# ENVIRH

# ENVIRONMENT AND HEALTH IN CHILDREN DAY CARE CENTERS

## AMBIENTE E SAÚDE EM CRECHES E INFANTÁRIOS

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FACULDADE DE CIÊNCIAS MÉDICAS
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Faculdade de Ciências Médicas
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Additional information about ENVIRH project see web site: http://envirh.fcm.unl.pt/

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**All children day care centers attendees**

**Parents and children who participated**

**Scientific Consultants**

Isabella Annesi-Maesano |Directeur de Recherche INSERM; Head: EPid Allergic Resp Dis Department, Paris, France

José Eduardo Rosado Pinto |Coordinator from GARD Portugal |Direção Geral de Saúde | H. Luz

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MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

## Contents

## Presentation of the study

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[2]ENVIRH Project - Environment and Health in Children Day Care Centres (PTDC/SAU-ESA/100275/2008) – Principal Investigator (PI)

This project addresses a set of common clinical problems in the context of children attending day care centres. It is common sense that children get sick more often as soon as they start attending a day care centre on a daily basis and this is particularly true for some groups at risk, as wheezing infants and wheezing pre-school children. Concerning this, some questions remain unclear:

1. The role of indoor air quality - what is the health impact of indoor air environment (including indoor pollutants, house dust mite, temperature and humidity) in wheezing children?

2. The role of virus infections - We don't know the real role of virus infections in respiratory conditions at day care centre level. There is a lack of information concerning how indoor air environment influence virus infections.

3. The role of building ventilation - what is the impact of building ventilation in the health of wheezing and non-wheezing children? How is ventilation affecting indoor air quality? How is ventilation of day care centres affected by the structure of the buildings?

4. Social impact of this study - what should be the recommendations to improve IAQ?

What is new in this project is the collaboration of a health team (medical doctors and other health professionals) with environment specialists, mechanical, civil engineers, epidemiologists and statisticians.

The project had three consultants:

Isabella Annesi-Maesano, Professor of Epidemiology at Université Pierre et Marie Curie in Paris and Researcher at INSERM, who helped us to develop an instrument to identify children who get sick with respiratory disease during the experimental periods and helped us reviewing of many of our manuscripts.

José Eduardo Rosado Pinto, Coordinator from GARD Portugal and from Direção Geral de Saúde made the connections with the national health authorities.

Carl-Gustaff Bornehag, Professor in Public Health Sciences at SP Technical Research Institute of Sweden, Karlstad University, who helped us making the bridge between health professionals and engineers.

## ENVIRH Project Framework and Objectives

Ana Luísa Papoila[7,8], Pedro Martins[1,2], João Viegas[3],Daniel Aelenei[4], Manuela Cano[5], João Paulo Teixeira[6], Paulo Paixão[1], José Araújo-Martins[1], Paula Leiria-Pinto[1,2], Iolanda Caires[1], Catarina Pedro[1], Nuno Neuparth[1,2]

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The **objectives** of the ENVIRH study were the following:

1. To study the role of indoor air quality on children's health
2. To measure ventilation in buildings of children day care center – what determines the ventilation of spaces?
3. How is children’s health affected by ventilation of spaces?
4. The role of viral infections – What viruses affect these children?
5. Social impact study – recommendations?

**Methods**

The project was designed to be carried out in two different phases with several tasks in each. During phase I, in order to get a more representative sample of our population, data was collected on building characteristics, some preliminary Indoor Air Quality (IAQ) indicators and on respiratory diseases using a small screening health questionnaire. 45 Children Day Care Centres (CDCC) were selected in this phase. From the lists provided by the authorities, CDCCs were selected from two major cities (Lisbon and Oporto). In each CDCC, children were selected using a stratified random sampling method. In total, 25 CDCCs were selected in Lisbon (out of 48) and 20 (out of 40) in Oporto. For phase II, CDCCs were selected after performing a cluster analysis based on "low-risk" and "high-risk" buildings groups defined using ventilation surrogate markers measured in phase I, thus ensuring a sample with which we could more successfully detect differences.

Phase I

All children in the included CDCCs were selected for health screening, comprising a target population of 5,161 children.

Technicians visited all CDCCs to collect data on building characteristics according to a thorough standard checklist made for the study. The items about which data was recorded included: type of building; construction year; area; type of surroundings; building envelope; ventilation type; building heating and air conditioning (strategies and fuel); water heating (device and location); cooking; past records and visual inspection for mold and dampness sites; occupant practices regarding climatization and ventilation on different seasons; and user perceived quality of climatization comfort and air quality on different seasons.

IAQ analysis included measurements of $CO_2$, which were considered surrogates for ventilation and also temperature and humidity in different compartments. These measurements took place at different hours of the day, after allowing 10 minutes at the beginning of each of them for equipment stabilization. Measurements were taken during a period of day care center activity. Room occupancy during the measurement period was also registered. In average, 3 rooms in each DCC were included in the sample for feasibility. After analyzing building characteristics, the selected rooms were those with a higher occupancy rate and for which a lower ventilation rate was expected.

Respiratory health status was assessed through the application of a short forms derived from the ISAAC (International Study of Asthma and Allergies in Children) questionnaire. Questionnaires were handed out to parents by the CDCC staff who collected them after they were filled out.

Phase II

Phase II consisted of two visits: visit 1 – Spring (taking place between March and April 2011) and visit 2 - Winter (between November 2011 and February 2012).

All children (n = 2,287) in the selected CDCCs were included and questionnaires distributed as per phase I.

The study was carried out at typical occupation conditions, during everyday activities and comprised the monitoring of chemical (carbon dioxide, carbon monoxide, formaldehyde, total volatile organic compounds and $PM_{10}$) and biological (bacteria, fungi and house-dust mites) contaminants, as well as thermal comfort parameters.

The effective total air change per hour was determined using passive samplers and homogeneous emission of perfluorcarbon tracers (PFT). This method allows measurement of ventilation over long periods of time because sample volume requirements are very low: sample units don't interfere with daily activities and measurements can be made at the lab instead of on-site.

Respiratory health was evaluated at baseline through the application of the full version of the ISAAC questionnaire and at two other time points through the application of a follow-up questionnaire: one month after visit 1 and during visit 2.

Airway inflammation markers (condensate pH and total nitrites/nitrates) were measured in breath condensate collected during 15 minutes using an RTube (Respiratory Research Inc., Austin, TX, USA).

Caregivers had been provided a phone number to which they could call, without charge, to report suspected respiratory infection to the study team. After each call, the medical team collected swab samples from the oro- and naso-pharynx of the ill children. Samples were tested for the following viruses: Adenovirus, Influenza A and B, Parainfluenza 1-4, Respiratory syncytial virus, Rhinovirus, Enterovirus, Human metapneumovirus, Human bocavirus and Coronavirus.

Parental stress evaluation was performed through questionnaires. These were based on instruments validated for Portugal. The questionnaires evaluated whether psychological (anxiety/depression), parental (parenting stress and life events) and marital (satisfaction) dimensions vary as a function of child disease variables. Child stress level was evaluated by measuring 24h urine samples cortisol levels from children aged 4-6 years old. Urine samples were collected and questionnaires filled in the same week. During visit 1, urines were collected from 127 children. During visit 2, only 98 of those 127 accepted to provide a second urine sample.

The project was submitted to and approved by the following authorities: the Ethics Committee from Faculdade de Ciências Médicas, the National Committee on Data Protection, the Social Security Institute and national authorities representing solidarity institutions (Confederação Nacional de Instituições de Solidariedade e União das Misericórdias Portuguesas). The selected CDCCs have only been included in the study after approval by their respective board of administration. Children were included only when caregivers signed informed consent.

Data gathered during the whole duration of study were recorded on a Microsoft Access™ database. This database file was specifically constructed for the project by the research team so that several data tables were associated, thus accommodating the large amount of data inputted while allowing variables from different evaluations to be analyzed, compared and tested for associations together. Data input was centralized on a few people and verified by a project researcher to ensure that all records were made correctly.

An exploratory analysis of the variables of interest were carried out using classical descriptive statistics to calculate frequencies, means, medians and associated dispersion measures and confidence intervals for population demographics, CDCC characteristics, exposure values and health parameters. These were followed by more complex statistical methods such as regression models that considered the structure of dependence between individuals within the same class/institution. Parameters of these models were estimated through mixed effects models. In Phase I, two-level logistic random-intercept models were used to take into account CDCCs. In Phase II, three-level logistic random-intercept models were used, as children were nested in rooms and classrooms were nested in CDCCs.

The software CONTAM (version 3.0.1.1) was used to model the airflow in the CDCCs. It is considered that the air permeability of the envelope is due just to windows and doors and the measured air permeability is extrapolated considering the length of the opening joint and, when relevant, the dimension of the gap between the casement and the ground sill.

In order to simulate the ventilation conditions corresponding to $CO_2$ gas tracer tests, steady-state conditions, the weather data and PFT results are considered. The model is then used to sequentially calculate ventilation changes in different situations: opening or closing doors/windows in different combinations, changing the ventilation sources and schedules.

# ENVIRH Project framework and objectives

## Metodologia e objetivos do Projeto ENVIRH

ENVIRONMENT AND HEALTH IN CHILDREN DAY CARE CENTERS
AMBIENTE E SAÚDE EM CRECHES E INFANTÁRIOS

## Summary

- Research Team
- Aims
- Tasks
- Phases
- Timetable

This research project brought together civil engineers, mechanical engineers, environmental technicians, architects, psychologists and physicians in order to contribute to create healthier spaces and improve the quality of life of children.

## Research Team

- Health
  - Faculdade de Ciências Médicas – UNL
  - CEDOC@FCM-UNL
  - Centro Hospitalar de Lisboa Central, EPE
- Environment
  - Instituto Nacional de Saúde Dr. Ricardo Jorge
- Buildings
  - Laboratório Nacional de Engenharia Civil
  - Faculdade de Ciências e Tecnologia – UNL
- Statistical Analysis
  - Centro de Investigação do CHLC, EPE
- Consultants
  - José Rosado Pinto
  - Isabella Annesi-Maesano
  - Carl-Gustaf Bornehag

## Aims

1. The role of indoor air quality on children's health – Are there risk groups?
2. The role of ventilation in buildings of children day care center – what conditions the ventilation of spaces?
3. How is children's health affected by a lack of ventilation of spaces?
4. The role of viral infections – What viruses affect these children?
5. Social impact study – recommendations?

## Tasks - Phase I

1. **Survey of children health and construction characteristics of kindergarten**

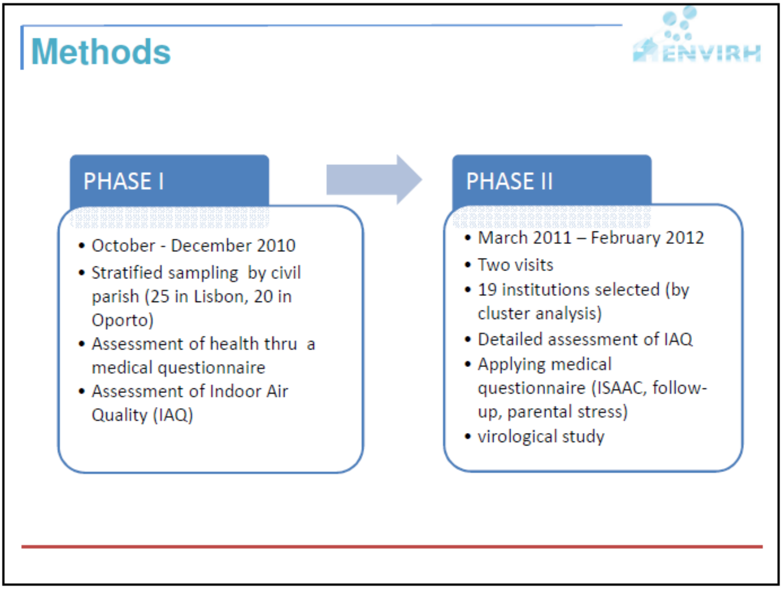
   All team members

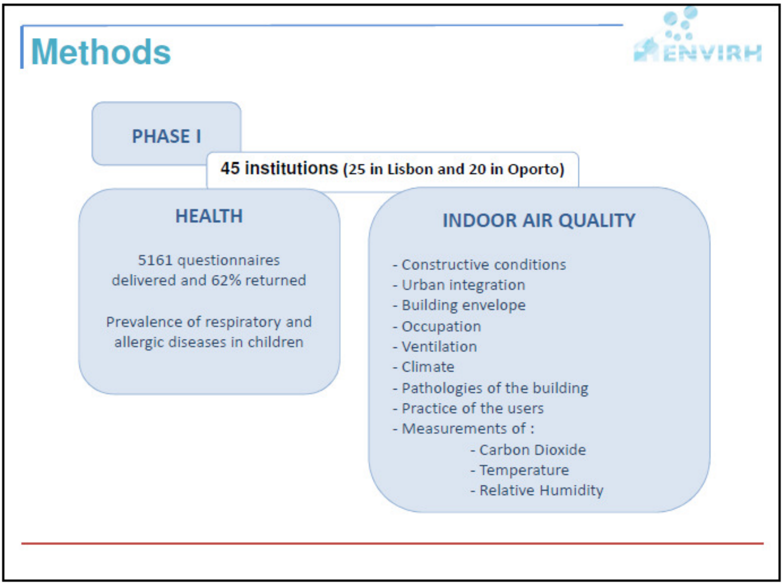
## Tasks - Phase II

2. **Day care center detailed survey (children health)**
   Team members: FCM-UNL, CHLC-EPE
3. **Indoor Air Quality and Thermal Comfort Analysis**
   Team members: INSA
4. **Survey of day-care center household behaviours, inspection of building physical characteristics and ventilation measurement campaign**
   Team members: LNEC, FCT-UNL
5. **Measurement of building ventilation**
   Team members FCT-UNL

## Tasks - Phase III

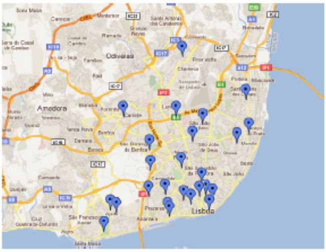
6. **Relation between health and environment**
   All team members
7. **Modelling and validation**
   Team members: LNEC, FCT-UNL
8. **Conclusions and specification of design recommendations**
   All team members


Methods
ENVIRH
PHASE I
• October - December 2010
• Stratified sampling by civil parish (25 in Lisbon, 20 in Oporto)
• Assessment of health thru a medical questionnaire
• Assessment of Indoor Air Quality (IAQ)
PHASE II
• March 2011 – February 2012
• Two visits
• 19 institutions selected (by cluster analysis)
• Detailed assessment of IAQ
• Applying medical questionnaire (ISAAC, follow-up, parental stress)
• virological study

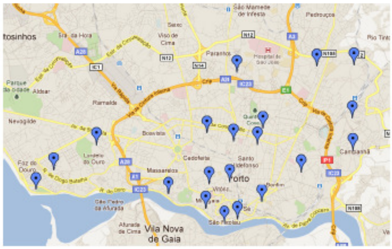

Methods
ENVIRH
PHASE I
45 institutions (25 in Lisbon and 20 in Oporto)
HEALTH
5161 questionnaires delivered and 62% returned
Prevalence of respiratory and allergic diseases in children
INDOOR AIR QUALITY
- Constructive conditions
- Urban integration
- Building envelope
- Occupation
- Ventilation
- Climate
- Pathologies of the building
- Practice of the users
- Measurements of :
- Carbon Dioxide
- Temperature
- Relative Humidity

## Children Day Care Centers included in phase I - 45

**Lisbon**

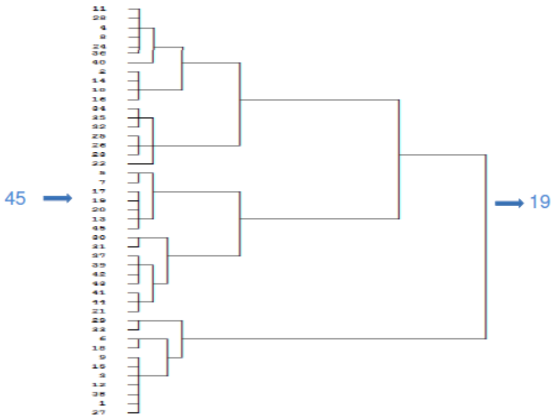


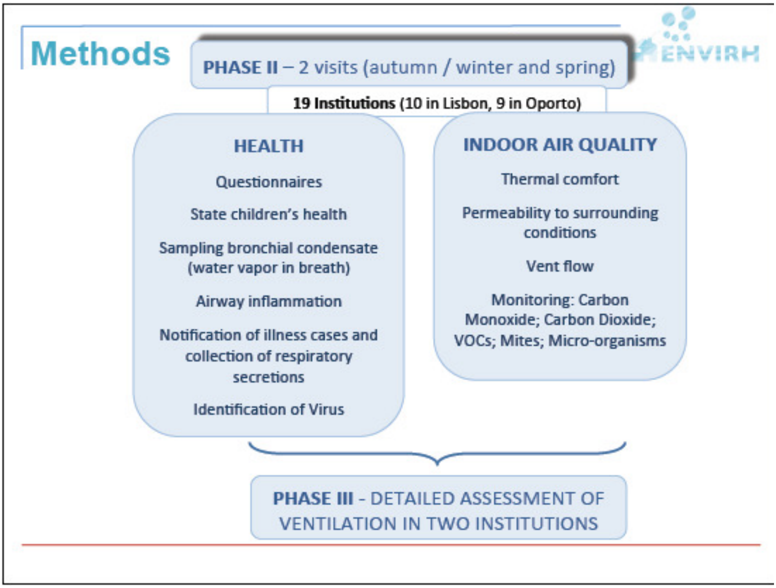

**Oporto**




## Cluster analysis

### 19 Children Day Care Centers






## To answer the question:

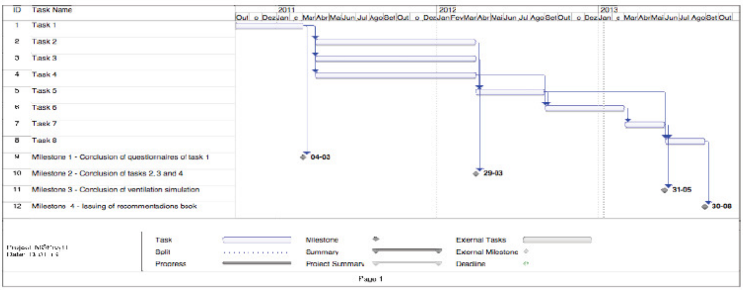
What is the impact of indoor environment on children's respiratory health?

## Phase II in 19 Institutions

**2 campaigns:** March - May 2011 and November 2011 - February 2012

- During periods of 8 weeks were evaluated:
  - IAQ
  - Warning system for identifying respiratory infections (free phone call)
  - Secretions to access virus
  - Biomarkers of exposure - pH and nitrites / nitrates in exhaled breath condensate - cooperative children (4 and 5 years)

## Timetable



# Assessment of Buildings Characteristics and Indoor Environment

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The relation between building physical characteristics and indoor environment in children day care centers (CDCC) has received increased attention in the past decades due to the importance of the respiratory illness of children. Although it is well known that poor ventilation of enclosed spaces contributes to spread bacteria and viruses, there is a lack of studies reporting on the measurement of ventilation rates in day care centers in Portugal.

This abstract presents a synthesis on airchange rates features investigated in a number of 16 CDCC´s located in the cities of Lisbon and Oporto using a passive tracer gas technique which uses perfluorocarbon tracer gases. The observational survey was carried out during January 2012, during which time ventilation measurements were performed in 9 CDCC of Oporto and 7 of Lisbon. In average, six activity rooms were monitored during a period of two consecutive weeks in each CDCC, according to children age group category and feasibility from the point of view of application of the PFT technique.

In an earlier phase of the study, information on parameters that can impact the comfort and ventilation characteristics was collected, including type and year of construction of buildings, type of windows (glazing and frame types, gaskets and moving leaf types) type of ventilation system (natural, mechanical, hybrid),

heating and air conditioning devices and user habits regarding ventilation strategies.

The application of the PFT technique has shown very low air change rates that varied between 0.04 $h^{-1}$ and 1.18 $h^{-1}$ in Oporto and between 0.01 $h^{-1}$ and 0.41 $h^{-1}$ in Lisbon, with the median values of 0.2 $h^{-1}$ and 0.13 $h^{-1}$, respectively. On the basis of the previous collection of information on parameters that can impact the ventilation characteristics, statistical analyses to explore the association between windows characteristics and air change rates were possible to perform.

A significant association was found between air changes per hour and type of moving leaf (casement, sliding or tilting) and between air changes per hour and type of gaskets (with or without). It was also found a significant association between air change rates and window frame material (wood or aluminium & steel), but this was expected since traditionally wooden frames are not equipped with gaskets.

Overall this study was able to show that CDCC have ventilation rates below the minimum design value of 0.6 ACH indicated by national regulation as default to avoid poor IAQ and that traditional wood frame window are more sensitive to air changes than modern windows equipped with gaskets. At the same time, the study calls for adequate strategies to improve ventilation in CDCC.

## Assessment of buildings characteristics and indoor environment

## Avaliação das características dos edifícios e do ambiente interior

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ENVIRONMENT AND HEALTH IN CHILDREN DAY CARE CENTERS
AMBIENTE E SAÚDE EM CRECHES E INFANTÁRIOS

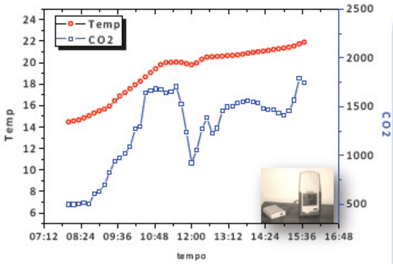
## Overview

- Objectives
- Survey of building characteristics and indoor environment in Phase I
- Ventilation air flow rates in Phase II
- Statistics
- Conclusions

1. **Survey of children health and construction characteristics of kindergarten** – All team members
2. **Day care center detailed survey (children health)** – Team members: FCM-UNL, CHLC-EPE
3. **Indoor Air Quality and Thermal Comfort Analysis** – Team members: INSA
4. **Survey of day-care center household behaviours, inspection of building physical characteristics and ventilation measurement campaign** – Team members: LNEC, FCT-UNL
5. **Measurement of building ventilation** – Team members – FCT-UNL
6. **Relation between health and environment** – All team members
7. **Modelling and validation** – Team members: LNEC, FCT-UNL
8. **Conclusions and specification of design recommendations** – All team members

PHASE I

**45 institutions** (25 in Lisbon and 20 in Oporto)




BUILDINGS CHARACTERISTICS & INDOOR ENVIRONMENT

- Constructive conditions
- Urban integration
- Building envelope — type of windows & gaskets
- Occupation
- Ventilation — type of ventilation
- Climate
- Pathologies of the building
- Practice of the users
- Measurements of :
  - Carbon Dioxide
  - Temperature
  - Relative Humidity

# Results from Phase I

## 45 schools (Lx 25; Pt 20)

| Ventilation & HVAC characteristics | | | Lisbon | | Oporto | |
|---|---|---|---|---|---|---|
| | | | Absolute frequency | Relative frequency | Absolute frequency | Relative frequency |
| Ventilation type | Mechanical | | 0 | 0% | 1 | 5% |
| | Mixed | Kitchen mechanical exhaust | 19 | 76% | 13 | 65% |
| | | Kitchen & bathroom mechanical exhaust | 1 | 4% | 4 | 20% |
| | | Bath mechanical exhaust | 0 | 0% | 1 | 5% |
| | Natural | | 5 | 20% | 1 | 5% |
| Declared ventilation habits | Windows opened | Winter | 11 | 44% | 2 | 10% |
| | | Spring/Autumn | 13 | 52% | 6 | 30% |
| | | Summer | 23 | 92% | 18 | 90% |
| Heating and air conditioning devices - type | Autonomous devices | | 23 | 92% | 13 | 65% |
| | Centralized with heat exchange fluid | | 2 | 8% | 7 | 35% |
| Energy source | Electricity | | 23 | 92% | 13 | 65% |
| | Gas | | 2 | 8% | 7 | 35% |
| Heating and air conditioning devices | With heating | | 22 | 88% | 20 | 100% |
| | Without heating | | 3 | 12% | 0 | 0% |
| | With cooling | | 20 | 80% | 7 | 35% |
| | Without cooling | | 5 | 20% | 13 | 65% |

# Results from Phase I

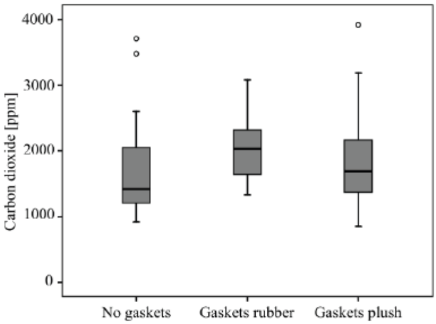
## 45 schools (Lx 25; Pt 20)

| Type of windows & gaskets | | | Lisbon | | Oporto | |
|---|---|---|---|---|---|---|
| | | | Absolute frequency | Relative frequency | Absolute frequency | Relative frequency |
| Window frame | Wood | | 5 | 20% | 14 | 70% |
| | Aluminium | | 19 | 76% | 5 | 25% |
| | Steel | | 1 | 4% | 1 | 5% |
| Glazing | Single | | 15 | 60% | 16 | 80% |
| | Double | | 10 | 40% | 4 | 20% |
| Type of window moving leaf | Casement | | 12 | 48% | 13 | 65% |
| | Sliding | | 8 | 32% | 4 | 20% |
| | Tilting | | 5 | 20% | 3 | 15% |
| Type of gaskets | No gaskets | | 6 | 24% | 14 | 70% |
| | Rubber gaskets | | 14 | 56% | 3 | 15% |
| | Plush gaskets | | 5 | 20% | 3 | 15% |
| Type of solar shading | Interior | Wood | 9 | 36% | 9 | 45% |
| | | Other | 3 | 12% | 6 | 30% |
| | Exterior | PVC | 13 | 52% | 5 | 25% |

# Results from Phase I

## 45 schools (Lx 25; Pt 20)

### Associations between $CO_2$ and type of window gasket



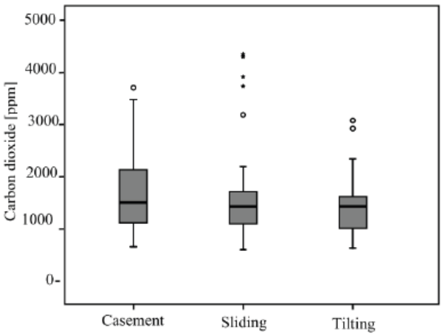

A significant association was found ($p$=0.012) between indoor $CO_2$ concentration and the type of window gaskets.

The gaskets type has a significant influence on the air permeability of the windows and, therefore, on the ventilation and indoor air quality!

# Results from Phase I

## 45 schools (Lx 25; Pt 20)

### Associations between $CO_2$ and type of window moving leaf




No significant association was found ($p$=0.302) between indoor $CO_2$ concentration and the type of windows moving leaf!

## PHASE II

**19 Institutions (10 in Lisbon, 9 in Oporto)**

### HEALTH

Questionnaires

State children's health

Sampling bronchial condensate (water vapor in breath)

Airway inflammation

Notification of illness cases and collection of respiratory secretions

Identification of Virus

### INDOOR AIR QUALITY

Thermal comfort

Permeability to surrounding conditions

**Ventilation airflow rates**

Monitoring: Carbon Monoxide; Carbon Dioxide; VOCs; Mites; Micro-organisms

## Results from Phase II

### 19 schools (Lx 10; Pt 9)

The effective total air changes per hour (ACH) was determined using passive samplers and homogeneous emission of PFTs (perfluorocarbon tracer gases )

Main advantages of PFT technique:

- can be used in any building regardless of the ventilation principle;
- test can be performed during use and occupancy of the building;
- it can be used for long-term monitoring.

Main disadvantages of PFT technique:

- emission of tracer gas might not result homogeneous in complex configuration buildings;
- values are average estimates.

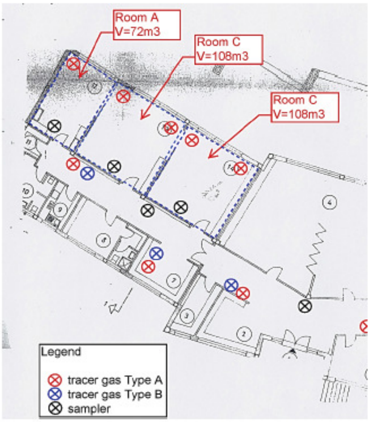
## Results from Phase II

### 19 schools (Lx 10; Pt 9)

Study was developed in January 2012 during which information was also collected on type and year of construction, wall's structural characteristics, state of maintenance (fungi and/or mould), type of windows, type of ventilation system, user habits regarding ventilation

PFT sources (type A) were positioned in each room, with tracer gas emission rates adjusted to the room volumes

To measure the time averaged concentration of the tracer gas in rooms an integrating sampling was performed, using diffusive samplers




## Results from Phase II

### 19 schools (Lx 10; Pt 9)

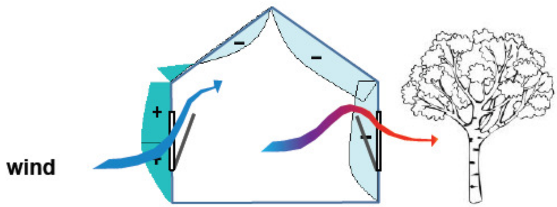
The application of the PFT technique revealed air change rates that varied between 0.04 $h^{-1}$ and 1.18 $h^{-1}$ in Oporto and between 0.01 $h^{-1}$ and 0.41 $h^{-1}$ in Lisbon

The median values are 0.2 $h^{-1}$ in Oporto and 0.13 $h^{-1}$ in Lisbon

## Airchange rates (ACH) differences

**Possible reasons:**

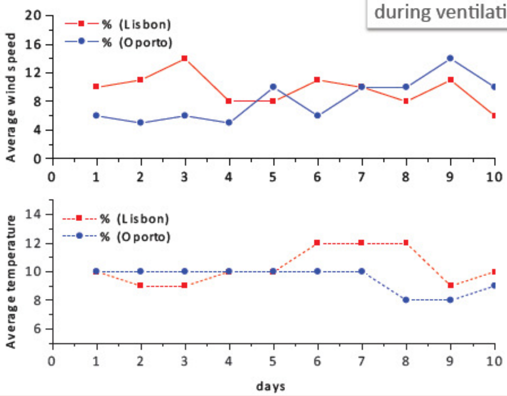
- Climate (temperature and wind)
- User behaviour (CDCC qualified personnel were asked to behave as they normally would with respect to ventilation)
- Building envelope characteristics




## Results from Phase II

### 19 schools (Lx 10; Pt 9)

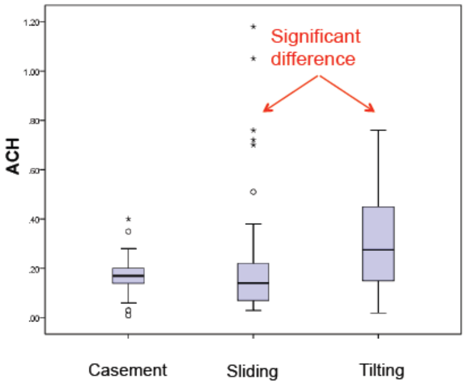
Weather history in Lisbon and Oporto during ventilation measurements



## Building envelope characteristics

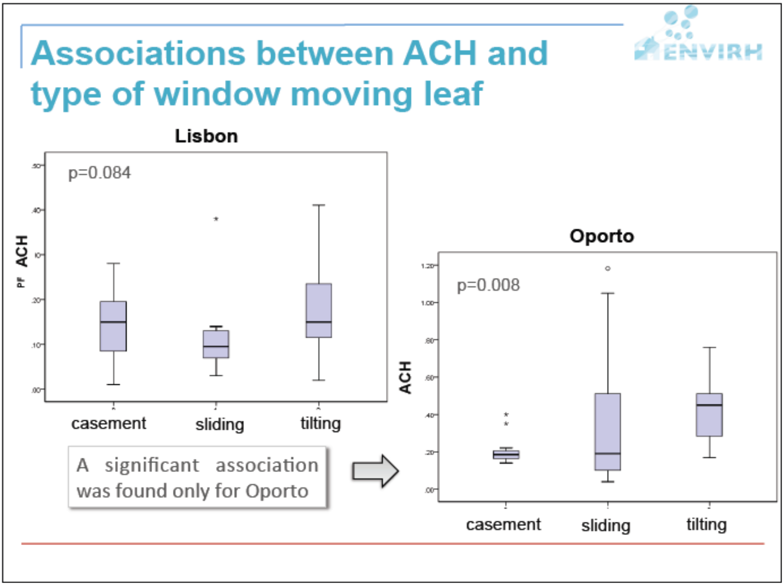
| | | | Lisbon (0 no gaskets 1 with gaskets) 0 | Lisbon 1 | Total | Oporto (0 no gaskets 1 with gaskets) 0 | Oporto 1 | Total |
|---|---|---|---|---|---|---|---|---|
| | casement | Count | 14 | 17 | 31 | 12 | 4 | 16 |
| | | % within moving leaf | 45.2% | 54.8% | 100.0% | 75.0% | 25.0% | 100.0% |
| | | % within gaskets | 63.6% | 38.6% | 47.0% | 50.0% | 15.4% | 32.0% |
| | sliding | Count | 1 | 18 | 19 | 6 | 16 | 22 |
| | | % within moving leaf | 5.3% | 94.7% | 100.0% | 27.3% | 72.7% | 100.0% |
| | | % within gaskets | 4.5% | 40.9% | 28.8% | 25.0% | 61.5% | 44.0% |
| | tilting | Count | 7 | 9 | 16 | 6 | 6 | 12 |
| | | % within moving leaf | 43.8% | 56.3% | 100.0% | 50.0% | 50.0% | 100.0% |
| | | % within gaskets | 31.8% | 20.5% | 24.2% | 25.0% | 23.1% | 24.0% |
| Total | | Count | 22 | 44 | 66 | 24 | 26 | 50 |
| | | % within moving leaf | 33.3% | 66.7% | 100.0% | 48.0% | 52.0% | 100.0% |
| | | % within gaskets ( 0 sem vedantes 1 com vedantes) | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

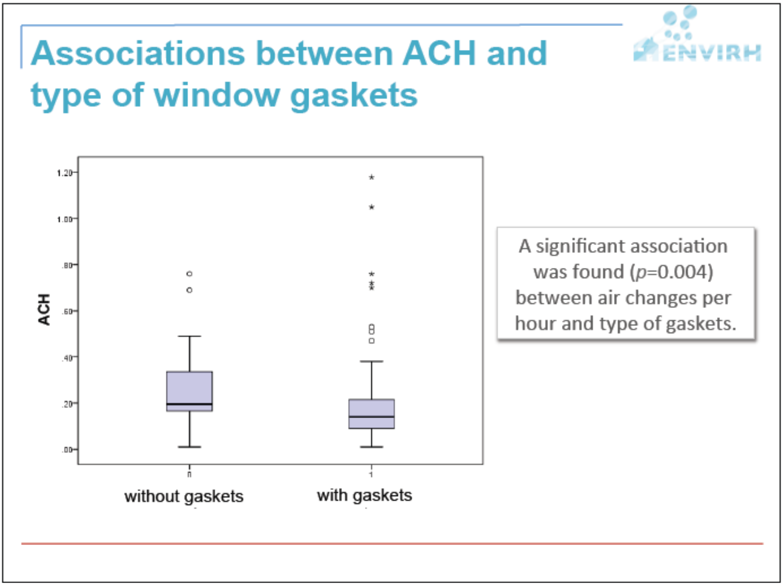
## Associations between ACH and type of window moving leaf

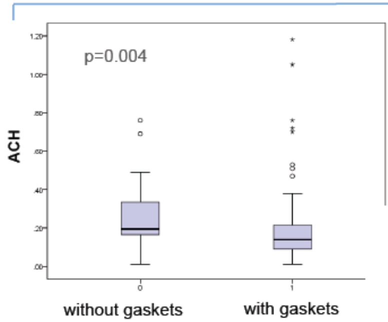



A significant association was found ($p$=0.015) between air changes per hour and type of window moving leaf.

The most significant association has been found between sliding and tilting types ($p$=0,016)

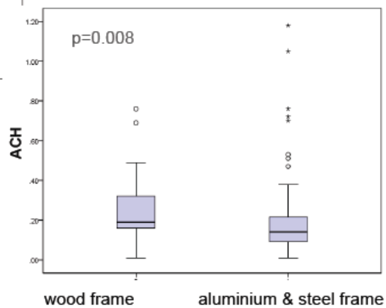

Associations between ACH and type of window moving leaf
ENVIRH
Lisbon
p=0.084
ACH
casement
sliding
tilting
A significant association was found only for Oporto
Oporto
p=0.008
ACH
casement
sliding
tilting


Associations between ACH and type of window gaskets
ENVIRH
ACH
without gaskets
with gaskets
A significant association was found (p=0.004) between air changes per hour and type of gaskets.




Type of gaskets is closely related to the window frame material

Wood frame windows (traditionally without gaskets ) are more sensitive to air changes




# Conclusions

- Measurements of $CO_2$ concentration (Phase I) and measurements of the tracers over a period of two weeks during winter time (Phase II) point out poor overall ventilation of indoors.
- Although air change rates during occupation periods is not known (as the results of ACH are average values), these low values cause concerns regarding possible impacts on health.
- Strong statistical correlation exist between building envelope characteristics (windows) and air change rates and this provides useful clues regarding the ventilation strategies to be adopted in order to improve the IAQ of CDCCs.

## Assessment of Indoor Air Quality

Manuela Cano[1], Susana Nogueira[2], Ana Luísa Papoila[3,4], Fátima Aguiar[1], Ana Mendes[1], João Paulo Teixeira[1] and Carmo Proença[1]

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[2]Laboratório Nacional de Engenharia Civil, Lisboa, Portugal

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[4]Centro de Investigação do Centro Hospitalar de Lisboa Central, EPE, Lisboa, Portugal

The growing concern about indoor air quality results from the knowledge that exposure to indoor air pollutants may be higher than outdoor air exposure. In developed countries, after their homes, the children day care center (CDCC) is the place where children spend most of their time, so it is essential to understand how environmental factors influence children respiratory health. The aim of ENVIRH (Environment and Health in children day care centres) project is to gather information on indoor environment in CDCC in order to correlate it with both ventilation and children's health.

This document describes the results from field measurements of physical parameters, chemical and biological indoor contaminants in 19 CDCC located in Lisboa and Porto. Associations between building characteristics and indoor air quality parameters were determined taking the season into account. Chemical contaminants (carbon dioxide, carbon monoxide, formaldehyde, total volatile organic compounds – TVOC and $PM_{10}$), biological contaminants (bacteria, fungi and house-dust mites) and thermal comfort parameters were monitored during routine activities between March 2011 and February 2012.

Most of the CDCC revealed carbon dioxide and bacterial levels above the reference levels defined by the Portuguese legislation. An association was found between carbon dioxide and bacteria, both in spring and winter. Nurseries presented lower bacterial concentrations than activity rooms. Lower differences between indoor and outdoor carbon dioxide were achieved in rooms with tilting windows when compared with rooms with other type of windows. Indoor $PM_{10}$ levels were higher indoors when compared with outdoor levels (I/O ratio>1) and are influenced by the floor covering material. Higher levels of formaldehyde were found in recent and refurbished CDCC. In spring were obtained higher concentrations of house dust mites in dust with 16% of the rooms surpassing the sensitization threshold. Fungal concentrations were generally below the maximum acceptable concentration defined by the Portuguese legislation. There could be some discomfort for the body as a whole among children due to the thermal environment as a result of a cool sensation.

This study highlights the need to improve CDCC indoor environmental quality conditions in order to achieve a healthier indoor environment for children.

## Assessment of Indoor Air Quality

## Avaliação da Qualidade do Ar Interior

ENVIRH
ENVIRONMENT AND HEALTH IN CHILDREN DAY CARE CENTERS
AMBIENTE E SAÚDE EM CRECHES E INFANTÁRIOS

## Aim

To gather information on indoor environmental quality of Children Day Care Centers (CDCC) in order to correlate it with both ventilation and children's health.

## Especific Tasks

1. Respiratory health of children attending these CDCC
2. Building characteristics and ventilation patterns
3. Assess indoor environmental quality

## Metodology 1

Phase II – March 2011 to February 2012

- Spring – visit 1
  March /April 2011
- Winter – visit 2
  November/February 2012

### Assessment of Indoor Air Quality (IAQ)

- Spring - 125 activity rooms (73 in Lisbon and 52 in Porto) from 19 CDCC
- Winter – 97 activity rooms (66 in Lisbon and 31 in Porto) from 17 CDCC
- In each school were studied activity rooms representative of all age groups (4-5 month to 5 years)
- IAQ assessment was carried out during routine activities

## Metodology 2

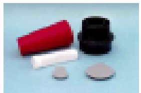
1. Walkthrough Inspection
   - Floor
   - Window type of moving leaf
   - Area
   - Occupation
   - Visible mould

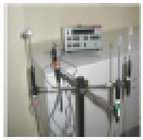
2. Thermal Comfort (ISO 7730:2005)
   - Air temperature, relative humidity, mean radiant temperature, air velocity
   - Metabolic rate and clothing

3. IAQ
   - Carbon dioxide, Carbon monoxide, formaldehyde, $PM_{10}$, TVOC
   - Bacteria, Fungi and House dust mites (Der p1 and Der f1)

## Metodology 3

- Carbon monoxide and carbon dioxide measurements were made using a Photoacoustic Multi-Gas Monitor INNOVA
- Viable microorganisms were collected using a MAS-100 and cultured
- House dust mites allergen were analyzed by a ELISA quantitative assay
- $PM_{10}$ were collected using PTFE filters and were analyzed gravimetrically
- Formaldehyde was analyzed according to the NIOSH 3500 method (UV-Vis)
- Total volatile organic compounds (TVOCs) were analyzed by gas chromatography according to ISO 16000 - part 6
- Thermal comfort was evaluated according to the ISO 7730



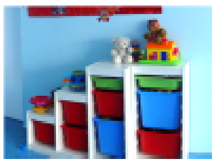


## Results 1

**Room Characteristics**

| Room (n=97) | Mean | SD | Range |
|---|---|---|---|
| Ocupation (occupants/room) | 16.31 | 5.43 | 4-29 |
| Area ($m^2$) | 36.14 | 11.86 | 11.89-67.0 |
| Occupancy rate (occupant/$m^2$) | 0.49 | 0.23 | 0.14-1.90 |

79% of the rooms comply with the law and 21% show higher occupation.



## Results 2

ENVIRH

Legislation

Nurseries - Portaria nº 262/2011 de 31 de Agosto do Ministério da Solidariedade e Segurança Social

Kindergarten - Despacho Conjunto nº 268/97 de 25 de Agosto do Ministério da Educação e Ministério da Solidariedade e Segurança Social

| Age Groups | Number of Children | Minimal area/child |
|---|---|---|
| 0 - to walk | 10 | 2m² |
| Walk - 24 month | 14 | $2m^2$ * |
| 24 month - 36 month | 18 | $2m^2$ * |
| 36 Month - 5 years | 20-25 | $2m^2$ |

* In case of impossibility to constitute groups according to the table, it is possible to create heterogeneous groups with more than 16 children adding $1m^2$ /child.

## Results 3 – Chemical Contaminants

ENVIRH

| Chemical contaminants | Median ($mg/m^3$) | $P_{25}$-$P_{75}$ | Reference ($mg/m^3$) | Rooms >Ref. (%) | I/O |
|---|---|---|---|---|---|
| Spring (n=125) | | | | | |
| Carbon dioxide | 2210 | 1410-2800 | 1800 | 62 | 2.23 |
| Carbon monoxide | 0.52 | 0.34-0.80 | 12.5 | 0 | 1.24 |
| $PM_{10}$ | 0.13 | 0.09-0.35 | 0.150 | 39 | 1.32 |
| TVOCs | 0.14 | 0.07-0.28 | 0.60 | 11 | 3.51 |
| Formaldehyde | 0.02 | 0.02-0.02 | 0.1 | 6 | - |
| Winter (n=97) | | | | | |
| Carbon dioxide | 2390 | 1697-3390 | 1800 | 73 | 3.30 |
| Carbon monoxide | 1.16 | 0.93-1.40 | 12.5 | 0 | 1.20 |
| $PM_{10}$ | 0.09 | 0.04-0.13 | 0.150 | 20 | 1.44 |
| TVOCs | 0.10 | 0.08-0.20 | 0.60 | 5 | 3.45 |
| Formaldehyde | 0.02 | 0.02-0.02 | 0.1 | 11 | - |

## Results 4 – Biological Contaminants

| Microbiological contaminants | Median (UFC/m³) | $P_{25}$-$P_{75}$ | Reference (UFC/m³) | Rooms >Ref. (%) | I/O |
|---|---|---|---|---|---|
| Spring (n=125) | | | | | |
| Total Bacteria | 3390 | 1960-8040 | 500 | 98 | 31.6 |
| Gram-negative Bacteria | 50 | 20-100 | - | - | 2.5 |
| Fungi | 410 | 250-610 | 500 | 37 | 1.1 |
| Winter (n=97) | | | | | |
| Total Bacteria | 3580 | 1680-5915 | 500 | 97 | 22.1 |
| Gram-negative Bacteria | 40 | 24-100 | - | - | 4.1 |
| Fungi | 336 | 225-552 | 500 | 34 | 1.1 |

## Results 5 – House Dust Mites

| House Dust Mites | Median (µg/g dust) | $P_{25}$-$P_{75}$ | Sensitization threshold (µg/g dust) | >Sens. Threshold µg/g dust (%) |
|---|---|---|---|---|
| Spring (n=124) | | | | |
| Allergen Der p1 | 0.67 | 0.46-0.83 | 2 | 16 |
| Allergen Der f1 | 0.40* | 0.40-0.40 | | |
| Winter (n=94) | | | | |
| Allergen Der p1 | 0.40 | 0.40-0.64 | 2 | 6 |
| Allergen Der f1 | 0.40 | 0.40-0.40 | | |

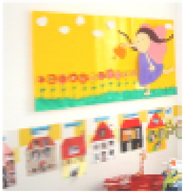
*LQ –Limit of Quantification

In 4 activity rooms the concentration of house dust mites was above 10 µg/g dust

## Results 6

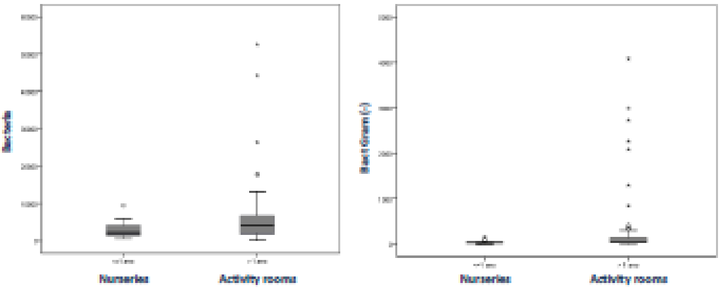
Characterization of the rooms - Nurseries *versus* Activity Rooms

| Mean | Nursery | Activity rooms |
|---|---|---|
| Occupation | 8.9 | 17.7 |
| Area ($m^2$) | 28.5 | 39.15 |
| Occupation rate (ocupant/$m^2$) | 0.34 | 0.49 |



## Results 7

Bacterial concentration *vs* type of room

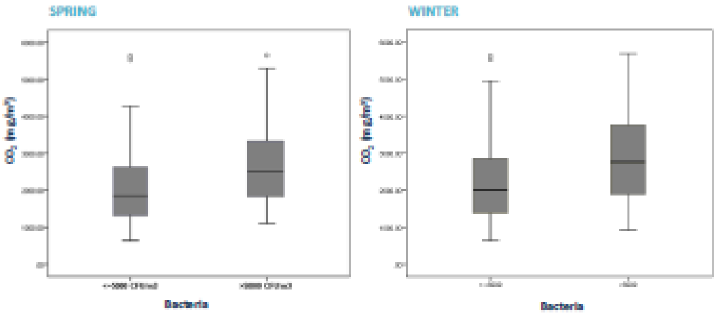



A significant association was found between total bacteria ($p$=0.017) Gram-negative bacteria ($p$=0.042) and type of room.

Lower bacterial concentrations in nurseries.

## Results 8

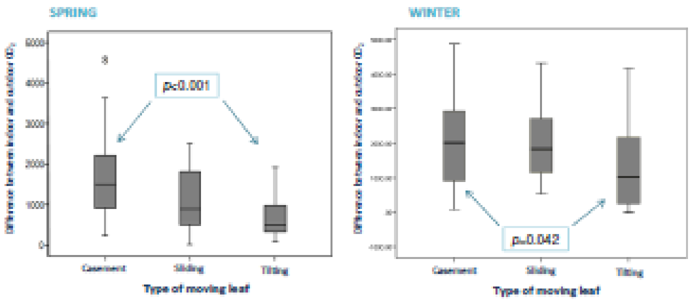
**Carbon Dioxide vs Total Bacteria**

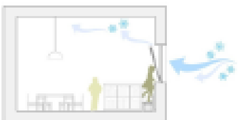



A significant association was found between bacteria and carbon dioxide in Spring ($p$=0.001) and Winter ($p$=0.009).

## Results 9

**$CO_{2\ indoor}$- $CO_{2\ outdoor}$ *vs* window type of moving leaf**



Rooms with tilting windows have a smaller difference between indoor and outdoor carbon dioxide

## Results 10

**$PM_{10}$ *vs* Floor Covering Materials**

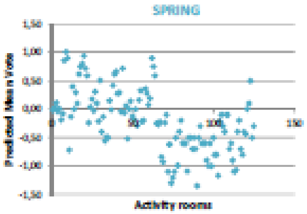
| Floor covering material | Median (mg/m$^3$) | $P_{25}$-$P_{75}$ |
|---|---|---|
| Wood/cork | 0.97 | 0.20-3.56 |
| Tile | 0.12 | 0.05-0.67 |
| PVC | 0.12 | 0.08-0.82 |

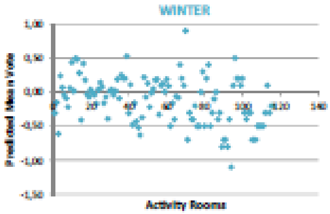
(Spring n=73)

Statistically significant association (overall $p$=0.011) between $PM_{10}$ and type of floor covering material, wood/cork *versus* tile ($p$=0.015), wood/cork *versus* PVC ($p$=0.005) and tile *versus* PVC ($p$=0.778), this one without statistical significance.

## Results 11

**Thermal Comfort**




| Predicted Percentage of Dissatisfied | Spring (n=125) | Winter (n=116) |
|---|---|---|
| PPD <6 % | 26 | 60 |
| PPD <10% | 65 | 97 |
| PPD <15 % | 92 | 109 |
| PPD >15 % | 33 | 7 |

PPD is due to a cool sensation

## Conclusions 1

- Carbon dioxide Indoor/outdoor rates were higher in winter.
- In winter there was a higher percentage of rooms with formaldehyde levels above recommended levels.
- More than 90% of the studied rooms revealed bacterial concentrations above the recommended levels.
- Bacterial concentrations were lower in nurseries.
- Der 1 allergen levels were above the sensitization threshold (2 µg/g dust) in 12% of the rooms in both visits and 1.8 % are also above 10 µg/g dust.

## Conclusions 2

- Rooms with tilting windows shown smaller differences between indoor and outdoor carbon dioxide concentrations.
- Rooms with washable floor shown a smaller $PM_{10}$ concentration.
- The high levels of human related contaminants such as carbon dioxide and bacteria demonstrate that is necessary to improve ventilation.
- There could be some discomfort for the body as a whole among children due to the thermal environment (PPD≥15%) as a result of a cool sensation.

## Role of Respiratory Viral Infections

Paulo Paixão[1,2], Cátia Piedade[2], Ana Luísa Papoila[3], Iolanda Caires[1], Catarina Pedro[1], Madalena Santos[4], Maria José Silvestre[4], Laura Brum[1,2], Baltazar Nunes[5], Raquel Guiomar[6], Martin D Curran[7], Ana Carvalho[8], Teresa Marques[1], Nuno Neuparth[1]

[1]Faculdade de Ciências Médicas, FCM, Universidade Nova de Lisboa, CEDOC, 1169-056 Lisboa, Portugal

[2]Laboratório de Patologia Clínica (Labco), Hospital da Luz, Lisboa, Portugal

[3]Faculdade de Ciências Médicas, FCM, Universidade Nova de Lisboa, CEAUL, 1169-056 Lisboa, Portugal

[4]Hospital Curry Cabral – Centro Hospitalar de Lisboa Central, Lisboa, Portugal

[5]Departamento de Epidemiologia, Instituto Nacional de Saúde Ricardo Jorge, Lisboa, Portugal

[6]Laboratório Nacional de Referência para o Vírus da Gripe, Instituto Nacional de Saúde Ricardo Jorge, Lisboa, Portugal

[7]Clinical Microbiology and Public Health Laboratory, Public Health England, Addenbrooke's Hospital, Cambridge, UK

[8]Unidade de Pediatria, Hospital da Luz, Lisboa, Portugal

The project "Environment and Health in children day care centers" (ENVIRH), where this study is nested, is a multidisciplinary project with the purpose of studying the health impact of indoor air environment in children in day care centers. One of the key points of this project was the study of the role of viral respiratory infections at day care center level, particularly influenza. To accomplish this, the study included parents´ phone contact to the research team whenever a child had symptoms of respiratory infection, in order to collect respiratory samples for virology analysis. The main objective of this study was to test the compliance of the parents to this report system and to see if this strategy would improve the detection, in pre-school children, during epidemic periods, when compared with current surveillance systems for influenza. The detection of other circulating respiratory viruses was the second objective of the study.

In the second year of the study, the circulating viruses at day care centers were compared with the detected viruses in children who attended a Hospital Emergency Department with respiratory infections. This Hospital approach would also test influenza detection by an Emergency Department team and would allow comparison with the results of the National Program, which also includes several hospitals.

Real-time PCR and RT-PCR were performed for influenza A and B, parainfluenza 1-4, adenovirus, human metapneumovirus, respiratory syncytial virus A and B, rhinovirus, enterovirus, group 1 coronaviruses, group 2 coronaviruses and human bocavirus.

One hundred children were included, 64 from the day care centers and 36 from the Hospital. Overall, 79 samples were positive for at least one respiratory virus. Influenza A (H3) was the virus most frequently detected: twenty-five cases, 20 of these in children under five years of age (10 from day care centers and 10 who went to the hospital) which was higher than those reported by the National Influenza Surveillance Programme for this age.

In conclusion, the results obtained in this study suggest that a surveillance system based on parents´ report could complement the implanted system of the National Influenza Surveillance Program, improving significantly the number of viral detections in young children. All the respiratory viruses searched in this study were found to circulate in the community, at least in one of the periods, causing acute respiratory infections in young children that were usually mild, but responsible for keeping most of the children and parents at home and, in some cases, for a Hospital consultation or even hospitalization.

## Role of respiratory viral infections

## Papel das infeções respiratórias virais

ENVIRH ENVIRONMENT AND HEALTH IN CHILDREN DAY CARE CENTERS

AMBIENTE E SAÚDE EM CRECHES E INFANTÁRIOS

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FCM, CHLC, INSA, LNEC , FCT

**Research project:**
**Environment and Health in Children Day Care Centers (ENVIRH)**

**Aim:**

Study the health impact of indoor air environment in children in day care centers (CDCC)

**Virology study: objectives**

- to test the compliance of the parents to a report system of respiratory infections
- to identify the viruses responsible for the respiratory infections that do not require hospital attending and compare them with the detected viruses in children who attended a Hospital Emergency

## Study Design

ENVIRH

February to May 2011 / October 2011 to April 2012

**Children**

Eight CDCC in Lisbon. A total of 764 children under five had parents' permission to participate in the study.

Parents were invited to participate in the study by calling to the ENVIRH team whenever their children presented at least two of the following clinical signs: fever, wheezing, cough or nasal congestion.

## Study Design

October 2011 to April 2012

**Children**

In the second period, children attending the Emergency Department of the Hospital da Luz, with the same clinical signs mentioned above, were also included.

## Study Design

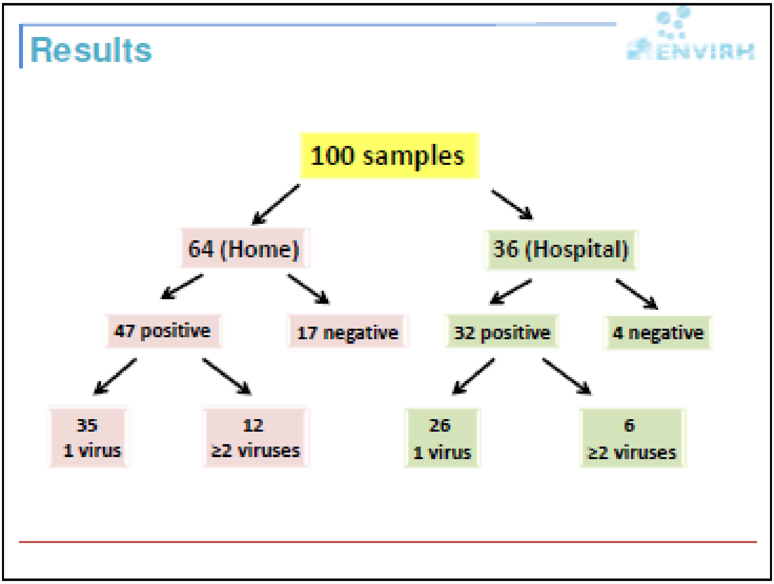
**Viral detection**

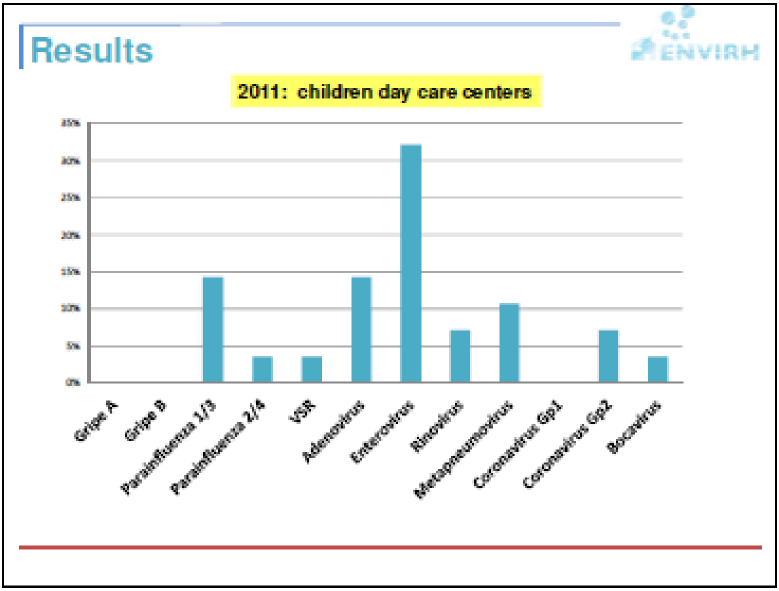
### Samples

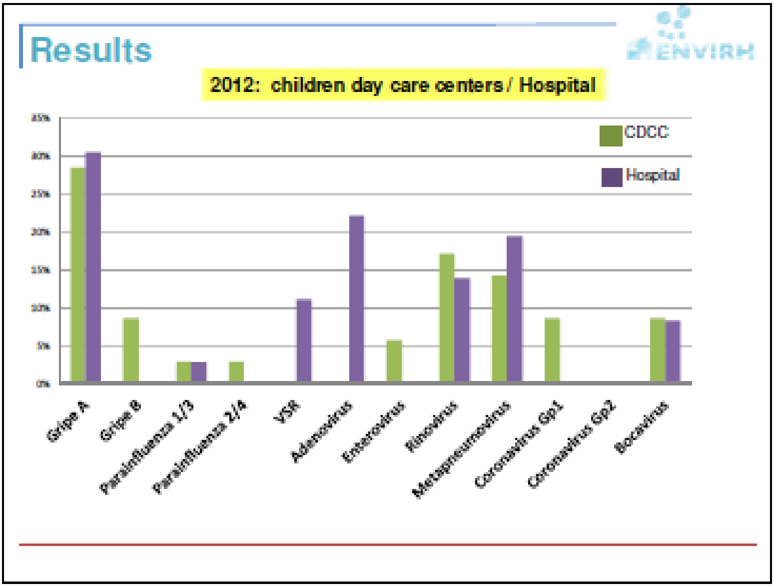
Two swabs:
nasopharyngeal and oropharyngeal

### Real-time PCR

- Influenza A and B
- Parainfluenza 1-4
- Adenovirus
- Human metapneumovirus
- Respiratory syncytial virus A and B
- Rhinovirus
- Enterovirus
- Group 1 coronaviruses (HCoV-229E, HCoV-NL63)
- Group 2 coronaviruses (HCoV-OC43, HCoV-HKU1)
- Bocavirus

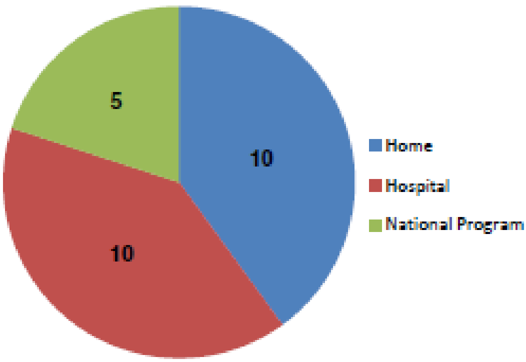

Results
ENVIRH
100 samples
64 (Home)
36 (Hospital)
47 positive
17 negative
32 positive
4 negative
35
1 virus
12
≥2 viruses
26
1 virus
6
≥2 viruses


Results
ENVIRH
2011: children day care centers
Gripe A
Gripe B
Parainfluenza 1/3
Parainfluenza 2/4
VSR
Adenovirus
Enterovirus
Rinovirus
Metapneumovirus
Coronavirus Gp1
Coronavirus Gp2
Bocavirus


Results
ENVIRH
2012: children day care centers / Hospital
CDCC
Hospital
Gripe A
Gripe B
Parainfluenza 1/3
Parainfluenza 2/4
VSR
Adenovirus
Enterovirus
Rinovirus
Metapneumovirus
Coronavirus Gp1
Coronavirus Gp2
Bocavirus

## Results

Number of Influenza detections in children <5 years




## Conclusions

Alarm system: low parents' compliance, except during flu epidemic period

The results obtained in this study suggest that a surveillance system at day care centers could complement the implanted system of the National Program for Flu Surveillance, improving significantly the number of viral detections in young children

Multiple respiratory viruses, old and recently described, circulate in the community, causing mild infections that do not require Hospital consultation but sufficient to keep children and parents at home.

## Conclusions

Adenovirus and RSV were more frequent in children attending the Hospital. However, the low number of samples do not allow conclusions with statistical significance, with the exception of adenovirus, linked to Hospital attending.

RSV and metapneumovirus were more frequent in children with wheezing. Wheezing was never detected in influenza infections.

The reasons for the negative results could be the presence of other viruses not included in the panels, bacterial infections or even non-infectious causes

# Ventilation Strategies for Indoor Air Quality Improvement

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Physical modeling of ventilation is strongly dependent on the characteristics of the building and the precise evaluation of such characteristics is a complex and time consuming work. As part of this research project, two CDCC have been selected in order to measure the envelope air permeability, the flow rate of mechanical ventilation systems and indoor and outdoor temperature. This data was used as input of CONTAM computer code for ventilation simulation. The results were compared with direct measurements of ventilation flow (short term measurements with $CO_2$ tracer gas and medium term measurements with PFT method). After validation, this model is used to predict the ventilation rates under a range of weather conditions in order to perform a sensitivity analysis of the main parameters that affect ventilation. The purpose of this assessment was to find the best practices to improve natural ventilation avoiding impairing the indoor comfort.

The following conclusions can be drawn:

1. The good agreement obtained between the simulation results and the short term $CO_2$ tracer gas measurements and the medium term PFT measurements sustain the validity of simulations input data. Therefore, it is expected that further predictions are representing the real ventilation performance of the buildings.

2. For both CDCC the wind is the main natural action to drive ventilation.

3. In general is much more effective for ventilation purposes to open the windows and doors during the day because the wind action is stronger.

4. For mechanical ventilation the flow rate obtained is higher than the design flow rate due to infiltrations and external actions (mainly the wind).

5. For natural ventilation systems the ventilation flow rate show high variation from activity room to activity room due to the envelope air permeability.

6. Contamination between rooms is shown to be quite important; the design of a natural ventilation system with conduits is shown to be very successful in reducing that contamination.

7. Predictions show that for these CDCC wind driven cross-ventilation may have performance equivalent to mechanical ventilation.

8. The adoption of a ventilation system (natural or mechanical) minimize the impact of outdoor conditions (weather and noise) in indoor comfort (thermal and acoustical) and reduces the disturbances in activity room due to noise emitted from other rooms of the CDCC. The performance may be adjusted adopting the adequate design requirements.

9. When a ventilation system (natural or mechanical) is not installed in CDCC building, procedures of opening external windows and internal doors should be adopted in order to ventilate the activity rooms. In order to reduce the discomfort, the windows and doors shall be kept opened while children are outside the activity rooms. It is desirable to open doors and windows at any activity break.

# Ventilation Strategies for Indoor Air Quality Improvement

## Estratégias de ventilação para a melhoria da qualidade do ar interior

ENVIRH
ENVIRONMENT AND HEALTH IN CHILDREN DAY CARE CENTERS
AMBIENTE E SAÚDE EM CRECHES E INFANTÁRIOS

## Summary

- Introduction
- Methodology
- Comparison with measurements
- Analysis of simulations results
- Conclusions

## Purpose of the presentation

- In the aim of the research project ENVIRH an initial field survey on the children day care centers (CDCC) characteristics was carried out (in 45 CDCC, 25 of them in Lisbon and 20 in Oporto).
- In this survey, the short term $CO_2$ measurements performed have shown, in general, a poor indoor air quality.
- In order to better understand the cause of this poor air quality, two CDCC were selected for computational simulation.

## Purpose of the presentation

- This presentation describes the simulations carried out in these CDCC located in Lisbon.


## The problem

ENVIRH

- Many CDCC are old buildings refurbished with new windows and doors.
- In general they do not have ventilation systems.

## Simulations

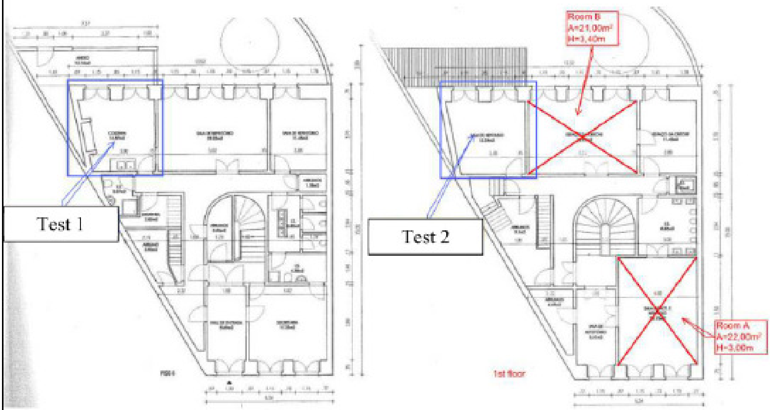
ENVIRH

- The purpose of the simulations are:
  - To explain the low ventilation rates observed in practice;
  - To find the best practices to increase the ventilation rates
- The simulation success is very dependent on:
  - the adequate assessment of air permeability of the envelope

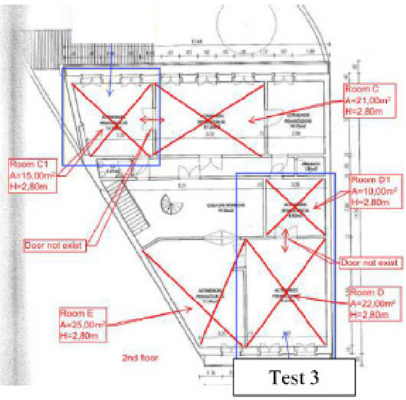
    **Difficult to know with detail**
    **Large number of windows**
  - The knowledge of the practices of the users

    **Very dificult to know**
    **Large time schedule**

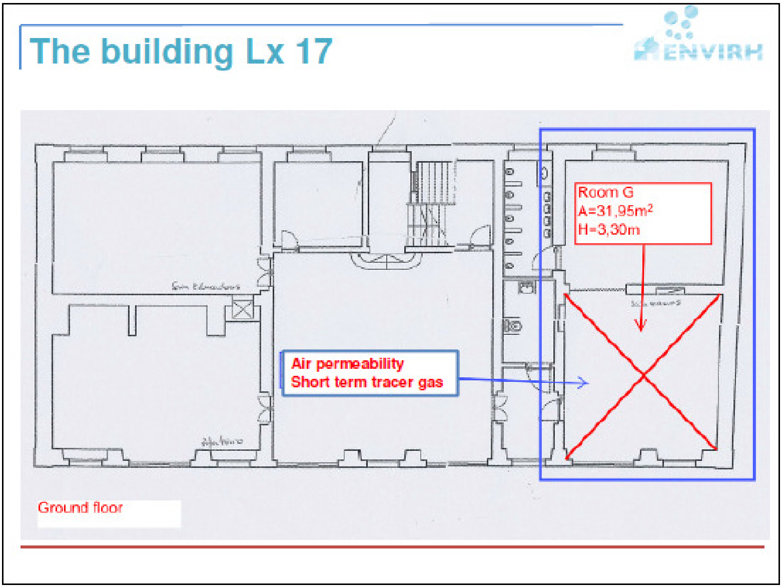
## The building Lx 13

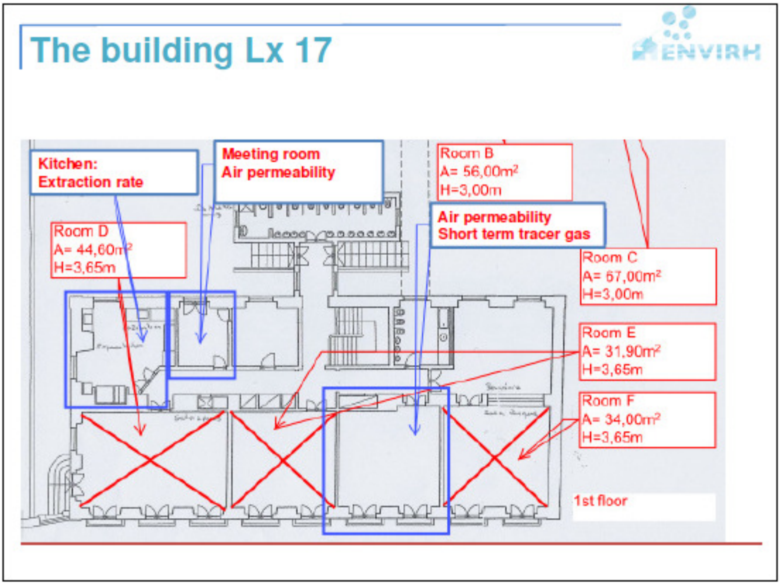



## The building Lx 13




- Traditionally, the room ventilation was carried out through the gaps existing in the opening joints of external windows and doors or just opening the windows.
- However, few years ago new aluminium external windows (with gaskets applied in the opening joints) replaced the old wooden windows.
- At that time no ventilation devices have been included in the construction.


The building Lx 17
ENVIRH
Room G
A=31,95m²
H=3,30m
Air permeability
Short term tracer gas
Ground floor


The building Lx 17
ENVIRH
Kitchen:
Extraction rate
Meeting room
Air permeability
Room B
A= 56,00m²
H=3,00m
Air permeability
Short term tracer gas
Room D
A= 44,60m²
H=3,65m
Room C
A= 67,00m²
H=3,00m
Room E
A= 31,90m²
H=3,65m
Room F
A= 34,00m²
H=3,65m
1st floor

## Methods

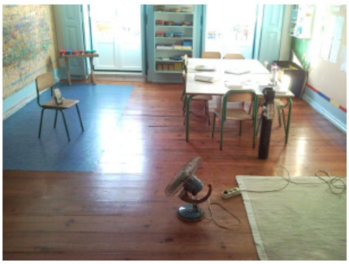
ENVIRH

- preliminary site survey and $CO_2$ concentration measurements in representative rooms;
- measurement of the air permeability of the envelope;
- measurement of the air permeability of internal doors;
- short term $CO_2$ tracer gas decay analysis in order to obtain reference values for comparison with simulation results;
- medium term PFT tracer gas decay analysis in order to obtain values of the building ventilation under normal use for comparison with simulation results;
- computer simulation (CONTAM) of the building ventilation in the conditions of the $CO_2$ tracer gas decay analysis;
- computer simulations of the building ventilation under normal use (corresponding to PFT measurements);
- computer simulations to assess the stack effect and the wind direction effect;
- computer simulations to assess possible improvements on ventilation.

## Methods – Measurement of the air permeability of the envelope

- On site blower door tests (Lx 13)
  - sliding windows (test 2)
    $Q = 0.14\Delta P^{0.8}$ m³/(h.m)
  - casement windows (test 3)
    $Q = 0.10\Delta P^{0.8}$ m³/(h.m)
  - internal doors (test 3)
    $Q = 24\Delta P^{0.5}$ m³/(h.m)

## Methods - Short term $CO_2$ tracer gas decay analysis



- $CO_2$ short term gas tracer tests,
  - using the decay method,
  - were carried out in order to measure the air exchange rate in the same rooms were the air permeability performance of the windows was measured
    - Lx 13 - test 2 carried out in 2011-11-15 and test 3 carried out in 2011-11-14
    - Lx 17 – tests at restaurant carried out in 2011-11-08 and tests at room G carried out in 2011-11-17

## Methods - Medium term PFT tracer gas decay analysis

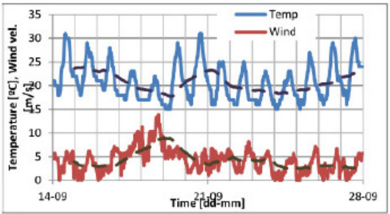
- Medium term gas tracer tests
  - In summer period were carried out between 2011-09-14 and 2011-09-28 and
  - In winter period were carried out between 2012-01-09 and 2012-01-26
  - PFT method was used.
  - The purpose of these tests was to assess the air change rate in a number of activity rooms in the children day care centre in normal use.

## Methods

- preliminary site survey and $CO_2$ concentration measurements in representative rooms;
- measurement of the air permeability of the envelope;
- measurement of the air permeability of internal doors;
- short term $CO_2$ tracer gas decay analysis in order to obtain reference values for comparison with simulation results;
- medium term PFT tracer gas decay analysis in order to obtain values of the building ventilation under normal use for comparison with simulation results;
- computer simulation (CONTAM) of the building ventilation in the conditions of the $CO_2$ tracer gas decay analysis;
- computer simulations of the building ventilation under normal use (corresponding to PFT measurements);
- computer simulations to assess the stack effect and the wind direction effect;
- computer simulations to assess possible improvements on ventilation.

# Lx 13 - Simulation of the measurement period in 2011 September

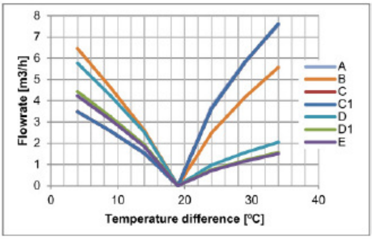
- Due to the uncertainty relating to the position of the windows and doors, two simulations have been carried out :
  - one with one external window opened in every room A, B, C, D and E (just in the period of use 9:00-16:00 and during weekdays) and
  - another with all the windows closed.
- The internal doors are always assumed closed.




# PFT gas tracer measurements and simulation results (Lx 17 - summer)

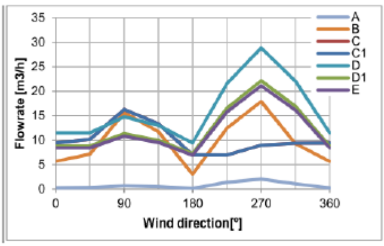
| Room | PFT measurements | | | Simulated flow rate [m3/h] | |
|---|---|---|---|---|---|
| | Local mean age of air [h] | Air change rate [$h^{-1}$] | Room volume [m³] | Window closed ACR [$h^{-1}$] | Window opened ACR [$h^{-1}$] |
| Room_D | 2.75 | 0.36±0.03 | 163 | 0.13 | 0.59 |
| Room_E | 3.20 | 0.31±0.03 | 113 | 0.01 | 1.03 |
| Room F | 3.82 | 0.26±0.03 | 124 | 0.01 | 0.70 |
| Room G | 1.59 | 0.63±0.06 | 105 | 0.17 | 1.22 |

## Lx 13 - Effect of external temperature



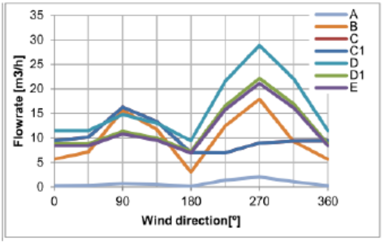

- A set of simulations was carried out considering that the indoor temperature is 19ºC (constant) and wind velocity 0 m/s.
- The external windows were kept closed and the outdoor temperature was ranging from 4ºC to 34ºC.

## Lx 13 - Effect of wind




- Another set of simulations was carried out in order to assess the effect of the wind direction.
- The wind velocity was kept constant (4.0 m/s) and indoor and outdoor temperature were equal (19ºC).
- The external windows were kept closed.

# Lx 13 - Effect of wind

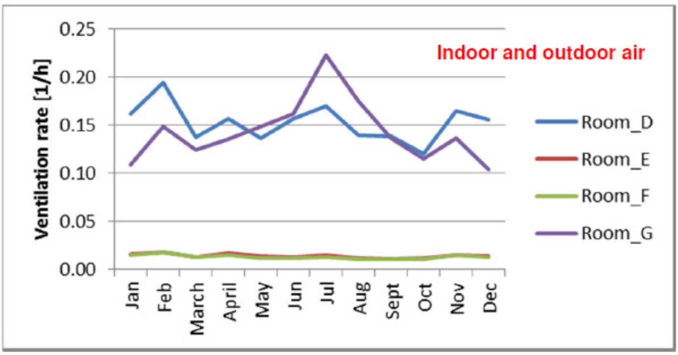



- The wind effect is varying strongly with the wind direction and is more effective when the wind is facing the west or east facades.

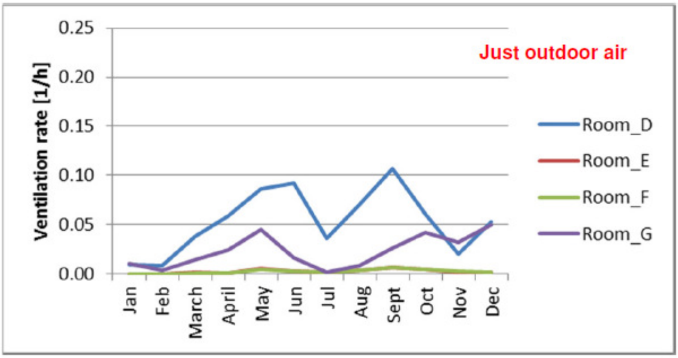
**Conclusion**:

- Wind is the most important action for ventilation of this type of building in Lisbon climate.

# Lx 17 - External windows and internal doors closed



# Lx 17 - External windows and internal doors closed

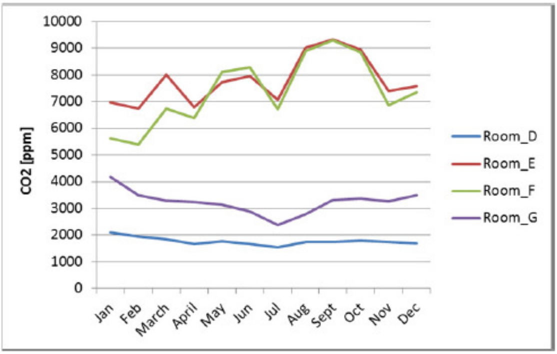



# $CO_2$ emissions

- Released by human breading
- The maximum number allowed for children per activity room was considered (+ 2 teachers)

| Age | Emission [l/s] |
|---|---|
| 8 months | 0.00108 |
| 12 months | 0.00121 |
| 2 years | 0.00172 |
| 3 years | 0.00192 |
| 4 years | 0.00215 |
| 5 years | 0.00238 |
| Sedentary adults | 0.00504 |

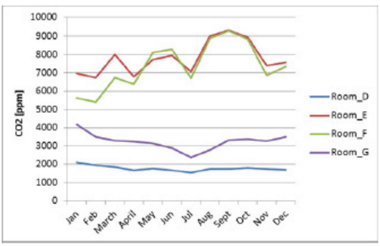
# Lx 17 - External windows and internal doors closed

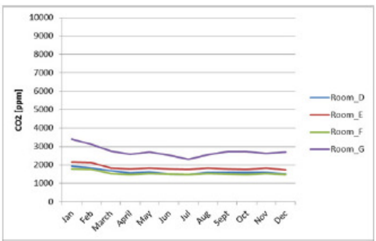



External windows and internal doors permanently closed

External windows and internal doors opened just in

- weekdays
- from 17:00 to 18:00



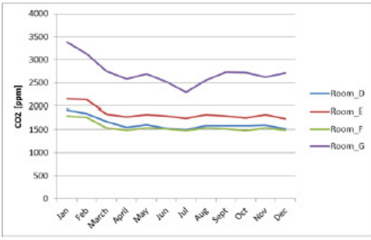




**Conclusion**:

- windows and doors shall be kept opened during cleaning period at the end of the day

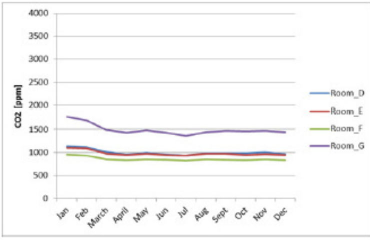
External windows and internal doors opened just in

- weekdays
- from 17:00 to 18:00



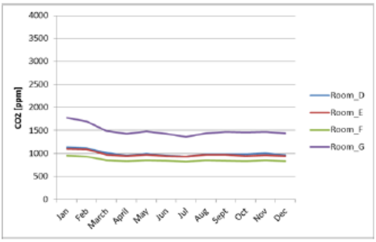

External windows and internal doors opened just in

- weekdays
- from 17:00 to 18:00
- and from 12:00 to 14:00



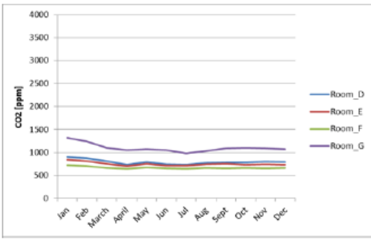

External windows and internal doors opened just in

- weekdays
- from 17:00 to 18:00
- from 12:00 to 14:00




External windows and internal doors opened just in

- weekdays
- from 17:00 to 18:00
- from 12:00 to 14:00
- 15 min at 11:00 and 15:00

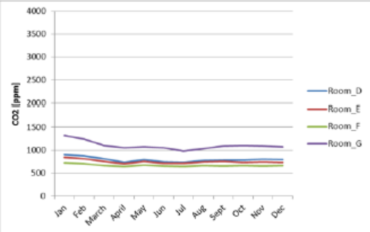



**Conclusion**:

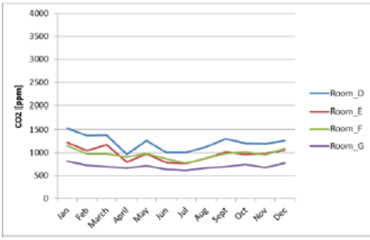
- windows and doors shall be kept opened during periods when children are outside activity room

External windows and internal doors opened just in

- weekdays
- from 17:00 to 18:00
- from 12:00 to 14:00
- 15 min at 11:00 and 15:00




- External windows opened from 9:00 to 18:00 (weekdays)
- Internal doors closed

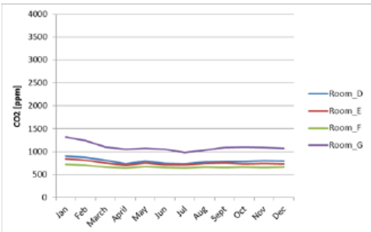



**Conclusion**:

- Depending on the room, keeping windows continuously opened and doors shut may be effective

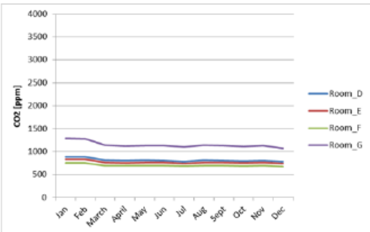
External windows and internal doors opened just in

- weekdays
- from 17:00 to 18:00
- from 12:00 to 14:00
- 15 min at 11:00 and 15:00




Mechanical ventilation

- external windows and internal doors kept closed
- 1 ach
- air inlets of 10 Pa self-adjustable

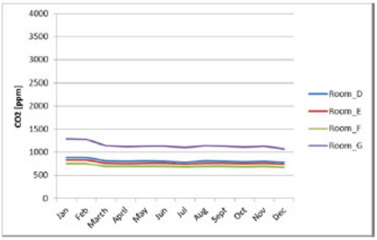


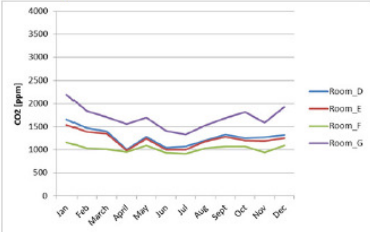

**Conclusion**:

- Mechanical ventilation is effective. Flow rate shall be calculated taking into account the emission sources.

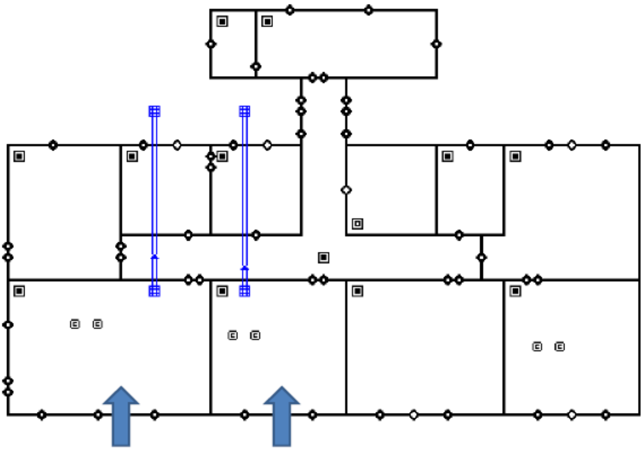
Mechanical ventilation
- external windows and internal doors kept closed
- 1 ach
- air inlets of 10 Pa self-adjustable

Natural cross ventilation
- external windows and internal doors kept closed
- int. air transfer dev. 3 Pa (1 ach)
- ext. air inlets 2 Pa (1 ach) self-adjustable



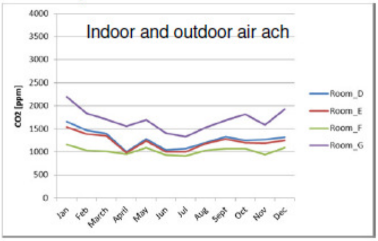




**Conclusion**:
- Natural cross ventilation may be effective. Depending on rooms, shall be aided by opening windows. May have contamination between rooms.



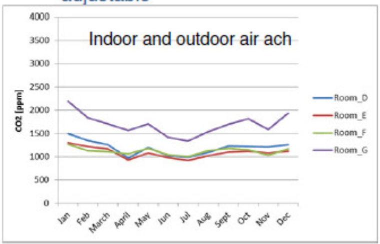
Natural cross ventilation

- external windows and internal doors kept closed
- int. air transfer dev. 3 Pa (1 ach)
- ext. air inlets 2 Pa (1 ach) self-adjustable



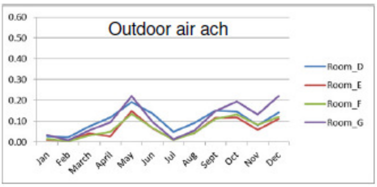

Natural cross ventilation

- external windows and internal doors kept closed
- air transf. ducts 8 Pa (1 ach)
- ext. air inlets 2 Pa (1 ach) self-adjustable



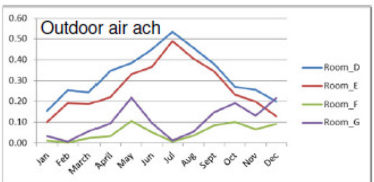

Natural cross ventilation

- external windows and internal doors kept closed
- int. air transfer dev. 3 Pa (1 ach)
- ext. air inlets 2 Pa (1 ach) self-adjustable




Natural cross ventilation

- external windows and internal doors kept closed
- air transf. ducts 8 Pa (1 ach)
- ext. air inlets 2 Pa (1 ach) self-adjustable




**Conclusion**:

- Contamination between rooms is reduced.

## General conclusions

- It is possible to improve the indoor air quality by ventilation:
  - Using mechanical ventilation
  - Using natural cross ventilation
  - In the absence of ventilation system, adopting scheduled procedures involving opening external windows and internal doors.

## Impact of Indoor Air Quality (IAQ) on Health

Pedro Martins[1,2], Iolanda Caires[1], José Araújo-Martins[1], Ana Luísa Papoila[4,5], Daniel Virella[5], Marta Alves[5], João Marques[1,2], Catarina Pedro[1], José Rosado-Pinto[9], Paula Leiria-Pinto[1,2], João Viegas[3], Daniel Aelenei[6], Manuela Cano[7], Ana Mendes[8], Susana Nogueira[3], Nuno Neuparth[1,2] and ENVIRH Study Group.

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[2]Serviço de Imunoalergologia, Hospital de Dona Estefânia, Centro Hospitalar de Lisboa Central, EPE, Rua Jacinta Marto, 1169-045 Lisbon, Portugal

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[4]Departamento de Bioestatística e Informática, CEAUL, Faculdade de Ciências Médicas (FCM), Universidade Nova de Lisboa, Campo dos Mártires da Pátria, 130, 1169-056, Lisbon, Portugal

[5]Epidemiology and Statistics Analisys Unit, Research Centre, Centro Hospitalar de Lisboa Central, EPE, Rua Jacinta Marto, 1169-045 Lisbon, Portugal

[6]Faculdade de Ciências e Tecnologia (FCT), Universidade Nova de Lisboa, Campus da Caparica, 2829-516, Caparica, Portugal

[7]Instituto Nacional de Saúde Dr. Ricardo Jorge – Lisboa, Avenida Padre Cruz, 1649-016 Lisbon, Portugal

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[9]Hospital da Luz, Avenida Lusíada, 100, 1500-650, Lisbon, Portugal

In order to evaluate the association between IAQ and health outcomes regression models that considered the structure of dependence between individuals within the same classrooms were used. Parameters of these models were estimated through mixed effect models. Crude and adjusted odds-ratios (OR) with 95% confidence intervals (95 % CI) were estimated. They included: age (in years), gender, personal history of atopic dermatitis (used as a children's atopy marker), parental history of allergic respiratory disease (defined as the presence of asthma or allergic rhinitis), parental education (primary or secondary *versus* high school or university), parental smoking exposure and existence of older siblings, dampness at home, pets at home, birth and gestational weight, and home surroundings.

In Phase I were included 3186 questionnaires and in Phase II were considered 1196questionnaires.

The main results were:

- $CO_2$ at day care centers was associated to wheezing in the previous 12 months (in Phase I).
- Each increase of 100 µg of TVOCs was associated with 5% more odds of reporting wheezing, after adjusting for confounders.
- Each increase of 1 µg of house dust mite (HDM) was associated with higher odds of reporting wheezing, after adjusting for confounders.
- Each increase of 1 µg of house dust mite (HDM) was associated with higher odds of had needed an emergency department visit due to wheezing, after adjusting for confounders.
- Each increase of 1 µg of house dust mite (HDM) was associated with higher odds of had needed an antibiotic in the last 12 months, after adjusting for confounders.
- Both effects of TVOCs and house dust mite were associated with higher odds of reporting wheezing, after adjusting for confounders.
- Day care centers which presented increments of 0,1 air change per hour were associated with higher odds of reporting wheezing, after adjusting for confounders.
- TVOCs were the only IAQ parameter associated with airways inflammation (nitrites on the exhaled breath condensate).

Parental stress was also assessed in the scope of ENVIRH through a validated questionnaire. The results so far show that mother's anxiety was associated with the number of wheezing episodes, emergency room attendance and antibiotic intake. The mother-child interaction was associated with the number of missing days to the children day care center.

# Impact of Indoor Air Quality on Health

## Impacto da Qualidade do Ar Interior na Saúde

ENVIRH
ENVIRONMENT AND HEALTH IN CHILDREN DAY CARE CENTERS
AMBIENTE E SAÚDE EM CRECHES E INFANTÁRIOS

- Attending a children day care center (CDCC):
  - Risk of infections
  - wheezing
- Attending CDCC *vs* staying at home:
  - higher incidence of airways infections
  - wheezing

## Aim

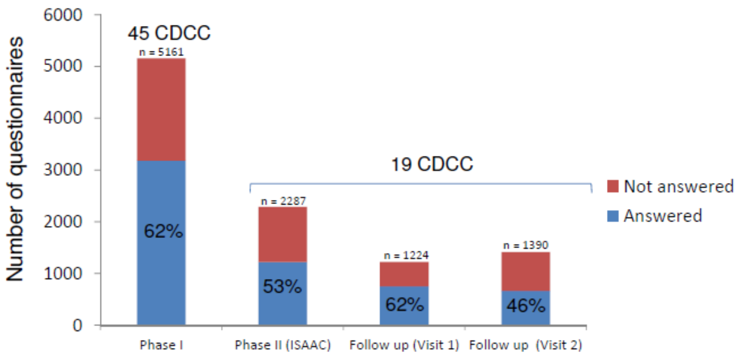
Evaluate the association between wheezing and indoor air quality (IAQ) / ventilation at CDCC.

## Respiratory evaluation tools

- Phase I: 45 CDCC
  - ISAAC: short version (Phase I)
- Phase II: 19 CDCC
  - ISAAC
  - Follow up questionnaire for respiratory diseases
  - Exhaled Breath condensate: pH, nitrites / nitrates
  - Parental stress questionnaire

| Phase I | | Phase II | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Out-10 | Dez-10 | Jan-11 | Fev-11 | Mar-11 | Abr-11 | // | Nov-11 | Jan-12 |
| ISAAC short version | | ISAAC | | Follow up (Visit 1) | | | Follow up (Visit 2) | |

## Questionnaires: Answer rate




## Characteristics of the participants during the study

| | Gender (boys %) | Wheezing in the previous 12 months |
|---|---|---|
| **Phase I** | 50.5% | 27.5% |
| **Phase II (ISAAC)** | 52.4% | 29.2% |
| **Follow up (Visit 1)** | 53.0% | 31.0% |
| **Follow up (Visit 2)** | 53.3% | 30.2% |

- Frequence of major outcome was similar across the study.
- Phase II
  - Gender: respondants *vs* non respondants, *p*=0.700
  - Age: respondants *vs* non respondants, *p*=0.068

PHASE I

## Phase I: Wheezing in the last 12 months

Adjusted associations (n=3186)

| | OR (CI 95%) | *p value* |
|---|---|---|
| Age (years) | 0.74 (0.70 – 0.78) | <0.001 |
| Parental history of asthma or Allergic Rhinitis (AR) | 1.99 (1.67 – 2.31) | <0.001 |
| Atopic dermatitis | 1.37 (1.15 – 1.59) | <0.001 |
| $CO_2$ (ppm) in the CDCC | 1.04 (1.01 – 1.07) | 0.008 |
| The following variables were considered: Gender, age, atopic dermatitis, parental history of asthma or AR, $CO_2$ concentration, parental education, parental smoking, older siblings. | | |

- Each increase of 200 ppm of $CO_2$ was associated with 4% more chance of reporting wheezing
- $CO_2$: IAQ surrogate

PHASE II

## Phase II: Sample characteristics

| Phase II (ISAAC questionnaire) | n = 1196 |
|---|---|
| Gender (boys) | 52.4% |
| Age - months (median; $P_{25}$-$P_{75}$) | 43 (28-58) |
| Age at admission - months (median; $P_{25}$-$P_{75}$) | 12 (6-24) |
| CDCC attendance time - months (median; $P_{25}$-$P_{75}$) | 25 (11-40) |
| Parental history of asthma / allergic rhinitis | 17%/35% |
| Parental smoking | 16% |

## Phase II: Frequency in the last 12 months

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| Phase II (ISAAC questionnaire) n = 1196 | |
|---|---|
| Wheezing | 29.2% |
| Emergency department visit due to wheezing | 13% |
| Otitis | 41% |
| Pneumonia | 3.5% |
| Antibiotic | 72% |

## Phase II: Associations between TVOCs and wheezing in the last 12 months

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Each increase of 100 µg of TVOCs was associated with higher odds of reporting wheezing, after adjusting for confounders.

## Phase II: House dust mite and wheezing in the last 12 months

Each increase of 1 µg of house dust mite (HDM) was associated with higher odds of reporting wheezing, after adjusting for confounders.

## Phase II: Need of an emergency department visit due to wheezing in the last 12 months

Each increase of 1 µg of house dust mite (HDM) was associated with higher odds of had needed an emergency department visit due to wheezing, after adjusting for confounders.

## Phase II: Need of an antibiotic in the last 12 months

Each increase of 1 µg of house dust mite (HDM) was associated with higher odds of had needed an antibiotic in the last 12 months, after adjusting for confounders.

## Phase II: TVOCs and HDM combined effects

Both effects of TVOCs and house dust mite were associated with higher odds of reporting wheezing, after adjusting for confounders.

## Phase II: Follow up questionnaire

Wheezing requiring medical evaluation (adjusted OR)

| | OR (CI 95%) | *p value* |
|---|---|---|
| TVOCs[1] | 1.07 (0.99 – 1.17) | 0.062 |
| CDCC attendance time - months | 2.49 (1.45 – 4.27) | 0.001 |

CDCC missing days (adjusted OR)

| | OR (IC95%) | *p value* |
|---|---|---|
| TVOCs[1] | 1.05 (1.01 – 1.09) | 0.017 |
| CDCC attendance time - months | 0.98 (0.96 – 0.99) | 0.002 |

1: increments of 100 µg/m³

## Phase II: and what about ventilation – PFTs?

Increments of 0,1 air change per hour were associated with a higher odds of reporting wheezing, after adjusting for confounders.

EXHALED BREATH CONDENSATE

- EBC - To study airways inflammation:

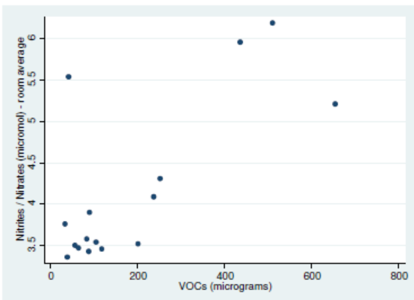
- Easy to collect
- Non invasive
- Wide range of biomarkers

## Phase II, Visit 2

- Children aged 4 to 6 years
- 100 samples
  - 57% boys
  - 5.0 ± 0.6 years
- Studied biomarkers:
  - pH
  - Nitrites/nitrates
- Only in Lisbon

## Phase II, Visit 2

- Nitrites / nitrates:
  - 4.42 ± 1.60 uM
- pH
  - 7.50 ± 0.37



## Phase II

TVOCs were the only IAQ parameter associated with airways inflammation.

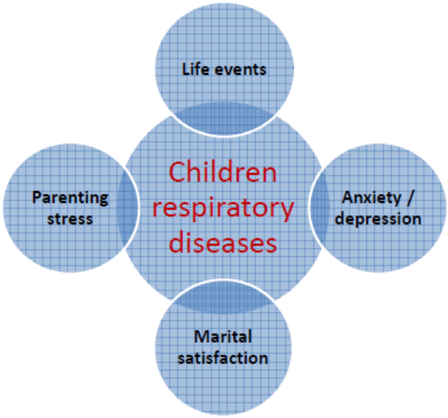
| Nitrites / nitrates - micromol (regression coefficient) | | |
|---|---|---|
| | β (CI 95%) | *p value* |
| TVOCs[1] | 0.32 (0.11 – 0.53) | 0.003 |

1: increments of 100 μg/m³

No association between pH and IAQ.

PARENTAL STRESS

To examine whether psychological dimensions varies as a function of children respiratory diseases.




- Anxiety:

  - Number of wheezing episodes ($p$=0.025)
  - Emergency room attendance ($p$=0.043)
  - Antibiotic intake ($p$<0.001)

- Mother-child interaction:

  - CDCC missing days ($p$=0.018)

## Conclusions

- Poor ventilation at CDCC was associated with a higher chance of wheezing.
- TVOCs were the  air pollutants associated with:
  - A higher chance of wheezing
  - More severe wheezing episodes
  - Airways inflammation

## Conclusions

- House dust mite at CDCC were associated with:
  - A higher chance of wheezing
  - Need of emergency department visits
  - Need of antibiotics
- Children disease was associated with parental stress.

## Summary of Conclusions and Recommendations for Improvement in Respiratory Health in Day Care Centers

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The production of recommendations is the final task of this project. They are based on the results and try to answer the following questions:

- How to decide if a child should attend a children day care center (CDCC)?
- How does time of attendance of a CDCC affect health?
- How to choose the CDCC?
- What CDCC characteristics interfere with health?

They are addressed to the public and to professionals and concern existing buildings and new buildings.

From the results of this project the following conclusions can be summarized as follow:

From Phase I, each increase of 200 ppm of $CO_2$ is associated with 4% more probability of reported wheezing.

From Phase II, poor ventilation in Children Day Care Centers (CDCC) is associated with a higher probability of wheezing; Indoor Total Volatile Organic

Compounds (TVOCs) are associated with a higher probability of wheezing, more severe wheezing episodes and airways inflammation; house dust mites at CDCCs are associated with a higher probability of wheezing, need for emergency department visits and increased intake of antibiotics; finally, children disease is associated with parental stress.

The observations concerning existing buildings included high levels of $CO_2$, high levels of TVOCs, high levels of house dust mites, high levels of formaldehyde in refurbished rooms and poor ventilation.

From Phase III (simulation of ventilation strategies), we can conclude that it is possible to improve indoor air quality (IAQ) by ventilation, using mechanical ventilation, using natural cross ventilation and, in the absence of a ventilation system, adopting schedule procedures involving opening external windows and internal doors.

Recommendations can be summarized as follows:

1 – Recommendations to the public

How to decide if a child can attend a CDCC – be careful if the child belong to a risk group. Ask for medical advice!

2 – Recommendations to professionals

Being human metabolism the main source of $CO_2$, we recommend reduction of CDCCs occupancy according to legislation; bacteria and other bioefluents are also affected by occupancy, should lead to the same recommendation; tobacco smoke is another source of high levels of $CO_2$, CO and formaldehyde so CDCCs must be smoking free places; heating systems based on combustion are also sources of CO and $CO_2$ and care should be taken in order to avoid release of combustion products into CDCC premises.

Concerning TVOCs and formaldehyde, the main source in new buildings are construction materials (insulating materials, pressed woods) and so buildings should not be used immediately occupied after construction. Ventilation should be promoted before use. In old buildings, the main source of TVOCs is human occupancy and its activities as cleaning materials, cosmetics and others. The recommendation is to clean at evening and promote room ventilation before occupation.

To avoid accumulation of high levels of house dust mites, cleaning should be promoted frequently, humidity should be controlled and appropriate mattresses and pillows should be used. Rugs should be properly washed and aerated and carpets should be avoided.

3 – Recommendations to existing buildings concerning ventilation strategies

There are three ways to increase indoor ventilation: using mechanical ventilation; using natural cross ventilation and adopting scheduled procedures involving opening of external windows and/or internal doors.

4 - Recommendations to new buildings concerning ventilation strategies

In new buildings a ventilation system with outdoor admission inlets should be installed. Two strategies are available to regulate indoor ventilation: one is mechanical ventilation; the other, is natural cross ventilation, an appropriate strategy in a windy country like Portugal. It is recommended to seek for engineer advice.

# Recommendations for improvement in respiratory health in day care centers

# Recomendações para a melhoria da saúde respiratória em creches

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ENVIRONMENT AND HEALTH IN CHILDREN DAY CARE CENTERS

AMBIENTE E SAÚDE EM CRECHES E INFANTÁRIOS

## Rational of recommendations

- Based on project results
- Answering the following questions:
  - How to decide if a child should attend a children day care center (CDCC)?
  - How to choose the CDCC?
  - What CDCC characteristics interfere with health?
- Recommendations to the public
- Recommendations to professionals
- Recommendations concerning existing buildings
- Recommendations concerning new buildings

## Summary of conclusions

- **Impact on health**
  - Phase 1
    - Each increase of 200 ppm of $CO_2$ was associated with 4% more probability of reporting wheezing
  - Phase 2
    - Poor ventilation at CDCC was associated with a higher probability of wheezing
    - TVOCs were the air pollutants associated with:
      - A higher probability of wheezing
      - More severe wheezing episodes
      - Airways inflammation
    - House dust mite at CDCC were associated with:
      - A higher probability of wheezing
      - Need of emergency department visits
      - Intake of antibiotics
    - Children disease was associated with parental stress

## Summary of conclusions

- **Impact on health**
  - Phase 3 (simulation of ventilation strategies)
    - It is possible to improve the indoor air quality (IAQ) by ventilation:
      - Using mechanical ventilation
      - Using natural cross ventilation
      - In the absence of ventilation system, adopting scheduled procedures involving opening external windows and internal doors

## Recommendations to the public

- **How to decide if a child should attend a CDCC?**
  - Be careful if the child belong to a risk group (wheezing) – ask for medical advise!

## Recommendations to the public

- **How to choose a CDCC?**
  - Indoor ventilation affects health (poor ventilation is associated with an increased probability of wheezing)
    - CDCCs should follow procedures concerning indoor ventilation

## Conclusions concerning existing buildings

- **What CDCC characteristics interfere with health?**
  - High levels of $CO_2$
  - High levels of TVOCs
  - High levels of house dust mites
  - Poor ventilation

## Recommendations to professionals

**What are the sources of high levels of $CO_2$**

| Source | Recommendation |
|---|---|
| Human metabolism | Reduce occupancy according to legislation |
| Combustion (vehicle emissions) | |
| Tobacco smoke | Smoking free spaces – apply legislation |
| Heating systems | Avoid release of combustion products into CDCC premises |

## Recommendations to professionals

### What are the sources of TVOCs?

| | Source | Recommendation |
|---|---|---|
| New buildings | Building and decoration materials | Do not use temporarily and increase ventilation |
| Old buildings | Occupancy and its activities: cleaning materials, cosmetics… | Clean in the evening and increase ventilation |

## Recommendations to professionals

### What are the sources and environmental determinants of house dust mites?

| Source / Environmental Determinant | Recommendation |
|---|---|
| Domestic dust | Clean frequently |
| Humidity (mattresses, pillows) | Control humidity, use appropriate covers in mattresses and pillows |
| Carpets, Rugs | Wash rugs at temperatures higher than 60°C and aerate properly<br>Avoid carpets |

## Recommendations to existing buildings

- **How to increase indoor ventilation?**
  - Using mechanical ventilation
  - Using natural ventilation
  - Adopting scheduled procedures involving opening external windows and/or internal doors

## Recommendations to new buildings

**In all cases install a ventilation system with outdoor admission inlets**

**Two alternatives**

- Install mechanical systems – the more regular
- In a windy country like Portugal – install natural cross ventilation systems

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ENVIRH

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This project addresses a set of common clinical problems in the context of children attending day care centres. It is common sense that children get sick more often as soon as they start attending a day care centre on a daily basis and this is particularly true for some groups at risk, as wheezing infants and wheezing pre-school children.

So, this project attempts to answer some questions, such as:

- The role of indoor air quality
- The role of virus infections
- The role of building ventilation

With the main objective to develop recommendations to create healthier spaces.

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