

Research Article

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Environmental noise assessment of Bhandara City in the adversity of COVID-19 pandemic: A crowdsourcing approach

<https://doi.org/10.1515/noise-2021-0020>

Received Mar 09, 2021; accepted Jun 17, 2021

Abstract: The strict enforcement of lockdown in India and worldwide to contain the spread of the COVID-19 pandemics has brought a significant change in the environmental quality, particularly in cities. The study deliberates an overview of the status of the ambient noise quality of the tier-2 city Bhandara, India, for lockdown and posts lockdown circumstances. In the course of lockdown, it is unfeasible to walk out with standard instruments for onsite noise monitoring with the conventional method in such adversity. Make use of the crowdsourcing approach proves to be the best alternative for collecting noise data with the help of an android-based noise application, “Noise Tracker.” On assessing gathered data, it ascertained that the noise levels deplete by 8.0 dB during the lockdown. Results indicated that the average noise levels in more than 80% of the locations are lowered during lockdown compared to post lockdown in Bhandara City. A significant reduction in average noise levels at all sites during the lockdown period attributing to limiting in the road, rail, and other traffic movements. The study is an exclusive example of ordinary people from tier-2 city indulging in environmental scientific research. The study also visualizes the noise pollution scenario of lockdown and post lockdown periods using noise maps.

Keywords: COVID-19, crowdsourcing, lockdown, Noise Tracker, noise mapping

1 Introduction

Noise is an emerging concern worldwide. At present, not only metro cities but also small towns and villages are affected by noise pollution's threat. Noise is the third most dangerous pollution after Air and Water pollution, says the World Health Organization (WHO) [1]. Noise pollution affects humans physically and psychologically. Noise pollution, especially at night, increases vascular oxidation stress and problems like arterial hypertension and endothelial dysfunction may occur [2]. Environmental noise pollution tends to develop cardiovascular risk such as hypertension, myocardial infarction, abnormality of the electrocardiogram, more heartbeat irregularities, high pulse rate, high cholesterol [3]. Mental health symptoms like depression and anxiety develop in people due to the high level of environmental noise [4]. High exposure to noise also responsible for auditory acoustic trauma, tinnitus, temporary and permanent hearing loss [5]. Loud noise harms health and can even cause sleep disturbances [6]. WHO claims that children are also highly affected by noise and might suffer early permanent hearing loss. Noise may cause side effects on children's physical and psychological health and negatively impact children's learning and behavior [7, 8]. Animals and birds are also affected by noise. Both birds and animals are depended on meaningful sound for communication pairing, navigation, avoiding danger, giving the signal, and search for prey, but noise causes disturbance in their communication. Disruption of noise causes damage such as hearing loss in vertebrae and genetic disorder, affecting their reproduction, and some changes are observed in their overall health and behavior [9].

At the end of 2019, the first COVID-19 patient was found in Wuhan city, China. By 2020, the contagious disease was rapidly spreading across the globe. Taking the severe concern to the outbreak of the coronavirus disease, the WHO on January 2020 declared a global health emergency and pandemic in March 2020. The standard approach that most countries enforced to minimize the pan-

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demic's spread was restricting people's mobility by imposing strict lockdown, resulting in large numbers of populations confined to their houses. As a possibility of a significant threat in the fourth week of March, India's Government declared the first phase of a complete lockdown across the country (25th March to 14th April). Subsequently, the further lockdown was executed in 5 phases viz. Phase II (15th April to 3rd May), Phase III (4th May to 17th May), Phase IV (18th May to 31st May), Phase V only for containment zone, different phases of lockdown had the different extent of restrictions depending upon the level of contamination of the area [10].

In this study, the lockdown means that phase when there was a complete shutdown of all these public and private services such as transport, educational institutions, recreation facilities, industries, etc., to control coronavirus spread. The only permitted services to operate were life necessities like dispensaries, pharmacy, vegetable and fruit shop, daily needs grocery shop, and petrol pump were on the condition to adhere with the lockdown safety norms. In India, cities are classified based on population to allocate house rent allowance to public servants. Tier-2 cities are cities with a population of 50000 to 99999. During the lockdown, the administration has initiated regular surveillance across the country, including a tier-2 city Bhandara. Moreover, the containment zone or red zone marked for those areas where many COVID-19 positive patients traced. There was a strict prohibition of both essential and non-essential shops in the containment zones, and the administration has to render necessities and food in the red zones. Most activities were permitted outside of containment zones, except for educational institutions, international air travel, recreation areas (swimming pools, gymnasiums, theatres, entertainment parks, bars, auditoriums, and assembly halls), and large gatherings of any kind. In contrast, the post lockdown was the phase where all the earlier imposed restrictions revoked except the educational institutions, including schools, colleges, coaching centers, etc., were closed. Also, community or religious events were restricted, public transportation, including buses, trains, and flights were operational with half of its capacity [11]. The lockdown restrictions generated unusual scenario on the streets and market places in the cities with the non-appearance of vehicles and commuters, leading to a significant noise pollution reduction across the city that might be expected. These major changes to daily life provide an opportunity to study the impact of COVID-19 on environmental pollution concerned with many pollutants such as air, water, and noise.

However, due to the government's strict regulations and the increased prevalence of COVID-19, it was impos-

sible to walk out with all standard equipment and perform noise monitoring across the city. It became necessary to work on an alternative method for monitoring noise levels without risking personal safety. The use of smartphones appears to be the best alternative in such a situation because the availability of digital sensors and GPS makes it accessible for real-time noise data collection and storage. Few of the recent studies carried out using smartphones reveal that crowdsourcing is a feasible technique for measuring noise with ordinary people's participation and subsequently creating noise maps [12]. In the present paradigm, with the increased adoption of smartphones, participatory sensing emerged as a popular concept for noise monitoring that empowers the user community to monitor the environmental noise and conveniently exchange the results for noise assessments and to process the data for designing noise maps [13]. A current development in mobile applications for sound level measurements running on smartphones featuring a number of advantages over SLM such as extensive availability, user friendly, handy and inexpensive and can be utilized for noise monitoring purpose. However, more studies are required to investigate the accuracy of noise measurements using these applications ("Apps"). Sound level apps incorporated into the smartphones ventured as a feasible tool for quick, cheap and convenient monitoring of noise levels [14, 15]. Similar studies of noise measurements with participatory sensing by engaging volunteers and students to create dense noise maps in urban environments for various cities worldwide reveal a successful methodology [16–18]. Picaut *et al.*, in their research, indicate that data collection by volunteers with the smartphone using the "Noise Capture" App should finally make realizable to have a different pragmatic representation of the environmental sound that those acquired by address based on numerical modeling [19]. Poslončec-Petrić *et al.* carried out their study using "QGIS" and "Noise Tube" for noise mapping, and monitoring respectively, states that the amount of data of noise pollution acquired from people increases day by day, and it is more accurate and complete [20]. Owayjan *et al.*, in their study, explains that the noise monitoring with a smartphone is useful as measured values are very close to the available decibel level [21].

During this COVID-19 pandemic, researchers from different countries studied noise levels in their respective cities and found significant reductions in noise pollution levels. One such study was carried out at various locations in London, UK during the pre-lockdown and lockdown of the COVID-19 epidemic and found an average reduction of 5.4 dB in the noise levels [22]. Recent research conducted by the University of Michigan in the United States showed

a significant drop in global noise pollution levels during the initial COVID-19 lockdown period. For the data collection, researchers used Apple's smartphones and smartwatches of volunteers in Florida, New York, California, and Texas, and found an overall decrease of 2.6 decibels in four states of the United States [23]. Similarly, noise levels were studied in Dublin, Ireland, and Madrid, Spain during the COVID-19 pandemic, and found a significant reduction in the sound level ranged from 2 to 6 dBA [24, 25]. Gevú *et al.* studied the noise level of the Rio de Janeiro city center before and during the COVID-19 pandemic and created a comparative noise map. The comparative analysis showed a considerable noise reduction in the range of 10 to 15 dB, for areas where the traffic noise was not extreme and where the human activities are predominant on the streets [26]. The sound level study conducted by Mishra *et al.* in Kanpur, India, during the COVID-19 epidemic, and concluded that the effect of road traffic noise on the risk of high annoyance and sleep disturbances during lockdown was found to be lower compared to the pre-lockdown and unlock phase, and the risk of sleep disturbances in the residential area was reduced from 37.76% during the pre-lockdown to 14.72% during the lockdown phase [27].

In India, most cities' noise levels exceed the limit prescribed by Central Pollution Control Board (CPCB), New Delhi. The cities of Maharashtra state are no exception. According to various studies, cities like Mumbai, Kolhapur, Pune, and Nagpur, noise pollution has surpassed all the limits. Growing population, congestion of vehicles and noise in social events contribute to the increase in noise. The study of noise pollution has not been carried out to a satisfactory extent in Maharashtra's small towns and villages. A study conducted in 2018 in Washim, a small city of Maharashtra, reveals that noise pollution is an emerging environmental concern [28]. Bhandara is also an emerging city of Maharashtra where investigation of noise pollution never conducted before. In light of the above context, this paper investigates the impact of COVID-19 lockdown on noise pollution in Bhandara city, India. This study gathered real-time noise data across the city through crowdsourcing technique and evaluate the sound pressure levels to investigate the changes in sound levels during the lockdown and post lockdown.

2 Study area

Bhandara city is located at 21.17°N, 79.65°E in the north-east part of the Maharashtra state, India. The city covers almost 30 sq. km area, with 91,845 (2011 Census) citizens.

Bhandara city is 60 km from Nagpur city, and it falls on the prime National Highway 6 (NH 06) joining the two metro cities Mumbai and Kolkata [29]. The city is important to the nearby villages as it is the center of education, hospital, market and government offices etc. Many working-class people, daily wagers and student travel each day from and to the city. The noise studies for Bhandara city have never been investigated before this study ascertained while conducting an extensive search on the internet to find out previously available research for reference. The environmental noise levels were investigated in the Bhandara city at 34 locations in different residential, commercial, and silence zones according to the guidelines stipulated by the CPCB. The study area map delineating details of noise monitoring location is illustrated in Figure 1.

3 Methodology

The research carries out a comparative study of noise levels between the lockdown and post lockdown phase of pandemic COVID-19 in Bhandara city. The data collection was performed as per the land use pattern during the lockdown with the crowdsourcing technique. Since android mobiles are commonly used in India and readily available to the common public than iPhones, the noise measurement carried out using android mobile phones. The selection of sound level measurement application ("apps") was based on the comparative ratings of the other common android apps freely available on the google play stores. The "Noise Tracker" sound measurement application was developed by the Council of Scientific and Industrial Research – National Environmental Engineering Research Institute (CSIR - NEERI), Nagpur, India. The app records one noise value per second or 300 measurements over 300 seconds. The data was collected during the daytime (06:00 am to 10:00 pm) in April 2020 using smartphones running on the android application "Noise Tracker" [30].

Volunteers for the events were localities and were graduate students from nearby institutions. For this research, study volunteers were encouraged to participate socially, and with their consent, registered for the event. The volunteers were assigned monitoring roots close to their residence for their convenience and safety concerns with the coronavirus pandemics. Before the monitoring, the volunteers were guided through sharing tutorial video and texted guidelines and were asked to take certain precautions necessary during the process. Accordingly, volunteers collected sound data with their android phone using "Noise Tracker" application. The volunteers collected

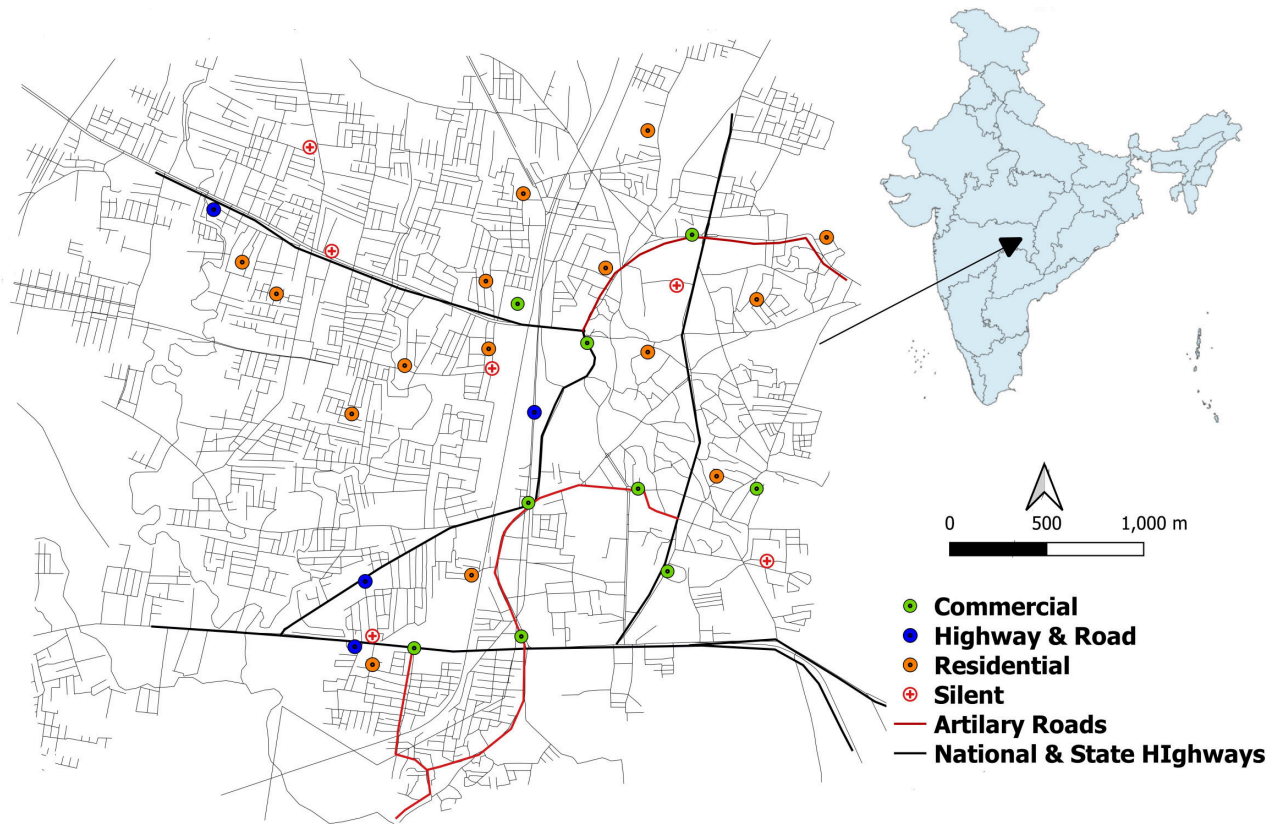


Figure 1: Sampling locations of ambient noise monitoring of Bhandara City



Figure 2: Volunteers monitoring noise levels using smartphones

three readings of a minimum of 300 seconds for each location during the lockdown period, and an average of the data sample was considered while assessing noise pollution. Volunteers shared their monitored data via text. Figure 2 shows the images of volunteer's measuring noise levels using smartphones in the study area. Post lockdown monitoring was carried out in September 2020. To date, it became feasible to carry out monitoring using standard equipment Type-1 Sound Level Meter "Casella". This instrument conforms to the international standard for acoustic measurement. The expert noise team of our laboratory and the volunteers performed the noise monitoring on post lockdown simultaneously with a standard sound level meter and with an android mobile application, "Noise Tracker", to validate the accuracy of the data obtained via smartphone application.

3.1 Noise mapping

Noise mapping is a useful method to describe noise level in a pictorial or visual representation of the extent of noise distribution across the study area. It is a valuable assessment method in urban regions and proves as an advisable document in planning and noise mitigation measures. Predictor Lima software (Type 7810; Version 12.00) is used to generate noise maps for this study. The tool conforms ISO 9613-2:1996 calculation method. The software predicts sound waves attenuation and gives a visual representation of sound waves behavior under geographical and meteorological factors in the environment [31]. In the recent year, noise mapping software Predictor Lima has been widely used in various areas around the world, such as industrial noise mapping, urban noise mapping, opencast mines noise mapping, traffic noise mapping and more [1, 32–34]. The noise mapping process begins with the geo-tagging of the locations in Google Earth, and thereby study map is imported into the prediction software for processing. Subsequently, all the noise sources were marked on the workspace of the mapping software while keeping the study area map in the background. The Sound power level for each source is entered in the software to compute the propagation of sound waves. Finally, the contour map is generated on the 200m × 200m grid, and each grid point is at the height of 4m, which acts as a receiver point.

4 Results and discussion

Table 1 summarizes the noise levels observed for all 34 identified locations for the different measurement periods. The field observation and collected data are statistically analyzed and discussed in this section. The study reveals that the noise level's average difference between lockdown and post lockdown period is 8.0 dB. The noise levels dropped down into the safer range during the lockdown phase in residential, silent, and in few commercial places. Whereas on post lockdown phase, there is a significant increase in the noise levels at every location, some residential areas are exceptional for this. The study's observations and findings explicitly reveal that due to the restricted human activities during the lockdown, the city's ambient noise levels drop substantially, as shown in Figure 3. Many factors contributed to lowering noise levels during the lockdown period, such as the absence of vehicles on the road, ban on tours & traveling, ban on social & religious gathering, and shutting down educational, commercial, and other institutes. If we evaluated the previously reported data of various studies for different cities so far, this extent of reduction in the noise level has never been reported or observed.

An average noise level in the residential areas increased by 7.6 dB during the post lockdown period, as depicted in Figure 4(a). In the lockdown phase, noise levels at all 15 locations ranged within the safety limit of 55 dB prescribed by CPCB. However, with partial revoke of restrictions, 6 out of 15 sites surpassing the permissible limit during the post lockdown phase. Shanaya Nagari and Sahakar Nagar show minor differences as being located away from road traffic influence. Moreover, the nearby schools were remained closed even in the post lockdown period. As in this period, vehicles are on the road, and the social and religious gathering allowed restrictedly the noise level increases exponentially in other residential locations on the post lockdown. Almost all stores, hotels, daily & weekly markets in commercial places were opened, which has led to an increase in human activity and congestion of vehicles, resulting in a steep rise in the noise levels.

The recorded noise levels at all the commercial areas were within the permissible limit during the lockdown phase as shown in Figure 4(b). However, as the restrictions relaxed, the noise levels at all the locations surpassed the limit of 65 dBA prescribed by the CPCB on post lockdown with an average hike of 7.6 dBA. Figure 3(b) also signifies that the data gathered from squares during lockdown the only 1 location out of 5 with a noise level exceeding the prescribed limit was Rajiv Gandhi square. Since this site is

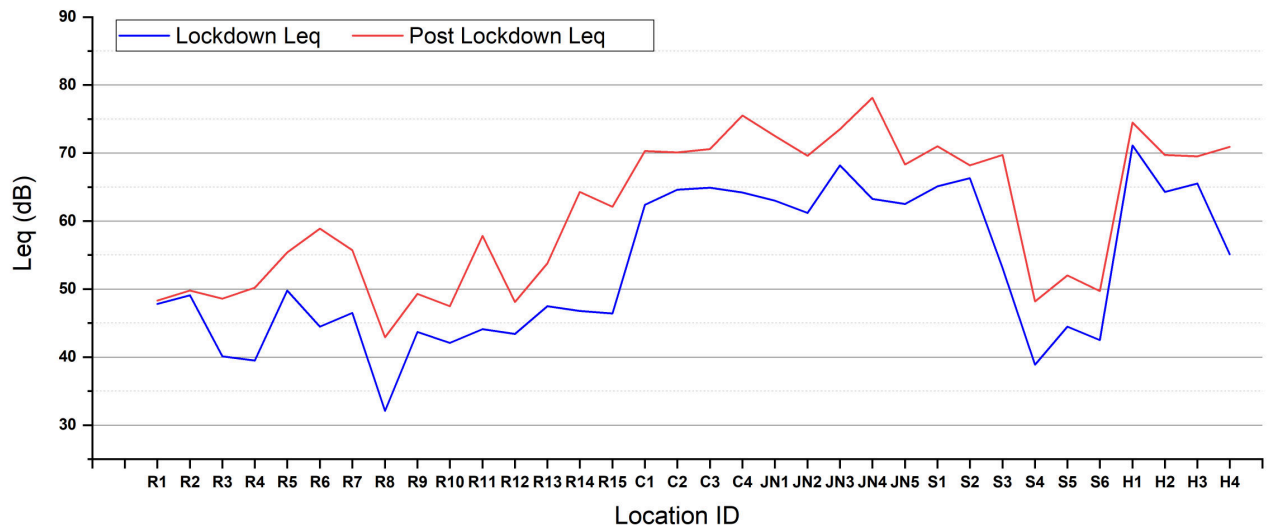


Figure 3: Comparison graph representing lockdown and post lockdown scenario

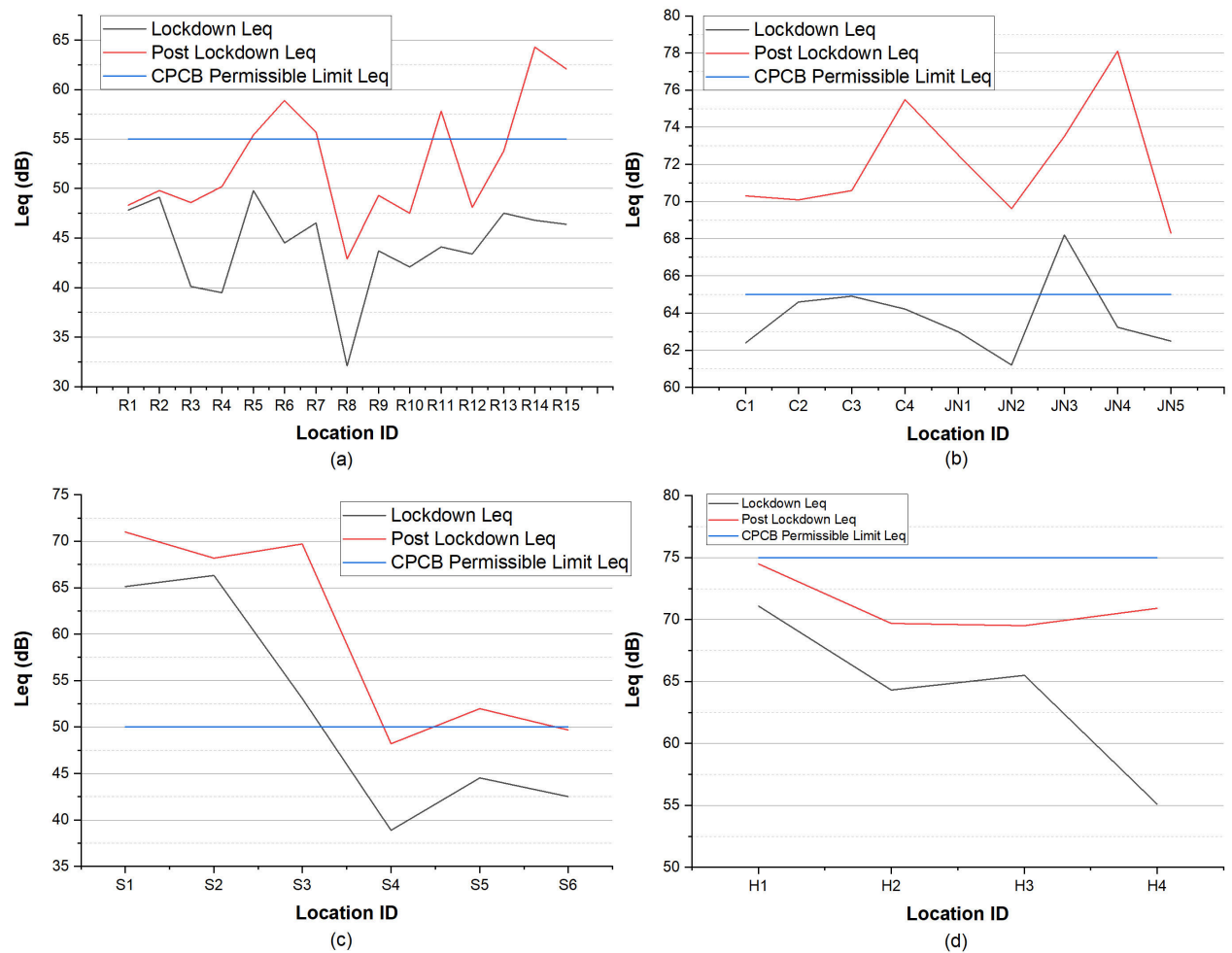
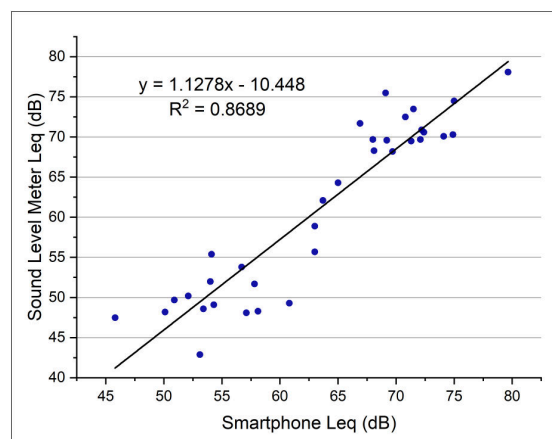


Figure 4: Comparison between lockdown and post lockdown Leq for different zones

Table 1: Lockdown and post lockdown period noise levels of various locations across the Bhandara city

Area/Zone	Location ID	Location	Lockdown Leq (dB)	Post lockdown Leq (dB)
Residential	R1	Sahakar Nagar	47.8	48.3
	R2	Shanaya Nagar	49.1	49.8
	R3	Khokharla	40.1	48.6
	R4	Samta Nagar	39.5	50.2
	R5	Takiya ward	49.8	55.4
	R6	Mukherjee Ward	44.5	58.9
	R7	Vaishali Nagar	46.5	55.7
	R8	Ganga Nagar	32.1	42.9
	R9	Mhada colony	43.7	49.3
	R10	Bhojapur	42.1	47.5
	R11	Mhada	44.1	57.8
	R12	Kesalwada road	43.4	48.1
	R13	Mendha	47.5	53.8
	R14	Ram Mandir ward	46.8	64.3
	R15	Patidar Bhawan	46.4	62.1
Commercial	C1	Bada bazar	62.4	70.3
	C2	MSEB office	64.6	70.1
	C3	Khat road bazar	64.9	70.6
	C4	Bus stop	64.2	75.5
	JN1	Muslim Library square	63	72.5
	JN2	Collector square	61.2	69.6
	JN3	Rajiv Gandhi square	68.2	73.5
	JN4	Shastri square	63.24	78.1
Silence zone	JN5	Khamb Talav square	62.5	68.3
	S1	Government Hospital	65.1	71
	S2	Chole Hospital	66.3	68.2
	S3	St. Marry School	53.1	69.7
	S4	Ashwini School	38.9	48.2
	S5	Nutan Kanya school	44.5	52
City roads and highways	S6	Spring-dale Convent	42.5	49.7
	H1	NH 06	71.1	74.5
	H2	Nagpur by-pass	64.3	69.7
	H3	Tuition galli	65.5	69.5
	H4	Bhandara-Ramtek SH	55.1	70.9

**Figure 5:** Correlation of smartphone and sound level meter noise levels (Leq)

densely populated and feature a vegetable and fruit market that was fully operational during the lockdown, apart from this, various hospitals around the market contribute to increased noise levels. Later on, in post lockdown, noise levels at all locations surpassing the prescribed limit with an average rise of 7.25 dB compared to lockdown.

Hospitals being the prominent centers treating the patients of COVID leads to higher noise levels. Figure 4(c) shows that in the silent zone locations such as hospitals, it delivers higher noise levels. In contrast, schools offer marginally lower noise levels for both phases of noise measurement.

Figure 4(d) demonstrates the relative noise levels for city roads and highways during lockdown and post lockdown period. On the interconnected city roads & highways, the only vehicles permitted during lockdown were essential goods and medical emergency, which were the

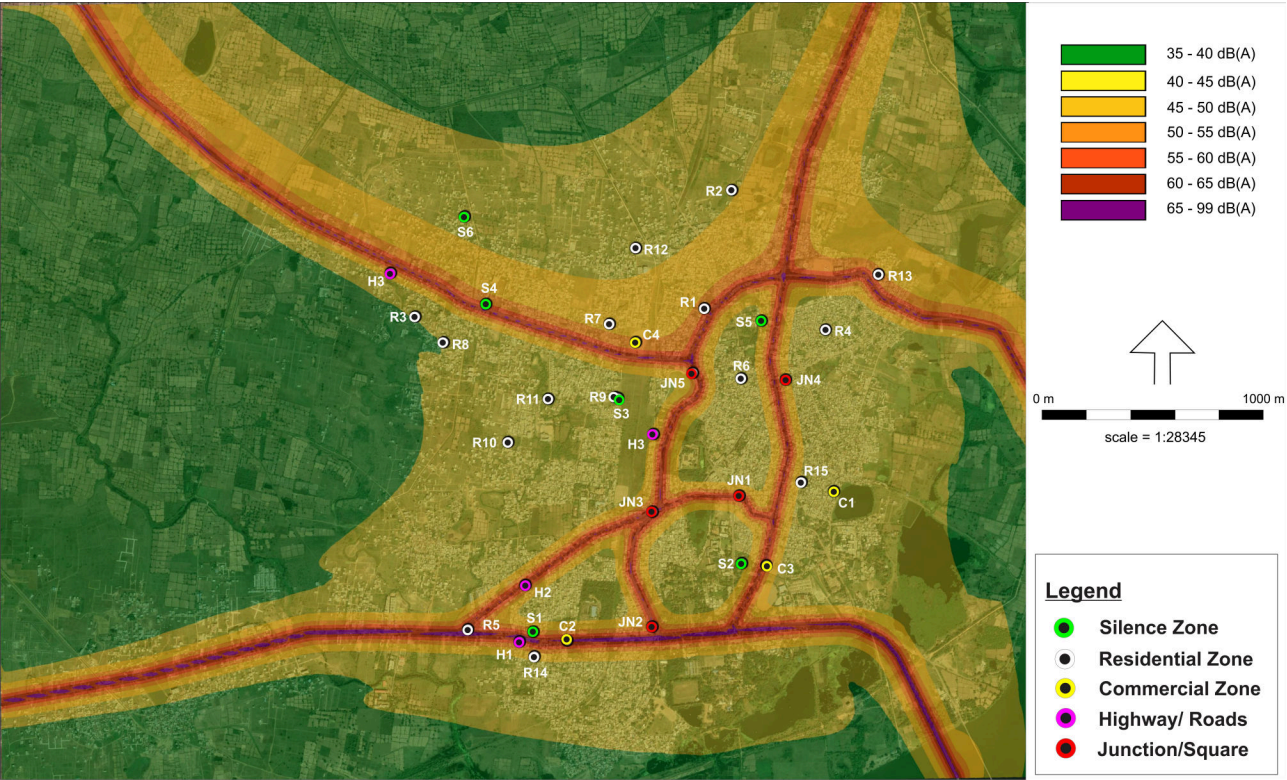


Figure 6: Noise map of Bhandara city during lockdown (April 2020)

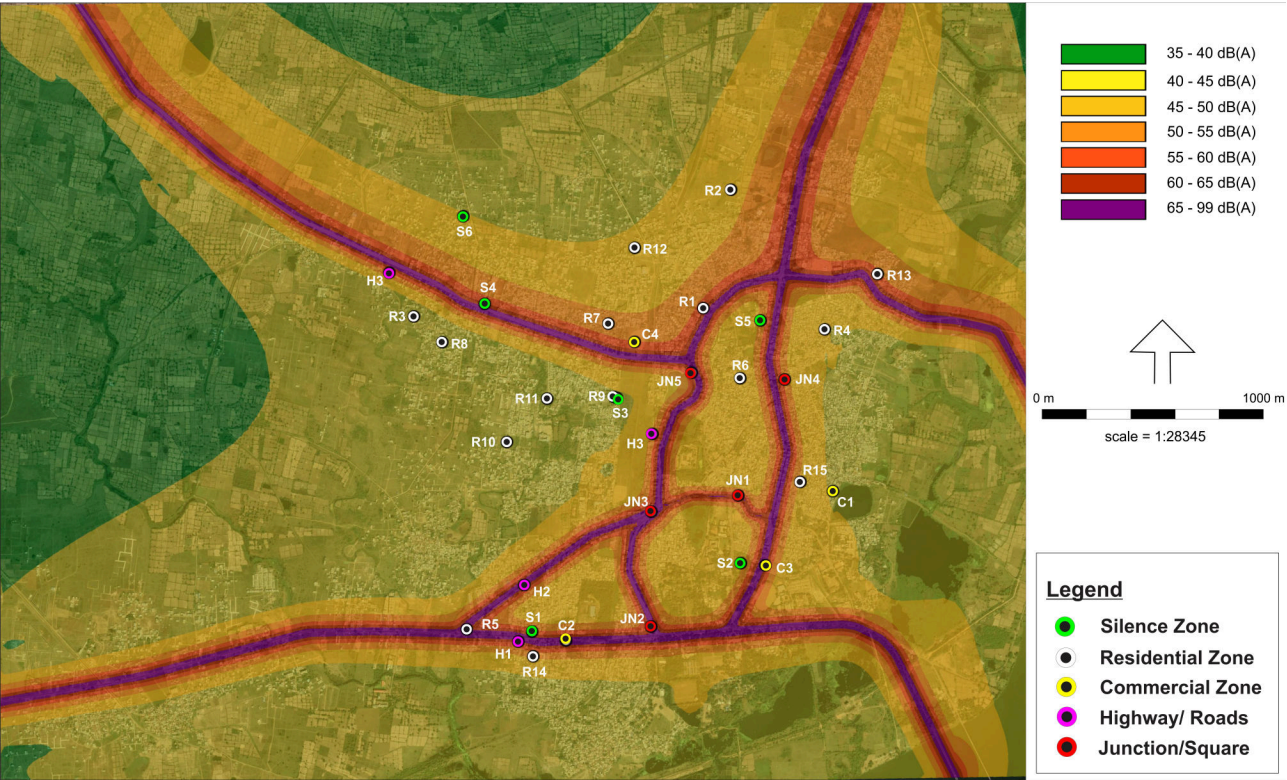


Figure 7: Noise map of Bhandara city post lockdown (September 2020)

only traffic noise source. Whereas in the post lockdown phase with partial revoke in the public transport restrictions in September, educational institutions were still shutdown, and public, private offices did adopt work from home. The noise level data obtained from nearby road and highway areas reveals that the noise levels at all 4 locations during the post lockdown rise by an average of 7.1 dB due to an extensive increase in the vehicles on the road that leads to noise levels surpassing the CPCB permissible limits.

4.1 Validation

This section discusses the comparative analysis of post lockdown noise levels of all 34 locations that gathered using smartphones and also with the standard instrument to validate the smartphone's accuracy for noise measurement. The average difference observed was 2.1 dB, which is significantly acceptable. The comparative evaluation of data shows that the smartphone application data correlates closely with the data obtained from the sound level meter with a determination of coefficient of 0.86, as shown in Figure 5.

The noise maps representing the noise level scenario of the Bhandara City during Lockdown & Post Lockdown, exhibiting the difference in the noise level of various locations across the city, are depicted in Figure 6 and 7, respectively. The average difference in the overall noise levels between the lockdown and post lockdown phase is 8.0 dB, which can be clearly perceived from the noise maps.

As per data, 55.9% of the location during lockdown ranges within the permissible limit of 55 dB. One can be view in Figure 6 that the noise map displays the Green and Yellow color's major occupancy, which represents the noise level ranging below 55 dB. The remaining 45.1% of the locations where noise levels ranged above the permissible limit indicated by Orange, Red & Violet color majorly covers Roads and Highways on the map.

In contrast, the post lockdown scenario is clearly portrayed in Figure 7, where Violet, Red, and Orange colors cover the utmost study area. As per data, 62.8% of the location post lockdown ranges above the safety limit, which can be easily perceived from the map. Simultaneously, the area distant from the roads and highways was influenced to a smaller extent. The study by Judicael picaut (2019) reveals that road transportation noise stands for the dominant noise source and accounts for 90% of the levels higher to 68 dB(A); here, in Figure 7, it is crystal clear that the road traffic noise influences the maximum study area.

5 Conclusion

The study investigated and revealed the noise environment status of a tier-2 city like Bhandara probably be the first attempt in India carried out with the help of participatory sensing approach using smartphones, which have never been attempted before. It is the first noise assessment study in Bhandara city, where common people of the town themselves participated and crowd sourced the data for the task. The overall analysis divulges that a significant impact of pandemic-lockdown on the noise pollution level of the city leads to the drop in the ambient noise level by 8.0 dB on comparing with post lockdown scenario. The city's average ambient noise level during lockdown and post lockdown is evaluated to be 53.2 dB & 61.1 dB, respectively, with a notable difference of almost 8.0 decibels (dB).

The study reveals that the significant source of noise during both lockdown and post lockdown was the commercial activities at market places and road traffic, which has majorly influenced the city's ambient noise level. In comparison, the study concludes that the smartphone application data correlates with the data obtained from the sound level meter with a correlation coefficient of 0.86, which is anytime acceptable. The study also highlights the city's noise level's concern during regular days as maximum locations are exceeding the safety limit prescribed by CPCB.

However, in the post lockdown phase (September 2020), the educational institutes including schools, colleges, coaching centers, etc., were closed. Also, community/ religious events were restricted. Moreover, public transportation including buses and trains, was partially operational else, the noise level would have been much more than observed.

Lockdown restrictions leads to behavioral shifts among the general public that cause positive impact on local and regional environmental pollution. Investigating noise pollution during global health emergencies such as the COVID-19 Pandemic is vital because such a situation occurs once in a century. This information is practically helpful for town planning and subsequently conceiving a strategy to mitigate the noise pollution in urban regions. The lockdown restricted mobility and access to the standard equipment of environmental monitoring, which turned out to be an opportunity to switch towards an adaptive system (use of smartphone). Previous research confirmed that noise pollution is associated with many adverse health hazards; consequently, the significant noise pollution reductions could provide essential public health benefits.

Acknowledgement: The authors wish to thank CSIR- National Environmental Engineering Research Institute, Nagpur, India, for giving this opportunity and facilitating us with all the requirements for this paper. The authors thank the volunteers for their selfless contribution by crowdsourcing the data in the Pandemic's adversity. The authors also thank the anonymous reviewers for their valuable suggestions and comments that helped improve this paper's content, quality, and presentation.

Funding information: The authors state no funding involved.

Author contributions: All authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Conflict of interest: The authors state no conflict of interest.

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