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ARTICLE

An Assessment of Indoor Environmental Quality in School Buildings in the State of Kuwait

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ABSTRACT

In this study, indoor quality and environmental comfort were investigated in secondary school buildings located in the State of Kuwait. Comfort variables such as temperature and relative humidity (thermal comfort), noise (acoustic comfort), illumination (visual comfort), as well as allocated classroom floor area per student (spatial comfort) were measured. Data was collected over a 7-month period on a spot basis during school hours in student-occupied classrooms at 46 selected schools. The measured data was then compared to international guidelines and standards related to indoor environment quality. The data for noise and allocated space were shown to be in the comfort ranges in all the schools. However, 11% of the schools are not adequately illuminated, 33% had temperatures not within the recommended limits, and 22% of the schools had humidity levels either higher or lower than the recommended levels. Also, 9% of the schools had low illumination readings.

In addition, during the data monitoring, a survey was conducted by which the student occupants completed a questionnaire so that subjective and objective evaluations could be compared. The findings of the questionnaire displayed significant correlations between the measured data and some ailments and other complaints experienced by the students.

Ultimately, the results found in this research will provide a baseline for comparison with future indoor environment quality assessments in buildings. Furthermore, recommendations are suggested in order to improve the environmental quality problems encountered in some of the schools, which may be beneficial for policymakers, facilities managers, and design engineers.

1. Introduction

Indoor environmental quality (IEQ) is a term used to depict the characteristics of indoor built space, including indoor air quality (IAQ), the acoustic, thermal, and visual environment. Both quantifiable physical and precept human comfort variables assume a vital part in characterizing IEQ. Clean and healthy Indoor air quality, acoustical comfort, visual comfort (lighting), thermal comfort as well as physiological comfort are the main fac-

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tors which can bring about a good or bad level of a particular indoor environment. With a building's IEQ having an effect on the comfort and health of building inhabitants, naturally, productivity at work will be impacted[1].

Sick Building Syndrome (SBS) is another term employed to portray symptoms involving illnesses and discomfort linked to the time building occupants spend in poor indoor environments. Colds, dry throat, skin rash, muscle aches, headaches, nausea, itchy skin, fever, asthma are just some of the SBS symptoms that have been credited to uncomfortable temperatures or humidity, poor air quality, inadequate lighting, poor acoustics, and crowded workspaces[2-5]. The SBS symptoms are likely to rise in significance with the time that individuals occupy the building and vanish when individuals exit the building[6].

The problem of SBS in offices and homes is causing lower levels of productivity and many other health complications. According to the Health and Safety Executive Report in the UK, approximately 30 to 50% of buildings suffer from poor IEQ, with up to 85% of its occupants suffering from SBS symptoms. SBS is an indoor environmental concern that has been studied and confirmed by various kinds of disciplines such as environmental agencies, contractors, policy makers; medicine as well as many other industries[7]. Due to poor indoor environments, the rates of absenteeism at offices, schools as well as other organizational environments have increased and been associated with physiological and psychological discomfort faced by various individuals[8].

IEQ in school environments is essential since growing youth are especially susceptible to poor indoor conditions. Students at this age are still physically growing, and in contrast with grown-ups, will endure the outcome of a poor indoor condition sooner[9]. Furthermore, except for being at home, students will occupy most of their time at school. Therefore, the acoustical, visual, thermal, and space conditions in classrooms have a noteworthy part with respect to students' comfort and health.

A review of previous studies on the classroom environment reveals research mainly centered on the effect of the indoor environment on student learning and achievement[10]. However, a variety of conditions related to IEQ can exist in classrooms that can be detrimental to their health resulting in absenteeism and associated long-term health ailments, but the data is limited. The poor environment of schools can cause difficulty in concentrating, fatigue, lethargy, and illness, consequently affecting the health and performance of student[11]. The National Center for Educational Statistics[12] reported that 43% of the schools in the United States were rated as unsatisfactory in either ventilation, lighting, temperature, indoor air quality, or noise control.

1.1 Space Density

The issue of occupant space density in a building can be assessed by the psychological effects of territoriality. The average space area allocated to building occupants impacts freedom of movement in a room, social distance, and personal space[27]. People who function in congested spaces may carry out their work badly, attain stress, and have a greater chance of catching contagious diseases[28, 29].

Classroom density (that is, the amount of space available to each pupil in a class) has received early attention in the literature. The implications of high-density spaces that comprise of too many students in a classroom or too little space are increased transmission of airborne diseases causing an infection risk, such as tuberculosis and influenza that can spread through coughing or sneezing[30]. In addition, as the density increases in a classroom, there will tend to be dissatisfaction, nervousness, and stress[31]. People naturally feel uncomfortable when others encroach upon their personal space and become defensive, aggressive or recluse. Therefore, over-crowded classrooms can cause discipline difficulties and behavioral disturbance that can produce noise and alter the clearness of verbal interaction[32]. In addition, crowding can cause personal loss of privacy, distraction, and excessive stimulation. These surroundings can cause mental fatigue, which can weaken a students' concentration[33,34].

Space standards pertaining to educational classroom occupancy define requirements for student capacity, area allocations, and utilization. These standards take into account comfort, overall efficiency, and safety to the classroom occupants[35]. Based on these standards, the space requirement per student is to be a minimum of 1.39 sq. m^2 per student to avoid the feeling of crowding in schools[36].

1.2 Noise

Acoustic comfort in an indoor environment is an equally important factor for comfortable indoor environments. Any excess sound or voices, normally of high intensities which are undesirable and cause irritation or discomfort by occupants, is considered noise pollution. Indoor environments having poor acoustics will create difficult environments for humans to live and work in, as a result of which lower rates of productivity and health are formed[54]. Excessive noise can produce many health problems such as hearing loss, fatigue, and high blood pressure. Also, long-term exposure to such noise can harmfully alter psychosocial relationships and working performance, interfere with communication, provoke annoyance, and change

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the social behavior[55]. Not only has noise been demonstrated to have harmful consequences after lengthy exposure, but it also can distress people in times of intermittent exposure and occurrences, depending on a person's sensitivity levels[56]. With abrupt elevated sound levels, there is a possibility of mechanical damage to the outer and the inner ear. Accordingly, acoustical evaluation studies that consider healthy noise exposure limits are critical.

In a classroom environment, noise disrupts communication and is unsettling and unfavorable to student learning[57]. Noise can be generated by many sources, including other students (both inside and outside the classroom), noise from sources in adjacent rooms and hallways, HVAC systems, and external noise, which is transmitted through a building's exterior walls, such as nearby industry, traffic, construction, and vehicular traffic. Road traffic is in most cases the chief external noise source, especially in urban areas[58].

Avoiding exposure to noise in classrooms is necessary and researchers are conscious of the complications produced by noise in school buildings. Studies regarding excessive noise in classrooms have shown that symptoms such as headaches, fatigue, difficulty concentrating, low performance, stress, and irritability exist for both teachers and students[59]. Studies also indicate that the heart rates of teachers are associated with the stress reaction to noise levels. Many teachers complain of vocal strain due to the need to speak at high vocal levels in order to prevail over the background noise[60]. Students show the same reaction with evidence of hearing loss[59]. Other studies showed that students at a school near an airport had reduced long-term memory[61], which improved after the closing of the airport. The most prevalent and documented reaction to noise is annoyance[62].

To deal with these noise problems, some countries have adopted legislation and standards concerning the acoustics of industries, including schools. The purpose of these guidelines is to make explicit proposals for the implementation of a practical hearing protection program. One such standard is recommended by the US Occupational Safety and Health Administration (OSHA), which is a regulatory agency, and therefore, the standard is binding by law in the U.S.A. The OSHA acoustics standard recommends maximum noise levels should not exceed 105 dBA[63].

Many studies, however, have still shown elevated levels of noise in school surroundings. Classrooms in urban area schools, in particular, didn't have acceptable acoustic conditions due to the effect of outdoor noise[64-67]. There is evidence of impaired performance in noise-exposed students especially around airports and the excessive exposure to noise was related to reduced reading comprehension, long-term memory, and motivation[68,69].

1.3 Lighting

People spend a large amount of their time indoors and lighting has a substantial bearing on IEQ. Without proper light, people may have physiological and psychological problems, which in some cases can cause sickness[13,14]. There is evidence of visual injury, allergic reaction, dry eyes, burning eyes, exhaustion, and headaches because of poor lighting in the workplaces[15]. Optimal lighting may enhance overall health and comfort. Lengthy spells of low light intensities can trigger depression and diminished functioning for some[16]. It has been shown that adequate lighting conditions decrease unfavorable health symptoms[17]. Lighting can also affect occupants' productivity, comfort, and overall wellbeing, amount of fatigue, in addition to safety[18,19]. Therefore, the lighting of any given room should accomplish its illumination design objectives.

According to Saade and Ramadan[20], the illuminance level of light, measured in lux, is the main parameter in order to achieve visual comfort. Several standards[21] prescribe that the illumination of school classrooms must be 300 lux or more at any point on a work surface. Analysis of research showed that overall, a lux illumination intensity of above 300 made people were more satisfied with the visual comfort of their indoor environment[22]. Research has also shown that adverse effects of poor lighting are commonly found when illuminance was below the recommended level. A study conducted by Juslén[23] showed that lower levels of illumination made it harder for the occupants to read, write, or work and concentration levels dropped. However, there is evidence in the literature that discomfort will be incurred such as glare, stress on vision, and the inability to concentrate when illuminance at pupils' desks is above 1000 lux[24-26].

1.4 Indoor Temperature

As stated by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE), Standard 55[37], thermal comfort is defined as "a state of mind which expresses satisfaction with the thermal environment". Essentially, thermal comfort in a space is attained by sustaining temperature, humidity, and air movement within a specified range. Indoor air temperature is one of the most significant factors controlling thermal comfort, which subsequently affects health. Of all the IEQ factors, Clements-Croome[38] report that building users are most dissatisfied with temperature and ventilation. Results from the evaluation and analysis of 95 buildings have shown sig-

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nificant effects of temperature on the prevalence of SBS [39]. When it gets too warm, people tend to feel stuffy and congested in a particular space. It can also lead to a feeling of nausea and suffocation. Therefore, it is very crucial to maintain a stable and comfortable thermal setting in a given environment, or else it may create tense and pressured conditions which negatively influences the performance and productivity of an in individual[40,41]. Cold air temperatures alternatively can too add immense discomfort and ill-health. Optimum indoor temperature varies between 19° to 23°C for IAQ and can be valid for assessments in classrooms[37]. One study proved that a thermally comfortable indoor environment can majorly help in the reduction of absenteeism by almost 35%[42].

Past research has evaluated the thermal environment in classrooms assessed by thermal comfort criteria. These studies mainly infer that the thermal preferences of the students were not in the comfort range specified by international standards[43]. Too high or low indoor air temperatures are commonly found to be outside the recommended ranges in school buildings[44,45].

Suitable IAQ and thermal comfort are vital for any space, but especially so for classrooms in order to assure health and comfort for its occupants. Thermal discomfort, whether it is excessively hot or cold classrooms, has been linked to physical stress, and hence, can cause health ailments and deficient pupil performance. Satisfactory IAQ and thermal comfort in an indoor environment will produce a feeling of general wellbeing resulting in improved student attention and productivity[38]. In an educational setting, researchers have presented data that thermal conditions can stimulate students' behavior[46], attitudes[47], comfort and preferences[48], personality development[49], learning[50] and performance such as understanding, reading, and calculating[51].

1.5 Humidity

Humidity is another factor affecting thermal comfort. Maintaining appropriate humidity indoors is essential for the comfort and health and of building inhabitants. The allowable range of relative humidity (RH) set by ASHRAE is between 30-60%[37]. Too high RH has been associated with SBS, which may be related to the progression of bacteria, mold, allergens, viruses, and fungi in spaces with poor ventilation[52]. On the other hand, overly dry air can raise the risk of upper respiratory infections[53].

1.6 Current study

Evidently, from previous research, the indoor environment in classrooms will have a great influence on students' health and comfort. It has been found that the improvement of the indoor environment factors such as air quality, temperature, and humidity, light, acoustic and space density need to be considered to provide healthy and comfortable surroundings. According to research, these factors can be evaluated readily by field measurements.

Many studies have evaluated the indoor conditions in educational buildings. Most, however, focused on one or two indoor environmental aspects only[70-75]. With little data obtainable in the literature regarding IEQ in schools in some developing countries, including Kuwait, there is a need for valid, current, and reliable data for this inquiry. IEQ issues not being fully investigated have resulted in occupants possibly being sick or uncomfortable.

As part of an ongoing research project, the goal of the current study is to examine the effectiveness of school facilities in the State of Kuwait regarding IEQ compared to international standards and the impacts of this on the students. A previously published study by the authors focused on the air quality aspect of IEQ in schools[76]. As such, this study was performed by measuring the remaining IEQ factors (temperature, humidity, light, acoustic and space density) and the data were compared with relevant standards and schools with substandard IEQ were identified. In addition, the association between these IEQ factors and the occurrence of SBS and perception of comfort in their respective indoor environments was evaluated through a subjective post-occupancy survey of the students. The combination of measured data and survey offers a more comprehensive indication of environmental quality and occupants' well-being. Several studies[74,77,78] implemented this way of investigation in order to look for a relationship between physical measurements and subjective responses.

The results of this study can be used to provide recommendations to school administration, architects, and engineers and as a guide for other researchers to obtain information about the efficiency of the current indoor environments in schools. Appropriate remedial measures can then be applied, if needed, to provide a satisfactory learning environment.

2. Materials and Methods

2.1 Overview of Target Buildings

Forty-six secondary schools were chosen as a sampling size for this research out of a total of 136 gender-segregated secondary schools that exist in Kuwait at the time of this study. The quantity of schools chosen represents a suitable statistical number (or more than 30% of the total number of schools in Kuwait). Roughly half of the selected schools, 24, were schools for girls. The schools were

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chosen arbitrarily and were situated geographically in all the urban areas of Kuwait (Figure 1). The selected schools varied in the age of construction with the most dated school being built in 1959 and the most contemporary school was erected in 2010.

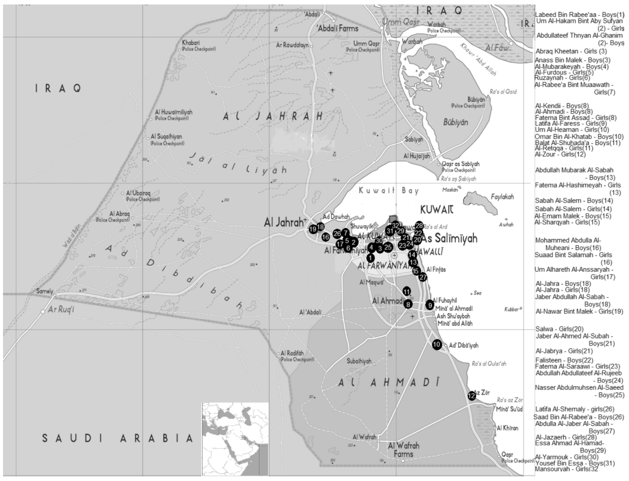

Figure 1. The locations of the 46 schools in Kuwait selected in this study

Before commencing of the testing, each selected school was inspected by the researchers to both familiarize the school administration with the current study and to expedite the research task. Previously, an official memorandum from the Ministry of Education had been conveyed to the administration of all the chosen schools for the study with a request of cooperation with the research team.

2.2 Indoor Environment Testing

A number of indoor environmental parameters for public schools were tested over a 7-month period from October 2017 to May 2018. The test measured five parameters, namely ambient air temperature (T), relative humidity (RH), illumination (ILL), noise (N), and available space per pupil (Sp). The daily testing for a chosen school took between 3.5 to 4 hours during regular school hours (7:30 AM to 1:45 PM). The data collection was done using three different devices or instruments and a measuring tape. All the devices utilized in the testing have previously been used in several published studies [79-82].

One device utilized in the research was the EVM-7 (S/N EML040010), produced by the Quest Technologies, as an environmental monitor that was factory calibrated. The EVM-7, which includes an automatic sensor recognition, is a compact device that is able to concurrently monitor temperature and relative humidity, as well as other parameters not within the scope of this research.

Simultaneously, the SoundPro SE/DL Series Sound Level Meter SP-DL-2-1/3, manufactured by M3, was used for sound level monitoring and comprehensive data analysis. The meter provides Class/Type 2 unit with 1/1 and 1/3 Octave RTA with real-time frequency analysis displayed and data storing capabilities. The SoundPro SE/DL Series features user-friendly calibration.

For the illumination measurements, the Advanced Light Meter (Model 840022C), manufactured by Sper-Scientific Ltd., was used every day during the experimental period. This device provides multi-detection ranges (40/400/4000/40000 and 400000 Lux) with a resolution of 0.01 to 100 Lux. The meter was calibrated in accordance with the National Institute of Standards and Technology (N.I.S.T.). The device's sensor uses an exclusive photodiode while the color and cosine corrected sensor meets the C.I.E. photopic spectrum. It offers measuring a variety of lighting such as tungsten, fluorescent, mercury, and sodium lights. The data measurements are registered within the device's LED screen.

Measuring space allocated to pupils was a direct process; the classroom area was calculated by measuring length and width using a measuring tape. This calculated area was divided by the total number of pupils in the classroom resulting in student density.

Data gathering in the occupied classrooms usually commenced at 8:30 A.M. Five classrooms were chosen in each selected school. The chosen classrooms were located on both school floor levels.

The data gathering process was performed in two phases. In the first phase, sound level and light meter devices were deployed and disseminated over the classrooms space (e.g., front right and left, rear right and left, and center of the classroom). The devices were fixed on a tripod at a height between 1.00 to 1.20 meter and 30 cm away from the pupils' facial position. This positioning of the device was to make certain that the relevant parameters being examined were in close proximity to the pupils, and in particular, the face. The testing was performed during the course of a teaching session which lasted 45 minutes. The devices logged the results at intervals according to their manufactured technology.

In the second phase, while the devices were still in operation, the researcher concisely clarified the research aims and framework of the questionnaire to the students. The researcher then asked interested pupils to answer the questionnaire. Usually, 10 to 12 students in each classroom agreed to participate. Consequently, the students' commitment was established to ascertain their reflection of the classroom environment. The participating students answered 23 questions which covered the parameters being studied. In other words, the researcher, through implementing the questionnaire, was trying to cross-check

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the devices' readings with the current feeling of the pupils or of any physical complaint when readings exceeded the recommended limits. During the questionnaire partaking, the classroom area was measured and the total number of students occupying the classroom was noted.

This data gathering operation was repeated in the other selected classrooms. After the daily operation ended, data collected from the devices and instruments were recorded, evaluated, and compared to the allowable threshold levels. The questionnaire data was input into a statistical package, SPSS, for subsequent analyses.

3. Results and Discussion

3.1 Space Density

After counting the number of pupils and measuring the areas of the selected 230 classrooms, it was found that the number of pupils occupying each classroom varied from 9 to 33. The average number of pupils in each classroom equaled 23, with a standard deviation of 4.18, and standard of error of 0.276, with the lone exception being the Al-Zoor Girls School. By dividing the classroom areas by the total number of pupils occupying those classrooms, an area allocated for every pupil was generated, which amounted to a range of 28 to 85.5 m^2. The calculated average area per student amounted to 50.65 m^2, with a standard deviation of 8.71 and a standard error of 0.57. The results confirm that all the schools provided adequate spatial density for students and complied with the recommended standard given by Spreiregen and De Paz[36]. Table 1 illustrates the minimum, maximum, and average values for the available area per pupil in the 230 classrooms located in the 46 schools under study.

Table 1. Allocated area per pupil data for all schools

No. of schools	Allocation of area per pupil (m^2)				
	Min.	Max.	Average	S.D.	S.E.
46	1.38	5.75	2.50	0.227	0.0335

3.2 Noise

The acoustical noise was measured for 230 classrooms in the selected 46 schools using the SoundPro device, which recorded the noise continuously over the testing period. Five random readings were taken for every classroom in locations described previously. Consequently, one average reading was calculated for those measurements. This calculated average was then compared to the permissible OSHA acoustics standard, which states that maximum noise levels should not exceed 105 dBA[63]. Table 2 illustrates the results of the noise readings in the 230 classrooms, which indicates all readings were below the permissible limit, and hence, conforms with the OSHA noise standard.

Table 2. Noise measurements showing conformance of with the OSHA standard

No. of measurements	Noise measurement (db)				
	Minimum reading	Maximum reading	Average	Standard deviation	Standard error
230	60	89.5	74.9	4.302	0.284

3.3 Illumination

In an endeavor to test the adequacy of illumination in the schools being studied, the Advanced Light Meter was used to record data in 230 classrooms. A one-side T-test was implemented for the illumination data to ascertain whether the readings were within the recommended minimum (300 lux) and maximum (1000 lux) levels according to the previously cited references[21,24,25,26]. The results showed that classrooms in four schools (about 9% of the total schools under study) were found to be suffering from low illumination levels. The results from those four schools are shown in Table 3 with a significant correlation at the 0.05 level. It was noted by the researchers during the testing that these schools with low illumination suffered from poor maintenance, such as broken and missing light fixtures in some classrooms.

Table 3. Data for schools with low illumination levels (H_0:μ=300 versus H_1:μ < 300) with significant correlation at 0.05 level

Variables	N	Mean	StDev	SE Mean	95% upper bound	T	P
Al-Mansouryah - Girls	5	192.4	60.111	26.883	249.71	-4.00	0.008
Al-Mubarakeyah -Boys	5	222.5	70.964	31.736	290.16	-2.44	0.036
Al-Jazae'r - Girls	5	192.4	60.111	26.883	249.71	-4.00	0.008
Al-Emam Malek - Boys	5	222.5	70.964	31.736	290.16	-2.44	0.036

The SPSS software was used to analyze the illumination data corresponding with the hypotheses (H0 and H1) of whether or not the measurement exceeded the recommended illumination level. In other words, H0 denoted the data is within the recommended level whereas H1 indicated the data exceeded the level. The data analysis revealed that there was only one school which exceeded the higher recommended value for illumination. Table 4 depicts that Al-Ahmadi Boys School was the lone school which exceeded the recommended higher limit with a significant

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correlation at the 0.05 level. The researchers noted that the possible reason for the elevated illumination at this school might be due to the windows having no curtains or blinds and being located in direct sunlight.

Table 4. Data for schools with elevated illumination levels (H_0:μ=1000 versus H_1:μ >1000) with significant correlation at 0.05 level

Variable	N	Mean	StDev	SE Mean	95% lower bound	T	P
Al-Ahmadi - Boys	5	1072.80	115.670	51.730	962.520	3.34	0.014

3.4 Indoor Temperature

Kuwait's climate is typically hot and arid and is characterized by its long summers where temperatures can reach more than 50°C [82]. Air conditioning systems in buildings are normally in constant use from the beginning of April until the end of October. Winters are mild and short, lasting only two months with average daily temperatures of about 14°C. The relatively mild temperatures do not impose a great demand on the use of heaters.

Air temperature data was measured in the 230 classrooms in the schools being investigated. The data was analyzed using the statistical software, SPSS, in accordance with the recommended temperatures range by ASHRAE[37]. In other words, below 19°C and above 23°C were selected as the norm limits. The software analysis established a null hypothesis (H0) which indicated that the reading does not satisfy the recommended ASHRAE standard, while the hypotheses (H1) indicated that the registered temperature data at the school meet the recommended standard. The hypotheses were repeated for both limits (below 19°C and above 23°C) alternatively. Descriptive statistics for the schools' temperature data are summarized in Table 5, which includes the school names, number of classrooms per school, temperature means, standard deviation, and standard error.

Table 5. School temperature data with their descriptive statistical analysis

Variables	N	Mean	StDev	SE Mean
Al-Ahmadi - Boys	5	26.44	0.7162	0.3203
Balat Al-Shuhada'a - Boys	5	25.46	0.6269	0.2804
Fatema Bent Asad - Girls	5	25.24	0.4930	0.2205
Al-Zoor - Girls	5	24.02	0.2950	0.1319
Anas Iben Malek - Boys	5	24.94	0.5983	0.2676
Al-Retqqa - Girls	5	24.84	0.6656	0.2977
Um Al-Haiman - Girls	5	24.00	0.3606	0.1612
Um Al-Hareth Al-Anssaryah - Girls	5	28.76	2.4583	1.0994
Sabah Al-Salem - Boys	5	24.98	0.9910	0.4432
Omar Ben Al-Khatab - Boys	5	23.96	0.5941	0.2657
Al-Emam Malek - Boys	5	24.74	1.2700	0.5680
Jaber Abdullah Al-Sabah - Boys	5	24.70	1.2510	0.5595
Labeed Iben Rabeea'a - Boys	5	23.96	0.9072	0.4057
Al-Jahra - Girls	5	24.18	1.2194	0.5453
Fatema Al-Hashemyah - Girls	5	23.40	0.4583	0.2049
Abdullah Mubarak Al-Sabah - Boys	5	23.62	0.7950	0.3555
Mohammed Al-Mehaini - Boys	5	23.84	1.5010	0.6713
Al-Kindy - Boys	5	23.38	0.7259	0.3247
Al-Jahra - Boys	5	24.06	5.2305	2.3391
Suaad Bent Salamah - Girls	5	23.02	0.6535	0.2922
Sabah Al-Salem - Girls	5	22.88	0.3962	0.1772
Fatema Al-Sara'awy - Girls	5	22.68	0.5891	0.2634
Al-Shargeyah - Girls	5	22.66	0.4393	0.1965
Lateefa Al-Fares - Girls	5	21.72	1.3554	0.6061
Al-Furdous - Girls	5	22.26	0.7570	0.3385
Nasser Abdulmuhsen Al-Saeed - Boys	5	22.54	0.3847	0.1720
Falasteen - Boys	5	21.90	0.9000	0.4025
Abdulateef Thnyan Al-Ghanim - Boys	5	22.18	0.6058	0.2709
Al-Mansouryah - Girls	5	21.56	0.9397	0.4202
Al-Mubarakeyah - Boys	5	21.06	1.0286	0.4600
Al-Rabee'a bent Mua'awath - Girls	5	21.32	0.8614	0.3852
Al-Nawar Bent Malek - Girls	5	22.02	0.4147	0.1855
Ruzainah - Girls	5	22.64	0.1517	0.0678
Abdullah Abdulateef Al-Rejaib - Boys	5	20.72	0.6611	0.2956
Abdullah Al-Jaber Al-Sabah - Boys	5	20.42	0.8643	0.3865
Jaber Al-Ahmad Al-Sabah - Boys	5	20.72	0.6611	0.2956
Yousef Ben Essa - Boys	5	21.84	0.3362	0.1503
Abraq Khaitan - Girls	5	21.06	0.4506	0.2015
Al-Jaberiah - Girls	5	21.10	0.4000	0.1789
Al-Jazae'r - Girls	5	18.62	0.2387	0.1068
Al-Yarmouk - Girls	5	20.92	0.3962	0.1772
Essa Ahmed Al-Hama - Boys	5	20.74	0.4980	0.2227
Lateefa Al-Shemali - Girls	5	20.26	0.4393	0.1965
Saad Ben Rabeea'a - Boys	5	20.68	0.5357	0.2396
Salwa - Girls	5	21.76	0.2702	0.1208
Um Al-Hakam Bent Abi Sufyan - Girls	5	19.28	0.4207	0.1881

In order to verify whether or not the classroom temperatures readings have complied with the ASHRAE standard, a one-side T-test was applied. The results revealed that classrooms in fifteen schools failed in terms of the minimum and maximum temperature limits. In more detail, Table 6 shows only one school, Al-Jazaer Girls, registered a marginally lower temperature reading in comparison with the recommended requirement, with an average temperature of 18.62°C and with a standard deviation of 0.2387. It is worth noting that Al-Jazaer Girls School was visited on the 27th of December when the registered temperature seemed to match the average seasonal weather temperature in Kuwait. On the other hand, fourteen schools which represent 30% of the total schools, registered temperatures exceeding the maximum recommended limit of 23°C as illustrated in Table 7.

Table 6. Lone school with marginally low temperature with a significant correlation at 0.05 level

Variable	N	Mean	StDev	SE Mean	95% upper bound	T	P
Al-Jazae'r - Girls	5	18.6200	0.2387	0.1068	18.8476	-3.56	0.012

Table 7. Temperature in schools with temperatures exceeding ASHRAE recommended limits with significant correlation at 0.05 level

Variables	N	Mean	StDev	SE Mean	95% lower bound	T	P
Al-Ahmadi - Boys	5	26.44	0.7162	0.3203	25.7571	10.74	0.000
Balat Al-Shuhada'a - Boys	5	25.46	0.6269	0.2804	24.8623	8.77	0.000
Fatema Bent Asad - Girls	5	25.24	0.4930	0.2205	24.7700	10.16	0.000
Al-Zoor - Girls	5	24.02	0.2950	0.1319	23.7388	7.73	0.001
Anas Iben Malek - Boys	5	24.94	0.5983	0.2676	24.3696	7.25	0.001
Al-Retqqa - Girls	5	24.84	0.6656	0.2977	24.2054	6.18	0.002
Um Al-Heaman - Girls	5	24.00	0.3606	0.1612	23.6563	6.20	0.002
Um Al-Hareth Al-Anssaryah - Girls	5	28.76	2.4583	1.0994	26.4163	5.24	0.003
Sabah Al-Salem - Boys	5	24.98	0.9910	0.4432	24.0352	4.47	0.006
Omar Ben Al-Khatab - Boys	5	23.96	0.5941	0.2657	23.3936	3.61	0.011
Al-Emam Malek - Boys	5	24.74	1.2700	0.5680	23.5292	3.06	0.019
Jaber Abdullah Al-Sabah - Boys	5	24.70	1.2510	0.5595	23.5073	3.04	0.019
Labeed Iben Rabeea'a - Boys	5	23.96	0.9072	0.4057	23.0951	2.37	0.039
Al-Jahra - Girls	5	24.18	1.2194	0.5453	23.0174	2.16	0.048

It should be noted that the higher temperature occurrences were observed during the end of March and April consecutively, where outside temperatures start to rise significantly in Kuwait. Thus, although air conditioning was in use at the schools, they were not satisfactorily efficient. In a number of those schools, particularly Um Al-Hareth Al-Anssaryah Girls School, the researchers observed irregular sounds when operating the AC unit, some damaged AC parts, inadequate airflow, and the temperature set by the remote control did not match the air temperature emitted by the AC unit. Therefore, although the classrooms had adequate unit sizes and number of units, they seemed to lack proper maintenance.

Since the results showed that 30% of the tested schools suffered from elevated indoor air temperatures, it was deemed worthy to ascertain if this statistic could be valid for all the schools in Kuwait. Consequently, a further ANOVA test was employed to compare the schools' data results and determine whether they were similar or had a significant difference. Table 8 illustrates the ANOVA test results, which compared the temperature variable at the different schools at a significance level of 0.05. In respect to temperature, the data results revealed that there were significant differences among the classrooms in the schools under study.

Table 8. ANOVA test for school temperatures with significant correlation at 0.05 level.

Temperature	Sum of Squares	df	Mean Square	F	Sig.
Between groups	875.942	45	19.465	15.698	0.000
Within groups	228.156	184	1.240		
Total	1104.098	229			

3.5 Humidity

Relative humidity testing was carried out in 230 classrooms in the 46 schools. Table 9 summarizes the schools' indoor humidity data in a descriptive statistic. Again, using the statistical software, SPSS, the humidity data was analyzed in accordance with the relative humidity range suggested by ASHRAE [37]. Specifically, below 30% and above 60% humidity were designated as the standard limits. The software analysis instituted a null hypothesis (H0) which indicated that the reading does not conform with the recommended ASHRAE standard, while the hypotheses (H1) specified that the registered temperature data at the school meet the recommended standard. The hypotheses were repeated for both limits (below 30% and above 60%), alternatively.

Table 9. Schools' indoor humidity statistics for all schools

Variables	N	Mean	StDev	SE Mean
Al-Jazae'r - Girls	5	66.2600	0.6804	0.3043
Al-Mansouryah - Girls	5	66.2600	1.2857	0.5750
Al-Furdous - Girls	5	64.1000	1.6416	0.7342
Um Al-Hareth Al-Anssaryah - Girls	5	66.9000	5.6859	2.5428

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Yousef Ben Essa - Boys	5	63.9400	3.3050	1.4780
Sabah Al-Salem - Boys	5	59.0000	1.0198	0.4561
Omar Ben Al-Khatab - Boys	5	54.8400	3.7407	1.6729
Al-Shargeyah - Girls	5	56.6400	2.0057	0.8970
Al-Yarmouk - Girls	5	58.2400	1.0502	0.4697
Abdullah Al-Jaber Al-Sabah - Boys	5	51.7400	2.6463	1.1835
Al-Jahra - Girls	5	54.2400	1.7170	0.7679
Al-Nawar Bent Malek - Girls	5	58.8400	0.3782	0.1691
Al-Zoor - Girls	5	50.5333	3.5161	1.4354
Essa Ahmed Al-Hamad - Boys	5	51.1000	2.9942	1.3390
Nasser Abdulmuhsen Al-Saeed - Boys	5	49.3400	2.8219	1.2620
Ruzainah - Girls	5	56.5400	0.9154	0.4094
Abdulateef Thnyan Al-Ghanim - Boys	5	52.1600	0.7092	0.3172
Abdullah Abdulateef Al-Rejeeb - Boys	5	43.6400	1.4775	0.6608
Abdullah Mubarak Al-Sabah - Boys	5	33.0600	2.8413	1.2707
Abraq Kheetan - Girls	5	43.2800	0.9257	0.4140
Al-Ahmadi - Boys	5	28.3600	1.1459	0.5124
Al-Emam Malek - Boys	5	36.0400	2.7107	1.2123
Al-Jabryah - Girls	5	47.7400	0.7232	0.3234
Al-Jahra - Boys	5	27.3800	3.2244	1.4420
Al-Kendy - Boys	5	33.4600	4.9873	2.2304
Al-Mubarakeyah - Boys	5	48.7000	2.0125	0.9000
Al-Rabee'a bent Mua'aawath - Girls	5	45.0600	0.7765	0.3473
Al-Retqqa - Girls	5	25.0000	0.7314	0.3271
Anas Iben Malek - Boys	5	55.1200	0.7530	0.3367
Balat Al-Shuhada'a - Boys	5	45.2400	1.9152	0.8565
Falasteen - Boys	5	52.7000	1.8207	0.8142
Fatema Al-Hashemyah - Girls	5	32.6000	3.2504	1.4536
Fatema Al-Sara'awy - Girls	5	48.5200	1.3971	0.6248
Fatema Bent Asad - Girls	5	26.1400	1.4153	0.6329
Jaber Abdullah Al-Sabah - Boys	5	42.3400	1.5947	0.7132
Jaber Al-Ahmad Al-Sabah - Boys	5	43.6400	1.4775	0.6608
Labeed Iben Rabeea'a - Boys	5	52.7667	0.8981	0.3667
Lateefa Al-Fares - Girls	5	27.2400	2.0562	0.9196
Lateefa Al-Shemali - Girls	5	50.7800	0.8927	0.3992
Mohammed AL-Meheani - Boys	5	21.2600	2.2579	1.0098
Saad Ben Rabeea'a - Boys	5	48.2200	1.0964	0.4903
Sabah Al-Salem - Girls	5	49.5800	1.6438	0.7351
Salwa - Girls	5	45.7800	0.4494	0.2010
Suaad Bent Salamh - Girls	5	31.7200	2.7179	1.2155
Um Al-Hakam Bent Aby Sufyan - Girls	5	44.9000	1.6355	0.7314
Um Al-Heaman - Girls	5	42.1400	1.8407	0.8232

In an endeavor to ascertain the level of indoor humidity at the schools within the recommended range of the ASHRAE standard, a one-side T-test was applied. In general, ten schools, or 21% of the total schools, had either higher or lower humidity than the recommended ASHRAE standard. The results showed that there were five schools that exceeded the higher limit, although marginally, while five other schools were below the recommended level. Tables 10 and 11 depict the results, consecutively.

Table 10. Schools with low humidity level with significant correlation at 0.05 level

	Variables	N	Mean	StDev	SE Mean	95% upper bound	T	P
1	Al-Retqqa-Girls	5	25.0000	0.7314	0.3271	25.6973	-15.29	0.000
2	Mohammed AL-Meheani-Boys	5	21.2600	2.2579	1.0098	23.4126	-8.66	0.000
3	Fatema Bent Asad-Girls	5	26.1400	1.4153	0.6329	27.4893	-6.10	0.002
4	Al-Ahmadi-Boys	5	28.3600	1.1459	0.5124	29.4525	-3.20	0.016
5	Lateefa Al-Fares-Girls	5	27.2400	2.0562	0.9196	29.2004	-3.00	0.020

Table 11. Schools with elevated humidity levels with significant correlation at 0.05 level

	Variables	N	Mean	StDev	SE Mean	95% lower bound	T	P
1	Al-Jazae'r-Girls	5	66.2600	0.6804	0.3043	65.6113	20.57	0.000
2	Al-Mansouryah-Girls	5	66.2600	1.2857	0.5750	65.0342	10.89	0.000
3	Al-Furdous-Girls	5	64.1000	1.6416	0.7342	62.5349	5.58	0.003
4	Um Al-Hareth Al-Ansaryah-Girls	5	66.9000	5.6859	2.5428	61.4791	2.71	0.027
5	Yousef Ben Essa-Boys	5	63.9400	3.3050	1.4780	60.7890	2.67	0.028

Given that 21% of the tested schools suffered from unsatisfactory humidity levels, a further ANOVA test was applied to establish if this statistic was similar or had a significant difference with the other schools in Kuwait. Table 12 illustrates the ANOVA Test results, which compared the humidity variable at the different schools at a significance level of 0.05. In respect to indoor humidity level, the results disclosed significant differences among the schools in regard to humidity.

Table 12. ANOVA test for school humidity levels with significant correlation at 0.05 level

Humidity	Sum of Squares	df	Mean Square	F	Sig.
Between groups	32065.133	45	712.559	145.896	0.000
Within groups	898.656	184	4.884		
Total	32963.789	229			

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3.6 Ambient Environment Comfort Questionnaire

In an attempt to verify any correlation between health symptoms the students were experiencing and with the measured data, a questionnaire was disseminated among the pupils in all the schools. An average of eleven students in each classroom agreed to participate. Only interested students were chosen to partake in the questionnaire in order to make sure of the pupils' commitment and to increase the actual reflection of the classroom environment.

The questionnaire contained 23 questions comprising a wide range of concerns relevant to ambient environment comfort with a focus on temperature, humidity, noise, and illumination, which were the parameters of interest in the current research. Subsequently, each question was verified with the parameter(s) that might be instigating any aggravation. Table 13 shows the relationship between the questionnaire questions and the pertinent parameters. The correlations were examined and revised by the Department of Occupational Health at the Ministry of Health in the State of Kuwait.

Table 13. Questionnaire answers with cross checking of parameters with health symptoms

Sr.	Question	Temperature	Relative Humidity	Noise	illumination
1	I feel uncomfortably hot in the classroom	S	S		
2	I perspire during my stay in the classroom	S	S		
3	My mouth and/or throat feels dry during class	S	S		
4	I feel that the classroom temperature is uncomfortable.	S	S		
5	I have trouble concentrating during lessons in the classroom.	A	A	S	S
6	I feel joint pain during lessons in the classroom.		S		
7	feel some dizziness in the classroom	A			
8	I get headaches in the classroom.	S			D
9	feel skin dryness in the classroom.		S		
10	I feel exhausted in the classroom.	S		D	D
11	I have trouble thinking during lessons in the classroom.	A	A	S	
12	I feel irregular heartbeats while in the classroom.	S		S	
13	I sometimes feel sudden cramping in my fingers or toes while in the classroom.		A		
14	I suffer from nasal congestion while in the classroom.	A	A		
15	I have difficulty breathing in the classroom.		S		
16	I feel chest tightness while in the classroom.		S		
17	I hear noise during the lecture			S	
18	I hear my teacher during the lecturing with difficulty			S	
19	I feel ear tinnitus during lecturing			S	
20	I feel irritation in the eye in the classroom.				
21	I feel exhausting when I look around in the classroom.	S		S	S
22	I feel cold in the classroom.	S	S		
23	I feel sleepy in the classroom.				A

Notes:

S: Chosen by the researcher based on information from theoretical framework and literature review

A: Was added to the table on recommendation of the Department of Occupational Health - Kuwait Ministry of Health

D: Was deleted from the table on recommendation of the Department of Occupational Health - Kuwait Ministry of Health

3.7 Pilot Test Analysis

In order to check the reliability of the questionnaire, which was given to students of both genders and as explained in the operation methodology, a Cronbach's Alpha test was performed. The outcome of this test indicated that the questionnaire's reliability was 0.847, which shows that the questions were neither vague nor missing data.

3.8 Statistical Validation

A Rotated Component Matrix was employed to decrease the breadth of the questionnaire to a rational number of independent, uncorrelated factors. Consequently, the questionnaire questions were condensed and grouped into seven main factors. The extraction method utilized was a Principal Component Analysis. The rotation method applied was a Varimax with a Kaiser Normalization and the rotation converged in nine iterations. Table 14 shows the classifications of the seven factors with the pertinent correlations. For clarification, the correlation between question #2 and Factor V is approximately 71%. Specifically, question #2 is accountable for 71% of the discrepancies in the pupils' answers in regard to Factor V. In another example, question #18 is correlated to Factor IV with a discrepancy of about 65%. Since each Factor comprised of several related questions, the authors devised a table representing the seven factors and proposed titles for the newly composed factors as shown in Table 15.

Table 14. Rotated Component Matrix classifications of the seven factors with the relevant correlations

	Factors						
Questions	1	2	3	4	5	6	7
Q1					0.788		

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Q2					0.710		
Q3							0.520
Q4					0.576		
Q5	0.534						
Q6	0.553						
Q7	0.682						
Q8	0.622						
Q9							0.539
Q10	0.623						
Q11							
Q12							
Q13						0.649	
Q14		0.617					
Q15		0.696					
Q16		0.538					
Q17				0.686			
Q18				0.651			
Q19							
Q20			0.675				
Q21							
Q22					0.701		
Q23	0.574						

Table 15. Newly proposed composed factors

Factors	Questionnaire question #	Suggested title
Factor I	5,6, 7, 8, 10 and 23	Pain, Tiredness & Faint
Factor II	14, 15 and 16	Allergy
Factor III	20	Eye Itching
Factor IV	17 and 18	Noise
Factor V	1, 2, 4 and 22	Heat
Factor VI	13	Sudden Cramping
Factor VII	3 and 9	Draught

An ANOVA Test was then employed to ascertain if the schools had any effect on each of these seven factors. The outcome, as shown in Table 16, reveals that the schools under study had significant differences to all factors.

Table 16. The schools under study showed significant differences to all factors

		Sum of Squares	df	Mean Square	F	Sig.
Factor I	Between Groups	139.590	45	3.102	3.340	0.000
	Within Groups	1232.410	1327	0.929		
	Total	1372.000	1372			
Factor II	Between Groups	71.102	45	1.580	1.612	0.007
	Within Groups	1300.898	1327	0.980		
	Total	1372.000	1372			
Factor III	Between Groups	65.049	45	1.446	1.468	0.025
	Within Groups	1306.951	1327	0.985		
	Total	1372.000	1372			
Factor IV	Between Groups	157.286	45	3.495	3.818	0.000
	Within Groups	1214.714	1327	0.915		
	Total	1372.000	1372			
Factor V	Between Groups	163.545	45	3.634	3.991	0.000
	Within Groups	1208.455	1327	0.911		
	Total	1372.000	1372			
Factor VI	Between Groups	70.855	45	1.575	1.606	0.007
	Within Groups	1301.145	1327	0.981		
	Total	1372.000	1372			
Factor VII	Between Groups	88.192	45	1.960	2.026	0.000
	Within Groups	1283.808	1327	0.967		
	Total	1372.000	1372			

Lastly, a correlation matrix was executed to discover the correlation between the newly composed factors and the significant parameter variables, such as noise, illumination, temperature, and humidity. The results in Table 17 reveals that noise measured in Factor IV (Noise) with significant correlation of 0.035 at a 95% significance level. Furthermore, the analysis revealed that illumination measured in Factor III (Eye Itching) and indicated a significant correlation of 0.004 at a 95% significance level. Temperature was shown to measure in both Factor III (Eye Itching) and Factor V (Heat) with a significant correlation of 0.001 and 0.01 at a 95% significance level, respectively. Humidity was represented in both Factor VI (Sudden Cramping) and Factor VII (Draught) with significant correlation of 0.012 at a 95% significance level and 0.005 at a 95% significance level, respectively.

Table 17. Correlation Matrix showing the correlation between the newly composed factors and the parameter variables

Parameters	Factor I	Factor II	Factor III	Factor IV	Factor V	Factor VI	Factor VII
Noise	-0.029	0.050	-0.003	0.057	-0.039	0.021	-0.009
	0.283	0.062	0.915	0.035**	0.148	0.432	0.735
Illumination	-0.021	-0.003	0.078	-0.032	0.072	-0.030	-0.038
	0.441	0.904	0.004**	0.231	0.007	0.267	0.161
Temp	-0.004	-0.007	0.091	-0.047	0.070	-0.039	-0.019
	0.897	0.800	0.001**	0.079	0.010**	0.151	0.477
Humidity	0.037	-0.034	-0.052	0.021	0.040	0.068	-0.076
	0.170	0.202	0.056	0.435	0.137	0.012**	0.005**

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Notes: (**) : Significant correlation at 0.05 level

4. Conclusion

4.1 Summary

The current research tested the IEQ in 46 public schools in the State of Kuwait. Testing involved spot-check monitoring of area allocated for each student, noise, illumination, temperature, and humidity. The measured area allocated per student and noise were deemed satisfactory when compared with international standards. However, in a number of classrooms, measured temperature, humidity, and illumination were not considered acceptable.

The data showed that in 30% of the tested schools, the temperature exceeded the upper recommended limits of ASHRAE during the end of March and April. This period of time coincides with outdoor temperatures beginning to rise significantly in Kuwait. It is believed that the inadequacy and inefficiency of the air-cooling systems in the suspect schools was the main culprit.

The data also revealed that about 21% of the schools considered in this study had humidity levels either higher or lower than recommended by ASHRAE. Results of the T-test disclosed that 8% of the schools exceeded the higher limit, while another 8% were below the recommended level.

Less of a concern was the illumination readings. Employing a T-test with a 95% confidence level revealed that 9% of the schools had low illumination. On the other hand, only one school had a value exceeding the recommended level of over 1000 lux. It is believed that improper lighting maintenance (e.g. missing and burnt bulbs) and suspect illumination design were the problems in these few cases.

The evaluation of the obtained data for noise and allocated student space was in the comfort ranges in all the schools when compared with international standards.

Suitable statistical procedures were used to analyze the questionnaire data output. The outcome of the analysis disclosed that the schools under study had significant differences in all comfort and health factors. Furthermore, it was determined from the applied statistical outputs that Illumination and "itchy eyes" indicated a significant correlation of 0.004, giving a 95% significance level. Furthermore, measured noise levels and "loudness discomfort" are correlated with a significant correlation of 0.035, giving a 95% significance level. Moreover, the measured temperature is correlated with both "itchy eyes" and "thermal discomfort" with significant correlation of 0.001 and 0.01, respectively, giving a 95% significance level. Finally, measured humidity levels depicted a correlation with "sudden cramping" and "draught discomfort" with a significant correlation of 0.012 and 0.005, respectively, for which the significance level was 95%.

4.2 Recommendations

Some environmental parameters researched in this study were unsatisfactory in some schools and could cause discomfort or impact the health of students. This reality offers prospects for improving the IEQ and as guidance for the supervision of future and existing educational buildings. Design for future school classrooms can be enhanced if indoor environment matters can be addressed earlier in the design and planning stage. In existing buildings, improvements should be carried out to ensure that the occupants of the building are comfortable with their working environment and to decrease the prevalence of SBS occurrence among occupants in school buildings. For example, monthly maintenance should be done to make sure that the air conditioners are functioning well. Proper functioning HVAC systems are important in a hot climate like in Kuwait to ensure a comfortable and healthy educational environment.

Policy implications need to be studied in order to understand why the design and build have failed to provide adequate IEQ in certain schools. In schools found to be adequate, it may help education policy makers to formulate and regulate schools to maintain these IEQ standards. Consequently, a healthy and comfortable environment will be sustained in these schools.

Long-term monitoring during school hours was not feasible in this research owing to the disturbance it would have produced in the classes. However, when the inhabitants are a sensitive group such as young aged students, then there is a certain need to measure continuously. The several schools measured to have unsatisfactory IEQ parameters would be candidates for long-term monitoring.

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