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Sound Level Measurement and Spectrum Analysis in Full and Empty Various Social Spaces

Serden BAŞAK[1], Kazim Onur DEMİRARSLAN[*2]

Abstract

The noise seen in different areas throughout human history has turned into a frequently complained problem with the increasing industry and technology. Unfortunately, the problem of noise has become a part of social life today. Noise pollution, which is a side effect of urbanization and industrialization, threatens society's mental and physical health. However, knowing the noise level makes it possible to take precautions. In some cases where the sound limit levels set by laws and/or regulations of many countries are not exceeded, people may complain about the noise. Noises that occur in different places in educational institutions such as universities can cause adverse effects on both students and the administrative and academic staff working there. The noise in the places where the staff and students spend their time both for relieving their hunger and resting and socializing during their rest periods prevents people from relaxing. This situation causes people not to feel rested when returning to their lessons or work. In this analysis, the Artvin Coruh University staff dining hall's sound levels, the student dining hall, and the cafeteria/bowling alley spaces used by the students were measured when they were empty and full. Besides, the bandgap of the sounds complained about by the users was determined by spectrum analysis. As a result of the study, noise levels of 29.43 dB(A), 30.75 dB(A), and 32.94 dB(A) were obtained in the measurements made in empty spaces, and 56.10 dB(A), 57.56 dB(A)and 69.76 dB(A) in the measurements made in filled areas.

Keywords: Dining hall-cafeteria, noise, sound level measurement, spectrum analysis, social space

1. INTRODUCTION

Sound has guided humanity since its early ages and is now an indispensable part of our daily life. Considering the definition of sound, it is seen that it is made in two ways, physical and physiological. Physically sound; is a change in the balance pressure of the environment by a source that causes periodic vibrations in a flexible environment.

These pressure changes are conveyed to the environment's distant points with a constant velocity and a particular phase difference.

Physiologically sound is the perception that results from the transmission of pressure changes to the brain through the communication mechanism in the ear [1]. The lowest pressure

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variation perceived by humans is $2x10^{-5}$ Pascal (Pa) or 0 decibel (dB) [2, 3]. Noise, a different type of sound, started to be a social problem, especially after the industrial revolution [1]. Noise can simply be defined as unwanted sound. It is also a physical hazard and an environmental risk that poses a threat. There are various types of noise, such as transport noise emanating from roads, rail, air traffic, the noise created by human activity from industrial facilities, workplace noise produced by unwanted noise in the working environment [4]. More than 30% of Europe's population are exposed to noise levels higher than 55 dB(A) [5]. Noise exposure; varies depending on the source that emits the sound, how it is received by the human, the environment required for its propagation and perception [6].

According to the "Regulation on the Protection of Employees from Noise Related Risks" published in the Official Gazette dated 2013 and numbered 28721 (Republic of Turkey), the lowest exposure action values (L_{EX}, 8 hours) 80 dB(A), the highest exposure action values (L_{EX}, 8 hours) 85 dB(A) and exposure limit values (L_{EX}, 8 hours) are determined as 87 dB(A) [7]. These values indicate the amount of noise that the employee may be exposed to during work. However, the dosimeter is used to take these measurements during working hours.

The undesired and undesirable state of noise can vary from person to person due to different effects on people's psychology, nervous systems, and performances. However, its impact, which does not usually differ, is its effect on hearing. The effects of noise are analyzed in four categories: physical effects, physiological effects, psychological effects, and performance effects [1].

Prolonged exposure to noise increases the risk of coronary heart disease as well as psychological effects such as attention deficit. Besides diabetes, myocardial infarction, and hypertension, a series of predictable and short-term physiological responses through the autonomic nervous system, increased blood pressure, and peripheral vasoconstriction can also be seen. Other factors, both physical and psychosocial, associated with high blood pressure are also indicators of noise exposure [4, 5, 8, 9]. Continuous exposure to noise of 85-90 dB(A), especially in industrial environments, can lead to hearing loss in the future, increasing the threshold of hearing sensitivity [8]. As an element of stress, noise can also cause public health problems such as tension, nervousness, and difficulty sleeping [10].

Environmental noise is the unwanted noise in the environment and open-air arising from vehicles, road traffic, railway traffic, airway traffic, sea road traffic, construction sites, equipment used in open areas, industrial facilities, manufacturing plants, workplaces, and similar places and recreation areas. Besides, noise refers to the internal noise arising from the mechanical systems and other building sources and negatively affecting people in another space [11].

Unlike standard noise measurements, which measure noise intensity in decibels (dB), octave band analysis measures both the volume of noise in an area and the frequencies at which the noise occurs. The test is known as the "octave band analysis" because it relies on categorizing sounds into separate categories called "bands." Each band's frequency spectrum is referred to as an "octave," as the name implies. Octave band analysis allows noises with similar physical properties to be grouped so that environmental noise can be understood in terms of the cumulative volume of all the sounds within a particular band [12].

According to some literature, people feel some voices as noise with characteristic features. For example, if the sound is stuck in the narrowband range, it is perceived as louder than the same energy's broadband sound. Another example is related to the sound's rising period, and a sound that rises faster than two sounds of the same point is perceived as louder. An irregular, variable sound can be perceived as more audible than a stable sound [11]. The frequency spectrum of complex sounds, which do not consist of a single frequency, is a crucial definition of noise, which physically indicates the wave frequency and tonal property in perception. The noise's frequency content also affects the perception and the degree of disturbance [1]. According to the frequencies, the sounds are classified into three as low frequency (25-125 Hz), medium frequency (160-400 Hz), and high frequency (500-10000 Hz) sounds [11].

Noise is an environmental problem that can directly affect people's attention and work performance. Thus, the workplace's noise affects the employees' physical and mental health, and this situation may cause performance issues. The effects of noise in schools and universities where education is offered have the same effect on individuals. People are exposed to noise, particularly in places for dining, resting, and leisure. This situation creates a variety of different issues.

While the recommended noise level in restaurants is in the range of 50-55 dB(A), the noise level is specified as 45-50 dB(A) for fair listening conditions desired [13, 14].

According to the "Regulation on the Assessment and Management of Environmental Noise (RAMEN)," which was first published in the Official Gazette in 2010 and later changed its current form in 2011 and 2015 (Rebuplic of Turkey), the required noise level in dining halls is also 45 dB(A) when the windows are closed, and there is no activity in the dining hall [15]. Later, with the Environmental Noise Assessment and Management Regulation (2002/49/EC) made in the EU harmonization process, this value was revised to be 55 dB(A) during the activity [16].

In studies available in the literature, noise levels in restaurants were measured and reported. In this study, on the other hand, octave band analyzes were also made and evaluated. This situation reveals its difference from other articles.

People using the Artvin Coruh University dining hall verbally stated that specific voices, such as forks and knives, disturbed them at a busy period. In this study, sound levels were measured in the staff dining hall, student dining hall, and cafeteria/bowling alley. Also, the bandgap of disturbing sounds was determined by spectrum analysis.

2. MATERIAL AND METHOD

This study was carried out using the pathway in Figure 1. The measurements were carried out in the middle of Artvin Çoruh University staff and student dining halls and cafeteria/bowling alley, according to ISO 1966-I and 1996-II standards, on a tripod with a CESVA brand and SC310SB model (Class 1, Spain) which had valid calibration (Figure 2). The measurements made before the Covid-19 pandemic shows the situation in which the dining hall did not start service and the staff on duty prepared the food stalls (empty state). The other measurement belongs to when the dining hall is most used and demonstrates the noise condition of certain employees in the queue of the table d'hote as some employees eat at the tables (full state). The measurements made were analyzed with the program called CESVA Capture Studio (ver.9.13.0). There are 38 tables in the staff dining hall where 152 people can eat simultaneously, and it has been found from plans and projects that the area of this space is 492 m^2, and its volume is 1771 m^3. The student dining hall dimensions and the cafeteria/bowling alley located on the ground floor are 503 m^2 and 1630 m^3 for each space. The graphical representation of the measured places is given in Figure 3 without scale.

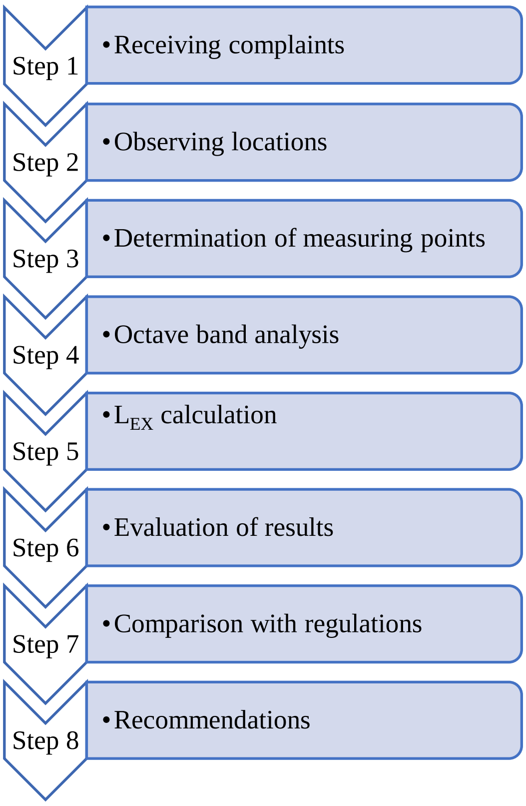

Figure 1 Pathway of the study

(A) (B)

Figure 2 (A) Staff dining hall empty measurement, (B) Full cafeteria/bowling alley measurement

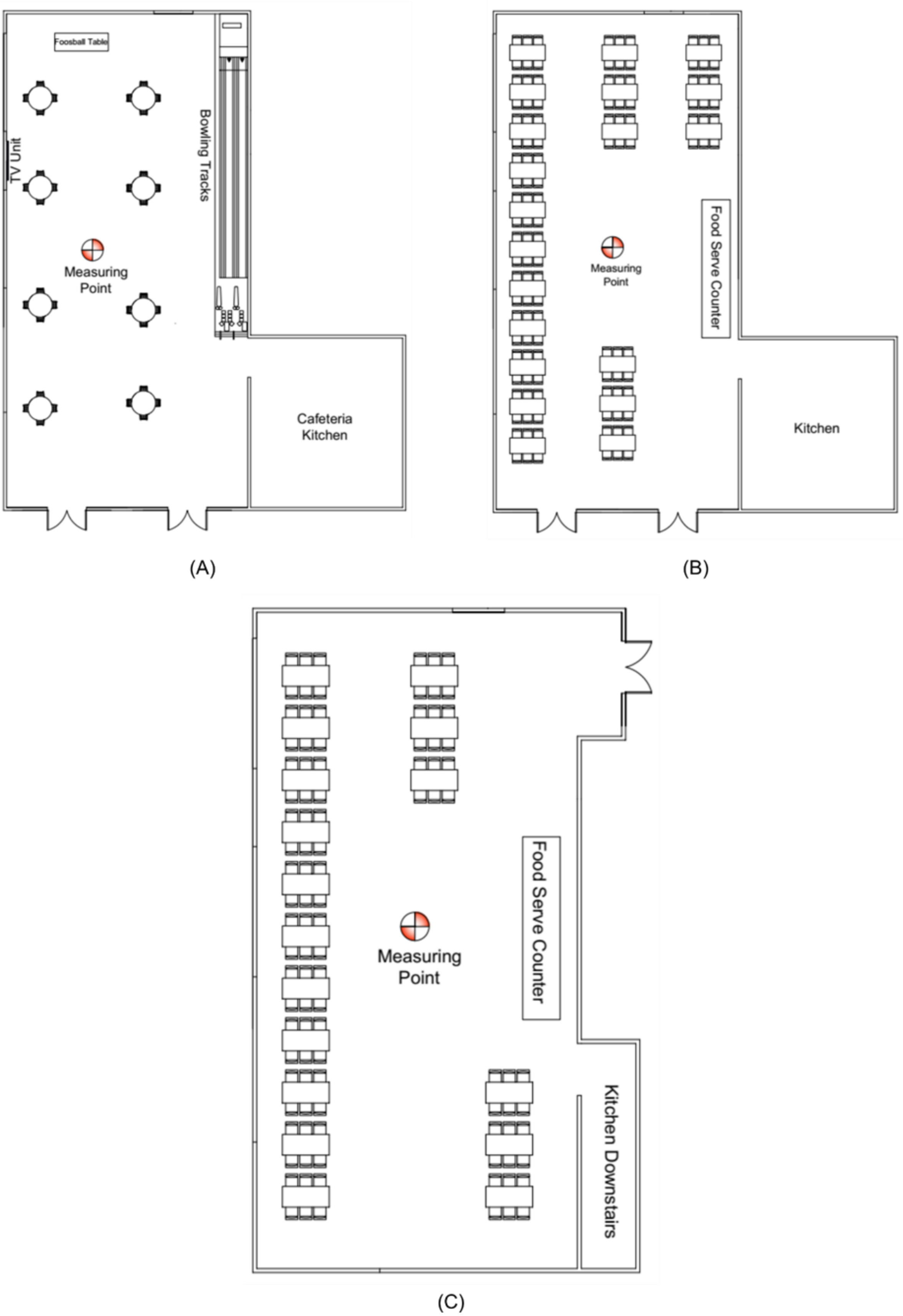

Figure 3 Measuring points (A) cafeteria/bowling alley, (B) student dining hall, (C) staff dining hall

3. RESULTS

The dB values obtained from the noise measurements made in the empty and full times of the dining hall and cafeterias are shown in Table 1. During the measurements, there were four staff members in the staff dining hall, while there were 120 people in the hall that were full. The student dining hall was empty while measurement was taken, and 170 students were eating that was full. The cafeteria/bowling alley is located in the same place. Six students watched TV during the measurements, unlike the dining halls. Throughout the midday measurement, only one of the bowling tracks remained in use for half of the measurement period. The frequency comparison of the two measurements for the staff dining hall is given in Figure 4.

Table 1 Sound level measurement results of the spaces

Measurement location	Measurement Results (dBA)	RAMEN (2015)	2002/49/EC
The staff dining hall is empty	30.75	-	-
The staff dining hall is full	56.10	45	55
The student dining hall is empty	29.43	-	-
The student dining hall is full	57.56	45	55
The cafeteria/bowling alley is empty	32.94	-	-
The cafeteria/bowling alley is full	69.76	45	55

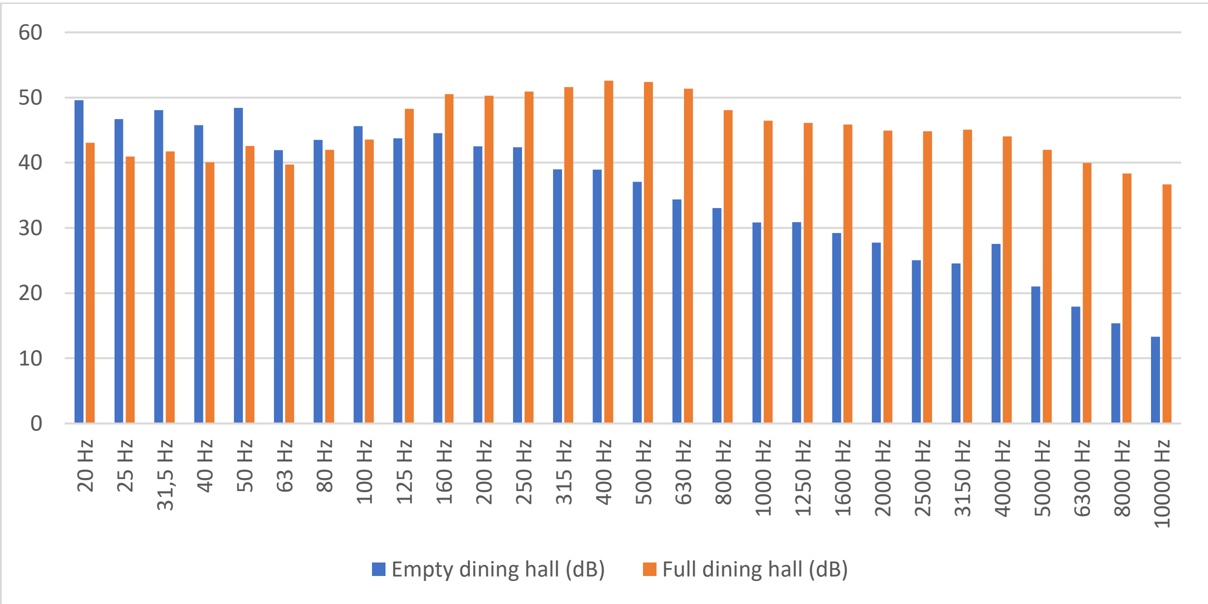

Figure 4 Staff dining hall frequency distribution comparison

The low-frequency distribution was higher when the staff dining hall was empty. This can be said to be the noises the staff made during the measurement while placing the heavy food containers on the presentation counter. After the dining hall was full, a significant increase was measured at 250 Hz and upper frequencies. The cause of the above condition is fork-knife noises and the employees' sounds when communicating among themselves. Comparing the frequency distribution of the full and empty student dining hall is given in Figure 5.

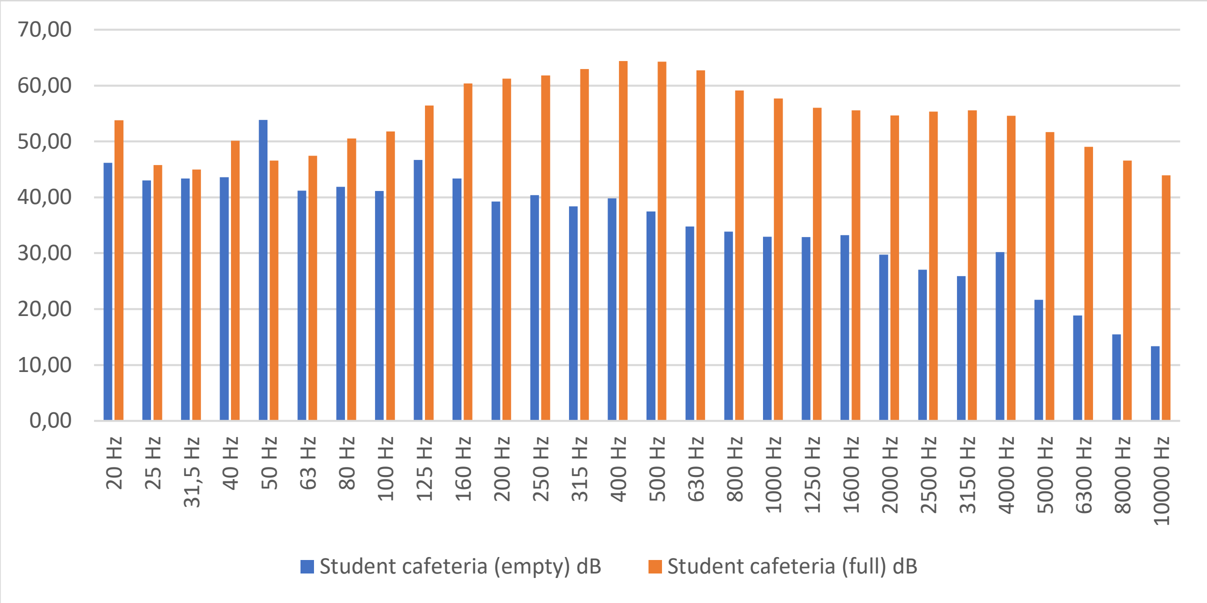

Figure 5 Student dining hall frequency distribution comparison

The full and empty student dining hall results are similar since the sound sources have been equivalent to the staff dining hall's sound sources. Since the student dining hall was more crowded than the staff dining hall and space's volumetric differences, the average noise was higher than the staff dining hall. Comparing the frequency distribution of full and empty cafeteria/bowling alley is given in Figure 6.

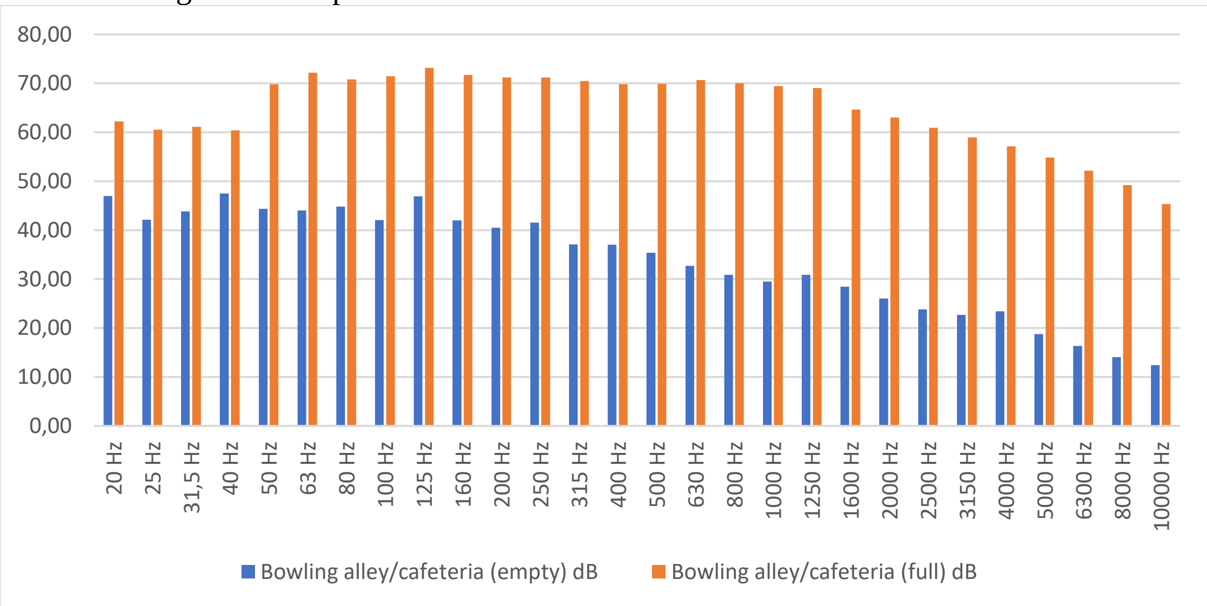

Figure 6 Cafeteria/bowling alley frequency distribution comparison

Figure 6 indicates a different distribution than the dining hall and student dining hall when the cafeteria/bowling alley is full, and the octave band analysis is studied. While fast food items are consumed in the cafeteria/bowling hall, there is not much cutlery use. Moreover, considering the limited number of students, the bowling game played during the full hall measurement, the bowling ball's sounds striking the ground, and bowling pins caused the low frequency sounds to be more in the full hall than in the empty hall. Simultaneously, foosball and the switched-on television raised the overall average, and significantly higher sound levels were measured at 50 Hz and upper frequencies.

4. DISCUSSION

In this study, the L_{EX} values obtained for the staff and student dining halls and cafeteria/bowling alley in the measurements made with the windows closed and without activity are well below the 45 dB(A) values specified in the standard, respectively 30.75, 29.43 and 32.94 dB(A). One of the most important reasons for this is that these places in the same building are located in an area where traffic and human circulation are not heavy. However, when the units are in service, the calculated values are L_{EX} 56.10, 57.26, and 69.76 dB(A) for the staff and student dining halls and cafeteria/bowling alley, respectively, and this value is above 55 dB(A) as stated in the standard. From the staff working in the cafeterias and dining hall, the measurements made even when the cafeteria is full are well below the lowest exposure action value. Besides, while the average of 8 hours is taken in the regulation, the time spent fully in the dining hall is a maximum of 1 hour. Therefore, from the regulation perspective, there is no need for any action planning for the employees.

In a similar analysis conducted in the cafeteria of the Rector building, 80.5 dB(A) values were calculated at Ege University (Izmir/Turkey) [17]. The average work conducted in the cafeteria of the 10 pre-primary schools in the province of Usak (Turkey) is 81.18 dB(A) [18]. In another study conducted in Germany, school cafeterias' average noise was reported as 75 dB(A) [19]. In the mentioned studies, the noise levels before cafeterias' activities and the number of people using the cafeteria were not reported. Therefore, it is not possible to make a complete comparison. However, the potential reasons that when the cafeteria is in service, the findings found in this analysis are smaller than those in the literature are that the amount of outside noise is very low and the cafeteria's capacity is lower than the other dining halls.

5. CONCLUSIONS

In this study, noise levels of 29.43 dB(A), 30.75 dB(A), and 32.94 dB(A) were obtained in the measurements made in empty spaces, and 56.10 dB(A), 57.56 dB(A), and 69.76 dB (A) in the measurements made in filled areas. The reason for the users' complaints at the staff dining hall noise level, which is 1.10 dB(A) above the limit value, is the humming of people during their conversation and the service teams' sounds, rather than this value difference. Since it is not possible to detect this only by noise measurement, spectrum analysis has been performed. Although the results show an increase in the noise level in general, high-pitched sounds (high frequencies) are more. Metallic noise emanating from the service sets explains this phenomenon. Similar spectrum changes were also recorded in the student dining hall. However, as the cafeteria and bowling alley are together and bowling was played during the measurement, spectrum analysis observed a significant rise in the low-frequency bands, indicating the bowling ball's sound is hitting the track.

To reduce the noise level in the environment in restaurants, panels can be placed on the walls to absorb high-pitched sounds. However, in normal restaurants, the walls may be less than the space's square meter or can be used as interior design. For these reasons, restaurant owners may not want such panels on the walls. For such cases, the tables are positioned in clusters and the panels suspended from the ceiling can reduce the time of ringing and therefore the sounds of forks, knives, and plates. Another element is furnishing details such as thick carpets and curtains.

Although it is not possible to use the furnishing details in the dining hall and the cafeteria/bowling hall where the measurement is made, it is possible that the walls are covered with sound-absorbing materials, unlike normal restaurants. According to octave band analysis, open foams may be preferred because they are predominantly high-pitched in cafeterias. It would be appropriate for the cafeteria/bowling hall to choose composite materials as there are both TV and bowling balls.

The results of many studies in the literature belong only to situations when space is full or in use. Therefore, it is not possible to calculate the net noise level of the activities. Besides, no sound sources were detected by octave band analysis in the measurements mentioned above. The most important difference of this study from other studies is that the empty and full sound levels of the spaces are measured, and octave band analysis is made in these environments. The study once again proved that the concept of noise is subjective as the units' levels were compared, while the users with the lowest noise level complained about the noise in the staff dining hall, the students who used the cafeteria/bowling alley with a noise rating of approximately 100 times that noise value did not complain. The purposes and duration of stay of the people in the cafeteria/bowling hall and dining halls are different. The main reason for not complaining from those in the cafeteria/bowling hall is that they do not notice the noise, but probably because they are satisfied with the activity and the environment.

Since the sound/noise level measurement alone may not exceed the limit value or be just above the limit value, as in this study, it may prevent any measures from being taken in the places where noise complains. For this reason, the primary source of the noise should be determined by performing spectrum analysis as well as sound level measurement in areas where noise complains. After this determination, damping the disturbing frequency can be achieved using an acoustic isolator for that frequency range.

Because the noise level that employees may encounter is below the limit values specified in the Official Gazette, there is no need to measure with a dosimeter during working hours. However, by taking the precautions above for the environment, people can socialize by talking while eating.

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The Declaration of Conflict of Interest/ Common Interest

No conflict of interest or common interest has been declared by the authors.

Authors' Contribution

The authors contributed equally to the study.

The Declaration of Ethics Committee Approval

This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics

The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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