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Analysis and Appraisal of Urban Road Traffic Noise of the City of Cuttack, India

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Abstract. The road traffic noise environment in the Cuttack city, commercial and judicial capital of the Indian state, Odisha, has been appraised in the present study. Noise pollution was analysed in 17 different squares (road sections) during four different specified times to assess the level of noise pollution of the city. Noise descriptors such as L_{10}, L_{50}, L_{90}, L_{eq}, TNI (traffic noise index), NPL (noise pollution level), NC (noise climate), Q (traffic volume) and P (truck-traffic mix ratio) were analysed to reveal the extent of noise pollution due to heavy traffic in this city. A systematic comparison between TNI and L_{eq} noise levels for all selected locations reveal that the TNI values are much more than respective L_{eq} levels. This simply demonstrates that although the noise levels during any period of the day are generally constant but the presence of single event noise is sufficient to affect the values of L_{10}, L_{50}, L_{90}, L_{eq} and consequently the TNI. Analysis of variance (F-test) is also computed for investigated squares to infer the level of significance. Even the minimum NPL and TNI values are more than 100 dB. Noise levels at all the road sections exceeded the standard ambient noise levels prescribed by WHO (70 dB).

Keywords: community response, Cuttack city, noise descriptors, traffic noise, traffic volume

Introduction

Major contribution to outdoor noise often comes from road transportation and is the main source of pollution. Noise survey in various cities throughout the world have revealed that traffic noise is typically the largest contributor to recorded sound levels and one of the most important sources of annoyance (WHO, 1999). With rapid urbanisation and the corresponding increase in the number of vehicles on roads, the noise pollution is increasing at an alarming rate in most of the important Indian cities. In India, some studies on the traffic noise monitoring have been carried out at different cities like Delhi (Prakash *et al.,* 2006, Nirjar *et al*., 2003; Singh and Jain, 1995; Kumar and Jain, 1994), Mumbai (Naik, 1998), Aurangabad (Bhosale *et al,.* 2010), Amravati (Patil *et al*., 2011), Dehradun (Ziaudin *et al.,* 2007), Lucknow (Kisku *et al*., 2006), Varanasi (Pathak *et al*., 2008, Tripathi *et al*., 2006), Jaipur (Agarwal and Swami, 2009a; 2009b; Agarwal *et al*., 2009; Choudhary *et al*., 2003), Kolkata (Chakraborty *et al.,* 2002), Asansol (Banerjee *et al.,* 2009; 2008; Banerjee and Chakraborty, 2006), Bolpur (Padhy and Padhi, 2008), Burdwan (Datta *et al*., 2006), Visakhapatnam (Rao and Rao, 1992), Chennai (Kalai Selvi and Ramachandraiah, 2009), Thiruvanatapuram, Kochi, Kozhikode (Sampath *et al*., 2004), Jharsuguda (Patel *et al*., 2006), Bhadrak (Goswami, 2011) and Balasore (Goswami, 2011; 2009) etc. The noise levels are showing an alarming rise and in fact, the levels exceed the prescribed levels in most of the areas. In the light of the rapid growth of vehicular population, there is a need to study noise pollution from the transportation point of view. In this study, an attempt has been made to study noise pollution due to vehicular traffic in this commercial city of Odisha state, India. As it is evident that primarily noise problem is the result of growing busy traffic, each year there is an increase in the number of vehicles in this city. This has led to overcrowded roads and pollution around this city. The road traffic noise levels at 17 different squares of this city have been assessed to predict the extent of vehicular noise pollution around the Cuttack, the business capital of Odisha. Total population of Cuttack is 2,618,708. Demographic characteristics of Cuttack (Table 1) explicitly demonstrate that the population is increasing at an alarming rate. An emerging IT hub, the boom in the metals and metal processing industries, around 3 universities, hundreds of colleges have made Cuttack as one of the fastest developing cities of India in recent years. The increase in number of industries, market complexes, institutions, urban highways constructed around residential and community areas of this city, growing population and consequently increase in number of vehicles have inevitably caused major noise pollution

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Table 1. Decadal population trend in the city of Cuttack, India

Year	Population	Male	Female	Population density
1961	3063072	1532583	1530489	278.94
1971	3827678	1927033	1900645	341.42
1981	4628800	2346690	2282110	799.56
1991	1122739	1027747	944992	528
2001	2341094	1207781	1133313	595
2011	2618708	1,339,153	1,279,555	666

Source = District Statistical Handbook, Odisha & Census of Odisha.

problems to city dwellers. Thus, noise level measurements were taken up with emphasis on traffic noise. The study also analysed variation of noise around the squares (road sections) and its relationship with traffic volume.

Materials and Methods

Acoustic study. The present study of noise monitoring was conducted with the help of sound level meter (Model LUTREN, SL-4010). This light weight instrument (wt = 460 g with batteries) is primarily designed for community noise survey. It is calibrated acoustically using an external reference source, which is placed over the microphone. Sound level meter works on the principle of evaluation of sound pressure on a linear or weighted scale. It normally indicates root mean square (rms) value of the sound.

Cuttack city is located at $20^0$05' north latitude and $85^0$38' east longitude and has an average elevation of 36 m. The city is basically situated at the apex of the Mahanadi delta. The geographical area of this city is 3932 sq. km. The noise levels were measured following standard procedure using calibrated sound level (dB) meter in between the month of May and June, 2011 at seventeen important and crowded squares (road sections) of Cuttack (Link road square, Buxi bazar square, College square, Naya bazar square, Chandini Chowk square, OMP square, Chandi mandir square, Sati chaura square, Dolamundai square, Ranihat square, Badambadi square, Mangalabag square, Choudhury bazar square, High court square, Balu bazar square) (Shelter square and Biju Pattanaik square) (Stephenson *et al*., 2011; Al-Ghonamy, 2010; Ghatass, 2009; Ozer *et al*., 2009; Szeremeta and Zannin, 2009; Zannin and Marcon, 2006; Piccolo *et al*., 2005; Yang and Kang, 2005; Yusoff and Ishak, 2005). Link road square and OMP square are located along the National Highway (Kolkata-Chennai: NH-5). All buses go to Bus stop (Badambadi) of the city of Cuttack through Link road square. Buxi bazar, Dolamundai, Ranihat, Mangalabag, Choudhury bazar squares are all commercial areas of the city and are located in the heart of the old Cuttack. College square is located near Ravenshaw university and Cuttack railway station. High court square is located near High court and office of the district administration. Famous temples of this city are located along the Chandini chowk, Chandi mandir, Dolamundai and Ranihat squares. The major residential colonies are located near Naya bazar, Sati chaura, Balubazar, Shelter and Biju Pattanaik squares. Irrespective of nature and composition of the above mentioned investigated squares, the noise source is predominantly attributed to road traffic noise.

Total 180 measurements were made within 3 h duration (i.e., at 1 min interval) during some specified times from 7-10 a.m., 11 a.m.-2 p.m., 3-6 p.m. and 7-10 p.m., in all 17 squares by holding sound level meter in hand at arm's length at the chest level in order to reduce errors due to reflection of sound from the body of investigator holding the instrument (Swain *et al.,* 2013; Goswami and Swain, 2012; Swain *et al*., 2012; 2011). The noise monitoring was done in a good climatic condition, where there was no sign for cloud. Also the monitoring was done in all working days excluding Sunday and local holidays in order to get good result.

***L**eq*. L_{eq} represents the equivalent energy sound level of a steady state and invariable sound. It includes both intensity and length of all sounds occurring during a given period. The noise levels of different squares in different time intervals were predicted along with their equivalent noise levels (L_{eq}). The value of L_{eq} in dB (A) unit is calculated by using the formula of Robinson (1971) i.e.,

$$L_{eq} = L_{50} + (L_{10}-L_{90})^2 / 56$$

For the present study, different percentile noise levels used are:

L_{10} : the level that were exceeded during 10% of the measuring time in dB(A)
L_{50} : the level that were exceeded during 50% of the measuring time in dB(A)
L_{90} : the level that were exceeded during 90% of the measuring time in dB(A)

NPL. As L_{eq} is an insufficient descriptor of the annoyance caused by fluctuating noise (Robinson, 1971), noise

pollution level (NPL) expressed in dB is calculated by using the following formula:

$$NPL = L_{eq} + a\ (L_{10}\text{-}L_{90})$$

where:

a = 1.0 (constant in the equation)

NPL takes into account the variations in the sound signal and hence serves as better indicator of the pollution in the environment for physiological and psychological disturbance of the human system.

TNI. Traffic noise index (TNI) is another parameter, which indicates the degree of variation in a traffic flow. This is also expressed in dB (A) and can be computed using the following relation (Robinson, 1971):

$$TNI = 4\ (L_{10}\text{-}L_{90}) + L_{90} - 30\ dB\ (A)$$

NC. Noise climate (NC) is the range over which the sound levels are fluctuating in an interval of time and is assessed using the following formula (Robinson, 1971):

$$NC = (L_{10}\text{-}L_{90})$$

where:

L_{90}, the level exceeded for 90 % of the time of record, is very near to the background noise level in the absence of any motor vehicle traffic.

Traffic volume (Q). The noise level near the highway depends on the number of vehicles. The noise level increases with an increase in traffic volume. Traffic volume is defined as the total number of vehicles flowing per hour (Robinson, 1971). The number of vehicles passing through a fixed point on the road was counted.

Truck-traffic mix ratio (P). Trucks and buses are contributing more noise to the environment, than compared to automobiles. It is evident that, besides the total noise level, the number of heavy vehicles will be an important parameter in the annoyance function. This is especially the case in the transition range between continuous noise and "just annoying noise events" (Gjestland, 1987). The ratio of heavy trucks and buses to total traffic is called truck-traffic mix ratio (Robinson, 1971). This was computed in terms of percentage. An increase in this ratio will increase the noise level.

Statistical analysis. The analysis of the measured noise levels generally depicts that there are existence of variations of noise with variables as the time of day, categories of zone specific sites, road way types, etc., (Goswami *et al*., 2011, Goswami and Swain, 2011). In order to determine the existence and statistical significance of these variations and trends, a cross classification analysis along with F-test were assessed on the data.

Survey of social attitudes. The questionnaire addressed the socioeconomic characteristics of the individual and individual attitudes towards traffic noise and their interference of noise with daily activities, such as sleeping, relaxation, speaking and studying etc. A sample of 315 general public (236 male and 79 female; including 60 students) was interviewed using the said questionnaire from May to June, 2011 to delineate the perception about the noise and its significance on health of community. The questionnaire consisted of general information about the purpose of the public health survey, i.e., collection of health-related data in order to improve health-care planning and prevention (Mohapatra *et al*., 2010), nowhere stating that traffic noise pollution specifically would be studied (Bodin *et al*., 2009). A random criterion was employed for the selection of the interviewed people. However, there was a substantial proportion of non-responders. To estimate annoyanace and sleep disturbances, questions with a scale of four were used: “yes, often”, “yes, sometimes”, “no, never” and “not relevant”. It is imperative to note that none of these questions involved the word ‘noise’ in order to avoid inducing responses about this issue. The word ‘noise’ (negative connotation) was replaced by “sound” (neutral connotation) (Szeremeta and Zannin, 2009). Depending on the exposure to environmental noise, two different groups i.e., exposed and nonexposed group were categorized. People of exposed group were those residing or having regular activity near the studied 17 squares, where sound pressure level exceeded 70 dB (A), while, nonexposed group was of those who lived or used to perform their activity away from noisy areas herein Cuttack, where sound pressure level did not exceed 55 dB (A). It is believed that in the present study, all the respondents belong to exposed group.

Results and Discussion

Noise pollution was assessed and analysed in seventeen different 17 traffic squares of the city (Table 2). The noise data collected from different monitoring sites displayed wide ranges of noise level varying in 4 different specified times namely; 7-10 a.m., 11 a.m.-2 p.m., 3-6 p.m. and 7-10 p.m. (Table 2). Central Pollution Control Board (CPCB), India has not mentioned prescribed basic noise levels on the roads and even there is no defined regulation for road traffic noise in ‘the Noise Pollution (regulation and control)

Table 2. Noise level (dB) variations at different squares of the city of Cuttack at different time intervals

Squares/ road sections	7 a.m. - 10 a.m.						11a.m. – 2 p.m.						3 p.m. – 6 p.m.						7 p.m.- 10 p.m.					
	Min	Max	L_{10}	L_{50}	L_{90}	L_{eq}	Min	Max	L_{10}	L_{50}	L_{90}	L_{eq}	Min	Max	L_{10}	L_{50}	L_{90}	L_{eq}	Min	Max	L_{10}	L_{50}	L_{90}	L_{eq}
Link road square	74.5	121.1	102.3	93.3	80.5	101.7	75.1	119.8	100.1	92.2	79.6	99.7	76.6	124.3	104.8	92.8	79.2	104.5	77.3	126.9	104.2	92.4	79.6	103.2
Buxi bazar square	72.1	125.7	97.4	85.2	75.9	93.4	72.9	120.5	98.6	81.7	75.6	91.1	73.5	124.8	98.2	86.4	76.7	94.6	76.7	123.3	99.6	87.7	80.6	94.1
College square	72.4	119.6	100.2	85.4	77.6	94.5	70.1	120.7	100.8	83.7	73.7	96.8	74.2	122.4	101.4	86.2	79.2	95.0	79.4	124.7	102.6	88.5	82.5	95.7
Naya bazar square	72.6	124.6	98.4	84.5	76.5	93.0	69.5	121	97.3	79.4	74.8	88.4	73.6	127.3	99.7	84.3	74.7	95.4	76.6	128.9	101.4	89.2	81.6	96.2
Chandini chowk square	74.6	119.6	98.4	85.2	77.8	92.7	70.6	123.4	96.6	81.4	75.1	89.6	76.5	120.4	101.3	89.5	81.8	96.2	78.3	131.8	104.6	90.4	86.2	96.4
OMP square	70.5	121.3	100.6	80.2	74.2	92.6	70.1	120.7	98.3	79.6	75.5	88.8	69.1	124.6	101.2	81.7	74.6	94.3	71.6	129.9	103.2	83.5	74.6	98.1
Chandi mandir square	68.4	120.6	101.4	82.5	72.7	97.2	71.6	120.4	100.6	80.2	74.7	92.1	68.2	121.4	102.3	83.5	73.6	98.2	70.3	125.6	104.5	86.1	72.6	104.2
Sati chaura square	74.2	120.3	100.1	88.5	80.6	95.2	72.6	121.7	99.4	86.1	76.7	95.3	75.3	119.9	99.7	90.1	79.8	97.1	80.3	121.8	102.3	90.3	83.2	96.8
Dolamundai square	70.5	126.3	100.7	85.1	74.8	97.0	69.7	124.7	98.7	80.4	73.6	91.6	71.8	128.9	102.3	87.4	75.7	100.0	71.1	126.8	104.5	86.5	76.6	100.4
Ranihat square	80.9	124.3	100.1	90.3	82.7	95.7	74.2	121.4	100.3	91.2	80.4	98.2	78.4	126.7	101.8	93.1	82.6	99.6	81.1	130.4	102.1	90.4	85.7	95.2
Badambadi square	72.6	123.7	100.6	90.3	79.2	98.4	71.1	121.6	100.6	89.2	77.4	98.8	79.5	125.8	101.1	92.1	85.7	96.3	82.3	129.6	102.3	93.2	88.7	96.5
Mangalabag square	70.8	120.3	102.3	91.5	76.6	103.2	74.1	121.3	100.2	89.1	77.6	98.2	72.7	120.4	102.3	90.1	78.6	100.1	71.6	126.9	102.6	91.4	79.5	100.9
Choudhury bazar square	71.1	121.1	100.6	89.4	75.8	100.3	70.8	127.3	102.1	84.5	76.6	96.1	72.3	122.6	100.2	89.1	78.6	97.4	73.8	128.6	103.1	92.2	79.6	102.0
High court square	70.5	123.7	101.1	87.5	76.2	98.5	70.4	124.1	101.1	87.2	73.9	100.4	71.1	125.6	102.2	89.4	75.5	102.1	72.2	129.7	102.3	89.5	78.6	99.5
Balubazar square	70.1	121.3	99.2	80.3	73.8	91.8	67.1	119.4	98.7	81.6	72.5	93.8	70.8	126.4	100.3	85.3	74.6	97.0	71.8	130.4	104.5	86.4	75.2	101.7
Shelter square	71.8	121.4	101.3	87.3	76.6	98.1	70.8	120.3	100.8	85.4	75.7	96.6	70.1	126.5	100.5	88.3	72.6	102.2	75.3	124.7	101.3	89.4	80.6	97.0
Biju pattanaik square	69.1	123	98.5	82.6	74.7	92.7	68.1	119.2	98.4	80.2	74.5	90.4	68.6	124.7	99.1	85.3	74.6	96.0	73.3	126.8	99.4	88.1	78.6	95.8

rules, 2000'. Thus, the detected noise levels of the study area in day time were compared with the prescribed basic noise level (tolerance limit) on roads (traffic noise) during day-time of United Kingdom i.e., 70 dB (A) (WHO, 1999) and of Nepal (Krishna Murthy *et al.*, 2007).

L_{10} values of all 17 monitored sites ranged from 97.4 to 102.3 dB; 96.6 to 102.1 dB; 98.2 to 104.8 dB and 99.4 to 104.6 dB during 7-10 a.m., 11 a.m.-2 p.m., 3-6 p.m. and 7-10 p.m., respectively (Table 2). Similarly, L_{50} and L_{90} values of all 17 monitored sites vary from 80.2 to 93.3 dB and 72.7 to 82.7 dB; 79.4 to 92.2 dB and 72.5 to 80.4 dB; 81.7 to 93.1 dB and 72.6 to 85.7 dB and 86.1 to 93.2 dB and 72.6 to 88.7 dB during 7-10 a.m., 11 a.m.-2 p.m., 3-6 p.m. and 7-10 p.m., respectively (Table 2). Accordingly, the calculated L_{eq} (equivalent noise levels) values ranged from 91.8 to 103.2 dB; 88.4 to 100.4 dB; 94.3 to 104.5 dB and 94.1 to 104.2 dB during 7-10 a.m., 11 a.m.-2 p.m., 3-6 p.m., and 7-10 p.m., respectively (Table 2). NPL values of all 17 monitored sites ranging from 100.1 to 128.9 dB; 110.9 to 127.6 dB; 111.7 to 130.1 dB and 110.1 to 136.1 dB during 7-10 a.m., 11 a.m.-2 p.m., 3-6 p.m., and 7-10 p.m., respectively (Table 3). TNI values ranged from 122.3 to 157.5 dB; 130 to 158.6 dB; 117.3 to 158.4 dB and 113.1 to 170.2 dB during 7-10 a.m., 11 a.m.-2 p.m., 3-6 p.m. and 7-10 p.m., respectively. Even the minimum NPL and TNI values are more than 100 dB. These high and distressing values of noise pollution level (NPL) and traffic noise index (TNI) clearly demonstrate that the extent of noise pollution in the studied crowded squares is alarming. It was also observed that at some locations the characteristics of noise caused by fast moving traffic, different from those caused by congested or slow moving traffic. Noise from congested traffic was found to contain occasional peaks and varied more in levels. A systematic comparison between TNI and L_{eq} noise levels for all selected locations revealed that the TNI values were much more than respective L_{eq} levels. This simply demonstrated that although the noise levels during any period of the day were generally constant but the presence of single – event noise was sufficient to affect the values of different noise percentile levels and consequently the TNI. This is due to overpopulated road ways with bad conditions, broken roads, minimal traffic management and hooting behaviour of drivers (Agarwal and Swami, 2009a). Similarly, NC values ranged from 17.4 to 28.7 dB; 19.9 to 27.2 dB; 15.4 to 28.7 dB and 13.6 to 31.9 dB during

Table 3. Noise descriptors (TNI, NPL, NC) variations observed at different squares of the city of Cuttack at different time intervals

Monitoring sites	7 a.m. - 10 a.m.			11a.m. – 2 p.m.			3 p.m. – 6 p.m.			7 p.m.- 10 p.m.		
	TNI	NPL	NC	TNI	NPL	NC	TNI	NPL	NC	TNI	NPL	NC
Link road square	137.7	123.5	21.8	131.6	120.2	20.5	151.6	130.1	25.6	148	127.8	24.6
Buxi bazar square	131.9	114.9	21.5	137.6	114.1	23	132.7	116.1	21.5	126.6	113.1	19
College square	138	117.1	22.6	152.1	123.9	27.1	138	117.2	22.2	132.9	115.8	20.1
Naya bazar square	134.1	114.5	21.9	134.8	110.9	22.5	144.7	120.4	25	130.8	116	19.8
Chandini chowk square	130.2	113.3	20.6	131.1	111.1	21.5	129.8	115.7	19.5	129.8	114.8	18.4
OMP square	149.8	119	26.4	136.7	111.6	22.8	151	120.9	26.6	159	126.7	28.6
Chandi mandir square	157.5	125.9	28.7	148.3	118	25.9	158.4	126.9	28.7	170.2	136.1	31.9
Sati chaura square	128.6	100.1	19.5	137.5	118	22.7	129.4	117	19.9	129.6	115.9	19.1
Dolamundai square	148.4	100.7	25.9	144	116.7	25.1	152.1	126.6	26.6	158.2	128.3	27.9
Ranihat square	122.3	113.1	17.4	130	118.1	19.9	129.4	118.8	19.2	121.3	111.6	16.4
Badambadi square	134.8	119.8	21.4	140.2	122	23.2	117.3	111.7	15.4	113.1	110.1	13.6
Mangalabag square	149.4	128.9	25.7	158.6	120.8	22.6	143.4	123.8	23.7	141.9	124	23.1
Choudhury bazar square	145	125.1	24.8	148.6	121.6	25.5	135	119	21.6	143.6	125.5	23.5
High court square	145.8	123.4	24.9	152.7	127.6	27.2	152.3	128.8	26.7	143.4	123.2	23.7
Balubazar square	145.4	117.2	25.4	147.3	120	26.2	147.4	122.7	25.7	162.4	131	29.3
Shelter square	154.4	122.8	24.7	146.1	121.7	25.1	154.2	130.1	27.9	133.4	117.7	20.7
Biju pattanaik square	139.9	116.5	23.8	140.1	114.3	23.9	142.6	120.5	24.5	131.8	116.6	20.8

7-10 a.m., 11 a.m.-2 p.m., 3-6 p.m. and 7-10 p.m., respectively (Table 3). All these values clearly show high noise levels in Cuttack city mostly throughout the day in general and during the evening (7 p.m. to 10 p.m.) in particular.

Analysis of variance is computed from all the seventeen investigated squares at their respective peak hours i.e., 7-10 p.m. (Table 4). The observed value of F (0.95) is less than the tabulated values and is not significant at both 5% and 1% levels of significance. Thus, it explicitly demonstrates that the noise levels of different squares do not differ significantly at their peak hours.

Every day, thousands of autorickshaws, two wheelers and cars, hundreds of cargo carrying trucks, dumpers and buses run along these roads. A comparative data on the number of different types of vehicles passes through the studied traffic squares in a day is presented in the Table 5. Maximum number of total vehicles passing in unit time was observed at Badambadi Square (14001) followed by Link road square (13963) and OMP square (13834), whereas, minimum number of total vehicles passing in unit time was observed at High court square (11689), Biju pattanaik square (11725) and College square (11744). The noise level increases with an increase in traffic volume. The numbers of vehicles passing through a fixed point on the studied road are counted to assess the traffic volume (Q) (Table 6). It was observed that noise levels are increasing with increased traffic volume. The percentage of heavy trucks and buses to total traffic is calculated to work out truck-traffic mix ratio (P) (Table 6). The data reveals that an increase in this ratio increases the noise level.

Moreover, individual contribution to environmental noise by the air horn of different motor vehicles has been assessed at and around Cuttack. A noise of short duration (typically less than one second), particularly of high intensity, such as that produced by an air horn by any vehicle, occurring at regular or irregular intervals is known as episodic and impulsive noise. The episodic and impulsive noise levels of different types of vehicles are presented in Fig. 1. Noise produced from cargo carrying truck, bus, bolero/trekker/travera, car,

Table 4. Analysis of variance for different traffic square locations

Peak hours	Sources of variation	Sum of squares (SS)	Degree of freedom (DF)	Mean squares	F-values	
					Observed	Tabulated
7 p.m.-10 p.m.	Between traffic squares	1599.4	16	99.9	0.95	$F_{0.5} = 1.57$
	Within traffic squares (error)	69145.1	662	104.4	–	$F_{0.5} = 1.88$
	Total	70744.5	678	–	–	–

Table 5. Total number of vehicles passing across different road squares in unit time and at different time-spels of a typical day

Monitoring sites	Number of vehicles that passed in a day												Total number of vehicles
	7 a.m. - 10 a.m.			11a.m. – 2 p.m.			3 p.m. – 6 p.m.			7 p.m.- 10 p.m.			
	2 & 3 W	LMV	HMV	2 & 3 W	LMV	HMV	2 & 3 W	LMV	HMV	2 & 3 W	LMV	HMV	
Link road square	2511	497	372	2404	645	313	2526	661	277	2743	628	386	13963
Buxi bazar square	2427	464	355	2164	529	286	2404	591	70	2557	585	68	12500
College square	2365	479	62	2321	426	53	2357	517	74	2483	523	84	11744
Naya bazar square	2543	637	89	2458	543	84	2511	564	69	2667	678	75	12918
Chandini chowk square	2437	582	102	2627	566	91	2489	528	83	2556	624	88	12773
OMP square	2562	615	278	2541	631	222	2401	651	285	2709	634	305	13834
Chandi mandir square	2473	611	96	2416	473	86	2481	555	86	2512	647	91	12527
Sati chaura square	2306	578	87	2469	461	75	2486	537	73	2445	624	86	12227
Dolamundai square	2381	524	63	2223	412	56	2474	486	66	2495	576	74	11830
Ranihat square	2527	457	71	2341	447	61	2426	534	81	2614	582	87	12228
Badambadi square	2568	604	286	2467	461	373	2612	663	281	2751	638	297	14001
Mangalabag square	2442	489	127	2511	592	86	2528	567	92	2564	506	95	12599
Choudhury bazar square	2416	476	93	2405	534	75	2435	547	76	2487	489	84	12117
High court square	2448	435	68	2351	418	59	2369	447	79	2411	513	91	11689
Balubazar square	2492	472	61	2362	434	62	2384	496	75	2451	584	82	11955
Shelter square	2436	423	70	2378	452	72	2394	501	66	2427	527	79	11825
Biju pattanaik square	2407	416	66	2366	445	68	2381	472	72	2446	509	77	11725

2 & 3 W = two and three wheelers; LMV = light motor vehicles; HMV = heavy motor vehicles.

Table 6. Q (traffic volume) and P (truck-traffic mix ratio) at different squares of the city of Cuttack at different time intervals

Monitoring sites	7 a.m. - 10 a.m.		11a.m. – 2 p.m.		3 p.m. – 6 p.m.		7 p.m.- 10 p.m.	
	Q	P (%)	Q	P (%)	Q	P (%)	Q	P (%)
Link road square	1127	11	1121	9.27	1155	7.96	1252	10.3
Buxi bazar square	1082	10.9	993	9.56	1022	2.34	1070	2.15
College square	969	2.16	933	1.92	983	2.54	1030	2.72
Naya bazar square	1089	2.75	1028	2.72	1048	2.19	1140	2.19
Chandini chowk square	1040	3.27	1095	2.74	1033	2.71	1089	2.66
OMP square	1152	8.07	1131	6.54	1112	8.54	1216	8.38
Chandi mandir square	1060	3.01	992	2.92	1041	2.78	1083	2.77
Sati chaura square	990	2.92	1002	2.49	1032	2.32	1052	2.75
Dolamundai square	989	2.12	897	2.12	1009	2.18	1048	2.38
Ranihat square	1018	2.35	950	2.1	1014	2.66	1094	2.65
Badambadi square	1153	8.24	1100	11.27	1185	7.93	1229	8.05
Mangalabag square	1019	4.12	1063	2.73	1062	2.91	1055	3.03
Choudhury bazar square	995	3.11	1005	2.48	1019	2.45	1020	2.74
High court square	984	2.33	943	2.12	965	2.69	1005	2.98
Balu bazar square	1008	1.98	953	2.2	985	2.54	1039	2.59
Shelter square	976	2.35	967	2.48	987	2.23	1011	2.57
Biju pattanaik square	963	2.28	960	2.39	975	2.46	1011	2.57

motorcycle, tractor, and tempo, ranges from 108.5 - 126.4 dB, 102.4-120.1dB, 94.8-118.3 dB, 94.0-115.5 dB, 91.5-114.2 dB, 107.3-119.4 dB and 96.7- 116.9 dB, respectively (Fig. 1). The findings of individual contribution of vehicle towards noise pollution are more than the traffic noise-limit i.e., 70 dB (A).

However, the peak traffic was observed during two specified times such as 7-10 a.m. and 7-10 p.m. at all

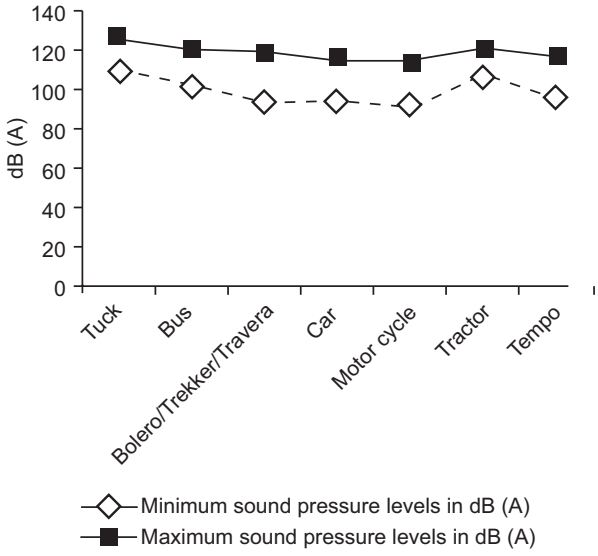

Fig. 1. Episodic and impulsive noise levels (40 observations) by the air horn of motor vehicles at Link road and OMP squares, Cuttack.

the monitoring squares of the city. Maximum numbers of peoples are traveling during the morning and evening time for office work and schools having similar working hours. High frequency sound emitted from electric horn and air horn of buses, trucks, cars, motorcycles, auto-rickshaws, engine of vehicles, crowding of general public create tremendous noise. The present study explicitly demonstrates that in most of the cases the average assessed noise levels are more than the permissible limit i.e., 70 dB for road traffic noise (Krishna Murthy *et al*., 2007; Kudesia and Tiwari, 2007; WHO, 1999) during day time.

Discussion on survey of social attitudes. A comprehensive questionnaire survey was undertaken, which sought information about traffic noise traits and its effects on exposed individuals. Noise (58%) and air (42%) pollution were recognised as the most important transport related urban problem. 62% of interviewed individuals opined that they personally affected by noise pollution more than any other pollution. 62% of interviewees stated that they are highly annoyed by the vehicular noise. The reasons for traffic noise pollution were evaluated as horn (61%) followed by traffic jam (30%), silencer (5%) and engine (4%). The distribution of annoyance due to vehicle categories are as 49% due to auto-rickshaws (tempos), followed by 21% due to bus and truck, 21% due to motorcycle and 9% due to four wheelers. 37% of the sample population reported frequent headaches as a result of being exposed to traffic noise. Nervousness was reported by 26% and 30% reported that traffic noise causes hearing damage. 31% respondents identified hypertension and loss of concentration as the main health effect of noise pollution. 12% interviewees were feeling mental stress and 11% were suffering from insomnia. 45% of students reported that their study was disrupted by frequent air horns of vehicles. 42% believed that traffic noise could cause loss of sleep. To estimate sleep disturbances questions with a scale of four were used: 11% opined "yes, often"; 23% respondents said "yes, sometimes", 31% opined "no, never" and 35% said "not relevant". It warrants a systematic survey of sleep quality, number of awakenings or number of changes in sleep state, changes in sleep pattern, sleep stages, subjective sleep quality to estimate the extent of sleep disturbance. The potential health impacts of traffic noise on individuals are also investigated. Excessive noise can lead to mental and physical health problems such as headache, bad temper, hearing problem, hearing impairment, loss of concentration, oral communication disturbances etc. (Lam *et al*., 2009; Kudesia and Tiwari, 2007). Non-auditory physical health effects in general and annoyance from noise exposure in particular include changes in blood pressure, heart rate, and levels of stress hormones, ischemic heart disease, biochemical effects, immune effects, birth weight and congenital effects (Bodin *et al.* 2009; Babisch, 2005). It has also effect on psychosocial well-being and performance.

Conclusion

It is inferred that the average assessed noise levels are often exceeding the permissible limit i.e., 70 dB for road traffic noise (WHO, 1999) during day time. The whole population of the Cuttack city including thousands of floating population coming to this commercial city for different purposes from nearby hundreds of small towns and villages are exposed to this urban noise levels of more than 70 dB (A). This is very high level, corresponding to the day time limit recommended by CPCB (2000) i.e., 55 dB for residential area and 65 dB for commercial area. Thus, it is concluded that noise level in and around Cuttack is high and much above the community annoyance limits recommended by WHO.

Recommendation

It is also worth noting that from the noise point of view, it is better to concentrate traffic along main roads then to distribute between parallel roads. Banning of hydraulic

horns; improvement and streamlining of roads and parking system; controlling noise from heavy vehicle exhausts and engine brakes; design and fabrication of silencing devices and public awareness would also be helpful in reduction of the present noise level of the city. Vegetation buffer zones must be created in different parts of this city by massive plantation of trees with dense foliage (rich canopy), as they were found to be highly effective in absorbing the acoustic noise and act as very good screens in bringing down the noise levels. Effective road design, road use and development should be examined time to time.

Thus, Integrated Road Traffic Noise Strategy (IRTNS) must be developed at government level to minimise noise pollution at this commercial city of Odisha State. Central Pollution Control Board (CPCB), India should lay down legal standards for noise levels from roads and Ministry of Environment and Forest should launch programmes to reduce noise from the motor vehicle. Therefore, Cuttack Municipal Corporation, Commissioner of Police, Cuttack and State Pollution Control Board should take some imperative steps and regulatory measures to abate such noise pollution.

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