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Article

Geospatial assessment of noise pollution status and public policy implementation in Chattogram, Bangladesh

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Abstract
Noise pollution is now a major environmental and public health concern in rapidly urbanizing areas of Bangladesh, especially Chattogram. This study aimed to determine the spatial distribution of environmental noise pollution in Kotwali Thana. It also assessed the enforcement of noise control policies using GIS-based spatial analysis, field noise measurement, a questionnaire survey, and key informant interviews. Researchers measured noise in the morning and evening at 26 representative sites across quiet, residential, commercial, and industrial areas. Almost all locations had noise levels above the permitted values set by the Bangladesh Environmental Conservation Rules and the World Health Organization. Commercial and industrial zones had the highest noise, ranging from 92÷100 dB(A). Silent zones near hospitals and educational institutions showed alarming noise levels of 67÷83.5 dB(A), higher than the recommended limit of 45 dB(A). Many residential areas also had noise above 80 dB(A), indicating significant urban noise exposure. Traffic and commercial zones were identified as noise hotspots through GIS-based heat maps. The study found increased concerns about sleep disturbance, stress, and reduced well-being due to long-term noise exposure. It also noted poor enforcement of noise regulations. The study suggests that Chattogram needs sustainable noise management strategies for ongoing monitoring and better enforcement of existing laws and policies.

Keywords*:* *noise pollution, noise distribution, health and socioeconomic status, geospatial assessment*

INTRODUCTION

Noise pollution poses a significant and growing urban health threat. It produces loud or harmful sounds that can immediately harm people, disrupt the environment, and endanger wildlife [1]. Industry, traffic, construction, loudspeakers, and household appliances loom as relentless sources, especially in fast-growing cities like Chattogram. Urbanization is intensifying the noise crisis here, with the population facing rapid health deterioration [1]. The consequences—hearing loss, high blood pressure, cardiovascular disease, sleep problems, anxiety, reduced sound comprehension, diabetes, and nerve damage—are already affecting many lives [2, 3].

Noise pollution has become a critical public health issue in Chattogram, demanding immediate and decisive action. The World Health Organisation recognizes environmental noise as the second-largest environmental health risk in Western Europe, coming just after air pollution [4]. In Chattogram, transportation, construction, industry, and high population density are now driving noise levels to dangerous heights. The impacts are urgent and acute near hospitals and schools on busy roads, where

noise levels drastically exceed safe limits for vulnerable groups, such as patients, students, and healthcare workers [5,6]. The neglect of quiet zones and the lack of noise monitoring intensify the crisis, relentlessly exposing residents in crowded neighbourhoods to harmful soundscapes. Without rapid and sustained action, urban well-being in areas like Kotwali Thana faces an immediate and sharp decline [7].

This study aims to address these gaps with GIS-based spatial noise analysis at 26 key sites in Kotwali Thana. These sites represent residential, commercial, and industrial areas. The objectives are to (1) map spatial noise distribution; (2) assess noise in sensitive zones like schools, hospitals, and places of worship; (3) analyse community perceptions; and (4) evaluate legal enforcement. This study uses noise measurements (Leq, Lmin, Lmax), surveys, and legal review. Together, these approaches provide an integrated understanding of urban noise. The evidence generated will support policy development and environmental management in Chattogram.

Noise has become a pressing health and environmental emergency in rapidly expanding cities like Chattogram. In Chattogram, residents especially children are at immediate and escalating risk of sleep problems, heart disease, and cognitive issues. Despite these mounting threats, data on noise levels in Bangladeshi cities is still severely lacking [8, 9]. Addressing these gaps is urgent for safeguarding urban health.

Kotwali is the most densely populated and mixed-use area among Chattogram's administrative wards. Yet, geospatial data have not been integrated with noise levels. Previous studies reported noise along urban roads and in commercial districts [10] or focused on spatio-temporal monitoring [11]. They used differing methodologies and traffic-centric approaches [12÷14]. Some studies investigated only selective days [15] Others assessed noise pollution in districts outside Chattogram's port city and megacity context [6, 16÷21]. A comprehensive analysis of noise exposure in vulnerable settings, such as schools, hospitals, and places of worship, is lacking. Laws classify these as silence zones under the Noise Pollution (Control) Rules, 2006 [22]. The enforcement of noise control policies and the use of high-resolution spatial analysis are rarely assessed. Violations in silence zones have been documented in Chattogram. However, there is a lack of analysis of spatial variation and its relationship to enforcement capacity [15].

MATERIALS AND METHODS

Study Area

This study was conducted in Kotwali Thana, an urban subdistrict of Chattogram District, southern Bangladesh (Fig. 1). According to the Bangladesh Population and Housing Census [23], Kotwali Thana has a population of 231,872 residents and a density of 39,566 inhabitants per square kilometer. The area encompasses residential, commercial, and industrial zones, with a diverse population that includes a significant number of workers. Due to its concentrated population and high business activity, varying levels of noise pollution occur. The study assessed these spatial differences using systematic sampling and geospatial reference points (Fig. 1).

Building on this demographic and economic context, the study proceeded with systematic data collection of noise levels during two specific time intervals. These intervals were from 8:00 AM to noon and from 4:00 PM to 8:00 PM, primarily on working days. A total of 26 major locations were selected for data collection. These are: Jamalkhan, Laldighi, Khulshi, Golpahar, Kajir Deuri, Bahaddarhat, GEC, Sholoshohor, Muradpur, Wasa, Halishahar, Chandgaon Residential Area, Amirbag Residential Area, Mehedibag, Nasirabad, Hillview, Bandartilla, Oxygen Mor, Panchlaish, Chawkbazar, Dampara, Probortok, and Bakalia.

The GPS coordinates of each of the 26 locations, classified into four zone types, were recorded. Silent zones are areas near educational institutions and hospitals. Commercial zones consist of business and shopping districts. Residential zones are primarily areas for housing, while industrial zones encompass areas with factories and workshops. Minimum, maximum, and average noise levels in decibels (dB) were measured during both sessions. These locations represent various levels of urban activity and include highly sensitive sites, such as educational and hospital areas [24, 14, 15].

Data Collection Process

The research employs a mixed-methodology approach, collecting both primary and secondary data. Primary data were collected through a questionnaire survey among residents. This revealed personal experiences of noise pollution and identified key noise sources in different areas. Key informant interviews with local authorities, experts, and community leaders broadened perspectives on noise management policies. Researchers used existing reports on typical noise levels alongside firsthand data. This facilitated evaluation against accepted noise criteria. By integrating these sources, researchers gained a comprehensive understanding of noise issues throughout Kotwali Thana [3, 1].

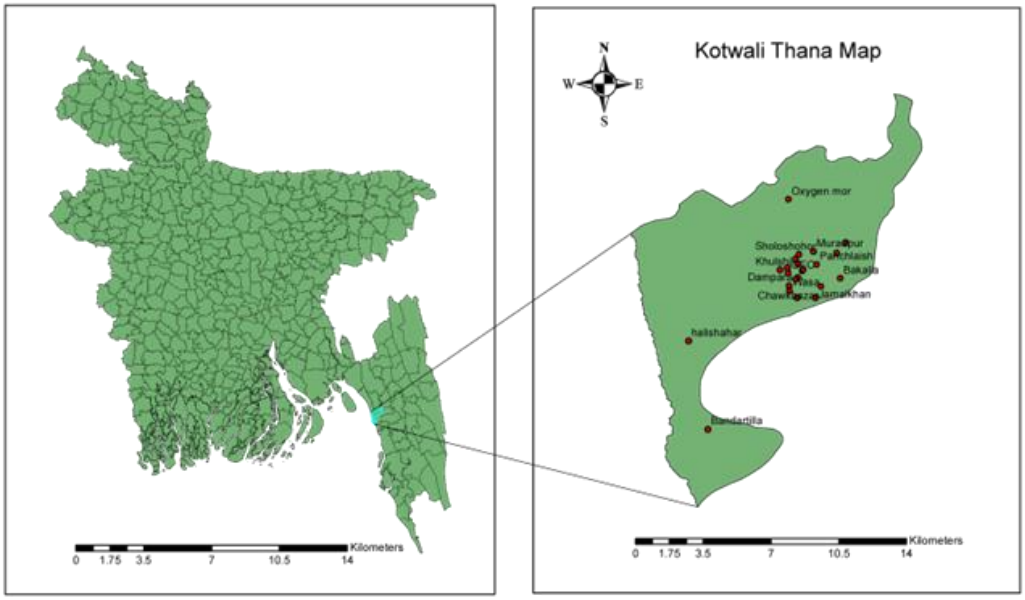

Fig. 1. Study Area Map of Kotwali Thana (both a geographic area and the police station itself) Chattogram District, Bangladesh

In this study, researchers aimed to comprehensively assess noise pollution patterns and their health impacts in Kotwali Thana, Chittagong District. Noise was measured at twenty-six locations using a digital environmental noise meter (model ST-8820) to understand relationships between noise levels, health implications, natural barriers (such as trees or walls that may block sound), and proximity to roads [25,26]. This method was chosen for its accuracy and reliability in urban environments.

To ensure precise and real-time assessment of noise pollution in a representative sample of twenty-six locations, researchers used a sound level meter (SLM) for its accuracy and efficiency in diverse environments, including both high-traffic and quieter residential areas.

Subsequent methodological steps provided reliable data essential for understanding noise pollution patterns in Kotwali Thana and informing local mitigation policies [27]. Before data collection, we calibrated the Sound Level Meter (SLM), a device that measures noise intensity, using a calibrator (a tool to ensure accurate readings) [28]. The device was set on a tripod about 2 meters above ground. Noise was monitored both on the roadside and at a distance of about 50 meters. The morning calibration yielded 96.7 decibels (dB), within a ±1.6 dB tolerance [29]. Evening measurements were 94.4 dB. Measurements were taken at 1 kilohertz (kHz) using the A-weighting scale (which adjusts measurement to reflect human ear sensitivity), quick response (rapid measurement setting), every five minutes. This approach allowed location-specific noise assessment and identification of noise parameters [27].

Data Analysis Process

Equivalent sound pressure level (Leq) is the statistical value of sound pressure level that can be equated to any fluctuating noise level [30]. Leq represents the continuous sound pressure level over a specified time, which matches the total energy of varying noise through the formula:

$$L_{eq} = 10\log \sum_{i=1}^{i=n} (10)^{\frac{Li}{10}} x\ t_i/t_t \quad (1)$$

where: n is the number of sound samples, Li is the noise level (in dB) of any i-th sample, ti is the time duration of the i-th sample, and tt is the total time period. A sound level meter with a "flat" response weighs all frequencies equally, reflecting both low and high-frequency sounds. Because the human ear is less sensitive to very low and high frequencies, the sound meter uses an A-weighted frequency filter. This filter ensures the measured sound levels, reported as Leq [dBA], better match human hearing across a wide range of frequencies [30].

RESULTS AND DISCUSSION

Figure 2 displays shift in average, peak, and minimum noise levels across the area. Environmental noise exceeds limits in several zones both during the day and at night. Levels range from 75 to 86 decibels, peaking at 87 decibels, mainly in the urban south and center [31].

These findings indicate that the area has a dense population, heavy traffic, and numerous businesses, all of which contribute to noise pollution [32]. Maximum noise in the southwest and southeast reaches 95-100 dB, creating a strong aural effect [33]. High environmental noise increases risks of heart disease, hearing loss, and cognitive issues [19].

Traffic, commerce, transportation firms, and mechanical industries generate the most noise in certain areas [34]. In contrast, quieter, less developed, and residential areas stay below 67 decibels [35]. However, some low-noise areas still exceed the World Health Organization's 55-decibel daily limit for residential zones [36]. Overall, noise pollution in the area remains a significant concern.

For a broader view of these results, the study included resident ratings of noise through Focus Group Discussions, Key Informant Interviews, and a survey during research.

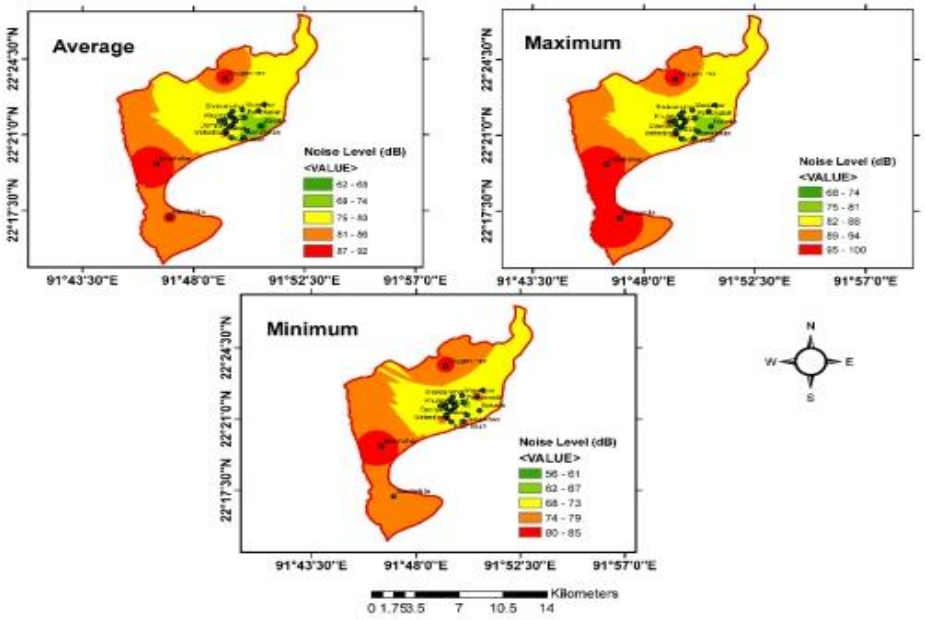

Fig. 2. Noise Level Map of Kotwali Thana (Morning)

Fig. 3 shows the spatial distribution of mean, peak, and minimum sound pressure levels (SPLs) measured in Kotwali Thana during the evening. The three maps illustrate acute environmental noise pollution in the western region, where red and orange isopleths indicate SPLs exceeding 86 dB(A) (peak) and 75 dB(A) (aggregate), reflecting severe auditory exposure, particularly above 82 dB(A). This is likely due to elevated population density, intensified commercial land use, and the development of multimodal transport infrastructure. In contrast, the eastern sector predominantly exhibits SPLs of 67÷77 dB(A), with intermittent increases to 72÷83 dB(A), as indicated by the yellow and pale green gradations, which correlate with more residential zones and open spaces, especially near the Bali courts. The arrangement of the maps highlights spatial clusters of elevated acoustic

emissions in larger open spaces. Notably, mean and peak SPLs above 88 dB(A) and 95 dB(A) are most pronounced in the western regions, while minimum SPLs remain elevated at 82÷87 dB(A) [37]. This indicates that excessive noise persists even during typically quieter periods. These findings underscore the urgent need to analyze environmental noise burdens in Kotwali and implement robust noise mitigation strategies [32].

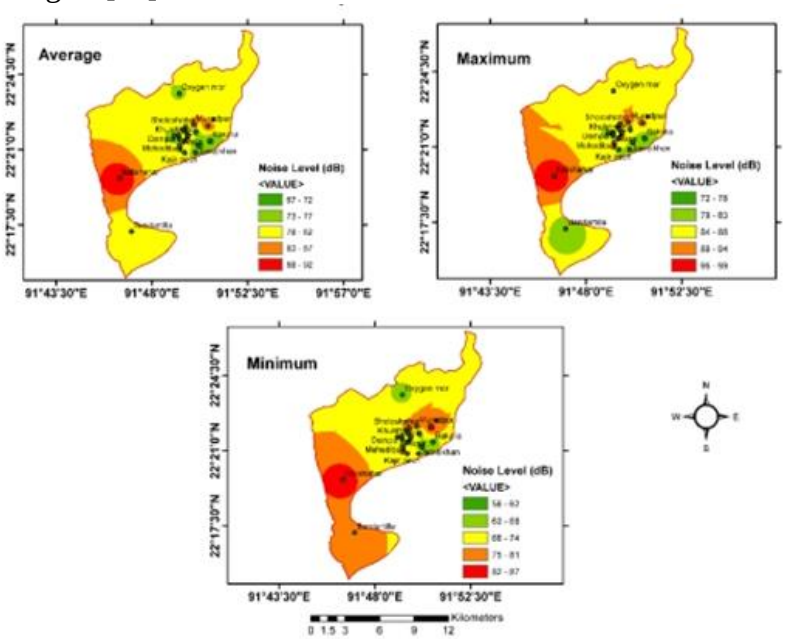

Fig. 3. Noise Level Map of Kotwali Thana (evening)

Nighttime noise levels in Kotwali Thana now average 65÷80 dB, far exceeding the WHO limit of 45 dB. This acute noise pollution presents an urgent public health crisis, driving increased risks of sleep disorders, cardiovascular disease, and psychological stress [19]. Vulnerable groups, including children, older adults, and low-income communities, are most affected, suffering from greater learning impairment, worsened health, and disproportionate sleep disruption. The crisis also impacts local wildlife, disrupting communication and endangering biodiversity. No zone in Chattogram, including quiet neighbourhoods and parks, meets safe noise standards. Immediate, decisive action is needed to address this citywide problem [34].

Figure 4 shows morning noise levels in quiet, commercial, residential, and industrial areas consistently exceeding recommended limits.

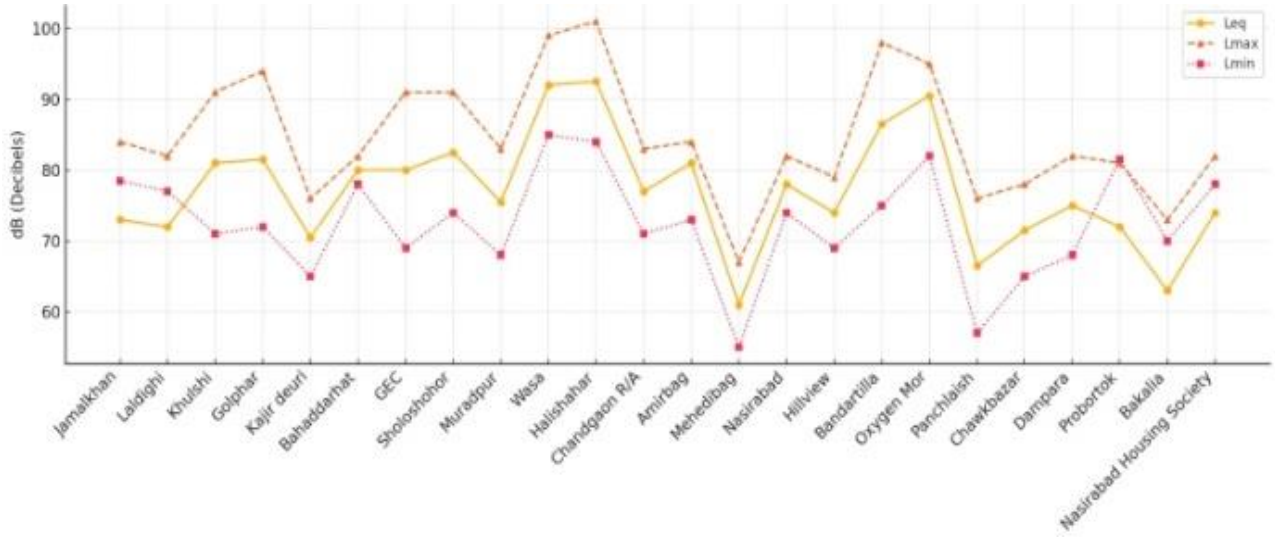

Fig. 4. Leq (Average), L_{max} (Maximum), and L_{min} (Minimum) noise levels in different study areas during the morning

Silent zones near schools and hospitals (e.g., Pachlaish, Dampara, Chawkbazar, Jamalkhan) all surpassed morning standards [19]. At some sites, such as Chawkbazar (70.03 dB) and Nasyrabad (82.22 dB), noise levels were especially high. Commercial zones recorded extreme readings (Lqeq: 92 dB; Halishahar Lqeq: 92.5 dB), with peaks of 101 dB, exceeding safe community thresholds [2, 36] (Hammer et al., 2014; Murphy & King, 2022). Industrial areas, such as Bonda, reported the highest morning noise levels up to 98 dB and concerning health figures, including oxygen saturation at 86.5% [38]. These findings underscore the importance of robust regulations to mitigate risk and safeguard public health.

Figure 5 shows evening noise levels (Leq, Lmin, Lmax) measured in silence, commercial, residential, and industrial zones. The Environmental Conservation Rules, 1997 (ECR'97), set the silence zone evening threshold at 45 dB(A). All quiet zone areas, such as Chawkbazar (Leq 67 dB), Panchlaish (72.5 dB), and Dampara (69.5 dB), exceeded this threshold. This indicates severe breaches of noise regulations [39]. The highest noise levels were in Nasirabad (Leq 83.5 dB) and Jamalkhan (Leq 80.5 dB). These areas are near schools and hospitals. This poses health risks to vulnerable populations [40].

Building upon the findings in silence zones, transitioning to commercial areas reveals that noise levels were consistently above the standard tolerable rate of 60 dB(A) during evening hours. The peak Leq was 92.5 dB in Halishahar. Wasa (91.5 dB) and Bahaddarhat (89 dB) followed. Business operations, heavy traffic, and large crowds are possible sources of high noise [41].

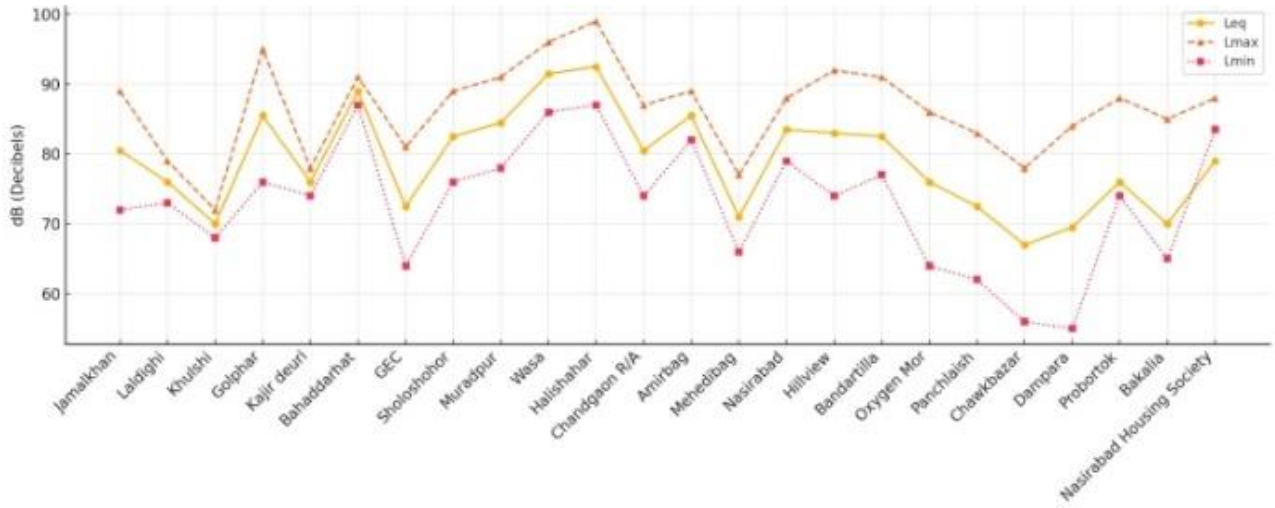

Fig. 5. Leq (Average), L_{max} (Maximum), and L_{min} (Minimum) noise levels in different study areas during the evening

Similarly, residential areas also experienced noise levels exceeding the recommended evening limit of 50 dB (a). Chandgaon and airbag residential areas had Leq values of 80.5 dB and 85.5 dB, which were significantly higher than the standard [42]. This suggests a decrease in overall well-being and possible negative health effects [43]. Bandartilla (Leq 82.5 dB) and Oxygen Mor (Leq 76 dB) exhibited high noise in the industrial zones. These results reflect the impact of heavy machinery, transport, and industrial processes during evening hours, which create an acoustically stressful environment [44]. Overall, the results reveal endemic noise pollution in all zones, with every area exceeding national regulatory levels [45]. It is crucial that policymakers and stakeholders take immediate action with urgent policy interventions, enhanced enforcement, and comprehensive public education campaigns to mitigate chronic noise exposure and safeguard public health [46].

To provide context for these findings, the study was conducted at 24 locations in Kotwali Thana, Chattogram. Locations included Jamalkhan, Laldighi, Bahaddarhat, and Halishahar. The Department of Energy (2006) sets ambient noise standards for morning hours (6:00 AM–11:00 AM) at 45 dB and for evening hours (3:30 PM–7:00 PM) at 50 dB for private zones. Calm zones have a standard of 40

dB. Commercial areas are reported at 70 dB (morning) and 60 dB (evening). Industrial areas are 75 dB (morning) and 70 dB (evening) [12, 47].
Reflecting on these standards, the analysis of noise measurements shows that the mean early morning and evening noise levels were above normal at most sites. For example, Mehedibag had an average morning noise level of 61 dB. Halishahar measured 92.5 dB. During twilight, Halishahar had an average of 92.5 dB. Chawkbazar had a lower average noise level of 67 dB. As sunset approaches, noise rises from 67 dB in Chawkbazar to 92.5 dB in Halishahar [13].
Further expanding on specific locations, average noise levels exceeded 50 dB in the mornings and 40 dB in the evenings. Levels were well above acceptable limits in residential areas like Jamalkhan, Laldighi, Khulshi, Golpahar, and Mehedibag. For example, Mehedibag measured 78.5 dB in the morning and 61 dB in the evening. Jamalkhan measured 80.5 dB in the morning and 73 dB in the evening. Noise levels in commercial areas, such as GEC, Kajir Deuri, and Chawkbazar, exceeded 70 dB in the morning and 60 dB in the evening. GEC recorded 72.5 dB in the morning and 80 dB in the evening. Chawkbazar was 67 dB in the morning and 71.5 dB in the evening [12]. Noise pollution in industrial zones, such as Halishahar and Wasa, was extremely high, exceeding 75 dB in the morning and 70 dB in the evening. Halishahar reached 92.5 dB in both the morning and evening. Wasa was 91.5 dB in the morning and 92 dB in the evening [12].
Examining variations over time of day, noise levels were higher in the morning in some areas, such as Jamalkhan and Golpahar. In other areas, such as GEC and Bandartilla, noise was higher in the evening. The first conversation took place between two sessions in Halishhar. In the morning, Mehedibag's vocalization levels dropped considerably. This may indicate a decrease in traffic or evening activities.
Taken together, these results underscore the critical need for immediate and strict adherence to noise control regulations, particularly in densely populated residential areas. To make a meaningful impact and protect public health, the study urges authorities to take decisive steps implement urban noise zoning, utilize acoustic screens, enforce traffic regulations, and conduct advocacy campaigns without delay [12, 47].

Comparison across all zones
Silent areas are important indicators for evaluating a city's quality of life. In Kotwali Thana's silent area, morning data (Fig. 6) show an Equivalent Noise Level of 75 dB. This value exceeds the standard of 45 dB, indicating a situation that may pose risks to the city environment. Continuous exposure to elevated sound levels can have adverse effects on human health, as well as on other living organisms and plants [19].
Commercial areas generally exhibit higher noise levels than other parts of the city due to increased human activity. In Kotwali Thana's commercial area, morning data (Fig. 7) indicate an Equivalent Noise Level exceeding 90 dB, which is above the standard of 70 dB. Some regions, such as Wasa and Halishahar, recorded levels over 100 dB. These findings raise concerns in commercial areas, as prolonged exposure to high sound levels may have a negative impact on human health [47]. In Bangladesh, individuals working in these busy areas are reportedly more likely to experience health issues compared to those in quieter or residential parts [12].
Residential areas must urgently remain peaceful, as they shelter people of all ages from infants to the elderly who are acutely sensitive to noise and can suffer serious health effects (Fig. 8). In Kotwali Thana's residential area, the morning Equivalent Noise level now exceeds 80 dB dangerously above the acceptable 50 dB standard. Alarmingly, regions such as Chandgaon and Hilview report levels above 90 dB [12]. These persistently extreme noise levels pose significant health risks [48, 12], underscoring that noise pollution in this context is an urgent public health crisis.
Similarly, industrial areas experience elevated noise levels due to the presence of heavy machinery and intense activity (Fig. 9). In Kotwali Thana, morning Equivalent Noise levels exceed 85 dB, surpassing the standard value of 75 dB [11]. This indicates a hazardous environment for workers and underscores the connection between workplace noise and increased health risks, as evidenced by reported illnesses among Bangladeshi industrial workers [17].

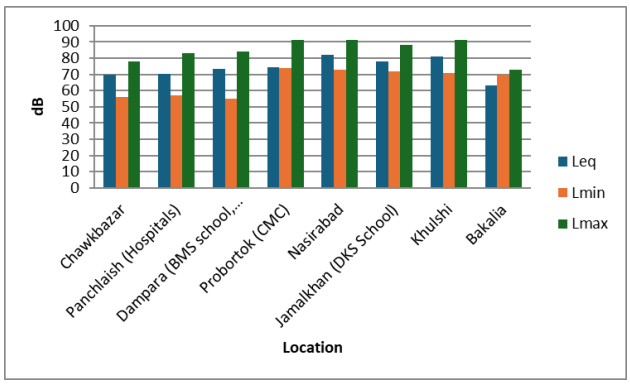

Fig. 6. Leq in Silent Area (morning)

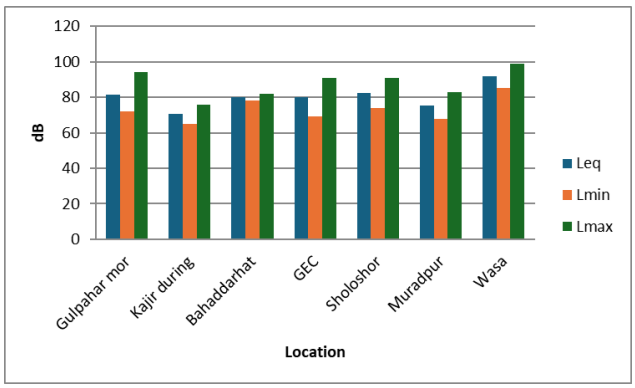

Fig. 7. Leq in Commercial Area (morning)

Fig. 8. Leq in Residential Area (morning)

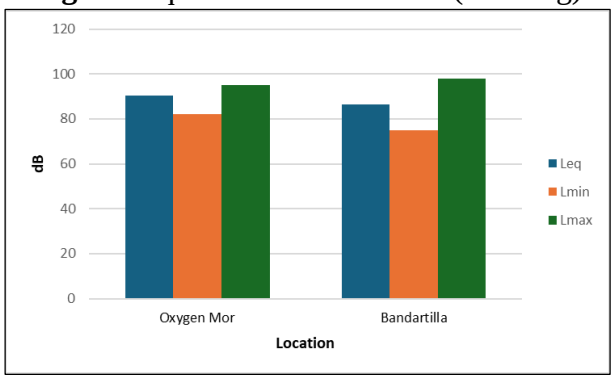

Fig. 9. Leq in Industrial Area (morning)

Overall, data demonstrate that in the morning (6:00 AM to 11:00 AM), the city's average noise exceeds 75 dB, regardless of the zone. This consistently high morning noise level across the city demonstrates the severity of noise pollution as a pressing public health issue [49].

In contrast to other areas, silent zones such as those with hospitals and educational institutions should be the least affected by noise. Yet, in Kotwali Thana, evening Equivalent Noise levels reach 75 dB, far exceeding the standard value of 35 dB (Fig. 10). Despite evening being considered off-peak, these levels are higher than morning measurements, highlighting a serious risk to the well-being of people and other living organisms in silent zones [50].

Commercial areas, such as residential and industrial zones, face significant noise challenges due to the intense human activity. In Kotwali Thana, evening Equivalent Noise levels exceed 80 dB, surpassing the standard value of 60 dB, with some regions, such as Wasa and Halishahar, recording over 96 dB (Fig. 11). Although the average noise level is higher in the evening, the expectation based on standard deviation is the opposite. This discrepancy highlights that noise pollution in these commercial zones is a distinct problem affecting both human livelihoods and the broader environment [19].

Evening data from the residential area of Kotwali Thana (Fig. 12) show Equivalent Noise levels exceeding 80 dB, double the standard of 40 dB. Chandgaon, Nasiarbad Housing Society, and Hilview also recorded noise above 80 dB [51]. These elevated readings highlight health risks for residents. Although evenings are expected to be quieter, noise levels remain similar to those of mornings, indicating a persistent noise problem that may impact patient well-being and students' concentration.

In the industrial area, evening noise levels remain high. Noise in Kotwali Thana's industrial area (Fig. 13) exceeds 85 dB, well above the 70 dB standard. This sustained exposure suggests workers may face unhealthy conditions even during typically quieter hours, as noise levels are nearly the same as during regular hours.

A comparison of morning and evening noise data reveals nearly identical levels at both times across all areas. This minimal distinction between working and off-time ambient noise is concerning. Residential and silent zones also exhibit noise levels comparable to those in industrial and commercial areas, often exceeding standard limits. These patterns highlight the persistent nature of excessive noise pollution across land-use zones.

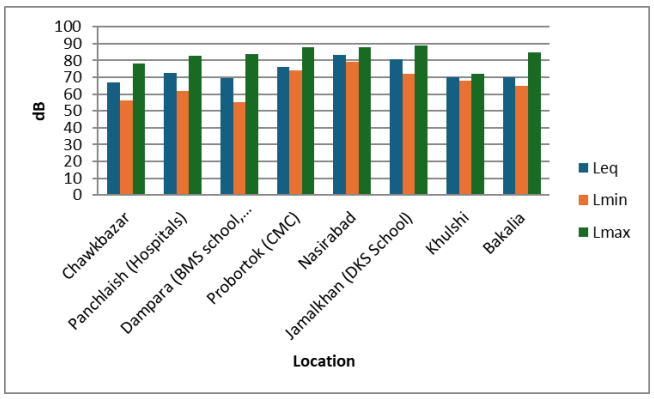

Fig. 10. Leq in Silent Area (evening)

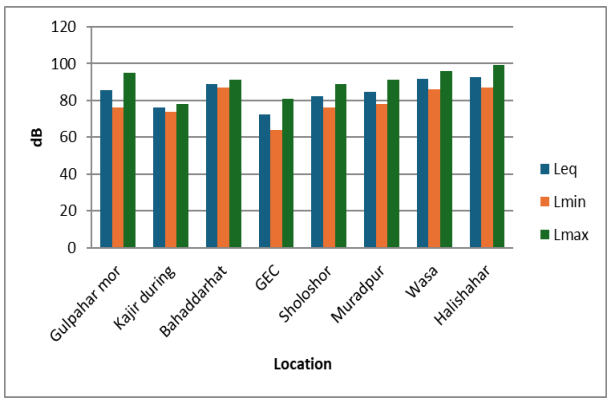

Fig. 11. Leq in Commercial Area (evening)

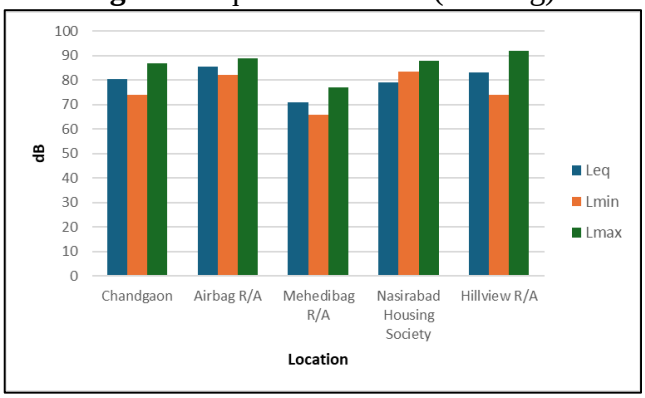

Fig. 12. Leq in Residential Area (evening)

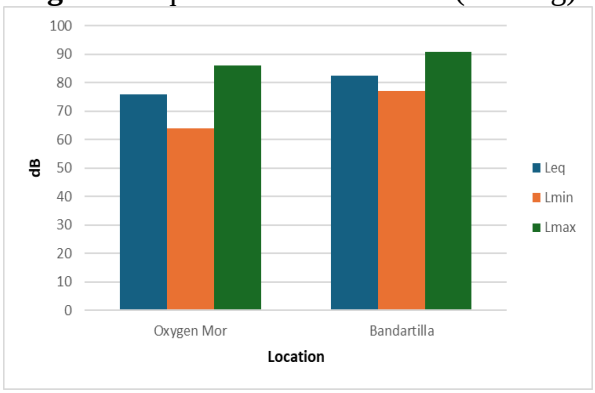

Fig. 13. Leq in Industrial Area (evening)

Limitations and Future Directions

This study focuses solely on Kotwali Thana, which may not accurately represent the noise problems in the rest of Bangladesh or Chattogram [52]. The lack of long-term monitoring also makes it difficult to identify noise patterns and changes [4, 52]. The surveys are limited and might not fully capture local views or health effects of noise [53, 54]. Sound measurement tools may be poorly calibrated, which can reduce accuracy [55]. Future research should study several thanas or nearby city areas for comparison. It should also use community-based methods to raise awareness and help control noise pollution.

To reduce noise pollution in Kotwali Thana, stakeholders must act now.

Key measures include: (1) Enforce restrictions on construction, industrial, and public event operations, particularly during sensitive hours; (2) Implement real-time noise monitoring with GIS tools for better management; (3) Require quieter construction equipment; (4) Establish green belts and promote sound insulation in buildings; (5) Launch educational campaigns for sustainable practices.

Traffic noise control should be prioritized through the immediate establishment of 'No Honking' zones, installation of intersection decibel meters, ongoing city noise mapping, and incentives for soundproofing and reducing vehicles in busy areas.

Further recommendations are: (1) Mandate the use of quieter construction materials in new buildings; (2) Increase enforcement of noise restrictions at public events; (3) Involve community groups in noise reduction campaigns.

CONCLUSIONS

This noise mapping survey reveals that Kotwali Thana in Chittagong District is plagued by significant noise pollution. Many sites exceed legal noise limits, posing a risk to public health. The area's road intersections cause noise spikes and social and developmental problems. Urgent action is needed. Local authorities, urban planners, and the public must enforce better regulations and planning. Educational programs are essential for protecting community health.

To combat noise pollution more effectively, agencies must collaborate closely with town planners, civic groups, and the public. Together, they can make stronger and clearer policies. Reducing noise and raising awareness will improve health and quality of life. These steps need to happen fast, so Kotwali Thana residents adopt sustainable habits. This study reveals that there was no prior noise pollution mapping in this part of Bangladesh, underscoring the need for timely responses.

AI Use Statement

We utilized Grammarly Premium, an AI-powered writing assistant, to support sentence structure correction, refine grammar, and enhance clarity during the manuscript preparation process. All AI-suggested changes were thoroughly reviewed, and final editorial decisions were made by the authors. We affirm that the content, interpretations, and any remaining errors are solely our responsibility.

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