An assessment of indoor environmental quality in schools and its association with health and performance

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Abstract

In order to examine the associations between different indoor environmental quality (IEQ) indicators and students' performance, absenteeism and health in Southwestern United States, sampling and monitoring were performed in a 70 school district during two academic years. These included measurements of temperature (T), relative humidity (RH), carbon dioxide (CO_2), and settled dust. A standardized cleaning protocol was employed for surface sampling and cleaning effectiveness evaluation utilizing adenosine triphosphate (ATP) monitoring systems to detect biological contamination, and contact agar (RODAC) plates to detect culturable bacteria. In addition, student data related to socioeconomic background, absenteeism, performance, and number of visits to school nurse was retrieved anonymously from the school district. Significant associations were observed between percentages of students scoring satisfactory in mathematics and reading tests and both indoor T ($r = -.353$ and $r = -.311$ respectively) and ventilation rate ($r = .417$ and $r = .479$ respectively), which was estimated based on CO_2 levels. In addition, ventilation rate was associated with mean number of visits to school nurse due to respiratory symptoms, and culturable bacteria with mean number of visits due to gastrointestinal symptoms; but there were no significant correlations between absenteeism and IEQ parameters in these school-level analyses. In conclusion, classroom ventilation rate, temperature, and hygiene of high contact surfaces appear to be important IEQ parameters, potentially related to student health and/or performance.

Key words: cleanliness, elementary schools, health symptoms, indoor air quality, thermal conditions

1 Introduction

It is recognized that poor indoor environmental quality (IEQ) in schools may result in illness leading to student absenteeism, as well as adverse health symptoms, and decreased student performance [1-4]. Various biological and chemical pollutants and their interplays may contribute to IEQ [5-6]. In addition, physical factors may modify the body response to indoor pollutants by interacting with it or have a direct effect on the occupants [7].

An earlier study of one hundred elementary schools from two school districts in the Southwest United States found that 87% of classrooms studied (one classroom per school) had ventilation rates below 7.1 l/s per person [8]. The 7.1 l/s per person value was the minimum prescribed rate in the 2004 version of ASHRAE Standard 62, and is comparable to the 2013 version of the ASHRAE Standard. In addition, there was a linear association between classroom ventilation rates and students' academic achievement within the range of 0.9–7.1 l/s per person. Further analyses indicated that classroom ventilation rates correlated significantly with mean indoor and outdoor temperatures (T), indoor $PM_{2.5}$ readings, and outdoor relative humidity (RH) [9]. Other studies conducted in cold climates have also associated low ventilation along with high indoor temperature with decreased air quality [10-12]. A Swedish experimental study recommended both sufficient air exchange and air conditioned building for a better classroom indoor air quality and thermal comfort [11].

Lack of maintenance coupled with inadequate cleaning practices can alter the ecosystem of school building and encourage the growth and spread of microorganism that can put students' health at risk. Hussin et al. (2011) found schools with unhygienic conditions to have high concentrations of both fungi and bacteria due to dusty floors and moldy surfaces like indoor furniture [13]. The study also found occupants to influence indoor bacterial concentration but not fungal concentration. In another study, all room surface sampled in a child-care facility were contaminated with bacteria [14]. One way to reduce the spread of disease causing microbes in schools is to teach personal hygiene to students [15]. However, effective cleaning practices appear to be equally important.

This study broadens the assessment of IEQ in an independent school district located in the Southwestern United States, including an assessment of surface cleanliness as well as ventilation rate, thermal conditions, and an analysis of settled dust. An aim was to study the relationships between different measures of IEQ, and their associations with performance, absenteeism, and health of students.

2 Material and methods

2.1 First school year monitoring and sampling

A district with 70 elementary schools participated in the study. The schools were surveyed and monitored for characterization of IEQ during the academic year of 2008-2009. Background information was collected by walkthroughs utilizing pre-designed checklists, addressing all building structural and operational components, such as building age and design, construction, finishing, and furnishing materials, impact history (e.g. damage, repairs, renovations, retrofits), maintenance schedules, cleaning methods and frequencies, etc.

Field measurements consisted of temperature (T), relative humidity (RH), carbon dioxide (CO_2), and settled dust. Fourteen TSI QTrak Monitors were rotated on a weekly basis to seven new schools between January 26 and April 18, 2009 for continuous logging of two fifth grade classrooms from each school for T, RH, and CO_2 (5-minute resolution).

Settled dust boxes were deployed in two classrooms in each school (two per classroom, a total of 280 boxes). The boxes were placed adjacent to each other on an unsheltered shelf area in each classroom at a height of approximately two meters above the floor for a minimum period of three months (between January 20 and May 11, 2009), after which the boxes were recovered to assess the quantitative gravimetric amount of dust and a "percent surface coverage" metric. Gravimetric analysis was conducted by vacuuming dust onto a 37 mm filter cassette, and then weighing on a Mettler-Toledo XS104 analytical balance. The reported amount of dust was quantified by grams per square meter per month. The percent surface coverage was determined by use of a BM-DustDetector technology, where an average of three readings with the Dust Detector was calculated. A comparison of the gravimetric analyses vs. the Dust detector values is described in an earlier study [16].

2.2 Second school year monitoring and sampling

Twenty seven schools from the 70-school district were randomly selected for further monitoring, as well as assessment of cleaning effectiveness by surface sampling conducted during the academic year of 2009-2010. Surface sampling included collection of pre- and post-cleaning data from critical contact transmission surfaces in classrooms, restrooms, and cafeterias, using three different monitoring systems to detect and quantify adenosine triphosphate (ATP), which is a well-recognized marker for biological contamination. In addition, levels of total culturable bacteria were quantified using contact agar (RODAC) plates. One week at a time allotted for sampling of the selected surfaces in each school over a 3-day period (one day for each ATP system) within the week. Thus, 27 schools were utilized over a 30-week period (between 11 October 2009 and 28 May 2010).

For each school, two fifth grade classrooms were selected for ATP and RODAC sampling of student desks. Ten total desk surfaces were selected for sampling each day. In the cafeteria areas, five cafeteria tables were selected and divided into two halves for a total of ten cafeteria sampling surfaces each day. For bathroom areas, two restrooms in each school were selected (one girl's and one boy's). In the bathrooms, a total of ten sink areas and ten stall doors were selected for sampling each day. The selected surfaces were sampled for ATP and RODAC pre-cleaning, they were then cleaned using the prescribed cleaning and disinfection protocol, and then sampled again for ATP and RODAC post-cleaning. Whereas the results from different ATP systems were significantly correlated both before and after the cleaning, the results using RODAC were correlated with only pre-cleaning ATP. More detailed analysis of ATP and RODAC data for assessment of cleaning effectiveness have been reported elsewhere [17]. In this study, the results from using one ATP system NovaLUM (Charm Sciences, Inc., Lawrence, Kans.) and RODAC (Item #823002; Carolina Biological, Burlington, N.C.) were selected for further analyses.

2.3 Cleaning Protocol

For the surface sampling and evaluation of cleaning effectiveness, a standardized approach to the cleaning and disinfection of critical surfaces was developed based on the cleaning products available in the school district at the time. A one-step cleaner/disinfectant with bactericidal, fungicidal, and virucidal capabilities was used in conjunction with microfiber cleaning cloths and vigorous activity. All cleaning was done by a trained research team to ensure that the protocol was followed precisely in each school building, thus eliminating school-to-school variability among cleaning personnel.

Parallel to surface sampling, further monitoring included measurements for T, RH, and CO_2, and settled dust similar to what had been recorded during the 2008-2009 school year. In addition to the school maintenance and operation checklists and individual classroom checklists, housekeeping services campus evaluation reports from all schools were collected and assessed, including a summary sheet for overall cleaning evaluation based on visual observation.

2.4 Student Data

Anonymous student individual, and classroom level composite data for 2008-2009 and 2009-2010 were obtained from the District to profile each of two 5th grade classrooms in every school (140 classrooms monitored in 2008-2009; in 2009-2010 focus was directed toward the 27 schools where surface samples were being collected) related to students' socioeconomic background, absenteeism, and performance. Background information of the 5th graders by school included percent of students by different ethnic groups (Native American, Asian, African American, Hispanic and Caucasian), gender, gifted or talented, eligible for free or reduced lunch, and limited English proficiency. Absenteeism data included total days of absence, and absence days due to illness by fifth grade students in the classrooms measured. These data were normalized by the number of students attending these classrooms, corresponding to average number of days absent per student.

With respect to students' performance data, the percentages of students scoring satisfactory (i.e. meeting the standard) mathematics and reading tests were assessed by using results of the State Standard tests. In addition, health data from nurses were received for 2009-2010 school year including the number of nurse's visits per 5^{th} grade based on specific symptoms / health outcomes. The analysis was focused on the number of nurse's visits due to: 1) "gastrointestinal" symptoms, including abdominal pain or stomach ache, diarrhea, nausea, or vomiting; 2) "respiratory" symptoms, including earache and ear related, eye related, nose related, sore throat, or cough and 3) headache. The total counts of nurse's visits due to the above reasons were normalized for the number of students attending 5th grade, corresponding to an average number of visits per student.

2.5 Data analyses

SPSS statistical package version 17.0 was used for all data analyses. Preliminary analyses included assessment of continuous indoor T and RH data, matched with hourly outdoor data over a school day. Average, minimum, and maximum thermal conditions during the occupied school hours were estimated for each school. Ventilation rates were estimated based on measured indoor CO_2 concentrations using the peak analysis approach [8].

With respect to data on IEQ, health, and absenteeism of students, the following three separate datasets were merged: 1) IEQ data, 2) background information about 5th grade students, absenteeism, and absenteeism due to illness, and 3) health data from school nurses during the school year of 2009-2010. Surface cleaning data that originally included ten ATP and RODAC samples from four different types of surfaces (classroom desks, cafeterias, bathrooms stall doors and sink surroundings) pre- and post-cleaning, were aggregated to school or grade level by estimating the mean log-transformed ATP and RODAC levels by school.

First, the data were analyzed descriptively by studying distributions, outliers, and variation both within and between schools for each variable. The data on IEQ and health / absenteeism were analyzed for bi-variate correlations. Spearman correlation was used for non-normally distributed variables. Linear regression analysis was performed for selected health symptoms and academic performance (dependent variables) and selected IEQ variables (independent variables). For models including more than one independent variable, the additional variables were selected stepwise, using criteria to enter $P<0.05$ and to remove $P<0.10$.

3 Results

3.1 Building and IEQ characteristics

Building characteristics and descriptive statistics of school level IEQ data, including T, RH, ventilation rate, and settled dust are shown in Table 1. It is noted that the differences between classrooms within a school with respect to all measured parameters are non-significant (data not shown). Therefore, an average of all measured classrooms for each school was used in the following school level analyses.

As illustrated in Figure 1, paired comparison of the 2008-2009 and 2009-2010 school year measurement data reveals correlation coefficient of 0.791 ($p<0.001$) between ventilation rates (N=22). In addition, there is a modest correlation (coefficient 0.287, $p<0.05$) between settled dust samples (N=57), although corresponding correlations are not significant for indoor T and RH (N=20) or dust detector readings (=57) (data not shown). The differences in median values are statistically significant for both settled dust and dust detector readings using the Wilcoxon Signed Rank Test, but no significant differences are observed for the other parameters.

Table 2 shows Spearman correlations between the selected measurement variables in 2008-2009. Statistically significant correlations exist between indoor and outdoor RH and between indoor T and both outdoor T and RH. In addition, ventilation rate has a negative correlation with indoor maximum T. In 2009-2010 data from 27 schools, these correlations are not statistically significant; however, there is a significant correlation between indoor RH and outdoor T (data not shown). In addition, there are significant correlations between pre- and post-cleaning ATP (Pearson correlation coefficient 0.874, $p<0.001$), and both pre- and post-cleaning ATP readings correlate negatively with outdoor T (correlation coefficient -0.51, $p<0.01$) and indoor RH (coefficient -0.465, $p<0.05$ for post-cleaning ATP).

3.2 Analyses of absenteeism and health

Descriptive statistics related to students' background variables and students' absenteeism and health are presented in Tables 3 and 4. On average, students were absent due to illness 2.1-2.5

days during a school year, and there was about one visit to nurse per student due to gastro-intestinal symptoms and 0.8 visits due to respiratory symptoms.

Twenty eight Spearman bivariate correlations between IEQ, performance, and absenteeism in 2008-2009 were explored, see Table 5. Statistically significant bivariate correlations are observed between both percentages of students scoring satisfactory in mathematics and reading tests and ventilation rate, indoor average T, and outdoor average RH.

In the following analysis, four school groups were generated, including: (1) 16 schools with indoor T < 23^{o}C (73^{o}F) and ventilation rate < 3.6 l/s per person, (2) 10 schools with T ≥ 23^{o}C and ventilation rate ≥ 3.6 l/s/person, (3) 16 schools with indoor T < 23^{o}C and ventilation rate ≥ 3.6 l/s per person, and (4) 28 schools with indoor T ≥ 23^{o}C and ventilation rate < 3.6 l/s per person. Schools in group 3 (consisting of classrooms with lower than average T and higher than average ventilation rate) have significantly (13-14 %) higher percentage of students scoring satisfactory in the mathematics and reading tests as compared to group 4 (consisting of classrooms with higher than average T and lower than average ventilation rate), see Table 6.

Table 7 presents Spearman correlations between selected IEQ variables, absenteeism and number of visits to school nurse in 2009-2010. Whereas the correlations between absenteeism and IEQ variables are weak and non-significant, there are significant correlations between health outcomes and indoor RH, ventilation rate, and ATP readings both before and after cleaning. It was also noted that there are significant negative correlations between outdoor T and health outcomes, therefore, some of the observed correlations could be driven by seasonal variation. To control for seasonal variation, linear models were formulated including outdoor T a priori. Based on step-wise selection, the additional IEQ parameters selected in the multivariate models include pre-cleaning RODAC for gastrointestinal symptoms and ventilation rate for respiratory symptoms (Table 8). These statistically significant associations are not affected by socio-economic and socio-demographic variables (data not shown).

4 Discussion

The studied population consists of 70 schools in Southwestern US, which were investigated during 2008-2009 school year; further monitoring was done for 27 of the schools during the following school year (2009-2010). As compared to the background information from the 70 schools, the sub-sample of 27 schools represented slightly newer buildings, and utilized fan coil units relatively more often than other types of HVAC systems. The group level ventilation rate is about 0.5 l/s –person higher in the sub-sample.

The high correlation between paired ventilation rates in 2008-2009 and 2009-2010 school years indicates that the measured ventilation rate is relatively constant and representative of a long term situation. As shown in the scatterplot (Figure 1), five schools had an increased ventilation rate of > 1 l/s – person, however, there were two schools that had decreased ventilation rate in a similar fashion. It is possible that some schools had the systems adjusted or changed, which could explain larger shifts in the ventilation rates, but it appears that no systematic improvement occurred during the study period. The amount of settled dust collected in 2009-2010 was considerably lower as compared to 2008-2009, but the reason for this difference is not apparent.

There was a significant positive correlation between outdoor and indoor RH (r = 0.638). In addition, there was a weak but statistically significant positive correlation between outdoor and indoor T. A recent US study concluded that, during warm weather, outdoor T is a good predictor of indoor T conditions, whereas outdoor RH is a poor predictor for indoor RH [18]. Our study was conducted between January and April 2009 when the temperature was apparently relatively cold, which could explain the different results. The season could also explain the inverse correlation between outdoor RH and average indoor T (r = -.284). In addition, there was a weak inverse correlation between maximum indoor T and ventilation rate. During the heating season, indoor T may be decreased with increased ventilation [19-21].

Students' background was similar for the two academic sessions. Total absenteeism increased in 2009-2010 session but absenteeism due to illness remained more stable. There were no significant correlations between absenteeism and IEQ parameters in this school level analysis, which contradicted previous findings from California[4] and upstate New York [3].

Significant correlations were observed between percentages of students scoring satisfactory in mathematics and reading test and both indoor T and ventilation rate. The correlation observed between outdoor RH and percentages of students scoring satisfactory is likely related to indoor T, which is correlated with outdoor RH. It has been reported that a high (room) temperature increases fatigue and reduces concentration, mental performance, and learning of students [22-24].

Based on the preliminary results from linear regression models, low classroom temperature along with a high ventilation rate could be associated with higher rates of students scoring satisfactory in mathematics and reading tests. These preliminary results are in line with the previous studies associating inadequate classroom ventilation and high indoor T with students' academic performance [25-27]. It is also possible that there are synergistic effects between indoor T and ventilation rate. It was already noticed in a previous analysis [28] that socio-economic variables also correlated with ventilation rate, but the sample size is not sufficient for more complex multivariable models using school or grade level data.

The amount of settled dust was not correlated with other IEQ parameters, nor students' health and performance in this study. Outdoor T appeared to confound the associations seen between respiratory symptoms and indoor RH, as well as associations between gastro-intestinal, respiratory, headache and ATP. However, the associations between visits to school nurse due to respiratory symptoms and ventilation rate as well as between gastro-intestinal symptoms and RODAC levels remained significant after adjusting for outdoor T. These statistically significant associations were not affected by socio-economic and socio-demographic variables, including percent of student eligible for free lunch, which is a commonly used indicator of family income.

Our study is limited in terms of detailed student level information on possible confounding factors, such as exposure to environmental tobacco smoke that could be related to respiratory symptoms, but are not routinely collected by school districts. However, the observed school or grade level associations seem plausible since, providing that outdoor air is free of contaminants, ventilation with outdoor air reduces the concentration of indoor air contaminants by diluting and dispersing them[10], thus decreasing the levels of exposure via inhalation. In addition, contact with surfaces with higher levels of culturable bacteria may naturally increase risks of communicable diseases such as stomach flu [13-15].

In conclusion, classroom ventilation rate and temperature, as well as hygiene of the high contact surfaces appear to be important IEQ variables, potentially related to student health and/or performance. The results concur with a general conclusion that heating, ventilation, and air conditioning, as well as surface cleaning comprises the fundamental operational strategies for adjusting the school environment to improve health and performance of students.

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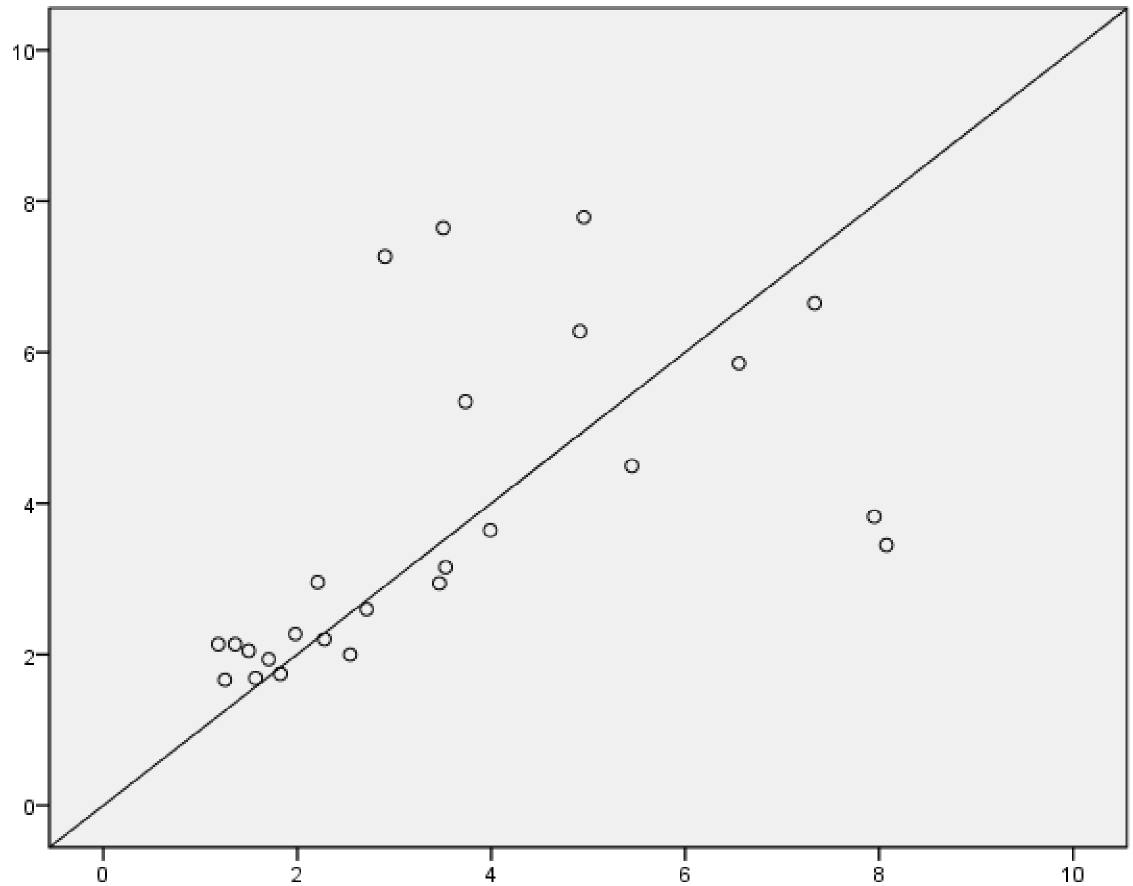

Figure 1. Pair comparison of ventilation rates (l/s per person) between the 2008-2009 and 2009-20010 sampling periods.

Table 1. Descriptive information about the schools and IEQ parameters.

		70 schools[1]	27 schools[2]	
Number of students, mean (SD)		576 (210)	599 (232)	
Floor area of the building [ft^2], mean (SD)		64417 (15260)	64418 (15295)	
Year of construction, mean (SD)		1967 (25)	1974 (28)	
Type of HVAC system	AHU's, N (%)	12 (17)	3 (11)	
	Fan coil units, N (%)	15 (21)	9 (35)	
	Unit ventilators, N (%)	44 (62)	14 (54)	
Main source of heating	Electricity, N (%)	48 (68)	16 (62)	
	Gas, N (%)	23 (32)	10 (38)	
Overall cleaning evaluation score, mean (SD)		91.9 (3.6)	91.2 (3.2)	
		2008-2009	2008-2009	2009-2010
Outdoor T [^{o} C][3)] average, mean (SD)		16.9 (3.2)	17.6 (1.8)	17.5 (7.7)
Indoor T [^{o} C][3)] average, mean (SD)		22.8 (1.1)	22.8 (0.8)	23.2 (1.8)
Indoor T [^{o} C] [3)] maximum, mean (SD)		25.5 (1.5)	25.3 (1.1)	26.1 (2.1)
Outdoor RH [%] average, mean (SD)		60.2 (16.9)	59.7 (16.9)	67.2 (10.5)
Indoor RH [%] average, mean (SD)		46.6 (7.8)	46.5 (7.3)	49.0 (10.3)
Ventilation rate [l/s-person], mean (SD)		3.6 (2.3)	4.1 (3.0)	4.1 (2.6)
Settled dust [mg/m^2/month], mean (SD)		172.3 (178.2)	205.7 (211.9)	130.5 (67.4)
Dust detector average (% coverage) mean (SD)		15.8 (4.7)	16.9 (4.0)	18.1 (5.2)
ATP pre-cleaning (log scale), mean (SD)[4)]		-	-	4.9 (0.2)
ATP post-cleaning (log scale), mean (SD) [4)]		-	-	3.8 (0.5)

RODAC pre-cleaning (log scale), mean (SD) [)]	-	-	1.4 (0.2)
RODAC post-cleaning (log scale), mean (SD) [)]		-	0.4 (0.3)

[1)] One school had two buildings

[2)] Due to some missing data related to building characteristics, number of schools may not total to 27 in all cells

[3)] Converted using [°C] = ([°F] - 32) × 5/9

[4)] Data not available

Table 2. Spearman correlations between selected measurement parameters in 2008-2009.

	1	2	3	4	5	6	7
1 Outdoor RH, average	1.000	-.122	.638**	-.284*	-.141	.171	.175
2 Outdoor T, average	-.122	1.000	.145	.243*	-.064	.040	.189
3 Indoor RH, average	.638**	.145	1.000	-.137	-.124	-.163	.148
4 Indoor T, average	-.284*	.243*	-.137	1.000	.632**	-.223	-.204
5 Indoor T, maximum	-.141	-.064	-.124	.632**	1.000	-.254*	-.034
6 Ventilation rate	.171	.040	-.163	-.223	-.254*	1.000	-.040
7 Settled dust mg/m2/month	.175	.189	.148	-.204	-.034	-.040	1.000

* Correlation is significant at the 0.05 level (2-tailed).

Table 3. Fifth grade students' background [percent of students per school].

	2008-2009					2009-2010		
	Mean	Median	SD	Min	Max	Mean	Median	SD
% Boys	51.3	51.6	7.4	29.5	72.4	51.0	51.3	7.4
% Native Americans	0.1	0.0	0.5	0.0	2.6	0.0	0.0	0.0
% Asian	3.5	0.0	5.9	0.0	29.7	3.2	1.0	4.0
%African American	13.6	9.4	13.0	0.0	65.6	16.3	11.2	15.0
% Hispanic	61.8	71.4	27.8	1.9	100.0	58.1	60.8	25.0
% White	21.0	5.2	26.5	0.0	92.8	22.4	7.8	26.2
% Free or reduced lunch	65.7	86.2	35.2	1.8	100.0	67.6	89.0	35.3
% Limited English	23.5	20.0	20.7	0.0	90.0	17.7	19.6	12.7
% Gifted or talented	9.4	9.0	6.2	0.0	31.9	9.9	9.0	5.2
% Satisfactory mathematics score[1)]	77.6	80.8	15.8	39.6	100	-	-	-
% Satisfactory reading score[1)]	78.1	76.7	14.7	45.1	100	-	-	-

[1)] Data not available for 2009-2010

Table 4. Students' absenteeism and health [average count per student].

	Mean	Median	SD	Min	Max
2008-2009					
Total days absent per student	5.9	5.7	1.5	3.0	9.2
Absent due to illness [days per student]	2.1	2.0	0.8	0.5	4.1
2009-2010					
Total days absent per student	10.7	10.0	3.8	5.6	23.8
Absent due to illness [days per student]	2.5	2.4	1.1	1.1	6.2
Number of visit to the nurse per student by illness category					
Gastrointestinal symptoms	0.98	0.82	0.39	0.34	2.04
Respiratory symptoms	0.83	0.78	0.37	0.25	1.72
Headache	0.60	0.51	0.28	0.29	1.28

Table 5. Spearman correlations between performance, absenteeism and IEQ in 2008-2009.

	% Satisfactory mathematics score	% Satisfactory reading score	Absence	Absence due illness
Outdoor RH, average	.330**	.288*	.115	.214
Outdoor T, average	-.111	-.130	-.176	-.080
Indoor RH, average	.078	.067	.088	.169
Indoor T, average	-.353**	-.311**	-.067	-.134
Indoor T, maximum	-.174	-.154	.110	.073
Ventilation rate	.417**	.479**	-.040	.052
Settled dust	.097	.131	.055	.123

Table 6. Simple linear regression models for mathematics and reading (% satisfactory)

	Unstandardized Coefficients		Standardized Coefficients		Sig.
Dependent Variable: Math	B	SE	Beta	t	
(Constant)	72.7	2.86		25.45	.000
Indoor T < 23^{o}C and ventilation rate < 3.6 l/s-person	6.13	4.74	.16	1.29	.200
Indoor T ≥ 23^{o}C and ventilation rate ≥ 3.6 l/s-person	1.46	5.57	.03	.26	.794
Indoor T < 23^{o}C and ventilation rate ≥ 3.6 l/s-person	14.28	4.74	.38	3.01	.004
Indoor T ≥ 23^{o}C and ventilation rate < 3.6 l/s-person	1				
Dependent Variable: Reading					
(Constant)	73.55	2.67		27.59	.000
Indoor T < 23^{o}C and ventilation rate < 3.6 l/s-person	3.73	4.42	.11	.84	.402
Indoor T ≥ 23^{o}C and ventilation rate ≥ 3.6 l/s-person	4.74	5.20	.11	.91	.365
Indoor T < 23^{o}C and ventilation rate ≥ 3.6 l/s- person	13.26	4.42	.38	3.00	.004
Indoor T ≥ 23^{o}C and ventilation rate < 3.6 l/s- person	1				

Table 7. Spearman correlations between absenteeism, number of visits to school nurse by illness category and IEQ in 2009-2010.

1= Absence; 2 = Absence due illness; 3= Gastro-intestinal; 4= Respiratory; 5= Headache

	1	2	3	4	5
Outdoor RH, average	-0.018	0.181	0.222	0.094	0.169
Outdoor T, average	-0.116	-0.072	-.448*	-.408*	-.463*
Indoor RH, average	0.047	0.169	-0.314	-.455*	-0.27
Indoor T, average	0.029	-0.247	0.164	0.164	-0.083
Ventilation rate	0.003	0.089	-0.214	-.427*	-0.297
Settled dust	0.284	-0.037	-0.198	-0.004	0.009
ATP pre-cleaning	0.137	0.006	.477*	.408*	.435*
ATP post-cleaning	0.101	0.056	.589**	.459*	0.376
RODAC pre-cleaning	0.324	0.176	0.374	0.265	0.286
RODAC post-cleaning	-0.192	-0.147	0.105	0.04	-0.069

Table 8. Linear regression models for health symptoms

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Dependent Variable: Gastro-intestinal symptoms	B	SE	Beta		
(Constant)	.339	.656		.516	.611
Outdoor T, average[1)]	-.011	.005	-.379	-2.120	.046
RODAC pre-cleaning	.896	.396	.405	2.265	.034
Dependent variable: Respiratory symptoms					
(Constant)	1.855	.339		5.476	.000
Outdoor T, average[1)]	-.012	.005	-.467	-2.559	.018
Ventilation rate	-.057	.026	-.407	-2.232	.037

1) per 0.6 ^{o}C (1 ^{o}F)