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Assessment of noise pollution indices in the city of Kolhapur, India

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Abstract

Noise pollution, in the recent times, has been well recognized as one of the major trepidations that impact the quality of life in urban areas across the globe. Kolhapur, an ancient city of India, is rapidly emerging as industrialized and urbanized city and has started facing severe noise pollution problems. Day-time urban noise quality assessment was studied in Kolhapur for five critical zones viz. Educational, Commercial-cum-residential, Industrial-cum-residential, Recreational and Silence zone. Noise pollution indices viz. L_{10}, L_{50}, L_{90}, noise climate (NC), equivalent continuous noise level (L_{eq}), noise pollution level (L_{np}) and noise exposure index (NEI) were computed for all zones. Results indicated that the highest L_{eq} of 72.25 dBA was observed in industrial-cum-residential zone followed by 64.47 dBA in commercial-cum-residential zone, 63.71 dBA in educational zone, 53.26 dBA in recreational zone and 42.84 dBA in silence zone. For educational zone, L_{eq} observed were above the statutory limits, while for other zones it was marginally below. The noise assessment study clearly revealed the alarming condition of noise pollution in Kolhapur.

Keywords: Equivalent continuous noise level (L_{eq}), Noise assessment, Noise pollution, Noise pollution indices, Noise standards

1. Introduction

Noise pollution, in the recent times, has been well recognized as one of the major trepidations that impact the quality of life in urban areas across the globe. Because of the rapid increase in industrialization, urbanization and other communication and transport systems, noise pollution has reached to a disturbing level over the years. Currently, residences far from the noisy sources and near

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silent secondary roads are becoming very popular and gaining immense importance. General public prefer to live in places far away from noisy urban environment (Yilmaz and Ozer, 1998).

Noise pollution is distinguished from other pollution categories due to its source and diffusion characteristics, which can adversely affect public health and environmental quality in urban environment. There has been a considerable increase in noise from manmade sources during last 100 years, which is now doubling after every ten years (Pandey, 1992). Major cities like Mumbai, Delhi, Kolkata and Chennai are listed among the noisiest cities in India (Shastri et al., 1996). Many surveys addressing the noise pollution problems has been conducted for several cities of the world (Alberola et al., 2005; Bhosale et al., 2010) and have clearly shown the scale of discomfort that noise causes in people's lives (Vidyasagar and Rao, 2006). The effects of noise on human health and comfort are divided into four categories depending on its duration and volume. They are – (i) physical effects such as hearing defects; (ii) physiological effects, such as increased blood pressure, irregularity of heart rhythms and ulcers; (iii) psychological effects, such as disorders, sleeplessness and going to sleep late, irritability and stress; and (iv) effects on work performance, such as reduction of productivity and misunderstanding what is heard (Evans and Hygge, 2000). Therefore, assessing the problem and programming actions for controlling noise and its adverse effects have become an issue of immediate concern for community. In the recent past, Government of India has also introduced the Noise Pollution (Regulation and Control) Rules, 2000 for the noise producing and generating sources.

Kolhapur, a district headquarters in Maharashtra State, is one of ancient cities of India. It is rapidly emerging as industrialized and urbanized city after Mumbai and Pune. Surrounded by beautiful green hills, pleasant climate, availability of ample space and fresh water, rich natural resources and first-rate road and railway network are some of the key features of Kolhapur. Apart from being a historic and religious place, Kolhapur also has large number of renowned educational institutions. Because of the increase in population, industrial areas, vehicles and other manmade activities, the city has started facing noise pollution problems. Moreover, the severity of noise pollution problem will increase in the years to come. It is, therefore, necessary to formulate and implement suitable strategies to combat noise pollution from the futuristic point of view. Although significant numbers of research papers have been published on various cities of India (Shastri et al., 1996; Vidyasagar and Rao, 2006), not much data is available on Kolhapur (Hunashal and Patil, 2011). The present paper on Kolhapur city highlights the zone-wise evaluation and analysis of noise pollution indices.

2. Materials and Methods

2.1. Area of study and measurement of noise

The present investigation on evaluation and analysis of environmental noise pollution was conducted in the city of Kolhapur during the period of winter season (December to February). Table 1 shows the data on Kolhapur city in context to demography, geographic locations and meteorological aspects during the course of study. Table 2 and Figure 1 depict the five sampling locations/zones of Kolhapur city that were selected for noise pollution study. Noise levels in 'A' weighting network were measured using Sound Level Meter (YFE Model YF-20). The meter was held 1.3 to 1.5 m above the ground surface and 3.0 to 3.5 m away from reflecting surface, if any. For each sampling location, noise measurements were carried out continuously for the period of ten days with seven hours of monitoring per day with a gap of one hour after every hour of reading. The schedule selected during the day time was as follows: morning 10.00-11.00 a.m., afternoon 12.00-1.00 p.m., 2.00-3.00 p.m., evening 4.00-5.00 p.m., 6.00-7.00 p.m., 8.00-9.00 p.m. and night 10.00-11.00 p.m. The night readings acted as a control. For each hour, the noise levels were recorded after every two minutes (i.e. 30 readings were recorded every hour). The data

collected from each location was processed for statistical analysis. All the noise monitoring experiments were carried out under ideal meteorological conditions as mentioned earlier (Table 1) and repeated twice for each location after a gap of 45 days.

Table 1. Demographic, geographic locations and meteorological aspects of Kolhapur city during the study period

Sr. No.	Parameters	Documented Values
1.	Population (2011 Census)	5,70,102
2.	Geographical area (km^2)	66.82
3.	Population density (No. of persons/km^2)	8531.9
4.	Latitude	16º42' N
5.	Longitude	74º14' E
6.	Mean sea level (m)	569
7.	Annual Rainfall (mm) (2008)	1025
8.	Max. temperature during winter (°C)	30±2
9.	Min. temperature during winter (°C)	19±4
10.	Humidity (%)	26±4
11.	Wind speed (km/h)	11.6±1.9

Table 2. Sampling locations for noise pollution monitoring in Kolhapur

Sr. No.	Zone (Location name)	Characteristics
1.	Educational zone (Ambai square, University Road area)	Being an educational area, it is considered to be as a silence zone
2.	Commercial-cum-residential Zone (Rajarampuri area)	One of the busiest zones of Kolhapur. Mixed area consisting of large number of shops and human dwellings
3.	Industrial-cum-residential zone (Shivaji Udyamnagar area)	Mixed area mainly consisting of large number of small scale industrial units and human dwellings
4.	Recreational zone (Rankala Lake area)	Popular tourist and picnic spot for residents of Kolhapur. Peripheral parts of lake surrounded by roads; enormous traffic noise thereby impeding people's enjoyment. Being a recreational spot, it is considered to be a silence zone
5.	Silence zone (New Palace area)	Quiet area and acted as control in our studies

2.2. Noise pollution indices

Various noise pollution indices were calculated using Gaussian percentile to obtain the noise pollution levels. Different percentile values like L_{10}, L_{50} and L_{90} were computed from the sampled data and these parameters were used for the evaluation of Noise Climate (NC), Equivalent Continuous Noise Level (L_{eq}) and Noise Pollution Level (L_{np}) (Tripathi et al. 2006). Following equations were used to compute the noise pollution indices.

$$NC = L_{10} - L_{90} \quad (1)$$

$$L_{eq} = L_{50} + [(NC)^2/60] \quad (2)$$

$$L_{np} = L_{eq} + NC \quad (3)$$

$$NEI = (t_1 / T_1) + (t_2 / T_2) + \ldots\ldots\ldots + (t_n / T_n) \quad (4)$$

Where, NC is Noise Climate; L_{10} is the level of sound exceeding for 10% of total time of measurement or Peak Noise Level; L_{50} is the level of sound exceeding for 50% of total time of measurement or Mean Sound Level; L_{90} is the level of sound exceeding for 90% of total time of measurement or Background or Residual Noise Level; L_{eq} is Equivalent continuous noise level and; L_{np} is the Noise Pollution Level; t_1 to t_n are the actual limit of exposure at the corresponding noise levels, and T_1 to T_n are the permissible limits of exposure at the corresponding noise levels. If the value of NEI thus calculated is greater than 1, the noise exposure level is deemed to be excessive.

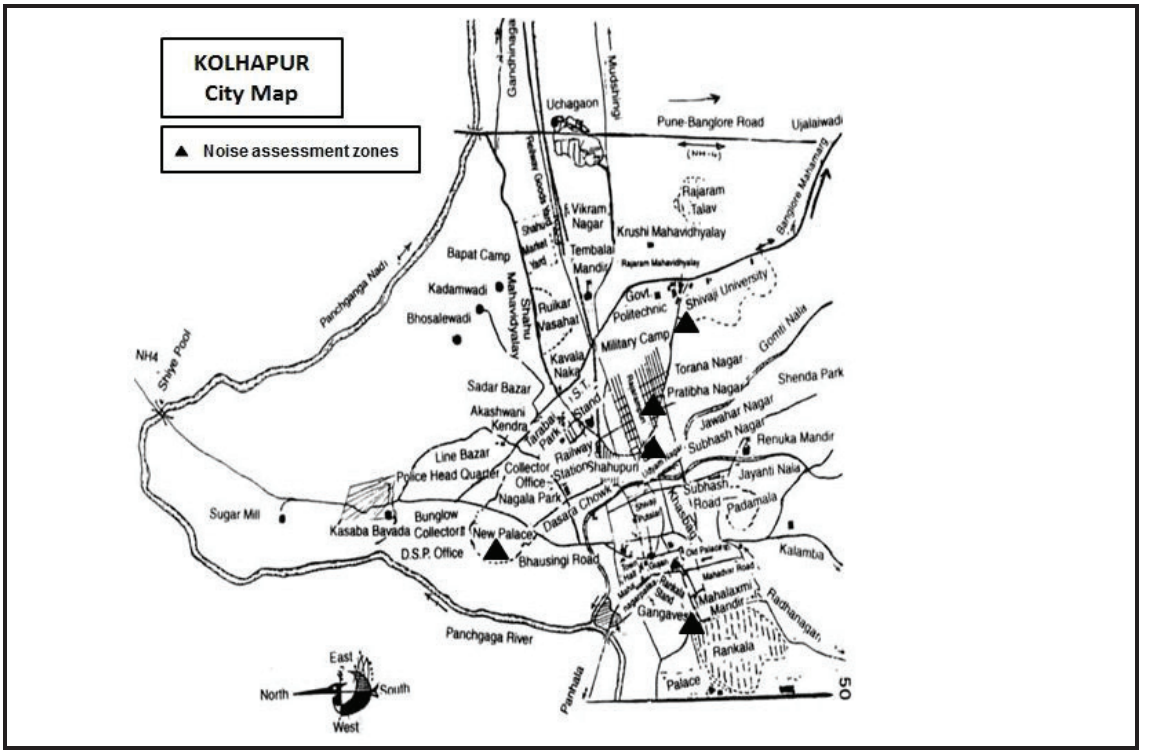

Fig. 1. Map of Kolhapur city showing five noise assessment zones

3. Results and discussion

Data in Fig. 2 depicts the average noise pollution indices viz. L_{eq}, L_{np}, L_{10}, L_{50} and L_{90} in Educational zone of Kolhapur city at various time intervals (i.e. 10.00 am to 11.00 pm). It clearly shows that the highest L_{10} observed during the tested period was 66 dBA between the time period 2.00-3.00 pm. Similarly, the average L_{90} observed was 59.8 dBA, while the average L_{50} was 63.3 dBA during the same time period indicating the maximum noise levels attained in Educational zone. Maximum L_{eq} recorded was 63.71 dBA between 2.00-3.00 pm, while it was minimum (42.51 dBA) during night from 10.00-11.00 pm. The day time L_{eq} observed in this zone was greater than the prescribed CPCB limits during day time, which is 50 dBA. L_{np} takes into account both NC and L_{eq} indices. It gives an idea of noise pollution with fluctuations in the noise level. It is considered as the best indicator of physiological and

psychological impact of noise. The highest observed L_{np} was 70.21 during 2.00-3.00 pm and 46.01 during the night 10.00-11.00 pm. Table 3 shows the data for NC and NEI for all the five studied zones of Kolhapur city. NC in Educational zone indicates the greater fluctuations in the noise levels. The maximum NC was 8.0 between 12.00-1.00 pm, while it was minimum (NC=3.2) between the time period 8.00-9.00 pm. As far NEI in Educational zone was concerned, it was 1.048 between 2.00-3.00 pm followed by 1.011 between 12.00-1.00 pm. These values exceeded the American National Standard (ANS) Specifications of 1 indicating excess noise in educational zone.

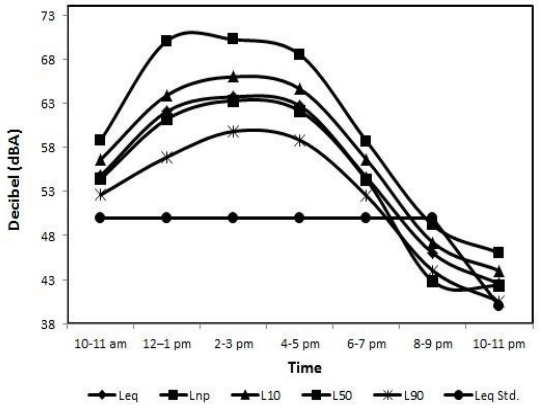

Fig. 2. Noise pollution indices of educational zone

Educational zone, which is considered to be as a Silence zone, the average sound pressure level (L_{eq}) was observed well above (63.71 dBA) the prescribed Environmental Noise Standards (50 dBA) as laid down by Central Pollution Control Board (CPCB), New Delhi in India (Table 4). This may be attributed to very busy Ambai square on which large number of people especially the students are moving and crossing around, business activities and large number of vehicles plying on the university road. It has also been experienced by the authors that the vehicles disturb the road side teaching classes of the educational institutions. Fig. 3 shows the noise pollution indices of Commercial-cum-residential zone (i.e. Rajarampuri area). It shows highest L_{10} during the period between 4.00-5.00 pm (65.3 dBA). Similarly, L_{90} and L_{50} observed in this zone was 62.2 and 59 dBA, respectively, indicating maximum noise levels attained between 4.00-5.00 pm. However, the L_{eq} calculated in this zone (range 57.45 to 62.9) during day time was consistently lower than the prescribed limits of CPCB (65 dBA). The corresponding NC and Lnp in this zone between 4.00 – 5.00 pm were 6.3 and 69.17, respectively. As regard to NEI, the values obtained were above 1 between the time period 2.00 to 7.00 pm (Table 3) indicating that it is exceeding the ANS specifications.

Fig. 4 depicts the data on noise pollution indices for industrial-cum-residential zone (i.e. Shivaji Udyamnagar area), while the data for NC and NEI is shown in Table 3 for over a period between 10 am to 11 pm. It was found that the average L_{10} value observed was 74.9 dBA between 4.00-5.00 pm. Correspondingly, the L_{50} and L_{90} values were also higher during the same period indicating that the noise emanated in this zone was maximum during 4.00-5.00 in the evening. As far L_{eq} in Industrial-cum-residential zone was concerned, it varied from 72.25 - 46.82 dBA, the maximum being 72.25 dBA between 4.00-5.00 pm and the minimum being 46.82 dBA between 10.00-11.00 pm.

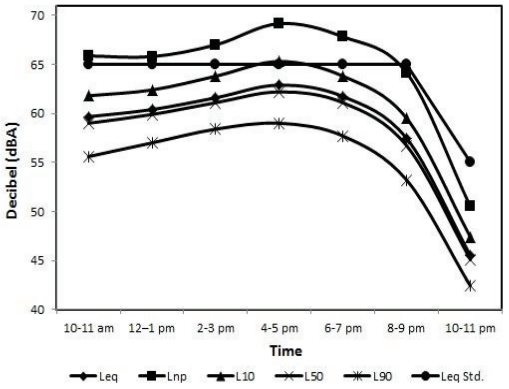

Fig. 3. Noise pollution indices of commercial-cum-residential zone

Table 3: Data on noise pollution indices with reference to Noise Climate (NC) and Noise Exposure Index (NEI) for different zones of Kolhapur city at different time interval

Average Values							
Time	10 – 11 am	12 – 1 pm	2 – 3 pm	4- 5 pm	6 – 7 pm	8 – 9 pm	10 – 11 pm
Educational zone							
NC	4	8	6.5	5.8	4.1	3.2	3.5
NEI	0.904	1.011	1.048	1.026	0.904	0.76	0.704
Commercial-cum-residential zone							
NC	6.2	5.4	5.4	6.3	6.1	6.7	5
NEI	0.979	0.993	1.016	1.033	1.012	0.94	0.749
Industrial-cum-residential zone							
NC	6.5	7.1	6.1	7.9	6.2	4.9	4.3
NEI	1.012	1.098	1.142	1.216	1.128	0.956	0.772
Recreational zone							
NC	5.7	5.7	5.7	4.7	5.6	3.9	3.4
NEI	0.784	0.823	0.874	0.852	0.871	0.764	0.717
Silence zone							
NC	2.8	2.5	2.8	2.2	2.1	2.2	2.1
NEI	0.7	0.706	0.712	0.69	0.692	0.689	0.685

NC: Noise Climate; NEI: Noise Exposure Index

The day time ambient noise standard of L_{eq} in India is 75 dBA and that for night time is 70 dBA for industrial area. In the present study, the observed average L_{eq} were marginally below (72.25 dBA) the prescribed limits of 75 dBA. However, when compared to Indian residential standards the observed values are more than the prescribed limits for day and night time (55 and 45 dBA, respectively). Udyamnagar in Kolhapur city is basically a mixed type of an area consisting of both industries and dwellings. However, industries were evolved first and then the residences. Therefore, the outdoor noises being generated by man-made activities are high when residences are taken into consideration.

According to Noise Standards the outdoor and indoor acceptable limits for industrial area is 50-60 dB(A) during day time. But as compared to this the observed values in the day time are more in this location. Data in Table 3 shows that maximum NC observed in industrial-cum-residential area was 7.9 between 4.00-5.00 pm, however the NEI was consistently exceeding above 1.00 from morning 10.00 upto 7.00 evening. This indicates that the noise exposure is quiet high in this zone thereby causing annoyance among the human population.

Table 4. Environmental noise standards as prescribed by Central Pollution Control Board (CPCB), New Delhi, India

Area code	Type of area	Environmental noise standards (L_{eq}) in dBA	
		Day time	Night time
A	Industrial area	75	65
B	Commercial area	65	55
C	Residential area	55	45
D	Silence area	50	40

Notes: Day time shall mean from 6.00 a.m. to 10.00 p.m.; Night time shall mean from 10.00 a.m. to 6.00 a.m.; Silence zone is defined as an area comprising not less than 100 metres around hospitals, educational institutions and courts. The silence zones are zones which are declared as such by the competent authority; Mixed categories of areas may be declared as one of the four above mentioned categories by the competent authority.

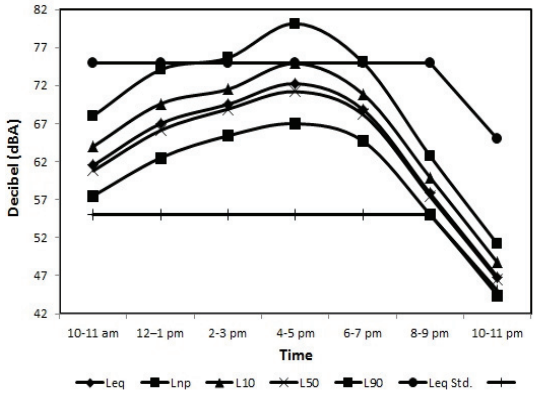

Fig. 4. Noise pollution indices of industrial-cum-residential zone

Industrial-cum-Residential zone (Udyamnagar) and Commercial-cum-Residential zone (Rajarampuri) are both mixed type of zones wherein the noise pressure levels (L_{eq}) are marginally below the prescribed industrial and commercial limits, respectively, but were well above the residential limits (Table 4 and 5). Although the noise levels in the said zones are marginally below in the current situation, it is expected to increase in the near future as evident from the present growth trend of industries and urban population in Kolhapur. Noise pollution indices for recreational zone (i.e. Rankala lake area) are shown in Fig. 5, while the data of NC and NEI is depicted in Table 3. It can be clearly seen that the corresponding values of L_{10}, L_{50}, L_{90}, L_{np} and L_{eq} were higher between the 2.00 pm to evening 8.00 pm. Since recreational zone is regarded as a silence zone and therefore in principle, noise standards of silence zone could be applicable to it (i.e. 50 dBA). Taking the said benchmark into account, it could be seen from Fig. 4 that the day time noise values exceeds the value of 50 dBA. The data on NC and NEI showed lesser degree of variation throughout the tested period when compared with other zones of Kolhapur.

Table 5. Comparative account of observed L_{eq} with Environmental Noise Standards

Sr. No.	Zone	Day time observed L_{eq} (dBA)	Day time Environmental Noise Standards dBA			Comments
			For Industrial or Commercial zone	For Residential zone	Silence zone	
1.	Educational zone (Silence zone)	63.71	-	-	50	Well above limits
2.	Commercial-cum-residential zone (Mixed zone)	65.3	65	55	-	Marginally below commercial limits but above residential limits
3.	Industrial-cum-residential zone (Mixed zone)	72.25	75	55	-	Marginally below industrial limits but above residential limits
4.	Recreational zone (Silence zone)	53.26	-	-	50	Above limits
5.	Silence zone (Control)	42.84	-	-	50	Below limits

As mentioned earlier, silence zone (New Palace area) acted as a control for our studies. Figure 6 depicts the noise pollution indices for this zone. The data clearly indicates that all the indices were found in the range of 40-46 dBA, which were well below the statutory limits of 50 dBA prescribed by the statutory agencies in India. One of the key noise pollution index (L_{eq}) is also known as average sound level. It quantifies the noise environment as a single value of sound level for any desired duration. This descriptor correlates well with the effects of noise on people. L_{eq} at different sampling zones varied from 72.25 dBA to 41.28 dBA. The highest L_{eq} was recorded in Industrial-cum-Residential zone (72.25 dBA) between 4.00-5.00 pm, while the lowest L_{eq} recorded was 46.82 dBA between 10.00-11.00 pm. In Commercial-cum-Residential area, the highest and lowest Leq observed were 64.47 dBA during 6.00-7.00 pm and 45.52 dBA during 10.00-11.00 pm, respectively. In Educational area the highest and lowest L_{eq} were 63.71 dBA during 12.00-1.00 pm and 42.51 dBA during 10.00-11.00 pm, respectively. Similarly, in Recreational zone the highest and lowest L_{eq} recorded were 53.26 dBA (during 6.00-7.00 pm) and 43.3 dBA (10.00-11.00 pm), respectively. In Silence zone, however, the highest and lowest L_{eq} were 42.84 dBA during 2.00-3.00 pm and 41.28 dBA during 10.00-11.00 pm, respectively. For highest L_{eq}, the sequence (in decreasing order) obtained was as follows: Industrial-cum-Residential > Commercial-cum-Residential > Educational > Recreational zone > Silence zone. Similar characteristic pattern of sequence was also observed for the lowest Leq data. Similar characteristic pattern of sequence was observed for lowest NC data as well. Another noise pollution index (L_{np}) is a combination of Noise Climate (NC) and Equivalent Continuous Noise (L_{eq}) as stated in Eq. 3. It gives an idea of noise pollution with fluctuations in noise level. It is considered as the best indicator of physiological and psychological impact of noise. Similar characteristic pattern of sequence was also observed for lowest L_{np} data.

The overall results on noise pollution in different zones of Kolhapur city indicates that the noise pressure levels (L_{eq}) were highly variable and significant at the different sampling zones/locations and were the manifestation of diverse man-made activities in these zones. It is well known that noise above certain level has the potentials to damage human health depending on its intensity, frequency and duration of exposure, as well as the individual's susceptibility. The disorders may be auditory or extra-auditory. Moura-de-Sousa and Cardoso (2002) noted that a noise up to 50 dBA may be annoying, but one can be adapted to the situation (Moura-de-Sousa and Cardoso, 2002). A 55 dBA noise causes a light stress, excitement, dependence and discomfort and a 65 dBA noise causes a deep stress. At a 80 dBA level of noise, the organism is likely to release biological morphine into the body, resulting in a feeling of pleasure that may lead to a type of dependence. At a 100 dBA it is possible to have an irreversible hearing loss. The hearing effects of a noise that is intense enough are noise-induced permanent threshold shift,

noise-induced temporary threshold shift, and acoustic trauma. Usually, these effects are accompanied by tinnitus (Singh and Davar, 2004).

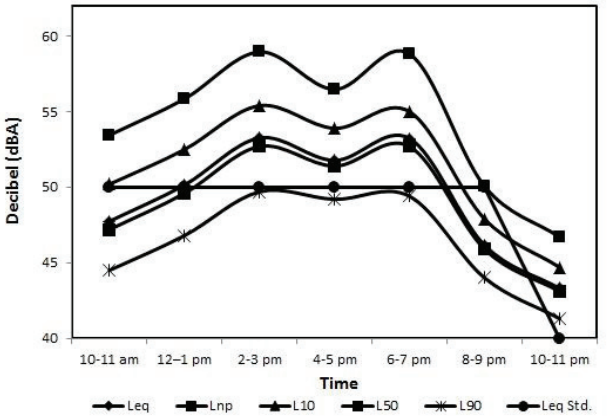

Fig. 5. Noise pollution indices of recreational zone

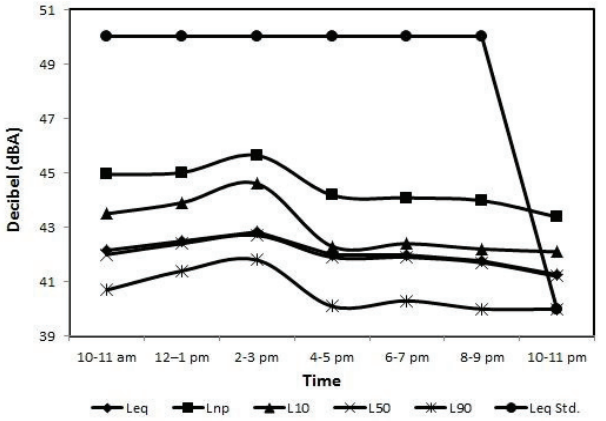

Fig. 6. Noise pollution indices of silence zone

Urban noise, or environmental noise pollution, however, is not a recent phenomenon. Presently, in Kolhapur, the urban noise complaints are restricted to only Diwali and Ganpati festivals. However, it is predicted that in the near future the frequency of noise complaints will increase significantly because of rapid increase in population, business activities and industrialization. Previously, several researchers worldwide have studied the urban noise pollution (Ozer et al., 2009; Tripati et al., 2006; Yusoff and Ishak, 2005). Overall trend of the research papers show that noise pollution is becoming a severe problem in the urban environment, and Kolhapur city is no exception to it. Furthermore, looking towards the current and future developmental trends of Kolhapur city, it is the high time for the local government to take precautionary actions to save people from the risk of noise pollution. The authors wish to put forth

some of the preventive measures that the local government and regulators could implement in order to control noise pollution in Kolhapur city. They are: (i) prohibition on the use of heavy vehicles in commercial and residential areas during day time or diversion of traffic to minimize noise pollution; (ii) intensive plantation in open spaces, near residential and industrial places; (iii) Periodic noise monitoring on the roads; (iv) noise impact assessment for any new or additional projects before granting the approval; (v) proper enforcement of already existing legislation to control noise pollution; (vi) creating awareness among the masses through awareness programmes, workshops, campaign, mass media, press, radio, TV, newspaper, etc.; (vi) improvement and proper maintenance of road conditions which will smoothen the flow of traffic; and (vii) enforcement to ban the use of horns in silence zones as well as restriction of horns by vehicles when passing by residential areas.

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