



RESEARCH ARTICLE

**A STUDY ON AMBIENT AND TRAFFIC NOISE POLLUTION IN VIJAYAWADA,
ANDHRA PRADESH, INDIA**

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ABSTRACT

The noise levels are increasing beyond the permissible limits at many cities due to rapid urbanization and its related activities. Increased noise levels beyond limits result in reduced work efficiency, loss of hearing, annoyance, psychological impacts. Increased traffic in all the cities is becoming the major source of noise pollution. The ambient and traffic noise levels are studied in and around Vijayawada. Sampling is done for 10 hrs from 7am-9am, 10 am-12 noon, 1pm-3 pm, 4pm-6 pm, 7 pm-9 pm. Ambient noise levels are beyond the permissible limits at the urban locations sampled based on Lavg, L10, L50, L90, Leq, NPL, NC parameters. Traffic flow is measured at four locations representing residential, commercial, industrial, and silent zones. Simultaneously, sound levels are collected and analyzed based on traffic flow, Lavg, L10, L50, L90, Leq, TNI, NC parameters. It is noted that, high noise levels are recorded at high traffic flows. The 2-and 3-wheelers are contributing to 69% of vehicular flow at the sampling locations.

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INTRODUCTION

Noise is unwanted sound that is harmful, annoying, causes disturbance and may adversely impact the work efficiency and hearing. Increased activities and needs in modern urban life are causing severe noise pollution. Noise pollution due to automobiles is a major source of pollution in urban areas. Fast growing vehicle population in urban regions in the recent years, has resulted in tremendous increase in traffic on roads causing alarming noise pollution, besides air pollution. Traffic noise is affected by factors like traffic volume, vehicle mix, pavement type and vehicle condition (Marathe, 2012). Noise level increases with traffic volume in an exponential manner and depends on several parameters such as source, medium, vehicle speed, road conditions, distance from source etc. (Vilas and Nagarale, 2013, Suhas and Adavi, 2015). Hence, the overall noise is dependent on the characteristics of the vehicle and the relative proportions of the vehicle types included in the flow. People generally hear sounds between the "threshold of hearing" and the "threshold of pain". In terms of pressure, this is 20 µPa – 20 kPa (Garg, 2014). Noise level is measured in terms of decibels (dB). The Noise levels are measured using a sound level meter and calculated values such as L10, L50, L90, are used to estimate equivalent value of sound level (Leq) while Traffic Noise Index (TNI), Noise Climate (NC), Noise

Pollution level (NPL) are used to analyse the variation of sound levels. The Leq value, can also be estimated using the formulae outlined in literature (Marathe, 2012, Swain and Shreerup, 2013, Garg, 2014). Leq denotes the time weighted average of the level of sound in decibels on scale A which is relatable to human hearing (CPCB, 2016). Leq on an energy basis is not sufficient to describe the degree of annoyance caused by fluctuating noise. NPL is used to assess noise pollution level in this regard (Marathe, 2012). TNI indicates the degree of variation in a traffic flow, expressed in dB (A) while NC is the range over which the sound levels are fluctuating in an interval of time. TNI includes the range of the noise climate, over the 24 hours, together with a smaller contribution from the 90% level representing the average background that is an absolute value. This combination is multiplied by four in order to eliminate the need for fractional quantities, and 30 units of TNI are subtracted merely to yield a convenient numerical scale (Langdon and Scholes, 1968). The Noise Pollution (Regulation and Control) Rules, 2000 prescribed the permissible limits of noise levels for different urban areas under Indian conditions (CPCB, 2016, Doshi et al., 2015) and are given in the Table-1.

Table 1. Prescribed ambient noise limits in India

Area category	Limits in dB (A), Leq	
	Day time	Night time
Industrial area	75	70
Commercial area	65	55
Residential area	55	45
Silence zone	50	40

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Note:

- Day time: 6 a.m. to 10 p.m. Night time: 10.00 p.m. to 6.00 a.m.
- Silence zone is an area comprising not less than 100 metres around hospitals, educational institutions, courts, religious places or any other area which is declared as such by the competent authority. Use of vehicular horns, loudspeakers and bursting of crackers shall be banned in these zones.
- Mixed categories of areas should be declared as one of the four above mentioned categories by the Competent Authority and the corresponding standards shall apply
- dB(A) Leq denotes the time weighted average of the level of sound in decibels on scale A which is relatable to human hearing.

Mishra *et al.*, (2008) studied the adverse impacts of noise on male and female population comprising of different age groups in Roorkee. The analysis indicated that automobiles and loud speakers are major sources of noise pollution. Significant adverse impacts such as effect on hearing, interference with communication, annoyance, sleep disturbance, deafness, are noticeable from the respondents. Public awareness and education are some of the probable solutions suggested for mitigating the problems. Vidyasagar and Nageswar Rao (2006) studied ambient noise levels in Visakhapatnam, an industrial and sea port city in coastal Andhra Pradesh. Ambient noise levels measured at six different locations representing residential, industrial, commercial, and silence zones indicated high sound levels which is alarming. Ambika *et al.* (2015) mapped noise levels in Mumbai, which is considered as commercial capital of India with massive development projects pertaining to infrastructural and commercial sectors that will be continuing on a regular basis, and observed that the noise levels in the city, on the whole, were very high and above the permissible limits. Balashanmugam *et al.*, (2013) studied the ambient sound levels in Chidambaram at various locations and found that they are higher than permissible limits. Vehicular traffic and air horns are found to be the main reasons for these high noise levels. Sundarakumar (2011) studied ambient noise levels in Vijayawada, a commercially busy city located along Krishna river in Andhra Pradesh. Thirty four noise samples analyzed in urban and rural areas indicated that the noise levels are elevated in urban areas compared to suburban areas. Balashanmugam *et al.* (2013) studied the noise levels at different locations belonging to four zones viz., residential, commercial, industrial and silence, in Cuddalore, Tamilnadu and opined that the ambient noise levels are exceeding the prescribed limits. Rapid and unplanned urbanization resulting in great influx of people from all parts of the region and country, improper management of town roads and traffics, lack of sufficient parking spaces and exponential growth of both private and public vehicles in the city are identified as the major reasons.

Traffic Noise

Noise descriptors such as L10, L50, L90, Leq, TNI, and NC are used (Swain and Shreerup, 2013) as indicators to assess the extent of noise pollution due to the traffic flow. Traffic flow at a particular time, Road surface type and its condition, Vehicle condition are the factors identified (Marathe, 2012) for increased noise levels. Annoyance, disturbance, interference to sleep and speak, reduced work efficiency, deafness, cardiovascular impact and increased blood pressure on long

exposure are some of the adverse impacts identified due to traffic noise pollution (Marathe, 2012). Traffic flow is usually represented in terms of Passenger Car Unit (PCU), which represents the same impact that a mode of transport has on traffic variables (such as headway, speed, density) compared to a single car (Wikipedia, 2017). Traffic noise levels are often correlated with PCUs (Tandel *et al.*, 2011, Swain and Shreerup, 2013, Vilas and Nagarale, 2013). Noise level in 12 different major intersection points of Baripada town is measured and analyzed (Swain and Shreerup, 2013) during four different specified times. The equivalent noise levels of all the 12 squares were found to be much beyond the permissible limit during day time. Kavita (2014) studied the noise levels due to vehicular traffic, counted the traffic flow, in peak hours during morning and evening at Akola, and observed that noise levels are very high beyond permissible limits and is predominantly caused due to a very high number of two wheelers. Mondal (2013) studied the vehicle origin noise at twelve different locations in Burdwan during specific time intervals and observed that noise levels are beyond the permissible limits. Based on the survey conducted through a questionnaire related to public health, he inferred that irritation, mental stress, annoyance, sleep loss are some of the adverse impacts caused due to increased noise pollution. Anurag *et al.*, (2013) noticed that the sound levels due to railway and vehicular traffic in Amaravati, Maharashtra, India are 1.5 times the permissible limits of the designated zone and felt an urgent need to control the sound levels.

Zuhdi and Husein (2012) observed higher values of urban traffic noise levels in Palestinian city of Hebron. Ozer *et al.* (2009) observed high traffic noise levels in fifty out of sixty five sampling locations in Tokat city of Turkey during evening hours and is alarming. Xie *et al.* (2013) developed a traffic noise prediction model based on traffic volume and distance of source from sampling point and compared the predicted values with that of measured values. Tandel *et al.* (2011) developed linear regression model for prediction of noise level in Surat based on PCU, building height along road side and open space for the road section considered. They concluded from the model that significant contribution to the noise levels are two- and three-wheelers in the city. Mondal (2013), Swain and Shreerup (2013) used statistical analysis for evaluation of the noise in their studies. Sundarakumar (2011) plotted spatial distribution of noise levels at Vijayawada. It can be inferred that increased noise pollution due to traffic flow is a serious problem at both National and International arena.

Study Zone

The Vijayawada city is situated at the foot of a low range hills on the northern bank of the river Krishna at 16° 31' North latitude and 80° 38' East longitude, around 70 km away from the coast. The population of Vijayawada city based on 2011 census is 1.04 millions. Vijayawada is the commercial capital of Andhra Pradesh, hence transport of commodities by heavy vehicles round the clock contributes to the noise pollution. With the advent of many educational organizations including Engineering colleges in and around the city, the transit of people also contribute a lot to noise pollution in the peak hours. After bifurcation of Andhra Pradesh and close proximity of new capital Amaravathi, the traffic volume in the city has increased tremendously. Distribution of noise levels in the city and some rural areas near the city will present a picture of increased urbanization. The study is divided into two parts (i)

study of ambient noise levels at few prominent locations in the city and (ii) study of noise levels due to traffic flows in the city. The study is taken up in March-April 2017 with the following objectives:

- To study the ambient noise levels at different traffic sections.
- To calculate the traffic volume.
- To estimate the equivalent noise levels due to the traffic volume.
- To analyze the noise levels using L_{avg} , L_{eq} , L_{10} , L_{50} , L_{90} , NC , NPL and TNI
- To compare the noise levels with the permissible limits

Sound levels are determined using Digital Sound Level Meter with a measuring range of 30~130dB ± 1.5 dB decibel accuracy. The traffic volume data is collected during 7-9 AM, 10AM-12 Noon, 1-3 PM, 4-6 PM, 7-9 PM. Sound levels are recorded simultaneously for every 2 minutes interval. Same time periods and sampling interval are followed for determining ambient noise levels. Nine locations are identified (Refer Table-2) for determining ambient noise levels and four locations are selected (Refer Table-3) on the basis of different land use like commercial, industrial, silent and residential zones for determination of traffic volume data and subsequent noise levels. Traffic volume is assessed on two days to minimize errors in assessment. Vehicles are graded as two-, three-, four- wheelers and others. The percentage contribution of these vehicle categories during sampling duration is computed.

Table 2. Sampling locations for determining Ambient Noise Levels

S. No	Classification	Area	Location
1	Residential Zone	Satyanarayana Puram	Vijayawada
2		Mylavaram	Mylavaram
3		Ramavarappadu	Ramavarappadu
4	Commercial Zone	Benz Circle	Vijayawada
5		Krishna Lanka	
6		Bhavani Puram	
7		Mogalraj Puram	
8	Silence Zone	Ramavarappadu Ring	Ramavarappadu
9		Near Ramesh Hospital	Vijayawada

Table 3. Sampling locations for determining Traffic flow and noise levels

S. No	Classification	Area	Location
1	Industrial Zone	NTTPS 2 nd Gate	Ibrahimpatnam
2	Commercial Zone	Chitti Nagar	Vijayawada
3	Residential Zone	Milk Project	
4	Silence Zone	LBRCE College	Mylavaram

Parameters used in the analysis

The parameters that are used in the analysis are L_{10} , L_{50} , L_{90} which represent the sound level in dB (A) that exceeded during 10%, 50%, 90% of the measuring time respectively. NPL and NC are used to analyze the noise level distribution. The L_{eq} value can be obtained (Marathe, 2012, Swain and Shreerup, 2013) from the above values using following equation:

$$L_{eq} = L_{50} + (L_{10}-L_{90})^2 / 56 \quad \text{----- (1)}$$

The parameters such as TNI and NC can be estimated (Marathe, 2012, Swain and Shreerup, 2013) using the following equations:

$$NC = L_{10}-L_{90} \quad \text{----- (2)}$$

$$NPL = L_{eq} + (L_{10}-L_{90}) \quad \text{----- (3)}$$

Alternately the L_{eq} value can be estimated (Garg, 2014) based on the sampled sound levels using following equation

$$L_{eq} = L_{avg} = 20 \log_{10} (1/n) \sum 10^{(L_i/20)} \quad \text{----- (4)}$$

The L_{10} , L_{50} , L_{90} values for traffic noise level estimation are computed (Swain and Shreerup, 2013) as-

$$L_{10} = 61 + 8.4 \log (Q) + 0.15P - 11.5 \log (d) \quad \text{----- (5)}$$

$$L_{50} = 44.8 + 10.8 \log (Q) + 0.12P - 9.6 \log (d) \quad \text{----- (6)}$$

$$L_{90} = 39.1 + 10.5 \log (Q) + 0.06P - 9.3 \log (d) \quad \text{----- (7)}$$

Where, Q = vehicles flow per hour.

P = percentage of heavy vehicles in %.

d = Distance from c/c of the road to source of receiver in meters.

$$TNI = 4 (L_{10}-L_{90}) + L_{90} - 30 \text{ dB (A)} \quad \text{----- (8)}$$

The values of L_{eq} , NC are determined for traffic flow condition using Equations 1-2.

RESULTS AND DISCUSSION

Ambient noise levels

The ambient noise levels are measured at 9 different locations (Refer Table-2) for a total of 600 minutes between 7 am to 9 pm as mentioned earlier at a sampling interval of 2 min while a sampling interval of 5 min. is used at Benz circle and Krishna Lanka points. The details are plotted on a graph with sound levels on X-axis and % time exceeding sound levels on Y-axis. The noise parameters of L_{10} , L_{50} and L_{90} values are obtained from the graph. The L_{eq} , NPL , and NC are calculated using equations 1-3. Alternately, the average sound level during sampling period is calculated using equation-4. The obtained values are compared with the permissible limits specified by the IS code for the appropriate zone. The sample graph obtained for sound levels recorded at Bhavanipuram is shown in Fig.1. The L_{10} , L_{50} , and L_{90} values in dB (A) can be obtained from Fig.1 as 78.1, 71.3 and 66 respectively. The L_{eq} , NPL , and NC values in dB (A) are calculated as 73.7, 85.8, and 12.1 respectively using equations 1-3. The average sound levels based on all sampling values covering 600 minutes of sampling is calculated as 71.8 dB (A) using equation 4. The Bhavanipuram sampling location is categorized as commercial zone and hence the obtained L_{eq} and L_{avg} values are compared with the prescribed limit of 65 dB (A) for day activities. In a similar manner, graphs are plotted for the values obtained at all the locations, relevant noise parameters are calculated and are summarized in Table-4. The L_{eq} values obtained are compared with permissible noise limits and are given in Fig.2. The following observations are drawn from Table-4 and Fig.2 with respect to ambient noise levels:

- The obtained L_{eq} value is higher than the permissible limit at all 9 locations under three zones selected for sampling. Sundarkumar (2011) also felt that high noise levels are prevailing in and around Vijayawada.

- The Lavg value gives an approximate value based on sampling values of sound levels. It is close to the value obtained Leq value. The Leq value is however is more reliable, as it takes into account the variation in sound levels in the form of L10, L50 and L90.

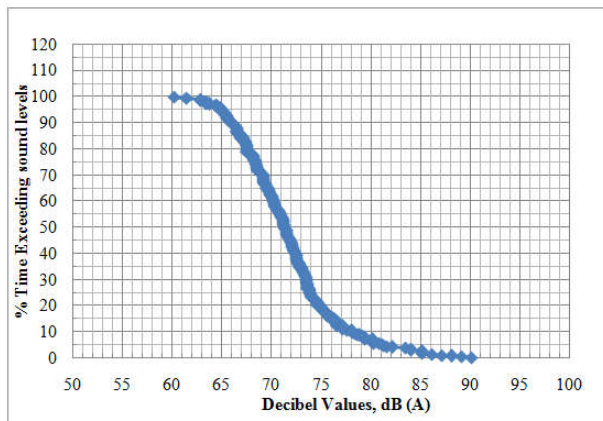


Fig.1. Ambient noise levels at Bhavanipuram

- The Noise Pollution Level (NPL) values are very high indicating severe noise distraction due to vehicular traffic in that area, which is alarming.
- The suburban and rural areas sampled in the study are yet to receive impact of urbanization and increased traffic flow resulting in low noise levels. Other locations are within the city and hence high noise levels are noticeable.

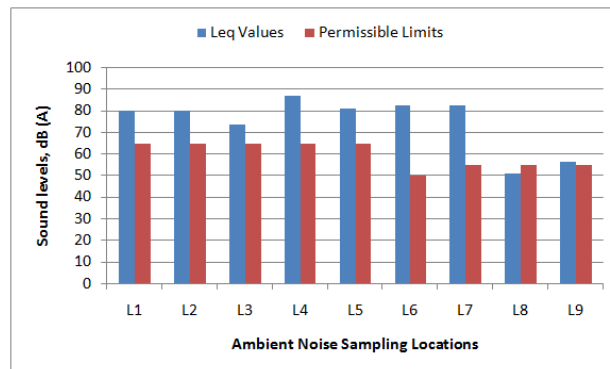


Fig. 2. Comparison of Leq values of ambient noise levels with permissible limits

Table 4. Summary of ambient noise levels at sampling locations

Location Code	Area	Zone	Sampling time (min)	Sampling interval (min)	L10	L50	L90	Leq	Lavg	NPL	N.C
L1	Benz Circle	Commercial	565	5	82.2	79.5	74.9	80.4	79	87.7	7.3
L2	Krishna Lanka		360	5	81.3	78.9	72.3	80.3	75.1	89.3	9
L3	Bhavani Puram		600	2	78.1	71.3	66	73.7	71.8	85.8	12.1
L4	Mogalrajpuram		600	2	92.5	78.9	71.1	86.5	80	107.9	21.4
L5	Ramavarappadu Ring		600	2	87	75.2	67.9	81.3	76.7	100.4	19.1
L6	Ramesh Hospital	Silent	600	2	87.9	76.9	69.2	82.7	77.9	101.4	18.7
L7	Satyanarayana Puram	Residential	600	2	85.9	77.5	68.5	82.5	77.3	99.9	17.4
L8	Mylavaram		600	2	54.7	48.3	41.6	51.2	48.4	64.3	13.1
L9	Ramavarappadu		600	2	57.3	47.7	34.2	56.6	46.6	79.7	23.1

- The NC values are low and in the range of 9-23, which indicates the variation of sound levels in the region. It should be noted that L90 indicates the background sound level and L10 indicates the 10% time exceeding sound levels. The sound level fluctuation in two locations viz., Benz circle and Krishna Lanka is low with as high as 72-74 dB (A) background sound levels prevailing.
- At Ramavarappadu, the NC value is 23.1 dB (A) indicating a low background sound level of 34.2 dB (A) and reaches high to 57.3 dB (A). It is a suburban area and hence the noise levels are slightly less than the permissible limits.
- Mogalrajapuram, is a commercial zone, where continuous movement of vehicle flow is taking place. A high L10 sound level of 92.5 dB (A) is recorded where as the background sound level is only 71.1 dB (A), which clearly indicates the impact of traffic noise levels at the location.
- Ramesh Hospital is a Cardiac hospital, where low sound levels are mandatory. However, the sound levels near the hospital reaches a L10 value of 87.9 dB (A) and a background value of 69.2 dB (A), both are very high when compared with permissible limit of 50 dB (A). The drawback is the hospital located near a traffic junction, where the vehicles moving to and fro at the junction are creating high sound levels leading to severe ambient noise pollution in that area.
- Mylavaram is a small village with around 45000 population and is located at a distance of 40 km from Vijayawada. The rural background of the area resulted in low Leq value of 51.2 dB (A) which is less than the permissible limit.

Traffic noise levels

The traffic noise levels are measured at four different locations representing industrial, commercial, residential and silent zones. The sampling is carried out in two days to reduce the bias. However, barring occasional sound levels at odd times, the results of sampling on these days are close to each other reflecting accurate work. The analysis is carried out in two ways: (i) from graph obtained by plotting sound levels measured during sampling (ii) from traffic flow considerations. In the first approach, the sound levels obtained during sampling are plotted on X-axis and % time exceeding sound levels on Y-axis. The L10, L50, L90 parameters are obtained from the graph. Leq value is calculated based on these parameters using equation-1. The TNI and NC are calculated using the above obtained L10, L50 and L90 values. The Lavg value is calculated using equation-4 from the sampled data for 10 hours of sampling time. In the second approach, the traffic flow is measured in terms of traffic flow i.e., vehicles flow/hour by categorizing the vehicles into 2wheeler, 3 wheeler, 4 wheeler and others. The percentage distributions of these vehicle categories are calculated. The sound levels are assessed using L10, L50, L90, Leq, TNI, NC values which are determined using equations 1 and 5-8 respectively. The values are compared with that of standard values prescribed (Refer Table-1). A sample graph obtained at Milk project (Residential zone) for sampling on day-1 is shown in Fig. 3. The noise parameters such as L10, L50, L90 obtained from Fig.3 are shown in Column-1 of Table-5. The Table-5 indicates the following:

- Parameters such as Leq, TNI, NC are computed from L10, L50, L90 values using equations 1, 2 and 8 (Column-3).
- The Lavg value is calculated using equation-4 (Column-3).
- The L10, L50, L90 parameters are calculated from the traffic flow considerations using equations 5-7 (Column-2).
- Similarly, the other noise parameters such as Leq, TNI, NC are computed (Column-2).
- The same data is calculated for Day-1 (Columns 2-3) and Day-2 (Columns 4-5).

The traffic flow parameters are collected on both the days of sampling and are given in Table-6. For convenience, the parameters are categorized as 2-, 3-, 4- wheelers and other vehicles. The percentage contribution of these vehicles is calculated. The total flow of vehicles per hour is calculated. The noise parameters L10, L50, L90 are calculated using equations 5-7, which incorporates the traffic flow and distance of sampling from the source in the equation for assessment. It

can be noted from Tables-5 and -6 that, the values obtained are in very close agreement with each other indicating accurate sampling and also similar traffic flow on both the days of sampling.

In a similar manner, the sound levels are measured at other three locations (NTTPS 2nd Gate – Industrial zone, Near LBRCE campus Mylavaram – Silent zone and Chittinagar – Commercial zone) and analyzed. The NTTPS, a Thermal Power Station, 20 km from Vijayawada is considered as suburban Vijayawada, a very busy location with heavy vehicles movement for downloading of coal and/or loading fly ash for supply to different vendor requirements. The LBRCE campus in Mylavaram is located on Vijayawada-Bhadrachalam highway, which is currently expanded to 4-lane from existing 2-lane and is a very busy route 24 hours. The LBRCE campus, is a silent zone with respect to its designated activity, is considered to study noise levels in the present context.

Table 5. Summary of noise parameters at Milk Project

Parameter	Day1		Day2	
	From traffic flow	From graph	From traffic flow	From graph
(1)	(2)	(3)	(4)	(5)
L10	80.65	73.30	80.82	73.20
L50	71.80	69.20	71.89	69.40
L90	64.79	58.58	64.78	59.58
Leq	75.99	72.34	76.20	72.49
Lavg	67.98	67.98	68.14	68.14
TNI	98.23	84.46	98.94	84.06
NC	15.60	13.72	16.04	13.62

All values in dB (A)

Table 6. Traffic flow variation at Milk Project

Timings	Number of Vehicles							
	2W		3W		4W		Others	
	Day1	Day2	Day1	Day2	Day1	Day2	Day1	Day2
7:00-9:00 (AM)	717	657	869	949	179	125	223	198
10:00-12:00 (AM-PM)	618	519	854	710	152	141	172	210
1:00-3:00 (PM)	306	250	582	419	96	105	70	79
4:00-6:00 (PM)	451	618	576	527	127	97	137	153
7:00-9:00 (PM)	117	262	90	110	85	74	56	112
Total	2209	2306	2971	2715	639	542	658	752
% of Vehicles	34.11	36.52	45.87	43.0	9.87	8.59	10.16	11.91

The total number of vehicles per 1 hour, $Q = (6477/10) = 647.70$ (Day1)

The total number of vehicles per 1 hour, $Q = (6315/10) = 631.50$ (Day2)

Distance from c/c of road to sampling location, $d = 4m$

Table 7. Traffic flow variation at Chittinagar

Timings	Number of Vehicles							
	2W		3W		4W		Others	
	Day1	Day2	Day1	Day2	Day1	Day2	Day1	Day2
7:00-9:00 (AM)	1356	1256	1012	1115	360	279	658	612
10:00-1200 (AM-PM)	1157	1006	972	912	215	324	552	495
1:00-3:00 (PM)	870	783	679	735	117	190	304	219
4:00-6:00 (PM)	1242	1123	1196	992	295	245	525	542
7:00-9:00 (PM)	1027	987	875	736	175	269	617	604
Total	5652	5155	4734	4490	1162	1307	2656	2472
% of Vehicles	39.79	38.40	33.33	33.45	8.18	9.74	18.70	18.41

The total number of vehicles per 1 hour, $Q = (14204/10) = 1420.40$ (Day1)

The total number of vehicles per 1 hour, $Q = (13424/10) = 1342.40$ (Day2)

Distance from c/c of road to sampling location, $d = 5.5m$

Table 8. Summary of noise parameters at Chittinagar

Parameter	Day1		Day2	
	Samples	Graph	Samples	Graph
L10	81.76	92.50	81.52	92.50
L50	73.98	78.90	73.68	78.90
L90	66.43	71.20	66.16	70.90
Leq	77.89	86.46	77.61	86.67
Lavg	86.46	86.46	80.21	80.21
TNI	97.89	126.40	97.60	127.30
NC	15.33	21.30	15.36	21.60

All values in dB (A)

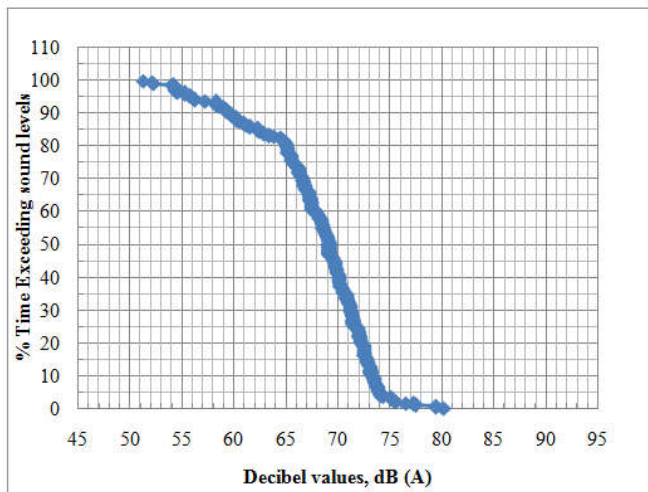


Fig. 3. Traffic sound levels at Milk Project on Day-1

Chittinagar is a very busy commercial area, where city buses and State road transport buses will be plying continuously besides active business life in the location. The details are given in Tables 7-12.

The Leq values determined at the four different locations on Day-1 and Day-2 based on traffic flow are logarithmically averaged. Similarly the Leq values determined using graphical method are logarithmically averaged. The Lavg values, computed using equation-4, obtained on Day-1 and Day-2 are also logarithmically averaged. All these values are compared with the permissible noise levels of that particular zone and shown in Fig.4. It can be noticed from Fig. 4 that all the values are higher than the permissible limits. It can be noted from the Fig.4 that the Leq values calculated using equations 5-7 and from equation-1 using graphical data are in close agreement while the Lavg values calculated using equation-4 are slightly lesser. The deviation is much wider in residential and silent zones indicating the significant impact of traffic flow on sound levels in the zones. In the silent zone, the sound levels obtained using traffic flow data are more dominant. The following observations are drawn from Tables-5-12 and Fig.4:

- The sound levels in Industrial zone (NTTPS 2nd gate) are similar to that of the permissible limits. This indicates the high noise level production in that area due to heavy vehicle movement.

Table 9. Traffic flow variation near LBRCE College, Mylavaram

Timings	Number of Vehicles							
	2W		3W		4W		Others	
	Day1	Day2	Day1	Day2	Day1	Day2	Day1	Day2
7:00-9:00 (AM)	424	374	167	215	112	114	48	51
10:00-12:00 (AM-PM)	417	324	103	149	98	124	55	67
1:00-3:00 (PM)	221	242	75	94	103	97	94	93
4:00-6:00 (PM)	382	415	148	187	192	142	137	142
7:00-9:00 (PM)	212	195	79	87	108	134	147	164
Total	1656	1550	572	732	613	611	481	517
% Of Vehicles	49.85	45.45	17.219	21.47	18.45	17.92	14.479	15.16

The total number of vehicles per 1 hour, Q = (3322/10) = 332.20 (Day-1)
 The total number of vehicles per 1 hour, Q = (3410/10) = 341.00 (Day-2)
 Distance from c/c of road to sampling location, d = 4m

Table 10. Summary of noise parameters at LBRCE College, Mylavaram

Parameter	Day1		Day2	
	Samples	Graph	Samples	Graph
L10	77.42	66.50	77.63	66.10
L50	67.98	58.20	68.19	57.10
L90	60.84	50.10	61.00	49.20
Leq	72.56	62.68	72.80	61.60
Lavg	58.28	58.28	57.58	57.50
TNI	97.16	85.70	97.52	86.80
NC	16.58	16.40	16.63	16.90

All values in dB (A)

Table 11. Traffic flow variation at NTTPS 2nd Gate

Timings	Number of vehicles							
	2W		3W		4W		Others	
	Day1	Day2	Day1	Day2	Day1	Day2	Day1	Day2
7:00-9:00 (AM)	734	689	315	434	527	624	410	427
10:00-12:00 (AM-PM)	357	542	294	367	318	396	160	193
1:00-3:00 (PM)	342	403	157	215	157	312	115	245
4:00-6:00 (PM)	635	947	426	476	492	684	384	478
7:00-9:00 (PM)	498	672	324	315	384	421	459	698
Total	2566	3253	1516	1807	1878	2437	1528	2.41
% Of Vehicles	34.27	34.11	20.246	18.95	25.08	25.55	20.406	21.40

The total number of vehicles per 1 hour, Q = (7488/10) = 748.80
 The total number of vehicles per 1 hour, Q = (9538/10) = 953.80
 Distance from c/c of road to sampling location, d = 5.5m

- The sound levels due to traffic are very high in Silent zone (LBRCE College). The ambient noise levels are also very high (62 dB (A)). However, this impact does not have a huge bearing on LBRCE campus as a good thick green cover is available in the campus which attenuates the noise levels. Further, the class rooms are 250-300 m away from the sampling location. The net impact of outside heavy traffic noise is not felt in the campus.

Table 12. Summary of noise parameters at NTTPS 2nd Gate

Parameter	Day1		Day2	
	Samples	Graph	Samples	Graph
L10	80.16	80.90	81.20	85.20
L50	71.50	72.50	72.84	74.10
L90	64.00	66.60	65.16	67.40
Leq	75.93	75.91	77.13	79.38
Lavg	73.26	73.26	75.23	75.23
TNI	98.64	93.80	99.32	108.60
NC	16.16	14.30	16.04	17.80

All values in dB (A)

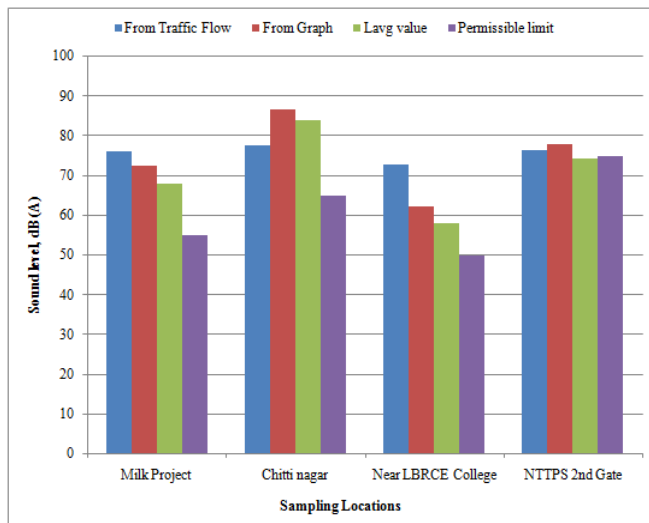


Fig. 4. Comparison of average value of Leq, Lavg values with Permissible limits for traffic flow noise

- The average ambient noise levels are higher in Chittinagar (Commercial zone) than the traffic noise. The location is a pretty busy area with lot of commercial establishments and the movement of customers. The alarming issue here is the high noise value (86.6 dB (A)) beyond the permissible limits (65 dB (A)). The public are advised to adopt safe measures while moving in this area and try to minimize the exposure period to the high sound levels.
- The Milk Project area is a residential area but the city bus route passes through that area. Currently, district service buses are also diverted in the route due to the ongoing construction activities in the regular route. This necessitates the increased sound levels (76 dB (A)) due to traffic flow beyond the permissible limits. The ambient noise levels are also on higher side (72.42 dB (A)) indicating a minimum increase of 17 dB (A) of sound levels beyond permissible limits during day time. Though a Milk Project is located close to the sampling location, based on field assessment during sampling, lesser contribution is expected in the high sound levels of the location. The high sound levels in the locality certainly cause a lot of irritation and annoyance to the public staying the area.

- The ranges of NC values at the locations are: 13.62 to 16.04 at Milk Project, 15.33 to 21.60 dB (a) at Chittinagar, 16.40 to 16.90 dB (A) near LBRCE, and 14.30 to 17.80 dB (A) at NTTPS 2nd gate. This information shows that, the range of values between L10 and L90 is high or in other words, the background sound level at the location is differing by a large value that is indicated by NC.
- The ranges of L10 values at these locations are: 73.20 to 80.85 dB (A) at Milk Project, 81.52 to 92.50 at Chittinagar, 66.10 to 77.63 dB (A) near LBRCE, and 80.16 to 85.20 dB (A) at NTTPS 2nd gate. The L10 values represent the background noise levels at the location. It can be noted that, at all the locations, the L10 values are higher than the permissible limits which indicates a high background noise levels at these locations.
- The ranges of TNI values are very high at all the four locations: 84.06 to 98.94 dB (A) at Milk Project, 97.60 to 127.30 dB (A) at Chittinagar, 85.70 to 97.52 dB (A) near LBRCE and 93.80 to 108.60 dB (A) at NTTPS 2nd Gate. This indicates very high noise levels at all these areas, which is also evident from the high L10 values obtained.
- It should be noted that, the noise parameters L10, L50, L90 for traffic flow depend on traffic flow (Q) and distance from c/c of road to the sampling point (d). Higher the traffic flow, higher will be the noise levels while higher values of 'd' indicate lesser values of noise values.
- The average sound levels based on traffic flow at these four locations are: 76.1 dB (A) at Milk Project, 77.75 dB (A) at Chittinagar, 72.68 dB (A) near LBRCE, and 76.55 dB (A) at NTTPS 2nd gate respectively. The corresponding average traffic flow per hour (Q) value is: 640, 1381, 337 and 851 respectively. Comparing the sound level with the Q value, it is noted that, the highest sound values from traffic flow are recorded at Chittinagar. This trend however, is more evident when the average Leq values obtained from graph on both the days of sampling are compared. The average Leq values are: 72.42 dB (A), 86.56 dB (A), 62.16 dB (A), 77.82 dB (A) respectively at each of these locations. Hence, the following sequence is followed with respect to descending order of sound levels with respect to Q value: Chittinagar (1381, 86.56 dB (A)), NTTPS (851, 77.82 dB (A)), Milk Project (640, 72.42 dB (A)) and LBRCE (337, 62.16 dB (A)) respectively. This analysis reveals that sound levels from a location depends on traffic flow at the location and in other words, traffic flow is the major contributor of noise pollution in these locations.
- The peak flows of traffic at the sampling locations are: 7am to 12 noon and 4-6 pm at Milk Project, LBRCE. The movement of public for office or schools/colleges will be more during this period. Almost continuous high traffic flow throughout the sampling period is observed at Chittinagar, as it is a very busy commercial area. At NTTPS, the peak hours are 7-9 am, 4-9 pm. This is understood from the fact that movement of heavy vehicles are restricted in peak hours while office or school going public will be travelling more during this period.
- The major percentage contribution of the traffic flow is from 2- and 3- wheelers compared with 4-wheelers and others (Refer Fig. 5). The ranges of percentage contributions of 2- and 3-wheelers at the sampling locations are: 79% at Milk Project, 73% at Chittinagar, 67% at LBRCE, 54% at NTTPS 2nd gate respectively. This is in agreement with Kavitha (2014) who opined that two wheelers are primarily responsible for high noise levels.

Balashanmugam *et al* (2011) also opined the movement of vehicles in narrow lanes and outdated vehicles, poorly managed vehicles are responsible for heavy noise in urban areas.

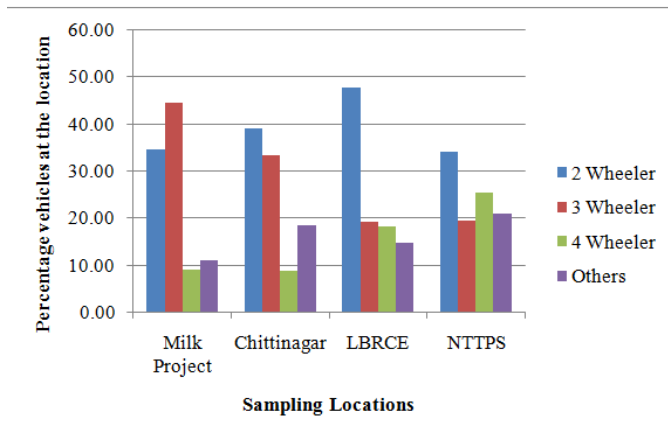


Fig. 5. Percentage distribution of vehicle flow at sampling locations

- The 4-wheeler movement is high at NTTPS 2nd gate and LBRCE with 25% and 18% respectively. Movement of heavy vehicle is very high at NTTPS, which is also located on Vijayawada-Bhadrachalam highway, for unloading of coal and/or procuring fly ash by the vendors for their requirements. Similarly, as LBRCE is located on the Vijayawada-Bhadrachalam highway, movement of heavy vehicles will be high compared to others.
- 69% of vehicular traffic in the sampled locations is from 2-, and 3-wheelers, only 14% of vehicles contribute towards the 4-wheeler movement (Refer Fig. 6). This clearly indicates that urban traffic is primarily composed of mainly 2- and 3-wheelers only and the movement of 4-wheelers such as buses, lorries, trucks etc is relatively less at the sampling locations.

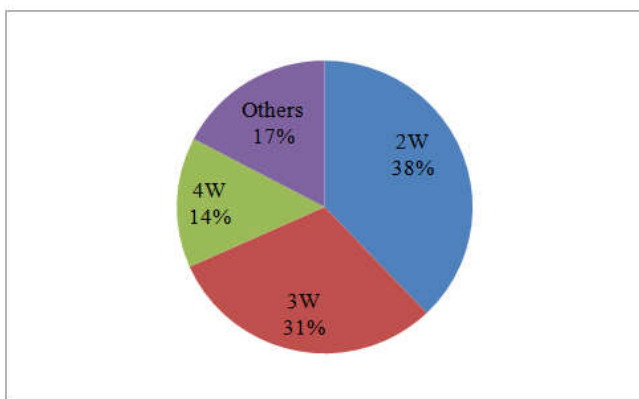


Fig. 6. Overall percentage distribution of vehicle flow at all the sampling locations

Based on the study and the alarming results the following suggestions are made:

- Phased elimination of diesel vehicles and replacing them with alternate fuel such as gasoline or biodiesel which can operate an engine producing less noise than that of a diesel engine.
- Avoiding traffic congestions by widening the existing roads.

- Construction of bye-pass roads for the heavy vehicles not to enter into the city during day time.
- Quickening of bye-pass constructions to avoid traffic diversions and protect health and safety of public from noise pollution.
- Use of greenery on the roads at lane dividers for sound attenuation.
- Diversion of traffic near silent zones such as hospitals, schools, religious places, etc.
- Provision of proper parking places for the vehicles. This is a major problem that is causing a lot of traffic congestion in that area.
- Traffic constables should be posted at all prominent locations other than the junctions to regulate the traffic and reduce the noise levels.
- Installation of continuous noise measurement units at prominent locations in the city which will induce awareness on public.
- Regular maintenance of the vehicles.
- Monitoring and penalizing vehicles that are old and emitting high noise.
- Avoiding fancy air horns as they cause lot of distraction to the traffic and increase the noise pollution.
- Creating awareness to the public through hoardings, cinema halls, print-audio-visual media about noise pollution and its impact on society.

Summary and Conclusion

The ambient and traffic noise levels are studied in and around Vijayawada. The results of ambient noise levels are analyzed based on Lavg, L10, L50, L90, Leq, NPL, NC parameters. Ambient noise levels are beyond the permissible limits at the urban locations sampled. Noise pollution due to traffic flow is studied. Traffic flow is measured at four locations representing residential, commercial, industrial, and silent zones. Simultaneously, sound levels are collected and analyzed using traffic flow, distance from sampling point to c/c of road, Lavg, L10, L50, L90, Leq, TNI, NC parameters. The results are compared with the permissible limits. The noise levels at all these locations are beyond the permissible limits. It is noted that, high noise levels are recorded at high traffic flows. The 2-, and 3-wheelers are contributing to 69% of vehicular flow at the sampling locations. Few suggestions are given to improve the situation.

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