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School air quality related to dry cough, rhinitis, and nasal patency in children.

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Abstract

Controls for indoor air quality (IAQ) in schools are not usually performed throughout Europe. **Aim**: To assess the effects of IAQ on respiratory health of schoolchildren living in Norway, Sweden, Denmark, France, and Italy**. Methods**: In the cross-sectional EU-funded HESE (Health Effects of School Environment) Study, PM_{10} and CO_2 levels in a day of normal activity (full classroom) were related to wheezing, dry cough at night, and rhinitis in 654 children (10 yrs) and to acoustic rhinometry in 193 children. **Results**: Schoolchildren exposed to PM_{10} >50 μg/m^3 and CO_2 >1000 ppm (standards for good IAQ) were 78% and 66%, respectively. All disorders were more prevalent in children of poor ventilated classrooms. Schoolchildren exposed to CO_2 levels >1000 ppm showed a significantly higher risk for dry cough (OR 2.99, 95% CI 1.65-5.44) and rhinitis (2.07, 1.14-3.73). By two-level (child, classroom) hierarchical analyses, CO_2 was significantly associated with dry cough (OR 1.06, 95% CI 1.00-1.13 per 100 ppm increment) and rhinitis (1.06, 1.00-1.11). Nasal patency was significantly lower in schoolchildren exposed to PM_{10} >50 μg/m^3 than in those exposed to lower levels. **Conclusions**: A poor IAQ is frequent in European classrooms, where it is related to respiratory disturbances and affects nasal patency.

Introduction

Indoor environments contribute to human exposure to pollutants [1]. Levels of some pollutants can be several folds higher indoors than outdoors; even low concentrations of indoor pollutants may have adverse biological effects when exposures are prolonged.

Several reports underline the role of indoor pollution in affecting respiratory health in both children and adults [2-7]. Since children spend a large part of their time at school, nation-wide initiatives in order to evaluate such indoor air quality (IAQ) were developed in the USA [8].

Respiratory/allergic disorders are common throughout Europe, and represent a substantial burden of health service cost. Studies on school environment and related health effects on children were performed in Europe, especially in Northern countries, although mostly in small samples [9-13]. An EU-funded project developed by the European Federation of Asthma and Allergy Associations [14] found the right of breathing clean air at school not to be widely respected throughout Europe. Then, the European Commission, through the Directorate General for Health and Consumer Affairs (DG SANCO) funded our study on Health Effects of School Environment (HESE) to be held in different European countries, which we aim to report of herein.

Methods

The cross-sectional HESE study involved six Operational Units in five European countries (Siena and Udine, Italy; Reims, France; Oslo, Norway; Uppsala, Sweden; Århus, Denmark). Twenty-one schools (46 classrooms) were selected, with heterogeneous characteristics, including a broad range of building's ages and location's characteristics (about half in environmentally more advantaged areas, and other half in less advantaged areas). The study, approved by the Ethical Committees of each study centre, was carried out in 2004-2005, during the heating season, and took a full week in each location.

The study protocol included: a) one *standardized questionnaire* on school characteristics and IAQ policy completed by the teachers; b) two *standardized questionnaires*, derived from the International Study of Asthma and Allergies in Childhood (ISAAC) questionnaire on children characteristics (i.e. health conditions, lifestyle, home environment), filled in by the pupils and their parents, respectively; c) school *environmental assessments*; d) non-invasive *clinical tests* on a sub-sample of pupils.

Symptoms/diseases

The standardized questionnaires were filled in by 547 pupils and 552 parents (response rate 84%, for both). In Denmark, only parents' questionnaires were available. Among children with both self and parental report (N=445, 68% of total), symptoms/diseases were considered as: present, when either children or parents reported any symptom/disease; absent, when both children and parents did not. In order to retain the highest number of children and countries in the analyses, data on children with only self-report (N=107, 16.4%) or only parental report (N=102, 15.6%) were also included in the data set. Thus, health status was derived for 654 children (47.2% males, mean age 10 years, SD 0.8).

The following recent symptoms/diseases were considered in the analyses: 1) wheeze ("Have you had - has your child had - wheezing or whistling in the chest in the past 12 months?"); 2) dry cough at night ("In the past 12 months, have you had - has your child had - a dry cough at night, apart from a cough associated with a cold or chest infection?"); 3) rhinitis ("In the past 12 months, have you had - has your child had - a problem with sneezing, or a runny, or blocked nose when you did not have a cold or the flu?").

Environmental measurements

During normal activities (full classroom), standard measurements (ventilation, temperature, relative humidity, lighting, particles, nitrogen dioxide, carbon dioxide, ozone, formaldehyde, dust and air allergens, moulds and bacteria) were performed, both inside and outside each school, by personnel from a single centre, where the instruments had been calibrated (Uppsala). Data were analyzed at the IVL Swedish Environmental research Institute in Gothenburg (Sweden) and at the Department of Occupational and Environmental Medicine, Orebro (Sweden).

Carbon dioxide (CO_2, parts per million, ppm) was measured by a Q-Trackt^{TM} IAQ Monitor (TSI Incorporated, ST Paul, Minnesota, USA), a direct reading instrument with an in-built data logger, by sampling one minute average intervals at 0.9 m above the floor during one day (minimum 4 h).

Respirable particles with aerodynamic diameter <10 µm (PM_{10}, µg/m^3) were measured by a Dust- Trackt^{TM} (Model 8520) with a sensor type 90 degree light scattering laser photometer, measuring 1-10 µ particles (TSI Incorporated, USA) during 1-2 h.

Personal outdoor air supply rate (A = ventilation rate, Litres/second per person) was computed from the graphically estimated equilibrium of CO_2 concentration, as following:

$A=P/(C_{mean}-C_0)*10^6/3600$

where P is the personal emission rate of CO_2 in L/s for sedentary office work at sea level (18 L/h), and C_{mean} and C_0 are the mean CO_2 levels in the classroom and outdoor, respectively. [15]

Clinical tests

Non-invasive clinical tests (skin prick tests, spirometry, acoustic rhinometry, exhaled nitrogen oxide, collection of breath condensate and nasal secretions, Break-up Time, and Tear film analysis) were performed on 5 randomized selected pupils in each class.

For the current analyses, we focused on the results by acoustic rhinometry, because we considered upper respiratory tract disorders, and because the relationship between school environment and nasal patency (the degree of openness of the nose) of schoolchildren has been never investigated. Acoustic rhinometry precisely locates the nasal minimum cross-sectional area (MCA) of each nostril, through the analysis of sound reflection from the nasal cavity. Acoustic rhinometry was not performed in Norway. Except for Denmark, the same equipment (Rhin 2000, SR Electronics, Denmark, wideband noise, continuously transmitted) was used. The continuous sound measurement makes very easy to hear if the nose adapter does not fit tightly with the nose. In Denmark, the measurements were performed through a rhinometer using a single-spark signal (G J Electronic, Skanderborg, Denmark). At start-up, both equipments were calibrated through a tube with the same fixed length and volume changes in order to obtain standardized measurements. Measurements were performed by medical staff with many years experience, with the child sitting, after at least 5 min of rest, but usually much longer time, because of queuing. All schoolchildren were waiting in their classroom for at least 1 hour, before the investigation. MCAs on each nostril were measured at a distance of 0-22 mm (anterior MCA) and 23-54 mm (posterior MCA) from the nasal opening [16]. Mean values were calculated from three subsequent measurements on each side of the nose, and presented data are the sum of the values recorded for the right side and the left side of the nose. Analyses on anterior MCA regard 193 children. Those on posterior MCA concern 140 children (in Denmark, only anterior MCA was measured).

Statistical Analyses

Statistical analyses were performed with SPSS-13.0 release, and STATA-9.0 release. Levels of $PM_{10} > 50$ μg/m^3 (standard by U.S. EPA for long-term exposure) [17] and $CO_2 >$ 1000 ppm (standard by ASHRAE, American Society of Heating, Refrigerating and Air-Conditioning Engineers) [18] were defined as *elevated.* A categorical variable of exposure was defined for both pollutants (*elevated vs low*).

Levels of personal outdoor air supply rate less than 8 L/s/p indicated insufficient ventilation, as suggested by ASHRAE [19]. To assess the relationship between ventilation and respiratory health, we used a cut-off of 10 L/s/p [20].

The following SPSS routines were applied: frequency distributions, analyses of correlation and variance (ANOVA), chi-square test, non parametric test of Kruskall-Wallis, multiple linear regression, and logistic regression models, with each disorder as dependent variable. CO_2 and PM_{10} were entered in the models either as binary exposure variables (*elevated vs low*) or continuous variables (PM_{10}: 10 μg/m^3 increments; CO_2: 100 ppm increments). Beside conventional logistic regression, we fitted random intercept two-level models for binary dependent variables, by using the STATA gllamm (generalized linear latent and mixed models) command, with logit link function, which estimates the maximum likelihood (numerical integration to evaluate the marginal log-likelihood and numerical derivatives to maximize it). Two hierarchical levels were considered: 1st level, the child; 2nd level, the classroom.

Results

School environment

In most centres, indoor mean concentration of PM_{10} exceeded the 50 μg/m^3 cut-off suggested by EPA for long-term exposures (Table 1): lower or slightly higher mean levels only occurred in Uppsala and Oslo. Elevated mean concentrations were mainly in Danish and Italian schools. An over 50 μg/m^3 level was found in 77.8% of the classrooms, and an over 150 μg/m^3 level (EPA standard for 24-h exposure) was found in Italy and Denmark (Figure 1). PM_{10} levels always were higher inside than outside the school (outdoor mean 63.6 μg/m^3, range 6-302), with a mean indoor/outdoor ratio of 3.4 (range 0.5-38.7).

Indoor CO_2 was correlated to indoor PM_{10} (Pearson $r=0.64$, $p<0.001$), but the relation was only moderately linear (about 40% of the variation of CO_2 explains the variation of PM_{10}).

Mean concentrations exceeded 1000 ppm in all schools, except for Sweden (Table 1), and in 66% of the classrooms (Figure 2). The highest values were measured in Italy, followed by France and Denmark. Mean outdoor CO_2 was 398 ppm, and mean indoor/outdoor ratio was 3.7 (range 1.3-9.1).

Mean personal outdoor air supply rate in the total sample was 7.64 L/s/p. The lowest values were found in Italy and France, whilst the highest in Sweden (Table 1). In 69.6% of the classrooms (France 100%, Italy 94%, Denmark 86% , Norway 33%, and Sweden 11%) mean personal outdoor supply rates were lower than the minimum school level suggested by ASHRAE for occupant comfort (8 L/s/p) (Figure 3) [19]. A poor ventilation rate was significantly more frequent in naturally ventilated classrooms (67%) than in those with mechanical ventilation (97 *vs* 13%, $p<0.001$). Mean personal outdoor supply rate was inversely correlated to both indoor PM_{10} ($r = -0.71$, $p<0.001$) and CO_2 ($r = -0.88$, $p<0.001$).

Respiratory health

In the total sample, dry cough at night (34%) and rhinitis (32%) were more reported than wheeze (13%). All symptoms/diseases were more frequent in Italy and France. Mean prevalence rate of wheeze in these two countries was 15% *vs* 11% in the others; corresponding values for dry cough and rhinitis were 41 *vs* 25%, and 39 *vs* 26%, respectively. Prevalence of rhinitis was elevated in Norway, too (Table 2).

In the whole sample, age did not affect respiratory health. At country level, symptomatic children were slightly older that the asymptomatic ones only for dry cough in France (9.7 *vs* 9.4 years, p=0.01), and rhinitis in Italy (10.0 *vs* 9.7 years, p=0.01).

Wheezing was more prevalent in males than females (16 *vs*11%), dry cough in females than males (38 *vs* 31%, p=0.06), whilst the prevalence of rhinitis was similar in girls and boys (31 and 33%, respectively).

About 34% of the children were exposed to tobacco smoking at home, ranging from 17.4% in Sweden to 48.4% in France. All disorders were more frequent in exposed than unexposed children, significantly for wheeze and dry cough (Table 2). Multiple logistic regression models, accounted for CO_2 and PM_{10} exposure, gender, and age showed an almost double risk for dry cough at night (OR 1.98, 95% CI 1.34-2.91) and wheeze (1.95, 1.15-3.32) in children exposed to passive smoking in comparison to unexposed ones.

Prevalence rates of all disorders were higher in children of classrooms with personal outdoor air supply rate <10 L/s/p (N=481, 74%), significantly for dry cough at night and rhinitis (40.4 *vs* 18.6%, $p<0.001$, and 34.6 *vs* 23.8%, $p<0.01$, respectively). No significant difference was evident for wheeze (14.3 *vs* 10.5).

Pupils exposed to an *elevated* level of indoor PM_{10} (N=508, 78%) and CO_2 (N=432, 66%) showed higher prevalence of all disorders than those exposed to a *low* level, significantly for dry cough at night, and, as regards CO_2, also for rhinitis (Table 3). The prevalence of dry cough significantly ($p<0.001$) decreased with decreasing mean indoor levels of PM_{10} and CO_2 (Figure 4).

After accounting for passive smoking at home, PM_{10}, gender, and age, the exposure to an *elevated* CO_2 level was a significant risk factor for rhinitis and dry cough at night (Table 3). The association with dry cough was confirmed by the two-level hierarchical logistic regression, too.

Dry cough at night and rhinitis were positively and significantly related to CO_2, by both multiple conventional and two-level logistic models, also when PM_{10} and CO_2 were included in the analyses as continuous variables. The risk significantly increased according to the increment of 100 ppm of CO_2 (Table 4).

Neither outdoor concentrations of PM_{10} nor presence of heavy vehicular traffic resulted related to considered disorders.

Table 5 depicts the results of acoustic rhinometry. Mean anterior MCA did not significantly differ among centres. Conversely, mean posterior MCA was significantly higher in Sweden than in Italy and France. Both anterior and posterior MCAs were significantly correlated to the inverse of PM_{10} and CO_2 concentrations, except for anterior area with CO_2. Schoolchildren exposed to an *elevated* PM_{10} level had lower mean MCAs than those exposed to a *low* level (0.69 *vs* 0.76 cm^2, $p<0.05$ by ANOVA, for anterior MCA, and 0.9 *vs* 1.21 cm^2, $p<0.01$, for posterior MCA). Multiple regression analyses accounted for CO_2 level, passive smoking at home, gender, and age, confirmed the significant inverse association of MCAs with the *elevated* level of PM_{10} (B = -0.10, p<0.05, for anterior MCA; B = -0.35, p<0.01, for posterior MCA). The other variables in the models did not significantly affect nasal patency.

Discussion

The HESE study has found a poor IAQ in European schools, in terms of CO_2 and PM_{10} concentrations. In most school-classes, such levels exceed the international standards for good IAQ and are related to respiratory disturbances and reduce nasal patency in children.

Current knowledge on IAQ in schools and its health effects in schoolchildren is still limited [21]. A limit of previous studies conducted in Europe [12, 22-24] is the use of different protocols which precludes an adequate data comparison among different countries. The HESE is a pilot study on a non-representative sample of European schools. However, it provides, for the first time, data from a wide range of locations from different countries, by using the same standardized procedure. It shows the feasibility of multi-centre studies on school IAQ, and represents an important base for further research on a representative sample.

In the HESE classrooms, mean personal outdoor supply rates often do not meet the minimum ASHRAE guidelines for ventilation, as observed in France [25], Poland [26], and in the USA [21]. Mechanical ventilation results in higher air exchange rates, when compared to natural ventilation [27]. The latter varies according to building characteristics, occupant activities and number, and weather conditions. CO_2 is a normal constituent of exhaled breath, and its levels are often used as a surrogate of ventilation rate. Even if levels below 1000 ppm do not always mean adequate ventilation rate, higher levels indicate poor ventilation, which can allow accumulation of other contaminants [21]. We found CO_2 levels < 1000 ppm only in classrooms with mechanical ventilation (Sweden and, in part, Norway), except for a classroom in Udine (900 ppm), and a classroom in Denmark (561 ppm). Even in the Shanghai Study, the natural ventilation resulted not enough to reduce CO_2 to normal levels: opening one section window reduced mean indoor CO_2 by only 90 ppm [28]. Likewise, in naturally ventilated Polish schools, CO_2 quite always exceeded 1000 ppm [26], as occurred in a US study [29].

Moreover, indoor PM_{10} exceeded the standard of 50 µg/m^3 in about 78% of the HESE classrooms. Even if outdoor and indoor levels were positively correlated (Pearson r=0.52, p<0.001), indoor variability was accounted for only 27% by the linear association with outdoor PM_{10}. In all centres, PM_{10} concentration was lower outside the school, thus suggesting indoor PM_{10} as mainly produced by indoor sources. This was also indicated by a study in Czech Republic, which, after comparing PM with different diameter, shows that an important portion of indoor PM_{10} had its source inside the classroom [30].

Few studies have investigated the relationships between symptoms in children and CO_2 concentrations at school. In Norway, CO_2 levels were significantly related to higher prevalence of upper airways irritation symptoms [31]. Dutch children complained more of building-related symptoms when exposed to higher indoor CO_2 concentrations at school [32]. In the USA, school attendance significantly decreased with increasing CO_2 in the classrooms [33]. HESE children exposed to an *elevated* level of CO_2 showed significantly higher occurrence of dry cough at night and rhinitis, also after accounting for confounders. Significant positive associations of dry cough at night and rhinitis were found also with a small increment (100 ppm) in CO_2 concentration. As regards its skewed distribution, CO_2 was additionally analyzed as categorical variable based on its quartile distribution, and significant trends to augment ORs with increase of exposure were found for both dry cough and rhinitis (data not shown). It is important to point out that the results did not substantially change when the multi-level hierarchical models were fitted.

There is evidence that indoor PM significantly affects children respiratory health. In Swedish schoolchildren, associations of respirable dust concentrations or amount of settled dust in the classroom with asthma symptoms, new onset of self-reported pet allergy, and new onset of asthma diagnoses were reported [12] [22]. We found a strong crude association between the elevated level of PM_{10} and the presence of dry cough at night (OR 2.39, 95% CI 1.49-3.86), but it was likely due to the confounding effect of CO_2 exposure. In fact, the association was still significant after accounting for gender, age, and passive smoking (OR 1.99, 1.15-3.18), whereas it was no longer significant when CO_2 concentration (increment: 100 ppm) was included in the model (OR 1.21, 0.63-2.31).

In the HESE study, PM_{10} was associated with lower MCAs, as measured by acoustic rhinometry. MCAs indicate the degree of openness of the nose, regulate airflow and correlate with symptoms of nasal obstruction [16]. Our results partly agree with Norback et al., who found a lower degree of nasal patency among school staff exposed to higher concentrations of respirable dust at schools [13]. Wälinder's study showed that better cleaning will increase nasal patency [34].

It seems that parents tend to report less symptoms than their children do, and that children 10-11 years old provide important independent information, especially on their nocturnal symptoms (e.g. dry cough) [35]. By comparing childish and parental reports, we also observed a different perception of symptoms. Children reported all disorders at higher frequency than their parents did. Except for wheezing, that showed a quite good concordance (Kappa of Cohen 0.60, 90% of absolute agreement), both dry cough at night and rhinitis had a poor concordance (0.30, 70%). By including information from both children and parents in the same data set, we might have over- or under-estimated symptoms/diseases. However, sensitivity analyses, stratified by information source, showed significant positive associations of CO_2 exposure with dry cough at night, independently on whether the information was taken from children or parents. The association with rhinitis was significant when the childish report was considered, and it was evident, but not significant, when we derived information from parents only (data not shown).

Conclusions

The HESE study shows levels of CO_2 and PM_{10} exceeding the suggested air quality standards in a large part of European classrooms. The exposure to elevated levels affects respiratory health of the schoolchildren. Such results foster the advocacy for improving school environments, initially by providing adequate ventilation.

Future research is needed to assess indoor environment in a larger sample of schools and its long-term health effects. An extension of the HESE study design to other Member States of the European Union would be worthwhile.

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Table 1. Indoor Particulate matter (PM_{10}), carbon dioxide (CO_2) and ventilation rate in the classrooms (CI = Confidence Interval).

Centre-Country **(n of schools, *classrooms*):**	**Mean (95% CI)**	**SD**	**Median**	**Range**
PM_{10} (μg/m^3)				
Siena-Italy (4, *8*)	148 (88-208)	72	141	69-247
Udine-Italy (4, *8*)	158 (118-198)	48	154	92-260
Oslo-Norway (3, *6*)	54 (9-99)	43	43	17-131
Uppsala-Sweden (4, *9*)	33 (23-43)	13	32	14-53
Århus -*Denmark* (2, *7*)	169 (124-214)	48	160	112-233
Reims-France (4, *7*)	112 (90-135)	24	106	86-151
Total (21, *45*)	112 (91-133)	69	106	14-260
CO^2 (ppm)				
Siena-Italy (4, *8*)	1954 (1750-2157)	243	1970	1550-2359
Udine-Italy (4, *8*)	1818 (1115-2520)	840	1563	897-3475
Oslo-Norway (3, *6*)	1158 (357-1959)	763	686	634-2248
Uppsala-Sweden (4, *9*)	681 (579-783)	133	657	525-934
Århus -*Denmark* (2, *7*)	1568 (965-2171)	652	1434	561-2601
Reims-France (4, *8*)	1660 (1407-1913)	303	1611	1199-2194
Total (21, *46*)	1467 (1265-1670)	683	1490	525-3475
Personal outdoor air supply rate (L/s/p)				
Siena-Italy (4, *8*)	2.61 (1.83-3.39)	0.94	2.23	1.62-4.50
Udine-Italy (4, *8*)	3.71 (1.42-6.00)	2.75	2.87	1.52-9.38
Oslo-Norway (3, 6)	12.10 (3.93-20.27)	7.79	16.52	2.01-18.32
Uppsala-Sweden (4, *9*)	16.88 (10.17-23.58)	8.72	14.58	6.31-34.97
Århus -*Denmark* (2, *7*)	6.09 (2.02-14.20)	8.77	3.14	1.79-25.91
Reims-France (4, *8*)	3.16 (2.04-4.28)	1.34	2.72	2.18-6.31
Total (21, *46*)	7.46 (5.10-9.81)	7.94	3.14	1.52-34.97

Table 2. Prevalence (%) of respiratory health of the studied schoolchildren, by country and passive smoking exposure at home (ETS).

	Total N=654	**Italy N=242**	**Norway N=29**	**Sweden N=134**	**Denmark N=90**	**France N=159**	**p by χ^2**
Wheeze	13.3	13.2	10.3	11.3	10.1	17.6	NS
Dry cough at night	34.4	47.1	31.0	17.2	25.8	35.1	<0.001
Rhinitis	31.7	35.4	41.4	25.6	11.1	41.6	<0.001

	ETS-no N=420	**ETS-yes N=217**	**p by χ^2**
Wheeze	10.6	18.1	<0.05
Dry cough at night	28.3	46.0	<0.001
Rhinitis	30.9	35.3	NS

NS: not significant.

Table 3. Prevalence of recent respiratory disorders by indoor exposure level of particulate matter (PM_{10}) and carbon dioxide (CO_2), and associations of respiratory disorders with exposure levels (ref: *low* level). Crude and adjusted Odds Ratios (OR) and 95% Confidence Interval (CI).

				Conventional logistic regression models		Two-level[a] hierarchical regression models
	PM_{10} level		**p**	**crude OR**	**Adjusted OR[c]**	**Adjusted OR[c]**
	low	**elevated[b]**	**by χ^2**	**(95% CI)**	**(95% CI)**	**(95% CI)**
Wheeze	11.8	13.8	NS	1.20 (0.65-2.22)	1.22 (0.51-2.91)	0.98 (0.93-1.04)
Dry cough at night	20.8	38.6	<0.001	2.39 (1.49-3.86)***	1.21 (0.63-2.31)	0.89 (0.27-2.96)
Rhinitis	28.6	31.9	NS	1.17 (0.76-1.82)	0.72 (0.38-1.36)	0.59 (0.22-1.57)
	CO_2 level					
	low	**elevated[b]**				
Wheeze	11.9	13.9	NS	1.20 (0.72-2.01)	1.24 (0.55-1.03)	1.52 (0.68-3.39)
Dry cough at night	21.0	40.0	<0.001	2.52 (1.69-3.76)***	2.99 (1.65-5.44)**	3.32 (1.21-9.09)*
Rhinitis	25.9	34.1	<0.05	1.47 (1.01-2.16)*	2.07 (1.14-3.73)*	1.76 (0.71-4.38)

[a] 1st level: child, 2nd level: classroom; [b] PM_{10} >50 μg/m^3, CO_2 >1000 ppm; [c] analysis accounted for passive exposure to tobacco smoking at home, gender, age, PM_{10} (increment: 10μg/m^3), and CO_2 (increment: 100 ppm), respectively; NS: not significant, * p<0.05, ** p<0.01, *** p<0.001.

Table 4. Associations of recent respiratory disorders with indoor concentrations of particulate matter (PM_{10}) and carbon dioxide (CO_2). Crude and adjusted Odds Ratios (OR) and 95% Confidence Intervals (CI).

	Conventional regression models		**Two-level[a] regression model**
	crude OR (95% CI)	**Adjusted OR[b] (95% CI)**	**Adjusted OR[b] (95% CI)**
PM_{10} (per 10μg/m^3 increment):			
Wheeze	1.00 (0.96-1.03)	1.00 (0.95-1.05)	1.00 (0.95-1.05)
Dry cough at night	1.04 (1.01-1.06)**	1.00 (0.97-1.04)	0.99 (0.93-1.05)
Rhinitis	1.00 (0.97-1.02)	0.97 (0.94-1.01)	0.97 (0.92-1.02)
CO_2 (per 100ppm increment):			
Wheeze	1.00 (0.96-1.03)	0.99 (0.94-1.04)	1.00 (0.95-1.05)
Dry cough at night	1.06 (1.03-1.09)***	1.05 (1.01-1.09)**	1.06 (1.00-1.13)*
Rhinitis	1.03 (1.01-1.06)**	1.05 (1.02-1.09)**	1.06 (1.00-1.11)*

[a] 1st level: child, 2nd level: classroom; [b] In the models: PM_{10} and CO_2 concentration, passive exposure to tobacco smoking at home, gender, age; * $p< 0.05$, ** $p< 0.01$, *** $p<0.001$.

Table 5. Rhinometry. Minimum cross-sectional areas (MCA) in the total sample and by centre (CI=Confidence Interval).

	Total N=193	**Italy N=81**	**Sweden N=39**	**Denmark N=53**	**France N=20**	**p by ANOVA**
Anterior MCA:						
Mean	0.70	0.72	0.74	0.66	0.70	NS
95% CI	(0.68-0.73)	(0.67-0.76)	(0.70-0.79)	(0.63-0.70)	(0.64-0.75)	
Median	0.69	0.72	0.71	0.67	0.70	
	Total N=140	**Italy N=81**	**Sweden N=39**	**-**	**France N=20**	
Posterior MCA:						
Mean	1.03	1.02	1.16	-	0.83	<0.01
95% CI	(0.97-1.10)	(0.92-1.11)	(1.05-1.28)		(0.74-0.92)	
Median	0.97	0.94	1.10	-	0.85	

NS = not significant

Legends of the Figures.

Figure 1. Indoor PM_{10} ($\mu g/m^3$). Classroom mean concentration by centre.

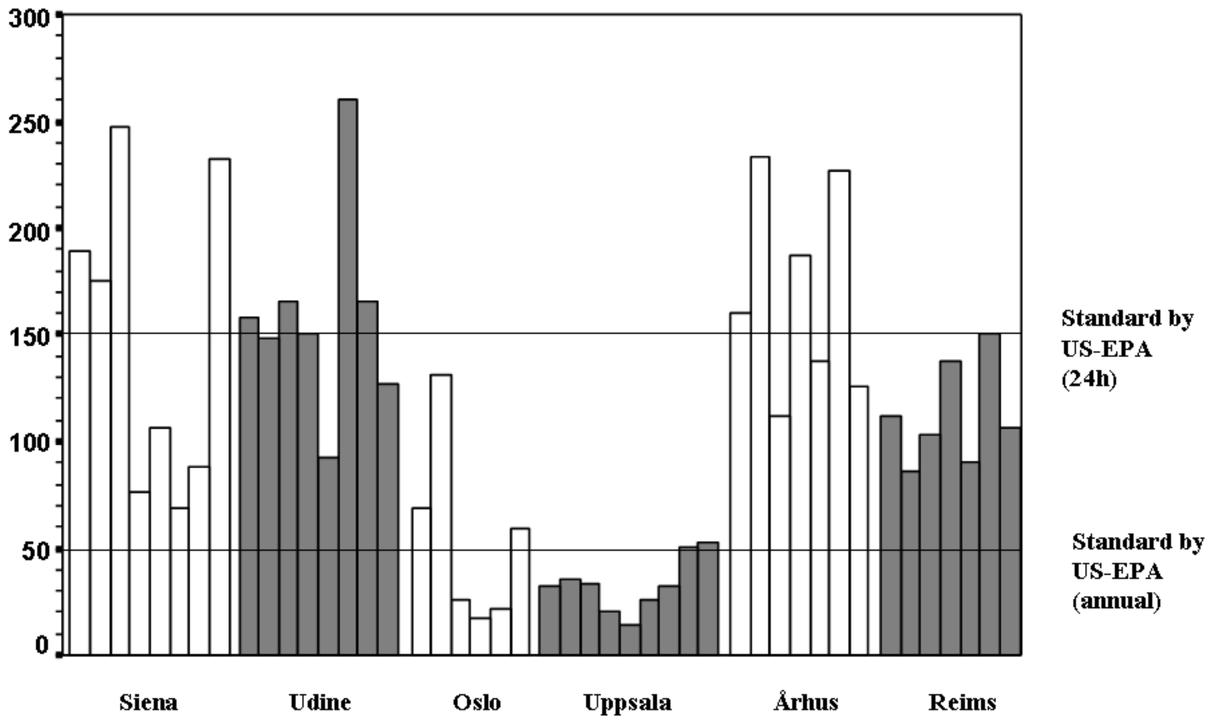


Figure 1

Figure 2. Indoor CO_2 (ppm). Classroom mean concentration by centre.

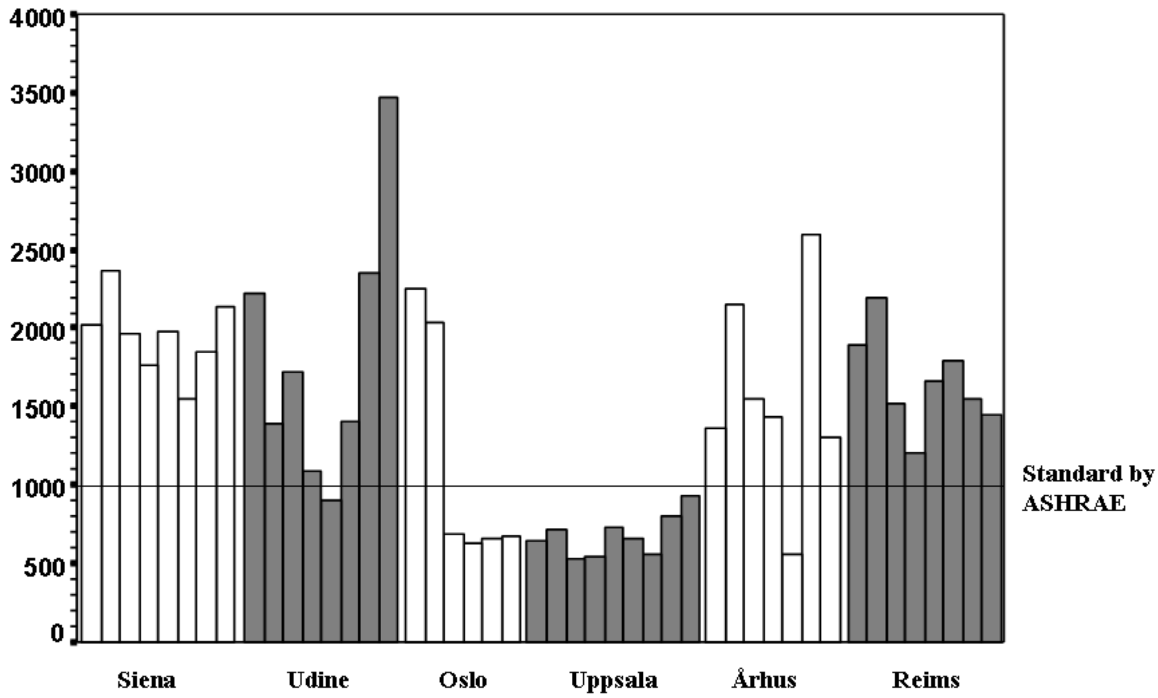


Figure 2

Figure 3. Ventilation rate. Mean personal outdoor supply rate (L/s/p) by centre.

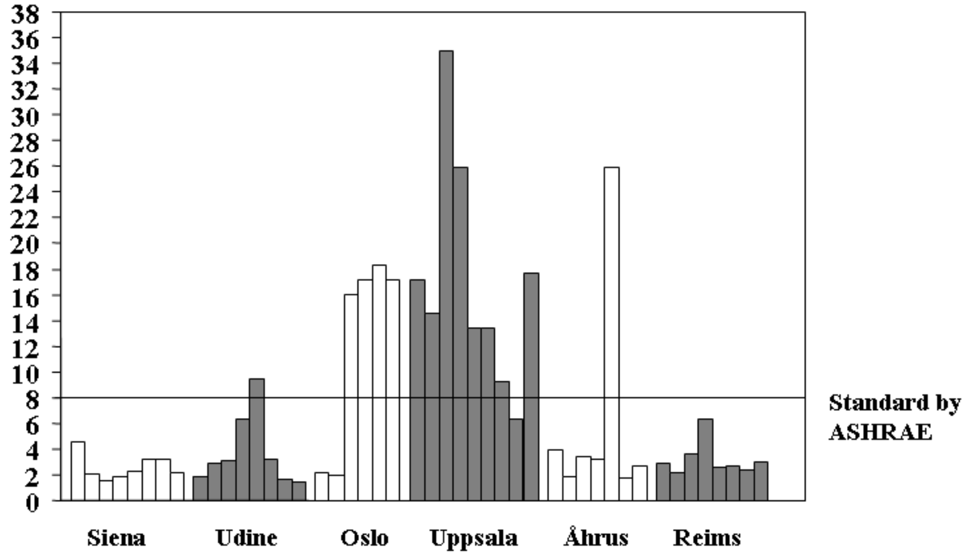
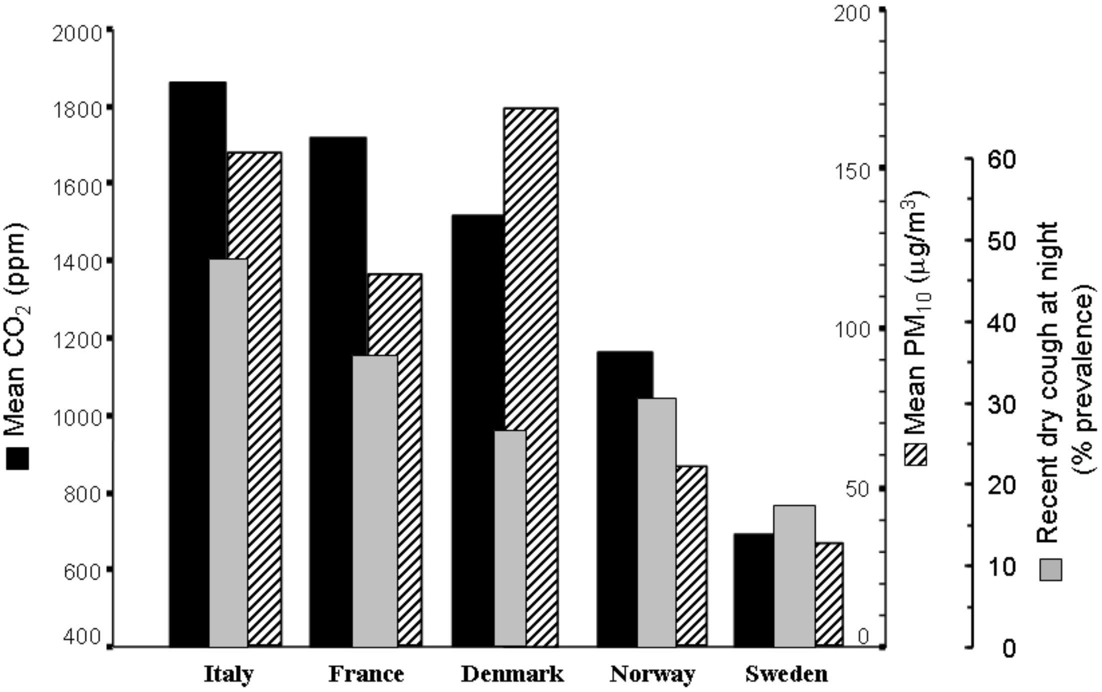


Figure 3

Figure 4. Prevalence of dry cough at night according to CO_2 and PM_{10} indoor mean concentration in the different countries.



Mean CO_2 (ppm)
2000
1800
1600
1400
1200
1000
800
600
400
200
150
100
50
0
Mean PM_{10} ($\mu g/m^3$)
60
50
40
30
20
10
0
Recent dry cough at night (% prevalence)
Italy
France
Denmark
Norway
Sweden

Figure 4