Archives of Acoustics Vol. 48, No. 1, pp. 103–126 (2023), doi: 10.24425/aoa.2023.144265

Research Paper

Evaluation and Analysis of Long-term Environmental Noise Levels in 7 Major Cities of India

Naveen GARG[(1),(2)*], Saurabh KUMAR[(1),(2)], Chitra GAUTAM[(1),(2)], Vishal GANDHI[(3)], Nalin Kumar GUPTA[(3)]

[(1)] *CSIR-National Physical Laboratory*
New Delhi 110 012, India

[(2)] *Academy of Scientific and Innovative Research*
Ghaziabad 201 002, India

[(3)] *Central Pollution Control Board*
Parivesh Bhawan, Delhi, India

*Corresponding Author e-mail: ngarg@nplindia.org

(*received January 1, 2022; accepted October 12, 2022*)

This paper describes the long-term noise monitoring data for ten consecutive years (2011–2020) acquired from the diversified National Ambient Noise Monitoring Network (NANMN) set up across 7 major cities of India and consisting of 70 stations for continuous noise monitoring throughout the year. The annual average ambient noise levels observed throughout these ten years in 70 locations under study, including 25 locations in commercial zones, 12 in industrial, 16 in residential, and 17 in silence zones, are described. The noise scenario in these ten years is compared and analyzed. It is observed that no site in residential or silence zones meets the ambient noise limits for the past ten years. The study suggests guidelines for a policy framework for environmental noise management and control to regulate noise pollution in Indian cities.

Keywords: National Ambient Noise Monitoring Network (NANMN); day equivalent sound level (L_{day}); night equivalent sound level (L_{night}).

1. Introduction

Environmental noise exposure and associated health effects have become a serious concern globally. The Guideline Development Group (World Health Organization [WHO], 2018) has enunciated to use the term "environmental noise" and defined it as "noise emitted from all sources except sources of occupational noise exposure in workplaces" (WHO, 2018). The recommended limits for noise exposure from road traffic noise are 53 dB L_{den} and 45 dB L_{night}, and for noise exposure from aircraft noise the recommended limits are 45 dB L_{den} and 40 dB L_{night} (WHO, 2018). Every nation is concerned about the health effects of noise emitted from the increasing number of vehicles on the roads and aircraft noise in residential areas near the airports (Babisch *et al.*, 2005; WHO, 2011; van Kempen *et al.*, 2018; Hansell *et al.*, 2013; Schmidt *et al.*, 2015). It is thus imperative to adopt long-term noise monitoring strategies to assess and control the accentuated environmental noise levels and plan for suitable noise abatement measures. The European Environmental Noise Directive 2002/49/EC requires that the values of acoustic parameters L_{den} and L_{night} are representative of a year period (The European Parliament and the Council of the European Union, 2002). The Directive articulates the assessment methods for the purpose of strategic noise mapping and the corresponding action plans, which imply the use of harmonized indicators and evaluation methods as well as criteria for noise mapping. The noise maps should present noise levels expressed in the harmonized indicators L_{den} and L_{night}. The WHO estimates that, in Western Europe alone, 1 million healthy life years are lost annually to environmental noise (WHO, 2011). Other estimates put the external cost of noise-related health issues in the European Union between 0.3–0.4% of GDP (European Conference of Ministers of Transport [EMCT], 1998) and 0.2% in Japan (MIZUTANI *et al.*, 2011). Some studies have correlated the relationship between environmental noise and real estate markets, with housing prices falling with the increase in noise levels (NELSON, 1982; THEEBE, 2004). Thus, it is imperative from an Indian perspective to monitor the environmental noise levels in citiesand devise Noise Action Plans (NAPs) for abatement and control of noise pollution. The Central Pollution Control Board (CPCB) in India initiated the process of developing the National Ambient Noise Monitoring Network (NANMN), through which it was decided to include ambient noise as a regular parameter for monitoring in specified urban areas (CPCB, 2011; 2012). The real-time noise monitoring network, the NANMN program, was established with the objective of getting real-time continuous noise monitoring data. The present work discusses the noise monitoring data from 70 sites located in 7 major cities for the past ten years (2011–2020) with the following objectives:

- ascertain the noise scenario and the annual average ambient noise levels of 70 sites for the ten years under study and compare them with ambient noise standards of India (Table 1 – Appendix);
- inculcate the awareness of the general public towards the status of noise pollution and dissemination of information publicly through the website (CPCB, n.d.);
- ascertain the Most Exposed Urban Sites (MEUS) among the 70 sites and suggest the need for Noise Action Plans required, if any;
- ascertain to what extent the residential and silence zone sites meet the current ambient noise standards;
- analyze the difference of L_{day} and L_{night} levels to ascertain the severity of night noise levels as compared to the day levels;
- annual increment or decrement in the ambient noise levels for each of these sites in the decade under study for forecasting the future noise scenario;
- recommendations on policy framework for reducing the noise pollution levels in Indian cities based on the long-term evaluation and analysis of noise monitoring data for the 70 sites of 7 metropolitan cities.

It may be noted that although the installation of 10 noise monitoring stations for each city is insufficient to represent the noise environment of the concerned cities, yet the present study is focused on the evaluation and analysis of continuous long-term noise levels obtained from these 70 stations to ascertain and analyze the status of ambient noise levels and planning for suitable measures to control them. The present study shall be very helpful for understanding the noise scenario, analyzing the status of compliance of sites in each zone with the ambient noise standards, and planning for suitable measures and action plans for noise abatement and control in metropolitan cities of India. The study shall be helpful for pollution control bodies and planning and development authorities in managing and controlling environmental noise levels in the metropolitan cities of India.

2. Materials and methods

The diversified NANMN project was established in 2011 covering 70 stations in 7 major cities of the country, namely, Bengaluru, Chennai, Delhi, Hyderabad, Kolkata, Lucknow, and Mumbai. The details of 70 locations under study established in 7 cities of India, with each city having 10 noise monitoring stations, are shown in Fig. 1. The 70 locations cover 25 commercial sites, 16 residential sites, 17 sites in silence zones, and 12 sites in industrial zones. The Noise Monitoring Terminals (NMTs) manufactured and installed by Geónica Earth Sciences, Spain, have been discussed in detail earlier (GARG *et al.*, 2016; 2017b; 2017c; 2017d). In addition, a website application (CPCB, n.d.) has been developed to disseminate the data in real time to the public to generate awareness. The Noise Monitoring Network so established is unique and one of the largest noise monitoring networks of its kind across the globe.

In the present study, day equivalent levels L_{day}, and night equivalent levels L_{night} were acquired through the CPCB website and analyzed for each year from 2011 to 2020. In order to compare the ambient noise scenario of the noise monitoring locations with international guidelines and several studies reported so far (WHO, 2009; BABISCH, 2002), the study also reports day-night average sound levels L_{dn}, and 24-hour equivalent sound levels $L_{\text{Aeq,24h}}$. The day equivalent levels are the average equivalent sound levels of 16 hours duration of the day from 06:00 AM to 10:00 PM and the night equivalent levels are the average equivalent sound levels of 8 hours duration from 10:00 PM to 06:00 AM (Ministry of Environment & Forests, 2000).

The average day and night equivalent sound levels for each year are calculated as (GARG *et al.* 2016):

$$L_{\text{day},n} = 10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n}10^{0.1(L_{\text{day},i})}\right], \tag{1}$$

$$L_{\text{night},n} = 10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n}10^{0.1(L_{\text{night},i})}\right], \tag{2}$$

where n is the number of days in the year, and $L_{\text{day},i}$ and $L_{\text{night},i}$ are the day and night equivalent sound pressure levels of the i-th day of the year, respectively.

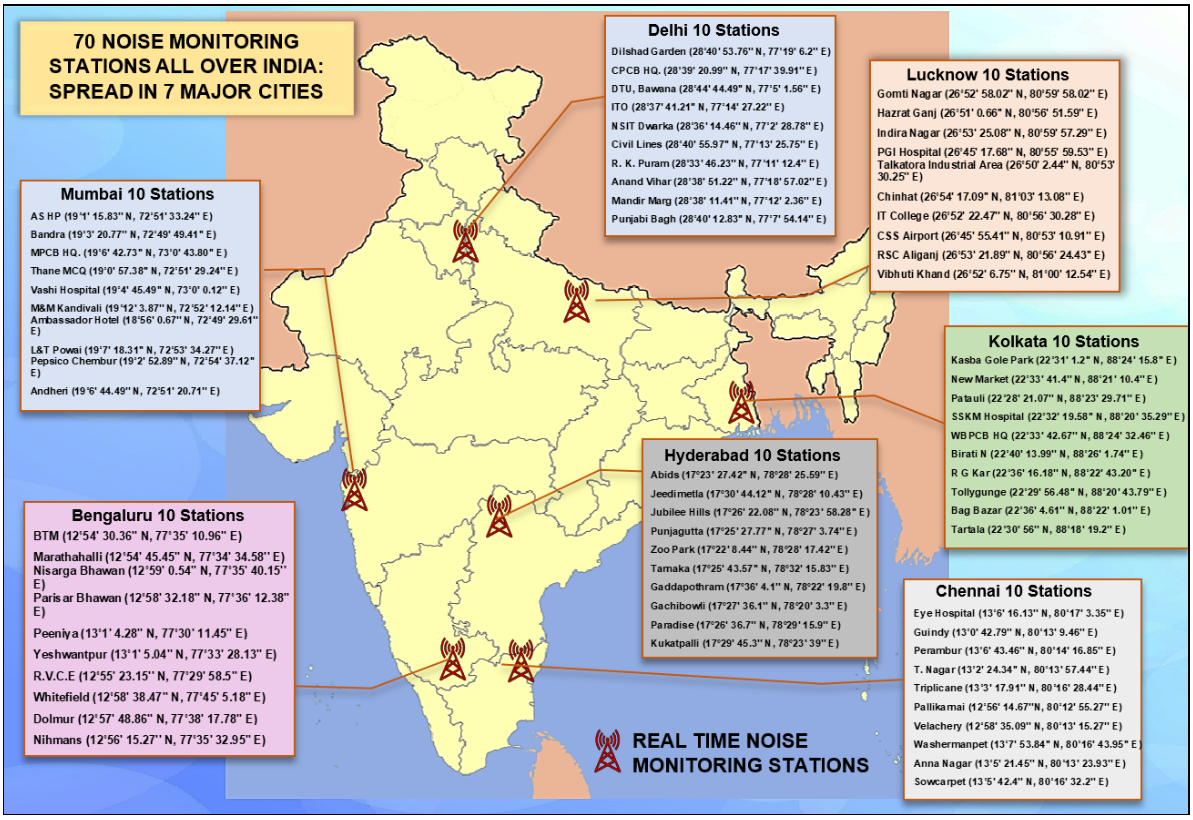

Fig. 1. Noise monitoring stations at 70 sites in 7 major cities of India installed by the CPCB, India for continuous noise monitoring throughout the year.

The 24-hour equivalent sound pressure levels are the average equivalent sound levels of 24 hours of a single day. Also, the annually-averaged day-night average sound pressure levels of the 70 noise monitoring sites are calculated (Garg *et al.*, 2016):

$$L_{\mathrm{dn}} = 10\log_{10}\left[\frac{16\cdot 10^{L_{\mathrm{day}}/10} + 8\cdot 10^{(L_{\mathrm{night}}+10)/10}}{24}\right], \quad (3)$$

where L_{day} and L_{night} are the day and night equivalent noise levels per year, respectively.

The standard deviation associated with the day equivalent sound levels of the noise monitoring sites is calculated as:

$$\sigma = \sqrt{\frac{\sum\limits_{i=1}^{n}(L_{\mathrm{day},i} - \overline{L_{\mathrm{day}}})}{n-1}}, \quad (4)$$

where $\overline{L_{\mathrm{day}}}$ is the average of the day equivalent sound levels per year. The standard deviation for the average night equivalent sound levels for each noise monitoring site is also calculated in the same way.

The study also analyzes the noise exceedance factor (EF) calculated in each zone, as shown in Eq. (5) (Chowdhury *et al.*, 2016), in order to assess the environmental noise pollution scenario of different zones. The noise EF of a site is defined as the ratio of the ambient noise level of the site and the permissible noise level limit of the zone in which the site is located. The average noise limit exceedance factor (NEF) for all the sites lying in one zone is called the average exceedance factor (AEF):

$$\mathrm{EF} = \frac{L_0}{L_p}, \quad (5)$$

where L_0 is the observed ambient noise level, and L_p is the legally permissible limit recommended by the CPCB, India (Table 1 – Appendix).

The study undertakes a zone-wise and site-wise analysis in order to analyze the noise scenario at various sites and a specific trend of noise scenario in the past ten years.

3. Results and discussion

Tables 2 and 3 (Appendix) show the details of the annual average ambient day and night equivalent levels monitored for the 35 stations installed in 7 cities from 2011 to 2020 (CPCB, 2015a; 2015b; 2016; 2018; Garg, 2022). Table 4 (Appendix) shows the details of the annual average day and night equivalent sound levels for the past five years (2015–2020) for the additional 35 noise monitoring stations in 7 cities, which were installed in November 2014 (CPCB, 2015a; 2015b; 2016; 2018; Garg, 2022). Figures 2 and 3 show the

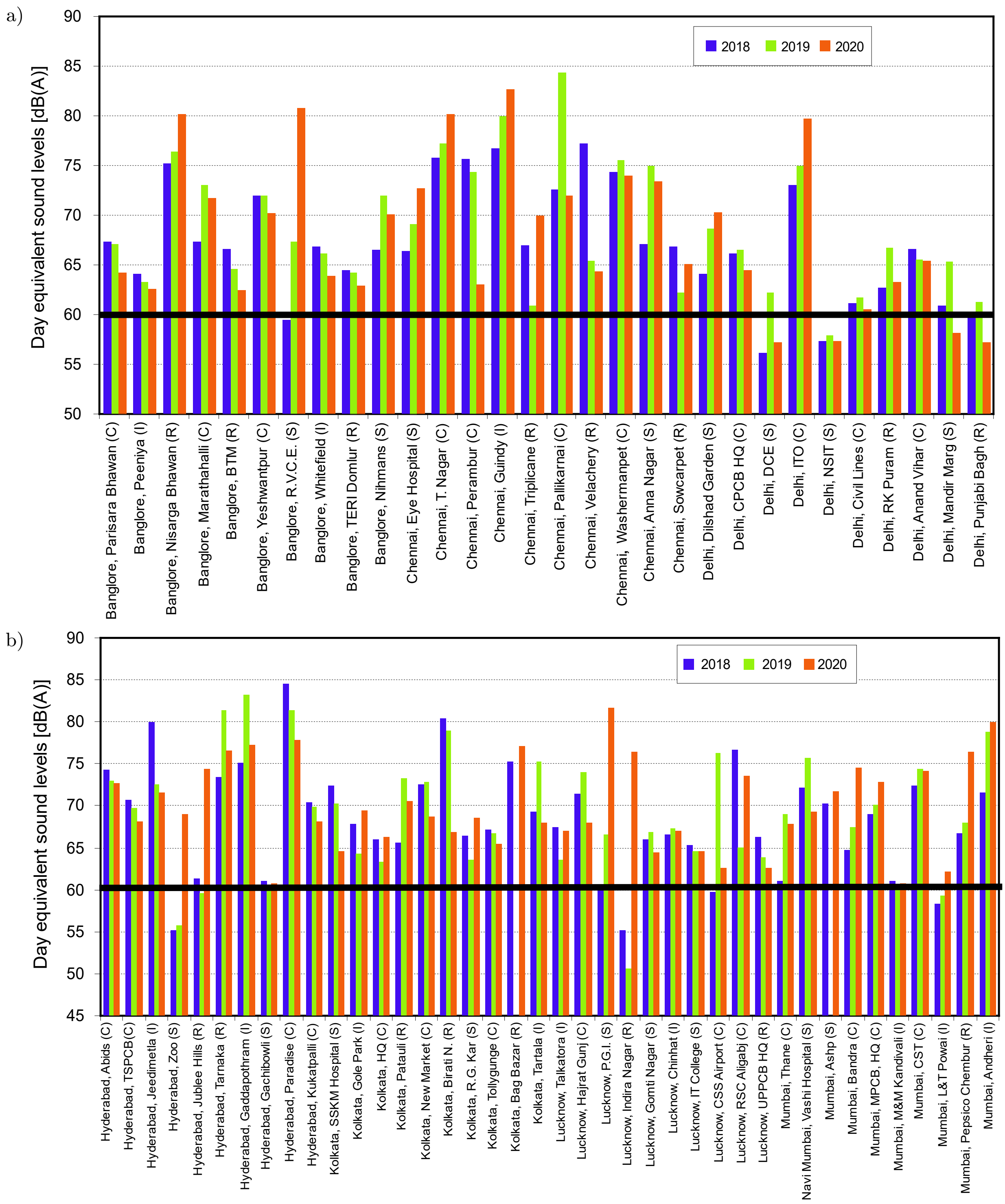

Fig. 2. Annual night equivalent average sound levels L_{night} [dB(A)] observed for the three years (2018–2020) for 7 major cities (Garg, 2022).

annual average day and night equivalent noise levels for the past three years (2018-2020) for the 70, sites in the 7 major cities of India (Garg, 2022). The 60 dB(A) L_{day} limit can be seen as NOAEL (no observed adverse effect level) for the correlation between road traffic noise and myocardial infarction (MI); the risk of MI increases incessantly for noise levels higher than 60 dB(A) (WHO, 2009; Babisch, 2002). It can be observed that the 60 dB L_{day} limit was met by only 4 sites in 2020, while 7 sites met the limit in 2019, and 9 sites in 2018. The Interim Target (IT) of 55 dB L_{night}, as recommended in the EU Night Noise Guidelines report (WHO, 2009), was met by only 4 sites in 2020, 7 sites in 2019, and 8 sites in 2018. The major-

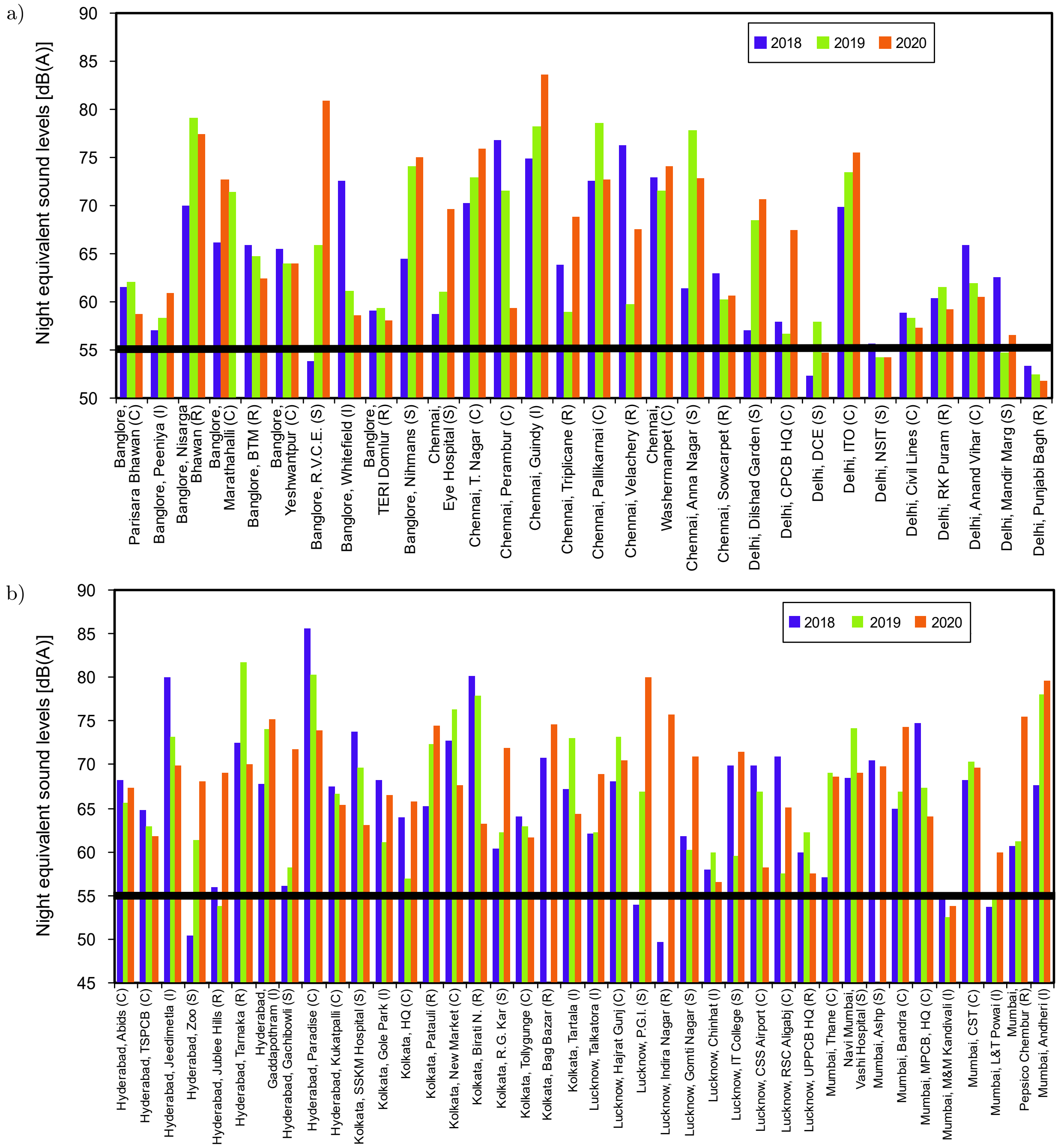

Fig. 3. Annual night equivalent average sound levels L_{night} [dB(A)] observed for the three years (2018–2020) for 7 major cities (Garg, 2022).

ity of sites (7 out of 10) in Chennai city showed day sound levels above 70 dB(A) and 6 sites showed night equivalent sound levels above 70 dB(A). However, in Delhi, only 2 sites showed day and night equivalent levels ≥70 dB(A). Also, in Mumbai and Hyderabad, 6 sites showed day equivalent levels ≥70 dB(A) and 5 sites showed night equivalent levels ≥70 dB(A). Overall, 32 sites (45.7%) comprising of 12 commercial, 5 industrial, 7 in silence zone, and 8 residential were observed to be the MEUS with day equivalent sound levels ≥70 dB(A). Thirty sites (42.9%) comprising of 9 commercial, 4 industrial, 11 in silence zone, and 6 residential were observed to be the MEUS with night equivalent sound levels ≥70 dB(A). Table 5 (Appendix) shows the frequency distribution of the noise descriptors: annual average day equivalent levels L_{day}, annual average night equivalent levels L_{night}, annual average 24-hour equivalent sound level $L_{\text{Aeq,24h}}$, and annual day-night average sound level L_{dn} for the 70 sites for the past four years (2017–2020). It was observed that the majority of the sites (75.7%) registered day equivalent noise levels between 60 to 75 dB(A), while

64.3% of the sites registered night equivalent noise levels between 60 to 75 dB(A). Also, the majority of sites (69.5%) showed L_{dn} values between 65 to 80 dB(A), and 77.6% of the sites showed $L_{\text{Aeq,24h}}$ values between 60 to 75 dB(A). Figures 4 and 5 show the 24-hour equivalent average annual sound levels $L_{\text{Aeq,24h}}$ and annual day-night average sound levels L_{dn} observed for the past three years (2018–2020) in the 7 major cities of India (Garg, 2022). It can be observed that the majority of $L_{\text{Aeq,24h}}$ values range from 60 to 75 dB(A) for commercial (83%) and industrial zone sites (65.9%), while for the residential (75%) and silence zone sites (76.9%), the majority of $L_{\text{Aeq,24h}}$ values range from 55 to 70 dB(A). The majority of L_{dn} values range from 65 to 80 dB(A) for commercial (66%), residential (69%), and industrial zone sites (67%), while for the silence zone sites, the majority (80.5%) of L_{dn} values range from 60 to 75 dB(A).

The zone-wise analysis was also conducted as shown in Table 6 (Appendix) in order to ascertain the range of day and night equivalent noise levels in all 4 zones (Garg, 2022). The analysis of the 2020 noise monitoring data shows that 88% of the commercial sites, 62.6% of the residential sites, 70.5% of the silence zone sites, and 74.9% of the industrial zone sites registered day equivalent sound levels between 60 to 75 dB(A). Furthermore, 76% of the sites registered night equivalent sound levels between 60 to 75 dB(A), while 56.4% of the residential sites, 70.6% of the silence zone sites, and 66.7% of the industrial sites registered

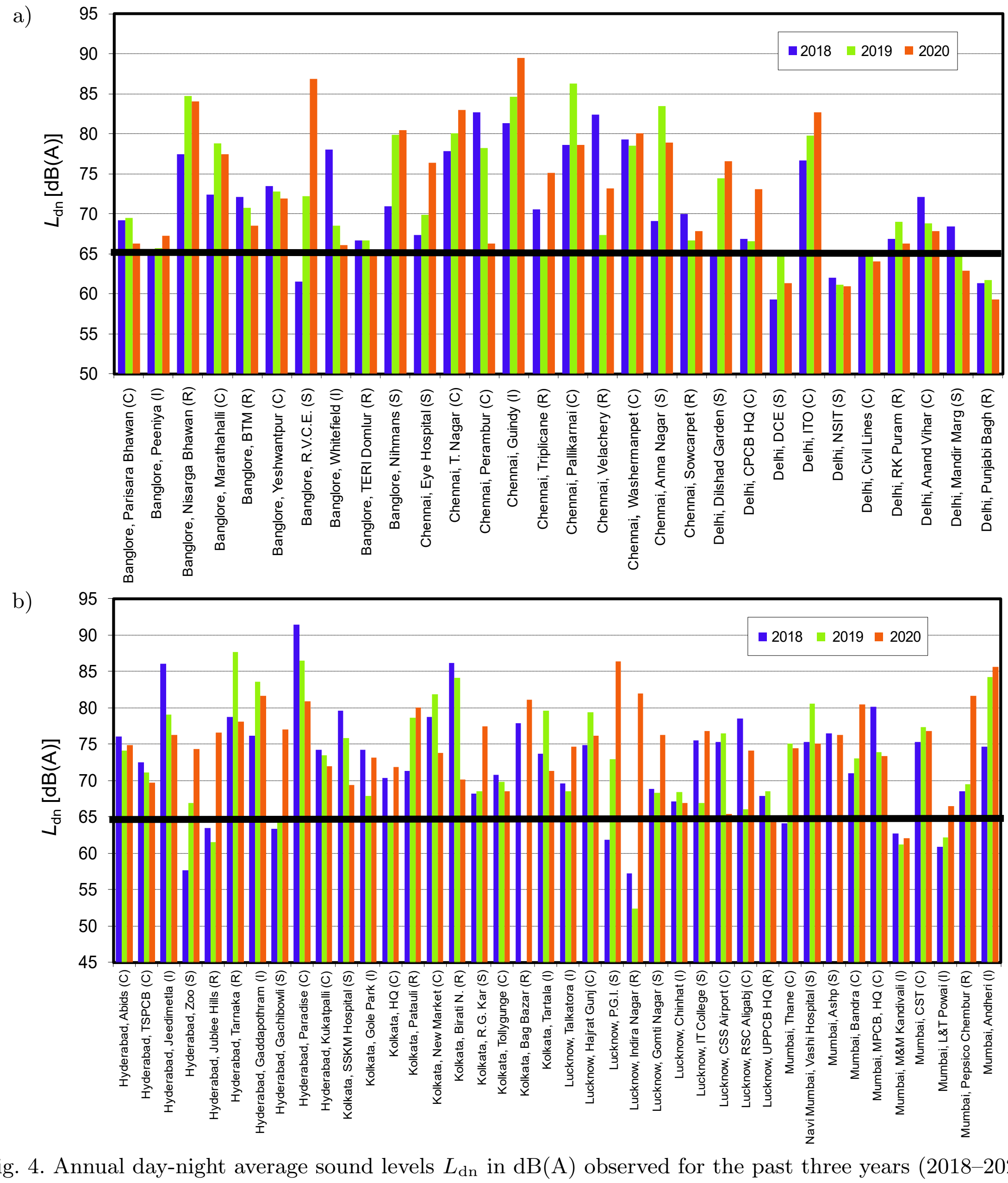

Fig. 4. Annual day-night average sound levels L_{dn} in dB(A) observed for the past three years (2018–2020) for 7 major cities (Garg, 2022).

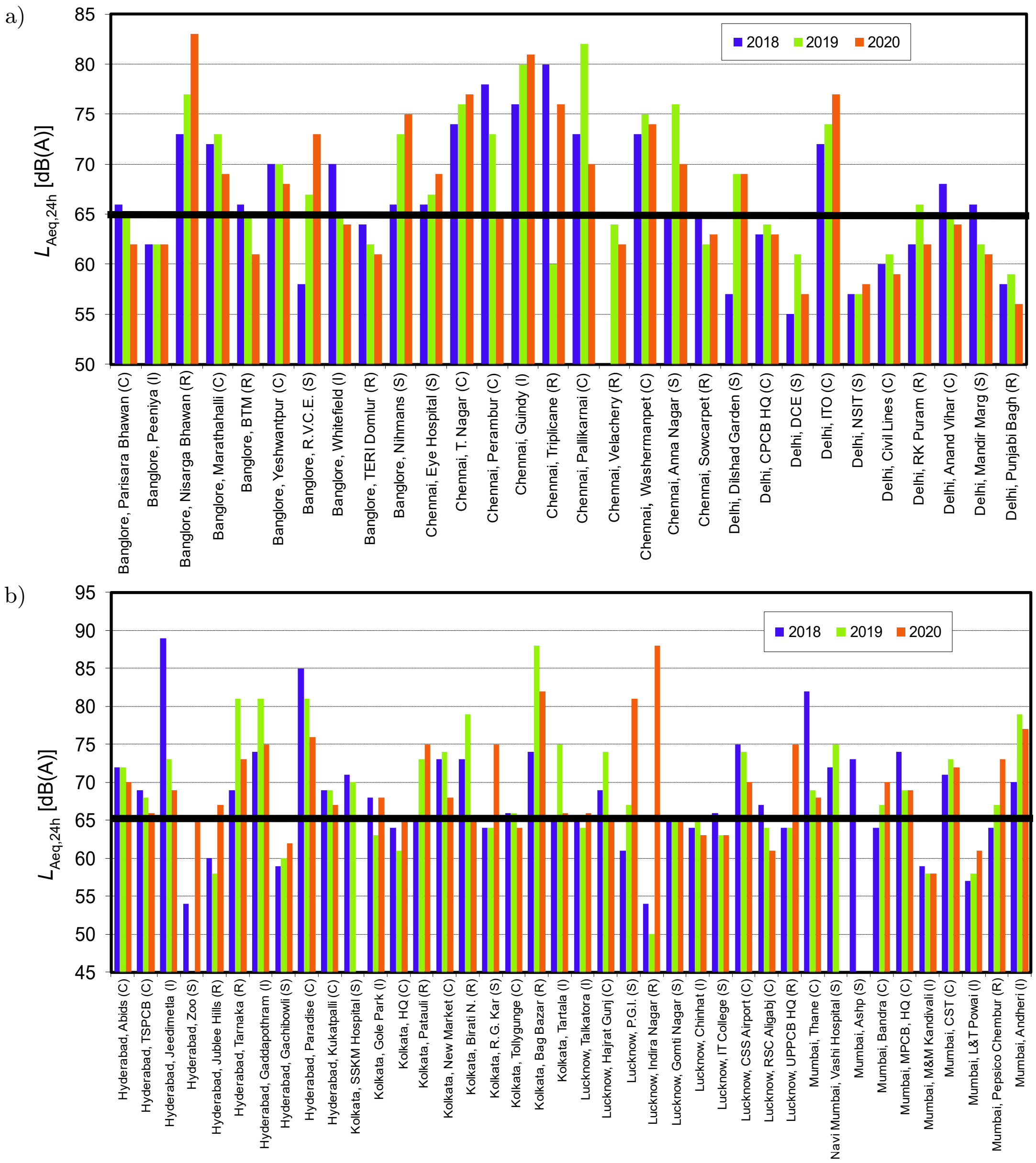

Fig. 5. Annual 24-hour equivalent average sound levels $L_{\mathrm{Aeq,24h}}$ in dB(A) observed for the past three years (2018–2020) for 7 major cities (Garg, 2022).

night equivalent noise levels between 55 to 70 dB(A). Thus, it is evident that the majority of the sites in all 4 zones registered day equivalent sound levels in the range of 60 to 75 dB(A), while the majority of sites in all zones except the commercial zone showed night equivalent sound levels between 55 to 70 dB(A). The analysis of (L_{day}–L_{night}) for the 70 sites was conducted to analyze the severity of day equivalent noise levels compared to night equivalent noise levels. Table 7 (Appendix) shows the frequency distribution (in %) of the difference of annual average (L_{day}–L_{night}) values observed in dB for the 70 sites spread across the 7 major cities of India (Garg, 2022). It is revealed that the majority of observations (75.7% for 2020 to 88.6% for 2014) showed a difference between 0 to 10 dB(A) and less than or equal to 5 dB(A) in the past ten years from 2011 to 2020 (31.4% in 2012 to 58.6% in 2020). These observations thus suggest that the night equivalent noise levels are comparable to the day equivalent levels for the majority of sites. The 10 dB night-time adjustment in day-night average sound level is not appropriate in such a scenario. On a similar analogy, these observations also suggest that the 5 dB evening time correction in the day-evening-night average sound level descriptor is not justified as the evening noise levels are similar to the day equivalent noise levels. Thus, the 24-hour equivalent continuous sound level $L_{\mathrm{Aeq,24h}}$ would be more suitable as it is a common way of expressing day-night average sound level without the 10 dB night-time adjustment (Garg, 2019). It may be noted that these results are observed for the case of metropolitan cities only, and the environmental noise scenario for other cities, especially tier 2 cities, shall be helpful to conclude a generic trend about the suitability of day-night average sound levels with the 10 dB night-time adjustment in India.

The comparison of the environmental noise levels in the 70 sites in comparison to the previous years was ascertained to understand the change in noise scenario in the past decade. Figure 6a shows the difference in day and night equivalent sound levels in 2020 sound levels for the 35 sites in which the NMTs were installed in 2011. It can be observed that 19 sites (54.3%) showed an increment in day and night equivalent sound levels of more than 5 dB(A) in these ten years, 9 sites (25.7%) showed an increment in day equivalent sound levels up to 10 dB(A), and 19 sites (54.3%) showed an increment in night equivalent sound levels up to 10 dB(A). Only 3 sites showed a decrement in day equivalent sound levels up to 5 dB(A) and 1 site showed a decrement in night equivalent sound levels by more than 5 dB(A). Figure 6b shows the difference in day and night equivalent sound levels in 2020 sound levels for the 35 sites in which the NMTs were

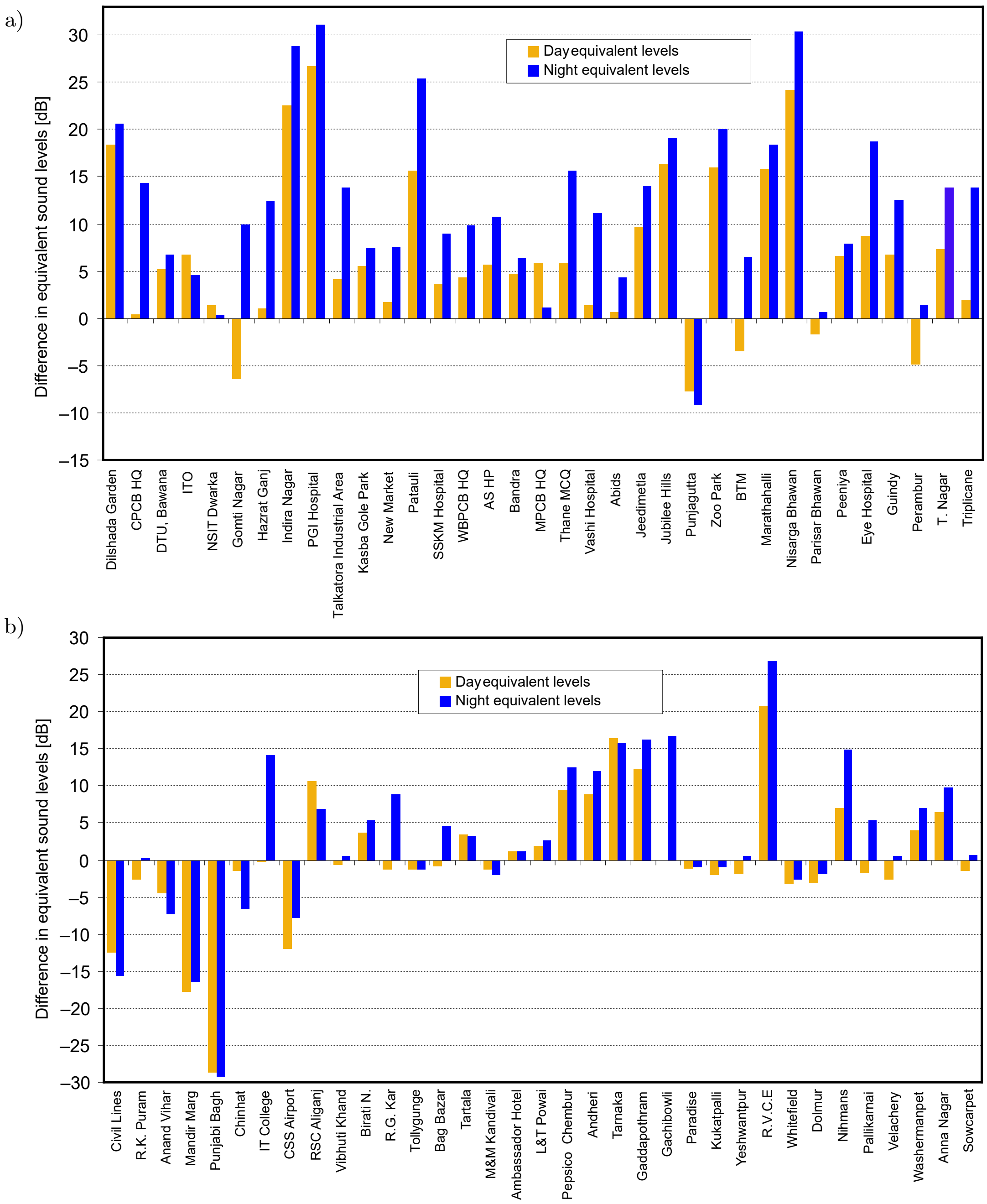

Fig. 6. Difference in equivalent sound levels: a) difference in day and night equivalent noise levels w.r.t. 2020 sound levels for 35 sites in which the NMTs were installed in 2011; b) difference in day and night equivalent sound levels w.r.t. 2020 sound levels for 35 sites in which the NMTs were installed in 2015.

installed in 2015. It can be observed that 8 sites (22.9%) showed an increment in day and night equivalent sound levels of more than 5 dB(A) in these five years, 5 sites (14.3%) showed an increment in day equivalent sound levels ≥10 dB(A) and 9 sites (25.7%) showed an increment in night equivalent sound levels ≥10 dB(A). Also, 4 sites (11.4%) showed a decrement in day equivalent sound levels ≥5 dB(A), while 6 sites (17.1%) showed a decrement in night equivalent sound levels ≥5 dB(A).

The comparison of $L_{\mathrm{Aeq,24h}}$ and L_{dn} levels for the 35 sites for the ten years under study, as shown in Fig. 7a, also revealed that 8 sites (22.9%) showed an increment in $L_{\mathrm{Aeq,24h}}$ levels ≥ 10 dB(A) and 14 sites (40%) showed an increment in L_{dn} levels ≥ 10 dB(A). Only 1 site showed a decrement in $L_{\mathrm{Aeq,24h}}$ and L_{dn} levels of more than 5 dB(A). Overall, it was observed that the commercial and silence zone sites exhibited higher increment in the day and night equivalent sound levels in the considered years.

The comparison of $L_{\mathrm{Aeq,24h}}$ and L_{dn} levels for the 35 sites for the past five years, as shown in Fig. 7b, also revealed that 5 sites (14.3%) showed an increment in $L_{\mathrm{Aeq,24h}}$ levels ≥10 dB(A) and 8 sites (22.9%) showed an increment in L_{dn} levels ≥10 dB(A). Additionally, 5 sites (14.3%) showed a decrement in $L_{\mathrm{Aeq,24h}}$ ≥5 dB(A), while 5 sites (14.3%) showed a decrement in L_{dn} levels ≥5 dB(A). These observations also revealed that commercial and silence zone sites exhibited higher increment in the 24-hour equivalent sound levels and day-night average sound levels in the considered years.

A piecewise linear regression analysis was also performed to assess the approximate rate of variation of day and night equivalent levels in the past ten and six years, for the new addition in 2014, on an annual basis. The slope of variation (in dB(A)/year) of day and night equivalent levels and the corresponding Pearson's correlation coefficients for all the 70 sites in the 7 cities of India were evaluated, as shown in Tables 8 and 9

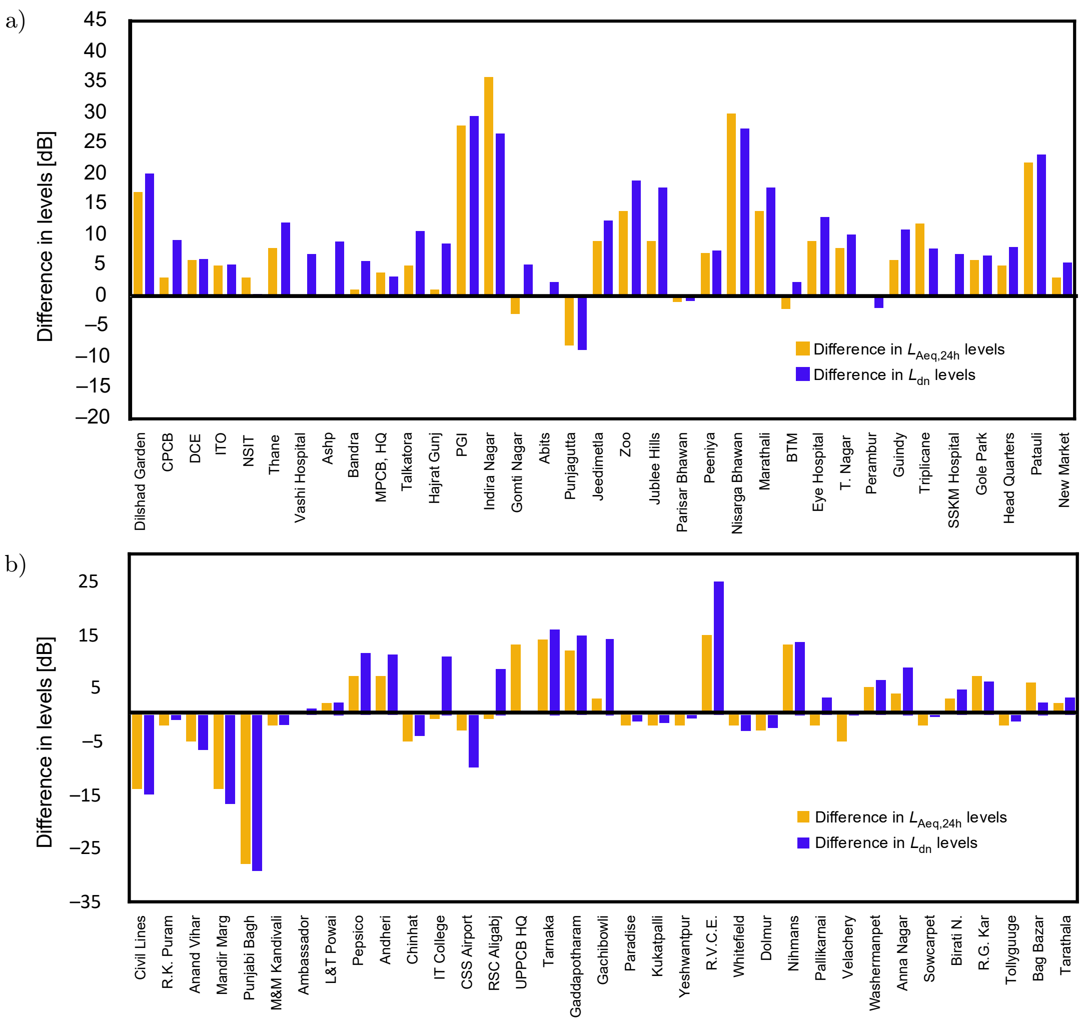

Fig. 7. Difference in equivalent sound levels: a) difference in 24-hour equivalent sound levels and day-night average sound levels w.r.t. 2020 sound levels for 35 sites in which the NMTs were installed in 2011; b) difference in 24-hour equivalent sound levels and day-night average sound levels w.r.t. 2020 sound levels for 35 sites in which the NMTs were installed in 2015.

(Appendix). Table 8 shows the slope of variation of ambient noise levels in the past ten years, 2011–2020, and the corresponding correlation coefficient for the 35 sites where the noise monitoring stations were established in 2011.

Table 9 presents the slope of variation of ambient noise levels in the past six years, 2015–2020, and the corresponding correlation coefficient for the 35 sites where the noise monitoring stations were established in 2014. It is revealed in Table 8 that except for 1 commercial, 2 residential, and 1 silence zone site, all other sites showed positive slopes for day equivalent levels and except for 1 commercial zone site, all other sites reported positive slopes for night equivalent levels for the past ten years (2011–2020), which indicates the increment in the ambient noise levels in these ten years. Also, for the variation of day equivalent levels, more than 70% of the 35 sites exhibited a slope within the range of 0 to 1.5 dB(A)/year, and almost 60% of the sites exhibited a slope within 0 to 1 dB(A)/year, while for the variation of night equivalent levels, nearly 77% of the 35 sites reported the slope of variation within 0 to 2 dB(A)/year. It is observed in Table 9 that for the past six years (2015–2020), 5 commercial, 3 industrial, 6 residential, and 4 silence zone sites exhibited a negative slope of variation of day equivalent levels and 4 commercial, 3 industrial, 4 residential, and 1 silence zone site reported negative slope of variation of night equivalent levels in the past six years (2015–2020), indicating a decrement in the day and night equivalent levels in these six years. Overall, 18 and 12 sites out of 35 sites reported a negative slope of variation for the day and night equivalent levels, respectively. Thus, it can be deduced that more commercial, industrial, and residential zone sites exhibited decrement in the day and night equivalent sound levels than the silence zone sites in the six years under study. Also, 21 out of 35 sites reported the slope of variation of day equivalent levels within the range −1 to 1 dB(A)/year, and 17 out of 35 sites exhibited a slope of variation of night equivalent levels within the range 0 to 2.5 dB(A)/year for the past six years from 2015 to 2020.

Population growth, rising transportation needs, an increase in vehicular density particularly heavy vehicles and cars, etc., and road congestion are all factors that are primarily attributed to the increased noise levels in the ten years under study (Jamir *et al.*, 2014). Also, the increased industrial activities account for the elevated ambient noise levels of the noise monitoring sites in ten years span of time. The increased encroachment of vehicles alongside the main roads in silence, residential, and commercial zones, congestion due to heavy vehicles, and unnecessary honking events are also associated with the elevated noise levels in these zones. Furthermore, loud music from the various night events (including marriage ceremonies and other concerts), noise from dog-barking at night at some sites, and movement of heavy trucks at night-time are primarily attributed to the higher noise levels at some sites.

The present study is the first study to comprehensively analyze the extensive noise monitoring data for 7 major cities of India for the past ten years from 2011 to 2020. Although the non-compliance of the silence and residential zone sites with the ambient noise standards is supported by several studies for other cities in India as well (Datta *et al.*, 2006; Aggarwal, Swami, 2011; Bhosale *et al.*, 2010; Garg *et al.*, 2016; 2017b; 2017c), a comprehensive study focussed in tier 2 and tier 3 cities shall give a broader picture of noise scenario in the country for the various zones.

4. Overall noise scenario and compliance with ambient standards

Long-term noise monitoring for the past decade revealed that the environmental noise levels were high compared to the recommended limits for some of the sites and thus noise control measures (or noise action plans) are essentially required for controlling the noise levels. It was observed that only 4 sites (5.7%) met the target of 55 dB L_{night}. Table 10 (Appendix) shows the status of compliance of the day and night equivalent levels explicitly for the various sites with the ambient noise limits. It can be observed that day-time compliance is observed in more sites than night-time compliance. A minimum of 9 to a maximum of 14 sites out of 70 sites have shown day-time compliance in the studied ten years, while a minimum of 5 to a maximum of 12 sites showed night-time compliance. No silence zone site ever met the ambient noise limits in the span of ten years under study, while only 2 residential sites showed compliance with the day ambient noise limits for 2011–2013, and 1 residential zone site showed day-time compliance in 2014, 2018, and 2019. Table 11 (Appendix) enlists the status of overall compliance of all the sites in 7 cities in the considered decade (Garg, 2022). It is evident that primarily the industrial sites met the ambient noise limits in these ten years. Also, in accordance with the U.S Department of Housing and Urban Development criteria (1984) that recommends the $L_{\mathrm{Aeq}} \leq 49$ dB(A) as clearly acceptable and $49 < L_{\mathrm{Aeq}} \leq 62$ dB(A) as normally acceptable. In 2020, 15 sites (21.4%), including 3 industrial, 5 commercial, 4 residential, and 3 silence zones, met these criteria. The level of significance for assessing noise impacts has been identified as an L_{dn} of 65 dB(A), whereby an L_{dn} value of 65 dB(A) is described as the onset of a normally unacceptable zone. In accordance with these criteria, 9 sites (12.9%) in 2020, including 1 industrial, 3 commercial, 3 residential, and 2 silence zones, met these criteria. These observations thus suggest a retrospective and prospective view of ambient noise standards, particularly for the residential areas and sites lying in the silence zones and mixed zone prevalent at some sites. It is rightly pointed out in the European Night Noise Guidelines (WHO, 2009) report that limits could be reasonably high but firmly imposed or very minimal with no legal obligation whatsoever.

Also, in order to ascertain the most severely affected zone, the NEF for each zone in the past four years was analyzed, as shown in Table 12 (Appendix). The NEF was calculated as the ratio of the ambient noise level (day/night) observed at the site to the noise limit recommended by the ambient noise standards (Chowdhury *et al.*, 2016). The analysis of NEF and AEF revealed that the silence zone has the maximum AEF of 1.4 for day equivalent sound levels and 1.7 for night equivalent sound levels, followed by residential zones (AEF 1.3–1.5) and commercial zone (AEF 1.1–1.2) in the 2020 noise monitoring data. The analysis of the four years AEF values suggested that the silence zone sites were the most affected sites, followed by residential zone sites. A planned land-use pattern of commercial, residential, silence, and industrial zones in a city shall be thus pivotal in reducing environmental noise levels. The numerical meta-analyses ascertaining the exposure-response relationship between community noise and cardiovascular risk recommends an empirical formulation as (WHO, 2011):

$$\text{OR} = 1.63-6.13\cdot10^{-4}\cdot L^2_{\text{day,16h}}+7.36\cdot10^{-6}\cdot L^3_{\text{day,16h}}, \quad (6)$$

where $L_{\text{day,16h}}$ is 16 hours ambient day level and OR is the odds ratio that is used to compare the relative odds of the occurrence of the outcome of disease, given exposure to the variable of interest (noise exposure level). Thus, for the Gunidy site in Chennai that experienced the highest day equivalent sound levels of 82.8 dB(A) in 2020 and the Bag Bazar site in Kolata that experienced the highest day equivalent sound levels of 87.2 dB(A) in 2019, the ORs of 1.6 and 1.8 were evaluated, respectively. The variation of OR was evaluated to be in the range of 1 to 1.6 for 2019 and 1 to 1.8 in 2020. Thus, epidemiological meta-analysis and noise annoyance studies are essentially required from an Indian perspectives to correlate noise exposure with the health effects. The empirically described conversion rules between the environmental noise exposure metrics as that presented by Brink *et al.* (2018) in Switzerland shall facilitate the estimation of the value of one (unknown) noise metric from the value of another (known) metric, e.g., in the scope of epidemiological meta-analyses or systematic reviews, when results from different studies are pooled and need to be related to one common exposure metric. Table 13 (Appendix) shows the inter-conversion of the various noise descriptors for the four zones based on the analysis of noise monitoring data of the past three years. The interconversion rule shall facilitate the prediction of noise descriptors eventually when short-term noise monitoring studies are carried out (Garg *et al.*, 2015a; Tiwari *et al.*, 2022).

5. Noise action plans and noise control policy

The undue violation of ambient noise limits for the residential and silence zone sites is primarily due to the mixed category zone prevalent for some of the locations. Thus, these observations suggest a need for the national policy framework for the management and control of noise pollution in India (Garg, Maji, 2016; Garg *et al.*, 2022). Figure 8 shows the proposed plan for management and control of noise pollution and the noise action plans for controlling noise pollution in the urban cities of India. The major elements of such a policy framework shall be: noise mapping, monitoring and certification, enforcement of ambient noise standards, selection and execution of appropriate noise action plans, traffic management policy, legal measures and noise screening policy, and noise awareness campaigns for inculcating awareness amongst the community towards reducing the noise pollution. The proposal in the master plan with major impetus on traffic decongestion includes the following: Unified Metro Transport Authority, synergy between land-use and transport integrated multi-modal public transport system for reducing the dependence on personalized vehicles, road and rail-based mass transport system recommended to be a major mode of public transport, and optimal use of existing road network. National Transport Oriented Development (TOD) policy can serve as guidelines and play a catalytic role in formulating state/city-level policies to promote transit-oriented development (CPCB, 2017). Decongestion plans for busy road junctions, special drives for "no honking", promotion of carpooling policy, and "work from home" culture for some of the offices (Kumar *et al.*, 2022) for reducing road traffic, launching of odd-even traffic measures for some time (Garg *et al.*, 2017a), launching car-free day initiatives, installing synchronized traffic signaling, constructing flyovers in metropolitan cities for deflecting the traffic, easing the traffic density, and restricting entry of heavy vehicles are some of the major administrative issues that should be implemented for reducing the environmental noise levels. Installation of noise barriers at hotspots in an adequate manner is also a feasible option for noise abatement in various zones of metropolitan cities of India (Lokhande *et al.*, 2021a). Demarcation of all the silence zone and residential zone sites in cities, demarcation of no-honking zones, proper land-use planning, and inculcating awareness amongst the community on associated health hazards due to noise exposure shall be very effective steps to control noise pollution. Periodic noise monitoring of sites in conjunction with noise mapping of cities and periodic review

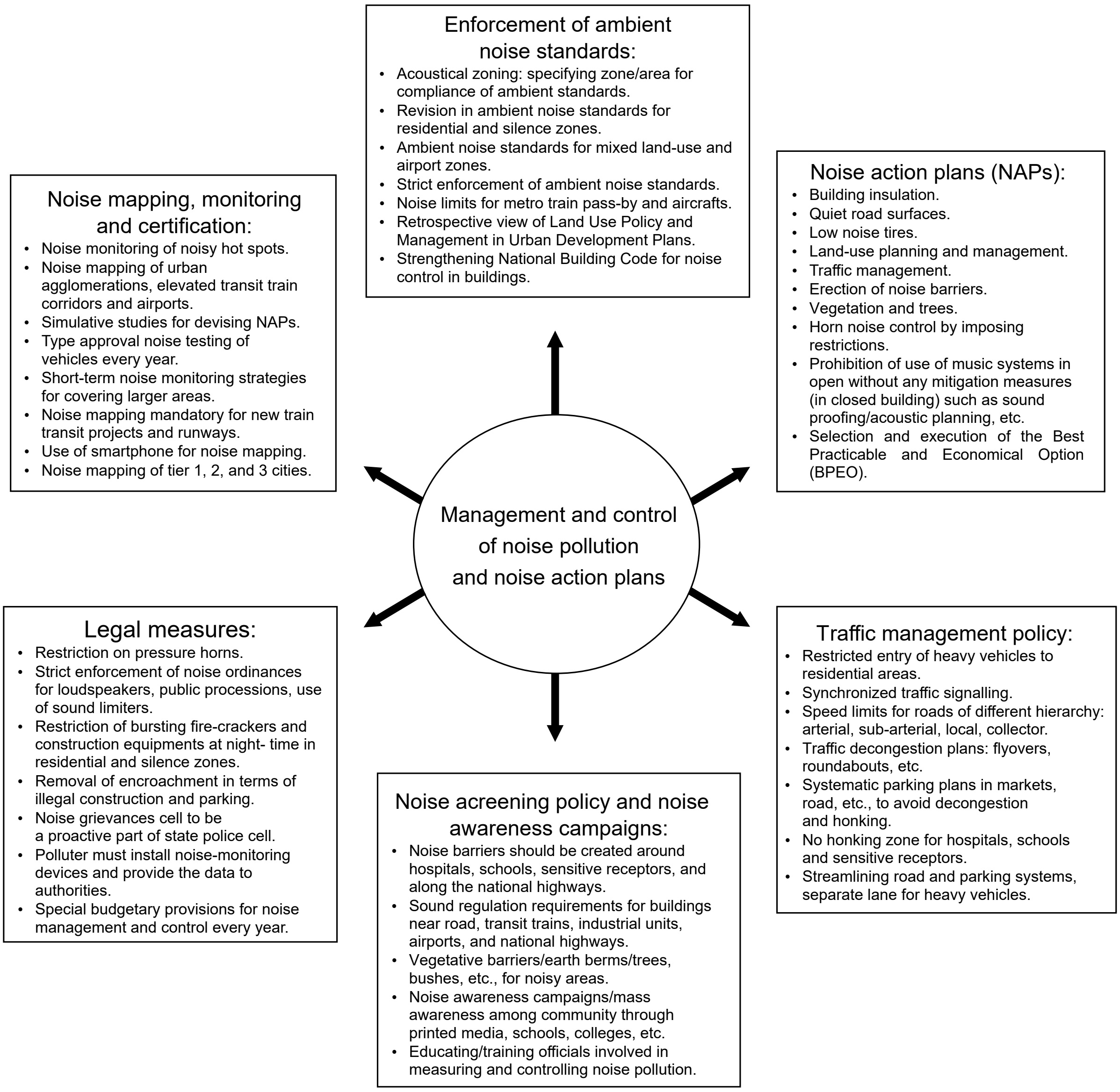

Fig. 8. Proposed plan for management and control of noise pollution and noise action plans in Indian scenario to effectively control noise pollution in urban cities.

of noise scenarios after fixed intervals shall be indispensable to analyze, understand, and devise suitable noise action plans (Garg *et al.*, 2015a; 2020; 2021; Kumar *et al.*, 2023; Lokhande *et al.*, 2019). In addition, noise measurements with the help of smartphone applications are also an effective, novel and economical way of disseminating awareness among the community, especially the young generations (Lokhande *et al.*, 2021b). It is recommended that a mixed zone category should be specifically considered for the noise abatement guidelines/ambient standards in the future from an Indian perspective. Reduction at the source (travel demand reduction, setting restrictive speed limits in residential areas and sensitive sites, prohibition of heavy vehicle traffic in residential areas and sensitive sites, minimization of slopes in urban roads, control of acoustic emissions generated by vehicles with sirens, strict enforcement of regulations governing the emission limits and conditions of use of vehicles, etc.) is the effective action plan for reducing the environmental noise levels (Torija *et al.*, 2021). The European Union has recently reported the noise action plans for major roads as the measures on the propagation path (40%) followed by the source-orientated measures (38%). Noise barriers and traffic management measures were the most commonly reported, followed by improving the road surface. However, the actions related to urban planning only account for a small percentage (13%) and the ones related to education and communication account for 6% (Blanes *et al.*, 2019; Conference of European Directors of Roads [CEDR], 2013; European Environment Agency, 2020). The costeffectiveness of the noise action plans is very crucial for selecting an optimal strategy (Münzel *et al.*, 2018; European Union, 2017; Lokhande *et al.*, 2022; Garg *et al.*, 2012; 2022; Tiwari *et al.*, 2021). Thus, an effective noise policy for a sustainable environment, including noise action plans in urban planning, is essential from an Indian perspective for accomplishing the desired goals towards noise pollution control in metropolitan cities. Thus, these measures have to be implemented for metropolitan cities of India while considering the recent WHO (2018) guidelines such as reducing noise exposure while conserving silence areas, promoting the interventions to reduce noise exposure and improve health, coordinating the various approaches to control noise source and other environmental health risks and information and involvement of the communities (WHO, 2018).

6. Conclusions and recommendations

This paper analyzed and reported the long-term noise-monitoring data for 2011–2020 obtained from the diversified NANMN set up across the 7 major cities of India and covering 70 stations for continuous noise monitoring throughout the year. The annual average ambient noise levels observed in these years for these 70 locations under study, in which 25 locations were in commercial zones, 12 in industrial, 16 in residential, and 17 in silence zones, were described. These observations were instrumental in ascertaining the noise scenario, the status of compliance with the ambient noise limits and planning a national policy framework for reducing noise pollution in metropolitan cities of India. Such a study shall be helpful for predicting and forecasting future noise scenarios in the decade. The following conclusions can be drawn from this study:

- the comparison of the ambient noise levels in the studied decade revealed that the majority of sites (19 out of 35) registered an increment in day and night equivalent sound levels of more than 5 dB(A) in this decade. Only 3 sites showed a decrement in day equivalent sound levels by 5 dB(A) and 1 site showed a decrement in night equivalent sound levels by 5 dB(A). Overall, it was observed that the commercial and silence zone sites exhibited a higher increment in the day and night equivalent sound levels in the past few years;
- in the past three years, from 2018 to 2020, 7 out of 10 sites in Chennai and Mumbai exhibited day and night equivalent levels greater than 70 dB(A). For Kolkata, 6 sites reported day and night equivalent sound levels greater than 70 dB(A). Also, 4 out of 10 sites in Lucknow, Hyderabad, and Bengaluru exhibited day and night equivalent levels greater than 70 dB(A). For Delhi, only 2 out of 10 sites showed day and night equivalent sound levels greater than 70 dB(A). Forty-two sites (60%) comprising of 18 commercial, 5 industrial, 9 in silence zone, and 10 residential were observed to be the most exposed urban sites with day equivalent sound levels ≥70 dB(A);
- the NOAEL limit of 60 dB(A) L_{day} was met by 4 sites only for 2020, while 7 sites met this limit in 2019 and 9 sites in 2018. The interim target (IT) of 55 dB L_{night}, as recommended in the EU Night Noise Guidelines report, was met by 4 sites in 2020, 7 sites in 2019, and 8 sites in 2018. Overall, 94.3% of the observations exceeded the interim target recommended by the Night Noise Guidelines (NNG) report, which indicates that 55 dB L_{night} is an ambitious target for all these sites under consideration;
- the zone-wise analysis of ambient noise levels showed that the majority of sites registered day equivalent sound levels in the range of 60 to 75 dB(A) in all 4 zones. Also, the majority of sites registered night equivalent sound levels in the range of 55 to 70 dB(A) for residential, silence, and industrial zones, while the majority of the sites (76%) in the commercial zones registered night equivalent sound levels in the range of 60 to 75 dB(A);
- the analysis of the noise monitoring data for the 70 sites for the year 2020 showed that the majority of $L_{\text{Aeq,24h}}$ values range from 60 to 75 dB(A) for commercial (83%) and industrial zone sites (65.9%), while for the residential (75%) and silence zone sites (76.9%), the $L_{\text{Aeq,24h}}$ values range from 55 to 70 dB(A). Also, the analysis of L_{dn} values revealed that the majority of these values range from 65 to 80 dB(A) for commercial (66%), residential (69%), and industrial zone sites (67%), while for the silence zone sites, the majority (80.5%) of L_{dn} values range from 60 to 75 dB(A);
- the analysis of compliance with the ambient standards showed that day-time compliance is shown by more sites than the night-time. A minimum of 9 sites and a maximum of 14 sites out of 70 sites showed day-time compliance from 2011 to 2020, while only a minimum of 5 sites and a maximum of 12 sites showed night-time compliance during the past ten years. Primarily, only the commercial and industrial zone sites complied with the ambient noise standards from 2011 to 2020. No silence zone site ever met the ambient noise limits, while only 2 residential sites showed compliance with the day ambient noise limits. No site met the limits of 53 dB L_{den} and 45 dB L_{night} recommended by the Guidelines Development Group of the WHO for road traffic noise. These observations suggest the need to reconsider ambient noise standards, especially for residential and silence zones. Also, the mixed category zone was available for some of these sites, however it was very

difficult to exclusively classify them as either residential or silence zones or commercial or industrial zones. It is recommended that a mixed zone category should be specifically considered for the noise abatement guidelines/ambient standards in the future from an Indian perspective;

– the analysis of (L_{day}–L_{night}) for 70 sites revealed that the majority of observations show a difference between 0 to 10 dB(A) and less than or equal to 5 dB(A) in the decade under study. Therefore, these observations suggest that the night equivalent noise levels are comparable to the day equivalent levels for the majority of sites. Thus, the 10 dB night time adjustment in the day-night average sound level is not appropriate in such a scenario. These observations also suggest that a 5 dB evening time correction in the day-evening-night average sound level descriptor is not justified in the Indian context as the evening noise levels are the same as the day equivalent noise levels. Thus, the 24-hour equivalent continuous sound level $L_{\text{Aeq,24h}}$ would be a more suitable descriptor as it is a common way of expressing the day-night average sound level without a 10 dB night-time adjustment. It is thus recommended that for developing exposure-effect relationships and correlating noise annoyance, and correlating noise exposure with the health aspects, the single noise descriptor, 24-hour equivalent continuous sound level $L_{\text{Aeq,24h}}$, would be more suitable compared to L_{dn} or L_{den} descriptors;

– it was observed that the approximate annual rate of variation of ambient noise levels was positive for 31 out of 35 sites for the ten years, indicating an increment in the ambient noise levels in the these ten years. For the rest of the 35 sites where the noise monitoring stations were installed in 2014, the approximate annual rate of variation of day equivalent levels of 18 out of 35 sites was negative and for the night equivalent levels, the approximate annual rate of variation of 12 out of 35 sites was negative, which indicates the decrement in day and night equivalent levels of 18 and 12 sites, respectively, in the past six years. Also, it was revealed that relatively more commercial, industrial, and residential zone sites exhibited a decrement in the day and night equivalent sound levels in comparison to silence zones in the same six years;

– the analysis of the NEF and AEF showed that the silence zone has the maximum AEF of 1.4 for day equivalent noise levels and 1.7 for night equivalent noise levels, followed by residential zones (AEF 1.3–1.5) and commercial zones (AEF 1.1–1.2) in 2020 noise monitoring data. Thus, it suggests that silence zone sites are the most affected sites, followed by residential zone sites.

The present study considered the analysis of noise monitoring data from 70 sites in 7 metropolitan cities. Future studies focusing on long-term evaluation and analysis of noise monitoring data of tier 2 and tier 3 cities shall be helpful in understanding the generic noise scenario of the country and developing a national, coherent noise policy from an Indian perspective. The undue violation of ambient noise limits for the residential and silence zone sites is primarily due to the mixed category zone prevalent for some of the locations. Figure 8 recommends the road map of national policy on noise management and control for controlling the noise pollution in metropolitan cities of India. Thus, the execution and implementation of the NAPs and the administrative measures such as traffic management policy, noise screening policy, legal measures, and strict enforcement of ambient noise standards can be very instrumental in reducing ambient noise levels. Thus, the future developments and establishment of "Smart Cities" should consider these aspects at the designing stages for controlling noise pollution and developing sustainable cities promoting good health and quality of life.

Acknowledgments

The authors are very thankful to the CPCB, India and web portal CPCB (n.d.) for sharing and disseminating the noise monitoring data of 70 sites. The present work is an extension of the previous work reported on the pilot project of establishment of the NANMN project by CPCB, India. The paper analyzes and reports the noise monitoring data and the views and opinions expressed in this article are those of the authors' own and do not necessarily reflect the official policy or position of any agency of the Government of India. The content of the papers is solely to present a retrospective and prospective view of noise levels in the studied ten years and may not be used or considered for dispute redressal in the legal framework.

Appendix

Table 1. Ambient noise standards of India (Ministry of Environment & Forests, 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.

Table 2. Annual average ambient levels L_{day} and L_{night} for 35 noise monitoring stations installed across 7 major cities in India from 2011 to 2014 (CPCB, 2015).

Name of location	City	Area characteristics	2011		2012		2013		2014	
			L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}
Dilshad Garden		Silence	52.0 ± 0.9	50.0 ± 1.4	52.0 ± 1.1	49.0 ± 2.1	51.0 ± 1.1	49.0 ± 2.4	52.0 ± 0.9	48.0 ± 1.6
CPCB HQ		Commercial	64.0 ± 2.0	53.0 ± 1.4	62.0 ± 1.0	53.0 ± 1.3	63.0 ± 0.8	53.0 ± 1.0	65.0 ± 1.7	54.0 ± 1.6
DTU, Bawana	Delhi	Silence	52.0 ± 1.3	48.0 ± 2.1	51.0 ± 0.9	49.0 ± 3.2	52.0 ± 1.7	49.0 ± 3.0	52.0 ± 1.1	48.0 ± 2.5
ITO		Commercial	73.0 ± 0.6	71.0 ± 1.0	72.0 ± 4.0	69.0 ± 5.3	74.0 ± 0.7	73.0 ± 0.4	74.0 ± 1.0	73.0 ± 1.4
NSIT Dwarka		Silence	56.0 ± 1.3	54.0 ± 0.8	56.0 ± 0.7	54.0 ± 1.1	56.0 ± 0.5	53.0 ± 0.9	56.0 ± 1.4	53.0 ± 1.8
Gomti Nagar		Silence	71.0 ± 0.8	61.0 ± 1.5	63.0 ± 0.9	55.0 ± 1.1	66.0 ± 2.2	57.0 ± 1.6	69.0 ± 1.4	61.0 ± 2.0
Hazrat Ganj		Commercial	67.0 ± 0.9	58.0 ± 1.0	72.0 ± 0.5	61.0 ± 1.0	72.0 ± 0.5	62.0 ± 1.3	72.0 ± 0.5	61.0 ± 1.5
Indira Nagar	Lucknow	Residential	54.0 ± 1.2	47.0 ± 2.9	53.0 ± 1.1	47.0 ± 3.0	54.0 ± 1.4	48.0 ± 3.6	57.0 ± 0.9	49.0 ± 4.7
PGI Hospital		Silence	55.0 ± 2.5	49.0 ± 2.8	58.0 ± 1.2	52.0 ± 3.6	60.0 ± 1.4	53.0 ± 3.0	62.0 ± 1.3	55.0 ± 3.5
Talkatora Industrial Area		Industrial	63.0 ± 0.4	55.0 ± 1.6	64.0 ± 0.7	56.0 ± 1.6	63.0 ± 0.5	56.0 ± 1.9	64.0 ± 1.2	57.0 ± 2.0
Kasba Gole Park		Industrial	64.0 ± 1.2	59.0 ± 1.3	65.0 ± 1.6	61.0 ± 2.6	68.0 ± 3.5	64.0 ± 4.7	70.0 ± 2.5	67.0 ± 2.9
New Market		Commercial	67.0 ± 0.5	60.0 ± 1.4	67.0 ± 0.7	59.0 ± 1.4	68.0 ± 0.5	60.0 ± 1.6	70.0 ± 2.3	65.0 ± 5.2
Patauli	Kolkata	Residential	55.0 ± 1.0	49.0 ± 2.0	55.0 ± 1.0	49.0 ± 3.2	55.0 ± 1.6	48.0 ± 6.2	55.0 ± 1.3	49.0 ± 4.5
SSKM Hospital		Silence	61.0 ± 0.4	54.0 ± 0.9	62.0 ± 0.8	56.0 ± 1.8	62.0 ± 1.2	57.0 ± 1.9	62.0 ± 1.1	56.0 ± 1.7
WBPCB HQ		Commercial	62.0 ± 0.6	56.0 ± 1.3	61.0 ± 0.7	54.0 ± 1.1	62.0 ± 1.4	55.0 ± 1.4	64.0 ± 0.6	58.0 ± 0.9
AS HP		Silence	66.0 ± 1.2	59.0 ± 1.5	65.0 ± 1.0	59.0 ± 0.3	65.0 ± 0.8	60.0 ± 1.5	66.0 ± 2.0	60.0 ± 0.9
Bandra		Commercial	70.0 ± 0.5	68.0 ± 0.8	69.0 ± 0.7	67.0 ± 1.9	69.0 ± 0.4	67.0 ± 0.5	70.0 ± 0.5	67.0 ± 0.7
MPCB HQ	Mumbai	Commercial	67.0 ± 0.6	63.0 ± 0.5	66.0 ± 0.5	63.0 ± 0.7	68.0 ± 1.6	65.0 ± 2.0	71.0 ± 0.6	68.0 ± 1.0
Thane MCQ		Commercial	62.0 ± 1.8	53.0 ± 2.3	62.0 ± 0.7	55.0 ± 1.9	62.0 ± 1.2	55.0 ± 1.4	64.0 ± 1.0	56.0 ± 1.3
Vashi Hospital		Silence	68.0 ± 1.7	58.0 ± 1.4	69.0 ± 0.9	57.0 ± 2.7	69.0 ± 0.8	57.0 ± 0.8	69.0 ± 1.5	59.0 ± 3.6
Abids		Commercial	72.0 ± 0.5	63.0 ± 0.9	72.0 ± 0.9	63.0 ± 1.9	72.0 ± 0.8	64.0 ± 2.1	74.0 ± 1.9	65.0 ± 2.5
Jeedimetla		Industrial	62.0 ± 0.5	56.0 ± 1.4	63.0 ± 1.2	56.0 ± 2.1	63.0 ± 1.3	56.0 ± 1.6	65.0 ± 0.6	58.0 ± 0.8
Jubilee Hills	Hyderabad	Residential	58.0 ± 1.0	50.0 ± 1.7	56.0 ± 0.7	49.0 ± 0.5	56.0 ± 0.6	49.0 ± 1.2	57.0 ± 1.6	49.0 ± 1.2
Punjagutta		Commercial	76.0 ± 0.6	71.0 ± 1.0	75.0 ± 0.5	70.0 ± 0.5	76.0 ± 1.7	71.0 ± 1.3	79.0 ± 0.7	73.0 ± 0.5
Zoo Park		Silence	53.0 ± 1.5	48.0 ± 2.8	54.0 ± 1.8	48.0 ± 2.0	54.0 ± 1.4	49.0 ± 1.1	56.0 ± 1.2	50.0 ± 2.2
BTM		Residential	66.0 ± 0.4	56.0 ± 0.4	66.0 ± 0.5	56.0 ± 1.0	66.0 ± 0.8	56.0 ± 0.8	66.0 ± 0.7	57.0 ± 1.1
Marathahalli		Commercial	56.0 ± 1.9	53.0 ± 1.8	54.0 ± 0.7	52.0 ± 0.6	57.0 ± 2.1	54.0 ± 2.8	59.0 ± 0.7	56.0 ± 0.8
Nisarga Bhawan	Bengaluru	Residential	56.0 ± 3.0	47.0 ± 1.8	56.0 ± 2.0	47.0 ± 1.9	56.0 ± 1.9	48.0 ± 1.6	56.0 ± 1.5	49.0 ± 1.4
Parisar Bhawan		Commercial	66.0 ± 1.1	58.0 ± 0.7	65.0 ± 0.3	57.0 ± 1.6	65.0 ± 0.7	57.0 ± 0.8	65.0 ± 0.8	57.0 ± 0.5
Peeniya		Industrial	56.0 ± 1.6	53.0 ± 2.6	56.0 ± 1.2	49.0 ± 1.2	58.0 ± 1.1	53.0 ± 2.3	58.0 ± 0.8	55.0 ± 2.0
Eye Hospital		Silence	64.0 ± 0.6	51.0 ± 1.2	62.0 ± 1.5	52.0 ± 3.1	64.0 ± 1.5	53.0 ± 2.2	61.0 ± 3.9	53.0 ± 1.2
Guindy		Industrial	76.0 ± 0.6	71.0 ± 1.1	75.0 ± 1.1	71.0 ± 1.3	75.0 ± 1.0	71.0 ± 1.5	76.0 ± 1.9	72.0 ± 1.2
Perambur	Chennai	Commercial	68.0 ± 0.9	58.0 ± 0.8	69.0 ± 1.2	58.0 ± 1.2	68.0 ± 0.5	57.0 ± 0.7	69.0 ± 1.3	58.0 ± 0.8
T. Nagar		Commercial	73.0 ± 0.5	62.0 ± 1.1	73.0 ± 0.3	62.0 ± 1.0	74.0 ± 1.0	64.0 ± 2.0	75.0 ± 0.9	67.0 ± 1.6
Triplicane		Residential	68.0 ± 0.4	55.0 ± 1.0	68.0 ± 0.5	56.0 ± 0.8	68.0 ± 0.5	56.0 ± 0.7	68.0 ± 1.4	57.0 ± 2.0

Table 3. Annual average ambient levels L_{day} and L_{night} for 35 noise monitoring stations installed across 7 major cities in India from 2015 to 2020 (CPCB, 2015a; 2015b; 2016; 2018; Garg, 2022).

Name of location	City	Area characteristics	2015		2016		2017		2018		2019		2020	
			L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}
Dilshad Garden	Delhi	Silence	57.3 ± 3.3	54.0 ± 5.6	53.0 ± 1.4	51.0 ± 2.7	54.0 ± 1.5	53.0 ± 0.4	64.1 ± 1.1	57.0 ± 0.6	68.7 ± 2.6	68.4 ± 2.8	70.4 ± 3.5	70.6 ± 3.5
CPCB HQ		Commercial	69.2 ± 1.8	59.1 ± 1.5	66.0 ± 0.9	57.0 ± 0.8	66.0 ± 0.5	57.0 ± 1.5	66.1 ± 0.4	58.0 ± 0.7	66.5 ± 0.5	56.7 ± 0.7	64.5 ± 2.3	67.4 ± 2.3
DTU, Bawana		Silence	63.0 ± 6.9	62.0 ± 11	57.0 ± 3.5	57.0 ± 7.6	56.0 ± 2.0	52.0 ± 3.1	56.2 ± 1.0	52.3 ± 2.0	62.2 ± 2.9	57.9 ± 2.3	57.2 ± 3.7	54.8 ± 3.3
ITO		Commercial	74.0 ± 0.9	70.0 ± 1.2	75.0 ± 4.2	71.0 ± 4.3	72.0 ± 0.9	67.0 ± 0.7	73.1 ± 0.4	69.9 ± 0.6	75.1 ± 3.1	73.5 ± 3.7	79.8 ± 4.4	75.6 ± 2.7
NSIT Dwarka		Silence	60.0 ± 2.0	56.4 ± 2.1	58.0 ± 1.0	55.0 ± 1.9	57.0 ± 0.6	54.0 ± 1.0	57.4 ± 0.5	55.6 ± 1.0	57.9 ± 0.9	54.2 ± 4.0	57.4 ± 1.9	54.3 ± 1.8
Gomti Nagar	Lucknow	Silence	–	–	72.0 ± 6.2	64.0 ± 6.4	67.0 ± 1.4	59.0 ± 1.3	66.1 ± 0.6	61.8 ± 2.8	66.9 ± 1.0	60.2 ± 1.1	64.5 ± 2.1	70.9 ± 4.1
Hazrat Gunj		Commercial	73.3 ± 0.8	64.1 ± 1.5	74.0 ± 0.9	66.0 ± 2.3	73.0 ± 5.2	69.0 ± 4.8	71.5 ± 2.6	68.0 ± 2.2	74.0 ± 4.1	73.2 ± 4.5	68.0 ± 3.3	70.5 ± 4.3
Indira Nagar		Residential	61.9 ± 2.8	56.0 ± 4.7	79.0 ± 6.2	77.0 ± 8.4	57.0 ± 1.1	51.0 ± 2.2	55.3 ± 4.0	49.6 ± 4.0	50.6 ± 1.9	44.7 ± 3.0	76.5 ± 4.5	75.8 ± 4.8
PGI Hospital		Silence	63.9 ± 1.0	58.0 ± 2.3	65.0 ± 1.7	59.0 ± 2.9	63.0 ± 3.7	59.0 ± 4.4	60.4 ± 3.1	53.9 ± 3.0	66.7 ± 2.1	67.0 ± 3.7	81.7 ± 3.7	80.1 ± 5.2
Talkatora Industrial Area		Industrial	67.3 ± 0.5	61.0 ± 3.1	68.0 ± 0.9	61.0 ± 2.5	67.0 ± 2.0	61.0 ± 2.7	67.4 ± 2.4	62.1 ± 3.3	63.7 ± 3.4	62.3 ± 4.4	67.1 ± 4.6	68.9 ± 8.7
Kasba Gole Park	Kolkata	Industrial	81.0 ± 6.7	81.0 ± 7.1	81.0 ± 9.7	83.0 ± 4.2	73.0 ± 4.4	73.0 ± 4.2	68.0 ± 2.6	68.3 ± 2.6	64.4 ± 5.2	61.1 ± 3.8	69.5 ± 3.2	66.5 ± 4.0
New Market		Commercial	80.0 ± 1.1	79.0 ± 1.0	87.0 ± 0.5	87.0 ± 0.8	78.0 ± 0.7	78.0 ± 0.8	72.7 ± 2.1	72.7 ± 1.9	72.9 ± 2.8	76.3 ± 4.0	68.8 ± 5.6	67.6 ± 5.1
Patauli		Residential	70.0 ± 1.3	69.0 ± 2.2	76.0 ± 1.4	76.0 ± 4.3	67.0 ± 2.4	67.0 ± 4.3	65.6 ± 2.9	65.2 ± 3.0	73.4 ± 5.2	72.4 ± 5.7	70.6 ± 4.9	74.4 ± 6.0
SSKM Hospital		Silence	63.9 ± 7.3	58.0 ± 8.2	64.0 ± 4.9	59.0 ± 4.2	67.0 ± 4.3	60.0 ± 4.2	72.4 ± 3.4	73.8 ± 2.7	70.4 ± 3.2	69.6 ± 3.9	64.7 ± 6.1	63.0 ± 5.3
WBPCB HQ		Commercial	64.0 ± 9.9	58.1 ± 1.2	62.0 ± 4.4	56.0 ± 4.6	63.0 ± 4.2	57.0 ± 4.6	66.1 ± 3.2	63.9 ± 3.5	63.4 ± 0.9	57.0 ± 1.1	66.4 ± 4.9	65.8 ± 6.3
AS HP	Mumbai	Silence	77.0 ± 1.6	75.0 ± 1.3	74.0 ± 1.1	74.0 ± 1.0	74.0 ± 1.2	74.0 ± 3.8	70.4 ± 4.4	70.5 ± 4.8	–	–	71.7 ± 11.5	69.8 ± 10.8
Bandra		Commercial	68.0 ± 1.3	64.0 ± 1.7	70.0 ± 7.4	69.0 ± 9.0	70.0 ± 4.6	70.0 ± 4.7	64.8 ± 3.2	65.0 ± 3.4	67.5 ± 4.6	66.9 ± 4.7	74.7 ± 5.3	74.4 ± 5.0
MPCB HQ		Commercial	71.0 ± 0.9	70.0 ± 0.7	69.0 ± 2.6	67.0 ± 5.9	66.0 ± 6.3	61.0 ± 12.9	69.0 ± 2.3	74.7 ± 7.5	70.2 ± 0.5	67.3 ± 3.3	72.9 ± 4.6	64.1 ± 5.1
Thane MCQ		Commercial	64.0 ± 7.6	57.0 ± 9.4	73.0 ± 1.9	75.0 ± 2.1	61.0 ± 1.9	58.0 ± 2.3	61.0 ± 4.0	57.1 ± 2.7	69.1 ± 0.5	69.1 ± 1.1	67.9 ± 0.9	68.6 ± 1.3
Vashi Hospital		Silence	69.0 ± 1.2	59.0 ± 1.5	70.0 ± 2.2	65.0 ± 4.2	78.0 ± 1.9	83.0 ± 4.7	72.1 ± 2.3	68.5 ± 3.9	75.8 ± 7.2	74.2 ± 7.7	69.4 ± 4.7	69.1 ± 5.1
Abids	Hyderabad	Commercial	77.6 ± 0.8	69.7 ± 1.8	53.0 ± 2.0	51.0 ± 2.6	74.0 ± 0.8	66.0 ± 1.5	74.4 ± 0.8	68.2 ± 1.3	73.1 ± 0.7	65.7 ± 1.4	72.7 ± 4.7	67.4 ± 4.7
Jeedimetla		Industrial	68.0 ± 0.6	63.0 ± 0.9	57.0 ± 1.3	57.0 ± 3.6	74.0 ± 1.5	85.0 ± 1.6	80.0 ± 1.0	80.1 ± 4.6	72.6 ± 5.3	73.2 ± 6.9	71.7 ± 4.0	70.0 ± 4.6
Jubilee Hills		Residential	60.0 ± 0.5	53.2 ± 0.8	58.0 ± 3.3	55.0 ± 5.2	61.0 ± 0.7	55.0 ± 1.3	61.4 ± 1.2	55.9 ± 1.2	59.7 ± 1.2	53.8 ± 1.1	74.4 ± 4.0	69.1 ± 4.6
Punjagutta		Commercial	80.0 ± 1.8	75.0 ± 3.0	66.0 ± 2.6	57.0 ± 3.5	72.0 ± 0.6	65.0 ± 1.0	70.7 ± 1.4	64.8 ± 1.4	69.8 ± 0.9	62.9 ± 0.8	68.2 ± 2.3	61.8 ± 2.5
Zoo Park		Silence	56.0 ± 0.7	51.0 ± 1.5	75.0 ± 2.0	71.0 ± 1.7	56.0 ± 1.9	50.0 ± 1.5	55.2 ± 0.8	50.4 ± 1.0	55.8 ± 3.4	61.4 ± 3.3	69.0 ± 8.9	68.1 ± 8.8
BTM	Bengaluru	Residential	65.8 ± 3.7	58.0 ± 5.0	66.0 ± 2.9	62.0 ± 2.3	66.0 ± 3.4	66.0 ± 4.0	66.6 ± 3.6	65.9 ± 3.6	64.7 ± 3.0	64.7 ± 3.3	62.5 ± 5.3	62.5 ± 4.6
Marathahalli		Commercial	59.0 ± 0.5	57.2 ± 0.9	56.0 ± 1.1	56.0 ± 1.2	64.0 ± 0.5	63.0 ± 1.1	67.4 ± 4.5	66.2 ± 5.2	73.1 ± 3.7	72.7 ± 7.2	71.8 ± 6.1	71.4 ± 6.4
Nisarga Bhawan		Residential	58.0 ± 2.6	52.0 ± 4.3	58.0 ± 1.5	53.0 ± 4.6	57.0 ± 1.0	50.0 ± 1.0	75.2 ± 3.7	70.0 ± 4.1	76.4 ± 4.0	79.1 ± 8.0	80.2 ± 8.8	77.4 ± 8.6
Parisar Bhawan		Commercial	66.7 ± 0.8	59.0 ± 1.1	67.0 ± 1.9	62.0 ± 3.1	67.0 ± 2.3	61.0 ± 2.4	67.4 ± 1.0	61.6 ± 1.0	67.2 ± 0.5	62.1 ± 0.6	64.3 ± 2.6	58.7 ± 3.4
Peeniya		Industrial	61.0 ± 1.2	59.0 ± 1.2	64.0 ± 0.5	57.0 ± 2.4	66.0 ± 9.3	60.0 ± 7.9	64.1 ± 1.1	57.0 ± 0.6	63.4 ± 0.8	58.4 ± 1.4	62.6 ± 2.5	60.9 ± 2.7
Eye Hospital	Chennai	Silence	67.0 ± 3.1	60.0 ± 4.3	67.0 ± 1.8	59.0 ± 2.3	67.0 ± 0.0	62.0 ± 3.3	66.4 ± 6.3	58.7 ± 3.3	69.2 ± 3.8	61.0 ± 4.3	72.8 ± 6.9	69.7 ± 5.3
Guindy		Industrial	79.8 ± 1.0	75.7 ± 2.5	79.0 ± 0.6	76.0 ± 1.9	76.0 ± 0.4	72.0 ± 2.0	76.8 ± 0.4	74.9 ± 1.4	80.1 ± 3.5	78.2 ± 4.8	82.8 ± 6.8	83.6 ± 7.1
Perambur		Commercial	72.0 ± 1.5	65.0 ± 4.7	73.0 ± 1.2	71.0 ± 4.5	75.0 ± 3.7	76.0 ± 4.5	75.8 ± 1.3	76.8 ± 5.7	74.4 ± 2.3	71.6 ± 2.7	63.1 ± 3.9	59.4 ± 5.4
T. Nagar		Commercial	76.6 ± 0.4	69.3 ± 0.7	76.0 ± 1.6	68.0 ± 5.2	75.0 ± 3.0	67.0 ± 1.0	75.8 ± 1.3	70.2 ± 2.0	77.3 ± 0.9	73.0 ± 1.9	80.3 ± 6.5	75.9 ± 4.0
Triplicane		Residential	73.0 ± 3.1	68.0 ± 5.6	73.0 ± 5.8	72.0 ± 7.3	69.0 ± 10.4	58.0 ± 4.6	67.1 ± 3.5	63.8 ± 3.5	60.9 ± 3.1	59.0 ± 4.1	70.0 ± 4.6	68.9 ± 5.0

Table 4. Annual average ambient levels L_{day} and L_{night} for additional 35 noise monitoring stations installed in November 2014 across 7 major cities from 2015 to 2020 (CPCB, 2015a; 2015b; 2016; 2018; Garg, 2022).

Name of location	City	Area characteristics	2015		2016		2017		2018		2019		2020	
			L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}
Civil Lines	Delhi	Commercial	73.0 ± 5.3	73.0 ± 5.3	69.0 ± 1.0	70.0 ± 1.9	66.0 ± 4.7	65.0 ± 5.7	61.2 ± 0.5	58.8 ± 0.6	61.7 ± 0.6	58.3 ± 0.5	60.6 ± 1.0	57.3 ± 1.1
R.K. Puram		Residential	66.0 ± 6.6	59.0 ± 7.6	65.0 ± 5.0	62.0 ± 7.8	62.0 ± 2.9	56.0 ± 4.9	62.8 ± 2.5	60.3 ± 4.4	66.8 ± 2.9	61.6 ± 1.0	63.3 ± 3.1	59.2 ± 3.3
Anand Vihar		Commercial	70.0 ± 3.3	68.0 ± 5.6	68.0 ± 0.8	67.0 ± 4.1	68.0 ± 1.4	65.0 ± 1.4	66.6 ± 1.3	65.9 ± 2.9	65.6 ± 0.4	61.9 ± 0.6	65.5 ± 5.0	60.6 ± 4.2
Mandir Marg		Silence	76.0 ± 5.8	73.0 ± 4.8	76.0 ± 12.8	61.0 ± 9.4	66.0 ± 7.6	49.0 ± 1.8	61.0 ± 3.9	62.6 ± 2.3	65.4 ± 2.6	54.8 ± 3.0	58.3 ± 3.5	56.6 ± 2.5
Punjabi Bagh		Residential	86.0 ± 1.1	81.0 ± 2.3	59.0 ± 1.0	53.0 ± 1.7	64.0 ± 5.7	62.0 ± 8.5	59.8 ± 1	53.4 ± 1.7	61.3 ± 1.1	52.4 ± 1.3	57.3 ± 1.2	51.7 ± 1.2
Chinhat	Lucknow	Industrial	68.6 ± 5.5	63.0 ± 9.1	68.0 ± 3.4	62.0 ± 5.2	65.0 ± 2.1	56.0 ± 1.8	66.7 ± 1.7	57.9 ± 2.2	67.3 ± 2.4	60.0 ± 4.0	67.1 ± 3.5	56.5 ± 4.8
IT College		Silence	65.0 ± 4.1	57.4 ± 1.3	65.0 ± 2.0	59.0 ± 1.9	68.0 ± 3.5	62.0 ± 4.6	65.3 ± 1.0	70.0 ± 3.8	64.7 ± 1.0	59.5 ± 1.3	64.7 ± 2.3	71.5 ± 2.8
CSS Airport		Commercial	74.7 ± 8.6	66.1 ± 6.0	76.0 ± 0.9	67.0 ± 0.8	76.0 ± 0.8	67.0 ± 4.7	59.8 ± 1.2	70.0 ± 3.8	76.3 ± 0.9	67.0 ± 1.1	62.7 ± 2.1	58.3 ± 2.7
RSC Aliganj		Commercial	63.0 ± 0.8	58.1 ± 0.7	66.0 ± 0.7	61.0 ± 0.7	66.0 ± 0.5	60.0 ± 0.6	76.7 ± 0.5	70.9 ± 2.6	65.1 ± 0.6	57.6 ± 0.6	73.6 ± 4.2	65.0 ± 4.6
Vibhuti Khand		Residential	63.4 ± 1.3	57.0 ± 2.1	64.0 ± 3.3	60.0 ± 4.8	64.0 ± 0.9	60.0 ± 2.2	66.4 ± 2.8	59.9 ± 1.7	63.9 ± 0.7	62.2 ± 1.3	62.7 ± 1.7	57.5 ± 1.4
Birati N.	Kolkata	Residential	63.2 ± 2.6	58.0 ± 4.2	67.0 ± 5.9	70.0 ± 3.6	64.0 ± 2.8	58.0 ± 3.6	80.4 ± 1.8	80.1 ± 3.5	79.1 ± 8.9	77.9 ± 10.6	66.9 ± 3.5	63.3 ± 3.8
R.G. Kar		Silence	70.0 ± 8.6	63.0 ± 6.0	64.0 ± 0.9	60.0 ± 1.7	64.0 ± 0.8	60.0 ± 1.7	66.5 ± 1.9	60.4 ± 1.3	63.7 ± 3.3	62.2 ± 3.0	68.7 ± 3.1	71.8 ± 3.0
Tollygunge		Commercial	66.8 ± 0.5	62.9 ± 0.7	67.0 ± 0.4	63.0 ± 0.6	67.0 ± 2.4	63.0 ± 0.6	67.2 ± 0.4	64.1 ± 0.4	66.8 ± 0.4	62.9 ± 0.6	65.5 ± 1.5	61.6 ± 1.4
Bag Bazar		Residential	78.0 ± 4.4	70.0 ± 2.5	78.0 ± 3.5	69.0 ± 1.0	75.0 ± 0.9	68.0 ± 1.0	75.3 ± 1.1	70.7 ± 1.8	87.2 ± 4.6	90.1 ± 3.9	77.1 ± 9.5	74.6 ± 11.2
Tartala		Industrial	64.7 ± 1.1	61.1 ± 1.7	65.0 ± 1.2	62.0 ± 1.3	65.0 ± 1.6	62.0 ± 1.3	69.3 ± 1.2	67.2 ± 1.2	75.3 ± 1.9	73.1 ± 1.6	68.1 ± 2.0	64.4 ± 2.0
M&M Kandivali	Mumbai	Industrial	62.1 ± 1.1	55.8 ± 1.6	66.0 ± 4.5	69.0 ± 11.5	62.0 ± 0.7	57.0 ± 2.7	61.1 ± 0.7	54.8 ± 1.2	60.4 ± 1.0	52.6 ± 1.5	60.8 ± 2.9	53.8 ± 2.4
Ambassador Hotel		Commercial	73.1 ± 0.9	68.5 ± 1.3	73.0 ± 0.8	68.0 ± 0.8	72.0 ± 0.9	67.0 ± 1.1	72.5 ± 0.6	68.1 ± 0.8	74.5 ± 2.9	70.3 ± 3.2	74.2 ± 3.8	69.6 ± 5.1
L&T Powai		Industrial	60.3 ± 1.2	57.4 ± 1.5	60.0 ± 1.2	57.0 ± 1.9	59.0 ± 1.7	55.0 ± 2.7	58.4 ± 1.6	53.6 ± 2.3	59.4 ± 2.7	55.1 ± 3.2	62.2 ± 2.8	60.0 ± 4.8
Pepsico Chembur		Residential	67.0 ± 4.3	63.0 ± 7.8	64.0 ± 1.0	58.0 ± 2.1	64.0 ± 1.6	60.0 ± 4.8	66.8 ± 2.6	60.6 ± 2.9	68.1 ± 1.9	61.3 ± 1.4	76.5 ± 4.5	75.4 ± 4.6
Andheri		Industrial	71.3 ± 1.4	67.6 ± 0.8	72.0 ± 2.7	67.0 ± 0.8	71.0 ± 1.6	68.0 ± 1.6	71.7 ± 2.1	67.7 ± 1.5	78.9 ± 3.1	78.0 ± 4.0	80.1 ± 5.3	79.6 ± 5.7
Tarnaka	Hyderabad	Residential	60.2 ± 1.1	54.2 ± 3.2	69.0 ± 2.7	70.0 ± 5.6	67.0 ± 5.6	62.0 ± 7.6	73.5 ± 2.8	72.6 ± 3.4	81.4 ± 10.7	81.7 ± 11.2	76.6 ± 6.4	70.0 ± 5.6
Gaddapothram		Industrial	65.0 ± 2.0	59.0 ± 3.5	65.0 ± 3.8	62.0 ± 5.1	78.0 ± 4.4	75.0 ± 3.9	75.1 ± 4.5	67.8 ± 5.3	83.3 ± 5.0	74.0 ± 6.9	77.3 ± 4.8	75.2 ± 5.2
Gachibowli		Silence	60.9 ± 2.2	55.0 ± 3.4	68.0 ± 4.9	67.0 ± 4.8	63.0 ± 5.6	60.0 ± 3.4	61.0 ± 2.3	56.1 ± 3.1	60.0 ± 2.5	58.2 ± 2.7	60.9 ± 2.4	71.7 ± 5.5
Paradise		Commercial	79.1 ± 0.9	74.9 ± 1.0	76.0 ± 3.1	61.0 ± 1.8	76.0 ± 4.6	75.0 ± 7.7	84.6 ± 3.5	85.6 ± 3.5	81.4 ± 2.5	80.3 ± 2.9	78.0 ± 2.7	73.9 ± 3.3
Kukatpalli		Commercial	70.3 ± 1.1	66.4 ± 1.0	59.0 ± 2.2	53.0 ± 2.7	71.0 ± 1.1	66.0 ± 1.7	70.6 ± 1.1	67.5 ± 0.8	69.9 ± 0.7	66.7 ± 0.8	68.2 ± 2.4	65.4 ± 3.1
Yeshwantpur	Bengaluru	Commercial	72.1 ± 0.5	63.4 ± 0.7	72.0 ± 0.5	64.0 ± 0.8	72.0 ± 0.5	64.0 ± 0.9	72.0 ± 0.6	65.5 ± 0.8	72.1 ± 0.4	64.0 ± 0.6	70.2 ± 2.1	64.0 ± 2.2
R.V.C.E		Silence	60.1 ± 0.7	54.1 ± 0.7	60.0 ± 0.7	55.0 ± 0.8	60.0 ± 1.2	55.0 ± 0.7	59.6 ± 0.9	53.9 ± 0.6	67.4 ± 0.9	65.9 ± 2.6	80.9 ± 3.0	80.9 ± 4.2
Whitefield		Industrial	67.1 ± 0.7	61.2 ± 0.6	68.0 ± 1.7	62.0 ± 0.2	72.0 ± 5.6	66.0 ± 4.8	66.9 ± 1.1	72.5 ± 4.2	66.2 ± 0.8	61.1 ± 1.1	63.9 ± 1.9	58.6 ± 2.1
Dolmur		Residential	66.0 ± 3.3	60.0 ± 4.5	64.0 ± 1.8	59.0 ± 1.9	68.0 ± 5.7	61.0 ± 5.8	64.5 ± 1.8	59.2 ± 2.5	64.3 ± 1.8	59.3 ± 2.6	62.9 ± 1.5	58.1 ± 2.7
Nihmans		Silence	63.0 ± 3.4	60.0 ± 5.1	63.0 ± 2.9	65.0 ± 8.1	67.0 ± 6.8	66.0 ± 9.2	66.6 ± 5.6	64.5 ± 3.8	72.0 ± 3.9	74.1 ± 3.0	70.1 ± 5.4	74.9 ± 4.0
Pallikarnai	Chennai	Commercial	73.8 ± 0.6	67.2 ± 0.6	77.0 ± 4.3	71.0 ± 0.5	78.0 ± 4.2	77.0 ± 6.7	72.6 ± 1.9	72.5 ± 2.2	84.4 ± 4.9	78.6 ± 5.0	72.0 ± 5.4	72.6 ± 9.9
Velachery		Residential	67.0 ± 3.2	67.0 ± 9.4	68.0 ± 3.8	70.0 ± 10.4	74.0 ± 6.0	69.0 ± 7.7	77.3 ± 4.9	76.2 ± 8.2	65.5 ± 1.8	59.7 ± 4.1	64.4 ± 2.6	67.6 ± 2.0
Washermanpet		Commercial	70.0 ± 1.4	67.0 ± 5.7	72.0 ± 1.9	65.0 ± 2.6	72.0 ± 2.0	66.0 ± 5.7	74.4 ± 2.8	72.9 ± 4.2	75.6 ± 4.4	71.5 ± 4.3	74.0 ± 4.4	74.1 ± 5.3
Anna Nagar		Silence	67.0 ± 1.7	63.0 ± 4.6	68.0 ± 2.5	66.0 ± 7.9	66.0 ± 1.4	60.0 ± 3.0	67.1 ± 1.7	61.5 ± 3.4	75.0 ± 4.3	77.8 ± 4.0	73.4 ± 5.7	72.8 ± 7.8
Sowcarpet		Residential	66.6 ± 1.2	60.0 ± 2.7	70.0 ± 3.2	69.0 ± 6.8	68.0 ± 3.4	65.0 ± 5.7	66.9 ± 1.4	62.9 ± 3.1	62.3 ± 3.5	60.2 ± 3.0	65.1 ± 4.7	60.7 ± 3.6

Table 5. Frequency distribution of L_{day}, L_{night}, $L_{\mathrm{Aeq,24h}}$, and L_{dn} [dB(A)] for 7 major cities (70 sites) for 2017–2020.

Variation of noise descriptors	L_{day}				L_{night}				L_{dn}				$L_{\mathrm{Aeq,24h}}$			
	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020
$40 < L_{\mathrm{eq}} \leq 45$ dB(A)	0	0	0	0	0	0	1.4	0	0	0	0	0	0	0	0	0
$45 < L_{\mathrm{eq}} \leq 50$ dB(A)	0	0	0	0	4.3	1.4	0	0	0	0	0	0	0	0	1.5	0
$50 < L_{\mathrm{eq}} \leq 55$ dB(A)	1.4	0	1.4	0	10.0	10.0	7.2	5.7	0	0	1.4	0	5.7	4.3	0.0	0
$55 < L_{\mathrm{eq}} \leq 60$ dB(A)	10	11.4	5.8	5.7	25.7	17.1	18.8	15.7	7.1	4.3	0.0	1.4	8.6	12.9	10.3	7.5
$60 < L_{\mathrm{eq}} \leq 65$ dB(A)	21.4	17.1	23.2	25.7	22.9	21.4	24.6	15.7	12.9	12.9	10.1	8.6	34.3	24.3	30.9	34.3
$65 < L_{\mathrm{eq}} \leq 70$ dB(A)	32.9	34.3	29.0	25.7	22.9	25.7	14.5	25.7	35.7	24.3	36.2	21.4	25.7	24.3	20.6	28.4
$70 < L_{\mathrm{eq}} \leq 75$ dB(A)	24.3	21.4	18.8	24.3	7.1	17.1	18.8	22.9	21.4	22.9	14.5	21.4	18.6	24.3	20.6	14.9
$75 < L_{\mathrm{eq}} \leq 80$ dB(A)	10	12.9	13.0	10.0	4.3	2.9	10.1	10.0	11.4	25.7	18.8	25.7	7.1	4.3	8.8	7.5
$80 < L_{\mathrm{eq}} \leq 85$ dB(A)	0	2.9	7.2	8.6	2.9	2.9	2.9	4.3	10.0	5.7	13.0	15.7	0	2.9	5.9	6.0
$85 < L_{\mathrm{eq}} \leq 90$ dB(A)	0	0	1.4	0	0	1.4	0	0	1.4	2.9	4.3	5.7	0	1.4	1.5	1.5
$90 < L_{\mathrm{eq}} \leq 95$ dB(A)	0	0	0	0	0	0	1.4	0	0	1.4	1.4	0	0	1.4	0	0

Table 6. Frequency distribution of annual average L_{day} and L_{night} values observed [dB] for the 70 sites spread across the 7 major cities of India for 2018–2020 (Garg, 2022).

Variation of L_{day} and L_{night} [dB]	Percentage of noise monitoring locations in various zones																							
	Commercial						Residential						Silence						Industrial					
	2018		2019		2020		2018		2019		2020		2018		2019		2020		2018		2019		2020	
	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}	L_{day}	L_{night}
$40 < L_{\mathrm{eq}} \leq 45$	0	0	0	0	0	0	0	0	0	6.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$45 < L_{\mathrm{eq}} \leq 50$	0	0	0	0	0	0	0	6.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$50 < L_{\mathrm{eq}} \leq 55$	0	0	0	0	0	0	0	6.3	6.3	12.5	0	6.3	0	23.5	0	12.5	0	11.8	0	16.7	0	8.3	0	8.3
$55 < L_{\mathrm{eq}} \leq 60$	4.0	12.0	0	16.0	0	16.0	12.5	18.8	6.3	18.8	6.3	18.8	23.5	23.5	12.5	18.8	17.6	5.9	8.3	16.7	8.3	25.0	0	25.0
$60 < L_{\mathrm{eq}} \leq 65$	12.0	20.0	8.0	20.0	20.0	20.0	18.8	25.0	37.5	31.3	31.3	18.8	23.5	29.4	25.0	25.0	23.5	41.2	16.7	8.3	33.3	25.0	33.3	16.7
$65 < L_{\mathrm{eq}} \leq 70$	28.0	36.0	36.0	24.0	32.0	32.0	37.5	18.8	18.8	0	18.8	18.8	35.3	11.8	37.5	25.0	17.6	23.5	41.7	33.3	16.7	0	33.3	25.0
$70 < L_{\mathrm{eq}} \leq 75$	40.0	24.0	32.0	28.0	36.0	24.0	6.3	12.5	6.3	6.3	12.5	18.8	17.6	11.8	18.8	12.5	29.4	5.9	8.3	16.7	8.3	25.0	8.3	0
$75 < L_{\mathrm{eq}} \leq 80$	12.0	4.0	16.0	8.0	8.0	8.0	18.8	6.3	12.5	12.5	25.0	18.8	0	0	6.3	6.3	0	0	25.0	0	16.7	16.7	8.3	16.7
$80 < L_{\mathrm{eq}} \leq 85$	4.0	0	8.0	4.0	4.0	0	6.3	6.3	6.3	6.3	6.3	0	0	0	0	0	11.8	11.8	0	8.3	16.7	0	16.7	8.3
$85 < L_{\mathrm{eq}} \leq 90$	0	4.0	0	0	0	0	0	0	6.3	6.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
$90 < L_{\mathrm{eq}} \leq 95$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7. Frequency distribution [%] of difference of annual average (L_{day}–L_{night}) values observed [dB] for the 70 sites spread across the 7 major cities of India from 2011 to 2020 (Garg, 2022).

Variation of difference (L_{day}–L_{night}) values [dB]	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
$-15 < (L_{\text{day}}-L_{\text{night}}) \le -10$	0	0	0	0	0	0	1.4	1.4	0	1.4
$-10 < (L_{\text{day}}-L_{\text{night}}) \le -5$	0	0	0	0	0	0	1.4	2.9	1.4	2.9
$-5 < (L_{\text{day}}-L_{\text{night}}) \le 0$	0	0	0	0	0	20.0	10.0	14.3	13.0	18.6
$0 < (L_{\text{day}}-L_{\text{night}}) \le 5$	34.3	28.6	40.0	31.4	50.7	47.1	47.1	45.7	52.2	58.6
$5 < (L_{\text{day}}-L_{\text{night}}) \le 10$	54.3	57.1	48.6	57.1	35.0	30.0	37.1	35.7	31.9	17.1
$10 < (L_{\text{day}}-L_{\text{night}}) \le 15$	11.4	14.3	11.4	11.4	14.3	2.9	1.4	0	1.4	1.4
$15 < (L_{\text{day}}-L_{\text{night}}) \le 20$	0	0	0	0	0	0	1.4	0	0	0

Table 8. Slope and correlation coefficient of L_{day} and L_{night} levels with respect to the transition period from 2011 to 2020 for the 35 sites in 7 major cities of India.

Area characteristics	Name of location	City	L_{day}		L_{night}	
			Slope	R	Slope	R
Commercial	CPCB HQ	Delhi	0.31	0.4654	1.14	0.7904
	ITO	Delhi	0.44	0.6006	0.24	0.2953
	Hazrat Ganj	Lucknow	0.15	0.1867	1.54	0.9561
	New Market	Kolkata	0.68	0.3108	1.82	0.5730
	WBPCB HQ	Kolkata	0.44	0.7374	0.90	0.7158
	Bandra	Mumbai	0.08	0.0938	0.37	0.3874
	MPCB HQ	Mumbai	0.43	0.5622	0.39	0.2948
	Thane MCQ	Mumbai	0.59	0.4416	1.66	0.6626
	Abids	Hyderabad	0.01	0.0038	0.39	0.2269
	Punjagutta	Hyderabad	−1.02	0.6629	−1.25	0.6604
	Marathahalli	Bengaluru	2.06	0.9016	2.37	0.9380
	Parisar Bhawan	Bengaluru	0.11	0.2956	0.48	0.6852
	Perambur	Chennai	0.31	0.2378	1.62	0.6087
	T. Nagar	Chennai	0.63	0.8749	1.40	0.9415
Industrial	Talkatora Industrial Area	Lucknow	0.40	0.5929	1.28	0.9274
	Kasba Gole Park	Kolkata	0.33	0.1598	0.66	0.2436
	Jeedimetla	Hyderabad	1.55	0.6787	2.68	0.7408
	Peeniya	Bengaluru	1.02	0.8483	1.03	0.8391
	Guindy	Chennai	0.64	0.7353	1.11	0.8264
Residential	Indira Nagar	Lucknow	1.27	0.3871	1.69	0.4280
	Patauli	Kolkata	2.21	0.7883	3.27	0.8415
	Jubilee Hills	Hyderabad	1.28	0.7198	1.57	0.7931
	BTM	Bengaluru	−0.23	0.5846	1.21	0.8633
	Nisarga Bhawan	Bengaluru	2.79	0.8405	3.71	0.8680
	Triplicane	Chennai	−0.20	0.1795	1.16	0.5621
Silence	DTU, Bawana	Delhi	0.92	0.6568	0.89	0.5614
	NSIT Dwarka	Delhi	0.21	0.4844	0.11	0.3219
	Gomti Nagar	Lucknow	−0.19	0.2132	0.89	0.6300
	PGI Hospital	Lucknow	1.86	0.7797	2.44	0.8167
	SSKM Hospital	Kolkata	0.96	0.7594	1.66	0.7824
	AS HP	Mumbai	0.97	0.6247	1.78	0.7320
	Vashi Hospital	Mumbai	0.63	0.5659	2.16	0.7474
	Zoo Park	Hyderabad	1.10	0.4516	1.83	0.6328
	Eye Hospital	Chennai	0.97	0.8430	1.73	0.9048
	Dilshad Garden	Delhi	2.12	0.8601	2.26	0.8430

Table 9. Slope and correlation coefficient of L_{day} and L_{night} levels with respect to the transition period within the years 2015–2020 for the 35 sites in 7 major cities of India.

Area characteristics	Name of location	City	L_{day}		L_{night}	
			Slope	R	Slope	R
Commercial	Civil Lines	Delhi	–2.53	0.9471	–3.42	0.9610
	Anand Vihar	Delhi	–0.89	0.9634	–1.47	0.9440
	CSS Airport	Lucknow	–2.15	0.5321	–1.03	0.4865
	RSC Aliganj	Lucknow	1.74	0.6003	1.01	0.3723
	Tollygunge	Kolkata	–0.20	0.6002	–0.16	0.3840
	Ambassador Hotel	Mumbai	0.30	0.5808	0.39	0.6069
	Paradise	Hyderabad	0.55	0.3085	1.81	0.4131
	Kukatpalli	Hyderabad	0.62	0.2536	1.07	0.3644
	Yeshwantpur	Bengaluru	–0.26	0.6533	0.13	0.3419
	Pallikarnai	Chennai	0.22	0.0900	1.29	0.5863
	Washermanpet	Chennai	0.95	0.8718	1.77	0.8519
Industrial	Chinhat	Lucknow	–0.23	0.3410	–1.05	0.6739
	Tartala	Kolkata	1.49	0.6815	1.57	0.6446
	M&M Kandivali	Mumbai	–0.69	0.6343	–1.75	0.5474
	L&T Powai	Mumbai	0.20	0.2866	0.17	0.1388
	Andheri	Mumbai	1.87	0.8398	2.65	0.8503
	Gaddapothram	Hyderabad	3.24	0.8157	3.14	0.8305
	Whitefield	Bengaluru	–0.76	0.5313	–0.26	0.0985
Residential	R.K. Puram	Delhi	–0.21	0.2047	0.12	0.1007
	Punjabi Bagh	Delhi	–4.02	0.7007	–4.48	0.7315
	Vibhuti Khand	Lucknow	–0.04	0.0599	0.26	0.2523
	Birati N.	Kolkata	2.03	0.4982	2.07	0.3984
	Bag Bazar	Kolkata	0.67	0.2788	2.54	0.5710
	Pepsico Chembur	Mumbai	1.79	0.7258	2.07	0.6183
	Tarnaka	Hyderabad	3.59	0.8948	3.56	0.7087
	Dolmur	Bengaluru	–0.52	0.5386	–0.30	0.5666
	Velachery	Chennai	–0.49	0.1793	–0.59	0.2077
	Sowcarpet	Chennai	–0.91	0.6472	–0.71	0.3791
Silence	Mandir Marg	Delhi	–3.58	0.8996	–2.49	0.5682
	IT College	Lucknow	–0.15	0.2148	2.29	0.7097
	R.G. Kar	Kolkata	–0.14	0.0967	1.20	0.5099
	Gachibowli	Hyderabad	–0.74	0.4691	1.52	0.4300
	R.V.C.E.	Bengaluru	3.59	0.7913	4.73	0.8150
	Nihmans	Bengaluru	1.77	0.9084	2.87	0.9140
	Anna Nagar	Chennai	1.55	0.7624	2.45	0.6541

Table 10. Status of compliance of day and night equivalent levels explicitly for the various sites with ambient noise standards of India.

Category	Number of compliant stations: day and night time exclusively																			
	2011		2012		2013		2014		2015		2016		2017		2018		2019		2020	
	a*	b*	a*	b*	a*	b*	a*	b*	a*	b*	a*	b*	a*	b*	a*	b*	a*	b*	a*	b*
Silence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Residential	2	0	2	0	2	0	1	0	0	0	0	0	0	0	1	0	1	1	0	0
Commercial	4	3	5	4	5	4	5	1	4	0	4	2	3	0	4	0	3	0	5	0
Industrial	4	4	5	4	5	4	4	4	10	10	10	10	10	8	10	9	9	9	9	9
Total	10	7	12	8	12	8	10	5	14	10	14	12	13	8	13	9	13	8	14	9

a* – Day-time, b* – Night-time.

Table 11. Status of compliance of various sites in the NANMN project with ambient noise standards of India (Garg, 2022).

Year	Number of sites meeting the ambient noise criteria	Name of the sites
2011	7 sites (3 commercial and 4 industrial)	CPCB Headquarters, Thane, Marathali, Peeniya, Jeedimetla, Talkatora, and Kasba Gole Park
2012	8 sites (4 commercial and 4 industrial)	CPCB Headquarters, West Bengal Headquarters, Thane, Marathali, Peeniya, Jeedimetla, Talkatora, and Kasba Gole Park
2013	8 sites (4 commercial and 4 industrial)	CPCB Headquarters, West Bengal Headquarters, Thane, Marathali, Peeniya, Jeedimetla, Talkatora, and Kasba Gole Park
2014	5 sites (1 commercial and 4 industrial)	CPCB Headquarters, Peeniya, Jeedimetla, Talkatora, and Kasba Gole Park
2015	10 industrial sites	Talkatora, Jeedimetla, Peeniya, Chinhat, Tartala, M&M Kandivali, L&T Powai, Andheri, Whitefield, and Gaddapothram
2016	12 sites (10 industrial and 2 commercial)	Talkatora, Jeedimetla, Peeniya, Chinhat, Tartala, M&M Kandivali, L&T Powai, Andheri, Whitefield, Gaddapothram, Kukatpalli, and Abids
2017	8 industrial sites	Talkatora, Peeniya, Chinhat, Tartala, M&M Kandivali, L&T Powai, Andheri, and Whitefield
2018	9 industrial sites	Peeniya, Gole Park, Tartala, Talkatora, Chinhat, M&M Kandivali, L&T Powai, Andheri, and Gaddapothram
2019	8 sites (7 industrial and 1 residential)	Whitefield, Gole Park, Talkatora, Peeniya, Indira Nagar, Chinhat, Kandivali, and L&T Powai
2020	9 industrial sites	Peeniya, Whitefield, Jeedimetla, Gole Park, Tartala, Talkatora, Chinhat, Kandivali, and L&T Powai

Table 12. AEF for different zones in 2017–2020.

Category of area/zone	L_{day}			L_{night}		
	Maximum value	Minimum value	AEF	Maximum value	Minimum value	AEF
2017 annual average values						
Industrial area ($n = 12$)	1.0	0.8	0.9	1.2	0.8	0.9
Commercial area ($n = 25$)	1.2	0.9	1.1	1.4	1.0	1.2
Residential area ($n = 16$)	1.4	1.0	1.2	1.5	1.1	1.3
Silence zone ($n = 17$)	1.6	1.1	1.3	2.1	1.2	1.5
2018 annual average values						
Industrial area ($n = 12$)	1.1	0.8	0.9	1.1	0.8	0.9
Commercial area ($n = 25$)	1.3	0.9	1.1	1.6	1.0	1.2
Residential area ($n = 16$)	1.5	1.0	1.2	1.8	1.1	1.4
Silence zone ($n = 17$)	1.4	1.1	1.3	1.8	1.3	1.5
2019 annual average values						
Industrial area ($n = 12$)	1.1	0.8	0.9	1.1	0.8	0.9
Commercial area ($n = 25$)	1.3	0.9	1.1	1.5	1.0	1.2
Residential area ($n = 16$)	1.6	0.9	1.2	2.0	1.0	1.4
Silence zone ($n = 17$)	1.5	1.1	1.3	1.9	1.4	1.6
2020 annual average values						
Industrial area ($n = 12$)	1.1	0.8	0.9	1.2	0.8	0.9
Commercial area ($n = 25$)	1.2	0.9	1.1	1.4	1.0	1.2
Residential area ($n = 16$)	1.5	1.0	1.3	1.7	1.1	1.5
Silence zone ($n = 17$)	1.6	1.1	1.4	2.0	1.4	1.7

Table 13. Inter-conversion of the various noise descriptors for the 4 zones.

Type of zone		L_{day}	L_{night}	L_{dn}	$L_{\text{eq,24h}}$
Commercial	L_{day}	–	+4.0	−3.3	+0.7
	L_{night}	−4.0	–	−7.4	−3.4
	L_{dn}	+3.3	+7.4	–	+4.0
	$L_{\text{eq,24h}}$	−0.7	+3.4	−4.0	–
Industrial	L_{day}	–	+3.2	−3.9	+0.5
	L_{night}	−3.2	–	−7.2	−2.7
	L_{dn}	+3.9	+7.2	–	+4.4
	$L_{\text{eq,24h}}$	−0.5	+2.7	−4.4	–
Residential	L_{day}	–	+3.9	−3.5	+0.5
	L_{night}	−3.9	–	−7.8	−3.9
	L_{dn}	+3.5	+7.8	–	+3.8
	$L_{\text{eq,24h}}$	−0.5	+3.9	−3.8	–
Silence	L_{day}	–	+2.3	−3.5	+0.5
	L_{night}	−3.9	–	−7.8	−3.9
	L_{dn}	+3.5	+7.8	–	+3.8
	$L_{\text{eq,24h}}$	−0.5	+3.9	−3.8	–

References

1. Agarwal S., Swami B.L. (2011), Road traffic noise, annoyance and community health survey – A case study for an Indian city, *Noise and Health*, **13**(53): 272–276, doi: 10.4103/1463-1741.82959.

2. Babisch W. (2002), The noise/stress concept, risk assessment and research needs, *Noise and Health*, **4**(16): 1–11.

3. Babisch W., Beule B., Schust M., Kersten N., Ising H. (2005), Traffic noise and risk of myocardial infarction, *Epidemiology*, **16**(1): 33–40, doi: 10.1097/01.ede.0000147104.84424.24.

4. Bhosale B.J., Late A., Nalawade P.M., Chavan S.P., Mule M.B. (2010), Studies on assessment of traffic noise level in Aurangabad city, India, *Noise and Health*, **12**(48): 195–198, doi: 10.4103/1463-1741.64971.

5. Blanes N., Domingues D., José Ramos M., Sáinz de la Maza M., Fons-Esteve J., Peris E. (2019), *ETC/ATNI Report 8/2019: Noise Action Plans. Managing Exposure to Noise in Europe*, European Environment Agency, https://www.eionet.europa.eu/etcs/etc-atni/products/etc-atni-reports/etc-atni-report-8-2019-noise-action-plans-managing-exposure-to-noise-in-europe (access: 11.06.2021).

6. Brink M., Schäffer B., Pieren R., Wunderli J.M. (2018), Conversion between noise exposure indicators $\mathrm{Leq}_{24\mathrm{h}}$, $\mathrm{L}_{\mathrm{Day}}$, $\mathrm{L}_{\mathrm{Evening}}$, $\mathrm{L}_{\mathrm{Night}}$, L_{dn} and $\mathrm{L}_{\mathrm{den}}$: Principles and practical guidance, *International Journal of Hygiene and Environmental Health*, **221**(1): 54–63, doi: 10.1016/j.ijheh.2017.10.003.

7. Central Pollution Control Board (CPCB) (2011), *National Ambient Noise Monitoring Network. Information Brochure*, https://cpcb.nic.in/.

8. Central Pollution Control Board (CPCB) (2012), *Annual Report 2011-12*, pp. 94–96.

9. Central Pollution Control Board (CPCB) (2015a), *Status of Ambient Noise Level in India in 2011–2014*, NANMN/02/2015-16.

10. Central Pollution Control Board (CPCB) (2015b), *Status of Ambient Noise Level in India in 2015*, NANMN/03/2015-16.

11. Central Pollution Control Board (CPCB) (2016), *Status of Ambient Noise Level in India in 2016*, NANMN/04/2016.

12. Central Pollution Control Board (CPCB) (2017), *Delhi's Ambient Noise Levels Influenced by Traffic Flow – Case studies*, CUPS/87/2017-18.

13. Central Pollution Control Board (CPCB) (2018), *Status of Ambient Noise Level in India in 2017*, NANMN/05/2017.

14. Central Pollution Control Board (CPCB) (n.d.), https://cpcb.nic.in/.

15. Chowdhury A.K., Debsarkar A., Chakrabarty S. (2016), Assessment of seasonal variations of average traffic pollution levels in curbside open-air microenvironments in Kolkata, India, *Health Scope*, **5**(2): e33081, doi: 10.17795/ jhealthscope-33081.

16. Conference of European Directors of Roads (CEDR) (2013), *Value for Money in Road Traffic Noise Abatement*, CEDR Project Group Road Noise, http://www.carreteros.org/explotacion/cedr/3_CEDR.pdf (access: 11.06.2021).

17. Datta J.K., Sadhu S., Gupta S., Saha R., Mondal N.K., Mukhopadhyay B. (2006), Assessment of noise level in Burdwan town, West Bengal, *Journal of Environmental Biology*, **27**(3): 609–612.

18. European Conference of Ministers of Transport (ECMT) (1998), *Efficient Transport for Europe. Policies of Internalisation of External Costs.*

19. European Environment Agency (2020), *Environmental Noise in Europe – 2020*, No. 22/2019, Publications Office.

20. European Union (2017), *Future Brief: Noise Abatement Approaches*, Publication Office, doi: 10.2779/01 6648.

21. Garg N. (2019), On suitability of day-night average sound level descriptor in Indian scenario, *Archives of Acoustics*, **44**(2): 385–392, doi: 10.24425/aoa.2019.128502.

22. Garg N. (2022), *Environmental Noise Control: The Indian perspective in an International Context*, Springer Nature Switzerland, doi: 10.1007/978-3-030-87828-3.

23. Garg N. *et al.* (2017a), Study on the establishment of a diversified National Ambient Noise Monitoring Network in seven major cities of India, *Current Science*, **113**(7): 1367–1383, doi: 10.18520/cs/v113/i07/1367-1383.

24. Garg N., Chauhan B.S., Singh M. (2020), Realization and dissemination of unit Watt in airborne sound: Measurement methodology, sound emission regulations and implications, *Sound Emission Regulations and Implications (MAPAN)*, **35**(4): 601–612, doi: 10.1007/s12647-020-00417-x.

25. Garg N., Chauhan B.S., Singh M. (2021), Normative framework of noise mapping in India: Strategies, Implications and Challenges ahead, *Acoustics Australia*, **49**(1): 23–41, doi: 10.1007/s40857-020-00214-1.

26. Garg N., Gandhi V., Gupta N.K. (2022), Impact of COVID-19 lockdown on ambient noise levels in seven metropolitan cities of India, *Applied Acoustics*, **188**: 108582, doi: 10.1016/j.apacoust.2021.108582.

27. Garg N., Maji S. (2016), A retrospective view of noise pollution control policy in India: Status, proposed revisions and control measures, *Current Science*, **111**(1): 29–38, doi: 10.18520/CS/V111/I1/29-38.

28. Garg N., Mangal S.K., Saini P.K., Dhiman P., Maji S. (2015a), Comparison of ANN and analytical models in traffic noise modeling and predictions, *Acoustics Australia*, **43**(2): 179–189, doi: 10.1007/s40857-015-0018-3.

29. Garg N., Sharma O., Mohanan V., Maji S. (2012), Passive noise control measures for traffic noise abatement in Delhi, India, *Journal of Scientific and Industrial Research*, **71**(3): 226–234.

30. Garg N., Sinha A.K., Dahiya M., Gandhi V., Bhardwaj R.M., Akolkar A.B. (2017b), Evaluation and analysis of environmental noise pollution in seven major cities of India, *Archives of Acoustics*, **42**(2): 175–188, doi: 10.1515/aoa-2017-0020.

31. Garg N., Sinha A.K., Gandhi V., Bhardwaj R.M., Akolkar A.B. (2016), A pilot study on the establishment of national ambient noise monitoring network across the major cities of India, *Applied Acoustics*, **103**(Part A): 20–29, doi: 10.1016/j.apacoust.2015.09.010.

32. Garg N., Sinha A.K., Gandhi V., Bhardwaj R.M., Akolkar A.B. (2017c), Impact of Diwali celebrations on environmental noise pollution in India, *Acoustics Australia*, **45**(1): 101–117, doi: 10.1007/s40857-017-0081-z.

33. Garg N., Sinha A.K., Gandhi V., Bhardwaj R.M., Akolkar A.B. (2017d), Effect of odd-even vehicular restrictions on ambient noise levels at ten sites in Delhi city, *Indian Journal of Pure and Applied Physics*, **55**(9): 687–692.

34. Garg N., Vishesh, Maji S. (2015b), Fuzzy TOPSIS approach in selection of optimal noise barrier for traffic noise abatement, *Archives of Acoustics*, **40**(4): 453–467, doi: 10.1515/aoa-2015-0045.

35. Hansell A.L. *et al.* (2013), Aircraft noise and cardiovascular disease near Heathrow airport in London: small area study, *BMJ*, **347**, doi: 10.1136/bmj.f5432.

36. Jamir L., Nongkynrih B., Gupta S.K. (2014), Community noise pollution in urban India: Need for public health action, *Indian Journal of Community Medicine*, **39**(1): 8–12, doi: 10.4103/0970-0218.126342.

37. van Kempen E., Casas M., Pershagen G., Foraster M. (2018), WHO environmental noise guidelines for the European region: A systematic review on environmental noise and cardiovascular and metabolic effects: A summary, *International Journal of Environmental Research and Public Health*, **15**(2): 379, doi: 10.3390/ijerph15020379.

38. Kumar S. *et al.* (2022), Effect of lockdown amid second wave of COVID-19 on environmental noise scenario of the megacity Delhi, India, *The Journal of the Acoustical Society of America*, **152**(3): 1317–1336, doi: 10.1121/10.0013827.

39. Kumar S., Chauhan B.S., Garg N. (2023), Significance and implications of noise mapping for noise pollution control, [in:] *Recent Advances in Metrology, Lecture Notes in Electrical Engineering*, Yadav S., Chaudhary K., Gahlot A., Arya Y., Dahiya A., Garg N. [Eds], Vol. 906, pp. 335–341, Springer, Singapore, doi: 10.1007/978-981-19-2468-2_36.

40. Lokhande S.K., Chopkar P.F., Jain M.C., Hirani A. (2021a), Environmental noise assessment of Bhandara City in the adversity of COVID-19 pandemic: A crowdsourcing approach, *Noise Mapping*, **8**(1): 249–259, doi: 10.1515/noise-2021-0020.

41. Lokhande S.K., Garg N., Jain M.C., Rayalu S. (2022), Evaluation and analysis of firecrackers noise: Measurement Uncertainty, legal noise regulations and noise induced hearing loss, *Applied Acoustics*, **186**: 108462, doi: 10.1016/j.apacoust.2021.108462.

42. Lokhande S.K., Gautam R., Dhawale S.A., Jain M.C., Bodhe G.L. (2019), Evaluation of practical framework for industrial noise mapping: A case study, *Noise and Health*, **21**(102): 194–199, doi: 10.4103/nah.NAH_7_17.

43. Lokhande S.K., Sakhareb D.S., Dange S.S., Jain M.C. (2021b), A short review of road noise barriers focusing on ecological approaches, *International Journal of Engineering & Technology Sciences*, **2021**: IJETS-2106092112346.

44. Ministry of Environment & Forests (2000), *The Noise Pollution (Regulation and Control) Rules*, 2000.

45. Mizutani F., Suzuki Y., Sakai H. (2011), Estimation of social costs of transport in Japan, *Urban Studies*, **48**(16): 3537–3559, doi: 10.1177/0042098011399597.

46. Münzel T., Schmidt F.P., Steven S., Herzog J., Daiber A., Sørensen M. (2018), Environmental noise and the cardiovascular system, *Journal of the American College of Cardiology*, **71**(6): 688–697, doi: 10.1016/j.jacc.2017.12.015.

47. Nelson J.P. (1982), Highway noise and property values: A survey of recent evidence, *Journal of Transport Economics and Policy*, **16**(2): 117–138.

48. Schmidt F. *et al.* (2015), Nighttime aircraft noise impairs endothelial function and increases blood pressure in patients with or at high risk for coronary artery disease, *Clinical Research in Cardiology*, **104**(1): 23–30, doi: 10.1007/s00392-014-0751-x.

49. The European Parliament and the Council of the European Union (2002), *Directive 2002/49/EC of the European Parliament and of the Council of 25th June 2002, Relating to the Assessment and Management of Environmental Noise*, Official Journal of the European Communities.

50. Theebe M.A.J. (2004), Planes, trains, and automobiles: The impact of traffic noise on house prices, *The Journal of Real Estate Finance and Economics*, **28**: 209–234, doi: 10.1023/B:REAL.0000011154.92682.4b.

51. Tiwari S., Kumaraswamidhas L.A., Garg N. (2021), Accuracy of short-term noise monitoring strategy in

comparison to long-term noise monitoring strategy, *Indian Journal of Pure & Applied Physics (IJPAP)*, **59**(8): 569–576, doi: 10.56042/ijpap.v59i8.48569.

52. Tiwari S.K., Kumaraswamidhas L.A., Garg N. (2022), Time-series prediction and forecasting of ambient noise levels using deep learning and machine learning techniques, *Noise Control Engineering Journal*, **70**(5): 456–471, doi: 10.3397/1/377039.

53. Torija A.J., Ruiz D.P., Alba-Fernandez V., Ramos-Ridao Á. (2012), Noticed sound events management as a tool for inclusion in the action plans against noise in medium-sized cities, *Landscape and Urban Planning*, **104**(1): 148–156, doi: 10.1016/j.landurbplan.2011.10.008.

54. U.S. Department of Housing and Urban Development (1984), *Environmental Criteria and Standards*, 24 CFR Part 51.

55. World Health Organization (WHO) (2009), *Night noise guidelines for Europe*, World Health Organization, Regional Office for Europe, Denmark.

56. World Health Organization (WHO) (2011), *Burden of disease from environmental noise: Quantification of healthy life years lost in Europe*, World Health Organization, Regional Office for Europe, Denmark.

57. World Health Organization (WHO) (2018), *Environmental noise guidelines for the European region*, World Health Organization, Regional Office for Europe, Denmark.