Available at www.ijcasonline.com ISSN:2349 – 0594

International Journal of Modern Chemistry and Applied Science

International Journal of Modern Chemistry and Applied Science, 2017, 4(3),535-543

Status of Mixed-Commercial Zone Day-Time Ambient Noise Pollution in Addis Ababa, Ethiopia-Case Study of the Yeka Sub-city

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Abstract: The aim of the study was to investigate the mixed-commercial zone day-time ambient noise pollution in Addis Ababa, Ethiopia through a case study of the Yeka sub-city. Direct 1-hour (3-4PM) afternoon sound levels were measured at 25 sites in the sub-city from December 2011 to March 2012 using integrating sound level meter of type Cirrus 811C to generate average energy equivalent (Leq), statistical (Ln: L10, L50, L90), minimum, maximum and peak sound values. Equipment built-in Deaf Defier software and MS excel version 7.0 were used for data analysis. Leq values were in the range of 60.6dBA-75.7dBA, the corresponding ranges being 82.1dBA-113.9dBA for the maximum and 42.7dBA-58.4dBA for the minimum sound values. The corresponding ranges for L10, L50 and L90 were 60.5dBA-78.8dBA, 53.1dBA-73.5dBA and 49.2 dBA-68.2 dBA respectively. The Leq values exceeded the day-time national commercial noise standard (Leq = 65dBA) at 84% of the sites while the residential noise standard (Leq = 55dBA) was significantly exceeded at all the sites. In conclusion, the national commercial and residential zone day-time noise release standards are being significantly exceeded in mixed zones of the city requiring proper attention.

Keywords: Addis Ababa, Mixed-commercial zone, Ambient noise, Leq sound values, Noise standards

1. Introduction

Sound is a form of mechanical energy with many applications such as in communication, defense and entertainment among others. If mismanaged, however, it becomes a problem called noise pollution, which is just unwanted sound. [1-3]

Many noise pollution sources exist in urban areas depending on local socio-economic, technological and other conditions. The major sources are sectors of transport, industry and construction. [4, 5] For example, vehicles along with pressure horns and music on those vehicles are notorious sources in urban areas. [6, 7] In Addis Ababa, road vehicles, religious institutions and dogs are the leading ambient noise pollution sources followed by commercial activities, stationary and on-the-vehicle advertisements, music and video shops, sporting activities, night-clubs and airplanes. [8]

A number of scientific studies indicate that noise pollution is associated with many adverse impacts. Hearing loss [9], psycho-physiological disorders such as annoyance and cardio-vascular problems [2, 10], and cognitive value deteriorations [10-13] could result from exposure to noise pollution. It does also have significant economic impact in terms, for example, of property value deterioration. [14, 15]

In response to its adverse impacts, control efforts were so far practiced in many parts of the world through technical or engineering solutions (at the source, at the path and receptor points), public education and legislations among others. Some countries and cities as in [16] have source specific technical noise control guidelines. Regarding legislation, international organizations such as the World Health Organization [2] and countries such as Ethiopia [17] have already set noise emission guidelines to legally control the problem.

Noise emission standards are usually set in the equivalent continuous sound pressure level or simply time average sound level (Leq), which is commonly used to evaluate more-or-less steady sound over the period of measurement. It is obtained by integrating the time dependent (fluctuating) sound pressure values over a fixed time and then dividing the result by that time. [9]

Environmental noise is emerging as one of the major problems in Addis Ababa evidenced by noise complaints, field observations and comments of noise discussion events. Accordingly, the general objective of this paper is to investigate the status of mixed commercial zone (commercial zone mixed with residences) ambient noise in the city through a case study of the Yeka sub-city. The specific objectives are to generate baseline noise level data; to indicate the status of noise pollution; to check tempo-spatial noise variability; and to compare the noise levels with the national noise standards.

2. Materials and Methods

Yeka sub-city found in the eastern Addis Ababa with surface area of 85.9km^2 is selected for the current case study. The sub-city was selected due to its leading contribution to the overall noise complaints in the city [8]. Accordingly, mixed commercial zones in the sub-city were identified based on the city's new digitized master plan, field visits and stakeholder consultation. The identified zones were then represented by 25 systematically selected measurement sites (Figure 1).

A 1-hour (3-4PM) direct day-time afternoon sound level measurements were conducted from December 2011 to

March 2012 in the sub-city using integrating data logging sound level meter of type Cirrus 811C with compatible calibrator of model Cirrus 515 to generate energy equivalent (Leq) and statistical (L10, L50, L90) as well as minimum (Lmin), maximum (Lmax) and peak (Lpeak) sound values in units of dBA: deci-bel in the A frequency range, a range that the human ear is more sensitive and responsive to. [18] Instantaneous sound values were generated at each second leading to around 3600 instantaneous values in an hour, from which were calculated (by the built-in software) the 1-hour Leq values. Ln values indicate the sound level exceeded for n% of the measurement time which is one hour in this case (e.g. L50 is the sound level exceeded for 50% of the measurement time: 30 minutes in this case). Lpeak is the highest sound measured during the 1 hour whereas Lmax and Lmin are root mean square values of fluctuating Lmax and Lmin values respectively.

The equipment has built-in software (Deaf Defier Software) which plots the time history of sound values such as Leq for further analysis. Measurements were taken on sunny, calm days, the microphone being placed at about 1.2 meters above the ground and at least 3 meters away from any acoustic reflectors. The equipment built-in Deaf Defier Software version 3.3 and MS excel software version 7.0 were then used for data analysis.

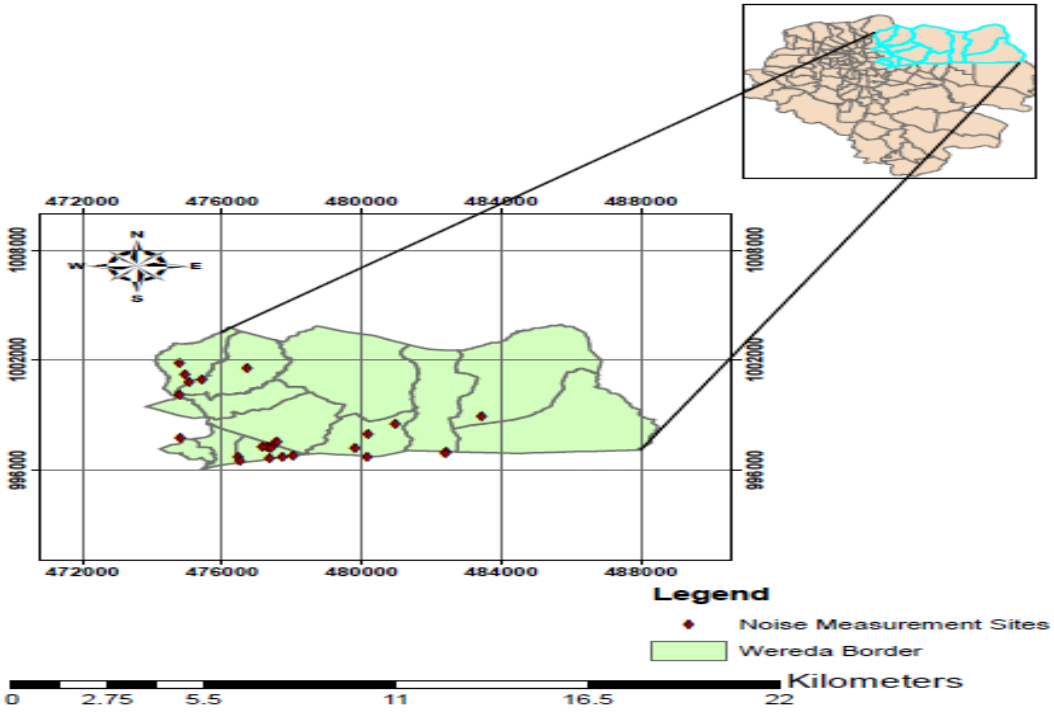


Figure 1. The Yeka sub city with the measurement sites

3. Results and Discussion

3.1. Measured Noise Levels and Comparison with Guidelines

The sound level measurement results of the actual study are shown in Table 1 whereas some statistical analysis results (the 25-site statistics) of the data are given in Table 2. The principal noise sources in the area were found to be vehicles, human voice (speech, arguments etc) and music from boutiques, music shops and other commercial centers. However, the vehicles were observed to be the dominant sources of noise at almost all the sites. The sources for the maximum and peak sound values in the sites were predominantly vehicle horns and noisy motors of mainly heavy vehicles.

As shown in Table 1 and Table 2, Leq sound levels of the 25-sites were in the range of 60.6dBA-75.7dBA, the mean value being 69.5 dBA. The recorded maximum values were in the range of 82.1dBA-113.9dBA while minimum values were in the range of 42.7 dBA-8.4 dBA. Regarding peak values, they were in the range of 105.1 dBA-120.8 dBA. The mean maximum and minimum sound values were 101.2 dBA and 50.5 dBA while the mean peak was 115.1 dBA.

Regarding statistical noise descriptors, the main parameters of interest were L10, L50 and L90. L90 usually represents background noise in the area. L50 represents the median noise level which could roughly approximate Leq if there is no high noise variability. L10 usually gives noise from temporary sources. Accordingly, the mean L10 value for the selected sites was 69.5 dBA, which is the same as the mean Leq value. L10 was in the range of 60.5dBA-78.8 dBA. The corresponding range was 53.1 dBA-73.5 dBA for L50 while its mean was 63.4 dBA. The background noise L90 was in the range of 49.2 dBA-68.2 dBA while its mean was 58.4 dBA.

The National (Ethiopian) day-time (6 A.M-9 P.M local time) noise standard is 65 dBA for commercial zones and 55 dBA for residential zones (FEPA and UNIDO, 2003). In this paper, the measured values were compared with those national standards (Figure 2).

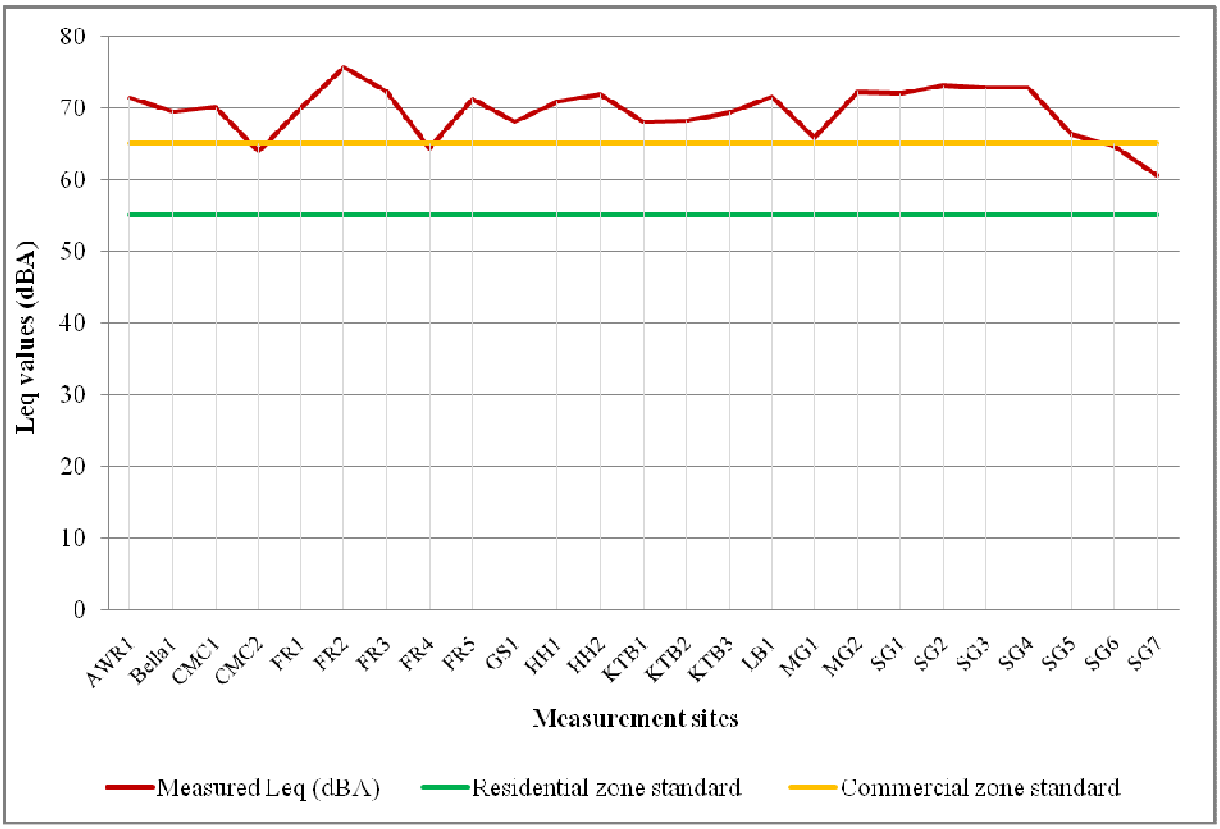
Table 1. Sound level measurement results (dBA)

Site	Area name	Leq	Lmax	Lpeak	Lmin	L10	L50	L90
AWR1	Aware Market	71.4	100.4	114.2	52.9	73.0	67.6	62.6
Bella1	Bella Megenteya	69.5	104.5	115.6	42.7	68.7	61.8	56.2
CMC1	CMC Altad-Michael	70.1	102.9	114.9	53.0	71.6	65.4	61.0
CMC2	CMC Altad-Police Station Area	63.9	90.5	120.8	49.0	66.3	60.0	55.2
FR1	Ferensay Embassy Area -A Local Market	70.0	107.2	116.7	43.9	64.0	57.0	51.9
FR2	Ferensay Embassy-Kella Sefer	75.7	108.0	118.3	53.1	78.8	73.5	67.7
FR3	Ferensay-Biret Dildiy Mazoriya	72.3	113.9	118.3	48.9	66.8	58.4	53.9
FR4	Ferensay-Eyesus 41	64.4	93.9	119.0	49.2	66.2	60.4	55.7
FR5	Ferensay Mazoriya_H12 School	71.3	108.9	118.2	53.5	70.1	63.6	59.6
GS1	Gurd Sholla infront of Tele Center	68.1	96.0	110.9	52.8	69.7	62.9	58.5
HH1	Hayahulet	70.9	96.5	109.9	48.6	73.8	69.3	60.5
HH2	Haya Hulet	71.9	111.0	118.9	48.1	70.4	64.2	55.3
KTB1	Kotebe Teachers Training College	68.0	90.6	110.5	52.1	70.4	64.7	60.6
KTB2	Yeka Wereda 9 Office	68.2	99.5	111.7	51.7	70.2	63.5	59.1
KTB3	Beg Tera-Sheep Market	69.4	94.4	118.9	46.0	71.7	64.4	56.7
LB1	Kotebe-Lamberet-Near Oillibiya	71.5	103.7	118.4	45.8	73.9	65.6	56.3
MG1	Megenagna Square	65.9	86.0	108.1	56.8	68.2	64.1	61.2
MG2	Megenagna Square	72.2	92.4	105.1	58.4	74.5	71.4	68.2
SG1	Sholla Gebeya Near Ethiopian Commercial Bank	72.0	111.3	117.7	53.8	70.3	64.0	60.0
SG2	Sholla Gebeya Near Police Department	73.1	111.2	118.8	55.9	72.3	67.9	64.4
SG3	Sholla Gebeya Opposite Lem Hotel	72.8	113.4	118.2	56.2	69.1	63.9	60.7
SG4	Sholla Gebeya Away From Main Road	72.8	111.0	117.9	53.4	68.5	62.1	58.7
SG5	Sholla Gebeya Sheep Market	66.4	99.6	113.5	46.8	65.8	59.4	55.4
SG6	Sholla Gebeya along road	64.8	101.0	113.9	44.1	60.5	53.1	49.2
SG7	Sholla Gebeya Along Road	60.6	82.1	109.8	45.5	62.8	56.2	51.7

Table 2. Some statistical analysis results of measured sound values in dBA (25 sites considered)

Statistics	Leq	Lmax	Lmin	L10	L50	L90
Mean	69.5	101.2	50.5	69.5	63.4	58.4
Median	70.1	101	51.7	70.1	63.9	58.7
Std. Dev	3.54	8.95	4.39	4.00	4.64	4.61
Range	15.1	31.8	15.7	18.3	20.4	19
Minimum	60.6	82.1	42.7	60.5	53.1	49.2
Maximum	75.7	113.9	58.4	78.8	73.5	68.2

Figure 2. Comparison of actual noise pollution levels with national day-time nose release standards



Accordingly, Leq values exceeded the day-time commercial noise release standard (Leq = 65dBA) at 84% of the sites, the exceedance figures ranging from 0.9 dBA at Megenagna square site to 10.7 dBA at Ferensay Embassy Kella Sefer. At 52% of the sites, the exceedance figures were between 5 dBA at Ferensay Embassy local market area to 8.1 dBA at Sholla Gebeya near Police Department. The day-time residential zone noise standard (Leq = 55dBA) was also significantly exceeded at all the sampling sites, the exceedance figures in this case ranging from 5.6 dBA at Sholla Gebeya along aroad to 20.7 dBA at Ferensay Embassy Kella Sefer.

Based on the actual study, among the selected sites, the top three noisiest areas were Ferensay Embassy Kella Sefer (75.7 dBA), Sholla Gebeya near Police Department (73.1 dBA) and Sholla Gebeya opposite Lem Hotel (72.8 dBA) whereas the top three least noisy areas (no or minor exceedance of the noise release standard) were Sholla Gebeya Along a road (60.6 dBA), Altad Police station area (63.9dBA) and Ferensay-Eyesus41 (64.4dBA).

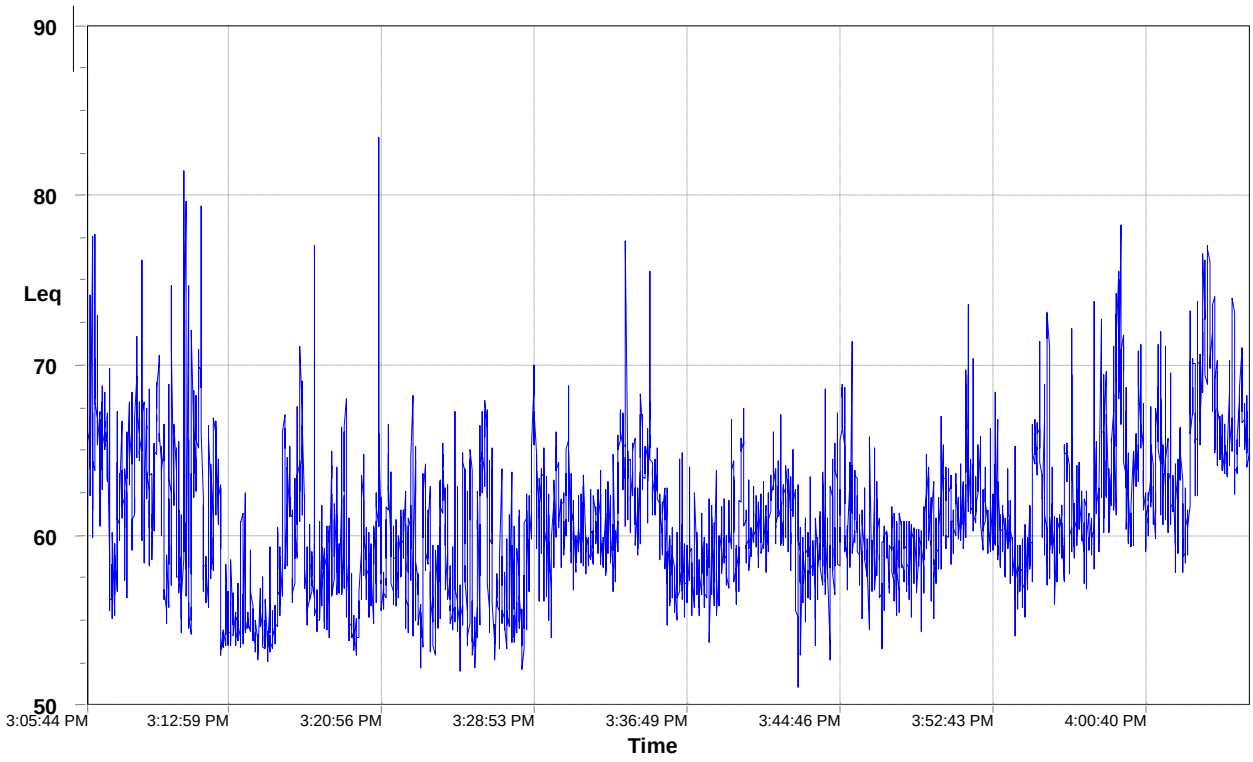


Figure 3. Sound level variation (3-4PM) for CMC Altad police station (1-hour average Leq = 63.9dBA

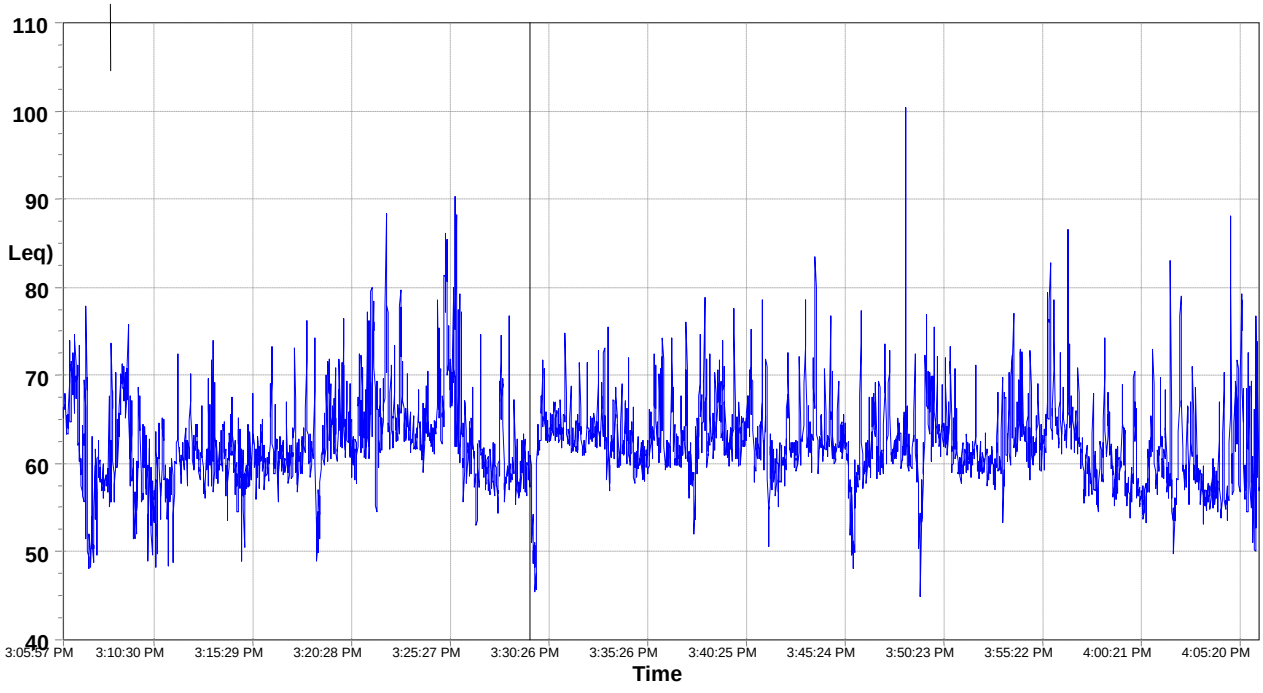


Figure 4. Sound level variation (3-4PM) for Bella megenteya (1-hour average Leq = 69.5dBA)

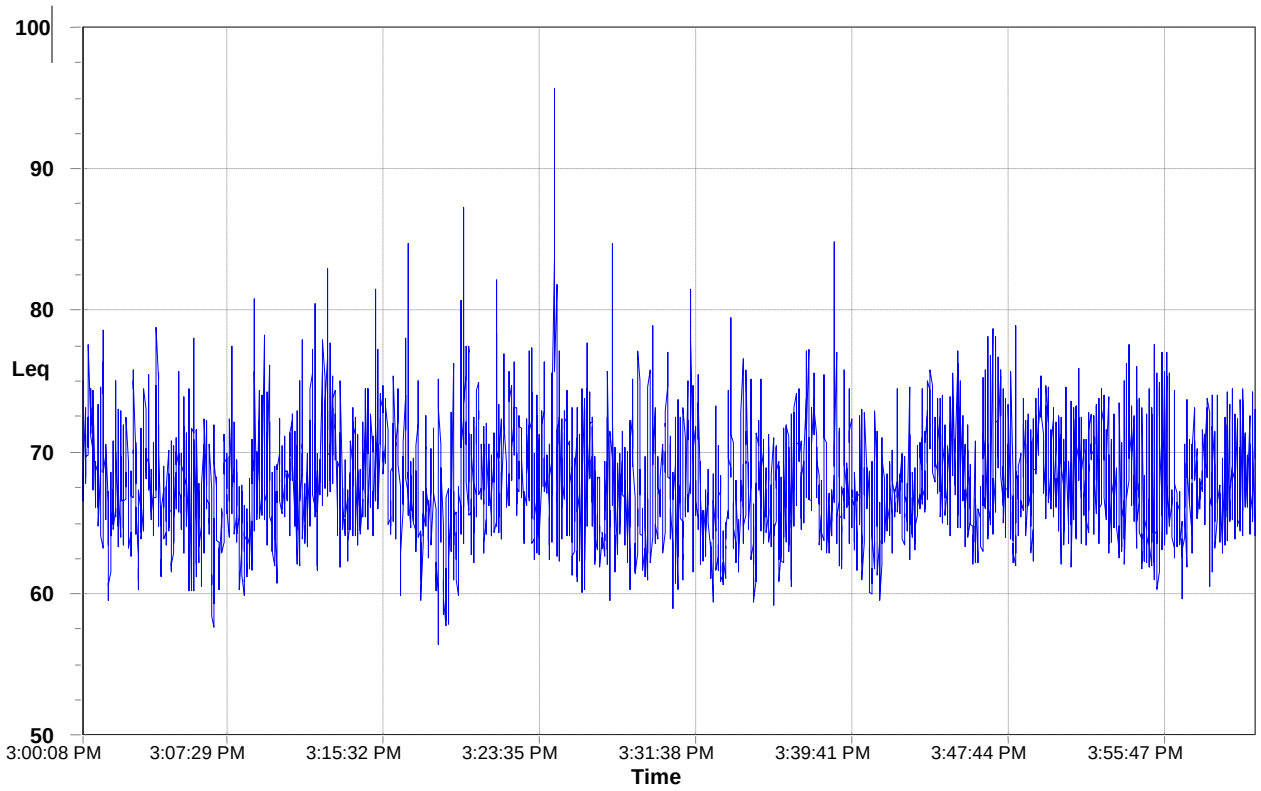


Figure 5. Sound level variation (3-4PM) for CMC Altad Michael (1-hour average Leq = 70.1dBA)

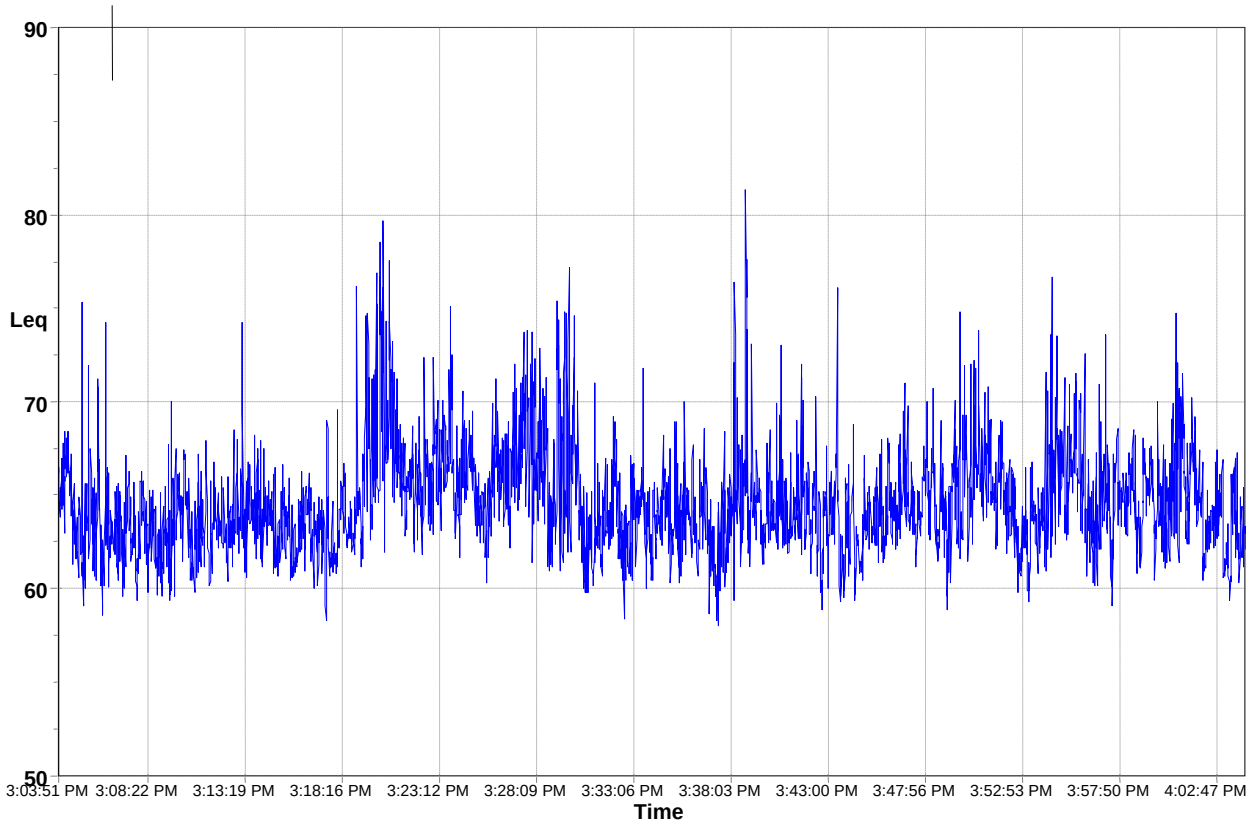


Figure 6. Sound level variation (3-4PM) for Megenagna square (1-hour average Leq = 65.9dBA)

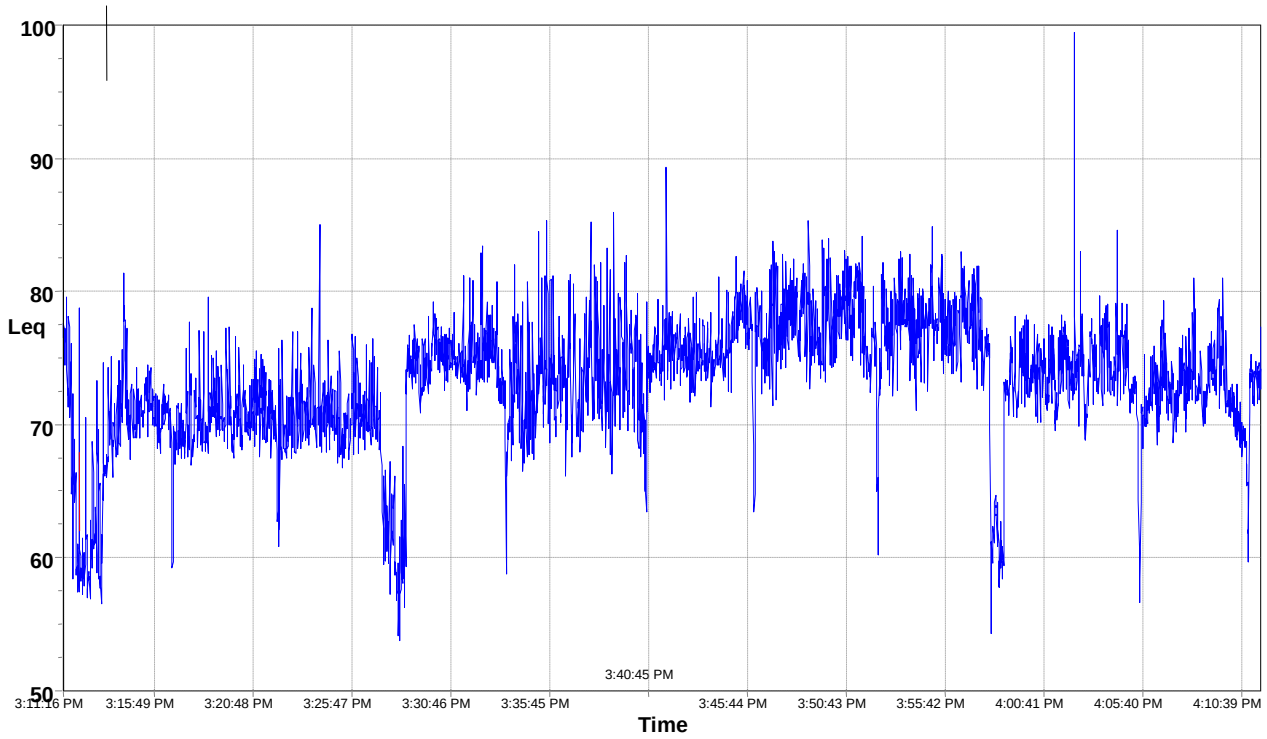


Figure 7. Sound level variation (3-4PM) for Ferensay Embassy Kella sefer (1-hour Leq = 75.7dBA)

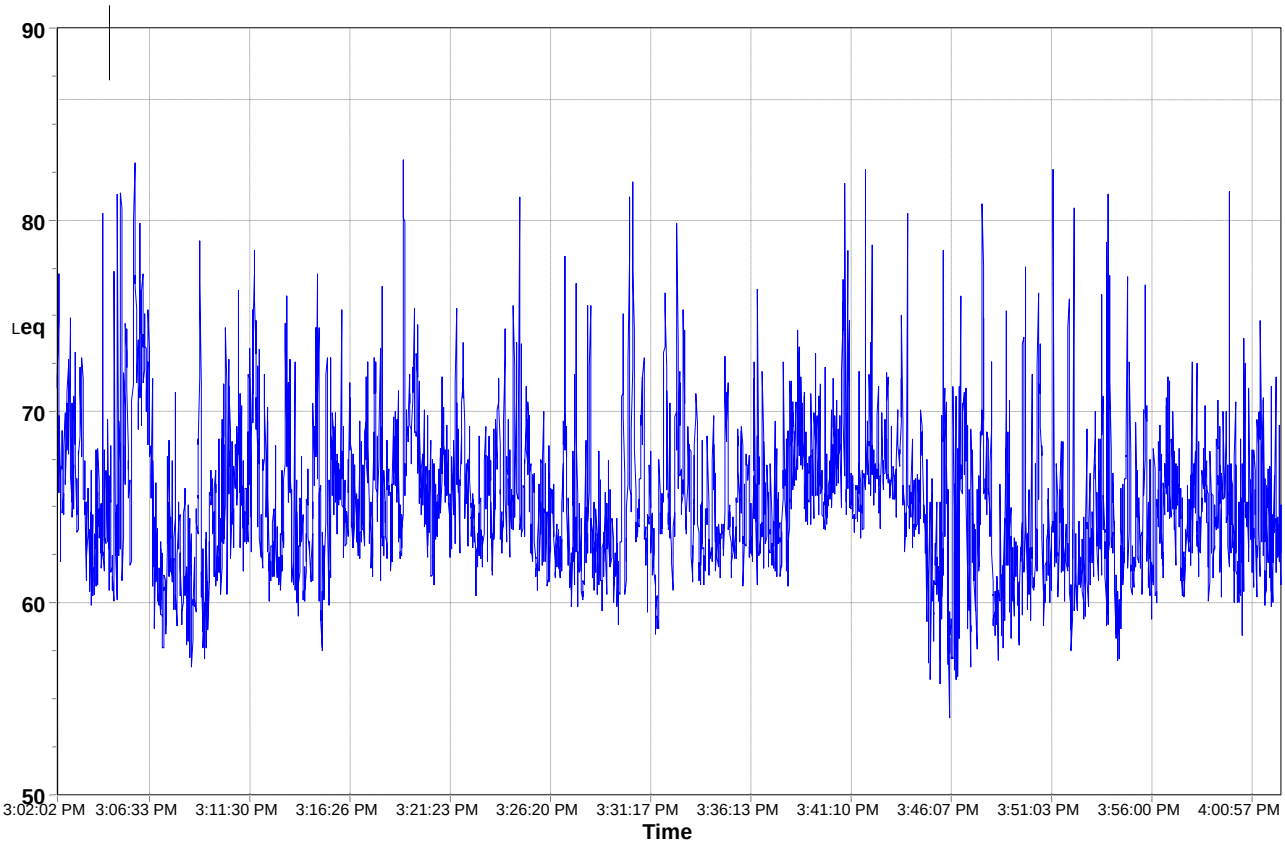


Figure 8. Sound level variation (3-4PM) for Kotebe teachers college (1-hour average Leq = 68dBA)

Table 3. Pearson correlation analysis results of some sound parameters

Parameter		L90	L50	L10	Leq
L90	Correlation	1	**.923**	**.843**	.600
	P value		.000	.000	.002
L50	Correlation	**.923**	1	**.970**	.663
	P value	.000		.000	.000
L10	Correlation	**.843**	**.970**	1	.719
	P value	.000	.000		.000
Leq	Correlation	.600	.663	.719	1
	P value	.002	.000	.000	

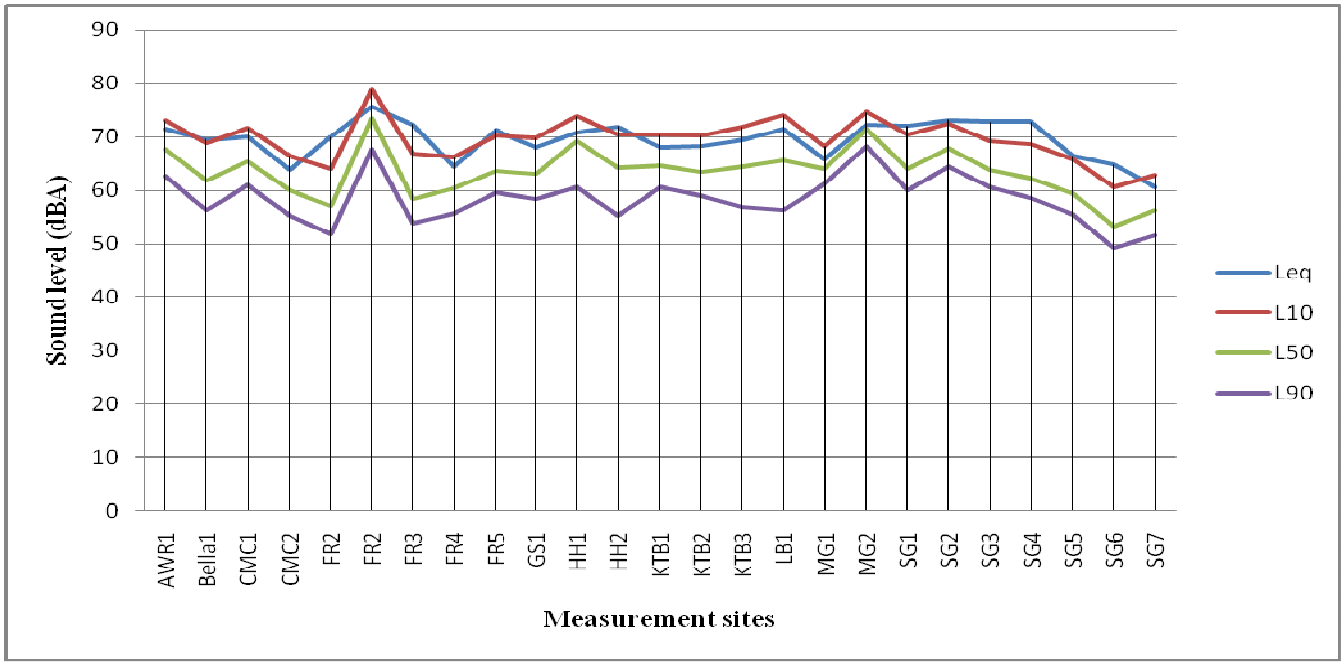


Figure 9. Graphical relationship of the measured noise parameters at each measurement site

3.2. Comparison of Actual Findings with other Research Results

The actual results were compared with other published results of researches conducted in Al-Dammam-Kingdom of Saudi Arabia [19], Sylhet-Bangladesh [20], Cape Coast–Ghana [21] and Yazd-Iran. [22] Accordingly, the actual spatial average sound level (69.5dBA) is well below those of Al-Dammam-Kingdom of Saudi Arabia (80.2dBA: commercial areas; 81dBA: residential-commercial areas), Sylhet-Bangladesh (79.1dBA) and Yazd-Iran (74.4dBA). However, it is almost equal to that of Cape Coast- Ghana where it is 70.9 dBA. However, the above comparisons are to be considered shallow, (imitations exist in those compared studies such as differences in the measurement equipments used) only roughly indicating the noise pollution level in Addis Ababa compared to other cities in the world.

3.3. Tempo-spatial Noise Variability

For the 25-sites, the standard deviation ranges from 3.54dBA for Leq (range: 15.1dBA) to 8.95dBA for Lmax (range: 31.8dBA) (Table 2). These data show that there is some, if not significant, spatial noise variability in the selected commercial zones especially for some parameters such as Lmax.

The results also indicate that there is significant time variability of sound levels over the 1-hour period of measurement as is well evidenced by the relationship between Leq, L10, L50 and L90 values as well as the results of the one-hour time history plots of the Leq values generated by the built-in Deaf Defier software (Figure 3 to Figure 8 show the time series plots for some of the sites). For example, the 25-sites mean Leq value (69.5dBA) equals that of L10 (69.5dBA) rather than approaching those of L50 and L90 whereas L10 is usually contributed by variability inducers such as temporary noise sources in the area. The

fact that there is significant time variability of noise levels is also indicated by the 1-hour time history plots. For example, for CMC Altad police station area, there is variability of instantaneous values over the 1-hour average Leq value of 63.9dBA as in Figure 3.

3.4. Correlation Analysis of Noise Parameters

earson correlation analysis was also conducted for Leq, L10, L50 and L90 whose results are shown in Table 3, their relationship also being indicated in Figure 9. Accordingly, it is observed that there is high correlation between values of L10, L90 and L50 (over 80% correlations) which is statistically significant (two-tailed test; p values < 0.01). On the other hand, correlation of up to 72% was found between Leq and L10 values with statistical significance ($p < 0.01$). These correlation results could show that if one parameter is determined, then the other could be approximated or guessed.

4.Conclusion

The principal noise pollution sources in mixed commercial zones in the city are road vehicles, though there are also sources such as music from boutiques and music shops. The day-time mixed-commercial zone noise pollution has reached the extent of significantly exceeding the national commercial and residential noise emission standards. The present research is believed to give at least baseline information on the level of noise pollution in the city. However, further research is strongly recommended in the area as still little is researched and known on the problem in the Ethiopian context especially in relation to its level in different land use systems as well as the observed human health effects.

5. Recommendation

Based on the findings, the following are recommended: awareness raising on the issue to commercial sectors and car drivers; better enforcement of noise standards especially in mixed residential-commercial zones; regular inspection of principal noise sources in those areas and incorporation of noise prevention issues in business licensing.

6. Acknowledgement

Sincere gratitude must go to the Yeka sub-city EPA (for help in site selection), the laboratory team of AAEPA (for equipment provision and important discussions) and the pollution research team of AAEPA (for coordination of resources and important comments). Finally, the study could have been impossible without the sponsorship of AAEPA.

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