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Gaseous pollutants on rural and urban nursery schools in Northern Portugal

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ABSTRACT

Indoor air quality in nursery schools is different from other schools and this has been largely ignored, particularly in rural areas. Urban and rural nursery schools have different environmental characteristics whose knowledge needs improvement. Thus, this study aimed to evaluate continuously the concentrations of CO_2, CO, NO_2, O_3, CH_2O and total VOC in three rural nursery schools and one urban, being the only one comparing urban and rural nurseries with continuous measurements, thus considering occupation and non-occupation periods. Regarding CO_2, urban nursery recorded higher concentrations (739–2328 mg m^{-3}) than rural nurseries (653–1078 mg m^{-3}). The influence of outdoor air was the main source of CO, NO_2 and O_3 indoor concentrations. CO and NO_2 concentrations were higher in the urban nursery and O_3 concentrations were higher in rural ones. CH_2O and TVOC concentrations seemed to be related to internal sources, such as furniture and flooring finishing and cleaning products.

1. Introduction

In recent years, numerous scientific studies highlighted that citizens spend most of their time in indoor environments (Jenkins et al., 1992; Silvers et al., 1994; Klepeis et al., 2001; Schweizer et al., 2007; de Gennaro et al., 2014; Wu et al., 2015). The largest part of human exposure to air pollution occurs in indoor environments, commonly considered non-polluted such as homes, offices and schools (WHO, 2006; de Gennaro et al., 2014; Branco et al., 2014). Nevertheless, it is actually known that indoor air pollution has equal or even greater impact on human health than outdoor pollution. This occurs because time spent indoor is usually higher than time spent outdoor; also, there is a great variety of indoor sources, that include outdoor and specific indoor sources associated with formaldehyde and volatile organic compounds (VOC) emissions, leading frequently to higher concentration than outdoor (Franklin, 2007; Faustman et al., 2000; Sofuoglu et al., 2011). Furthermore, children are more vulnerable to air pollution exposure than adults, being considered a risk group (Sousa et al., 2012). Exposure to indoor air pollution has been related to long and short-term health problems. Respiratory, cardiovascular and central nervous systems are the most affected, leading also to adverse effects on children's productivity and academic performance (Jones, 1999; Wang et al., 2015; Annesi-Maesano et al., 2013; Mohai et al., 2011).

Indoor pollutant sources are related to structural conditions of buildings (interior finishes, coverings and furniture), occupants' activities (heating, cooling and cooking habits, metabolism, hygiene, cleaning and disinfection products) and outdoor pollution (Jones, 1999). The control and analysis of indoor air quality (IAQ) assume an extremely important role because indoor pollutants' concentrations may vary significantly with location and time (de Gennaro et al., 2014). Studies of IAQ in schools have been performed mainly in primary or secondary schools. Nevertheless, IAQ in nursery schools is different from other schools and this has been largely ignored, particularly in rural areas (Ashmore and Dimitroulopoulu, 2009). IAQ studies comparing urban and rural contexts are relevant because there are evident environmental and social differences. On the environmental level this idea is supported essentially by the influence of traffic emissions. On the social level, habits and life styles in these two contexts are significantly different. Studies already made in nursery schools were essentially of three types: i) only focusing on comfort parameters (Gładyszewska-Fiedoruk 2013), and/or on CO_2 concentration as global IAQ indicator (Theodosiou and Ordoumpozanis, 2008;

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Carreiro-Martins et al., 2014); or ii) focusing on the study of one specific pollutant such as PM, allergens or phthalates (Arbes et al., 2005; Fromme et al., 2013). As far as known there are only five studies focussing on various gaseous pollutants in nursery schools' indoor air, from which one was in rural areas. Zuraimi and Tham (2008) investigated comfort parameters, air velocity and air exchange rates, as well as concentrations of several pollutants in nursery schools of Singapore, concluding that outdoor concentrations and occupant density were the main determinants for CO_2 concentrations. For indoor CO and O_3 levels, outdoor concentrations were the main precursors. Yang et al. (2009) characterized the concentrations of different indoor air pollutants in Korean nursery schools and compared them according to age and characteristics of buildings. The main problems reported in that study were caused by chemicals emitted from building materials or furnishing, and insufficient ventilation rates. Yoon et al. (2011) measured IAQ in rural and urban preschools in Korea, by investigating the indoor air concentrations of PM and several chemical compounds, and they found evidences that pollutant concentrations were in general higher in urban context and indoors than in rural context and outdoors. However, indoor/outdoor (I/O) ratios of CH_2O, CO and total volatile organic compounds (TVOC) were higher in rural schools.

Cano et al. (2012) studied IAQ in nursery schools in Lisbon and Porto (Portugal) considering various chemical pollutants, comfort parameters and microbiological parameters. The results of that study demonstrated an association between CO_2 concentrations and the number of children present in classrooms, as well as the need to improve ventilation and comfort of the spaces to promote healthier indoor environments.

Despite considering a large number of nursery schools, gaseous compounds, comfort parameters and comparisons between rural and urban nursery schools, in the above mentioned studies, samplings were only conducted during weekdays and during occupation periods. That did not allow understanding differences in IAQ between occupation and non-occupation periods (including nights

Table 1
Summary of the main characteristics of each studied microenvironment and sampling periods.

Nursery	Room	Type of use	Children's age (years)	Floor	Area (m^2)	Occupation (children + staff)	Period of occupation	Ventilation	Sampling time (weekdays + weekend days)
RUR1	A	Classroom	4–5	Ground floor	63	FO[a]: 25 + 2 PO[b]: 6 + 2	09 h–12 h 14 h–15h30	DNV[c] (Door to inner corridor frequently closed; Windows frequently open; AVAC system off)	2 + 2
	B	Classroom	5	Ground floor	48	20 + 2	09 h–12 h 14 h–15h30	DNV (Door to inner corridor frequently closed; Windows frequently open; AVAC system off)	3 + 2
	LR	Lunch room	3–5	Ground floor (back)	56	FO: ~200 PO: ~21	12 h–14 h	DNV (Open to kitchen and to inner corridor; Windows open during the occupation; AVAC system off	1 + 0
RUR2	A	Classroom	3–6	Ground floor (back)	32.5	14 + 2	09 h–11h30 12h15–16 h	DNV (Door to inner corridor always open; Windows frequently closed; A/C[d] and heating off)	4 + 2
	LR	Lunch room	3–6	Ground floor	26	14 + 2	11h30–12h15	DNV (Door to inner corridor always open; Windows open during the occupation)	3 + 0
RUR3	A	Classroom	<1–2	Ground floor	23.5	23 + 2	08 h–11h30 13h30–18 h 12h30–15h30 (sleeping time)	DNV (Door to inner corridor frequently closed; Windows frequently open; AVAC system off)	4 + 2
	B	Classroom	2–3	Ground floor	37.5	1 (Functioned as support room)	8 h–11h30 12h30–18 h	DNV (Door to inner corridor always closed; Windows always closed; AVAC system off)	3 + 0
	LR	Lunch room	<1–3	Ground floor (back)	104	24	11h30–12h30	DNV (Door to inner corridor always open; Windows always closed; AVAC system off)	3 + 0
URB1	A	Classroom	<2	1st floor (back)	38	23 + 2	07h30–19h30 12 h–13 h (sleeping time)	DFV[e] (Door to inner corridor always closed; A/C and dehumidifier frequently used)	4 + 2
	B	Classroom	2–3	1st floor (back)	21	23 + 2	08h30–10h50 11h45–18h30 12 h–15 h (sleeping time)	DFV (Door to inner corridor always closed. Windows sometimes open; A/C and dehumidifier frequently used)	4 + 0
	C	Classroom	4	2nd floor (front)	59	29 + 2	09 h–11h30 14 h–18 h	DNV (Door to inner corridor always closed; Windows sometimes open)	3 + 2
	LR	Lunch room	2–5	Ground floor (back)	38	21 to 74	11h30–13h30	DNV (Opening to the kitchen and to the inner corridor; No direct opening to the outside)	3 + 0

Note: adapted from Nunes et al. (2005).
[a] FO – full occupation.
[b] PO – partial occupation.
[c] DNF – Dominate natural ventilation.
[d] A/C – Air Conditioner.
[e] DNF – Dominate forced ventilation.

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