Characterization of Environmental Noise Pollution Based on Noise Measurement and Mapping at USM Engineering Campus

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Abstract. This paper describes an analysis of visualizing noise impact on the environment by producing the noise mapping, determining the noise sources and characterization of sound levels measurements at USM Engineering Campus, Nibong Tebal, Penang. Measurements were taken at a total of 30 points with the duration of 3 minutes during working hours using the sound level meter. The ArcMap 10.3.1 software and Google Maps were used to create the noise mapping based on the coordinates and each sampling point. The results revealed that 23 points exceeded the maximum permissible limit, 55 dB(A). The maximum measured sound level was obtained at point 4 (68.3 dB(A)), while the lowest sound level was 43.8 dB(A) at point 26. Characterization of sound levels by measuring the noise levels and performing noise mapping is substantial to analyse and determine the level of noise pollution in institutional and educational areas. In addition, such practices would help in understanding the activities that contribute to the increase in sound level.

1. Introduction

Noise can be defined as the excessive or annoying unwanted sound in a specific area. However, noise pollution occurs when the noise level is above the allowable limit for a given environment [1]. Noise acts as an environmental stressor, which can lead to physiological health issues that can influence human’s daily activities and interfere with communications. Excessive exposure to noise has also been found to cause sleeplessness and reduce the sleeping efficiency [2]. According to the world health organization (WHO), noise can be observed at different areas such as schools, preschools, educational institutions, industrial and commercial buildings, and traffic areas. Countries have been encouraged to assess and determine the levels of noise pollution in their territories by conducting noise mapping studies [3].

In educational institutions, noise-induced leads to complications hinder in communication between the teacher and the student. Moreover, noisy learning environments may disrupt the performance of students, as it can affect their focus in the class, which can lead the students to achieving lower grades and lower evaluation. Thus, the teacher’s sound is important to be heard by receptors without any outside interferences; as the great task of knowledge transmissions must be clear and harmonious than any competitive noise [4]. Several authors have performed noise measurements studies in educational...
institutions. Ibrahim [5] assessed the noise pollution at the University of Technology in Baghdad, Iraq using noise mapping. His findings stated that the main sources of noise at the campus were caused by the electrical generators, traffic movements, parking lots, and engineering workshops with open doors. The maximum noise levels observed in his study ranged from 85 dB(A) to 95 dB(A). In a similar study, Ibrahim [3] focused on noise mapping of the campus of the School of Engineering at the University of Al-Mustansiriya. Based on his noise mapping studies, it was observed that noise levels greater than 90 dB(A) were recorded when the generators are turned on, and the lowest levels overlapped with noise levels generated by the industrial buildings, Bab Al-Moatham road industrial buildings and parking lots. The high sound levels were recorded in and around the areas where students would gather, near the generators and other noise sources, without awareness of the high noise levels to which the students are being exposed to.

Zannin and Ferraz [6] conducted a study in Hospital de Clínicas of the Federal University of Parana and found that measured noise levels were mostly in the range of 55 to 60 dB(A) and reached up to 60 and 65 dB(A) in the central part of the frontal facade of the university hospital. The noise maps presented showed that the source of noise pollution was mainly due to the traffic congestions and heavy vehicles. Zannin et al. [7] stated on a case study performed at the campus of the Polytechnic Center of the Federal University of Paraná, Brazil, that the road that connects the two entrances to the campus displayed dominant noise levels above 70 dB(A), thus being the main noise source inside the campus. From these observations, it can be indicated that noise can affect the communication and concentration, particularly during learning and teaching sessions. In addition, it was revealed that a variety noise sources can be detected in campuses, such as noise generated due to events and different activities at the campus.

The purpose of this study is to visualizing noise impact on the environment by producing noise maps that can easily illustrate the measured sound levels at the studied area. Furthermore, this study also aims on determining the sources that affect the noise levels and to characterize sound levels measurements to find the noise levels at which people are exposed during the working day at USM Engineering Campus.

2. Materials and method

The study was carried out at Universiti Sains Malaysia, USM Engineering campus at Nibong Tebal. USM is located at the south of Seberang Perai. The campus covers an area of 320 acres and currently has approximately 4000 registered students. The average temperature is 32.2°C, with an approximate annual rainfall of 267cm. The locations of measurements included the internal streets with all main roads, such as the main gate, and some of the branch roads. Type of buildings included: (1) educational (such as college buildings), (2) administrative (such as the main administrative building of the campus) and (3) services buildings (such as library and restaurants).

2.1. Sampling method

Thirty measurement points were selected as in Figure 1. For each point, the measurement duration was 3 minutes, and the measurement period for all point were between 12:30 pm and 6:00 pm [7]. Meanwhile, the human activities, vehicles, and any noise source that can affect the readings in each location were recorded. The exact locations coordinates were taken using Google Maps (Table 1).
Figure 1. Map pinpoint the location of 30 noise measurement at USM Engineering Campus.

Levels of noise intensity were measured using Cirrus Research plc type CR:1710 Sound Level Meter (SLM) as shown in Figure 2.

This SLM has the ability to measure the following values instantaneously (which represents the now live noise level, in which, a reading every 5 seconds is automatically recorded), $L_{A\text{max}}$ and $L_{A\text{min}}$ (which represent the maximum and minimum noise levels during the overall period of measurement), and the equivalent continuous level $L_{Aeq}$ (which represents the measured value which needs to be averaged over a period of time for all $L_{A\text{f}}$ readings [8]. The instrument was calibrated on 39.7 dB (A) before taking noise measurements and was set to record noise samples at 5-sec intervals during the 3 minutes exposure time. The sound level meter was placed at a height of 1.5 meter above the ground level and at a minimum distance of 3 meter from the building facade [9]. Acoustic descriptors such as A-weighted equivalent sound pressure levels ($L_{Aeq}$) were used and were expressed in decibel (dB). The start-up time of this SLM depends on the state the instrument was in when last switched off, and it may take up to 2 min from a
cold start, or up to 10 s if the instrument is already in standby mode, (i.e., from a warm start). The collected data was analysed by using ArcMap 10.3.1 software to create a noise map.

2.2. Noise mapping
Noise mapping is a graphic representation of the sound level distribution existing in a given region, for a defined period which is shown on map of that region which is coloured according to the noise levels in the area [10]. Measured noise level was subjected to noise mapping based on the data in Table 1. The ArcMap 10.3.1 software was used in analyses of the data. The values were mapped as the coordinate X and coordinate Y including one parameter of sound level measurement \( L_{10}, L_{50}, L_{90}, L_{eq}, L_{max} \) and \( L_{min} \). The contouring method by using Inverse Distance Weighted (IDW) spatial interpolation technique were used to capture the adjoining areas and to cover the entirety of the study area. Generally, interpolation predicts cell values in a raster format using a given albeit limited number of sample data. It is a veritable tool for prediction of unknown values for a given geographic point data which in this study is noise [10]. The Google Maps were used to provide the real photo of the location by taken 4 points of each location at the boundary on the study area.

3. Results and discussion
The noise level measurements at USM Engineering Campus were determined and compared with the noise limits recommended by the Malaysian Standards of Planning Guidelines for Environmental Noise Limits and Control (2004) [11] and also WHO [1] for institutional areas. Figure 2 shows the equivalent sound pressure level \( L_{eq} \) measured on the campus with the noise limit recommended by Malaysian Standard 50 dB(A) and WHO limit 55 dB(A). The measurement indicated 23 of the 30 measured points exceeded the maximum permissible sound level, 55 dB (A) of the \( L_{eq} \). The remaining 7 points are up to 55 dB(A) in the range of sound levels. The maximum sound level recorded was 68.3 dB(A) at point 4 and followed by 65.9 dB(A) at point 12 (Table 1). These measured high noise levels are attributed to the traffic movements and other activities nearby the points, such as the laboratory works, where noisy equipments were in operation. Moreover, the mosque located near to point 4 contributed to increased sound levels, due to the elevated number of pedestrians passing by especially during the prayers. The noise limit above 55 dB (A) is generally considered to be an anxiety level and above 65 dB(A) is a noise level that affects the quality of life if the noise is continuous in the region [12].

Figure 4 until Figure 6 show the noise mapping of the USM engineering campus, identifying the six parameters for each of the sampling points throughout the campus. The measured parameters are \( L_{10}, L_{50}, L_{90}, L_{eq}, L_{max} \), and \( L_{min} \). Figure 4 shows the noise mapping of the USM campus for the \( L_{eq} \) measurement, which the highest equivalent continuous level is 68.3 dB(A) with the constant noise level over a given time period. The mechanical school generated noise from the laboratory machineries and compressors. This noise level would contribute greatly to diminishing people’s quality of life inside the campus. Unwanted sound of sufficient intensity and duration can cause temporary and permanent hearing loss [13]. It can also interfere with speech communication, the transmission of other auditory signals, disturb sleep, act as a general source of annoyance or disturbance, and interfere with the performance of complicated tasks and the opportunity for privacy [12].

Exposure of people to daytime noise levels above 65 dB(A) can cause severe health problems [13]. Thus, the noise level should be well controlled in order to ensure that people’s lives can be safe without causing any health issues or damaging their hearings. The collected data indicated that the mechanical school building is subjected to sound pressure levels exceeding the limit established by guidelines for the educational areas above the limit of 55 dB(A). Furthermore, an analysis of noise maps in Figure 6 indicates that the schools of civil, electrical, aerospace, chemicals, and materials have generated noise within 60 to 64 dB(A). These areas also impacted by the highest sound pressure level which exceeded the limits for noise level in Malaysia.
On the other hand, the hostel and sports center are located far from the school center. Therefore, those areas are not being affected by the noise generated from the school center which has more students, lecturers, and staff during the working hour. Most of the student spent most of their time at the school center instead of staying in the hostel during the class sessions. Thus, the school center and cafeteria contributed to being the main noise source inside the campus as shown in Figure 6 with the noise level measured around 57.5 and 60.6 dB(A). However, the noise is also caused by airplanes, air-conditioning, and laboratory machinery in the school’s buildings. The generated noise is about 53.5 dB(A). Additionally, as the main roads on the campus allow the distribution of pedestrians, bicycles, light vehicles, utility vehicles and buses, the noises are not too affected in comparison with residential areas located near the campus. The main roads are still under control and not busy with vehicles around the campus [7].

Table 1 shows the raw data and converted to passenger car unit (PCU) for the number of vehicles and pedestrians for each sampling point at the USM engineering campus during the measurement period. The table reveals that traffic volume is considered as a major source of noise at USM engineering campus. Generally, traffic contributed to the increase in noise levels, as shown in Figure 3 which contributed to higher noise levels at the sampling points. It is worth mentioning that the number of pedestrians also contributed to higher recorded values of noise levels. For instance, at sampling point 4, the number of people passed that point reached 12 during that period, and the measured $L_{eq}$ was 68.3 dB(A), compared to only 43.8 dB(A) at sampling point 26, where no pedestrians existed at that point.

The influence of traffic on the measurement of noise levels was in accordance with several studies [7][9] conducted in different cities around the world. Zannin et al. [7] studied the characterization of environmental noise at a university campus in Brazil and showed that elevated noise levels were measured above 70 dB(A) in the areas near the main roads inside the campus, specifically near the main gate, where more circulation of vehicles was allowed in that area. In addition, these findings were in accordance with a study conducted in Kolhapur, India, where the observed results indicated that high $L_{eq}$ measurements that reached up to 63.71 dB (A) were recorded in the educational and institutional zones [14].

Table 1. GPS coordinate and noise descriptors of each point in this study.

| No. | Cars | Motorcycle | Medium Lorries | Buses | Pedestrian | PCU | No. | Cars | Motorcycle | Medium Lorries | Buses | Pedestrian | PCU |
|-----|------|------------|----------------|-------|------------|-----|-----|------|------------|----------------|-------|------------|-----|
| 1   | 3    | 9          | 0              | 0     | 13         | 10  | 16  | 4    | 1          | 0              | 0     | 10          | 5   |
| 2   | 3    | 5          | 0              | 0     | 12         | 17  | 6   | 3    | 0          | 0              | 0     | 6           | 9   |
| 3   | 3    | 5          | 0              | 1     | 11         | 10  | 18  | 0    | 0          | 0              | 0     | 0           | 0   |
| 4   | 3    | 1          | 0              | 0     | 12         | 19  | 4   | 9    | 0          | 0              | 0     | 0           | 11  |
| 5   | 2    | 1          | 0              | 2     | 3          | 20  | 5   | 2    | 0          | 0              | 0     | 0           | 7   |
| 6   | 3    | 3          | 0              | 0     | 6          | 21  | 8   | 10   | 0          | 0              | 0     | 0           | 16  |
| 7   | 6    | 1          | 1              | 2     | 10         | 22  | 4   | 1    | 0          | 0              | 0     | 0           | 5   |
| 8   | 6    | 1          | 0              | 5     | 7          | 23  | 0   | 1    | 0          | 0              | 0     | 0           | 1   |
| 9   | 0    | 0          | 0              | 0     | 0          | 24  | 4   | 3    | 0          | 0              | 0     | 1           | 8   |
| 10  | 4    | 2          | 0              | 0     | 6          | 25  | 0   | 0    | 0          | 0              | 0     | 0           | 1   |
| 11  | 0    | 1          | 0              | 4     | 1          | 26  | 0   | 0    | 0          | 0              | 0     | 0           | 0   |
| 12  | 0    | 1          | 0              | 1     | 1          | 27  | 4   | 3    | 0          | 0              | 0     | 0           | 7   |
| 13  | 1    | 0          | 0              | 2     | 1          | 28  | 9   | 8    | 0          | 0              | 0     | 0           | 15  |
| 14  | 0    | 1          | 0              | 2     | 4          | 29  | 3   | 3    | 0          | 0              | 0     | 0           | 6   |
| 15  | 1    | 1          | 0              | 0     | 2          | 30  | 0   | 2    | 0          | 0              | 0     | 0           | 2   |
Figure 3. The equivalent sound pressure noise level measured at USM Engineering Campus.

Figure 4. Noise mapping of the USM Engineering Campus for $L_{eq}$. 
Figure 5. Noise mapping of the USM Engineering Campus for $L_{\text{max}}$.

Figure 6. Noise mapping of the USM Engineering Campus for $L_{\text{min}}$. 
4. Conclusions

In conclusion, this case study characterized the noise levels at USM engineering campus for six parameters: L_{10}, L_{50}, L_{90}, L_{eq}, L_{max}, and L_{min}, at 30 different points distributed around the campus, as shown in the noise mapping Figures. Such work is important to be conducted to be able to analyse the level of noise pollution in educational areas. Throughout this study, we have observed that most of the measured sampling points experienced high noise levels that exceeded the maximum permissible sound level, 55 dB(A) of L_{eq} for institutional areas. However, only seven sites were within the allowable standards of the noise level. The high sound levels measured at USM campus was mainly affected by the traffic volume inside the premises of the campus. Additionally, other activities like the use of noisy equipment and machineries at the engineering laboratories also contributed to high levels of noise. Moreover, the gathering of students in certain areas like the cafeteria, or assembling points, increased the values of sound levels.

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