Analysis of the Factors Affecting Noise in Schools Using Experimental Design

Ali Yurdun Orbak (Corresponding author)
Industrial Engineering Department, Bursa Uludag University
Gorukle, 16059, Bursa, Turkey
E-mail: orbak@uludag.edu.tr

Fikret Umut Aydin
School of Natural and Applied Sciences, Bursa Uludag University
Gorukle, 16059, Bursa, Turkey
E-mail: aydin_umutt@hotmail.com

The research is financed by TUBITAK (The Scientific and Technological Research Council of Turkey) Project No. 114K738, Noise Pollution at School: Causes, Effects and Control (Sponsoring information)

Abstract

Sounds that are high enough to negatively affect our perceiving are called noise. Noise adversely affects students' success. The term (four different terms), the time when the noise measurement is taken (during courses or breaks), and location (corridor or classroom) are usually considered as main reasons of noise in schools. In this study, noise measurements are collected in several of Bursa's primary and secondary schools and factors which affect noise significantly are investigated. To analyze the data, general full factorial experimental design with four factors (term, time, location and school) is constructed. MINITAB 17 and Brüel & Kjaer Measurement Partner Suite programs are used for data analysis. Analysis results indicate that noise values exceed the limit values set by the World Health Organization (WHO) and also noise regulations currently in effect in Turkey. According to the experimental design results, for secondary schools, the school which has partial acoustic insulation, is less noisy than the school which doesn't have any acoustic insulation. Similarly, for primary schools, it was observed that school which has partial acoustic insulation, is less noisy than the school which doesn't have any acoustic insulation. Besides, among the four schools which measurements are collected, it was noted that the private school is less noisy than the selected public schools.

Keywords: Noise, noise pollution, experimental design, general full factorial designs

DOI: 10.7176/JSTR/5-5-06

1. Introduction

According to the researches conducted by the World Health Organization (WHO) and International Labor Organization, 0 dB(A) is the hearing threshold of the human ear, and there is no discomfort to the sounds between 0-30 dB(A). Psychological symptoms are observed for sounds between 30-60 dB(A) depending on personal sensitivity. Psychological, physiological and otologic disorders emerge for sounds between 65-85 dB(A) (Berglund et al., 1995).

Considering the regulations related to noise in schools, the Ministry of Environment and Urbanization (1986, 2005, 2008, 2010, 2011 and 2015), have taken necessary steps since 1986 when the first noise regulation was published in Turkey. According to the regulation in effect, the Ministry of Environment and Urbanization (2017) categorized buildings from A(for the best) to F(for the worst) according to acoustic classes, identified the permissible values of 39 dB(A) in classrooms and 49 dB(A) in corridors for the C class, which is the lowest level that buildings need to have and classified for the first time regarding reverberation (0.8 seconds for classrooms and 1.2 seconds for corridors). World Health Organization (WHO) determined the noise limit in schools as 55 dB(A) (Berglund et al., 1995).

Noise does not affect only people. The areas where animals are present also change depending on traffic noise (McClure et al., 2013). In their study, Nassiri et al. (2013) assigned tasks to university students for performing in various noisy environments, analyzed the completion period of these tasks and observed that intermittent high-level noise was more disruptive than continuous noise. People expect that the improvements to be made for reducing the environmental noise should be appropriate both technically and aesthetically (Hong and Jeon., 2014).

Lepore et al. (2010) investigated the effect of noise on blood pressure of students and discovered that students in noisy schools had higher body mass index compared to noise-free schools and noise could lead to obesity. In their study conducted in Hong Kong, Choi and McPherson (2005) argued that loudly speaking of teachers for a long time to make themselves heard caused health problems and schools needed to be improved about this issue. There are many examples in the literature putting forward the negative impact of noise on students' academic achievement. Ronsse & Wang (2013) observed in their study conducted in Nebraska that background noise affected the performance in language test while Dockrell & Shield (2006) observed in their study conducted in England that the noise occurring in the class while students are talking affected their performance in the test. Hygge (2003) reported the effects of the airport, train and road noises on students. In addition, Klatte et al. (2010) observed in their study conducted in Germany that reverberation duration did not directly affect the achievement of students.

In a research conducted in Torino, Astolfi & Pellerey (2008) detected that there was a stronger correlation between (the maximum value that the measured sound reaches) La_{max} and the noise disturbance of students compared to (the average value that the measured sound obtained through A filter) LA_{eq} and (the value more significant than 90% of the measured sound) LA_{90}. In the study mentioned in Trane Engineers Newsletter (2003), it was specified that even if the ventilation devices were turned off, there was a background noise 10-15 dB(A) higher than the recommended level, and one-third of the students could not be able to understand what their teachers said because of the architectural order of the class. In another study, it was observed in a questionnaire conducted on university students that they were mostly disturbed by the noise in the common halls (Hernandez et al., 2016).

Mealings (2016) determined the optimum conditions by examining the noise standards in the countries in the world.

In this study, noise measurements were made in order to investigate the causes of noise pollution in primary and secondary schools in Turkey and analyses were performed with the help of the experimental design by using these measurements. The student and physical structure of the schools determined for these measurements and analysis are briefly as follows. The first school is a private school consisting of 34 classrooms and 816 students and providing full-time education for primary and secondary school students. There is acoustic insulation in the corridors and classrooms. The second school is a public secondary school, which provides dual education, consists of 690 students and 24 classrooms. It is exemplary as a secondary school without any acoustic insulation precautions. Similarly, the third school, which is a dual education public primary school and does not have any acoustic insulation, consists of 1162 students and 19 classrooms. The last school, which is another public secondary school, provides full-time education and consists of 804 students and 25 classrooms. It has acoustic insulation similar to the first school. Private school is located in roadside and others are located at the center of the city. The schools, where this analysis was performed, are classified as insulated-uninsulated, private-public and primary-secondary and set a good example for Bursa and the metropolises in Turkey.

Another important point of this study is that no experimental design has been made regarding noise pollution in schools in Turkey until today.

2. Material and Method

Bursa is the fourth largest city of Turkey in addition to being an industrial center. In Bursa, full-factorial experimental designs were made with noise measurements including one private school (ÇEK) and three public schools (Sadettin Türkün, MMO and Dilek Özer). In this study which investigated the factors affecting noise in schools, the general full factorial design with two replications was performed (Montgomery, 2012). Table 1 shows the factors while Table 2 shows the results of the experiment.

Table 1. Factors and levels

Factor	Number of Levels	Levels
School	4	Schools (ÇEK, DİLEK ÖZER, MMO, SADETTİN)
Measurement Term	4	November2015, October2016, February2017, May2017
Time	2	During Course, During Break
Location	2	Class, Corridor

Table 2. Experiment Results

School	Measurement Term	Time	Location	Replication-1 La_{eq}, dB(A)	Replication-2 La_{eq}, dB(A)
ÇEK	November2015	During Course	Class	65.47	65.58
ÇEK	November2015	During Course	Corridor	54.38	54.78
ÇEK	November2015	During Break	Class	80.15	81.1
ÇEK	November2015	During Break	Corridor	81.49	81.77
ÇEK	October2016	During Course	Class	63.09	63.62
ÇEK	October2016	During Course	Corridor	53.99	54.68
ÇEK	October2016	During Break	Class	77.12	76.87
ÇEK	October2016	During Break	Corridor	74.85	74.4
ÇEK	February2017	During Course	Class	63.19	63.65
ÇEK	February2017	During Course	Corridor	55.91	55.72
ÇEK	February2017	During Break	Class	77.67	77.79
ÇEK	February2017	During Break	Corridor	80.16	81.37
ÇEK	May2017	During Course	Class	63.54	63.21
ÇEK	May2017	During Course	Corridor	58.68	58.93
ÇEK	May2017	During Break	Class	79.63	80.39
ÇEK	May2017	During Break	Corridor	80.72	80.07
DİLEK ÖZER	November2015	During Course	Class	60.48	59.9
DİLEK ÖZER	November2015	During Course	Corridor	55.74	57.39
DİLEK ÖZER	November2015	During Break	Class	73.92	78.16
DİLEK ÖZER	November2015	During Break	Corridor	81.64	83.41
DİLEK ÖZER	October2016	During Course	Class	66.1	67.45
DİLEK ÖZER	October2016	During Course	Corridor	61.92	62.59
DİLEK ÖZER	October2016	During Break	Class	79.5	79.64
DİLEK ÖZER	October2016	During Break	Corridor	77.48	77.41
DİLEK ÖZER	February2017	During Course	Class	70.89	71.87
DİLEK ÖZER	February2017	During Course	Corridor	62.25	62.59
DİLEK ÖZER	February2017	During Break	Class	81.01	80.79
DİLEK ÖZER	February2017	During Break	Corridor	82.49	82.52
DİLEK ÖZER	May2017	During Course	Class	66.38	67.06
DİLEK ÖZER	May2017	During Course	Corridor	61.08	61.36
DİLEK ÖZER	May2017	During Break	Class	82.91	83.76
DİLEK ÖZER	May2017	During Break	Corridor	80.11	80.22
MMO	November2015	During Course	Class	66.72	67.43
MMO	November2015	During Course	Corridor	57.96	57.78
MMO	November2015	During Break	Class	83.32	78.2
MMO	November2015	During Break	Corridor	82.59	83.98
MMO	October2016	During Course	Class	66.87	65.57
MMO	October2016	During Course	Corridor	65.51	65.34
MMO	October2016	During Break	Class	81.92	83.07
MMO	October2016	During Break	Corridor	80.9	82.74

School	Measurement Term	Time	Location	Replication-1 La_{eq}, dB(A)	Replication-2 La_{eq}, dB(A)
MMO	February2017	During Course	Class	62.98	63.63
MMO	February2017	During Course	Corridor	68.95	69.2
MMO	February2017	During Break	Class	78.77	76.69
MMO	February2017	During Break	Corridor	82.31	82.59
MMO	May2017	During Course	Class	66.43	66.6
MMO	May2017	During Course	Corridor	66.87	67.56
MMO	May2017	During Break	Class	76.91	75.95
MMO	May2017	During Break	Corridor	78.72	78.46
SADETTİN	November2015	During Course	Class	67.38	67.68
SADETTİN	November2015	During Course	Corridor	57.62	58.11
SADETTİN	November2015	During Break	Class	79	81.28
SADETTİN	November2015	During Break	Corridor	79.07	78.96
SADETTİN	October2016	During Course	Class	65.97	64.84
SADETTİN	October2016	During Course	Corridor	58.36	58.6
SADETTİN	October2016	During Break	Class	77.88	78.62
SADETTİN	October2016	During Break	Corridor	80.89	82.31
SADETTİN	February2017	During Course	Class	64.62	65.37
SADETTİN	February2017	During Course	Corridor	58.05	58.28
SADETTİN	February2017	During Break	Class	82.07	82.7
SADETTİN	February2017	During Break	Corridor	77.83	76.78
SADETTİN	May2017	During Course	Class	67.05	67.77
SADETTİN	May2017	During Course	Corridor	56.89	57.12
SADETTİN	May2017	During Break	Class	80.78	80.89
SADETTİN	May2017	During Break	Corridor	74.2	74.53

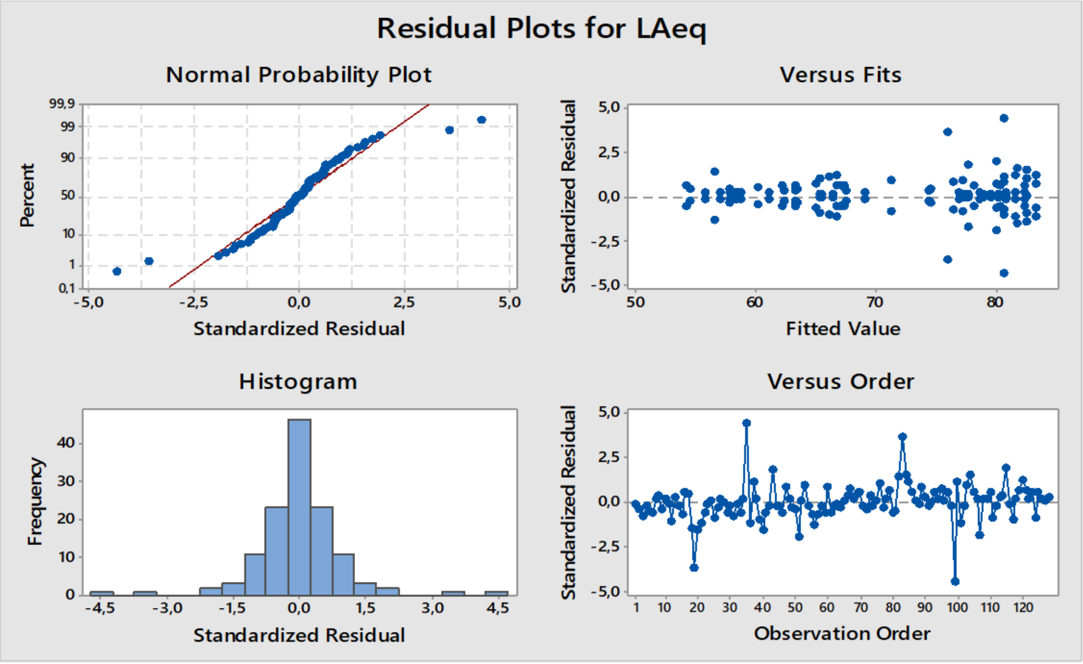

Figure 1. Residual Plots

When the residual analysis graphics in Figure 1 are examined, it can be stated that the data set is appropriate for experimental design.
When the mean of LA_{eq}'s change line showing the change according to measurement period of noise averages in Figure 2 is analyzed, it is observed that there is an increase in the three periods in Dilek Özer and a decrease in the following periods. In MMO, the average of noise decreases after one-period increase while there is a tendency to increase after a one-period decrease in ÇEK. There is a steady downward tendency in Sadettin Türkün.

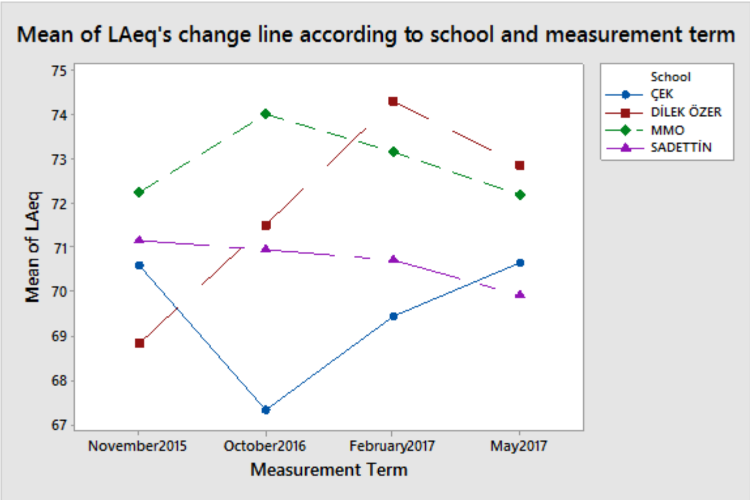

Figure 2. Mean of LA_{eq}'s Change Line

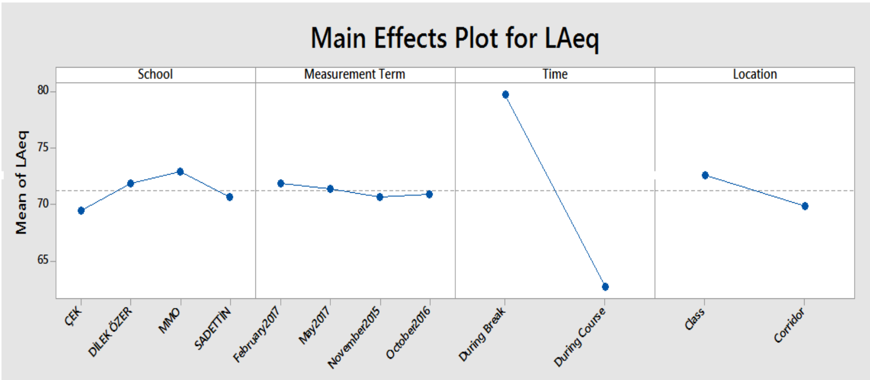

Figure 3. Main Effects Graph

When the results of the analysis were examined, the main effects graphic in Figure 3 showed that the time of measurement was the most effective factor.

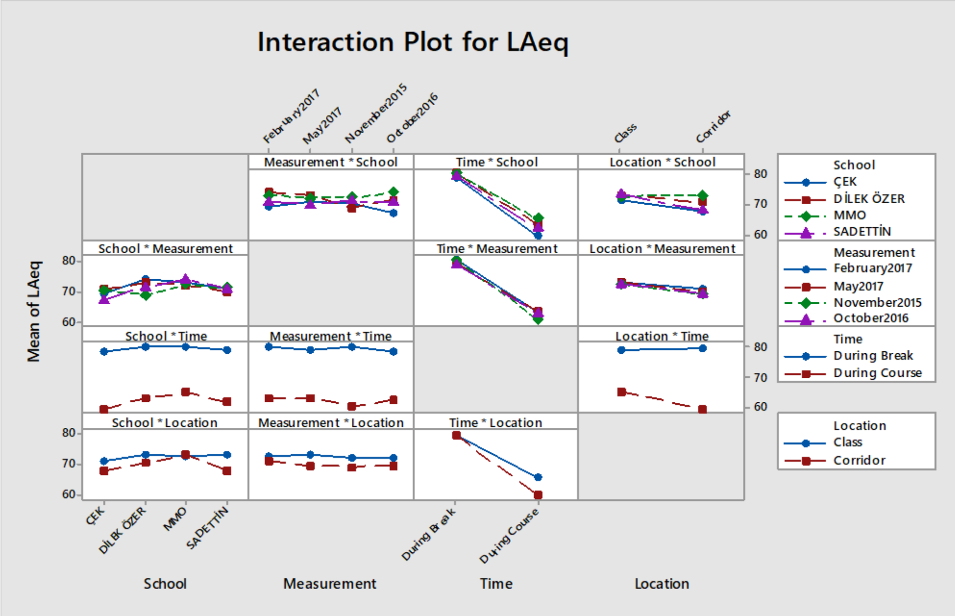

Figure 4. Interaction Plot

According to the interaction plot in Figure 4, it is seen that the school-measurement period, school-time, measurement period-time, measurement time-place, and time-place affect each other.

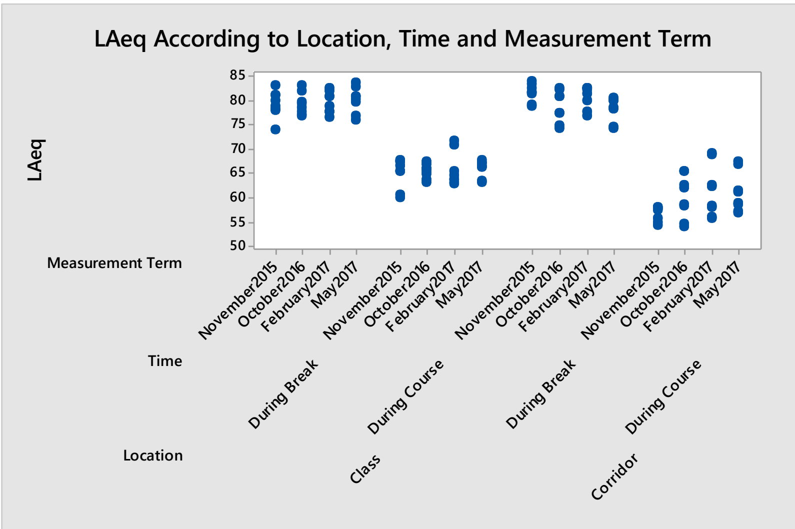

Figure 5. LA_{eq} According to Location, Time and Measurement Terms

When the graphic in Figure 5 showing the LA_{eq} changes depending on place, time and measurement period was analyzed, the measurements made in the class were lower than the measurements made in the break, the measurements made in the classroom during the course were higher than the measurements made in the corridors during the course and the noise levels in the classrooms and corridors were close to each other in the breaks. A decrease was observed in the measurements made in the corridor during the break depending on the measurement period.

ANOVA results were given in Figure 6. According to Figure 6, 3-way and 4-way interactions were found to have a statistically significant effect in addition to the main factors and 2-way interactions (R^2 = 99.60%). The effective factors were determined by taking p= 0.05. According to this experimental design, the noise in the break hours was higher than the noise in the course hours and the noise in the classroom was higher than the noise in the corridor. In addition, the lowest level of noise was observed in ÇEK which is a private school.

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	63	11018,5	174,90	255,33	0,000
Linear	8	9806,0	1225,75	1789,44	0,000
School	3	207,5	69,16	100,97	0,000
Measurement Term	3	26,8	8,92	13,02	0,000
Time	1	9330,6	9330,63	13621,53	0,000
Location	1	241,1	241,15	352,05	0,000
2-Way Interactions	22	785,0	35,68	52,09	0,000
School*Measurement Term	9	185,6	20,62	30,10	0,000
School*Time	3	67,3	22,44	32,75	0,000
School*Location	3	157,2	52,39	76,48	0,000
Measurement Term*Time	3	71,5	23,85	34,82	0,000
Measurement Term*Location	3	13,3	4,43	6,47	0,001
Time*Location	1	290,1	290,13	423,56	0,000
3-Way Interactions	24	365,3	15,22	22,22	0,000
School*Measurement Term*Time	9	100,6	11,18	16,32	0,000
School*Measurement Term*Location	9	173,1	19,23	28,07	0,000
School*Time*Location	3	30,5	10,16	14,84	0,000
Measurement Term*Time*Location	3	61,2	20,39	29,76	0,000
4-Way Interactions	9	62,1	6,89	10,07	0,000
School*Measurement Term*Time*Location	9	62,1	6,89	10,07	0,000
Error	64	43,8	0,68		
Total	127	11062,3			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0,827642	99,60%	99,21%	98,41%

Figure 6. ANOVA Results

3. Conclusion and Discussion

In this study which analyzed the factors affecting noise in schools by the means of experimental design, different changes were observed in the level of noise depending on the interaction between school-place according to the general full factorial design with 2 replications where the difference between a private school (ÇEK) and three public schools (SADETTİN TÜRKÜN, MMO, DİLEK ÖZER). While MMO School had similar levels of noise in its classrooms and corridors, the measurements in the classroom at Sadettin Türkün, ÇEK, and Dilek Özer Schools were higher than the measurements in their corridors. The most distinct difference was found in Sadettin Türkün School (5.39 dB(A)).

According to the interaction between time and place, a difference of 14.06 dB(A) in the measurements in the classes and 20.09 dB(A) in the corridors was observed in the noise levels between the course hours and breaks for all schools. The reason for the higher level of difference in the corridors can be explained by the fact that the corridor noise in the course hour was lower than the noise in the classroom.

Depending on the period, a difference of 2.67 dB(A) between the measurements in the course hour and a difference of 1.40 dB(A) between the measurements in the break time occurred. Accordingly, the break measurements did not show a significant change depending on the period.

Between the break and course hours according to the change of noise level in school based on the measurement time, a difference of 19.20 dB(A) was observed in ÇEK school, 16.87 dB(A) in Dilek Özer, 15.11 dB(A) in MMO and 17.12 dB(A) in Sadettin Türkün. This result once more revealed the effectiveness of the measurement time.

According to the change of the noise levels based on the measurement period, a steady downward tendency was only observed in Sadettin Türkün.

On the other hand, Sadettin Türkün had a lower noise level than Dilek Özer according to the comparison between secondary schools and ÇEK school had a lower noise level than MMO according to the comparison between primary schools. The partial acoustic insulation precautions in the schools of Sadettin Türkün and ÇEK were effective in the emergence of this result.

When the four schools were compared together, the noisiest school was MMO, and the quietest school was ÇEK. It is not surprising that ÇEK had the lowest level of noise since a certain amount of acoustic insulation can be accepted because of suspending ceiling.

The noise in the break hours was higher than the noise in the course hours and the noise in the classroom was higher than the noise in the corridor. School types (private or public school) were found to have a significant effect on noise. When the binary interactions were taken into consideration, the noise in the corridors and classrooms was similar during breaks while the noise in the classroom was higher than the noise in the corridor during the course hours. It was observed that the measurement period was the main factor having the lowest level of effect.

Although the levels of noise in the course seem to be low, according to World Health Organization (55 dB(A)) and the regulation prepared for the protection of the buildings against noise by the Republic of Turkey Ministry of Environment and Urbanization (2017), these noise levels were far above the boundary values in every measurement type.

Improvement can be made with the help of noise awareness training defined in the project “Noise Pollution at School: Causes, Effects, and Control” numbered 114K738 and supported by TÜBİTAK for reducing noise in schools.

In addition to training, acoustic insulation should be enabled in buildings. Some suggestions about this issue are as follows:

1-Acoustic Baffle

Acoustic baffle ceiling panels can be placed on the ceiling on the areas where the teacher desks are located. These panels are acoustic arrangement panels which provide sound insulation and a modern look to the environment.

These are modern sound insulation products used for solving reverberation, resonance, and noise in the environment. Baffle absorbs a high level of noise due to its particular glass wool structure and provides a healthier working environment. The energy in the acoustic wave hitting the surface of the sound baffle panels is turned into thermal energy due to the friction in the pores of the panel and decreases the sound energy reflecting backwards from the surface. The thickness in these panels is generally taken as 40 or 50 mm. Panels with 50x120 size can be placed on the ceiling at a distance of approximately 75-100 cm. This distance can be reduced according to the size and reverberation characteristics of classrooms.

2-Acoustic PVC Floor Coverings

The floor covering of the areas such as classrooms, cafeterias, corridors, multi-purpose halls (for reducing noise in case of pulling desks-tables, running or hitting) should be covered with noise reduction materials such as linoleum, etc. Acoustic PVC floor coverings are composed of many layers, and they come to the forefront with their flexibility and resistance. They can be used especially in kindergartens, meeting halls, conference halls and reading halls of libraries.

3-Acoustic Fabric Covered Panel

Since acoustic fabric covered panels are decorative products, they are generally preferred in acoustic places. They are used to regulate the acoustics in the site. They are among the materials that can provide more effective sound absorption when used in large areas. They are decorative products used to provide acoustic isolation. These panels can be used with 100-150cm x 50-75cm sizes on the walls of the classrooms with a very high level of noise. These products can be purchased or supplied from the stores selling building materials and made in a carpentry workshop or at home by placing in a wood frame.

In addition to these improvements, watchmen can be assigned on the floors.

As an application and to justify the results in this paper, in another private school (which is very similar in classroom and corridor size to ÇEK), the aforesaid improvements are implemented, and the noise level in classrooms was reduced to 63.18 dB(A) from 63.41 dB(A) in class during course and reduced to 68.52 dB(A) from 78.07 dB(A) in class during breaks. Much better improvements were obtained for corridors. Additionally, average reverberation of the improved school was measured to be 1.2-1.4 s. These values are very close to the regulation.

References

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.

Berglund, B., Lindvall, T. & Schwela, D. (1995) Guidelines for community noise. [Online] Available: https://infrastructure.planninginspectorate.gov.uk/document/2322958 (February 2, 2019)

Choi, C. ve McPherson, B. (2005) Noise levels in Hong Kong primary schools: Implications for classroom listening. *International journal of disability, development and education*. 52(4): 345-360.

Dockrell, J. ve Shield, B. (2004) Acoustical barriers in classrooms: the impact of noise on performance in the classroom. *British Educational Research Journal*. 32: 509-525.

Hernandez, E., Garcia I, Navarro, J.M.L., Campos-Canton, I. & Kolosovas-Machuca, E. S. (2018) Evaluation of psychoacoustic annoyance and perception of noise annoyance inside university facilities. *International Journal of Acoustics and Vibration*, 23(1):3-8.

Hong, J. ve Jeon, J. (2014) The effects of audio–visual factors on perceptions of environmental noise barrier performance. *Landscape Urban Plann*. 125: 28–37.

Hygge, S. (2003) Classroom experiments on the effects of different noise sources and sound levels on long-term recall and recognition in children. *Applied Cognitive Psychology*. 17: 895–914.

Klatte, M., Hellbrück, J., Seidel, J. & Leistner P. (2010). Effects of classroom acoustics on performance and well-being in elementary school children: A field study. *Environment and Behavior*. 42(5): 659-692.

Lepore, S., Shejwal, B., Kim, B. & Ewans, G.W. (2010). Associations between chronic community noise exposure and blood pressure at rest and during acute noise and non-noise stressors among urban school children in India. *Int. J. Environ. Res. Public Health*. 7(9): 3457-3466.

McClure, C.J., Ware, H.E., Carlisle, J., Kaltenecker, G. & Barber, J. R. (2013). An experimental investigation into the effects of traffic noise on distributions of birds: avoiding the phantom road. *Proc R Soc B*. 280(1773). DOI: 10.1098/rspb.2013.2290.

Mealings, K. (2016) Classroom acoustic conditions: Understanding what is suitable through a review of national and international standards, *Proceedings of Acoustics*, 9-11 November 2016, Australia, 1-10

Montgomery, D. (2012) *Design and Analysis of Experiments*, Eighth ed., Wiley.

Nassiri, P., Monazam, M., Dehaghi, B. F., Ibrahimi Ghavam Abadi, L., Zakerian, S. A. & Azam, K. (2013) The effect of noise on human performance: A clinical trial. *Int J Occup Environ Med*. 4(2): 87-95.

Republic of Turkey Ministry of Environment and Urbanization, (1986), Noise Control Regulation. [Online] Available: http://www.resmigazete.gov.tr/arsiv/19308.pdf (June 15, 2017)

Republic of Turkey Ministry of Environment and Urbanization, (2005), The Environmental Noise Assessment and Management Regulation. [Online] Available: http://www.resmigazete.gov.tr/eskiler/2005/07/20050701-7.htm (June 22, 2017)

Republic of Turkey Ministry of Environment and Urbanization, (2008). The Environmental Noise Assessment and Management Regulation. [Online] Available: http://www.resmigazete.gov.tr/eskiler/2008/03/20080307-6.htm (July 24, 2017)

ISSN 2422-8702 (Online), **DOI:** 10.7176/JSTR/5-5-06
Vol.5, No.5, 2019

Republic of Turkey Ministry of Environment and Urbanization, (2010). The Environmental Noise Assessment and Management Regulation. [Online] Available: http://www.resmigazete.gov.tr/eskiler/2010/06/20100604-5.htm (September 12, 2017)

Republic of Turkey Ministry of Environment and Urbanization, (2015). Amendment of The Environmental Noise Assessment and Management Regulation. [Online] Available: http://www.resmigazete.gov.tr/eskiler/2015/11/20151118-4.htm (September 19, 2017)

Republic of Turkey Ministry of Environment and Urbanization, (2011). Amendment of The Environmental Noise Assessment and Management Regulation. [Online] Available: http://www.resmigazete.gov.tr/eskiler/2011/04/20110427-3.htm (November 5, 2017)

Republic of Turkey Ministry of Environment and Urbanization, (2017). Regulation on the Protection of Buildings against Noise. [Online] Available: http://www.resmigazete.gov.tr/eskiler/2017/05/20170531-7.htm (December 14,2017)

Ronsse, L. & Wang, L. (2013) Relationships between unoccupied classroom acoustical conditions and elementary student achievement measured in eastern Nebraska. *J. Acoust. Soc. Am.* 133(3): 1480-1495

Trane Engineers Newsletter (2003). A new standard for acoustics in the classroom. 32(1).