
Other rooms		
Permanent		
Non permanent		
Days per week		
Hours per day		

3.3. Air handling units (AHU)

		Additional comments
100% fresh air		
Recirculation ____________% of fresh air		
With free cooling system		
Other (specify) ____________________		

3.4. Type of control

		Additional comments
Manual (on/off) – central		
Manual (on/off) – local		
Automatic		
CO2 controlled		
Other (specify) ____________________		

3.5. Outdoor air filter type

		Additional comments
Pre filter	________________________________	
Main filter	________________________________	

3.6. How often are the filters replaced

		Additional comments
No regular period		
Twice a year or often		
Once a year		
Once every two years		
Less often		
Date of last replacement ______________________		

3.7. How often are the filters cleaned

		Additional comments
No regular period		
Twice a year or often		
Once a year		
Once every two years		
Less often		
Date of last cleaning ______________________		

Building checklist Page 4 of 8

3.8. Heating systems

		Additional comments
No		
Yes		
In the whole building		
In some parts of the building		

3.9. Cooling systems

		Additional comments
No		
Yes		
In the whole building		
In some parts of the building		

3.10. Air duct material

		Additional comments
Asbestos cement		
PVC		
Galvanised steel		
Other (specify) ____________		

3.11. Duct insulation

		Additional comments
None		
Internal		
Mineral fibre		
Other (specify) ____________		
External		
Mineral fibre		
Other (specify) ____________		

3.12. How often are the air ducts cleaned

		Additional comments
No regular period		
Twice a year or often		
Once a year		
Once every two years		
Less often		
Date of last cleaning ____________		

Building checklist Page 5 of 8

4. Past Occurrences or Visible Problems

4.1. Water leakage or flooding in the last 12 months (if yes, specify the date)

		Additional comments
No		
Yes		
Roof	___/___/___	
Windows	___/___/___	
Façade	___/___/___	
Basement	___/___/___	
Water pipes	___/___/___	
Other (specify) ____________	___/___/___	

4.2. Fire damage (if yes, specify the date)

		Additional comments
No		
Yes ___/___/___		
Extent of the fire damage		
Building wide		
Limited spaces		
Floors damaged		

4.3. Visible air leaks (cracks in the construction) in the structure?

		Additional comments
No		
Yes		

Building checklist Page 6 of 8

5. Building Use IAQ Sources

5.1. Use of pesticides in the last 12 months

	Indoors	Outdoors	Additional comments
Rats			
Mice			
Cockroaches			
Ants			
Other (specify) ____________			

5.2. Is there a pesticide treatment plan for the building?

		Additional comments
No		
Yes (frequency) ____________		

5.3. Is there any storage location inside for the pesticides?

		Additional comments
No		
Yes (where) ____________		

5.4. Distance from the building to the outdoor trash storage _________ m

5.5. Is there a cleaning schedule for the communal parts of the building?

		Additional comments
No		
Yes		

5.6. Is there a kitchen inside the building?

		Additional comments
No		
Yes		
With air exhaustion (for ex. hood)		
Without air exhaustion		

5.7. Are there copy machines inside the building?

		Additional comments
No		
Yes		
How many ____________		

5.8. Are there bathrooms with hot water showers inside the building?

		Additional comments
No		
Yes		

5.9. Special use spaces

		Additional comments
Laboratory		
Graphic arts		
Computer rooms		
Gymnasium		
Swimming Pool		
Sauna		
Mechanical workshops		
Training kitchen/ Cafeteria		
Trash storage or trash separation room		
'Smoking allowed' rooms		
Other (specify) ____________		

Building checklist Page 7 of 8

6. Building Information for Modelling Purposes

6.1. Is there meteorological information for the outdoor of the building available?

		Additional comments
No		
Yes		
Temperature (acquisition time-step)		
Relative humidity (acquisition time-step)		
Wind speed (acquisition time-step)		
Wind direction (acquisition time-step)		

6.2. Is indoor temperature measured?

		Additional comments
No		
Yes		
Acquisition time-step		

6.3. Is indoor relative humidity measured?

		Additional comments
No		
Yes		
Acquisition time-step		

6.4. Are there traffic counting (and car fleet characterization) available for the main roads nearby?

		Additional comments
No		
Yes		

6.5. Is the buildings volumetry in a small domain around the building available? (GIS file with the buildings 3D coordinates)

		Additional comments
No		
Yes		

6.6. Are there any point sources (industries) in the nearby* of the building?

		Additional comments
No		
Yes (distance) ____________		

* The nearby can vary from 1 km to a few km radius, depending on the definition of the case study and the potential impact of dominating winds

6.7. Are emissions for those point sources available?

		Additional comments
No		
Yes (distance) ____________		

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Classroom checklist code ☐☐☐☐☐☐☐ - ☐☐☐

B. Classroom

Identification

School	☐
Kindergarten	☐

Location of the classroom in the building:
(a sketch of the basic plan, per floor, with location of the windows, board, desks, trash storage...)

Investigator ______________________________ Date ____________

1. Indoor Characterization

1.1. Storey number ____________

1.2. Floor area ____________ m^2

1.3. Ceiling height ____________ m

1.4. Windows area ____________ m^2

1.5. Type of classroom

		Additional comments
Normal		
Special use (specify) ____________		

1.6. Occupation

		Additional comments
Same class		
Several classes		

1.7. Number of students* (nominal) ____________
*If not constant please consider the predominant occupancy

1.8. Days per week the classroom is occupied ____________

1.9. Hours per day the classroom is occupied

		Additional comments
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		

1.10. Type of lighting

		Additional comments
Natural		
Artificial		
Mixture		

1.11. Glass % in the different façades

		Additional comments
North		
South		
East		
West		

1.12. Windows frames

		Additional comments
Metal		
Wood		
PVC		
Aluminium		
Other (specify) ____________		

Classroom checklist   Page 1 of 12

1.13. Type of glazing

		Additional comments
Single glazing		
Double glazing		
Double clear glazing with filling (Argon or other)		
Double clear glazing with coating		
Double glazing with tinted internal pane		
Triple glazing		
Other (specify) ____________________		

1.14. Solar shading devices

		Additional comments
None		
South side only		
Other façades ____________________		
External		
Internal		

1.15. Solar shading devices hamper the use of windows or decrease the ventilation capacity?

		Additional comments
No		
Yes		

1.16. Control of the shading devices

		Additional comments
No control (fixed)		
Individual		
Central down, individual up		
Automatic		
Other (specify) ____________________		

1.17. Are the materials used indoors low emitting materials? (classified by any recognized labelling system, the identification of the scheme should be done: GEV, AgBB…)

		Additional comments
Adhesives & sealants		
Paints & coatings		
Ceiling and wall systems		
Flooring systems		
Composite wood & agrifiber products		
Furniture & furnishings		
Other (specify) ____________________		

1.18. Presence of asbestos

		Additional comments
No		
Yes, exposed		
Yes, but sealed		

1.19. Presence of lead elements

		Additional comments
No		
Yes		
Water pipes		
Paint		
Other (specify) ____________________		
Not known		

Classroom checklist Page **2** of **12**

1.20. Is there a suspended ceiling?

		Additional comments
No		
Yes		

1.21. Main ceiling surface

		Additional comments
Concrete		
Paint		
Wallpaper		
Synthetic material		
Mineral fibre tiles		
Wood fibre tiles; cork tiles		
Wood		
Gypsum/plaster		
Other (specify) ____________________		

1.22. Main type of wall covering

		Additional comments
Concrete		
Water based paint		
Solvent based paint		
Wallpaper		
Porous fabrics including textiles		
Stone/ceramic tiles		
Wood/cork		
Gypsum/plaster		
Other (specify) ____________________		

1.23. Main type of floor covering

		Additional comments
Concrete		
Carpet		
Synthetic smooth (linoleum, vinyl, …)		
Laminate parquetry		
Stone/ceramic tiles		
Wood/cork		
Other (specify) ____________________		

1.24. Modifications in the last 12 months (if yes, specify the date)

		Additional comments
Floor structure	__/__/__	
Insulation	__/__/__	
Walls	__/__/__	
Ceiling/roof	__/__/__	
Heating system	__/__/__	
Ventilation system	__/__/__	
Windows	__/__/__	
New furniture	__/__/__	
Other (specify) ____________________	__/__/__	

Classroom checklist Page **3** of **12**

2. Visible Problems

2.1. Visible mould growth in the room

		Additional comments
No		
Yes		
Where ____________		
Extent ____________		

2.2. Other damp/mould symptoms

	No	Yes	Additional comments
Noticeable mould odour			
Visible damp spots on walls, ceiling or floor			
Bubbles or yellow discoloration of plastic floors			
Blackened wood floor			

2.3. Tendency for formation of condensation on windows

		Additional comments
No		
Yes		
Inside		
On the frame		

Classroom checklist Page 4 of 12

3. Heating Characterization

3.1. Heating system

		Additional comments
Heating only		
Heating + domestic hot water		

3.2. Energy used for heating

		Additional comments
Electricity		
Joule effect (electric resistance)		
Heat pump		
Gas		
Natural		
Butane/Propane		
Oil		
Solid fuel		
Wood		
Coal		
Other (specify) ____________		

3.3. Heating terminal units

		Additional comments
Hot water radiators or convectors		
Electrical radiators or convectors		
Heating floor		
Warm air flow		
Fireplaces		
Open		
Closed		
Other (specify) ____________		

3.4. Are heaters located below windows to prevent draught in winter?

		Additional comments
No		
Yes		

3.5. Temperature set point and deadband range in winter

		Additional comments
Not controlled by the system		
Set point ____________ ºC		
Range min ________ ºC max ________ ºC		

Classroom checklist Page 5 of 12

4. Natural Ventilation

4.1. How is the classroom ventilated

		Additional comments
Openable windows		
Other natural ventilation (e.g. passive stack)		
Hybrid/mixed model (natural + mechanical)		

4.2. Can the windows be open?

		Additional comments
No		
Yes		
All		
Some (estimate % of openable windows)		
But occupants are not allowed to open them		

4.3. Number of windows usually open

		Additional comments
Heating season		
Cooling season		

4.4. Usually, when are the windows open?

		Additional comments
Before school time		
During breaks		
During teaching hours		
After school time		
During night		
Other (specify) ______________________		

4.5. Location of grids (passive ventilation)

		Additional comments
Ceiling		
Walls		
Windows		
Other (specify) ______________________		

4.6. Are the grids open?

		Additional comments
Always		
Often		
Sometimes		
Never		

4.7. In naturally ventilated, or exhaust only ventilated buildings, are there air transfer openings between rooms?

		Additional comments
No		
Yes		

Classroom checklist Page 6 of 12

5. Mechanical Ventilation

5.1. Type of control

		Additional comments
Manual (on/off) – central		
Manual (on/off) – local		
Automatic		
CO2 controlled		
Other (specify) ______________		

5.2. Position of ventilation system intake

		Additional comments
Roof		
Façade		
Ground		
Other (specify) ______________		

5.3. Height of ventilation system intake above ground level ______________ m

5.4. Shortest distance of system intake from exhaust outlets

		Additional comments
Vertical	__________ m	
Horizontal	__________ m	

5.5. Shortest distance of system intake from cooling towers

		Additional comments
Vertical	__________ m	
Horizontal	__________ m	

5.6. Other potential sources close to the system intake

	Distance (m)	Additional comments
Car parking		
Garage		
Busy road		
Highway		
Power plant for the building		
Other power plant		
Gasoline dispensing facilities		
Other (specify) ______________		

5.7. Outdoor design flow rate

____________ m^3/h ____________ ach^{-1} ____________ $m^3/(h.person)$

5.8. Designed air distribution principle

		Additional comments
Mixing		
Displacement		
Other (specify) ______________		

5.9. Location of air supply devices

		Additional comments
None		
Floor		
Windowsill		
Ceiling		
High on wall		
Low on wall		
Other (specify) ______________		

Classroom checklist Page 7 of 12

5.10. Location of air exhaust grids

		Additional comments
None		
High		
Low		

5.11. How often are the supply air devices cleaned

		Additional comments
No regular period		
Twice a year or often		
Once a year		
Once every two years		
Less often		
Date of last cleaning ____________		

5.12. How often are the exhaust air devices cleaned

		Additional comments
No regular period		
Twice a year or often		
Once a year		
Once every two years		
Less often		
Date of last cleaning ____________		

Classroom checklist Page 8 of 12

6. Classroom Use IAQ Sources

6.1. Board (tick the two most used)

		Additional comments
Black board with chalk		
White board with markers		
Electronic interactive board		
Flip over chart		
Other (specify) ____________		

6.2. Electronic equipment (specify the number)

		Additional comments
Audiotape		
Computers/printers/photocopiers		
Data/video projector/TV/Video conference		
Slide projector		
Servers		
Other (specify) ____________		

6.3. Other apparatus (specify the number)

		Additional comments
Air cleaners (specify type) ____________		
Space heaters		
Humidifiers		
Dehumidifiers		

6.4. Furniture materials

		Additional comments
Wood		
Wood veneer		
Plywood		
Textiles		
Metal		
Plastic laminate or composite		
Other (specify) ____________		

6.5. Are there any curtains?

		Additional comments
No		
Yes (area) ____________		
Natural textile		
Synthetic textile		
Other (specify) ____________		

6.6. Are there any rugs?

		Additional comments
No		
Yes (area) ____________		
Natural textile		
Synthetic textile		
Other (specify) ____________		

6.7. Are there any cushions?

		Additional comments
No		
Yes (area) ____________		
Natural textile		
Synthetic textile		
Other (specify) ____________		

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6.8. Closet with medicines

		Additional comments
No		
Yes		

6.9. Closet or shelves with gouaches, inks, etc. for graphic arts

		Additional comments
No		
Yes		

6.10. Are there any special precautions when they are used?

		Additional comments
No		
Yes		
Windows are open		
Used under a hood		

6.11. Air fresheners

		Additional comments
No		
Yes		
Permanent (passive or electric plugged)		
Occasionally (spray or other)		
How often used? ________		

6.12. Is there a sink in the room?

		Additional comments
No		
Yes		

6.13. Animals/Pets

		Additional comments
No		
Yes, stuffed		
Yes, live		
Fish/Turtle (aquariums)		
Birds		
Rodents		
Other (specify) ________		

6.14. Number of plants in pots ________

6.15. Cleaning schedule

		Additional comments
Early in the morning or before school time		
During breaks between the classes		
In the afternoon or after school time		
Other (specify) ________		

6.16. Are the windows open during cleaning of the classroom?

		Additional comments
No		
Yes		

6.17. Cleaning activities frequency

	Frequency*						Date of last cleaning
	a	b	c	d	e	f	
Trash pins emptied							
Floors/carpets swept							
Floors/carpets vacuumed							
Smooth floors washed							
Smooth floors waxed							
Smooth floors polished							
Walls dry wiped/vacuumed							
Walls washed							
Ceilings dry wiped/vacuumed							
Ceilings washed							
Surfaces dusted							
Surfaces polished							
Surfaces cleaned							
Curtains washed							
Windows washed							
Other items dusted (e.g. doors)							
Other items polished							

* a) daily; b)twice a week; c)once a week; d) once a month; e) once a year; f) never

6.18. Deep clean* of the floor

		Additional comments
How often		
No regular period		
Once every three months		
Once every six months		
Once a year		
Less often		
Date of last cleaning ________		

* deep clean - activity different from the everyday cleaning, usually a more detailed one, that can include scrubbing or the use of specific cleaning products as for example disinfectants.

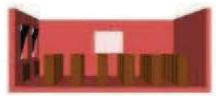
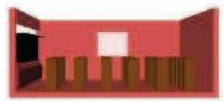
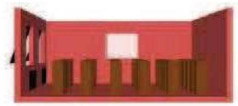
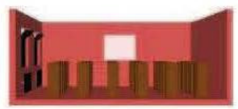
6.19. Type of consumer products used

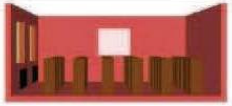
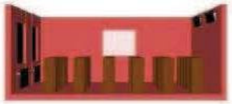
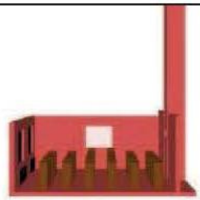
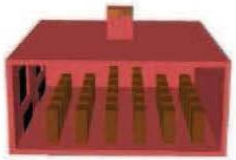
	Spray	Liquid	Additional comments
For **floor** cleaning or conservation			
Bleach or detergent with bleach			
Detergent without bleach			
Polish			
Other category relevant ________			
For **wall** cleaning or conservation			
Bleach or detergent with bleach			
Detergent without bleach			
Polish			
Other category relevant ________			
For **windows** cleaning			
Detergent with ammonia			
Detergent without ammonia			
Other category relevant ________			
For **furniture** cleaning or conservation			
Detergent			
Polish			
Other category relevant ________			

7. **Classroom Additional Useful Information**

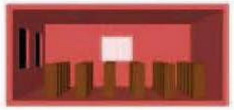
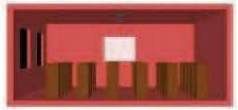
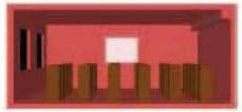
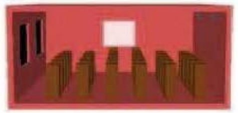
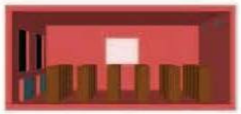
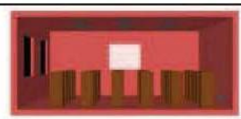
Classroom checklist code ☐☐☐☐☐☐☐ - ☐☐☐

Annex
Ventilation Scenarios

Indoor space layout	Ventilation Strategy	Notes
	Vertical sash windows	
	Horizontal sash windows	
	Mid façade centre pivot windows	
	Single sided ventilation via bottom hung inward lights	
	Single sided ventilation via top hung windows	
	Single sided ventilation via two openings	

	single sided ventilation via one opening: Louvres windows	
	Cross ventilation via front low level and rear high level openings	
	Cross ventilation via front low level and rear high level bottom hung windows	
	Cross ventilation by front and rear bottom hung windows	
	Front low level and rear high level vents (Passive stack ventilation)	
	Top down natural ventilation by a split-duct roof mounted ventilator	

Annex to Classroom checklist Page 2 of 3

	Mechanical ventilation: air supplied by ceiling mounted diffusers and extracted by ceiling mounted grilles	
	Ceiling mounted supply swirl diffusers and ceiling outlet	
	Side wall mounted supply linear grilles and wall mounted linear extract grilles	
	Sill mounted supply grilles and side wall mounted extract grilles	
	Floor mounted supply swirl diffusers and ceiling mounted extract grilles	
	Displacement ventilation supply diffusers and side wall mounted extract grilles	
	Ceiling mounted displacement diffusers and low level side wall mounted extract grilles	

Annex to Classroom checklist Page 3 of 3

Annex 4. Teachers and cleaning staff classroom checklist

Código | | | E | | | S | | - | | E | |

País Escola Sala JI/E

Check list para Professores

Número total de ocupantes: __________ (professor(es) + alunos)

Início das medições (data): ____/ ____/ ____

Importante!!

Se surgir alguma questão ou dúvida relacionadas com o preenchimento desta check list ou com algum outro aspecto relacionado com as medições, não hesite em nos contactar!

Eng.º Joana Madureira Laboratório da Qualidade do Ar Interior	Telefone: 22 557 4184	E-mail: jvm@fe.up.pt
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MUITO OBRIGADA PELA SUA COOPERAÇÃO!!

Segunda-feira, ____________________ 2012

Professores

Número total de alunos na sala de aula: ____________________ | Condições meteorológicas externas Sol ○ Nublado ○ Muito nublado ○ Chuva ○

Aulas		Nº alunos na sala		Janelas			Portas			Aquecimento		Atividades laboratório	Trab. Manuais	Cozinha	Leitura, escrita	Outras (pf, especifique) ____________
		(pf, assinale no □*)		(pf, assinale uma das opções)			(pf, assinale uma das opções)			(pf, assinale no □ sempre que aplicável						
Início aula	___h ___min	□ Sim [___]	□ Não	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ On	□ Off	□	□	□	□	□ ________
Intervalo	___h ___min	□ Sim [___]	□ Não	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ On	□ Off	□	□	□	□	□ ________
Aula	___h ___min	□ Sim [___]	□ Não	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ On	□ Off	□	□	□	□	□ ________
Almoço	___h ___min	□ Sim [___]	□ Não	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ On	□ Off	□	□	□	□	□ ________
Aula	___h ___min	□ Sim [___]	□ Não	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ On	□ Off	□	□	□	□	□ ________
Intervalo	___h ___min	□ Sim [___]	□ Não	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ On	□ Off	□	□	□	□	□ ________

* Se sim, por favor indique o número de alunos. Por exemplo, [__20__]

Professores das Atividades Extra Curriculares

Número total de alunos na sala de aula: ____________________ | Condições meteorológicas externas Sol ○ Nublado ○ Muito nublado ○ Chuva ○

Atividades extra curriculares		Nº alunos na sala		Janelas			Portas			Aquecimento		Especifique as atividades desenvolvidas
		(pf, assinale no □*)		(pf, assinale uma das opções)			(pf, assinale uma das opções)			(pf, assinale uma das opções)		
Início aula	___h ___min	□ Sim [___]	□ Não	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ On	□ Off	____________________
Intervalo	___h ___min	□ Sim [___]	□ Não	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ On	□ Off	____________________
Início da aula	___h ___min	□ Sim [___]	□ Não	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ Fechadas	□ Parcialmente abertas	□ Abertas	□ On	□ Off	____________________

* Se sim, por favor indique o número de alunos. Por exemplo, [__20__]

Checklist code

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Note: example of the daily record during the week.

Annex 5. Home checklist

INDOOR AIR POLLUTION AND HEALTH IN SCHOOLS

IDMEC-FEUP COORDINATOR AND PROJECT PARTNER OF SINPHONIE PROJECT

HOME WALKTHROUGH CHECKLIST

(TO BE FILLED BY THE TECHNICAL STAFF OF IDMEC-FEUP)

U.PORTO FMUP FACULDADE DE MEDICINA UNIVERSIDADE DO PORTO

ISPUP

PT E _ _ S _ - _ _ _

PT C _ _

General Information

Identification

- Single family house ☐
- Semi-detached house ☐
- Apartment ☐
- Other (specify) ___________ ☐

Address: ______________________________

GPS coordinates: ______________________________

Contact person: ______________________________

(phone) ______________________________

(e-mail) ______________________________

Building shape, orientation of the building and shading by nearby buildings:
(a sketch of the basic plan of the building and surrounding; an air photo, Google maps picture,...)

Investigator ______________________ Date ___________

Checklist

Page 1 of 14

A.Building

1. Outdoor Characterization

1.1. [obs.] Building location

		Additional comments
Industrial area		
Mixed industrial/residential area		
Commercial area		
Mixed commercial/residential area		
City centre, densely packed housing		
Town, with or without small gardens		
Suburban, with larger gardens		
Village in a rural area		
Rural area with no or few other homes nearby		

1.2. [obs.] Nearby potential sources of outdoor air pollution that might influence the indoor environment

		Additional comments
None		
Car parking		
Attached garage		
Direct access from basement or roof car park		
Busy road (at least part of the day)		
Highway		
Power plant for the building		
Other power plant (up to 1 km)		
Gasoline dispensing facilities		
Industry (up to 10 km)		
Cooling towers		
Built on a landfill site		
Waste management site (tip or garbage dumpsters) (up to 3 km)		
Agricultural sources (up to 3 km)		
Other (specify) ___________________________		

*up to 1km

2. Construction Characterization

2.1. [obs.] Number of storeys (Total _________)

		Additional comments
above ground		
below ground		

Checklist Page 2 of 14

2.2. [obs.] Building is constructed mostly of

		Additional comments
Brick		
Other ______________________		

2.3. [Obs., ask] Type of foundation/ground floor

		Additional comments
Basement		
Slab on grade		
Crawl space		
Other (specify) ________________________		

2.4. [ask] Has the building been certified by any program*?

		Additional comments
No		
Yes		
Which _______________________________		

* Legislation, Regulation (Energy Performance, IAQ, Sustainability)...

3. Use IAQ Sources

3.1. Distance from the building to the outdoor trash storage _________ m

3.2. Special use spaces (in case of apartment buildings)

		Additional comments
Pharmacy		
Bakery		
Restaurant		
Stationery		
Service shop		
Trade		
Other (specify) ______________________________		

Checklist Page 3 of 14

B.Home environment

1. Indoor characterization

1.1. [ask] For how many years have you been living in this home ____________

1.2. [obs.] Storey number ____________

1.3. [obs.] Sketch of the home with the respective identification of room compartments

Sectional view	Plant view	Room exists	Nr.	Area [m^2]	Window Cod.	Area [m^2]
		Kitchen (K)			V1	
		Bathroom (B)			V2	
		WC (WC)			V3	
		Corridor (C)			V4	
		Room (R)			V5	
		Living room (LR)			V6	
		Laundry (L)			V7	
		Storage (S)			V8	

1.4. [ask] Total number of occupants (permanently in this home) ____________

1.5. [ask] Smoke allowed

		Additional comments
No		
Yes		

1.6. [ask] Place where smoke is allowed

		Nr of smokers	Nr cigarettes/day	In which period of the day
Kitchen				
WC				
Corridor				
Room				
Living room				
Laundry				
Storage				
Other ____________				

Checklist Page 4 of 14

1.7. [ask] Are the materials used indoors low emitting materials? (Classified by any recognized labelling system, the identification of the scheme should be done: GEV, AgBB...)

		Additional comments
Adhesives & sealants		
Paints & coatings		
Ceiling and wall systems		
Flooring systems		
Composite wood & agrifiber products		
Furniture & furnishings		
Other (specify) ____________		

1.8. [ask] Modifications in the last 12 months (if yes, specify the date)

		In which specific room	Additional comments
Floor structure	___/___/___		
Insulation	___/___/___		
Walls	___/___/___		
Ceiling/roof	___/___/___		
Heating system	___/___/___		
Ventilation system	___/___/___		
Windows	___/___/___		
New furniture	___/___/___		
Other (specify) ____________	___/___/___		

Checklist Page 5 of 14

C. Sampling site

1. General characterization

1.1. [ask] Where does (child) usually sleep

		Additional comments
Bedroom		
Family room		
Living room		
Other ____________		

1.2. [obs.] Floor area ____________ m^2
1.3. [obs.] Ceiling height ____________ m
1.4. Total number of windows in that local ____________
1.5. [obs.] Windows area ____________ m^2
1.6. [ask] Number of occupants (permanently) in the local where the children sleep ____________
1.7. [obs.] Glass % in the different façades

		Additional comments
North		
South		
East		
West		

1.8. [obs.] Windows frames

		Additional comments
Metal		
Wood		
PVC		
Aluminium		
Other (specify) ____________		

1.9. [obs.] Type of glazing

		Additional comments
Single glazing		
Double glazing		
Double clear glazing with filling (Argon or other)		
Double clear glazing with coating		
Double glazing with tinted internal pane		
Triple glazing		
Other (specify) ____________		

Checklist Page 6 of 14

1.10. [obs.] Solar shading devices

		Additional comments
None		
South side only		
Other façades ____________		
External		
Internal		

1.11. [obs.] Solar shading devices hamper the use of windows or decrease the ventilation capacity?

		Additional comments
No		
Yes		

1.12. [obs.] Main surface

	ceiling	wall	Additional comments
Concrete			
Paint			
Wallpaper			
Synthetic material			
Mineral fibre tiles			
Wood fibre tiles; cork tiles			
Wood			
Gypsum/plaster			
Other (specify) ____________			

1.13. [obs.] Main type of floor covering

		Additional comments
Concrete		
Carpet		
Synthetic smooth (linoleum, vinyl, ...)		
Laminate parquetry		
Stone/ceramic tiles		
Wood/cork		
Other (specify) ____________		

2. Specific characteristics about children sleeping area

2.1. [obs.] Does the child live within 200m from a street with heavy traffic?

		Additional comments
No		
Yes		
Highway		
Street		
Boulevard		
Other		

Checklist Page 7 of 14

2.2. [ask] Room door is opened in:

	Open	Partially open	Closed	Additional comments
Early in the morning				
During the morning				
In the afternoon				
In the evening				
During the sleep period				

2.3. [ask] What does (child) sleep on

		Additional comments
Bed with mattress		
Mattress on floor		
Sofa		
Sofa bed		
Cot (no mattress)		
Futon		
Other ______________________		

2.4. [ask] What is the pillow filled with

		Additional comments
Feather		
Polyester		
Foam		
Other ______________________		
No pillow		
Can't tell		

2.5. [ask] What types of blankets/bedcovers do you use on bed

		Additional comments
Comforter		
Wool blanket		
Cotton blanket		
Acrylic blanket		
Blend (specify ____________)		
Don't know		

2.6. [ask] Stuffed toys visible in room

		Additional comments
No		
Yes		

Checklist Page 8 of 14

2.7. [obs.] Furniture materials

		Additional comments
Wood		
Wood veneer		
Plywood		
Textiles		
Metal		
Plastic laminate or composite		
Other (specify) ____________		

2.8. [obs.] Are there any curtains?

		Additional comments
No		
Yes (area) ____________		
Natural textile		
Synthetic textile		
Other (specify) ____________		

2.9. [obs.] Are there any rugs?

		Additional comments
No		
Yes (area) ____________		
Natural textile		
Synthetic textile		
Other (specify) ____________		

2.10. [obs.] Are there any cushions?

			Additional comments
No			
Yes (area) ____________			
Natural textile			
Synthetic textile			
Other (specify) ____________			

Checklist Page 9 of 14

2.11. [obs., ask] Animals/Pets

	Nr.	Local day	Local Night	Additional comments
No				
Yes, stuffed				
Yes, live				
Dog				
Cat				
Fish/Turtle (aquariums)				
Birds				
Rodents				
Other (specify) ____________				

2.12. [obs.] Number of plants in pots:

		Additional comments
Kitchen		
Bathroom		
WC		
Corridor		
Room		
Living room		
Laundry		
Storage		

2.13. [ask] In what area does (child) spend most of her/his time playing

		Average of time spent [h/day]	Additional comments
Bedroom			
Family room			
Living room			
Other ____________________________			

3. Ventilation

3.1. [obs.] Can the windows be open?

	Child´s area	Other space	Additional comments
No			
Yes			
All			
Some (estimate % of openable windows)			
But occupants are not allowed to open them			

Checklist Page 10 of 14

3.2. [ask] Number of windows usually open

	Child´s area	Nr.	Other space	Nr.	Additional comments
Early in the morning					
During the morning					
In the afternoon					
In the evening					
Other (specify) ____________________					

4. Heating Characterization

4.1. [obs.] Does this building have a heating system

	Child's area	Other space	Additional comments
Yes			
No			

4.2. [obs.] Heating system

	Child's area	Other space	Additional comments
Heating only			
Heating + domestic hot water			

4.3. [obs.] Heating terminal units

	Child's area	Other space	Additional comments
Hot water radiators or convectors			
Electrical radiators or convectors			
Heating floor			
Warm air flow			
Fireplaces			
Open			
Closed			
Other (specify) ____________________			

4.4. [obs.] Are heaters located below windows to prevent draught in winter?

	Child's area	Other space	Additional comments
No			
Yes			

Checklist Page 11 of 14

5. Visible Problems

5.1. [obs., ask] Water leakage or flooding in the last 12 months (if yes, specify the date)

	Child's area	Other space	Additional comments
No			
Yes			
Roof	___/___/___	___/___/___	
Windows	___/___/___	___/___/___	
Façade	___/___/___	___/___/___	
Basement	___/___/___	___/___/___	
Other (specify) ______________	___/___/___	___/___/___	

5.2. [obs.] Fire damage (if yes, specify the date)

	Child's area	Other space	Additional comments
No			
Yes	___/___/___	___/___/___	
Extent of the fire damage			
Building wide			
Limited spaces			
Floors damaged			

5.3. [obs.] Visible air leaks (cracks in the construction) in the structure?

	Child's area	Other space	Additional comments
No			
Yes			

5.4. [obs.] Visible mould growth

	Child's area	Other space	Additional comments
No			
Yes			
Extent ____________________________			

5.5. [obs.] Other damp/mould problems

	Child's area		Other space		Additional comments
	No	Yes	No	Yes	
Noticeable mould odour					
Visible damp spots on walls, ceiling or floor					
Bubbles or yellow discoloration of plastic floors					
Blackened wood floor					

Checklist Page 12 of 14

5.6. [obs., ask] Tendency for formation of condensation on windows

	Child's area	Other space	Additional comments
No			
Yes			
Inside			
On the frame			

6. Use IAQ Sources

6.1. Use of pesticides in the last 12 months

	Indoors		Outdoors		Additional comments
	frequency	Last date	frequency	Last date	
Yes					
No					

6.2. [obs.] Electronic equipment (specify the number)

	Child's area	Other space	Additional comments
Audiotape			
Computers			
Printers			
Photocopiers			
TV			
Other (specify) ____________________			

6.3. [obs., ask] Other apparatus (specify the number)

	Child's area	Other space	Additional comments
Air cleaners (specify type) ________________			
Humidifiers			
Dehumidifiers			
Air fresheners			
Permanent (passive or electric plugged)			
Occasionally (spray or other)			
How often used?______________________			

6.4. [ask] Cleaning schedule

		Additional comments
Early in the morning		
During the morning		
In the afternoon		
In the evening		
Other (specify) __________________________		

Checklist Page 13 of 14

6.5. [ask] Are the windows open during cleaning?

	Child's area	Other space	Additional comments
No			
Yes			

6.6. [ask] Cleaning activities frequency and type of consumer products used

	Child´s area				Other spaces			
	Spray	Liquid	Name	Freq*	Spray	Liquid	Name	Freq*
For floor cleaning or conservation								
Bleach or detergent with bleach								
Detergent without bleach								
Polish								
Other ________________								
For wall cleaning or conservation								
Bleach or detergent with bleach								
Detergent without bleach								
Polish								
Other ________________								
For windows cleaning								
Detergent with ammonia								
Detergent without ammonia								
Other ________________								
For furniture cleaning or conservation								
Detergent								
Polish								
Other ________________								

Trash pins emptied		
Curtains washed		
Windows washed		
Other items dusted __________		
Other items polished _________		
Additional comments		

*Frequency: a) daily; b) twice a week; c) once a week; d) once a month; e) once a year; f) never

Checklist

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Annex 6. Time activity diary

PT	E			S		-	C		

PT	C		

Check list para Pais/Encarregados de Educação

Espaço estudado:

Quarto ☐

Sala ☐

Número total de ocupantes: __________

Início das medições (data): ____/ ____/ ____

Importante!!

Se surgir alguma questão ou dúvida relacionadas com o preenchimento desta check list ou com algum outro aspecto relacionado com as medições, não hesite em nos contactar!

Eng.º Joana Madureira Laboratório da Qualidade do Ar Interior	Telefone: 22 557 4186	E-mail: jvm@fe.up.pt
Eng.º Ricardo Pereira Laboratório da Qualidade do Ar Interior		E-mail: rfp@feup.idmec.pt

MUITO OBRIGADA PELA SUA COOPERAÇÃO!!

Gostaríamos que preenchesse a seguinte checklist com informação relacionada com a casa e o ambiente interior. Por favor assinale com um "X" as opções que se apliquem referentes a cada um dos dias da semana.

Sábado

		Sábado																							
	Horas	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
N.º ocupantes																									
Informação relativa ao Quarto/Sala																									
Janelas	Fechadas																								
	Parcialmente abertas																								
	Abertas																								
Portas	Fechadas																								
	Parcialmente abertas																								
	Abertas																								
Aquecimento	Ligado																								
	Desligado																								
Uso de	Velas																								
	Incenso																								
	Ambientadores																								
	Pesticidas/inseticidas																								
	Fotocopiadoras/impressoras																								
	Tintas																								
	Colas																								
Limpeza do mobiliário	Seco																								
	Húmido																								
	Spray																								
Limpeza do pavimento	Aspirar																								
	Varrer																								
	Esfregona/pano húmido																								
Fumar no	Interior do quarto/sala																								
	Exterior do quarto/sala (varanda)																								
Informação relativa a outras divisões																									
Janelas	Fechadas																								
	Parcialmente abertas																								
	Abertas																								
Portas	Fechadas																								
	Parcialmente abertas																								
	Abertas																								
Aquecimento	Ligado																								
	Desligado																								
Uso de	Velas																								
	Incenso																								
	Ambientadores																								
	Pesticidas/inseticidas																								
	Tintas																								
	Colas																								
Fumar no	Interior da habitação																								
	Exterior da habitação (varanda)																								
Confeção de alimentos																									
Outros ______________________																									

Checklist code_pais/encarregados de educação

Página 2 de 10

Note: example of the daily record during the week.