Int. J. Environ. Sci. Technol. (2016) 13:2011–2024
DOI 10.1007/s13762-016-1035-y

ORIGINAL PAPER

Assessment of noise exposure and associated health risk in school environment

M. F. Yassin[1] · H. Almutairi[2] · N. Alhajeri[3] · F. Al-Fadhli[4] · M. S. Al Rashidi[1,6] · T. Shatti[5]

Received: 23 November 2015 / Revised: 13 March 2016 / Accepted: 30 May 2016 / Published online: 20 June 2016

Abstract Noise exposure has become one of the most important factors in determining the quality of life in indoor environments. This paper assesses and analyzes noise exposure levels at school and preschool classrooms with different indoor environments. The sound level [A-weighting equivalent steady sound level L_{Aeq} (dBA)] was measured using a CEL-63× digital sound level meter. The noise level measurements were performed inside two preschools at three classrooms (an activity room, classroom KG1 and classroom KG2) and three schools at different classrooms, starting from grade 1 to grade 12. The logarithmic average noise levels ($L_{Aeq\ avg}$) and the 8-h average noise exposure level ($L_{EX,\ 8\text{-}h}$) were estimated for each classroom. Furthermore, health risk issues associated with the exposure to high noise levels were investigated using a questionnaire and an interview with more than 250 teachers at the preschools and the schools. Then, the results were analyzed using different statistical tools and were compared with the World Health Organization, Occupational Health and Safety and National Institute for Occupational Safety and Health standards. Also, the results were compared with those from different countries worldwide. The study results show that the 8-h average noise exposure level exceeded the allowable limits in some schools, which indicates that students and teachers can face a serious health effects from noise exposure. The comparisons show that the values of noise levels in Kuwait are higher than those in different countries. The maximum value of noise levels was found in secondary schools. The health problems found during the survey are potentially associated with issues related to hearing, voice, headache and the physiological function of teachers.

Keywords Indoor environment · Health risk · Sound level · Noise exposure · Schools

✉ M. F. Yassin
mohamed_f_yassin@hotmail.com

1 Environmental Pollution and Climate Program, Environment & Life Sciences Research Center, Kuwait Institute for Scientific Research, PO Box 24885, 13109 Safat, Kuwait

2 Department of Civil and environmental engineering, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada

3 Department of Environmental Technology Management, College for Life Science, Kuwait University, PO Box 5969, 13060 Safat, Kuwait

4 Department of Chemical Engineering, College of Engineering and Petroleum, Kuwait University, PO Box 5969, 13060 Safat, Kuwait

5 Communication Disorders Science, College for Life Science, Kuwait University, PO Box 5969, 13060 Safat, Kuwait

6 Crisis Decision Support Program, Environment & Life Sciences Research Center, Kuwait Institute for Scientific Research (KISR), PO Box 24885, 13109 Safat, Kuwait

Introduction

Children and teachers spent the vast majority of their time in kindergartens and schools. Therefore, indoor noise pollution has become one of the most important topics in indoor environmental studies in kindergartens and schools due to its significant impact on students and teachers' health as well as the quality of education. Quiet environments are important to all humans, but are most important to students in educational facilities in which information is predominantly presented orally to learners. Thus, listening is an important precondition for successful learning, especially in kindergarten and school classrooms, which play an important role in early childhood education. High levels of noise can harm children's and teacher's physical and psychological health, including their learning and behavior. Frequent exposure to noise during critical periods of development could affect a child's and teacher's acquisition of speech, language and language-related skills such as reading and listening.

Several studies on indoor noise pollution have been performed, and many have focused on the noise pollution in schools, e.g., Hodgson (1999), Koszarny (1990, 1992), Noweir and Ikhwan (1994), Ibrahim and Richard (2000), Schick et al. (2000), Shield and Dockrell (2003, 2004), Boman and Enmarker (2004), Schonwalder et al. (2004) and Carmen and Paulo (2004). The effect, if any, of chronic exposure to external and classroom noise on the test results of children ages 7–11 years has been examined by Shield and Dockrell (2008). External noise has been found to have a significant negative effect on performance, with a more significant effect on the older children when compared with the younger children. Measurements and evaluation of the ambient noise levels, reverberation time and transmission loss for classrooms in a public school were carried out by Zannin and Loro (2007) and Zannin and Zwirtes (2009). Both studies found that the equivalent noise levels during class were 73.7–74.0 dB(A). Astolfi and Pellerey (2008) evaluated the acoustic quality of the public school classroom. They found that the noise which came from inside the school buildings has a great impact on acoustic quality. Furthermore, Ana et al. (2009) randomly selected four schools from eight participating schools in their overall project. The study administered 200 questionnaires, 50 per school, assessing health and learning-related outcomes and measured noise levels (A-weighted decibels, dBA) with calibrated sound level meters. The results have indicated that cross-sectional school-day noise levels ranged from 68.3 to 84.7 dBA. Zannin and Ferreira (2009) conducted field measurement in university classrooms to evaluate external and internal acoustic quality. Apparent weight sound reduction indices of all classrooms facades of both the buildings showed values below than those recommended by international standard DIN 4109.

The noise level of 244 classrooms in 90 random samples consisting of primary, secondary and high schools in Tehran has been measured by Golmohammadi et al. (2010). The results indicate that the average equivalent noise levels inside classrooms and corridors, in yards and on side streets in teaching area were 72, 65.8, 64.1 and 64.5 dBA, respectively. In addition, the effects of classroom reverberation on reading abilities, annoyance due to indoor noise and school attitudes in second graders were analyzed by Klatte and Hellbrück (2010). The results underline the importance of good acoustical conditions in elementary school classrooms. Woolner and Hall (2010) have reviewed the weight of evidence in relation to noise, and the results emphasized four key points. First, noise above a given level does appear to have a negative effect on learning. Second, noise beneath these levels may or may not be problematic, depending on the social, cultural and pedagogical expectations of the students and teachers. Third, the study argues that when noise is deemed to be a difficulty, this finding cannot simply be translated into design prescriptions. Finally, the study suggests that the solution to noise problems is by understanding how to use learning spaces in schools. In another study, Xie et al. (2011) investigated the relationships among the environmental noise levels of secondary schools in Greater London and a set of academic achievement factors. It has been shown that the environmental noise levels of secondary schools in Greater London have nearly no significant relationships with those academic achievement indicators. In addition to schools, the assessments of noise levels have also been carried out in universities. For example; Otutu (2011) has obtained noise measurements from 22 locations within Campus 2 of Delta State University in Abraka, Nigeria, during and after working hours. The results have indicated that the average noise level of 87 dBA on Campus 2 is mostly generated by the business centers due to the electricity generated from different power plants situated nearby the university. Pujol et al. (2012) performed a noise measurement campaign at the residences of 44 schools. The results show that an association was found between the type of view from the window and the outdoor sound level (L_{Aeq}) value, but no significant association was observed between the view from the window and the indoor (L_{Aeq}) value. Montazami et al. (2012) have used surveys, monitoring of indoor temperatures and testing of air quality and aircraft noise levels. The results have shown that those schools located near Heathrow airport are more likely to experience overheating and poor air quality due to aircraft noise, which can subsequently have a negative effect on students' achievements.

The noise level and its associated health issues in the indoor microenvironments in Kuwait have not been investigated yet. Thus, the main aim of this study is to assess the noise pollution level in school and preschool classrooms in order to recognize the important parameters that cause noise pollution in classrooms. Moreover, the study evaluates the effect of noise pollution on health risk of children by comparing measured noise pollution with the World Health Organization (WHO), Occupational Health and Safety (OHS) and National Institute for Occupational Safety and Health (NIOSH) standards and for teachers by a self-answered survey questionnaire. Therefore, in order to undertake this aim and gain further understanding of the noise levels, three classrooms in two preschools (activity room and two classrooms (KG1 classroom and KG2 classroom)) were studied. The study also assesses the levels of noise in three schools (primary, secondary and high schools, from the 1st- to the 12th-grade classrooms) which were selected at different locations in Kuwait.

Materials and methods

The preschools and schools chosen for this study were based upon the local government regions of Kuwait. It was important for this study that the region chosen should be representative of Kuwait to reduce the number of potentially confounding variables. Noise level assessment in the preschools, primary, secondary and high schools classrooms was built-in 18 classrooms for different regions in Kuwait. Four classrooms and two activity rooms were selected in two different preschools for children ages 4–5 years. Table 1 shows detailed information on preschools and schools.

The first preschool is considered to be a new preschool, and it is located in Mubarak Al-Kabeer governorate, surrounded by a quiet residential area. The second preschool is an older school located in Al-Ahmadi governorate. The older school has a central open space in which all of the classrooms are situated. Each classroom contains its own toilet. In contrast, the new school has a closed design, and each of the three classrooms shares a public toilet.

Although education is free, compulsory education in Kuwait starts from the primary level. Kindergarten is limited only to registration, and there are no rules to force parents to bring their children to a kindergarten every day; therefore, the daily attendance, usually, does not exceed 90 % which can affect (reducing) the noise levels as shown later in results.

The other twelve classrooms were selected in three schools that have different levels of education (primary, secondary and high schools) for children ages from 6 to 17 years. The three schools are located in Saad Al-Abdullah residential area and were built a few years ago. Saad Al-Abdullah residential area is considered to be a quiet area where no heavy traffic or airplanes fly around it. The primary school students are supposed to complete their study in the selected secondary and high schools, and this could give an indication and a comprehensive view of the environment that each student will pass through in 12 years. For the primary school, noise levels are measured inside the 1st- to the 5th-grade classrooms (ages are 6–10 years). The school has a symmetric design. For the secondary school, noise levels are measured inside the 6th- to the 9th-grade classrooms (ages are 11–14 years). For the high school, noise levels are measured inside the 10- to the 12th-grade classrooms (ages are 15–17 years). It can be noticed that the occupancy rate of the high school is very high, and it reaches 100 % in all examined classrooms at the time of measurements.

Sound level measurements

The energy in a sound wave can be measured by the intensity and frequency of the sound waves that strike

Table 1 Information on each classroom in the preschool, primary, secondary and high schools

Location	Size of the location (m^2)	Flooring material	Wall material	Age of students	Total number of students	Attendance in the day of measurement	Occupancy (%)
Activity (old)	200	Carpet	Wood + cement	4–6	200	120	60
Activity (new)	180	Plastic	Wood + cement	4–6	96	72	75
KD1 (old)	36	Plastic	Cement	4–5	22	11	50
KD1 (new)	30	Plastic	Cement	4–5	20	10	50
KD2 (old)	36	Plastic	Cement	5–6	15	9	60
KD1 (new)	30	Plastic	Cement	5–6	17	14	82.4
G1	42.25	Ceramic	Cement	6–7	25	22	88
G2	42.25	Ceramic	Cement	7–8	25	20	80
G3	42.25	Ceramic	Cement	8–9	25	24	96
G4	42.25	Ceramic	Cement	9–10	27	25	92.5
G5	42.25	Ceramic	Cement	10–11	29	24	82.7
G6	27.5	Cement	Cement	11–12	30	27	90
G7	27.5	Cement	Cement	12–13	30	28	93.3
G8	27.5	Cement	Cement	13–14	30	25	83.3
G9	27.5	Cement	Cement	14–15	30	30	100
G10	42.5	Ceramic	Cement	15–16	25	25	100
G11	42.5	Ceramic	Cement	16–17	25	25	100
G12	42.5	Ceramic	Cement	17–18	25	25	100

the ear (Lane et al. 2003). For this study, all data were collected within a period of 15 weeks, with a maximum of 3 weeks per school. The noise level was measured using CEL-63x series models for a period of 24 h, in which the children spend the day with their teachers. For details of CEL-63x series models, refer to Casella Measurement (2015). In general, dBA measurements are used for noise risk assessments, while dBC measurements are used for hearing protector selection (Casella Measurement 2015). The maximum, minimum and time-averaged noise levels are calculated and stored for all of the measurements, with all of the valid combinations of frequency weightings and time responses. Calibration of these meters is extremely simple and virtually error proof. CEL-63x calculates the average value of the sound level every 15 min. An Excel spreadsheet was created using the values from the device for each of the locations.

Questionnaire survey

The Occupational Health and Safety (OHS) Regulation requires that the noise exposure be reported for all workers exposed to noise levels (L_{Aeq}) higher than 85 dBA. Usually, the measured and analyzed data do not adequately assess the hearing issues associated with the exposure to high levels of noise. Thus, in order to assess the health issues associated with the noise levels on workers (teachers), a structured questionnaire (Table 2) was prepared to obtain the annoyance responses and negative effects on teachers because of noise pollution in the classrooms. The questionnaire was directed to the teachers, and several interviews were conducted. The questionnaires consisted of different questions that cover general information about the nature of the work, the health and learning-related conditions of teachers and the environmental characteristics of the study domain. The questionnaires were self-administered.

Statistical analysis

The OHS Regulation requires that worker's noise exposure be presented as: the daily noise exposure ($L_{EX,\ 8\text{-h}}$) in dBA, or peak sound level in dBA (The OHS 1996). Part 7 of the OHS (issued in August 1999 and revised in January 2005) states that the worker must not be exposed to noise levels above either of the exposure limits, which are 85 dBA $L_{EX,\ 8\text{-h}}$ daily noise exposure level, or 140 dBC peak sound level (The OHS 2005). In response to the Occupational Safety and Health Act of 1970 (Public Law 91-596, 1970), the National Institute for Occupational Safety and Health (NIOSH) developed the recommended exposure limit (REL) and permissible exposure limit (PEL) (NIOSH 1972). The NIOSH REL and PEL for occupational noise exposure are 85 and 90 dBA, respectively, as an 8-hour time-weighted average. Exposure at or above this levels is hazardous. Both REL and PEL are derived using $L_{EX,\ 8\text{-h}}$, and therefore, this study focuses also on estimating the $L_{EX,\ 8\text{-h}}$ for each class room.

$L_{EX,\ 8\text{-h}}$ can be estimated as shown in Eq. 1

$$L_{EX,\,8-h} = 10 \times \log 10 \times \left[\frac{t \times 10^{\left(\frac{L_{Aeq\,avg}}{10}\right)}}{8} \right] \quad (1)$$

where $L_{EX,\ 8\text{-h}}$ is the 8-h average noise exposure level in dBA, above which risk of hearing loss exists. $L_{EX,\ 8\text{-h}}$ is estimated based on the standard 8 h per day, 5 days per week work pattern. t is the time of exposure in hour (h). $L_{Aeq\ avg}$ is the logarithmic average of the noise levels in the class room during the working hours. $L_{Aeq\ avg}$ can be calculated as shown in Eq. 2.

$$L_{Aeq\,avg} = 10 \times \log 10 \times \left[\frac{\sum_{i=1}^{n} 10^{\left(\frac{X_i}{10}\right)}}{n} \right] \quad (2)$$

where X_i is the equivalent steady sound level (L_{Aeq}) in dBA and n is the total number of measurements in the class room during the working hours (7:30 AM to 1:45 PM).

Table 2 Questionnaires provided to teacher's interview

No.	Questionnaires	Symbol
1	Teachers spent more than two hours in the classroom with the children	Q1
2	Teachers suffer from vocal cords problem sometimes	Q2
3	Teachers suffer from hoarseness, straining and intermittently voice problems sometimes	Q3
4	Teachers suffer temporary or chronic headache problems sometimes	Q4
5	Teachers have sleep disorders symptoms sometimes	Q5
6	Teachers feel tired and fatigue after work time	Q6
7	Teachers agreed that they use load voice over long periods of time	Q7
8	Teachers agreed that noise sometimes effect on the concentration of students in the classroom	Q8
9	Teachers agreed that noise outside the classroom leads to less attention while teaching	Q9
10	Teachers close windows and doors in order to increase the concentration of the students in the classroom	Q10

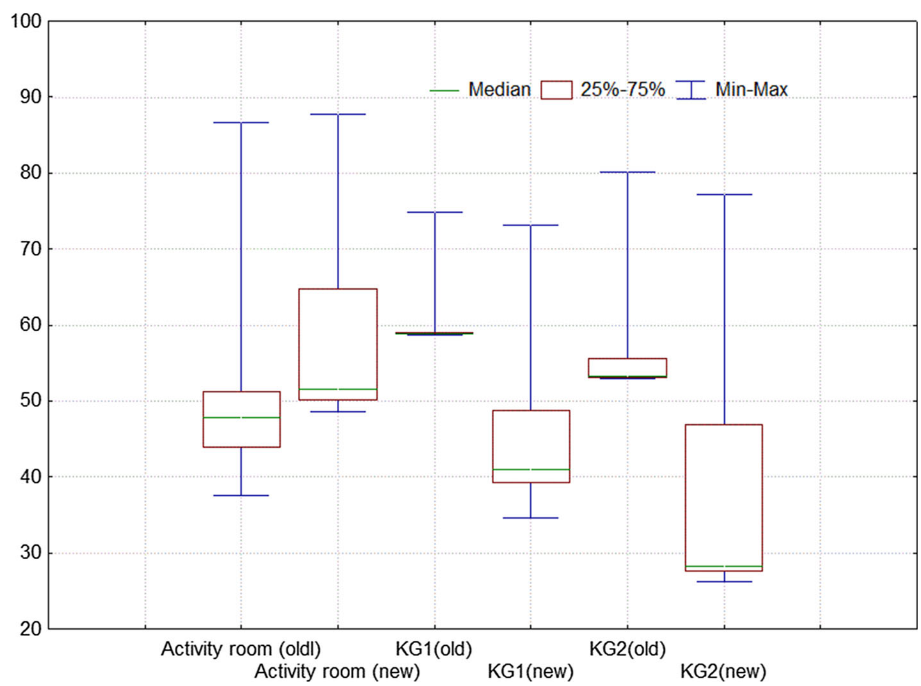
The collecting data from the CEL-63x and the completed questionnaires were entered in Microsoft Excel spreadsheets and were imported into the Statistica software package for analyses. In addition to that, frequency distribution tables and other descriptive statistics such as the median, maximum, minimum and percentages were used to summarize the study data in tabular and graphical formats. A graphical tool was used to highlight and clarify the main findings.

Results and discussion

Noise pollution levels in preschools

The World Health Organization (WHO) has specified standard background noise level for classrooms as 35 dBA [A-weighting equivalent sound level (L_{Aeq})] during teaching sessions in the guideline for community noise (WHO 1999). The results show that the new preschool classrooms meet the WHO standard for background noise level, while the old preschool classrooms violate these standards. Figure 1 shows the maximum, minimum and median noise levels (L_{Aeq}) values in the preschools. The maximum values in KG 1 and KG 2 classrooms were found in the older school, and the minimum values were found in the new school. This result is due, in part, to the materials used in building the schools and the size of the classrooms. The results also show that there is a fluctuation in noise levels that appeared in the new school, whereas the older school shows a steadily variation most of the day. For the activity rooms in the preschools, the recorded L_{Aeq} values were largely similar for the preschools before the nonworking hours. During the working hours, the results show a different pattern in which the noise levels were differed greatly between the two schools. During the school day, this area could not reach the allowable standard noise level in school facilities. The minimum noise levels are 37.5 dBA and 48.6 dBA in the old and new preschools, respectively. These measurements were taken in a quiet environment in which neither children nor teachers were present to be an indicator for the background noise level. The primary source for the noise was the air conditioning system. It was reasonable that the maximum L_{Aeq} value is found to be 87.7 dBA in the new preschool at 8:00 am when the activity hour is in progress and 86.6 dBA at 11:15 am in the older preschool when a special activity for all of the children was performed. A lower occupancy during the measurement period in the older preschool contributed to the reduction in the noise level when compared with the new preschool. The presence of carpeted floors may be another primary reason for the reduced noise level. The noise produced by the children varied according to the activity they were performing inside the room, such as painting and writing, which are quieter activities than free activities and games. For the KG 1 and KG 2 classrooms, the results prevailed different trends. Higher noise levels were observed in the old preschool. For the KG 1 classrooms, the background noise levels were 58.7 and 34.6 dBA for the old and new preschools, respectively. Figure 2

Fig. 1 L_{Aeq} in the two preschools



shows that during the school day, the schools do not reach the standard noise level, except for the new school at nonworking hours, when the minimum L_{Aeq} value recorded was 34.6 dBA. At that time, all of the children had relocated to the activity room, except for the students who were late. On the day of measurement, only two late students were in the classroom. The children in KG1 (new school) are exposed to an average L_{Aeq} value of 45.2 dBA and a maximum L_{Aeq} value of 73.1 dBA. Conversely, the classroom in the older preschool exhibited higher L_{Aeq} values than the classroom in the new preschool. The maximum L_{Aeq} value was recorded at 10:45 am as 74.8 dBA. For the KG2 classrooms in the preschools, it was shown that the L_{Aeq} values measured at the older school were higher compared with those at the new school, exceeding the maximum permitted level according to the reference standards (see Fig. 2). The background noise level at the older preschool in KG2 classroom was 53 dBA, which is 18 dBA higher than the acceptable limit. On measurement day, the classroom air conditioner in the old preschool did not function properly and required maintenance, which could be a major reason that the minimum L_{Aeq} was not equal to the standard limit. Among all the rooms tested in the preschools, only KG 2 classroom in the new school met the standard limits and did not exceed 35 dBA during the nonworking hours. Table 3 represents the detailed statistical information of all of the measurements.

The logarithmic averages of the noise levels ($L_{Aeq\ avg.}$) in the activity rooms from 7:30 to 11:30 AM were calculated using Eq. 2 and were 76.9 and 78.3 dBA for the old and new schools, respectively. The activities duration in that day was 4 h, and thus Eq. 1 was used to estimate the noise exposure levels ($L_{EX,\ 8\text{-}h}$) averaged over 8 h. $L_{EX,\ 8\text{-}h}$ for the activity rooms in the old and new schools were 73.9 and 75.3 dBA, respectively. The activity room in the new school has a smaller area, which could be the main reason for the higher levels of noise in that room. Table 4 summarizes the logarithmic averages of the noise levels ($L_{Aeq\ avg.}$) and the noise exposure levels ($L_{EX,\ 8\text{-}h}$) averaged over 8 h for all activity and classrooms in the old and new preschools.

When they are unoccupied, the new school classrooms have a lower noise levels compared with the old one classrooms. The A-weighting equivalent steady noise level (L_{Aeq}) for KG1 and KG2 in the new preschool ranged between 31 and 41 dBA, while the old preschool shows a higher noise levels that ranged between 54 and 59 dBA when it is unoccupied, which violates WHO standards for unoccupied classrooms. Nevertheless, KG2 class room in the new preschool had higher $L_{Aeq\ avg.}$, leading to higher $L_{EX,\ 8\text{-}h}$. The reason beyond this increase is the larger number of students in the new preschool (14 students) relative to the old one (10 students) in the day of measurements as given in Table 1. In general, the noise exposure levels in the preschool class rooms did not violate OHS and NIOSH standards.

Noise pollution levels in schools

Primary school

In grade 1 and grade 2, every four student shared the same table, and there are five large tables per classroom. Classes from grade 3 to higher grades contain a disk for each student. Therefore, the noise produced by moving disks could be neglected in grades 1 and 2 classrooms. $L_{Aeq\ avg.}$ and $L_{EX,\ 8\text{-}h}$ were estimated for primary school classrooms and given in Table 4. Grade 5 has the highest $L_{Aeq\ avg.}$ (93.2 dBA), while the lowest $L_{Aeq\ avg.}$ were found in grade 3 classroom. The highest $L_{EX,\ 8\text{-}h}$ was estimated to be

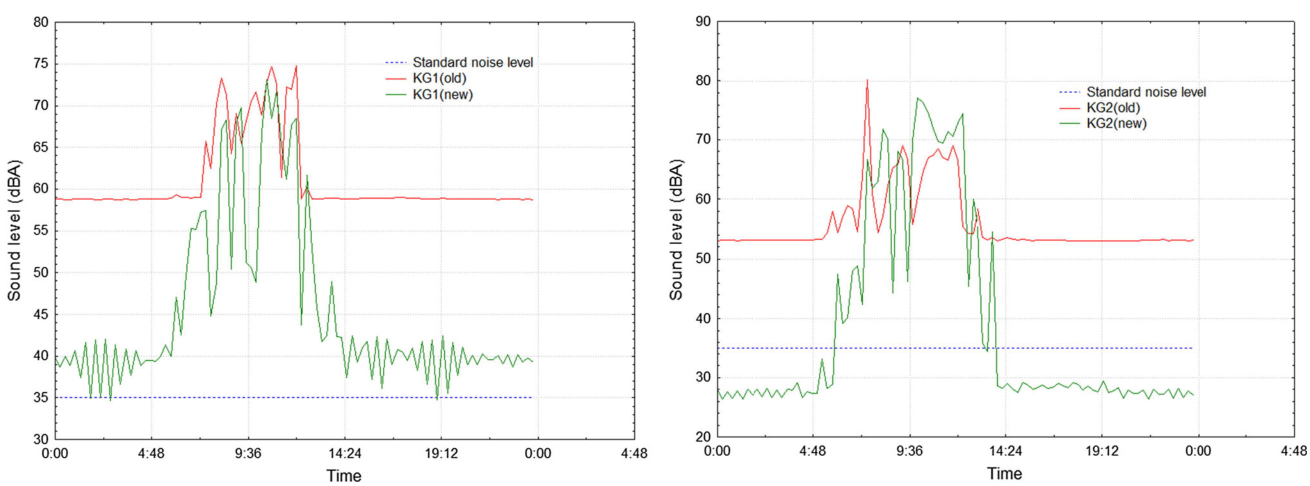


Fig. 2 L_{Aeq} measurements in KG1 and KG2 classrooms

Table 3 $L_{Aeq\ avg.}$ and $L_{EX,\ 8\text{-}h}$ data in dBA for preschool, primary, secondary and high schools

Grade number	$L_{Aeq\ avg}$	$L_{EX,\ 8\text{-}h}$
Activity room (old)	76.9	73.9
Activity room (new)	78.3	75.3
KG1 (new)	70.9	68.4
KG1 (old)	66.9	64.4
KG2 (old)	69.6	67.1
KG2 (new)	71.3	68.8
One	84.4	83.3
Two	79.2	78.1
Three	76.3	75.2
Four	79.5	78.4
Five	93.2	92.1
Six	85.8	84.7
Seven	95.8	94.7
Eight	88.6	87.6
Nine	76.1	75.0
Ten	81.4	80.3
Eleven	84.2	83.1
Twelve	74.3	73.2

92.1 dBA and found in grade 5 classroom. One exceedance was recorded in the primary school, specifically in grade 5, in which the $L_{EX,\ 8\text{-}h}$ exceeded the OHS standard and the recommended exposure limit (REL) and permissible exposure limit (PEL) of the NIOSH.

Additionally, Fig. 3 shows the continuous noise levels (L_{Aeq}) in each classroom. The arithmetic mean noise levels in the unoccupied classrooms are 40.3, 38.4, 50.7, 50.8 and 51.7 dBA for grades 1 to 5, respectively, and 78.3, 66.3, 67.3, 76.6 and 52.6 dBA when the classrooms are occupied, respectively. Therefore, empty classrooms in the primary school do not meet the standard limit of classroom noise level of the WHO. The maximum noise level of 105.4 dBA is observed in grade 5 classroom. While grade 5 classroom has the maximum noise level, grade 1 classroom has the lowest noise levels (30.4 dBA) when compared with other grades as shown in Fig. 3. Moreover, Fig. 3 shows a significant drop in the noise measurement during the working hours (7:30 AM to 1:45 PM). Grade 5 window lies on the backyard of the school, this area is very quiet during the classes, and thus most of the time teacher opens the window to let fresh air in. This could be the main reason for the

Table 4 Statistical analysis of noise levels during occupied and unoccupied school's classrooms

Grades	Unoccupied levels				Occupied levels			
	Arithmetic mean	Minimum	Maximum	Standard deviation	Arithmetic mean	Minimum	Maximum	Standard deviation
Activity (old)	–	–	–	–	52.5	37.5	86.6	15.8
Activity (new)	–	–	–	–	57.7	48.6	87.7	12.0
KG1 (old)	–	–	–	–	60.96	58.7	74.8	4.6
KG2 (new)	–	–	–	–	45.3	34.6	73.1	10.1
KG2 (old)	–	–	–	–	55.9	53.0	80.2	5.4
KG2 (new)	–	–	–	–				
G1	40.6	30.7	63.5	6.7	78.9	65.1	94.7	7.3
G2	38.3	35.3	75.2	6.6	67.5	35.6	89.9	16.5
G3	50.9	50.2	70.4	2.4	67.2	50.6	81.7	13.2
G4	50.9	49.4	72.1	4.2	77.1	53.0	84.7	6.8
G5	51.7	50.6	72.7	3.3	52.7	35.4	105.4	23.0
G6	56.2	55.2	81.1	3.1	77.4	53.3	96.5	9.9
G7	59.3	56.4	74.2	2.9	78.2	59.2	106.9	12.3
G8	48.2	45.4	63.2	3.4	72.3	47.8	100.9	14.2
G9	53.7	41.8	76.8	5.7	71.3	57.8	83.5	7.8
G10	41.5	40.7	51.8	1.3	70.5	48.6	91.7	11.6
G11	43.5	42.0	56.6	2.2	71.7	51.4	97.8	10.0
G12	43.3	41.1	66.7	3.8	69.7	50.9	81.1	8.9

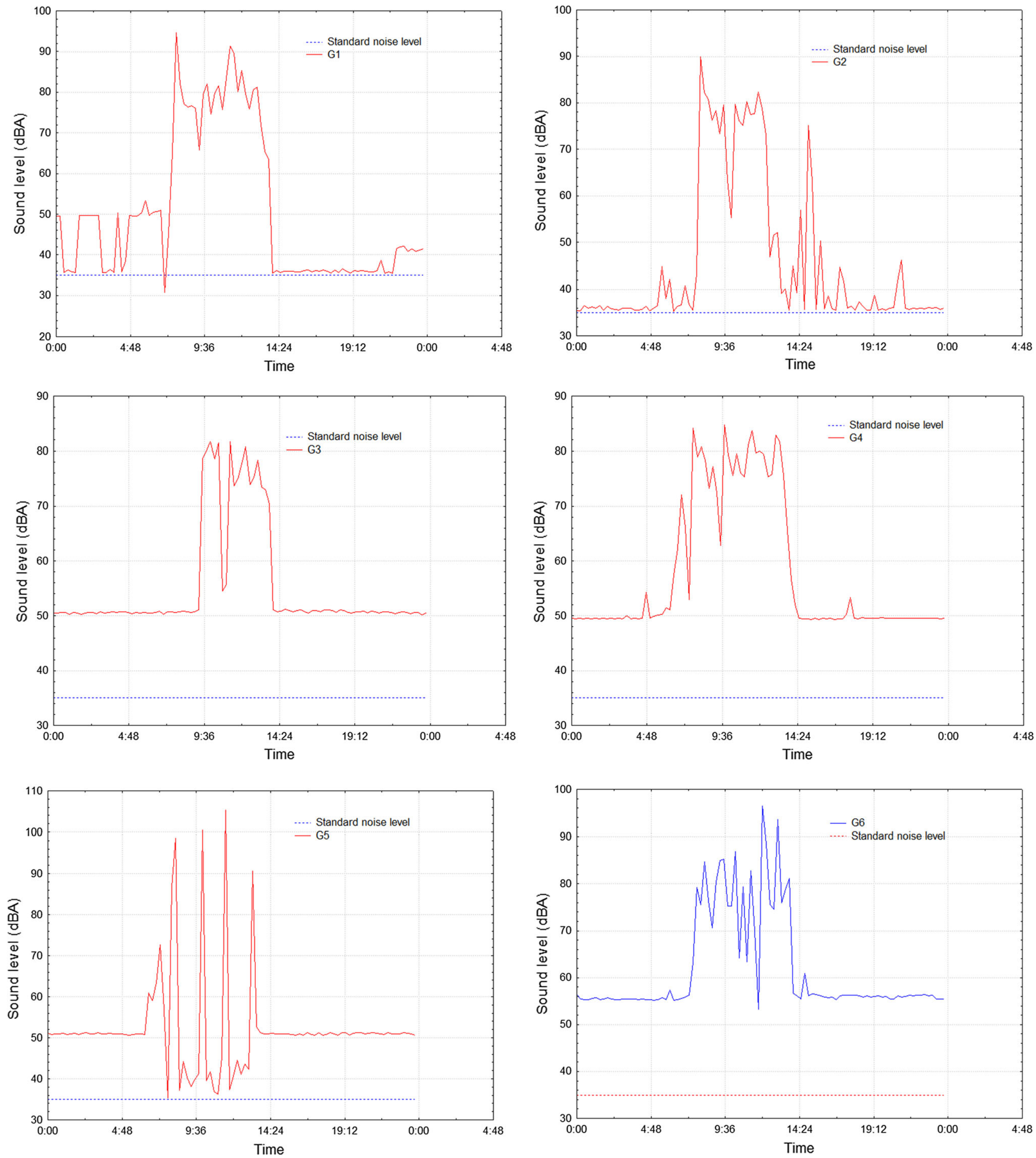


Fig. 3 Noise pollution levels in grade 1 to 6 classrooms

dropping noise levels most of the time. All of the classrooms show a maximum noise level that is higher than 80 dBA. This acoustic environment is not suitable for enhancing learning and teaching. When comparing the noise measurements data of this study with those from international studies, the results show that the arithmetic mean noise level in the primary school classrooms is relatively close to those measured worldwide. For example, the arithmetic mean noise level in this study is only a three-decibel difference than the arithmetic mean measured in 41 classrooms in Greece primary schools (Sarantopoulos et al. 2013).

Secondary school

Two exceedances were recorded in the secondary school, in grades 7 and 8 classrooms as given in Table 3.

Grade 8 classroom has $L_{EX,\ 8\text{-}h}$ of 87.6 dBA, that is, 2.6 decibels higher than the OHS standard and NIOSH recommended exposure limit (REL); however, the classroom does not violate the permissible exposure limit (PEL) of the NIOSH, which is 90 dBA. On the other hand, the noise exposure levels of grade 7 classroom violate the permissible exposure limit (PEL) of the NIOSH by approximately 5 decibels.

The equivalent continuous noise levels measured at different classrooms in the secondary school (grades 6 to 9) are shown in Figs. 3 and 4. When the classes were unoccupied, the minimum noise level for the most quiet classroom was 45.4 dBA (grade 8) and for the most noisy classroom was 56.4 dBA (grade 7), while the maximum sound level for the most quiet classroom was 57.6 dBA (grade 9) and for the most noisy classroom was 74.2 dBA (grade 7). The criterion for selecting the most quiet and noisy classrooms was based on the average noise level. During the school day (when the classes were occupied by students), the minimum sound level for the most quiet classroom was 47.8 dBA (grade 8) and for the most noisy classroom was 59.2 dBA (grade 7), while the maximum sound level for the most quiet classroom was 100.9 dBA (grade 8) and for the most noisy classroom was 106.9 dBA (grade 7). All of the unoccupied classrooms had a minimum noise level that exceeded the proposed limit value of 35 dB (WHO 1999; ANSI 2010; ASHA 2010), even the arithmetic mean noise level of unoccupied classrooms represented in Table 10 was greater than 35 dB, indicating a deteriorated acoustic environment. The unoccupied arithmetic mean noise levels are 56.2, 59.3, 48.2 and 53.6 and for the occupied classrooms 77.3, 78.2, 72.3 and 71.3 for grades 6, 7, 8 and 9, respectively, a range similar to those previously reported by other studies (e.g., Shield and Dockrell 2004).

High school

The high school contains very organized classrooms with curtains on windows that could be the reason for the relatively lower noise level in unoccupied classrooms. As a result, no violations were recorded for the high school classrooms. Table 11 lists the $L_{Aeq\ avg.}$ and $L_{EX,\ 8\text{-}h}$ for each classroom in the high school.

In addition, Fig. 4 shows equivalent steady noise levels in each classroom from grade 10 to grade 12. The arithmetic average noise levels measured in unoccupied classrooms of grade 10, 11 and 12 were 41.4, 43.5 and 43.1 dBA, respectively. This is about 7 decibels higher than the standard limit for unoccupied classrooms. The minimum noise level in unoccupied classroom was detected in grade 10 classroom to be 40.7 dBA, while the maximum noise level was detected in grade 12 classroom to be 66.7 dBA. When the classrooms were occupied by students, the average noise levels were 69.8 dBA, 70.7 dBA and 69.1 dBA for grade 10, grade 11 and grade 12 classrooms, respectively. The minimum sound level in the occupied classroom was detected in grade 11 classroom to be 44.9 dBA, while the maximum sound level was detected in grade 11 classroom to be 97.8 dBA.

The arithmetic mean, median, maximum and minimum noise levels in the twelfth occupied and unoccupied classrooms of the three schools are shown in Fig. 5. In an occupied classroom, the arithmetic mean values seem to be in the middle distance between the minimum and the maximum sound levels. Even though the secondary school seems to have the most annoying classrooms, primary school has higher noise levels with respect to their arithmetic mean values. As opposed to the primary and secondary school, the selected high school takes some precautions to reduce the noise levels in the classrooms. For example, the school uses quiet music to mark the beginning and the end sessions instead of using the regular bell. In addition, the high school tends to use curtains on the windows that could absorb the sound vibrations. Unfortunately, all of these precautions could not ensure a fully supportive acoustic environment for the classrooms. In the empty classrooms, the sound level does not meet the ultimate limit that WHO recommended, except in the 1st and 2nd grade where the minimum sound level recorded was 30.7 dBA and 35.3 dBA, respectively. In the secondary and high school, the minimum sound level recorded was above 40 dBA in all classrooms, meaning that the noise is coming from indoor sources rather than the outdoor environment.

According to the above discussion, the two preschools and high school are considered safe indoor microenvironments with respect to noise pollution. However, the primary and secondary schools could be classified to have physical hazards with respect to their acoustic environment. By comparing the above results with the limits of the noise levels in classrooms in different countries (Zannin and Loro 2007), e.g., Brazil (40 dBA), Iran (40 dBA),

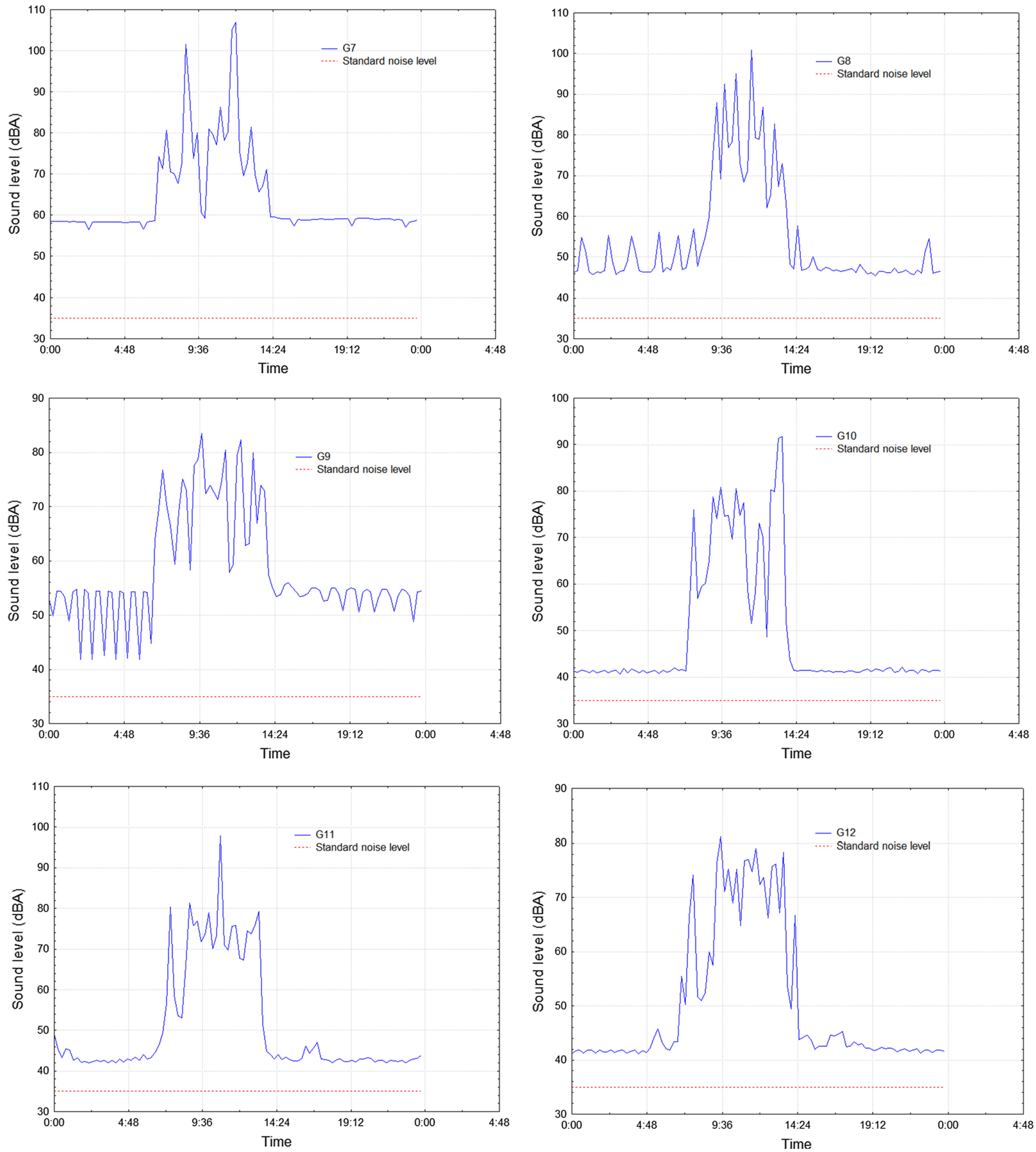
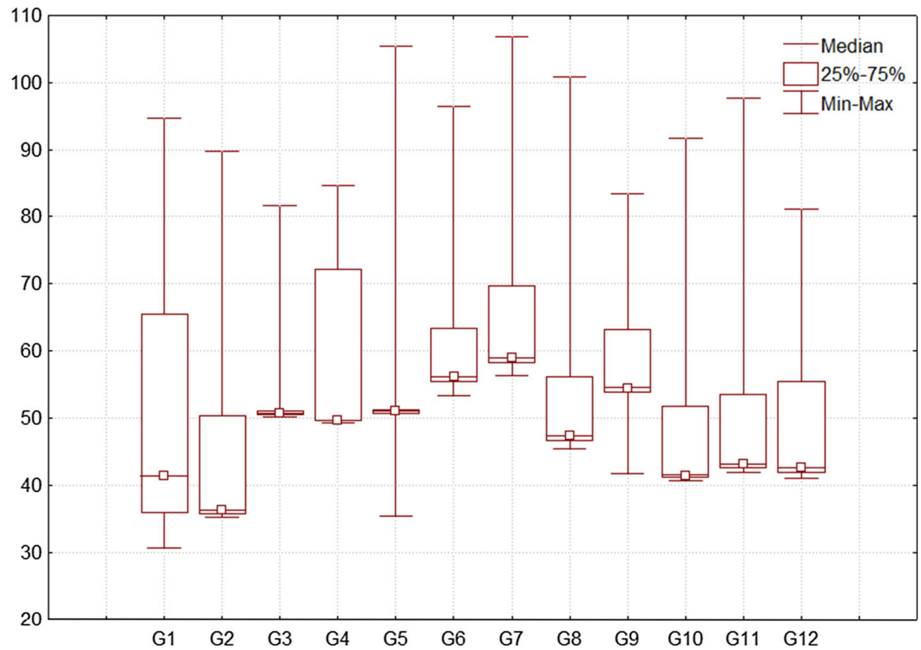


Fig. 4 Noise pollution levels in grade 7 to 12 classrooms

Japan (40 dBA), UK (35 dBA) and USA (40 dBA), it was indicated that the noise levels in Kuwait were higher than these countries. Not only exceeded the ultimate noise level states by WHO, but also did not satisfy the minimum classroom size and number of students per classroom addressed in the classic works of Hawkins and Lilly

Fig. 5 Statistical analysis of the noise pollution levels measured in 12 classrooms in the three different schools



(1998). This problem is clearly visible in the secondary school where 30 students share a 27.5-m^2 classroom. Since the schools located in quiet residential areas, the outdoor noise sources can be neglected. Thus, the contribution of various indoor noise sources such as the air conditioning (A/C), chair and desk movements and the students themselves could be the main reason beyond the high levels of noise. The three schools use old AC systems with lack of maintenance. Therefore, the AC systems produce annoying noise during the operation, resulting in an unacceptable background noise level that was observed in those schools when the classrooms were empty.

Noise pollution levels on teachers

Data from social survey are important to further assess and evaluate the health issues associated with exposure to high levels of noise, thereby ensuring that the study achieves its objectives. Several personal interviews were performed with many teachers who work in the preschools and schools of this study, to discuss the noise pollution problem in detail and its effect on their health. The questionnaires were distributed to 50 teachers in the two preschools and more than 200 teachers in the three schools. In analyzing the questionnaires data, the Cronbach's alpha (α) was used to measure the reliability of data. The value of α was 0.8, indicating a strong reliability of the questionnaires data between teachers.

The survey of this study shows that most of the teachers were speaking with high vocal efforts so that their speech can be understood. The survey also shows that teachers agree that their work is harmful to their physiological function. Many of the teachers had an abortion, premature delivery and even abnormal embryo cases caused by using loud voices while teaching.

Figure 6 shows the percentage of teachers who answered with YES to the questionnaire questions. More than 63 % of the teachers suffer from different voice problem, such as vocal cord problems, hoarseness, voice strain and intermittent voice problems, but only 25 % of them had visited a specialized doctor. The highest suffer of voice problems was found in the secondary schools. High school teachers appeared to be less suffering from vocal cords problems. When asked about temporary and chronic headaches, 50 % of the teachers consistently suffer from one and 40 % reported occasional headaches. According to the questionnaire, 30 % of the teachers visited a specialized doctor for headache problems. The majority of teachers reported feeling tired and fatigued after the school day. Teachers from preschools, primary, secondary and high school with a percentage of 60, 62, 63 and 56 % suffered fatigue after work time. Fifty percent of two preschool teachers suffer from sleep disorder problems, while 38 % of three schools teachers claim to have a sleep disorders problem. Several factors contribute to the enhancement of the noise pollution problem in the school's environment. One factor is the loud voice that teachers use in classrooms (85 % agreed). Another factor is students' loud voices or shouting while participating in the class activity (90 % agreed). In

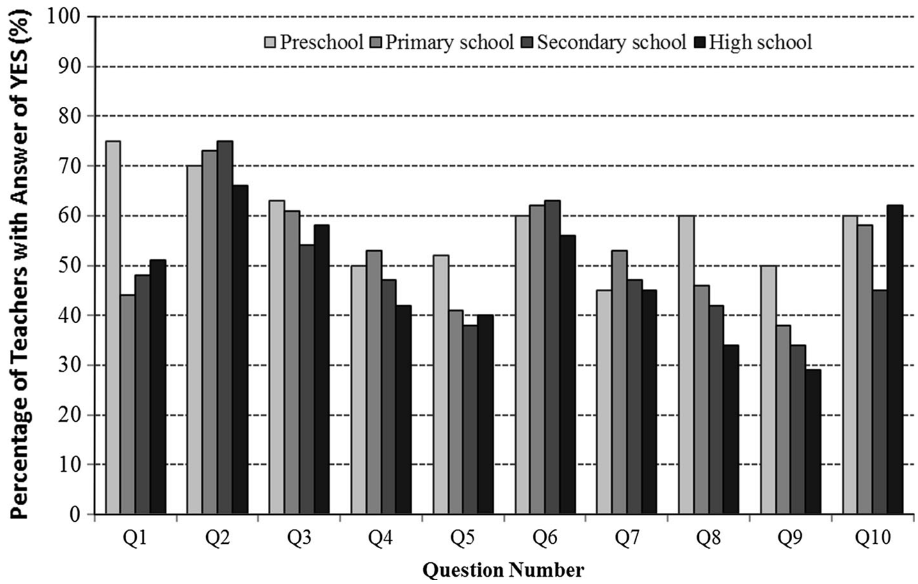


Fig. 6 Proportion of answers in percent of the distributed survey

addition, 55 % of the teachers agreed that outdoor noises, which lead to disturbances in studying and teaching, can contribute greatly to the noise pollution inside the classroom when speech with more vocal effort. Therefore, 62 % of high school teachers tend to close windows and doors in order to enhance student attentions in the classroom as 60 % of the preschools and 29 % of high school teachers agreed that the attention of students in the classroom could be affected seriously by ambient noise. Almost half of the teachers agreed that they always use loud voice over long periods of time.

Additionally, most of the teachers reported that they suffer from ear discomfort, such as ear ringing, ear pain and hearing loss because of their exposure to high noise levels in their schools. According to statistics, approximately 50 % of those who are exposed to noise levels above 75 dBA for a prolonged time lose their hearing. Other teachers reported feeling discomfort and feeling distracted because of high noise levels in their schools which could occasionally cause a decrease in their work efficiency.

Finally, most of the teachers admitted that they did not know about the noise level standards and regulations that are adopted by Kuwait government, indicating that the public remain uninterested in learning about the occupational health and safety regulations. Awareness of the effects of noise on the public is insufficient and should be given more attention.

Conclusion

The aim of this study was to evaluate the equivalent continuous, logarithmic average and 8-h average exposure to noise levels in all grades classrooms in preschools and schools using a digital sound level meter. The measured L_{Aeq}, $L_{Aeq\ avg.}$ and $L_{EX,\ 8\text{-}h}$ values were compared with the exposure limits according to the WHO, OHS and NIOSH standards and indicated the requirement for a serious reconsideration of noise pollution in educational facilities. Exceedances to these standards were observed in the primary and secondary schools. Thus, there is a concern that schoolchildren are exposed to high levels of chronic noise. The maximum value of noise levels appears in the secondary school. The values of noise levels in Kuwait were compared with those from different countries worldwide and found to be higher than the levels in many of these countries. Noise should be viewed as a nuisance that constitutes a health hazard to the recipients. The health issues associated with the exposure to high noise levels were also evaluated. The health problems found during the survey are potentially associated with hearing and voice problems, headaches and physiological function. Therefore, severe exposure to high sound levels could represent either directly or indirectly a serious threat to human physiology and hearing functions. The results of this study suggest that the ministry of education should have another view when designing new schools, such as building larger classrooms and wider schoolyards. Also, the new schools should not be located near main ambient noise sources. In addition, regular AC maintenance should be maintained to prevent noise during operation in schools. Isolation materials could be installed for ceiling in schools where central AC is available to minimize sound levels. Finally, it is recommended to use materials that reduce noises in classroom such as carpets and curtains. Awareness among people plays a vital role in implementing these recommendations and to minimize the noise pollution everywhere not only in schools.

Acknowledgments This work was carried out with funding from Kuwait University.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Abbreviations

dBA	A-weighting equivalent steady sound level L_{Aeq}
KG	Kindergarten
WHO	World Health Organization
OHS	Occupational Health and Safety
NIOSH	National Institute for Occupational Safety and Health

List of symbols

$L_{\text{Aeq avg}}$	Logarithmic average noise levels
$L_{\text{EX, 8-h}}$	Eight-hour average noise exposure level
X_i	Equivalent steady sound level (L_{Aeq}) in dBA
n	Total number of measurements in the class room
α	Cronbach's alpha

References

American National Standards Institute (ANSI) (2010) Specification for audiometers (ANSI S3.6-2010). ANSI, New York

American Speech-Language-Hearing Association (ASHA) (2010) Guidelines for manual pure tone threshold audiometry [Guidelines] 2005. Retrieved February 8, 2010 from http://www.asha.org/policy

Ana G, Shendell D, Brown G, Sridhar M (2009) Assessment of Noise and Associated Health Impacts at Selected Secondary Schools in Ibadan, Nigeria. J Environ Public Health 2009(739502):1–6

Astolfi A, Pellerey F (2008) Subjective and objective assessment of acoustical and overall environmental quality in secondary school classrooms. J Acoust Soc Am 123(1):163–173

Boman E, Enmarker I (2004) Factors affecting pupils' noise annoyance in schools: the building and testing of models. Environ Behav 36(2):207–228

Carmen PL, Paulo TZ (2004) Classroom acoustics in public schools: a case study. J Acoust Soc Am 115(5):2371–2375

Casella Measurement (2015) CEL-63x environmental and occupational noise meter, HB3356-03, user manual. http://www.casellasolutions.com/in/en/document-library/support-docs/63x-user-manual-hb3356_en.pd

Golmohammadi R, Ghorbani F, Mahjub H, Daneshmehr Z (2010) Study of school noise in the capital city of Tehran-Iran. Iran J Environ Health Sci Eng 7(4):365–370

Hawkins HL, Lilley HE (1998) Guide for school facility appraisal

Hodgson M (1999) Experimental investigation of the acoustical characteristics of university classrooms. J Acoust Soc Am 106(4):1810–1819

Ibrahim Z, Richard H (2000) Noise pollution at school environment located in residential area. Jurnal Kejuruteraan awam (J Civil Eng) 12(2):47–62

Klatte M, Hellbrück J (2010) Effects of classroom acoustics on performance and wellbeing in elementary school children: a field study. In: INTERNOISE 2010, Lisbon, Portugal, June 13–16, pp 1–9

Koszarny Z, Gorynski P (1990) Pupils's and teachers's exposure to noise in school. Rocz PZH 41:5–6

Koszarny Z (1992) Evaluation of school noise by teacher and assessment of its effect on health and general feeling. Rocz PZH 43(2):201–210

Lane WC, Kovacs J, McHarris O (2003) Intensity and energy in sound waves. Project PHYSNET, MISN-0-203

Montazami A, Wilson M, Nicol F (2012) Aircraft noise, overheating and poor air quality in classrooms in London primary schools. Build Environ 52:129–141

Noweir MH, Ikhwan MA (1994) Study of noise pollution in Jeddah schools. J Egypt Public Health Assoc 69(3–4):149–162

Otutu O (2011) Investigation of environmental noise within campus 2, Delta State University, Abraka, Nigeria. IJRRAS 6(2):223–228

Pujol S, Berthillier M, Defrance J, Lardiès J, Petit R, Houot H, Levain J, Masselot C, Mauny F (2012) Urban ambient outdoor and indoor noise exposure at home: a population-based study on schoolchildren. Appl Acoust 73:741–750

Schick A, Klatte M, Meis M (2000) Noise stress in classrooms. In: Contributions to psychological acoustics: results of the 8th Oldenburg symposium on psychological acoustics, pp 533–369

Schonwalder H, Bernde J, Strover F, Tiesler G (2004) Noise in schools-causes and reduction. Publication series from the Federal Institute for occupational safety and health, pp 1–16

Shield B, Dockrell JE (2003) The effects of noise on children at school: a review. Build Acoust 10(2):97–116

Shield B, Dockrell JE (2004) External and internal noise surveys of London primary schools. J Acoust Soc Am 115(2):730–738

Shield B, Dockrell J (2008) The effects of environmental and classroom noise on the academic attainments of primary school children. J Acoust Soc Am 123(1):12

The National Institute for Occupational Safety and Health (NIOSH) (1972) Occupational noise exposure. http://www.cdc.gov/niosh/docs/98-126/

The Occupational Health and Safety (OHS) Regulations (1996) Noise control and hearing conservation. http://www.qp.gov.sk.ca/documents/English/Regulations/Regulations/O1-1R1.pdf

The Occupational Health and Safety (OHS) Regulations (2005) Part 7 noise, vibration, radiation and temperature. http://www2.worksafebc.com/publications/ohsregulation/part7.asp

The United States Department of Labor, Occupational Safety and Health Administration (OSHA) (1970) Public law 91-569. https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=OSHACT&p_id=2743

The World Health Organization (WHO) (1999) Guidelines for community noise. http://www.who.int/docstore/peh/noise/guidelines2.html

Woolner P, Hall E (2010) Noise in schools: a holistic approach to the issue. Int J Environ Res Public Health 7:3255–3269

Xie H, Kang J, Tompsett R (2011) The impacts of environmental noise on the academic achievements of secondary school students in Greater London. Appl Acoust 72:551–555

Zannin PH, Ferreira AM (2009) Field measurement of acoustic quality in university classrooms. J Sci Ind Res 68:1053–1057

Zannin PH, Loro CP (2007) Measurement of the ambient noise level, reverberation time and transmission loss for classrooms in a public school. Noise Control Eng J 55(3):327–333

Zannin PH, Zwirtes DP (2009) Evaluation of the acoustic performance of classrooms in public schools. Appl Acoust 70:626–635