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Technical Note

Traffic Noise and its Impact on Wellness of the Residents in Sambalpur City – a Critical Analysis

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Noise is unwanted sound judged to be unpleasant, loud or disruptive to hearing. Like air pollution, noise pollution is one of the serious matters of concern in urban areas. Noise pollution occurs when noise level exceeds certain limit and has deleterious effects on human health and wellness. The major sources of noise pollution are industries, road traffic, railways, airplane traffic and social celebrations. The traffic noise is notably high in cities due to higher density of population, frequent movement of people, good transport system coupled with increasing numbers of vehicles (on road). In this work, the assessments of traffic noise in Sambalpur city is presented. Twelve important locations were chosen for the assessment. Noise contours were drawn to visualize the spreading of traffic noise into its surroundings. At the same time, the effect of noise pollution on wellness of the exposed people was studied. The study shows that the traffic noise level and its effects, are both in an alarming stage in the city.

Keywords: traffic noise; equivalent continuous noise level; annoyance; wellness; noise exposure index.

1. Introduction

Noise is unwanted sound judged to be unpleasant, loud or disruptive to hearing. Noise pollution occurs when noise level exceeds certain limit and has deleterious effects on human health and environmental quality in eco system. The sources of noise pollution are industries, road traffic, railways, airplane traffic, social celebrations and many more (Singh, Davar, 2004). In cities, because of higher density of population, good transport system and increasing numbers of vehicles (on road) enhance the traffic noise level. Nowadays, traffic noise has a big share in noise pollution in cities and affects the normal life of inhabitants.

Sambalpur is one of the oldest cities in India. It is the Western Odisha region's administrative, commercial and educational hub. Gangadhar Meher College/University, Indian Institute of Management Sambalpur and Odisha State Open University (OSOU), The Sambalpur University, Veer Surendra Sai Institute of Medical Sciences and Research (VIMSAR), Veer Surendra Sai University of Technology (VSSUT) are the premier educational institutes in the city. Sambalpur has a well networked transport facilities for commercial and public transportation. It is connected to the rest of Odisha and India by national highway-6 (NH-6)/Economic Corridor 1 (EC1), which is a part of Asian Highway-AH46 (Mumbai-Kolkata Highway).

NH 55 connects the city with Bhubaneswar, capital of Odisha. It is also in a close proximity to Raipur (i.e. capital of Chhattisgarh). The development of road infrastructure of the city increases to accommodate the needs of growing populations and results into rise of traffic volume and traffic noise.

2. Literature review

More than half of the world's population lives in urban areas. In India, one third of population is urban residents. Living in an urban area can be culturally and economically beneficial, since it can provide greater opportunities for access to the employment, better education, housing, and safety conditions, and reduce the time and expense of commuting and transportation. Among all sources, traffic noise is a major source of noise in urban areas. The traffic noise is one of the most widespread sources of environmental stress in the daily lives. In cities, the noise due to traffic possesses lion's share of the total noise generated and has an undesirable physiological and psychological impact on human health (Basner, McGuire, 2018; Guski *et al.*, 2017; Marks, Griefahn, 2007; Stansfeld, Matheson, 2003). The impacts of traffic noise on human life are: annoyances, irritation, sleeplessness, low work performance, hearing disability, impaired cognitive ability, etc. (Dzhambov, 2015; Stansfeld *et al.*, 2000; Jakovljević *et al.*, 2006; Okokon *et al.*, 2015; Muzet, 2007). Also, hypertension and cardiovascular problems appears due to traffic noise (Vienneau *et al.*, 2015; Bluhm *et al.*, 2007; Münzel, Sørensen, 2017). Nowadays, dealing with the menace of noise is a big challenge for the environmentalists and scientists.

Park *et al.* (2018) stated that the traffic noise has adverse health effects (like highly-annoyed and highly-sleep-disturbed) on exposed population of the Korean city, Gwangju. In (Zannin *et al.*, 2003), it was found that 20% of respondents suffers from insomnia and headaches due to traffic noise in Brazilian city. Another traffic noise and health study conducted in Jaipur city reported that about 52% of population was suffering from frequent irritation, 46% respondent felt hypertension, and 48.6% observed loss of sleep due to noise pollution (Agarwal, Swami, 2011). The traffic noise levels in Jaipur are higher (range 73–86 dB) compared to the permissible values (65 dB). A study conducted in Netherland showed that the annoyance due to noise was highly correlated with traffic noise level and noise indices: day-night level (DNL) and day-evening-night level (DENL) (Miedema, Oudshoorn, 2001). Regardless of air pollution, exposure to traffic noise is considered as an important environmental factor having a significant impact on health in Madrid City (Spain) (Tobías *et al.*, 2015).

Although, Sambalpur is a premier and growing city with national and international standards of organizations, no work on traffic noise analysis and its effects has been carried out in so far. The present works e focuses on the analysis of traffic noise and its impact on wellness of the residents of the city.

3. Methodology and experimentation

3.1. Location of study

This experimental work attempts to analyze the traffic noise pollution and its impact on residents in Sambalpur city. The geographic and demographic data about Samablpur city is mentioned in Table 1. Twelve important traffic locations of Sambalpur city were considered for analysis of the noise level. These locations were chosen on the basis of the categories of specific areas: silence area, residential area, commercial area and commercial area (on National Highway, NH). The locations are shown in Fig. 1. Zilla School, GM College, District Hospital are silence areas, Budharaja, Modipara, Dhanupali are residential areas. Similarly, Laxmi Talkies Chak, Gole bazaar, Kacheri Road are commercial areas, and Ainthapali Chak, Bareipali Chak, Remed Chak are commercial areas on NH. The classifications of locations are mentioned in Table 2. Noise level limits recommended by the Central Pollution Control Board (CPCB, India) for different areas during working hours and in night hours are shown in same table.

Table 1. Demographic of Sambalpur city.

Sl. No.	Parameters	Values
1	Populations (2011 Census)	3.36 lakhs
2	Geographical area [km^2]	55.0
3	Latitude/Longitude	21° 0.27′ N/83° 0.58′ E

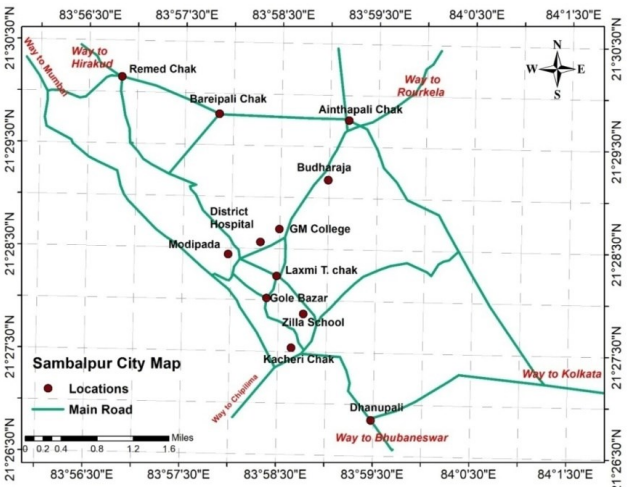

Fig. 1. Road network of Sambalpur city and important traffic locations.

Table 2. Locations and the respective zones.

S.N	Locations	Features/areas	CPCB Standards L_{eq} [dB(A)]	
			Working hours (6 am – 10 pm)	Night hours (10 pm – 06 am)
01	Zilla School, GM University, District Hospital	Silent	50	40
02	Budharaja, Modipara, Dhanupali	Residential	55	45
03	Laxmi Talkies Chak, Gole Bazaar, Kacheri Road	Commercial	65	55
04	Ainthapali Chak, Bareipali Chak, Remed Chak	Commercial (on National Highway)	65	55

3.2. Instrumentation and methodology

The sound level meter (SLM)-cum-analyzer (B, K make) was used to take the observations of noise level. The analyzer was calibrated before measurements. Noise levels (L_{10}, L_{50}, L_{90}, L_{eq}) were measured on A-weighing scale. Readings were taken at 2.5 meters distance from the kerb of road and 1.2 meter above the road level. The observations were taken in the day when there was no rainfall. The measurements of traffic noise level were made at twelve different locations. The observations were taken from March to April 2019. All readings were taken on hourly basis in all working days. The whole day was divided into three different timings: day hours (6 am – 6 pm), evening hours (6 pm – 10 pm) and night hours (10 pm – 6 am). Along with the noise level measurement, wellnesses of people (i.e. annoyance, loss of concentration and forgetfulness, low work performance and fatigue, loss of sleep and headache) was studied. The opinions/data were collected from the people in different locations and further processed for statistical analysis.

Percentile values as L_{10}, L_{50}, L_{90} were assessed from the experimental data and used for evaluation by using equations of noise climate (NC), noise pollution level (L_{np}) and noise exposure index (NEI) by using following equations:

$$\text{Noise climate (NC)} = L_{10} - L_{90}, \tag{1}$$

$$\text{Noise pollution level } (L_{np}) = L_{eq} + \text{NC}, \tag{2}$$

$$\text{Noise exposure index (NEI)} = \frac{l_1}{L_1}, \tag{3}$$

where l_1 is actual exposure sound level, and L_1 is permissible sound level as per guideline given by the country or as per local laws.

Equivalent noise for day hours, evening hours and night hours is calculated by using the formula:

$$L_{eq} = 10 \log_{10} \left(\frac{1}{T} \sum 10^{(0.1) L_i T_i} \right), \tag{4}$$

where L_i is equivalent noise in the hour T_i, and T is time in hours of the calculation period. L_{10} is the level of sound exceeding for 10% of total time of measurement, L_{50} is the level of sound exceeding 50% of total time of measurement; L_{90} is the level of sound exceeding 90% of total time of measurement.

A wellness survey on traffic noise impact was carried out at all study locations. Present status of wellness due to noise was studied by the method of questionnaire and personal interviews. People of different gender, different occupation, different education and different age groups participated in the survey. Out of total 3780 people, 2538 people were interviewed and 1242 people were assessed through questionnaires. The questionnaires consisted of two parts. The first part related to their personal information and second part related to the effect of noise on their physiological and psychological well beings.

4. Results and discussions

The results and discussion of the present work mainly consists of the following:

(i) Assessment of equivalent continuous noise level (L_{eq}) at different locations.
(ii) Evaluation of NEI and L_{np} at different locations.
(iii) Noise mapping of the town during different timing.
(iv) Wellness study of population exposed to traffic noise.

4.1. Assessment of L_{eq} at different locations

At all locations, the L_{eq} (for each hour) are presented in Table 3 (6 am – 6 pm) and in Table 4 (6 pm – 6 am), separately. The timing *versus* corresponding L_{eq} graphs for each areas are plotted. Those are shown in Figs 2 to 9. The traffic volume and its structure at different locations are shown in Table 5. It is observed that the traffic volume (at all locations) is at peak during 10.00–11.00 am as the state government offices, schools, shopping malls and other commercial offices begin working from 10.30 am.

The noise levels at all locations of silent areas during day hours and evening-night hours are shown in Figs 2 and 3, respectively. During day hours and evening hours, noise level at each location exceeds the prescribed limit. It was observed that in educational institutes i.e. the Zilla School and GM College, the

Table 3. Hourly L_{eq} at different location during day hours.

Locations	L_{eq} [dB]											
	6–7 am	7–8 am	8–9 am	9–10 am	10–11 am	11–12 noon	12–1 pm	1–2 pm	2–3 pm	3–4 pm	4–5 pm	5–6 pm
Zilla School	64.1	68.4	72.2	74.4	76.1	74.9	74.6	73.2	70.3	69.2	72.5	74.6
GM College	65.6	72.4	75.2	78.1	79.2	77.9	77.1	73.2	72.8	71.7	76.7	77.2
District Hospital	61.3	68.9	71.8	74.1	75.2	73.9	73.1	70.2	68.8	67.7	72.7	75.4
Budharaja	62.2	68.3	72.7	73.8	76.8	75.9	75.6	71.6	70.8	68.7	72.1	73.5
Modipada	63.2	72.4	76.1	78.2	78.8	77.9	77.1	74.2	72.8	70.7	74.3	75.9
Dhanupali	64.5	69.2	73.3	75.4	76.1	75.7	75.1	74.3	71.6	70.2	73.2	74.1
Laxmi T. Chak	66.1	72.5	75.3	77.2	78.8	78.6	77.1	73.2	71.8	70.7	73.1	74.5
Gole Bazar	62.5	71.1	74.4	76.2	75.8	74.9	74.1	71.2	70.2	68.7	71.1	73.2
Kacheri Chak	63.2	67.1	70.5	74.3	75.2	74.5	73.2	72.7	71.3	69.1	72.7	73.2
Ainthapali Chak	72.4	75.3	78.5	79.2	80.5	80.2	79.4	78.3	75.2	73.2	75.5	77.5
Bareipali Chak	69.1	72.4	75.2	76.3	77.2	76.1	75.3	74.2	73.5	70.1	72.1	73.2
Remed Chak	70.3	73.5	76.2	77.4	78.3	77.5	76.3	75.2	74.5	71.4	72.1	73.2

Table 4. Hourly L_{eq} at different location during evening-night hours.

Locations	L_{eq} [dB]											
	6–7 am	7–8 am	8–9 am	9–10 am	10–11 am	11–12 noon	12–1 pm	1–2 pm	2–3 pm	3–4 pm	4–5 pm	5–6 pm
Zilla School	73.8	73.7	72.2	69.1	65.3	59.7	51.4	47.1	44.1	42.3	47.4	58.3
GM College	75.3	74.5	73.3	71.1	67.2	62.1	50.3	46.5	44.2	43.7	47.3	56.8
District Hospital	72.6	71.2	70.4	68.2	64.4	59.5	49.3	43.2	42.5	43.1	46.3	55.2
Budharaja	74.5	73.1	72.5	70.6	67.2	62.4	51.2	46.2	45.4	43.4	47.2	57.1
Modipada	75.2	75.4	74.5	71.2	67.2	62.3	50.2	45.2	44.3	42.2	46.2	55.3
Dhanupali	73.3	72.7	71.2	68.2	65.1	60.2	51.1	47.2	47.1	44.3	48.7	58.5
Laxmi T. Chak	75.5	74.4	74.2	71.3	67.4	62.1	51.1	46.2	45.4	43.1	47.1	57.8
Gole Bazar	73.8	73.6	72.6	70.2	64.1	59.2	50.4	44.2	43.2	42.2	44.2	56.1
Kacheri Chak	73.1	72.4	71.4	68.6	64.4	58.5	49.2	46.1	43.9	41.7	46.2	56.1
Ainthapali Chak	78.2	76.8	75.5	74.2	72.5	71.5	68.1	65.2	63.9	63.2	64.1	70.4
Bareipali Chak	74.2	73.1	71.4	70.8	70.1	68.5	65.3	62.3	61.8	61.2	61.1	68.2
Remed Chak	75.4	73.9	72.4	71.2	70.1	69.5	66.2	63.1	62.8	62.2	62.1	68.2

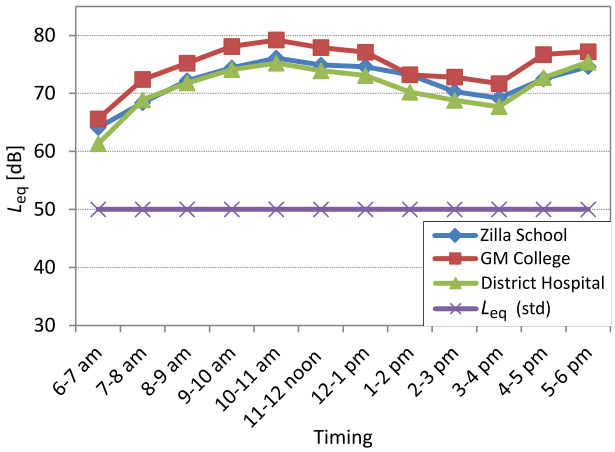

Fig. 2. L_{eq} at different locations (of silent area) during day hours.

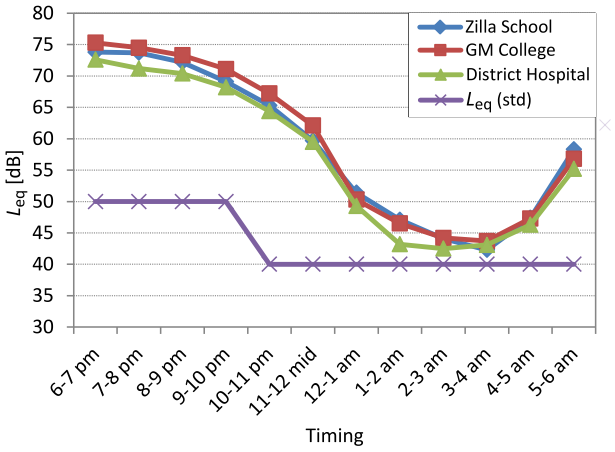

Fig. 3. L_{eq} at different locations (of silent area) during evening-night hours.

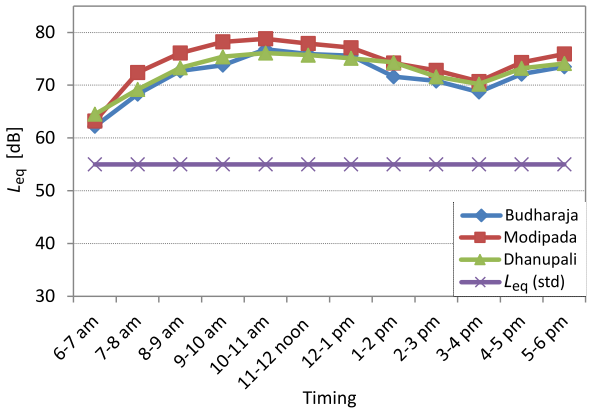

Fig. 4. L_{eq} at different locations (of residential area) during day hours.

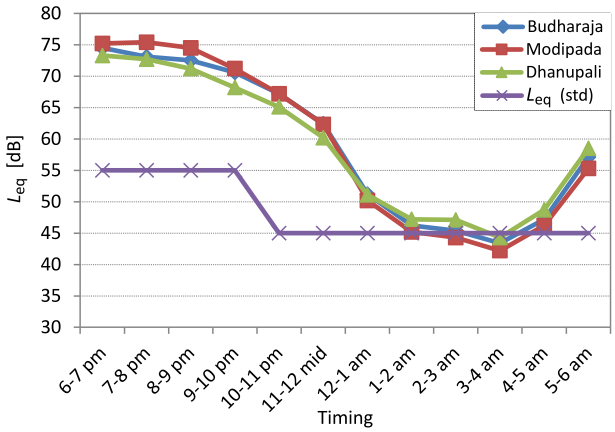

Fig. 5. L_{eq} at different locations (of residential area) during evening-night hours.

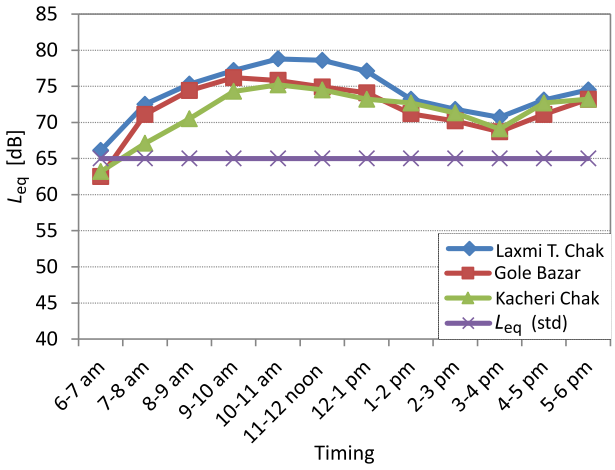

Fig. 6. L_{eq} at different locations (of commercial area) during day hours.

noise level was so high that it affected the concentration of the c students. During night hours, though the noise levels was marginally higher than prescribed limit and the difference was very small, i.e. between 1 am and 5 am.

The noise levels at all locations of residential areas during day hours and evening-night hours are shown

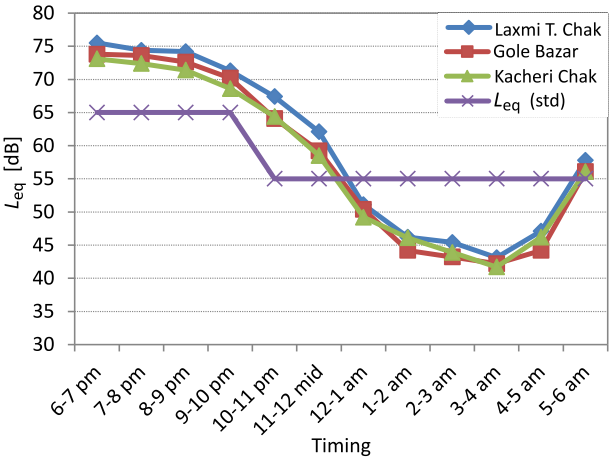

Fig. 7. L_{eq} at different locations (of commercial area) during evening-night hours.

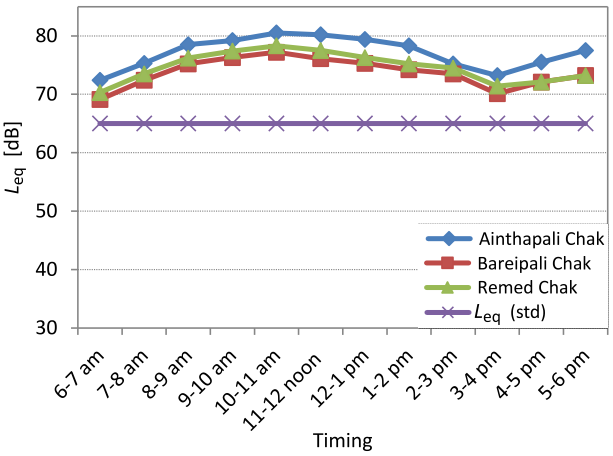

Fig. 8. L_{eq} at different locations (of commercial area on NH) during day hours.

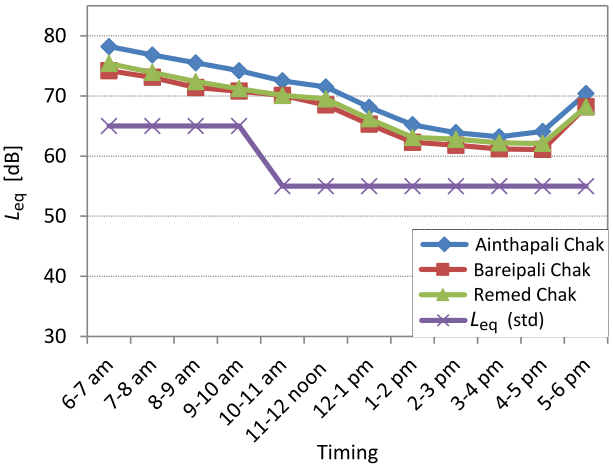

Fig. 9. L_{eq} at different locations (of commercial area on NH) during eve-night hours.

in Figs 4 and 5, respectively. During day hours and evening hours, the noise level at each location exceeded the prescribed limit. It was observed that the people residing in these areas were annoyed and distracted.

Table 5. Traffic volume and its structure at different location*.

SN	Locations	Traffic volume during peak hours (HV + LV + MC)	Corresponding peak hour	Average (hourly) traffic volume during day–evening hours (HV + LV + MC)
1	Zilla School	6 + 474 + 756	10.00–11.00 am	8 + 284 + 505
2	GM College	8 + 432 + 570	10.00–11.00 am	6 + 210 + 386
3	District Hospital	2 + 312 + 430	10.00–11.00 am	3 + 180 + 312
4	Budharaja	18 + 600 + 1306	10.00–11.00 am	16 + 340 + 785
5	Modipada	4 + 302 + 538	10.00–11.00 am	4 + 185 + 362
6	Dhanupali	36 + 198 + 460	10.00–11.00 am	38 + 120 + 286
7	Laxmi T. Chak	6 + 522 + 780	10.00–11.00 am	8 + 360 + 520
8	Gole Bazar	0 + 132 + 626	10.00–11.00 am	1 + 96 + 430
9	Kacheri Chak	14 + 216 + 640	10.00–11.00 am	12 + 166 + 454
10	Ainthapali Chak	188 + 368 + 492	10.00–11.00 am	185 + 340 + 374
11	Bareipali Chak	124 + 310 + 366	10.00–11.00 am	130 + 232 + 288
12	Remed Chak	138 + 280 + 310	10.00–11.00 am	150 + 212 + 245

* HV – number of heavy vehicles, LV – number of light vehicles, and MC – number of motorcycles.

During night hours, the noise level was below the prescribed limit for few hours. For these few hours, people in these areas could sleep well without being disturbed because of traffic noise.

Figures 6 and 7 show the noise level at all locations of commercial areas during day hours and evening-night hours, respectively. During day hours and evening hours, the noise level at each location ex-

Table 6. Hourly NEI and L_{np} during day hours.

Locations and noise indices		6–7 am	7–8 am	8–9 am	9–10 am	10–11 am	11–12 am	12–1 pm	1–2 pm	2–3 pm	3–4 pm	4–5 pm	5–6 pm
Zilla School	NEI	1.28	1.36	1.44	1.48	1.52	1.49	1.49	1.46	1.4	1.38	1.45	1.49
	L_{np}	88.4	92.7	92.2	93.2	89.8	89.8	92.8	94.5	88.4	87.6	90	92.3
GM College	NEI	1.31	1.44	1.50	1.56	1.58	1.55	1.54	1.46	1.45	1.43	1.53	1.54
	L_{np}	89.4	96.7	96.2	97.2	93.8	93.8	96.8	98.5	92.4	91.6	94	96.3
District Hospital	NEI	1.22	1.37	1.43	1.48	1.50	1.47	1.46	1.40	1.37	1.35	1.45	1.50
	L_{np}	89.1	90.3	90.4	91.2	92.6	90.8	91.7	92.4	91.7	93.2	93.4	91.1
Budharaja	NEI	1.13	1.24	1.32	1.34	1.39	1.38	1.37	1.30	1.28	1.24	1.31	1.33
	L_{np}	89.8	88.8	92.2	96.2	94.6	95.2	95.6	95.2	94.3	95.2	95.2	93.3
Modipara	NEI	1.14	1.31	1.38	1.42	1.43	1.41	1.40	1.34	1.32	1.28	1.35	1.38
	L_{np}	88.6	89.8	90.5	92	92.3	92.5	93.2	93.2	91.3	86.3	88.4	91.5
Dhanupali	NEI	1.17	1.25	1.33	1.37	1.38	1.37	1.36	1.35	1.30	1.27	1.33	1.34
	L_{np}	89.9	90.6	84.4	88.6	92.3	92.9	89.6	86.3	92.2	88.8	89.6	90.8
Laxmi T. Chak	NEI	1.01	1.11	1.15	1.18	1.21	1.20	1.18	1.12	1.10	1.08	1.12	1.14
	L_{np}	91.5	93.4	94.1	96.7	99.5	96.9	98.2	94	95.3	97.1	99.2	96.8
Gole Bazar	NEI	0.96	1.09	1.14	1.17	1.16	1.15	1.14	1.09	1.08	1.05	1.09	1.12
	L_{np}	88.1	92.5	93.8	95.9	96.6	96.2	94.8	94.9	94.5	96.2	94.7	97.2
Kacheri Chak	NEI	0.97	1.03	1.08	1.14	1.15	1.14	1.12	1.11	1.09	1.06	1.11	1.12
	L_{np}	89.4	92.8	93.4	93.8	95.2	95.6	94.8	96.5	91.3	93.1	89.3	88.2
Ainthapali Chak	NEI	1.11	1.15	1.20	1.21	1.23	1.23	1.22	1.20	1.15	1.12	1.16	1.19
	L_{np}	92.3	94.9	98	97.9	98.8	96.4	97.8	95.7	96.2	96.7	99.2	98.2
Bareipali Chak	NEI	1.06	1.11	1.15	1.17	1.18	1.17	1.15	1.14	1.13	1.07	1.10	1.12
	L_{np}	89.8	94.2	94	96.8	97.2	96.7	99.1	97.8	95.6	97.3	96.1	99.2
Remed Chak	NEI	1.08	1.13	1.17	1.19	1.20	1.19	1.17	1.15	1.14	1.09	1.10	1.12
	L_{np}	91.7	93.2	93.6	97.5	95.9	96.3	96.4	97.3	94.2	92.1	95.4	98.4

Table 7. Hourly NEI and L_{np} during evening and night hours.

Locations and noise indices		6–7 pm	7–8 pm	8–9 pm	9–10 pm	10–11 pm	11–12 mid	12–1 am	1–2 am	2–3 am	3–4 am	4–5 am	5–6 am
Zilla School	NEI	1.47	1.47	1.44	1.38	1.63	1.49	1.28	1.17	1.10	1.05	1.18	1.45
	L_{np}	92.2	91.5	89	88.5	83	72.2	67.3	52.2	51.8	50.8	56.7	66.8
GM College	NEI	1.50	1.49	1.46	1.42	1.68	1.55	1.25	1.16	1.10	1.09	1.18	1.42
	L_{np}	92.3	94.2	94.2	92	82.7	77.3	70.4	56.2	52.3	51.4	53.3	64.7
District Hospital	NEI	1.45	1.42	1.40	1.36	1.61	1.48	1.23	1.08	1.06	1.07	1.15	1.38
	L_{np}	91.3	89.9	87.7	83.6	80.8	75.4	71.8	57.9	50.8	50.1	54.4	63.7
Budharaja	NEI	1.35	1.32	1.31	1.28	1.49	1.38	1.13	1.02	1.00	0.96	1.04	1.26
	L_{np}	93.4	92.8	91	88	82.3	72.3	69.2	58.3	52.4	51.8	54.5	67.8
Modipada	NEI	1.36	1.37	1.35	1.29	1.49	1.38	1.11	1.00	0.98	0.93	1.02	1.22
	L_{np}	92.3	93.4	93.1	90.6	82.5	75	69	657	52.2	50.7	58.3	65.1
Dhanupali	NEI	1.33	1.32	1.29	1.24	1.44	1.33	1.13	1.04	1.04	0.98	1.08	1.3
	L_{np}	91.1	89.9	91.2	94.8	87.2	72.2	69.5	58.7	53.7	51.7	55.4	70.8
Laxmi T. Chak	NEI	1.16	1.14	1.14	1.09	1.22	1.12	0.92	0.84	0.82	0.78	0.85	1.05
	L_{np}	90.6	91.2	92.4	90.2	88.4	75.1	70.5	61.3	56.7	55.7	59.8	69.8
Gole Bazar	NEI	1.13	1.13	1.11	1.08	1.16	1.07	0.91	0.80	0.78	0.76	0.80	1.02
	L_{np}	94.8	93	91.6	90.7	86.3	76.4	68.2	58.6	54.8	53.3	55.9	68.4
Kacheri Chak	NEI	1.12	1.11	1.09	1.05	1.17	1.06	0.89	0.83	0.79	0.75	0.84	1.02
	L_{np}	91.8	91	88.6	87.7	83.3	73.4	68.2	55.6	53.8	51.3	55.4	66.4
Ainthapali Chak	NEI	1.20	1.18	1.16	1.14	1.31	1.3	1.23	1.18	1.16	1.14	1.16	1.28
	L_{np}	98.4	96.3	95.2	90	84.5	78.4	75.7	72.8	74.3	75.4	76.8	77.3
Bareipali Chak	NEI	1.14	1.12	1.09	1.08	1.27	1.24	1.18	1.13	1.12	1.11	1.11	1.24
	L_{np}	97.2	97.2	95.2	92.3	86.3	78.2	72.2	74.2	74	73	74.6	77.2
Remed Chak	NEI	1.16	1.13	1.11	1.09	1.27	1.26	1.20	1.14	1.14	1.13	1.12	1.24
	L_{np}	95.7	98.8	99.6	92.3	88.4	79.2	75.2	74.7	71.8	75.7	76.7	773

ceeded the prescribed limit. During night hours, the noise level was below the prescribed limit from midnight till 5 am. Figures 8 and 9 show the noise level at all locations of commercial areas (on NH) during day hours and evening-night hours, respectively. Throughout the day and night, the noise level at each location exceeded the prescribed limit. These locations are on NH-6, which is one of the busiest NH in India, connecting Mumbai to Kolkata. Even, during the night hours, traffic volume (mostly heavy vehicles) is high.

4.2. Evaluation of NEI and L_{np} at different locations

The L_{10}, L_{50} and L_{90} values obtained from the observations were used to calculate the noise pollution indices: NEI and L_{np}. These are presented in Tables 6 and 7.

Tables 6 and 7 show that during day hours and evening hours, at all locations, the value of NEI exceeds 1, which is not desirable and in some cases quite objectionable. It may be the causes of physiological and psychological disturbances. Also, at all locations, L_{np}'s are high, which is the cause of irritation and displeasure.

4.3. Traffic noise mapping of study locations

Equivalent noise levels at different locations during day hours, evening hours and night hours were calculated using the Eq. (4). Here, T is taken as 12 for day hours (6 am – 6 pm), 4 for evening hours (6 pm – 10 pm) and 8 for night hours (10 pm – 6 pm). The L_{eq} for the whole day (i.e. 6 am – 6 am) is treated as L_{dn} and T is 24. The L_{eq} for day hours, evening hours, night hours and for whole day (L_{dn}) are calculated and mentioned in Table 8.

The noise mapping does not only show the noise at particular place but also represents the noise level at adjoining areas. Considering the above data, noise contour maps were drawn (using simulation) to visualize the equivalent noise level at the traffic (and adjoining areas) during day hours, evening hours and night hours separately. These are shown in Figs 10–12, respectively. The noise level at surrounding area shows the spreading of noise if there are no obstacles.

It is observed that Ainthapali chak is the noisiest place inside the city during day, evening and night hours. It is located next to the national highway and in close proximity to a bus stand and it is one of

Table 8. L_{eq} at different locations during day hour, evening hour and night hour.

Locations	L_{eq} [dB] (day hour) 6 am – 6 pm	L_{eq} [dB] (evening hour) 6 pm – 10 pm	L_{eq} [dB] (night hour) 10 pm – 6 am	L_{dn} [dB] (whole day) 6 am – 6 am
Zilla School	73.0	72.6	58.3	71.2
GM College	75.9	73.8	59.8	73.8
District Hospital	72.3	70.9	57.2	70.3
Budharaja	73.0	72.9	60.0	71.4
Modipada	75.6	74.4	59.8	73.6
Dhanupali	73.6	71.7	58.4	71.5
Laxmi T. Chak	75.3	74.1	60.1	73.3
Gole Bazar	73.1	72.8	57.6	71.3
Kacheri Chak	72.4	71.7	57.2	70.5
Ainthapali Chak	77.8	76.4	69.7	76.0
Bareipali Chak	74.3	72.6	67.1	72.5
Remed Chak	75.3	73.5	67.7	73.3

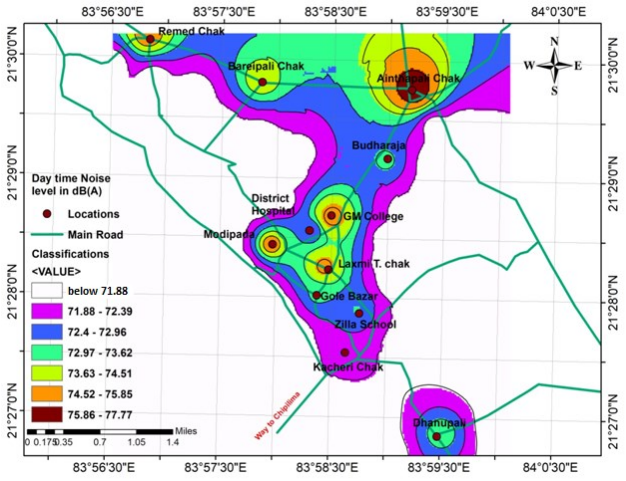

Fig. 10. Noise mapping of the city (due to traffic noise) during day hours.

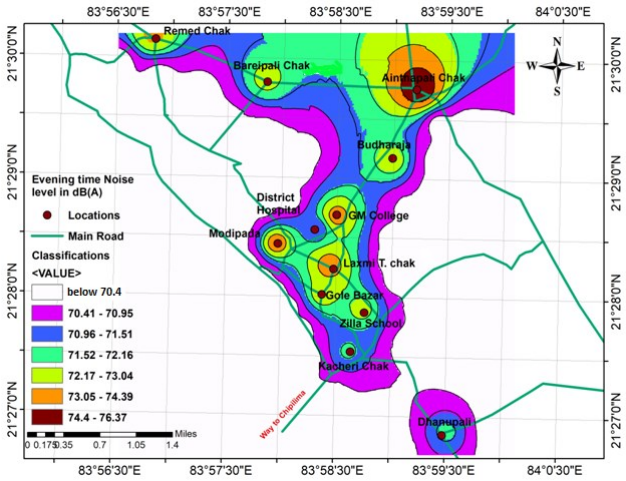

Fig. 11. Noise mapping of the city (due to traffic noise) during evening hours.

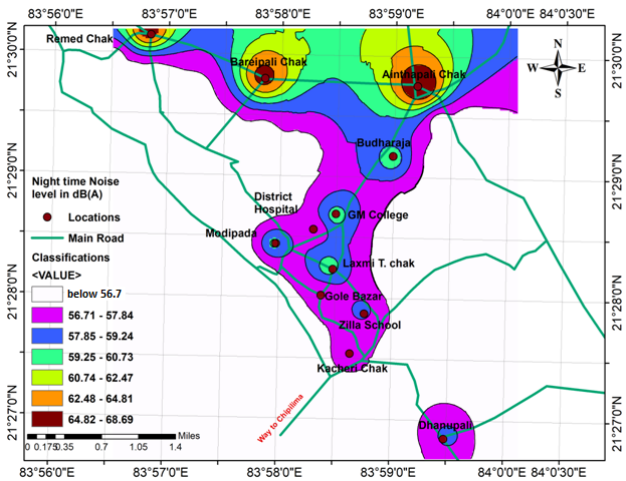

Fig. 12. Noise mapping of the city (due to traffic noise) during night hours.

the entrances to the city. Laxmi Talkies chak is another busy place, but there are less heavy vehicles. So, its noise level is lower in comparision to Ainthapali chak. The noise level at District Hospital is high (and like commercial place) during day and evening hours.

4.4. Socio-health study of exposed population at different locations

The wellness study of exposed population was conducted on four aspects of physiological and psychological wellbeing (i.e. annoyance, loss of concentration, forgetfulness, low work performance, fatigue, loss of sleep, headache) of people exposed to the traffic noise at different locations. People of different gender, different occupation, different education and different age group participated in a survey. Only opinions of par-

Table 9. Socio-health survey of participants at different locations.

Aspects of participants	Participants at different locations											
	1 ZS	2 GM	3 DH	4 BR	5 MP	6 DP	7 LT	8 GB	9 KC	10 AC	11 BC	12 RC
L_{dn} [dB]	71.2	73.8	70.3	71.4	73.6	71.5	73.3	71.3	70.5	76.0	72.5	73.3
% of people highly annoyed	27.5	45.5	26	27.1	43.1	38.8	40.7	27.1	32.3	46	41.4	34.1
% of people suffering from loss of concentration and forgetfulness	29.3	37	23.3	27.1	31.6	32.6	37.5	25.6	22.2	37	30.7	39
% of people suffering from low work performance and fatigue	20	30.1	19.5	25.9	24.2	24.8	30.5	21.9	20.4	30.6	25.1	29.2
% of people suffering from loss of sleep and headaches	18.1	28.2	19.5	16.5	24.2	18.6	27.3	15.5	15.2	26.9	18.1	24.6

ticipants exposed for more than 4 hours a day to traffic noise were analyzed. The opinions and views of participants/respondents are shown in Table 9.

At the time of survey, it is observed that, among all those respondents, mostly the students suffer from loss of concentration and forgetfulness. This is more a case of the students, who travel to school by bus/van regularly. Suffering from low work performance and fatigue affects people who work in various offices, corporate sectors, etc. Loss of sleep afflicts more severely people who spend more time in traffic, e.g. road side shop keepers, salesmen and auto-rickshaw's drivers. Regardless of the type of occupation, all people are annoyed because of the traffic noise.

The noise level and its impact on wellness of inhabitant's is shown in Figs 13 to 16. Figure 13 shows L_{dn} *versus* percentage of highly annoyed people. Similarly, Fig. 14 shows the L_{dn} *versus* percentage of people suffering from loss of concentration, forgetfulness and Fig. 15 shows the L_{dn} *versus* percentage of people suffering low work performance, fatigue. Figure 16 shows the L_{dn} *versus* percentage of people suffering from loss of sleep, headaches.

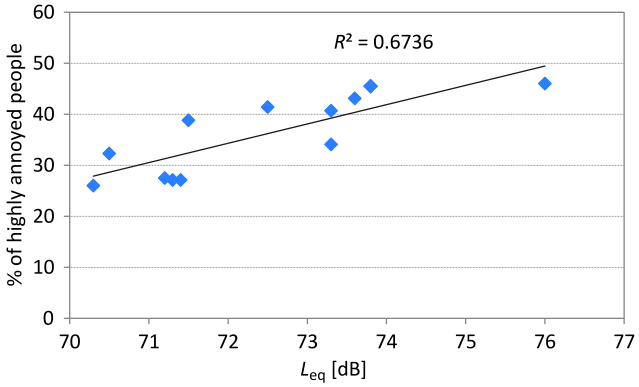

Fig. 13. L_{dn} *versus* percentage of highly annoyed people at different locations.

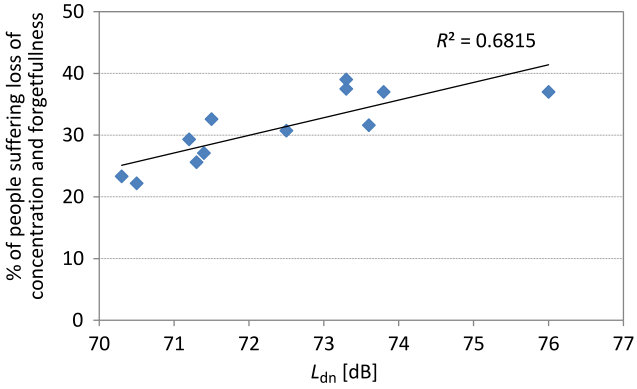

Fig. 14. L_{dn} *versus* percentage of people suffering from loss of concentration and forgetfulness at different locations.

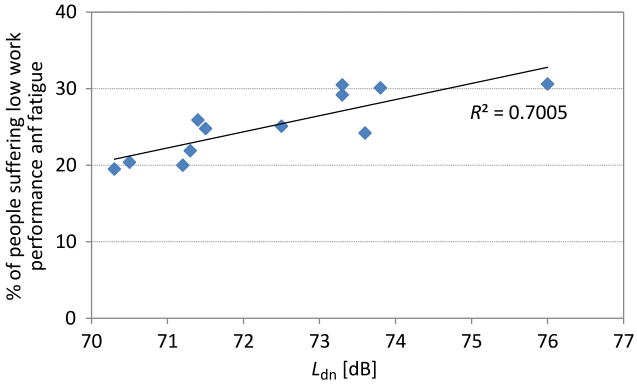

Fig. 15. L_{dn} *versus* percentage of people suffering from low work performance and fatigue at different locations.

As mentioned above, Fig. 13 shows that when L_{dn} increases, the percentage of annoyed person increases. Similarly, Fig. 14 shows that when L_{dn} increases, the percentage of people having loss of concentration and forgetfulness increases. Figure 15 shows the percentage of people experiencing low work performance and fatigue which increases with the increase of L_{dn}. The percentage of people suffering from loss of sleep and

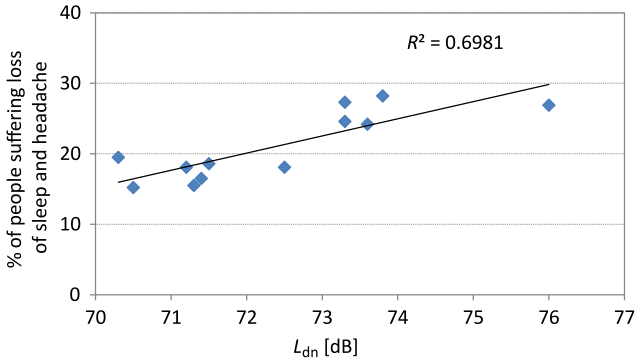

Fig. 16. L_{dn} *versus* percentage of people suffering from loss of sleep and headache at different locations.

headaches increases as L_{dn} increases, which is shown in Fig. 16. The coefficients of correlation (R) for all above cases are 0.82, 0.82, 0.83, and 0.83, respectively. Also, these statistical results show that at 5% confidence level, the t-statistical values (i.e. 4.6, 4.6, 4.8, and 4.8, respectively) are higher than the t-critical (i.e. 1.812). This implies that the correlations are very significant.

Though there are some regulations on noise pollution (like CPCB guideline), Sambalpur city (and local administration) do not pay adequate attention to assess and control the traffic noise. The doctors in a district hospital and other hospitals has expressed the opinion that like air pollution, noise pollution is a serious health hazard in the city. Noise-induced hearing loss (NIHL) is most likely the dominant cause of acquired hearing loss. Exposure to excessive noise and/or for sufficient duration can lead to a loss of hearing sensitivity, termed a threshold shift. That may be temporary or even permanent.

5. Summary

The study reveals that the traffic noise level and its effects have reached an alarming level in the city. The main cause of higher traffic noise is a rapid and unplanned urbanization along with unplanned road network. Improper traffic management also increases the traffic noise. The current experimental study in Sambalpur city draws the following observations:

1) The noise level at all traffic location exceeds the prescribed limit during day hours and evening hours. The exceeding (differential) level is higher at some locations e.g.: District Hospital and GM College.
2) During night hours, at all locations (except silence area), noise level is lower than prescribed limit for few hours and is a little higher than prescribed limit for remaining hours.
3) During day hours, at all locations, the value of NEI is more than one, which is not desirable.
4) At all locations, as the equivalent noise level for whole day (L_{dn}) increases, the number and percentage of annoyed people increases.
5) High traffic noise does not only cause annoyance but also affects the concentration, work performances and sleep comfort of the exposed people.
6) As the L_{dn} increases, the percentage of people suffering from loss of concentration, forgetfulness, low work performance, fatigue, loss of sleep and headaches increases at all locations.
7) Co-efficient of correlation of above cases is high (i.e. more than 0.8) and t-stat value is less than t-critical, which implies that the correlations are very significant.

Researchers in any sphere has a duty to find a path to sustainability. The authors wish to be at service to local administration on mitigation of this threat. Our recommendations are as follow:

(i) Battery auto-rickshaws should be encouraged to replace diesel auto-rickshaw. As diesel auto-rickshaw generates noise level of 100 dB, where battery auto-rickshaw only 80 dB.

(ii) Vehicles emitting high noise should be restricted or diverted.

(iii) At few locations (like education/silence zone), there should be restriction of traffic and these places should be treated as no horn zones.

(iv) Road side plantation of trees,especially in residential districts, should be provided.

(v) Periodic traffic noise monitoring is required.

(vi) Awareness programmes should be conducted by local administration.

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