An Evaluation of Noise Pollution in the Urban Landscape of Solapur City: A GIS-Based Mapping Technique

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***Abstract*—The present study deals with monitoring and mapping of the noise pollution threat in the urban environments of the Solapur city of Maharashtra. Noise pollution is an invisible threat to human health and cause of much ill effect on the surroundings. Proper monitoring and evaluation using the recent technologies helps to identify the level of susceptibility to human population. Measurement were carried out for 100 sampling locations across four types of zones namely, industrial, residential, commercial and silence during day and night time. The urban noise levels were assessed using a sound level meter, capturing both day and night measurements to calculate the equivalent continuous noise (Leq). The Leqmin and Leqmax values were determined for each location. Using GIS software and interpolation techniques, a noise map was generated based on the Leq readings. The analysis revealed that industrial zones had a daytime noise level of 84.88 dB and nighttime level of 47.6 dB, residential zones had a daytime level of 64.86 dB and nighttime level of 46.74 dB. Commercial zones exhibited higher noise levels with daytime levels reaching 91.36 dB and nighttime levels at 78.56 dB. In contrast, silence zones had an average daytime noise level of 67.74 dB and nighttime level of 61.75 dB. The severity of noise pollution ranked as follows: commercial zone > industrial zone > silence zone > residential zone. The study plays a pivotal role in identifying areas with high noise levels and exploring nature-based solutions. Additionally, in landscape planning and urban design, the final output map generated using a GIS platform can serve as a blueprint for reducing noise exposure in future settlements.**

***Index Terms*—Geographical Information System, Noise pollution, Urban landscape, Urban noise.**

I. INTRODUCTION

Pollution, which refers to the uncontrolled discharge of human-generated waste into the air, land, water, and oceans without considering its impact or consequences, poses a significant risk to human health, planetary health, and the long-term sustainability of our societies (Fuller et al., 2022). According to EPA (2022), the traditional definition of noise is "unwanted or disturbing sound". Sound becomes unwanted when it either interferes with normal activities such as sleeping, conversation, or disrupts or diminishes one's quality of life.

In urban planning, noise plays a crucial role as it helps identify and prioritize areas such as schools, hospitals, and parks that need to be situated away from noise pollution. Noise maps are invaluable tools used in the city planning process to assess and mitigate existing noise levels, ensuring a more peaceful and sustainable environment for residents (Harman et al., 2016). Noise pollution is a major form of pollution, especially in urban regions, and it has substantial impacts on human health. Addressing noise-related concerns is a crucial societal and public health matter, prompting authorities to establish regulations and measures to mitigate noise pollution (Picaut et al., 2021).

Noise pollution mapping involves the process of identifying and analyzing noise levels in a particular area or region. It is typically done to assess the extent and impact of noise pollution on the environment and human health.

The objectives of this research article are to assess noise pollution levels in residential, commercial, and industrial zones, identify high-noise locations, and map the noise level values using GIS platform and provide urban planning recommendations. Such studies are significant as they provide insights into noise pollution's impact on health and the environment. The study will guide urban planners in mitigating noise, prioritize public health interventions, and enhance community well-being.

II. STUDY AREA

Solapur is a city shown in Fig. 1 and located at (Latitude: 17°40'23.08"N, Longitude: 75°54'24.60"E) in the southwestern part of the state of Maharashtra, India. It is situated on the banks of the Sina River and serves as the administrative headquarters of the Solapur district. Renowned for its textile manufacturing industry, it holds a prominent position in Bidi manufacturing as well. The city is also

renowned for its Solapur Chadars. Situated on a crucial north-south railway route, the city plays a vital role in India's transportation network (SMC, 2023). Solapur is positioned at the crossroads of major highways, making it an important transportation hub. It lies about 400 kilometers east of Mumbai and is well-connected to other major cities in Maharashtra, including Pune and Hyderabad.

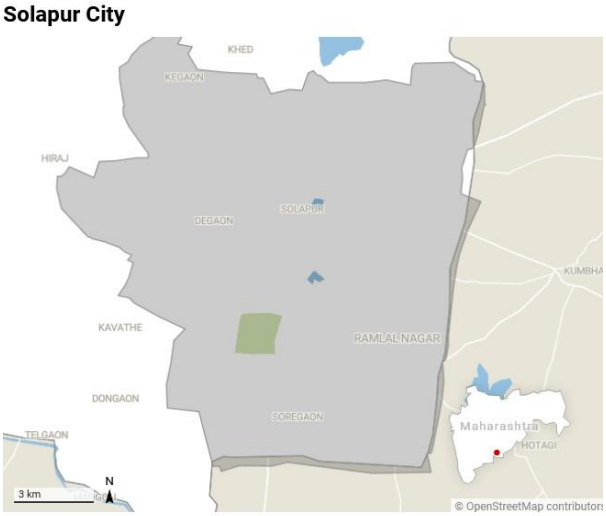

Fig. 1 Location of Solapur city in Maharashtra, India

III. MATERIAL AND METHODOLOGY

A. Data

For the present study, field based noise level data was collected using the SLM 109, a Class 1 integrating sound level meter. It complies with the IEC61672 as well as ANSI S 1.4 standards. The accuracy of the measurement device is ± 1.0 dB with a resolution of 0.1 dB (envirotechindia.com, 2023).

Fig. 2 SLM 109 used for monitoring of noise in the study area

B. Noise Sampling Strategies

Measurements were taken for noise levels during different time periods: early morning rush hour (7:00–9:30 AM), late morning (9:30 AM–12:00 PM), early afternoon (12:00–2:30 PM), and late afternoon rush hour (2:30–5:00 PM). The samples were collected by following the guidelines of CPCB recommending that, to locate the station at an ambient level, away from direct noise sources, vibrations, and obstructions. The area should be categorized based on its land use pattern. Furthermore, when conducting monitoring, it is advised to use a tripod stand placed 1 to 1.5 meters above the ground level, while avoiding handheld monitoring (CPCB, 2015).

C. Measurement of Noise

Noise pollution is generally measured by using Leq, the equivalent continuous noise level expressed in dB(A), which is the average rate at which sound is received by the human ear during the period mentioned (Marale et al., 2011). This method is favored to represent sound levels that fluctuate over time. It provides a single decibel value that considers the total sound energy throughout the specific period of interest. When measuring noise levels, it is customary to utilize the A-weighting setting available in sound level meters. In such instances, the appropriate term for the measurement is LAeq, and the results should be expressed accordingly, such as LAeq = 73 dB or Leq = 73 dBA. Following equation was used to express the factors while calculating the Leq (CPCB, 2016):

$$Leq = 10 \log \Sigma(10)^{(Li/10)} \times (ti/tt) \quad (1)$$

Where, n = number of sound samples, Li = The noise level of any ith sample, ti = time duration of ith sample, tt = total time period of event.

D. Use of GIS for Interpolation using IDW

Geographic Information System (GIS) is a valuable tool in noise pollution mapping as it allows for the integration, visualization, and analysis of spatial data related to noise levels and their sources. A study conducted by Gheibi et al. (2022), employed software-based mapping approach to model and map the levels of noise pollution. The Inverse Distance Weighting (IDW) method is a technique used for mapping the noise and to create map by interpolation (Harman et al., 2016). It calculates the noise value at a specific point (N_0) using the following formula:

$$N_0 = \Sigma(Ni \times Pi) / \Sigma(Pi) \quad (2)$$

The formula for calculating the noise value at position i (Ni) in the IDW method takes into account the number of measurement points (n), the weight of the noise value at position i (Pi), and the distance between the reference point and the interpolation point.

According to the World Health Organization, nearly 50% of persons aged 12–35 years could be exposed to unsafe levels of sound from the use of personal audio devices. Around 40% of persons in that age range could be exposed to potentially damaging levels of sound at entertainment venues (cdc.gov, 2018). Noise mapping assesses urban noise, aids in planning mitigation measures, and presents the environmental scenario through contour-based maps (Chauhan et al., 2023).

E. Laws and Legislations Regarding Noise

The Central Pollution Control Board (CPCB) in India has established guidelines and standards for noise pollution. These standards aim to protect public health and the environment from excessive noise levels.

Table 1 CPCB Ambient Air Quality Standards in Respect of Noise

Area code	Category of area zone	Limits in dB(A) Leq Day time	Limits in dB(A) Leq Night time
A	Industrial	75	70
B	Commercial	65	55
C	Residential	55	45
D	Silence	50	40

Note: 1. Day time shall mean from 06:00 AM to 10:00 PM. 2. Night time shall mean from 10:00 PM to 06:00 AM.

F. Relationship Between Noise and Human Interaction

Noise adversely affects human health, leading to hearing loss, stress, high blood pressure, sleep disturbances, reduced productivity, and a decline in quality of life. Quantifying the effects is challenging due to varying tolerance levels and the diverse nature of noise sources (Singh & Davar, 2004). Sensitivity to different frequencies varies among individuals, with a decrease in sensitivity to higher frequencies observed with age and exposure to noise. As noise exposure can come from various sources at different times, it is common to measure the average sound pressure level over a specific time period (Nongkynrih et al., 2014).

IV. RESULTS AND DISCUSSION

A. Noise Pollution near Public Transportation Centres

By georeferencing noise source locations, such as highways, airports, or industrial sites, GIS allows for the visualization of noise distribution and helps identify the main contributors to noise pollution.

B. Noise Pollution Status in Industrial Zone

From the provided noise pollution readings in the residential, commercial, and industrial zones of Solapur city, it is evident that noise levels vary significantly across different areas and time periods. Residential zones generally exhibit lower noise levels compared to commercial and industrial zones, indicating a potential impact on the quality of life for residents. According to the analysis, industrial zones exhibited a daytime noise level of 84.88 dB and a nighttime level of 47.6 dB. Of the collected 25 sampling points in the industrial zone, only 2 locations (4%) had values under the daytime limits and 22 locations (88%) follow the nighttime limits.

C. Noise Condition of Residential Zone

Based on the provided noise pollution readings in the residential zones of Solapur city, it can be concluded that there is significant variation in noise levels across different areas. Some areas, such as Police Colony and State Bank Colony, exhibit relatively lower noise levels both during the daytime and nighttime. The analysis showed that residential zones had a daytime noise level of 64.86 dB and a nighttime noise level of 46.74 dB. Among the 25 sampling points in the residential zone, only 7 locations (28%) had daytime noise levels within the prescribed limits, while 11 locations (44%) complied with the nighttime standards.

D. Noise Condition of Commercial Zone

The noise pollution readings in Solapur city's commercial zones reveal some key findings. Areas such as the Railway Station, Ranghabhavan Chowk, Vijapurves Chowk, and Bijapur Highway consistently experience high noise levels exceeding 100 dB(A).

Conversely, locations like Zila Parishad exhibit relatively lower noise levels. Street-level sound emerges as a significant contributor to the urban environment's auditory landscape (McAlexander et al., 2015). Noise levels in commercial zones were found to be significantly higher, with daytime measurements reaching 91.36 dB and nighttime measurements reaching 78.56 dB. Of the 25 sampling points in the commercial zone, only 1 location (4%) had values under the daytime limits and 2 locations (8%) follow the nighttime limits.

E. Noise Condition of Silence Zone

Based on the data, the noise levels vary across different locations in Solapur city. Some places, such as Solapur Court and Solapur University, have relatively lower noise levels. On the other hand, places like Civil Hospital and Markendary Hospital exhibit higher noise levels. Among the 25 sampling points at the silence zone, only 4 locations (16%) had values under the daytime limits and 2 locations (8%) follow the nighttime limits as guided by CPCB. The silence zones showed an average daytime noise level of 67.74 dB and a nighttime level of 61.75 dB.

F. GIS-Based Analysis and Chart Representation

Table 2 Industrial Zone Locations used for Monitoring of Noise

Sr.	Location	Day Lmax	Day Lmin	Day Leq	Day Limit?	Night Lmax	Night Lmin	Night Leq	Night Limit?
1	A.N Bhimanath	101	85	93	No	57	48	52.5	Yes
2	Pogul Textile	107	82	94.5	No	60	40	50	Yes
3	Pulgam Textile	112	100	106	No	68	39	53.5	Yes
4	Dhoddi Textile	103	75	89	No	69	40	54.5	Yes
5	Garuda Textile	100	75	87.5	No	58	32	45	Yes
6	Laxminarayan Textile	101	72	86.5	No	55	35	45	Yes
7	Nalla Textile	95	78	86.5	No	56	30	43	Yes
8	Udagiri Textile	97	65	81	No	48	29	38.5	Yes
9	Kondyal Mile	93	68	80.5	No	42	25	33.5	Yes
10	M.K Gullapalli Textile	108	60	84	No	40	31	35.5	Yes
11	Purati Textile	101	86	93.5	No	38	22	30	Yes
12	M.N Bhairi	85	85	85	No	58	29	43.5	Yes
13	Basutkar Industry	101	85	93	No	50	30	40	Yes
14	Gurram Textile	97	65	81	No	52	28	40	Yes
15	V.M Bhairi	93	75	84	No	40	25	32.5	Yes
16	Kshirsagar Textile	85	60	72.5	Yes	39	23	31	Yes
17	Durga Textile	11	57	34	Yes	40	29	34.5	Yes
18	Vipul Textile	103	58	80.5	No	39	23	31	Yes
19	Shrinath Industry	93	73	83	No	40	25	32.5	Yes
20	Rajshri Industry	85	72	78.5	No	69	47	58	Yes
21	Shrujan Food	101	85	93	No	41	52	63	Yes
22	Precision	107	75	91	No	63	74	85	No
23	Tharmax	106	85	95.5	No	58	68	78	No
24	Ambey	85	65	75	No	41	53	65	Yes
25	Balaji Chemical	110	78	94	No	49	62	75	No

Table 3 Locations in Commercial Zones used for Monitoring of Noise

Sr.	Location	Day Lmax	Day Lmin	Day Leq	Day Limit?	Night Lmax	Night Lmin	Night Leq	Night Limit?
1	Railway Station	112	90	101	No	124	62	112.5	No
2	Bus Stand	112	85	98.5	No	95	35	78.5	No
3	Zila Parishad	65	41	53	Yes	55	25	45	Yes
4	SMC	65	35	100	No	49	97	74	No
5	Ranghabhavan Chowk	120	103	112	No	107	91	102	No
6	Sathrasta Chowk	98	71	84.5	No	106	83	98.5	No

Sr.	Location	Day Lmax	Day Lmin	Day Leq	Day Limit?	Night Lmax	Night Lmin	Night Leq	Night Limit?
7	Vijapurves Chowk	124	107	116	No	102	63	92.5	No
8	Saiful Chowk	97	69	83	No	85	59	74	No
9	Jule Solapur Chowk	91	62	76.5	No	76	72	67.5	No
10	Gandhi Nagar Chowk	102	85	93.5	No	98	67	85	No
11	70Fit Road Chowk	100	89	94.5	No	85	70	76	No
12	Ashok Chowk	95	77	86	No	89	74	79.5	No
13	Akkalkot Road Chowk	111	95	103	No	92	87	83	No
14	Hyderabad Highway	114	101	108	No	103	73	95	No
15	Pune Highway	112	95	104	No	95	82	84	No
16	Aurangabad Highway	109	95	102	No	100	87	91	No
17	Bijapur Highway	115	103	109	No	101	41	94	No
18	Laxmi Market	100	75	87.5	No	65	55	53	Yes
19	Kasturba Market	85	65	75	No	75	49	65	No
20	Market Yard	115	95	105	No	68	58	58.5	No
21	D-Mart	98	71	84.5	No	89	64	73.5	No
22	Oasis Mall	95	69	82	No	97	53	80.5	No
23	Reliance Market	85	62	73.5	No	72	66	62.5	No
24	Sai Super Market	93	65	79	No	85	52	75.5	No
25	Big Bazar	87	59	73	No	75	101	63.5	No

Table 4 Locations in Residential Zone used for Monitoring of Noise

Sr.	Location	Day Lmax	Day Lmin	Day Leq	Day Limit?	Night Lmax	Night Lmin	Night Leq	Night Limit?
1	Dafrin Chowk Colony	72	52	62	No	31	22	26.5	Yes
2	Mantri C. Colony	62	39	50.5	Yes	33	19	26	Yes
3	State Bank Colony	50	36	43	No	29	19	24	Yes
4	Police Colony	41	23	32	Yes	22	12	17	Yes
5	Karnik Nagar	64	32	48	Yes	24	14	19	Yes
6	Ravivar Peth	65	35	50	Yes	25	19	22	Yes
7	Chate Galli	79	59	69	No	39	24	32	Yes
8	Mahaveer Chowk	62	39	51	Yes	33	19	26	Yes
9	Platinum Apartment	45	27	36	Yes	29	17	23	Yes
10	Jule Solapur	57	33	45	Yes	21	15	18	Yes
11	Vasant Vihar	85	63	74	No	72	45	59	No
12	Avanti Nagar	70	60	65	No	72	57	65	No
13	Shelgi Colony	72	62	67	No	83	65	74	No
14	Damani Nagar	72	59	66	No	65	42	54	No
15	Gandhi Nagar	101	85	93	No	98	79	89	No
16	K.Thobade Nagar	102	85	94	No	95	70	83	No
17	Rajaswa Nagar	89	62	76	No	78	55	67	No
18	Sakhar Peth	78	65	72	No	89	71	80	No
19	Bhavani Peth	69	43	56	No	57	39	48	No
20	Navi Peth	89	55	72	No	95	65	80	No
21	Mallikarjun Nagar	73	62	68	No	71	55	63	No
22	Antrolokar Nagar	97	70	84	No	62	29	46	No

Sr.	Location	Day Lmax	Day Lmin	Day Leq	Day Limit?	Night Lmax	Night Lmin	Night Leq	Night Limit?
23	Shivaji Nagar	95	96	96	No	62	35	49	No
24	Railway Line	98	67	83	No	65	27	46	No
25	Pratik Nagar	79	59	69	No	39	24	32	Yes

Table 5 Locations in Silence Zone used for Monitoring of Noise

Sr.	Location	Day Lmax	Day Lmin	Day Leq	Day Limit?	Night Lmax	Night Lmin	Night Leq	Night Limit?
1	Solapur Court	45	21	33	Yes	37	21	29	Yes
2	Haribhai Devkaran	95	72	83.5	No	81	63	72	No
3	Dhnyanprabhodhni	85	63	74	No	77	60	68.5	No
4	Diagambher Jain Guruk	66	38	52	No	70	55	62.5	No
5	Shinde High School	85	60	72.5	No	85	63	74	No
6	Saraswati High School	82	63	72.5	No	85	65	75	No
7	Shiddheswar School	89	71	80	No	93	75	84	No
8	Social School	65	32	48.5	Yes	75	55	65	No
9	Asava High School	82	67	74.5	No	87	72	79.5	No
10	Kuchan Prashala	72	62	67	No	83	65	74	No
11	Narayanrao Pri School	82	69	75.5	No	70	43	56.5	No
12	Vidyanikaten School	95	72	83.5	No	89	62	75.5	No
13	Markandey School	75	49	62	No	68	37	52.5	No
14	S.V.C.S High School	75	45	60	No	67	41	54	No
15	K.L.E. School	85	62	73.5	No	74	59	66.5	No
16	Mangalvedekar College	73	62	67.5	No	87	55	71	No
17	Shivaji Night College	75	49	62	No	63	51	57	No
18	Social College	72	51	61.5	No	69	40	54.5	No
19	Government Polytech	59	39	49	Yes	64	52	58	No
20	Solapur University	55	35	45	Yes	52	25	38.5	Yes
21	Chidgupkar Hospital	75	55	65	No	69	35	52	No
22	Markendary Hospital	95	70	82.5	No	61	47	54	No
23	Unique Hospital	85	63	74	No	62	39	50.5	No
24	Yashodhara	95	69	82	No	67	45	56	No
25	Civil Hospital	101	85	93	No	72	57	64.5	No

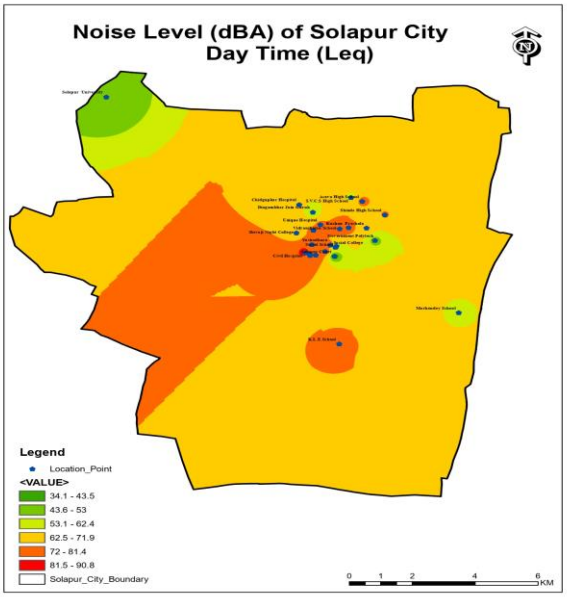

Fig. 3 GIS-based noise pollution map of Solapur city

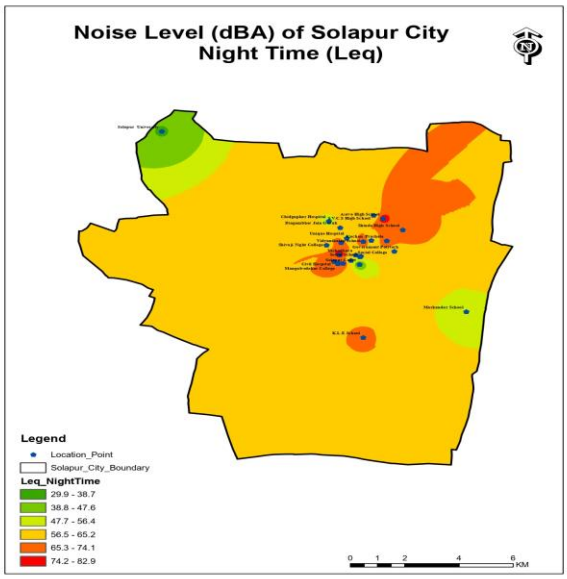

Fig. 4 GIS-based noise distribution map

V. CONCLUSION

Noise pollution mapping helps in identifying problem areas, informing urban planning decisions, implementing noise control regulations, and taking steps to minimize the adverse effects of excessive noise on human health and well-being. GIS can assist in mapping and characterizing noise sources within a given area. To mitigate noise pollution and improve the overall acoustic quality of the city, new public awareness and traffic management could be essential approaches to create a silent, ambient noise-free environment.

DECLARATIONS

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