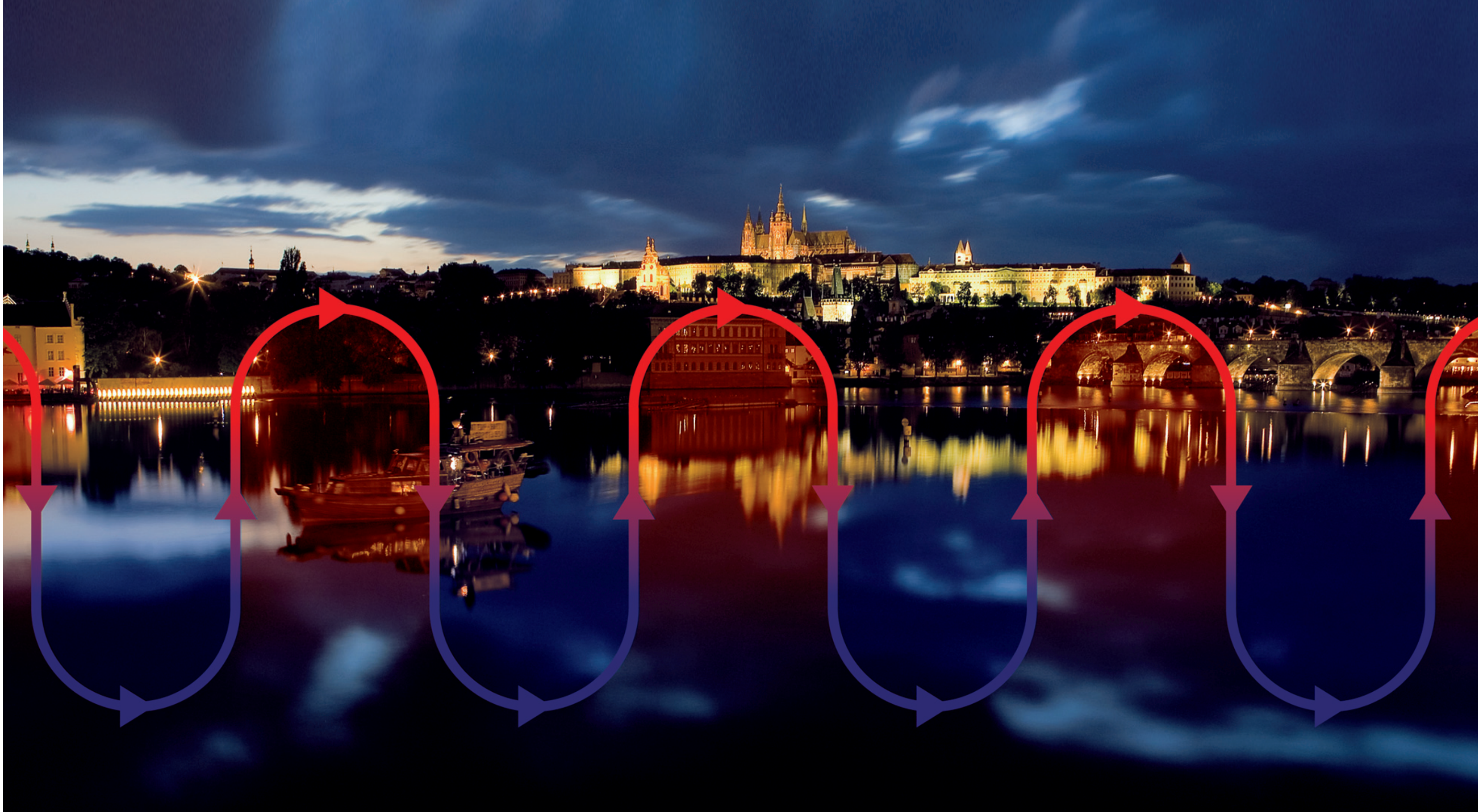
CLIMA 2013

11th REHVA World Congress
& 8th International Conference on IAQVEC



June 16–19, 2013
Prague Congress Centre, Czech Republic

„Energy Efficient, Smart and Healthy Buildings"

REHVA 50 1963 2013
Federation of European Heating, Ventilation and Air-conditioning Associations

IAQVEC 2013

SPOLEČNOST PRO TECHNIKU PROSTŘEDÍ
SOCIETY OF ENVIRONMENTAL ENGINEERING

2013 CLIMA CZ

Environment and Health in Children Day Care Centres in Portugal Results from Phase II on the Ventilation Characteristics of 16 Schools

D. Aelenei[1], S. Azevedo[2], J. Viegas[3], A. Mendes[4], A. L. Papoila[5], M. Cano[6], P. Martins[7], N. Neuparth[8]

[1]*Departamento de Engenharia Civil, Faculdade de Ciência e Tecnologia, Universidade Nova de Lisboa, Caparica, Portugal*

[1]aelenei@fct.unl.pt

[2,3]*Laboratório Nacional de Engenharia Civil, Lisboa, Portugal*

[2]snogueira@lnec.pt

[3]jviegas@lnec.pt

[4,6]*Instituto Nacional de Saúde Dr. Ricardo Jorge IP, DSA, Portugal*

[4]asestevao@gmail.com

[6]manuela.cano@insa.min-saude.pt

[5]*Departamento de Bioestatística e Informática, Faculdade de Ciências Médicas, Universidade Nova de Lisboa, CEAUL, Lisboa, Portugal*

[5]apapoila@gmail.com

[7,8]*Departamento de Fisiopatologia, FCMCEDOC, Faculdade de Ciências Médicas, Universidade Nova de Lisboa, Lisboa, Portugal*

[7]pmartinsalergo@gmail.com

[8]nneuparth@gmail.com

Abstract

The relation between building physical characteristics and indoor environment in children day care centres (CDCCs) has received increased attention in the past decades as statistics on respiratory illness in children continue to cause concern. Although it is well known that ventilation plays a key role in maintaining acceptable indoor quality, there is a lack of studies exploring the relationship between ventilation rates, pollutant sources and health in day care centers in Portugal. The present study is part of the research project "Environment and Health in Children Day Care Centres", and aimed at surveying the ventilation characteristics of 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 measurements of the tracers over a period of two weeks in January 2012, pointed out low specific air flow rates (or air change rate per hour, ACH), varying between 0.04 and 1.18 in Oporto and between 0.01 and 0.41 in Lisbon. The purpose of this paper is to present and discuss these results.

Keywords – children day care centres; ventilation;tracer gas; PFT

1. Introduction

The negative impact of a poor indoor air quality in children's health is well recognized and the development of a relation between air quality, ventilation and children's health is considered crucial from this point of view. Children attending CDCCs have been reported to be more prone to infectious diseases when compared with those cared for at home, and are exposed to conditions that may increase the risk of allergies and asthma [1, 2]. Recent studies indicate poor ventilation conditions associated with high levels of carbon dioxide to be common in CDCCs [3, 4] a fact which can affect the health of children [2, 3, 5]. Child day care centres in Portugal provide care during a period of time ranging from six to ten hours daily, a sufficient amount of time for the children to be exposed to existent indoor pollutants. Although this is well known, there is need of studies exploring the relationship between ventilation rates, pollutant sources and health in day care centres as little data exists [5]. In order to fill this apparent gap in literature, an interdisciplinary team of researchers have developed the project Environment and Health in Children Day Care Centres – ENVIRH, which is co-financed by Portuguese Foundation for Science and Technology (FCT). After an initial survey on the IAQ and building physical characteristics of 45 CDCC´s located in Lisbon and in Oporto [6], which provided evidence that IAQ is inadequate [7], the aim of this research is to determine the ventilation characteristics of a number of a reduced number of CDCCs. In order to better understand the cause of the found poor air quality, the effective total air change rate was estimated using a passive tracer gas technique which uses perfluorocarbon tracer gases (PFT-method).

2. Experimental Survey

2.1 Methods

The effective total air changes per hour (ACH) was determined using passive samplers and homogeneous emission of PFTs, as described in standard Nordtest Method VVS 118 [8] and in ISO Standard 16000-8 [9]. The use of PFT technique for determining air infiltration rates into homes and buildings has been reported by numerous studies [10, 11] while the applicability and the effectiveness of the method have been discussed elsewhere [12, 13].

The PFT technique has several advantages over other methods given that any building can be tested, regardless of the ventilation principle (mechanically ventilated, naturally ventilated or a mixture of both). Also, the test can be performed during use and occupancy of the building and is applicable regardless of the use of the building (dwelling, office building, school, industrial building etc.) [8]. In addition to this, given that PFTs exist only at very low concentrations in the ambient environment and that are easily detected (to a few parts per billion or less), the amount of tracer gas required to carry out airflow measurements is reduced to the size of very small injection units. This allows measurements of ventilation rate in buildings to be performed without the need for analytical equipment on site. Also, the samplers and sources are free-standing units that can be used for long-term monitoring of airflows in occupied buildings without interfering with the activities of the occupants. However, the main disadvantages of the PFT technique are related to the complex configuration of buildings (multiple rooms connected with each other through multiple corridors) in which case the emission of tracer gas might not result homogeneous in the whole building. Given that in the PFT technique the value of the air change rate of the building as a whole is estimated from a volume weighted average of the measured local mean ages of air, if the emission rates of tracer gas is not homogeneous in the building, the ACH values might be overestimated. The other disadvantage could be that the results in terms of ACH obtained following measurement conducted over a period of time are average values, and therefore do not allow to draw any conclusions regarding characteristics of specific periods of time during the measurement period (such as night periods or when the building is not occupied).

2.2 Study Design

The observational survey was carried out during January 2012, during which time ventilation measurements were performed in 16 CDCCs, nine of which are located in Oporto and seven in 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.

Before performing the measurements, information on parameters that can impact the comfort and ventilation characteristics was collected, including type and year of construction of buildings, structural characteristics of the walls, state of maintenance (pathologies related with the presence of fungi and/or mould), type of windows and shading characteristics, type of ventilation system, heating and air conditioning devices and user habits regarding ventilation strategies.

In order to perform the measurements, PFT sources (miniature container with liquid tracer compound - type A in Fig. 1) were positioned in each room, with tracer gas emission rates adjusted to the room volumes. The tracer gas diffused out of the sources with a known constant rate and was mixed into the room air. To measure the time averaged concentration of the tracer gas in rooms an integrating sampling was performed, using diffusive samplers (miniature tubes packed with activated carbon as adsorption material). Given that rooms under investigation were not isolated but connected to the rest of the building by corridors or connecting rooms, in order to distinguish between inflow of outside “fresh air” and inflow of “old” air from the rest of the building, a second tracer gas (type B in Fig. 1) was spread in the spaces outside the measured rooms.

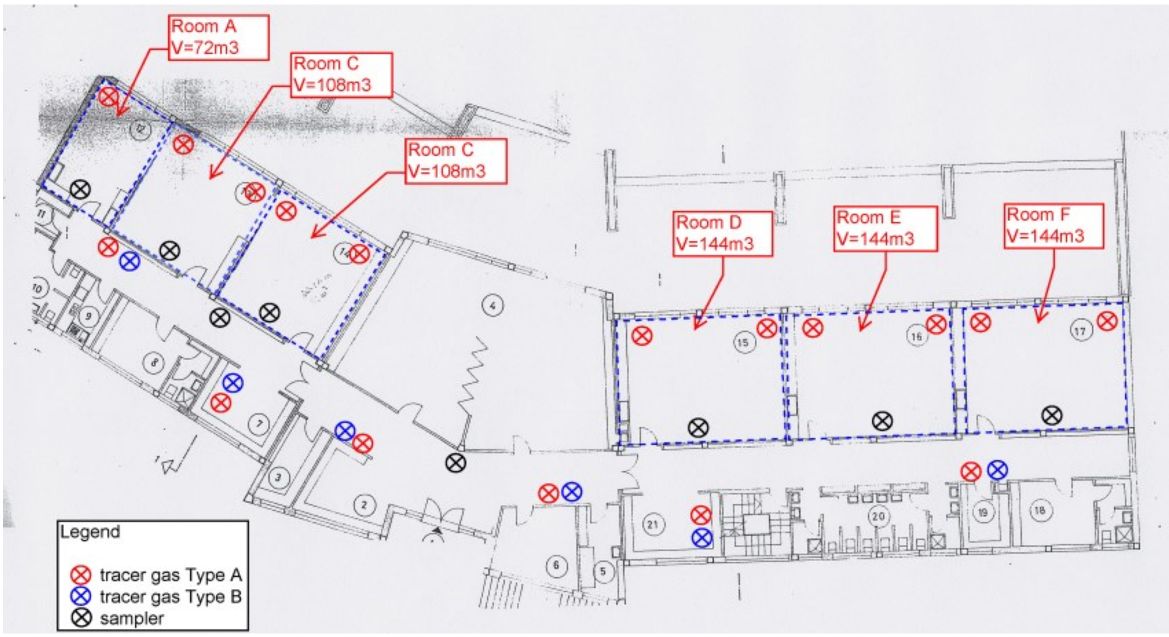


Fig. 1 Illustration of the location of tracer gas sources and samplers in the case of one of the 16 day care centres under investigation – view of the floor plan

Indoor air temperature and relative air humidity has been measured in each CDCC using between one and three dataloggers, according to the number of rooms. The outdoor temperature, relative humidity and wind velocity was obtained from the meteorological stations of Oporto and Lisbon.

Concerning user behavior, the occupants (CDCC qualified personnel) were asked to behave as they normally would with respect to ventilation.

The PFT sources and samplers were supplied by PENTIAQ A.B. Sweden, which was also responsible for performing the analysis of the passive samplers at the end of the measurement period. They estimate that the precision including the repeatability and reproducibility is within 10% and that systematic errors will probably yield less than 5% deviation from the true value.

3. Results

A total number of 91 activity rooms (52 in Oporto and 48 in Lisbon) corresponding to the 16 CDCCs were studied over the measurement period. The characteristics of the buildings with respect to type of ventilation, heating system, type of windows and type of gaskets are presented in Table 1, whereas buildings age, number of children per CDCC and play area per child characteristics are presented in Table 2. Relative humidity, air temperature and wind velocity measurements are reported in Table 3.

As it can be seen from Table 1, one of the buildings is equipped with mechanical ventilation (Oporto) whereas several others have mechanical extraction in the kitchen and/or bathrooms (identified as mixed ventilation). Only two CDCCs are fully naturally ventilated (Lisbon).

Most of the CDCCs use an electric heating system in both cities. With regard to the type of windows, most of the CDCCs in Oporto are equipped with sliding windows whereas in Lisbon the most common type is casement. Concerning the type of gaskets, 50% of CDCCs in Oporto are equipped with windows with no gaskets compared with 25% in Lisbon. Also, rubber gaskets are more common in CDCCs in Lisbon whereas in Oporto the most common type is plush gasket, which is associated with the use of sliding windows.

Table 1. Main characteristics of the 16 CDCCs under investigation

Building characteristics	Oporto		Lisbon	
	n	%	n	%
Type of ventilation (per CDCC)				
Mechanical ventilation	1	11.1	0	0
Natural ventilation	0	0	2	28.6
Mixed ventilation	8	88.9	5	71.4
Heating system (per CDCC)				
Electric	8	88.9	6	85.7
Gas	1	11.1	1	14.3
Type of windows (per room)				
Tilting	12	23.1	12	25.0
Sliding	22	42.3	16	33.3
Casement	18	34.6	20	41.7
Type of gaskets (per room)				
No gaskets	26	50.0	12	25.0
Rubber gaskets	10	19.2	21	43.8
Plush gasket	16	30.8	15	31.2

As it can be seen from table 2, there are significant differences in terms of building age between CDCCs of both cities. The median building age of CDCCs of Oporto is 22 years old whereas in Lisbon is 61 years old (the oldest CDCC building in Lisbon is approximately 230 years old whereas the second oldest is approximately 150 years old). Differences are also noticed with regard to the number of children per CDCC, the median in Oporto is 74 versus the 99.8 of Lisbon, though the floor space per child is more or less equal. This fact is due both to the higher number of activity rooms per CDCC in Lisbon (an average of 5.6 rooms/CDCC in Oporto and 6.9 rooms/CDCC in Lisbon) and to the higher number of children per activity room in Lisbon (an average of 10.1 children/room in Oporto and 14.2 children/room in Lisbon). However, all CDCCs have a median value of floor space higher than the minimum required by the recent Directive of the MSSS, which requires, with some exceptions, at least $2m^2$/child [14].

Table 2. Descriptive statistics of selected parameters of the 16 CDCCs under investigation using 25th percentile (Q1), median (Q2) and 75th percentile (Q3)

Parameters	Oporto			Lisbon		
	Q1	Q2	Q3	Q1	Q2	Q3
Building age (years)	18	22	32	50	61	146
N.º of children per CDCC	59	74	92	92	98	122
Play area (m^2)/per child	1.8	2.3	2.9	1.9	2.5	2.9

As it can be seen from Table 3, there are no significant differences between indoor environments of Oporto and Lisbon CDCCs. Regarding data reported in Table 3, one should note that the distribution of measurements was performed using daily average values.

Table 3. Distribution of measurements of temperature and relative humidity in the 16 CDCCs under investigation using 25th percentile (Q1), median (Q2) and 75th percentile (Q3)

Parameters	Oporto			Lisbon		
	Q1	Q2	Q3	Q1	Q2	Q3
Indoor temperature (ºC)	16	16.7	18.1	16.3	16.7	17.1
Indoor relative humidity (%)	58	61	66	53	56	63
Outdoor temperature (ºC)	8	10	10	9	10	10
Outdoor relative humidity (%)	66	75	84	72	80	83
Wind velocity (km/h)	7	8	10	7	8	10

The application of the PFT technique over the two weeks measurement period in January 2012 resulted in 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 (Fig. 2). As it can be seen from Figure 2, the differences in ACH between Oporto and Lisbon CDCCs are significant given the median values are 0.2 h^{-1} and 0.13 h^{-1}, respectively.

For reasons which are unclear to authors, the ACH values found in the CDCC with mechanical ventilation (a specific flow rate of 0.06 h^{-1} was estimated for all building) are the lowest among Oporto CDCCs. This is contrary to what expected as mechanical ventilation is typically associated to more efficient ventilation [3].

In the present study, it should be noted that no associations have yet been made between the ACH values and the building characteristics or indoor air quality parameter. As referred above, this study is part of a major research project undertaken to analyze the association between ventilation rates, pollutant sources and health in CDCCs in Portugal by means of field measurements, building physical characteristics and children health evaluation. In spite of the availability of field measurements of chemical (carbon dioxide, carbon monoxide, formaldehyde, total volatile organic compounds and PM_{10}) and microbiological (bacteria and fungi) indoor contaminants, no statistical analyses have yet been performed due to the fact that the corresponding data is currently under review.

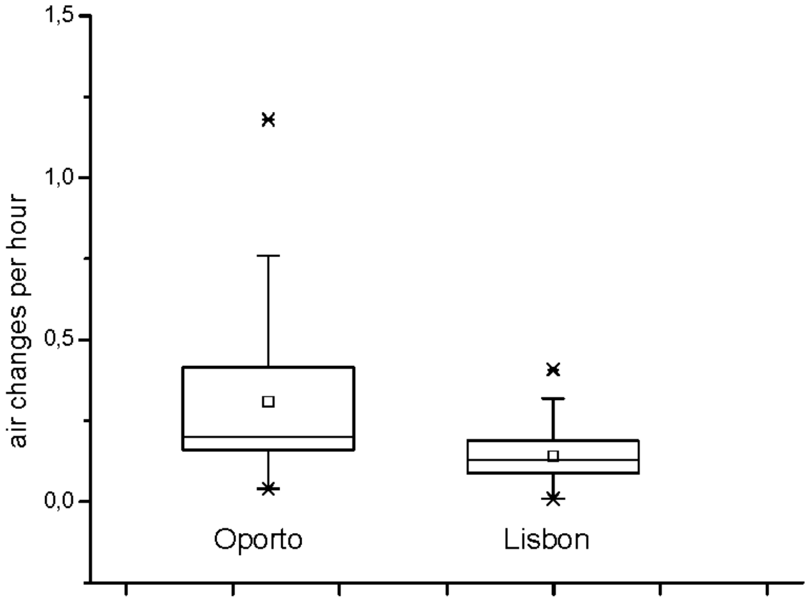


Fig. 2 Box plot of data corresponding to air changes per hour measured in CDCCs in Oporto (n = 52 activity rooms) and Lisbon (n = 48 activity rooms). The squares represent the arithmetic mean

4. Discussion

This experimental study provides evidence that air change rates in CDCCs of Oporto and Lisbon are very low. Although air change rates during occupation periods is not known (as the results of ACH are average values), it is believed that such conditions are likely to increase children exposure when sources of contaminants are present. As already referred, as the data collected regarding the presence of chemical and indoor contaminants was under review at the time when this article was written, it was not possible to compare ventilation measurements with indoor air pollutants. However, the initial survey developed earlier on the basis of the CO_2 concentrations collected randomly in the same buildings, provided evidence that IAQ is inadequate [6]. It was also found that windows that have rubber gaskets have higher concentrations of CO_2 than rooms with windows with no gaskets [15], and that rooms with casement windows have higher concentrations of CO_2 than rooms with sliding or tilting windows. If one admits low ventilation rates as the cause for high CO_2 concentrations, given the higher percentage of windows with no gaskets in Oporto (50% versus 25%) and given higher percentage of casement type windows in Lisbon (41.7% versus 34.6%), then these findings are also supported by the present study.

Among the most recent studies on indoor environments of CDCCs [1, 3, 4, 16], only one assessed the buildings ventilation rates. In this study, Ramalho et al. have estimated air exchange rates from the decay of CO_2 concentration in 101 CDCCs in different regions of France (including overseas territories) and observed values with a median level around 0.2 h^{-1} [16]. However, and as discussed by St-Jean et al. [3], studies based on decay of CO_2 concentration are subject to limitations as currently there is no specific guideline available for estimating air change rates using the levels of CO_2 in CDCCs. When performing measurements of ventilation on the basis of CO_2 concentration one should be aware of the fact that the decay may be also due to air exchange with adjacent compartments, a fact which does not guarantee the removal of the indoor air pollutants.

In spite of the fact that it was not possible to achieve a true homogeneous distribution of tracer emission in all the buildings in the present study (due to complex configuration of CDCCs physical structures and the high cost associated), it is believed that room to room transfer of air was rather limited in average. Indeed, this hypothesis is supported by the results obtained in a recent study where ventilation simulations were performed together with decay of CO_2 concentration in one of the CDCCs under analysis in the present work [15].

5. Conclusions

This study aimed at surveying the ventilation characteristics of a number of 16 CDCC´s located in the cities of Lisbon and Oporto using a passive tracer gas technique which uses perfluorocarbon tracer (PFT) gases. The measurements of the tracers over a period of two weeks in January 2012 resulted in air change rates (ACH) 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. Based on these results one can conclude that during the measurement periods, all CDCCs had ventilation rates below the minimum design value of 0.6 ACH (outdoor air intake) indicated by TPBR as default to avoid poor IAQ [17]. Although the role played by low air change rates on IAQ and health remains to be demonstrated, it is believed that this paper presents useful insights regarding the quality of ventilation and it may help identifying the ventilation strategies which are likely to improve the IAQ of CDCCs.

6. Acknowledgements

The authors gratefully acknowledge the assistance of Prof. Manuel Pinto of “Escola Superior de Tecnologia e Gestão” de Viseu, Portugal, provided during the design of experimental study.

Funding was provided by the research project supported by the Portuguese Ministry of Science and Technology, “Fundação para a Ciência e Tecnologia”, Project reference “PTDC/SAU-ESA/100275/2008 (ENVIRH).

7. References

[1] M. S. Zuraimi, K. W. Tham, F. T. Chew and P. L. Ooi. The effect of ventilation strategies of child care centers on indoor air quality and respiratory health of children in Singapore. Indoor Air 17 (2007) 317-327.
[2] L. Hagerhed - Engman, C.G. Bornehag, J. Sundell and N. Åberg. Day-care attendance and increased risk for respiratory and allergic symptoms in preschool age. Allergy 61 (2006) 447-453.
[3] M. St-Jean, A. St-Amand, N. L. Gilbert, J. C. Soto, M. Guay, K. Davis and T. W. Gyorkos. Indoor air quality in Montreal area day-carecentres, Canada. Environmental Research 118 (2012) 1-7.
[4] G. Clausen, A. Høst, J. Toftum, G. Bekç, C. Weschler, M. Callesen, S. Buhl, M. B. Ladegaard, S. Langer, B. Andersen, J. Sundell, C.-G. Bornehag and T. Sigsgaard. Children s health and its association with indoor environments in Danish homes and daycare centres – methods. Indoor Air 22 (2012) 467 - 475.
[5] J. Sundell, H. Levin, W.W. Nazaroff, W.S. Cain, W.J. Fisk, D.T. Grimsrud, F. Gyntelberg, Y. Li, A.K. Persily, A.C. Pcikering, J.M. Samet, J.D. T. Spengler and C.J. Weschler, Commemorating 20 years of Indoorair. Ventilation rates and health: multidisciplinary review of the scientific literature. Indoor Air 21 (2011) 191–204.
[6] S. Azevedo, J. Viegas, D. Aelenei, A. L. Papoila and A. Mendes. Environment and health in children day care centres results from phase i – preliminary analysis of buildings physical characteristics. In: The 10th International Conference on Industrial Ventilation - Ventilation 2012, Paris, 17-19th of September, 2012
[7] M. Cano, S. Nogueira, A. L. Papoila, F. Aguiar, P. Martins, J. Marques, I. Caires, J. Martins, C. Pedro, P. Paixão, J. Rosado-Pinto, P. Leiria-Pinto, D. Aelenei, A. Mendes, J. P. Teixeira, C. Proença and N. Neuparth. Indoor air quality in Portuguese children day care centres – ENVIRH Project. In: The Second International Conference on Building Energy and Environment 2012, Boulder, Colorado, USA, 1- 4 August, 2012.
[8] Nordtest 1997. Nordtest method NT VVS 118. Ventilation: Local mean age of air - Homogeneous emission techniques [http://www.nordicinnovation.net/nordtestfiler/vvs118.pdf]
[9] ISO Standard 16000-8. Determination of local mean ages of air in buildings for characterising ventilation conditions. 2007.
[10] L. Øie, H. Stymne, Carl-Axel Boman and V. Hellstrand. Indoor Air 8 (1998) 190 - 196.
[11] D. Crump, S. Dimitroulopoulou, R. Squire, D. Ross, V. Brown, B. Pierce, M. White and S Coward. Ventilation and indoor air quality in new homes. Pollution Atmospherique (2005) 71-76.
[12] H. Stymne and A. Eliasson. A new passive tracer gas technique for ventilation measurements.In: Proceedigs of 12th AIVC Conference, Canada, Vol., pp. 1-16, 1991.
[13] M. Sherman. Analysis of Errors Associated with Passive Ventilation Measurement TechniquesVentilation. Building and Environment 24 (1989) 131 - 139.
[14] MSSSP - Ministry for Solidarity and Social Security of Portugal. Directive 262/2011 from 31st of August.
[15] J. Viegas, D. Aelenei, S. Azevedo, H. Cruz, A. P. Santos and A. Pinto. Environment and health in children day care centre - analysis and simulation of ventilation. In: Proceedigs of The 10th International Conference on Industrial Ventilation, France, 17 - 19 September 2012.
[16] O. Ramalho, C. Mandin, J. Ribéron and G. Wyart. Air stuffiness and air exchange rate in french schools and day-care centres. In: Proceedigs of The 10th International Conference on Industrial Ventilation, France, 17 - 19 September 2012.
[17] TPBR - Thermal Performance Building Regulation. Directive 80/2006 from 4th of Abril.