

Evaluation and Analysis of Environmental Noise Pollution in Seven Major Cities of India

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The paper describes the noise monitoring data acquired from the pilot project on the establishment of National Ambient Noise Monitoring Network (*NANMN*) across seven major cities in India for continuous noise monitoring throughout the year. The annual average L_{day} (06–22 h) and L_{night} (22–06 h) values observed in year 2011–2014 for the 35 locations under study in which 14 locations are in commercial zone, 5 in Industrial, 7 in residential and 9 in silence zones are described. The long-term noise monitoring shows that ambient noise levels have marginally increased for 29 sites (82.9%) since past four years. The present study is focused on evaluation and analysis of environmental noise pollution at 35 noise monitoring sites in seven major cities of India and shall be instrumental in planning for the noise abatement measures for controlling the noise pollution in these sites.

Keywords: National Ambient Noise Monitoring Network (*NANMN*); day equivalent level, L_{day} ; night equivalent level, L_{night} ; day-night average sound level, L_{dn} ; equivalent continuous sound pressure level, $L_{\text{Aeq,24h}}$.

1. Introduction

The rapid urbanization and growth of urban population has led to many health challenges including the environmental air and noise pollution. Amongst all the pollution problems, noise is considered as an important environmental issue. Motor vehicles are the main sources of urban noise emission contributing about 55% to the total noise (BANERJEE *et al.*, 2008; PANDYA *et al.*, 2002; SINHA *et al.*, 2003). The growing vehicular population gives rise to noise pollution and associated health effects and can cause both short-term and long-term psychological and physiological disorders. Noise is regarded as a pollutant under the Prevention and Control of Pollution Act, 1981 of India (MoEF 1981 Act). The World Health Organization (WHO) estimates that 10% of the world population is exposed to sound pressure levels that could potentially causes noise induced hearing loss (OISHI *et al.*, 2011; BASNER

et al., 2014). Environmental noise causes numerous psychological effects such as annoyance (ÖHRSTRÖM *et al.*, 2004; OUIS, 2001; PATHAK *et al.*, 2008), anxiety, depression and serious health effects such a cardiovascular disease (BABISCH, 2008; BABISCH *et al.*, 2005; DAVIES *et al.*, 2012; JAMIR *et al.*, 2014; WHO-JRC, 2011; SELANDER *et al.*, 2009). Noise has been found to have significant negative impact on children's blood pressure and mental health. Some studies show that people who are exposed to high road traffic noise levels have significantly higher prevalence of hypertension (CHANG *et al.*, 2011). It is thus essential to conduct noise monitoring studies especially for the noisy spots so as to monitor the sound levels and devise suitable abatement measures for controlling the noise pollution. The European Environmental Noise Directives, 2002/49/EC requires all the member states to produce strategic noise mapping, estimate population exposure to noise, develop noise action plans and disseminate

the noise information to the public (MURPHY *et al.*, 2010; TO *et al.*, 2015). Studies have been conducted in the different parts of the world for monitoring the ambient noise and implementing the noise abatement measures to control them (LI *et al.*, 2002; MORIALLAS *et al.*, 2002; ZANNIN *et al.*, 2002; CHAKRABARTY *et al.*, 2006; MURPHY *et al.*, 2009; NAISH *et al.*, 2010; DINTRANS *et al.*, 2013; HAMMER *et al.*, 2014; ABBASPOUR *et al.*, 2015; GARG *et al.*, 2015a; CAI *et al.*, 2015; MCALEXANDER *et al.*, 2015). Also, validated road traffic noise models have been developed for predicting the traffic noise and noise mapping of cities (STEELE *et al.*, 2001; GARG *et al.*, 2015b; 2015c; FIEDLER *et al.*, 2015). In India, the pilot project of National Ambient Noise Monitoring Network (NANMN) established by Central Pollution Control Board (CPCB) in the year 2011 covering 35 locations in seven metro cities (Delhi, Hyderabad, Kolkata, Mumbai, Lucknow, Bangalore and Chennai) is a great step for monitoring and analyzing the ambient noise levels and disseminating the noise information to the public. The Central Pollution Control Board in association with State Pollution Control Boards is continuously monitoring and analyzing the noise levels and working on devising and implementing the noise abatement measures for controlling the noise pollution in India.

The present work is an extension of the previously reported study (GARG, MAJI, 2016a) on the establishment of National Ambient Noise Monitoring Network (NANMN) across seven major cities in India for continuous noise monitoring throughout the year and analyzes the noise monitoring data acquired for the 35 sites for the year 2014 and past four years (2011–2014) to analyze and report the status of noise pollution at these sites in the past four years and consideration of noise abatement strategies to be implemented to bring the noise levels below the ambient noise standards. The focus of the present study is thus to:

- ascertain the annual average ambient noise levels of 35 sites and compare them with ambient noise standards of India,
- ascertain whether the current ambient noise standards are suitable for residential areas and areas within silence zones and suggesting the need of amendments required if any,
- analyze the difference of L_{day} and L_{night} levels so as to ascertain the severity of night noise levels in comparison to the day levels,
- recommend the suitability of 10 dB adjustment in L_{dn} in Indian scenario in the light of development of a noise annoyance model in terms of single-noise descriptor, and
- finding out the noise spots and planning for implementing suitable control measures to bring these levels below the ambient standards.

Although 35 monitoring locations are insufficient to represent the noise environment of the concerned cities, yet the present study is based on evaluation and analysis of continuous long-term noise levels acquired under the NANMN programme at these 35 sites, which is one of the first networks established in India with special budgetary allocations. It may be noted here that the day equivalent level, L_{day} and night equivalent level, L_{night} is calculated from the 24 hours noise data for each day of the year. The day-time is from 6.00 a.m. to 10.00 p.m., while the night time is considered from 10.00 p.m. to 6.00 a.m. The current ambient noise standards followed in India are in terms of L_{day} and L_{night} as shown in Table 1. The silence zone is an area comprising not less than 100 m around hospitals, educational institutions, courts, religious places or any other area which is declared as such by the competent authority. Mixed categories of areas may be declared as one of the four mentioned categories in Table 1 by the competent authority (Noise Pollution Rules, 2000; CPCB report, 2011–12; NANMN brochure, 2011).

Table 1. Ambient air quality standards in respect of noise in India (Noise Pollution rules, 2000).

Area code	Category of area/zone	Limits in dB(A) L_{eq}^*	
		Day time	Night time
A	Industrial area	75	70
B	Commercial area	65	55
C	Residential area	55	45
D	Silence zone	50	40

* L_{eq} denotes the time weighted average of the sound level in decibels in A-weighting.

2. Material and methods

The noise monitoring data is acquired from the pilot project on the establishment of National Ambient Noise Monitoring Network (NANMN) established in the year 2011 across the seven major cities in India for continuous noise monitoring throughout the year. The details of the project and instrumentation used can be found in reference (GARG, MAJI, 2016). The 35 locations under study constitute of 14 locations are in commercial zones, 5 in industrial, 7 in residential and 9 in silence zones. The Noise Monitoring Terminal manufactured and installed by Geónica Earth Sciences, Spain (Geonica website, www.geonica.com) is an automated system consisting of a sound level meter traceable to the national standards for continuously measuring the ambient noise through the year at 35 locations under study. The sound level data acquired is transmitted to National Noise Monitoring Centre, NMMC located at CPCB Headquarters, Parivesh Bhawan, New Delhi whereby the data is received, processed and displayed. In addition, a website

application, <http://www.cpcbnoise.com>, is developed to disseminate the data in real time to the public for generating awareness towards reducing the noise pollution in different parts of the country (SGS Weather and Environmental Systems Pvt. Ltd, India website, www.sgsweather.com). The remote stations collect and store the data which is then transmitted via a GPRS communications system to the central database, where they are stored. The noise monitoring data can be accessed on the website, <http://www.cpcbnoise.com>, showing the daily ambient sound levels: L_{day} value and L_{night} values for all the 35 sites under consideration. Figure 1 shows the display of ambient noise levels at CPCB office reception at Parivesh Bhawan, New Delhi of seven cities of India. The scope of the NANMN project has been enhanced with the installation of 35 more stations in the same seven metropolitan cities since November, 2014. The Noise Monitoring Network now covers 70 locations in seven metropolitan cities of India and is a unique and one of the largest noise monitoring networks of its kind across the globe.

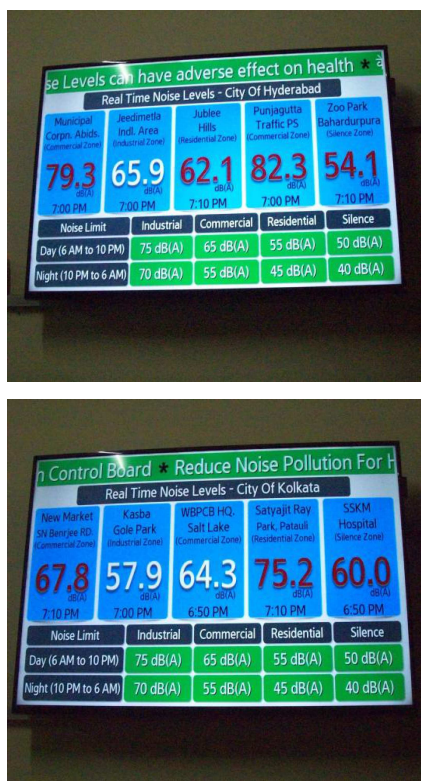


Fig. 1. Display of ambient noise levels at CPCB office reception at Parivesh Bhawan, New Delhi of seven cities of India.

3. Analysis of noise pollution

3.1. City wise analysis

The ambient noise levels: day equivalent level, L_{day} and night equivalent level, L_{night} were observed for all

the 35 sites and compared to the ambient noise standards. Table 2 shows the annual average ambient levels, L_{day} and L_{night} for the past years, 2011–2013 as reported earlier in (GARG, MAJI, 2016) and for the year 2014 the annual average ambient levels for 35 noise monitoring stations installed under NANMN programme across seven major cities in India. The city wise and zone wise analysis of annual average ambient levels, L_{day} and L_{night} is conducted to identify the noisy spots for implementation of suitable noise abatement measures. Also, the difference of ($L_{day} - L_{night}$) for all the zones in past four years (2011–2014) is analyzed to ascertain the severity of night noise levels in comparison to the day levels as reported earlier (GARG, MAJI, 2016) and consider the suitability of 10 dB night time adjustment in day-night average sound level, L_{dn} that accounts for the increased sensitivity to noise at night, the expectation that the night time noise will be lower than during the day and for sleep disturbance protection is not appropriate in such a scenario. Day-night average sound level, L_{dn} and day-evening-night average sound level, L_{den} is the widely used noise descriptor recommended in many studies for developing exposure-effect relationship (EU’s Future Noise Policy, 2002; MIEDEMA *et al.*, 1998; SCHOMER, 2002; 2005).

3.1.1. Delhi city

It is observed that there is a marginal increase in ambient noise levels in Delhi city since the past four years. The maximum increase in L_{day} value since past four years is 2.1 dB(A) for CPCB, Head quarters and maximum increase in L_{night} levels is 2.1 dB(A) for the ITO area. The L_{night} levels are very high as compared to the ambient noise standards for Dilshad Garden, Delhi Technological University (DTU), ITO and NSIT Dwarka sites. The ambient noise levels at ITO site are very high as compared to the ambient standards. The ambient noise levels have decreased for Dilshad garden site by 0.7 dB(A) for L_{day} and 2.1 dB(A) for L_{night} since the past four years. Also, for the DTU, Bawana site; the ambient noise levels have decreased by 0.5 dB(A) for L_{day} and 0.3 dB(A) for L_{night} since the past four years It can be observed that no site in Delhi region meets the ambient noise standards. The CPCB site marginally meets the ambient noise standards as L_{day} levels are 0.9 dB(A) higher than the recommended standards.

3.1.2. Lucknow city

The ambient noise levels have significantly increased in four years for the Gomti nagar area and that for PGI Hospital. The L_{day} levels have increased by 8.2 dB(A) and L_{night} by 7.5 dB(A) for Gomti nagar area since past four years. The PGI Hospital site experienced an increase in L_{day} levels by 7.1 dB(A)

Table 2. Annual average ambient noise levels for 35 monitoring stations installed across seven major cities in India for past four years (year 2011–2013 [GARG *et al.*, 2016], 2014).

Name of location	City	Area characteristics	Geographical coordinates	2011		2012		2013		2014	
				L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}
Dilshad Garden	Delhi	Silence	77°19'E, 28°40'N	52.4±0.9	50.8±1.4	51.9±1.1	50.0±2.1	51.3±1.1	49.4±2.4	51.7±0.9	48.7±1.6
CPCB HQ.		Commercial	77°17'E, 28°39'N	63.8±2.0	53.9±1.4	62.2±1.0	52.7±1.3	63.2±0.8	53.4±1.0	65.9±1.7	54.4±1.6
DTU, Bawana		Silence	77°5'E, 28°44'N	52.3±1.3	49.4±2.1	51.3±0.9	50.0±3.2	52.3±1.7	49.8±3.0	51.8±1.1	49.1±2.5
ITO		Commercial	77°14'E, 28°37'N	73.1±0.6	70.8±1.0	72.0±4.0	70.6±5.3	73.6±0.7	73.0±0.4	74.2±1.0	72.9±1.4
NSIT Dwarka		Silence	77°2'E, 28°36'N	56.6±1.3	54.0±0.8	56.6±0.7	53.8±1.1	56.1±0.5	53.4±0.9	56.6±1.4	53.3±1.8
Gomti Nagar	Lucknow	Residential	80°59'E, 26°51'N	61.3±0.8	53.7±1.5	62.9±0.9	55.3±1.1	67.0±2.2	57.3±1.6	69.5±1.4	61.2±2.0
Hazrat Ganj		Commercial	80°53'E, 26°51'N	72.0±0.9	61.8±1.0	72.4±0.5	61.1±1.0	72.5±0.5	62.0±1.3	72.5±0.5	61.7±1.5
Indira Nagar		Residential	80°59'E, 26°52'N	54.2±1.2	48.8±2.9	53.6±1.1	48.1±3.0	54.2±1.4	49.3±3.6	57.0±0.9	50.6±4.7
PGI Hospital		Silence	80°55'E, 26°45'N	55.3±2.5	49.8±2.8	58.2±1.2	52.3±3.6	60.5±1.4	53.3±3.0	62.4±1.3	55.8±3.5
Talkatora Industrial Area		Industrial	80°53'E, 26°50'N	63.1±0.4	55.7±1.6	63.6±0.7	55.9±1.6	63.4±0.5	56.1±1.9	64.1±1.2	57.3±2.0
Kasba Gole Park	Kolkata	Industrial	88°23'E, 22°30'N	63.6±1.2	59.6±1.3	65.2±1.6	62.0±2.6	68.8±3.5	66.2±4.7	70.3±2.5	68.1±2.9
New Market		Commercial	88°21'E, 22°33'N	67.3±0.5	60.0±1.4	67.0±0.7	59.6±1.4	67.6±0.5	60.5±1.6	70.2±2.3	67.5±5.2
Patauli		Residential	88°22'E, 22°28'N	55.2±1.0	49.4±2.0	54.7±1.0	50.2±3.2	54.7±1.6	54.3±6.2	55.1±1.3	53.9±4.5
SSKM Hospital		Silence	88°20'E, 22°32'N	61.4±0.4	54.3±0.9	62.0±0.8	56.6±1.8	62.3±1.2	57.1±1.9	62.4±1.1	56.7±1.7
WBPCB HQ		Commercial	88°24'E, 22°34'N	61.9±0.6	55.7±1.3	61.0±0.7	54.5±1.1	62.1±1.4	55.5±1.4	63.9±0.6	57.7±0.9
AS HP	Mumbai	Silence	72°51'E, 19°1'N	66.5±1.2	59.7±1.5	65.5±1.0	58.7±0.3	65.4±0.8	60.6±1.5	66.5±2.0	60.7±0.9
Bandra		Commercial	72°49'E, 19°3'N	69.8±0.5	67.4±0.8	69.0±0.7	67.9±1.9	69.2±0.4	66.5±0.5	69.9±0.5	67.0±0.7
MPCB HQ.		Commercial	72°52'E, 19°6'N	66.7±0.6	62.8±0.5	66.4±0.5	63.1±0.7	68.4±1.6	65.3±2.0	71.0±0.6	67.9±1.0
Thane MCQ		Commercial	72°51'E, 19°0'N	62.6±1.8	55.0±2.3	61.7±0.7	54.9±1.9	62.5±1.2	55.4±1.4	64.5±1.0	56.4±1.3
Vashi Hospital		Silence	73°0'E, 19°4'N	68.2±1.7	58.7±1.4	68.8±0.9	59.3±2.7	68.7±0.8	57.0±0.8	69.0±1.5	60.9±3.6
Abids	Hyderabad	Commercial	78°28'E, 17°23'N	71.9±0.5	63.1±0.9	72.4±0.9	63.7±1.9	72.4±0.8	64.0±2.1	74.1±1.9	65.5±2.5
Jeedimetla		Industrial	78°28'E, 17°30'N	62.3±0.5	56.2±1.4	63.0±1.2	56.8±2.1	63.0±1.3	56.5±1.6	65.0±0.6	58.6±0.8
Jubilee Hills		Residential	78°24'E, 17°25'N	57.4±1.0	50.7±1.7	56.2±0.7	48.6±0.5	56.3±0.6	48.9±1.2	57.3±1.6	49.2±1.2
Punjagutt		Commercial	78°27'E, 17°25'N	75.7±0.6	71.0±1.0	75.5±0.5	70.3±0.5	76.6±1.7	71.1±1.3	78.5±0.7	73.4±0.5
Zoo Park		Silence	78°28'E, 17°22'N	53.8±1.5	50.5±2.8	54.2±1.8	48.7±2.0	54.4±1.4	48.7±1.1	56.1±1.2	51.0±2.2
BTM	Bengaluru	Residential	77°35'E, 12°54'N	66.4±0.4	56.5±0.4	66.1±0.5	56.0±1.0	66.0	56.3±0.8	66.4±0.7	57.1±1.1
Marathahalli		Commercial	77°34'E, 12°54'N	56.9±1.9	54.1±1.8	54.5±0.7	51.9±0.6	57.3±2.1	55.3±2.8	59.5±0.7	56.6±0.8
Nisarga Bhawan		Residential	77°35'E, 12°59'N	58.1±3.0	48.4±1.8	56.6±2.0	47.7±1.9	56.7±1.9	48.0±1.6	55.7±1.5	48.8±1.4
Parisar Bhawan		Commercial	77°34'E, 12°58'N	66.5±1.1	58.2±0.7	64.9±0.3	57.0	65.0±0.7	57.3±0.8	64.8±0.8	56.6±0.5
Peeniya		Industrial	77°30'E, 13°1'N	56.5±1.6	55.0±2.6	55.7±1.2	49.2±1.2	58.1±1.1	53.1±2.3	58.1±0.8	54.9±2.0
Eye Hospital	Chennai	Silence	80°17'E, 13°6'N	64.2±0.6	51.7±1.2	62.5±1.5	53.2±3.1	64.3±1.5	53.8±2.2	61.7±3.9	53.5±1.2
Guindy		Industrial	80°12'E, 13°0'N	76.1±0.6	71.8±1.1	75.5±1.1	70.9±1.3	75.2±1.0	70.8±1.5	76.9±1.9	72.2±1.2
Perambur		Commercial	80°14'E, 13°6'N	68.5±0.9	59.1±0.8	68.8±1.2	58.3±1.2	68.3±0.5	57.6±0.7	69.1±1.3	57.9±0.8
T. Nagar		Commercial	80°13'E, 13°2'N	72.4±0.5	61.9±1.1	73.1±0.3	62.2±1.0	73.9±1.0	64.7±2.0	75.0±0.9	66.9±1.6
Triplicane		Residential	80°16'E, 13°3'N	67.8±0.4	56.2±1.0	67.6±0.5	56.3±0.8	67.7±0.5	56.2±0.7	68.4±1.4	57.6±2.0

and L_{night} by 6.0 dB(A) since past four years. The night levels, L_{night} at Gomti nagar, Harat Ganj and PGI Hospital are very high as compared to the ambient noise standards. It is observed that only one site (Talkatora industrial site) meets the ambient noise standards. The day equivalent level, L_{day} has increased by 1.0 dB(A), while night equivalent level, L_{night} has increased by 1.6 dB(A) in the past four years for Talkatora industrial site.

3.1.3. Kolkata city

The ambient noise levels have marginally increased in four years in Kolkata city except for Kasba Gole park site and New Market area, whereby the L_{day} levels have increased by 6.7 dB(A) and L_{night} by 8.5 dB(A) since the past four years for Kasba Gole park site and L_{day} levels have increased by 2.9 dB(A) and L_{night} by 7.5 dB(A) since past four years for New Market site. The night levels, L_{night} at Patauli residential area, New Market and SSKM hospital area are very high as compared to the ambient noise standards. The night levels, L_{night} have increased by 4.5 dB(A) for Patauli area, 2.4 dB(A) for SSKM hospital and 2 dB(A) for WBPCB, head quarters since the past four years. The Kasba Gole park industrial site site meets the ambient noise standards.

3.1.4. Mumbai city

The ambient noise levels have marginally increased in four years in Mumbai city for all the sites under consideration except the MPCB, head quarters site. The maximum increase in L_{day} value since the past four years is 4.3 dB(A), while that for L_{night} is 5.1 dB(A) for the MPCB, head quarters site. The night levels, L_{night} at Acworth Hospital (ASHP), Bandra, Maharashtra Pollution Control Board (MPCB) and Vaishi hospital are very high as compared to the ambient noise standards. No site meets the ambient noise standard out of all the sites in the city under consideration.

3.1.5. Hyderabad city

The ambient noise levels have marginally increased in four years in Hyderabad city for all the sites under consideration. The maximum increase in L_{day} and L_{night} levels since the past four years is 2.7 dB(A) and 2.6 dB(A) for Jeedimetla site. The Jubilee Hills residential area experienced a decrease in the ambient noise levels since the past four years. The L_{day} value has decreased by 0.1 dB(A), while L_{night} has decreased by 1.5 dB(A). The night levels, L_{night} at Abids and Punjagutta area are very high as compared to the ambient standards. Only one location (Jeedimetla industrial site) meets the ambient noise standards.

3.1.6. Bengaluru city

The ambient noise levels have marginally increased in four years in Bengaluru city for all the sites under consideration. The maximum increase in L_{day} value since the past four years is 2.6 dB(A), while that for L_{night} is 2.5 dB(A) for Marathahalli area. Some areas like Parisar Bhawan have experienced a decrease in the ambient noise levels since the past four years. The L_{day} value has decreased maximum by 1.7 dB(A) for Parisar Bhawan, while L_{night} has decreased by 1.6 dB(A). The Nisarga Bhawan site shows a decrement in L_{day} value by 2.4 dB(A), while the L_{night} levels has marginally increased by 0.4 dB(A) in the past four years. The night levels, L_{night} at BTM, Bengaluru are very high as compared to the ambient noise levels. It is observed that only one location namely, Peenya industrial site meets the ambient noise standards.

3.1.7. Chennai city

The ambient noise levels have marginally increased in four years in Chennai city for all the sites under consideration. The maximum increase in L_{day} value since the past four years is 1.6 dB(A), while that for L_{night} is 5 dB(A) for T. Nagar area. The L_{day} value has decreased maximum by 2.3 dB(A) for Eye hospital, while L_{night} has decreased by 1.2 dB(A) for Perambur area. The night levels, L_{night} at Eye Hospital and T. Nagar are very high as compared to the ambient noise standards. No site meets the ambient noise standards of all the sites under consideration.

3.2. Zone wise analysis

3.2.1. Commercial zone

Figures 2 and 3 describe the monthly variation of day equivalent level and night equivalent level, L_{day} and L_{night} for commercial areas in Chennai, Lucknow, Bengaluru and Kolkata in the year 2014. These observations suggest that T. Nagar, Hazrat Ganj, Perambur and New Market requires noise abatement measures in order to bring the levels below the ambient noise standards. The day levels have increased by 4 dB(A) in the year 2014 while comparing the January and December levels; while the night levels have considerably

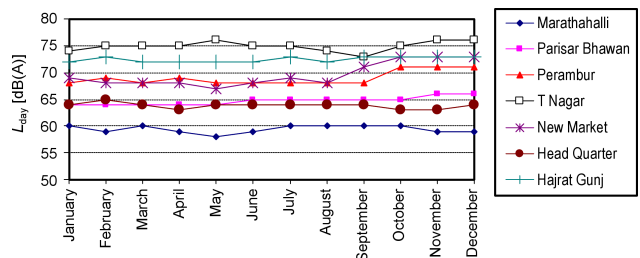


Fig. 2. Monthly variation in equivalent sound pressure level, L_{day} for commercial areas in Chennai, Lucknow, Bangalore and Kolkata in year 2014.

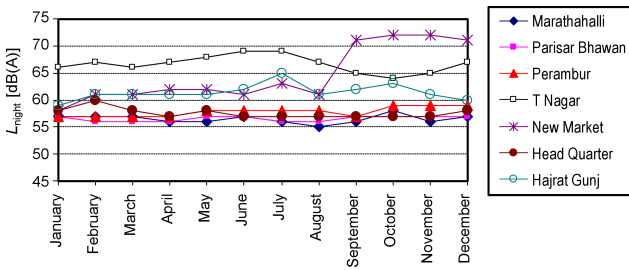


Fig. 3. Monthly variation in equivalent sound pressure level, L_{night} for commercial areas in Chennai, Lucknow, Bangalore and Kolkata in year 2014.

increased by 13 dB(A) for New Market site. Figures 4 and 5 show the monthly variation of equivalent sound level, L_{day} and L_{night} for commercial areas in Delhi, Mumbai and Hyderabad in the year 2014. No commercial site unlike the previous years meets the ambient noise standards as in year 2013, four sites namely CPCB site, Thane site, Marathahalli and WBPCB, head quarters site complied with the ambient stan-

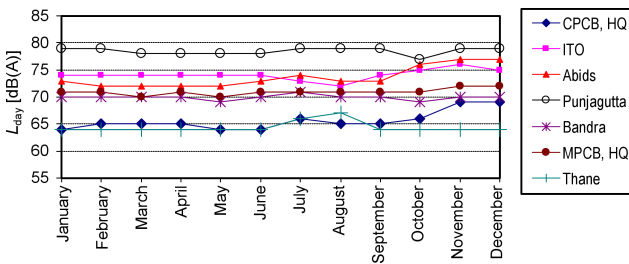


Fig. 4. Monthly variation in equivalent sound pressure level, L_{day} for commercial areas in Delhi, Mumbai and Hyderabad in year 2014.

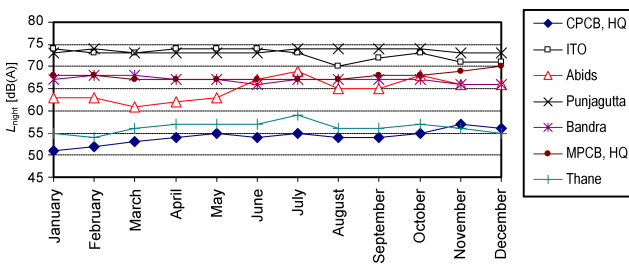


Fig. 5. Monthly variation in equivalent sound pressure level, L_{night} for commercial areas in Delhi, Mumbai and Hyderabad in year 2014.

dards. The CPCB site marginally meets the ambient noise standards. The monthly variation of ± 5 dB(A) for L_{day} levels and ± 6 dB(A) for L_{night} levels is observed in case of CPCB, Headquarters and Abids area. It can be observed that ITO, Bandra, MPCB Head quarters, Abids, Punjagutta and Perambur areas also require immediate noise control measures for bringing the noise levels below the ambient noise standards. Table 3 shows the variation of L_{day} and L_{night} values; $L_{\text{Aeq},24\text{h}}$ and difference ($L_{\text{day}} - L_{\text{night}}$) values in dB(A) for different areas in year 2014. The L_{day} levels varied from 59.5 dB(A) for Marathahalli area to 78.5 dB(A) for Punjagutta area, while the L_{night} levels varied from 54.4 dB(A) for CPCB headquarters to 73.4 dB(A) for Punjagutta area. The average difference between ($L_{\text{day}} - L_{\text{night}}$) is 6.5 dB(A) as shown in Table 3 whereby the maximum difference of 11.5 dB(A) is observed for CPCB, Head quarters and minimum difference of 1.3 dB(A) for ITO area. The day-night average sound level varies from 63.3 dB(A) at Marathahalli site to 80.8 dB(A) for Punjagutta site; while the $L_{\text{Aeq},24\text{h}}$ ranges from 58.7 dB(A) at Marathahalli site to 77.4 dB(A) for Punjagutta site.

3.2.2. Industrial zone

Figures 6 and 7 describe the monthly variation of day equivalent level and night equivalent level, L_{day} and L_{night} in the year 2014 for all the industrial sites under consideration. It can be observed from the L_{day} levels that the Guindy site requires immediate noise control measures. The Peeniya industrial site and Jeedimetla site has the ambient noise levels well within the ambient noise standards. The monthly variation of L_{day} and L_{night} is not so high except in

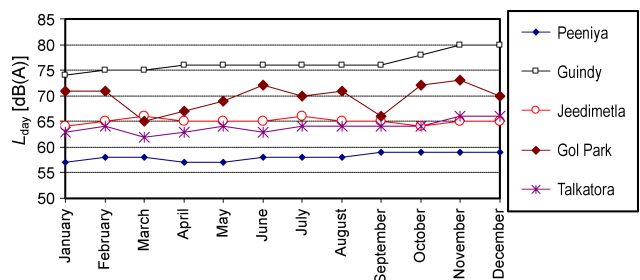


Fig. 6. Monthly variation in equivalent sound pressure level, L_{day} for industrial areas in seven cities in year 2014.

Table 3. Variation of L_{day} and L_{night} values; $L_{\text{Aeq},24\text{h}}$ and difference ($L_{\text{day}} - L_{\text{night}}$) values in dB(A) for different areas/zone in year 2014.

Category of area/zone	L_{day}		L_{night}		$(L_{\text{day}} - L_{\text{night}})$			$L_{\text{Aeq},24\text{h}}$		L_{dn}	
	Min	Max	Min	Max	Min	Average	Max	Min	Max	Min	Max
Industrial area	58.1	76.9	54.9	72.2	2.2	4.7	6.80	57.3	75.8	61.6	79.4
Commercial area	59.5	78.5	54.4	73.4	1.3	6.5	11.5	58.7	77.4	63.3	80.8
Residential area	55.1	69.5	48.8	61.2	1.2	7.3	10.8	54.4	68.0	57.0	70.1
Silence zone	51.7	69.0	48.7	60.9	2.7	5.4	8.20	50.9	67.6	55.4	69.7

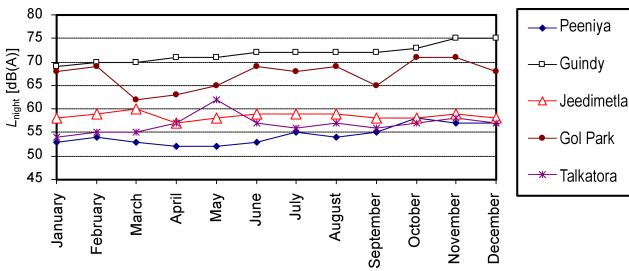


Fig. 7. Monthly variation in equivalent sound pressure level, L_{night} for industrial areas in seven cities in year 2014.

case of Gol Park area and Guindy site. The L_{day} levels varied from 58.1 dB(A) for Peeniya site to 76.9 dB(A) for Guindy site, while the L_{night} levels varies from 54.9 dB(A) for Peeniya site to 72.2 dB(A) for Guindy area. Four sites out of the five sites meets the ambient noise standards, whereby the Guindy site requires immediate noise control measures. The average difference between ($L_{\text{day}} - L_{\text{night}}$) is 4.7 dB(A), whereby the maximum difference of 6.8 dB(A) is observed for Talkatora area and minimum difference of 2.2 dB(A) for Kasba gole site. The day-night average sound level varies from 61.6 dB(A) at Peeniya site to 79.4 dB(A) for Guindy site; while the $L_{\text{Aeq,24h}}$ ranges from 57.3 dB(A) at Peeniya site to 75.8 dB(A) for Guindy site.

3.2.3. Residential zone

Figures 8 and 9 describe the monthly variation of day equivalent level and night equivalent level, L_{day} and L_{night} in the year 2014 for residential sites under consideration. It can be observed that for Triplicane, BTM and Gomti nagar area, there is an immediate

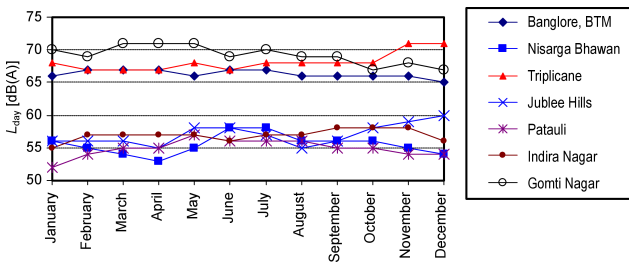


Fig. 8. Monthly variation in equivalent sound pressure level, L_{day} for residential areas in seven cities in year 2014.

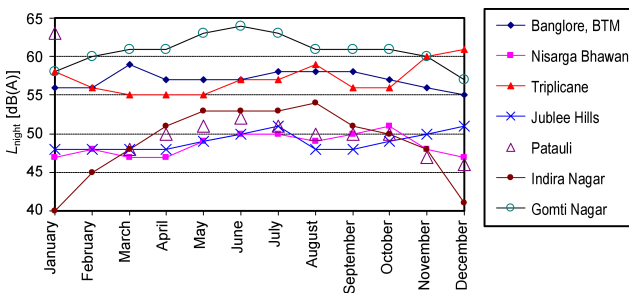


Fig. 9. Monthly variation in equivalent sound pressure level, L_{night} for residential areas in seven cities in year 2014.

requirement of noise control measures. The monthly variation of L_{night} values for Triplicane, Gomti nagar and Indira nagar is very high. The Patauli site experienced an L_{night} value of 63 dB(A) for January, 2014, while for the rest of months of the year; the levels is ≤ 52 dB(A). The L_{day} levels varied from 55.1 dB(A) for Patauli area to 69.5 dB(A) for Gomti nagar, while the L_{night} levels varied from 48.8 dB(A) for Nisarga bhawan to 61.2 dB(A) for Gomti nagar. Out of seven residential sites, no site meets the ambient noise standards. The average difference between ($L_{\text{day}} - L_{\text{night}}$) is observed to be 7.3 dB(A); whereby the maximum difference of 10.8 dB(A) is observed for Triplicane area and 1.2 dB(A) for Patauli area (Table 3). The day-night average sound level varies from 57.0 dB(A) for Nisarga bhawan site to 70.1 dB(A) for Gomti nagar site; while the $L_{\text{Aeq,24h}}$ ranges from 54.4 dB(A) for Nisarga bhawan site to 68.0 dB(A) for Gomti nagar site.

3.2.4. Silence zone

Figures 10 and 11 describe the monthly variation of day equivalent level and night equivalent level, L_{day} and L_{night} in the year 2014 for sites under consideration lying in silence zone. It can be observed that Eye hospital, SSKM hospital, Vaishi hospital and Acworth hospital have high ambient levels as compared to the standards and thus require immediate noise control measures. The monthly variation of L_{day} at Eye hospital is high and that of L_{night} for PGI, Dilshad garden, DTU, Bawana and Vashi hospital is very high. For the

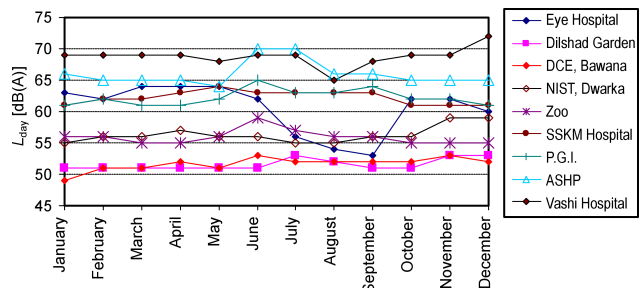


Fig. 10. Monthly variation in equivalent sound pressure level, L_{day} for areas lying under silence zone across seven cities in year 2014.

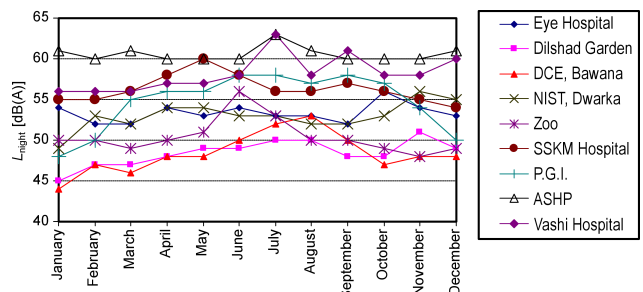


Fig. 11. Monthly variation in equivalent sound pressure level, L_{night} for areas lying under silence zone across seven cities in year 2014.

DTU, Bawana site, the monthly variation in L_{night} is up to 9 dB(A). The L_{day} levels varied from 51.7 dB(A) for Dilshad garden to 69.0 dB(A) for Vashi hospital, while the L_{night} levels varied from 48.7 dB(A) for Dilshad garden to 60.9 dB(A) for Vashi hospital. The average difference between ($L_{\text{day}} - L_{\text{night}}$) is observed to be 5.4 dB(A), whereby the maximum difference of 8.2 dB(A) is observed for Eye hospital and minimum difference of 2.7 dB(A) for DTU, Bawana site. The day-night average sound level varies from 55.4 dB(A) at Dilshad garden site to 69.7 dB(A) for Vashi hospital site; while the $L_{\text{Aeq},24\text{h}}$ ranges from 50.9 dB(A) at Dilshad garden site to 67.6 dB(A) for Vashi hospital site.

4. Overall noise pollution scenario

The L_{day} and L_{night} levels observed for 35 sites for the year 2014 reveals that only 4 industrial sites (11.4%) meet the ambient noise standards. The CPCB, head quarters site marginally meets the ambient noise standards. The situation is quite alarming as in the past two years 2012 and 2013, 9 sites including 4 commercial and 5 industrial sites meet the ambient noise standards. It is observed from the year 2011 noise monitoring data that 8 sites including 4 commercial and 4 industrial meet the ambient noise standards. The 4 commercial sites that complied with the ambient noise standards were CPCB, headquarters; West Bengal headquarters; Thane MCQ and Marathahalli. However, the annual average ambient levels observed for the year 2014 reveals that L_{night} levels for West Bengal WBPCB headquarters; Thane MCQ and Marathahalli are very high as compared to the ambient standards. Table 4 shows the frequency distribution of L_{day} and L_{night} ; L_{dn} and $L_{\text{Aeq},24\text{h}}$ in dB(A) for seven major cities (35 sites) in the year 2014. It can be observed that 13 sites (37.1%) experienced L_{night} levels more than 60 dB(A), while 25 sites (71.4%) experienced L_{day}

levels more than 60 dB(A). It can be also observed from Table 4 that 22 sites (62.9%) experienced L_{dn} levels > 65 dB(A), while 15 sites (42.9%) experienced $L_{\text{Aeq},24\text{h}}$ levels > 65 dB(A). Figure 12 shows the $L_{\text{Aeq},24\text{h}}$ levels for all the 35 sites under consideration for past four years. It is observed that $L_{\text{Aeq},24\text{h}}$ levels ranges from 50.9 dB(A) for Dilshad garden site to 77.4 dB(A) for Punjagutta commercial area. The U.S Department of Housing and Urban Development (HUD) recommends the $L_{\text{Aeq}} \leq 49$ dB(A) as clearly acceptable; $49 < L_{\text{Aeq}} \leq 62$ dB(A) as normally acceptable, $62 < L_{\text{Aeq}} \leq 76$ dB(A) as normally unacceptable and $L_{\text{Aeq}} > 76$ dB(A) as clearly unacceptable (U.S Department of Housing and Urban Development, 1984; OLAYINKA *et al.*, 2013). It can be observed from Fig. 12 that 13 sites (37.1%) have $L_{\text{Aeq},24\text{h}}$ levels between 49 and 62 dB(A) and thus is classified as normally acceptable, while 21 sites (60%) are normally unacceptable as $L_{\text{Aeq},24\text{h}}$ levels range between 62 and 76 dB(A). The Punjagutta site experienced $L_{\text{Aeq},24\text{h}}$ levels of 77.4 dB(A), which is clearly unacceptable. Figure 13 shows the day-night average sound levels, L_{dn} for all the 35 sites under consideration for past four years. The L_{dn} levels ranges from 55.4 dB(A) for Dilshad Garden site to 80.8 dB(A) for Punjagutta commercial area. It can be observed that 13 sites (37.1%) have L_{dn} levels less than 65 dB(A) and are classified as acceptable; while 18 sites (51.4%) have levels between 65 to 75 dB(A) and are classified as normally unacceptable. Four sites namely, ITO, Punjagutta, Guindy and T. Nagar have L_{dn} levels above 75 dB(A) and are classified as unacceptable as per HUD criteria (U.S. Department of Housing and Urban Development, 1984). The recent study on proposed amendments in ambient noise standards of India based on single-noise descriptor proposes $L_{\text{Aeq},24\text{h}}$ of 70 dB(A) for industrial zone; 65 dB $L_{\text{Aeq},24\text{h}}$ for commercial area and mixed residential and commercial zones; 60 dB(A) for residen-

Table 4. Frequency distribution of L_{day} and L_{night} ; L_{dn} and $L_{\text{Aeq},24\text{h}}$ in dB(A) for seven major cities (35 sites) in year 2014.

Variation of parameters, L_{day} , L_{night} and L_{dn} [dB(A)]	L_{day}		L_{night}		L_{dn}		$L_{\text{Aeq},24\text{h}}$	
	No of sites	Percentage of noise monitoring locations	No of sites	Percentage of noise monitoring locations	No of sites	Percentage of noise monitoring locations	No of sites	Percentage of noise monitoring locations
$45 < L_{\text{eq}} \leq 50$	0	0	4	11.4	0	0	0	0
$50 < L_{\text{eq}} \leq 55$	2	5.7	7	20.0	0	0	5	14.3
$55 < L_{\text{eq}} \leq 60$	8	22.9	11	31.4	6	17.1	5	14.3
$60 < L_{\text{eq}} \leq 65$	8	22.9	4	11.4	7	20.2	10	28.6
$65 < L_{\text{eq}} \leq 70$	8	22.9	6	17.1	11	31.4	8	22.9
$70 < L_{\text{eq}} \leq 75$	7	20.0	3	8.6	7	20.0	5	14.3
$75 < L_{\text{eq}} \leq 80$	2	5.7	0	0	3	8.6	2	5.7
$80 < L_{\text{eq}} \leq 85$	0	0	0	0	1	2.9	0	0

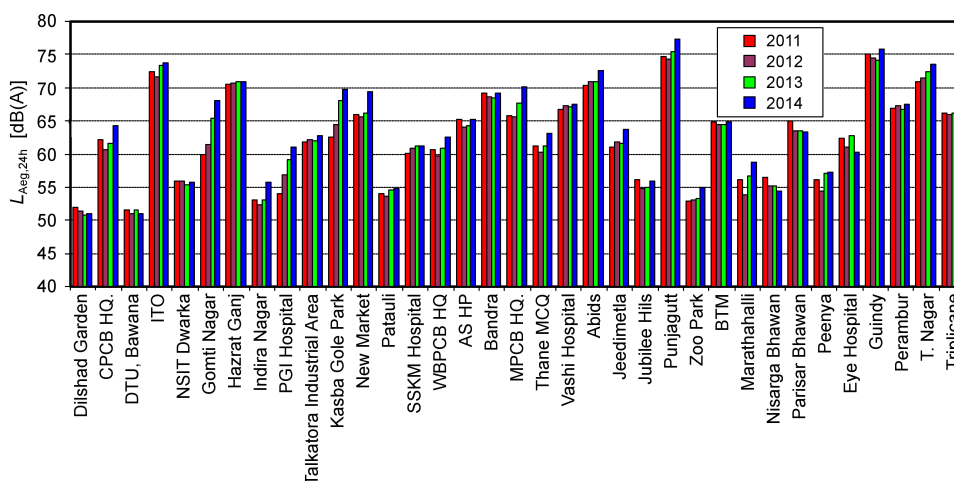


Fig. 12. $L_{Aeq,24h}$ at 35 locations spread across seven major cities all over India in year 2011–2014.

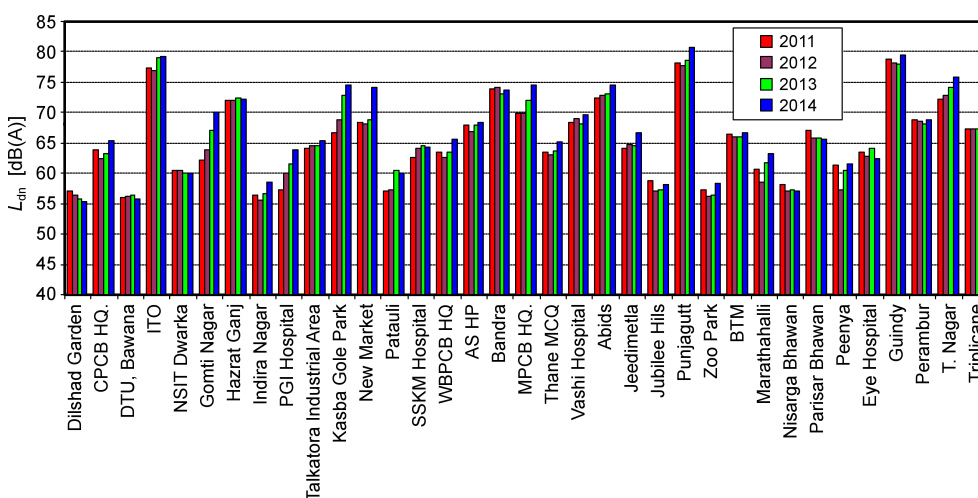


Fig. 13. L_{dn} at 35 locations spread across seven major cities all over India in year 2011–2014.

tial zone and 55 dB(A) for silence zone (GARG *et al.*, 2015d). In accordance with these criteria; 16 sites out of 35 sites (45.7%); 17 sites (48.6%) in 2013; 16 sites in 2012 and 18 sites in 2011 meets the ambient noise standards. The lowest observed adverse effect level (LOAEL) of night noise, 40 dB L_{night} can be considered a health-based limit value of the night noise guidelines (NNG) necessary to protect from adverse health effects of noise. An interim target of 55 dB L_{night} is recommended in the situation wherein the achievement of NNG is not feasible (WHO report, 2009; KIM, BERG, 2010). Thus, considering the target of 55 dB L_{night} , 11 locations meets the criteria for the year 2014 noise monitoring data. These observations thus suggest the need for a review of ambient noise standards in India especially for the residential and silence zones as relatively higher limits imposed for residential and areas under silence zones, but strictly enforced can be a great step in controlling the ambient noise levels and reducing the health hazards associated with noise pollution.

Figure 14 shows the $(L_{day} - L_{night})$ in dB at 35 locations spread across seven major cities all over India in the year 2014. The lowest value of 1.2 dB(A) is observed for Patauli area, while the highest value of 11.5 dB(A) is observed for CPCB, Head quarters site. The past two years annual average L_{day} and L_{night} levels reveal that the minimum value of $(L_{day} - L_{night})$ of 0.4 dB(A) for Patauli area (in the year 2013) and 1.1 for Bandra site (in the year 2012) was observed. The maximum difference of annual average L_{day} and L_{night} levels was observed for Vashi hospital (in the year 2013) and 11.3 dB(A) for Hazrat Ganj and Triplicane area. Table 5 shows frequency distribution of difference $(L_{day} - L_{night})$ values in dB(A) for all 35 sites in the past four years. The $(L_{day} - L_{night})$ value for Bandra site in the year 2014 was 2.9 dB(A). The analysis of $(L_{day} - L_{night})$ for the year 2014 ambient noise levels shows that 11.4% of the observations show a difference ≥ 10 dB(A), 54.3% of observations show a difference between 5 to 10 dB(A) and

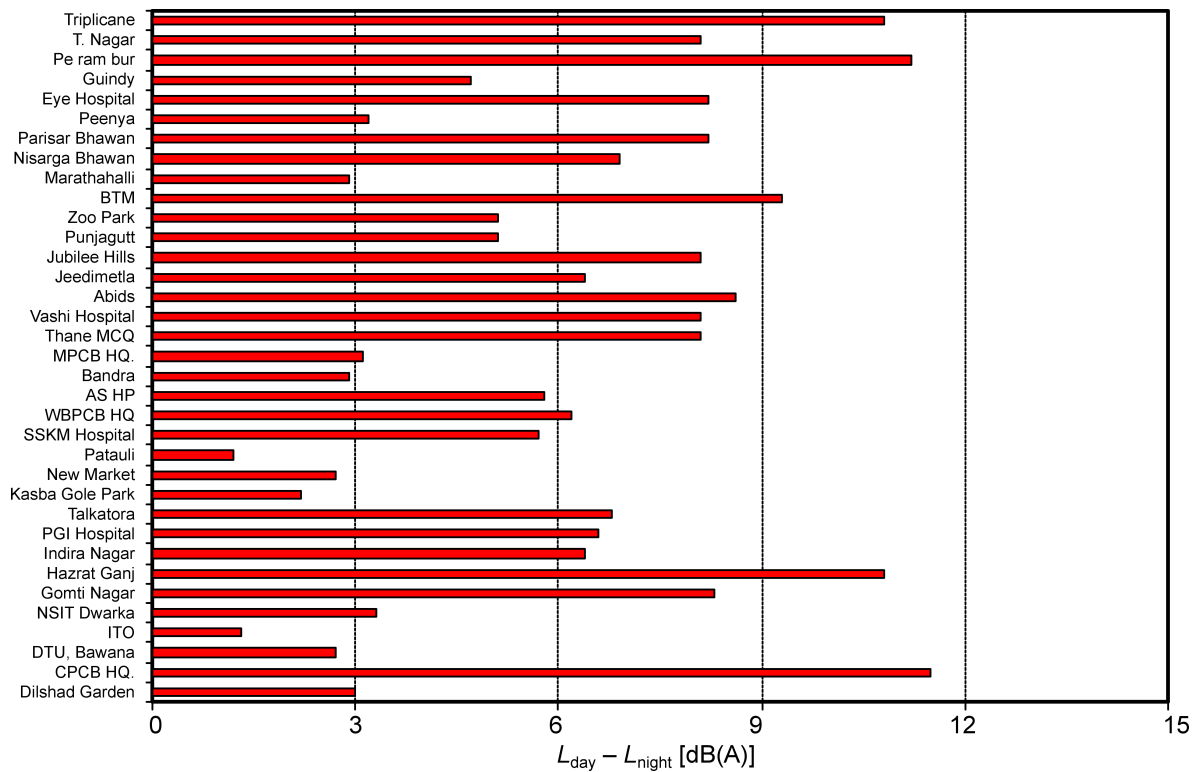


Fig. 14. $(L_{day} - L_{night})$ in dB at 35 locations spread across seven major cities all over India in year 2014.

Table 5. Frequency distribution of difference $(L_{day} - L_{night})$ values in dB(A) for all 35 sites in past four years.

Variation of difference $(L_{day} - L_{night})$ values [dB(A)]	2011		2012		2013		2014	
	No of sites	Percentage of noise monitoring locations	No of sites	Percentage of noise monitoring locations	No of sites	Percentage of noise monitoring locations	No of sites	Percentage of noise monitoring locations
$0 < (L_{day} - L_{night}) \leq 5$	12	34.3%	11	31.4%	12	34.3%	12	34.3%
$5 < (L_{day} - L_{night}) \leq 10$	19	54.3%	19	54.3%	18	51.4%	19	54.3%
$10 < (L_{day} - L_{night}) \leq 15$	4	11.4%	5	14.3%	5	14.3%	4	11.4%

34.3% of the observations show a difference less than 5 dB(A). The analysis of $(L_{day} - L_{night})$ levels for past four years shows that 12.9% of the observations show a difference ≥ 10 dB(A), 53.6% of observations show a difference between 5 to 10 dB(A) and 33.5% of the observations show a difference less than 5 dB(A). This implies that 10 dB night time adjustment in day-night average sound level, L_{dn} to account for the increased sensitivity of noise at night, the expectation that the night time noise will be lower than during the day and for disturbance sleep protection is not appropriate in such a scenario.

The high ambient noise levels at many sites are attributed to road traffic noise. The recent study reported by MANDAL and BANDYOPADHYAY (2014) reveals that environmental pollution in developing countries of the world was due to the fast growth rate of automobile technologies coupled with the slow adaptabil-

ity of upgraded technology and other socioeconomic factors. Thus, it is essential in Indian scenario to control the noisy spots especially those located in residential areas and in silence zones. Installation of noise barriers (GARG *et al.*, 2012; 2015e; KUMAR *et al.*, 2014), planting vegetation and earth barriers (TYAGI *et al.*, 2006; 2013), increasing sound insulation of facades (AMUNDSEN *et al.*, 2011; GARG *et al.*, 2013, 2014b; RASMUSSEN, 2010), using double glazing's of high sound insulation (GARG *et al.*, 2011; 2014a), using porous elastic road surfaces (WATTS *et al.*, 1999; MEIARASHI *et al.*, 1996), traffic and speed reductions (MURPHY *et al.*, 2011). However, all these measures when combined shall be instrumental in bringing the noise levels well below the ambient noise standards. Consequently, a comprehensive noise abatement programme considering all the Best Practicable and Economical Options (BPEOs) shall be helpful in control-

ling the noise pollution at these sites (GARG *et al.*, 2012; GARG, MAJI, 2016; LEE *et al.*, 2008; MOHANAN *et al.*, 2010).

5. Conclusions and recommendations

The paper describes the noise monitoring data available from the pilot project on the establishment of National Ambient Noise Monitoring Network (NANMN) across seven major cities in India for continuous noise monitoring throughout the year. The annual average L_{day} (06–22 h) and L_{night} (22–06 h) values observed in the year 2011–2014 for the 35 locations under study in which 14 locations are in commercial zone, 5 in Industrial, 7 in residential and 9 in silence zones are described. The long-term noise monitoring shows that ambient noise levels have marginally increased since the past four years for 29 sites (82.9%) out of 35 sites under consideration. The L_{day} and L_{night} levels observed for 35 sites for the year 2014 reveals that only 4 industrial sites (11.4%) meet the ambient noise standards. The analysis of ($L_{\text{day}} - L_{\text{night}}$) for all the zones in past four years (2011–2014) reveals that 53.6% of observations show a difference between 5 to 10 dB(A) and 33.5% observations show a difference less than or equal to 5 dB(A), which implies that 10 dB night time adjustment in day-night average sound level, L_{dn} to account for the increased sensitivity of noise at night, the expectation that the night time noise will be lower than during the day and for disturbance sleep protection is not appropriate in such a scenario. Thus, it is imperative to adopt a comprehensive noise abatement strategy for controlling the noise pollution at these sites and bringing the ambient levels particularly the night noise levels, L_{night} below the ambient noise standards as 13 sites (37.1%) experienced L_{night} levels more than 60 dB(A). The day equivalent levels, L_{day} were higher than 65 dB(A) for the 17 sites (48.6%). 11 locations meets the criteria of less than or equal to 55 dB L_{night} levels for the year 2014 noise monitoring data. In accordance with U.S Department of Housing and Urban Development (HUD), it can be observed that 13 sites (37.1%) have $L_{\text{Aeq},24\text{h}}$ levels between 49 and 62 dB(A) and thus is classified as normally acceptable. These observations thus suggest a review of ambient noise standards and implementing suitable amendments in them particularly for areas under silence and residential zones so as to enforce effectively the legal policy for controlling the noise pollution levels in India.

Thus, suitable noise abatement measures like ban on pressure horns of vehicles, installation of noise barriers around hospitals and schools; extensive plantation of trees, vegetation and earth berms; noise monitoring and control of loudspeakers, generator sets; enforcement of type approval testing legislations for vehicles in respect of noise, planning roadways especially for the new projects, use of porous elastic road surfaces,

timing traffic lights and restricted entry of heavy vehicles in residential areas and silence zones should be undertaken to bring the ambient noise levels well below the standards. The strengthening of National Ambient Noise Monitoring Network (NANMN) in this regard to 35 more stations in same seven metropolitan cities since November, 2014 shall be indispensable in analyzing a wider noise scenario situation in the country and adoption of noise abatement measures for controlling the noise pollution in India. Further widening of NANMN network to other cities of India, noise mapping of cities similar to that established in European Directives 2002/49/EC, formulation and implementation of noise abatement goal on similar lines as recommended in Dutch noise abatement goal (NIJLAND *et al.*, 2003) shall be indispensable in reducing the ambient noise levels. Future studies focussed on noise induced health effects, annoyance and health effects caused due to high ambient noise levels and noise maps generated for various metropolitan cities of India shall be helpful in ascertaining the environmental noise impact assessment in respect of noise and controlling the noise pollution in India.

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