# Noise Exposure Parameters of Auto Rickshaws Compare by Statistical Regression Technique

Tirtharaj Sen, Pijush Kanti Bhattacharjee, *Member, IACSIT,* Debamalya Banerjee, and Bijan Sarkar

***Abstract*— The objective of this work is to measure, evaluate and study the noise exposure from auto rickshaws in running condition in Kolkata city of India. Statistical Regression analysis is done among the different parameters like $L_{Aeq}$, $L_{90}$, and calculated parameters like TNI and $L_{np}$. TWA (Time Weighted Average) values are given as an output by the Noise Dosimeter. While $L_{np}$ (Equivalent Noise Pollution) and TNI (Traffic Noise Index) are computed using the standard formula, TNI (Traffic Noise Index) is maximum in summer (152.08 dBA) and $L_{np}$ (Equivalent Noise Pollution) is maximum in monsoon (130.78 dBA). TWA (Time Weighted Average) is 58.81 dBA. It is found from correlation coefficient data, the winter data set ($L_{Aeq}$ vs. $L_{90}$) is the most linearly correlated ($r^2 = 0.490$). TNI and $L_{np}$ for different runs in summer ($r^2 = 0.750$) and winter ($r^2 = 0.451$), data follow polynomial trend line of order two. This study suggests that noise exposure and noise induced hearing loss can interfere with the safety of driver daily life, since working in such places noise dose exceeded 89 dBA is more dangerous causing deafness due to extreme environmental pollution.**

***Index Terms*— TNI (Traffic Noise Index), TWA (Time Weighted Average), $L_{Aeq}$ (Equivalent continuous A-weighted sound level), $L_{np}$ (Equivalent Noise Pollution), Noise Dose.**

## I. Introduction

According to a very rough estimate from the auto rickshaw drivers, in Kolkata metropolitan city alone, about 76 thousand auto rickshaws are playing every day, out of which 40 thousands are having licensed.

According to some media reports, the unlicensed auto rickshaws sometimes use very low grade fuels like kerosene mixed with diesel etc., for which much noise and gases are emitted. The daily job of these auto rickshaw drivers is hazardous and strenuous. Maximum routes of this city are congested and roads are not properly maintained. The auto rickshaw drivers are exposed to heat, noise, diesel exhaust, body vibration etc. Some auto rickshaws are earlier using kerosene mixed with diesel or low quality fuel etc. It is so dangerous that it is not only increased environmental pollution in form of black colored gas, but increases engine noise also. The problem, to some extent, has been solved by enforcing conversion of all older auto rickshaws to LPG fuel by the Judiciary. Traffic noise level in Calcutta (which has been renamed as Kolkata) was previously measured by Pancholy *et al.*, [10] and Roy *et al.* [11]. Exposure of drivers to noise, heat and dust in Kolkata has been done by Mukherjee *et al.* [8]. They find that auto drivers exposure to noise depends on the number of trips performed per day and it is exceeded the recommended American Conference of Governmental Industrial Hygienists threshold limit value, mostly after a second trip. According to them, auto drivers undertaking consecutive trips within Kolkata city traffic routes along with other vehicles like bus, lorry, taxi etc. have higher noise exposure than the recommended standard and the conditions are more acute during summer, because of thermal stress. In their paper they conclude that the application of brakes, inside and outside horn effects, slamming of bus doors, and running in top gear produce appreciably higher in-bus noise pollution. Picard *et al.* reported on accident analysis and tried to find the possible causes with suggestion their prevention techniques [9]. Chakraborty *et al.* [3] reported on the status of road traffic noise in Calcutta. Noise levels are measured at each of twenty four sites, by them, based on predetermined sampling interval and altogether 2880 observations are generated by recording data continuously for 24 hours. The $L_{Aeq}$ 24, exceedence levels, LD, LN, LDN, LNP and TNI are determined. Traffic flow density as measured along with noise data recording are then compared for establishing relationship with noise level. Finally the clustering of the sites is made based on variable viz. $L_{Aeq}$ 24 and traffic follow density.

Griefahn *et al.* [5] reported noise emitted from road, rail, air traffic and their effects on sleep. The polysomnogram is recorded during all nights, sleep quality is assessed and performance tests are completed in the morning. It has been found that subjectively evaluated sleep quality is decreased and reaction time is increased gradually with the noise levels, whereas most physiological variables is revealed the same reactions to both the lower and considerably stronger reactions to the highest noise load. According to them, aircraft noise, rail and road traffic noise caused similar after-effects but physiological sleep parameters are most severely affected by rail noise. The equivalent noise level seems to be a suitable predictor for subjectively evaluated sleep quality, but not for physiological sleep disturbances.

All these previous studies are indicating towards a very dismal picture of traffic noise exposure of auto drivers of different vehicles in the metropolitan cities in India as well as everywhere in the world. The motivation of the work comes from the fact that the auto rickshaw drivers, hand-pulled rickshaw drivers, cyclists, pedestrians etc. are the people who are the worst affected by noisy sound, since their working level is very near to the ground, and making them susceptible to maximum exposure to all the pollutants, including noise. The basic aim of this study is to do a

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sample survey of the noise exposure in Kolkata, India; the auto rickshaw drivers are subjected to noise exposure throughout his period of duty. This study can go a long way in indicating the most problematic areas of traffic noise pollution.

## II. Methods

### A. Procedure and Sample

The frequently-used terms depicted in this paper have standard definitions. Like, $L_{Aeq}$ (Equivalent continuous A-weighted sound level) is the equivalent steady sound level of a noise energy-averaged over time. Occupational noise is often a complex signal; the noise level needs to be averaged over a minimum sample time. The sampling time can be as short as a few minutes, if the noise signal is steady or repetitive over a short cycle; some jobs require a full day's monitoring. Whatever the actual duration, it should be a representative sample of the entire exposure. In the same way, TWA (Time Weighted Average) is a measure of noise exposure that is an average of varying levels of noise experienced in a given eight-hour workday.

The $L_n$ (n-percent exceeded level) is the sound pressure level exceeded for n percent of the time. In other words, for n percent of the time, the fluctuating sound pressure levels are higher than the $L_n$ level. $L_n$ can be obtained by analyzing a given noise by statistical means, e.g., $L_{10}$ and $L_{90}$.

For studying the characteristics of noise at different sites, a group of twelve (12) auto rickshaw drivers in South Kolkata city of India are selected. The auto rickshaw drivers are informed verbally just before the readings taken about the requirement and necessity of this study. When a detail of this work with the aim is intimated to them, i.e., how much noises are exposed to them while working on hazardous roads in Kolkata, they are actively give consent for whole hearted helping to this research work. SPL (Sound Pressure Level) are measured at different routes in South Kolkata in running condition in winter, summer and monsoon season. Also TWA (Time Weighted Average), SPL (Sound Pressure Level), threshold level, criterion level are calculated using the definitions stated above and from the standard formulae of those. A brief and subjective history of discomforts from the auto drivers is obtained through a questionnaire by asking different auto rickshaw drivers in different routes. The discomforts include headache, feeling of tiredness, irritability etc. and ultimately causing temporary or permanent deafness. Tremendous environmental pollution is caused by this noise emanating from different vehicles.

### B. Instruments Used

The approximate noise dose (ND) for drivers on each trip are calculated from:

$$ND = T/8X \text{ antilog } \{0.1 (L-90)\}, \quad (1)$$

where T is the duration in hours when a specified noise level reaches ear and L is level of noise reaching the ear in dB (A).

The $L_{Aeq}$ is calculated over a particular route from ND.

$$L_{Aeq} = 10\log (ND) + 90\text{dB (A)}. \quad (2)$$

All recordings are taken at the time slot mentioned above when the auto rickshaws are in motion and in the presence of the researchers. Though, the noise dose is not taken over the full day and it is taken only when the auto rickshaws are in motion, yet, an in-built feature in the Noise Dosimeter gives the projected noise dose over an eight hour period.

Noise Dosimeter made by Bruel & Kjaer Type 4444, is a lightweight and robust instrument and is used for assessment and recording of noise levels associated with auto rickshaw drivers in Kolkata [1]-[2], [12].

Specifications of the Noise Dosimeter for National and International Standards are noted below:

IEC61252, ANSI S1.25, IEC60651.1979 Type 2a, IEC60804.2000 Type 2a, ANSIS1.4.1983 Type S (1) ANSIS1.43.1997.

The Microphone for recording noise level has the following specification:

Type: 1/4″ Microphone with Integral Cable Connector: 5-pin LEMO

The Measurement Control has the specification as stated herein:

Manual Control**:** using keys for Start/Pause/Continue and Stop. After the Start key is pressed, measurement starts and the clock reaches 00 seconds.

The Measuring Ranges are as follows:

Linearity and Indicator Ranges at 4 kHz (IEC60804): 30.100: 43b.100 dB (A and C), 50.120: 50.120 dB (A and C), and 70.140: 70.140 dB (A and C).

The Peak Range is as below:

C-weighted or Linear Peak over the top 40 dB of each measurement range: 30.100: 63.103 dB Peak,
50.120: 83.123 dB Peak, 70.140: 103.143 dB Peak.

The Frequency Weightings are supplied as:

RMS Detector: A or C, Peak Detector: C or L (Linear).

The Time Weightings can be taken as:

Fast, Slow and Impulse (RMS detector).

The Exchange Rate for the instrument is: 3 dB (always), plus on+e additional exchange rate of 4, 5 or 6 dB.

Summary of Default Setups [12] are: Measurement Range (dB) for OSHA, MSHA, DOD, ACGIH, METER, SLM are 70 to 140 dB. Time weighting for OSHA, MSHA, DOD and ACGIH are slow and for METER and SLM are fast. Exchange Rate for OSHA, MSHA, and DOD are 3 and 5 and for ACGIH, METER, SLM are only 3. Threshold (dB) value for OSHA, MSHA, DOD, ACGIH are 80 dB and this is not applicable for METER and SLM. Criterion Level (dB) for OSHA and MSHA is 90 dB, whereas 85 dB for DOD and ACGIH. This Criterion Level is not applicable for METER and SLM.

A Noise meter type 4444 [7]-[8] comes with different (seven) built in setups, which includes OSHA, MSHA, DOD, ACGIH (USA Standards) etc. which corresponds to today's most widely used standards. U.S. Occupational Safety & Health Administration - OSHA - Standards are widely available. Since OSHA standards are accepted and used in most parts of the World, as is evident from the works of the previous researchers, they were used in this study. MSHA, DOD, and ACGIH (USA Standards) details can be obtained likewise.

### C. Method of Measurement

The noise exposure to twelve (12) auto rickshaw drivers are taken during January to August, 2009 over a period of 32 weeks, which covered winter, summer and monsoon seasons. An area of South Kolkata is selected and measurements are taken in different routes in morning (9.30 AM to 11.30 AM), noon (12.30 PM to 2.30 PM) and afternoon (3.30 PM to 5.30 PM) time. The different routes

have been shown in Table 1. Each route (equivalent to number of runs) is studied at least two times during the to-and-fro journey with one auto rickshaw driver at a time. The noise, actually, a weighted noise, $L_{Aeq}$, is recorded for the driver by connecting the mouthpiece to the driver's collar (10 cm approx. from the driver's right ear). It is estimated by recording the dBA value in $L_{Aeq}$ mode.

TABLE I: ROUTE CHART WHERE MEASUREMENTS ARE TAKEN IN SOUTH KOLKATA

| Route No | Name of Route | Distance in Km |
|---|---|---|
| 1 | Jadavpur to Tollygunge | 5 |
| 2 | Tollygunge to Jadavpur | 5 |
| 3 | Jadavpur to Garia | 4 |
| 4 | Garia to Jadavpur | 4 |
| 5 | Jadavpur to Dhakuria | 3 |
| 6 | Dhakuria to Jadavpur | 3 |
| 7 | Jadavpur to Golpark | 4 |
| 8 | Golpark to Jadavpur | 4 |
| 9 | Jadavpur to Keyatala Road | 5 |
| 10 | Keyatala road to Jadavpur | 5 |
| 11 | Jadavpur to Taratala | 8.5 |
| 12 | Taratala to Jadavpur | 8.5 |

### D. Statistical Regression Theory

(i) Regression lines: Consider the problem for an individual, the value of one variable is x, the other variable is y. It would be necessary to express the relationship between x and y in a mathematical form to solve the problem. Let in a particular case the approximate relation may be represented by a line: y = a + bx, where a and b are two constant terms. To get an appropriate line, it is necessary to determine a and b from the observed data. Assume that there are n number of given pairs for values of x and y, the $i^{th}$ pair is denoted by ($x_i$, $y_i$). The above line gives as an estimate of $y_i$, in which the value $a + bx_i = y_i$ (say).

The difference $y_i - Y_i$ is given the error of estimate for the $i^{th}$ pair, where i = 1, 2.....n. It is reasonable to require that a and b should be such that these errors of estimate are as small as possible, since the line is to be used for estimating purpose. Now it will not be enough to minimize the sum of these errors, because the errors, which may be positive or negative, may even add up to zero for a line which the individual errors are of high magnitude. Most cases a satisfactory method of determining a and b would be called the method of least squares, which consists in minimizing the sum of squares of the errors of estimation. So the problem is to chose a and b in such a way as to minimize $S^2$.

$$S^2 = \sum_i (y_i - Y_i)^2 \quad (3)$$

or,

$$S^2 = \sum_i (y_i - a - bx_i)^2 \quad (4)$$

The desired values are obtained by solving the simultaneous equations, called normal equations.

(ii) Correlation Analysis: Correlation analysis is a mathematical tool. It is used to describe the degree to which one variable is linearly related to the other. Therefore it is directed towards measuring the degree of association of the two variables. All measures of correlation are defined in such a fashion that a measures of zero (0) signifies no correlation at all, and the perfect correlation is indicated by a magnitude of one (1), positive for direct linear relationship and negative for an inverse linear relationship.

Most measures of correlation are based on finding the sum of square of the deviations from the regression line and relating it to the inherent variability of the data itself. Thus, one measures the coefficient of determination, termed as $r^2$, which is defined by followings:

$$r^2 = 1 - \frac{Variations\ of\ y\ from\ the\ regression\ line}{variations\ of\ y\ values\ from\ their\ own\ mean} \quad (5)$$

or,

$$r^2 = 1 - \frac{\sum(y-Y)^2}{\sum(y-\bar{Y})^2} \quad (6)$$

This is based on treating the variations of the sample values from the regression predicted-values $\sum(y-Y)^2$ as random or the 'unexplained variations' so that part $\sum(y-Y)2 - \sum(y-Y)2$ can be taken to be the variation which can be explained by the observed relationship. Its ratio with the total variation $\sum(y-\bar{Y})^2$ is then a natural measure of the strength of correlation of the two variables as revealed by the data.

It can be shown easily on substituting the value of Y by using the regression equation and this reduces to eq. (7).

$$r^2 = \frac{cov^2(x,y)}{var(x).\ var(y)} \quad (7)$$

The value of r itself is termed as the Karl Pearson's coefficient of correlation.

The basic formula for determination of the coefficient of correlation

$$r = \frac{\sum(y-\bar{y})(x-\bar{x})}{\sqrt{\sum(y-\bar{y})^2\sum(x-\bar{x})^2}} \quad (8)$$

The long formula is:

$$r = \frac{\sum xy - (\sum x)(\sum y)/N}{\sqrt{\sum x^2 - (\sum x)^2/N}\sqrt{\sum y^2 - (\sum y)^2/N}} \quad (9)$$

### E. Computation of data

Data is taken between 9.30 AM and 5.30 PM (8 Hrs) at each route. Computation of the hourly equivalent continuous noise level $L_{Aeq}$, and the noise exceedance level $L_{10}$, $L_{90}$ are done by the Noise Dosimeter itself. TNI (Traffic noise index) and $L_{np}$ (Noise pollution level) are calculated later.

The different formulas are used for computation of these parameters are jotted down below:

$$L_{(h)} = L_{eq(h)} = 10 \log \frac{1}{n} \sum_{i=1}^{n} 10^{L_i/10}, \quad (10)$$

where n = Total number of recorded data in the period of six hours and $L_i$ = The i-th sound-pressure level data:

$$L_{Aeq}(12) = 10\log \frac{1}{12} \sum_{i=1}^{12} 10^{\frac{Li}{10}} \quad (11)$$

$$TNI = 4(L_{10} - L_{90}) + L_{90} - 30 \quad (12)$$

$$L_{np} = L_{Aeq}(12) + (L_{10} - L_{90}) \quad (13)$$

## III. Results

Mean values for $L_{Aeq}$ in winter is 86.65 dBA, for summer it is 85.09 dBA and in monsoon it is 83.80 dBA.

The output from 4444 Noise Dosimeter and derivations from computation are depicted in Table numbers 2 to 4. Table-2 shows Traffic Noise Index and Equivalent Noise Pollution in winter, Table-3 shows Traffic Noise Index and Equivalent Noise Pollution in summer and Table-4 shows Traffic Noise Index and Equivalent Noise Pollution in Monsoon.

TABLE II: Traffic Noise Index & Equivalent Noise Pollution in Winter

| No of runs | $L_{Aeq}$ dBA | $L_{10}$ dBA | $L_{90}$ dBA | TNI (Traffic Noise Index) dBA | $L_{np}$ (Equivalent Noise Pollution) dBA |
|---|---|---|---|---|---|
| 1 | 86.21 | 95.20 | 72.84 | 132.28 | 108.56 |
| 2 | 85.90 | 90.73 | 74.44 | 127.48 | 102.16 |
| 3 | 88.52 | 98.22 | 75.94 | 134.98 | 110.76 |
| 4 | 87.20 | 93.22 | 72.64 | 124.88 | 107.76 |
| 5 | 81.30 | 98.20 | 71.14 | 149.38 | 108.36 |
| 6 | 89.33 | 99.21 | 75.04 | 141.68 | 113.46 |
| 7 | 87.22 | 97.21 | 75.64 | 133.68 | 108.76 |
| 8 | 87.31 | 95.73 | 73.54 | 132.18 | 109.46 |
| 9 | 84.10 | 98.71 | 72.74 | 146.58 | 110.06 |
| 10 | 86.70 | 92.20 | 71.44 | 124.48 | 107.46 |
| 11 | 86.71 | 91.72 | 74.14 | 114.38 | 104.26 |
| 12 | 89.30 | 94.74 | 74.74 | 124.58 | 109.26 |

From Table-2 it is found that maximum Traffic Noise Index is 149.38 dBA, whereas minimum is 114.38 dBA. Maximum Equivalent Noise Pollution is 113.46 dBA and minimum is 102.16 dBA.

TABLE III: Traffic Noise Index & Equivalent Noise Pollution in Summer

| No of runs | $L_{eq}$dBA | $L_{10}$ dBA | $L_{90}$ dBA | TNI (Traffic Noise Index) dBA | $L_{np}$(Equivalent Noise Pollution) dBA |
|---|---|---|---|---|---|
| 1 | 84.20 | 90.21 | 75.04 | 105.68 | 99.36 |
| 2 | 87.31 | 99.11 | 74.74 | 142.18 | 111.60 |
| 3 | 85.44 | 96.75 | 72.81 | 138.37 | 109.29 |
| 4 | 83.32 | 99.32 | 75.04 | 142.08 | 107.56 |
| 5 | 85.41 | 95.62 | 71.44 | 138.08 | 109.56 |
| 6 | 83.10 | 92.35 | 71.14 | 125.78 | 104.26 |
| 7 | 87.45 | 92.27 | 72.62 | 120.94 | 106.98 |
| 8 | 88.01 | 98.37 | 75.14 | 137.78 | 105.66 |
| 9 | 82.53 | 99.12 | 71.44 | 152.08 | 110.16 |
| 10 | 87.42 | 93.50 | 75.94 | 116.18 | 104.96 |
| 11 | 84.71 | 94.70 | 73.54 | 128.18 | 105.86 |
| 12 | 82.20 | 99.30 | 72.84 | 148.68 | 108.66 |

In Table-3, maximum and minimum Traffic Noise Index is 152.08 dBA and 105.68 dBA respectively and maximum and minimum Equivalent Noise Pollution is 111.60 dBA and 99.36 dBA respectively.

As it is seen in Table-2 that $L_{Aeq}$ values of all the runs slightly exceeds the OSHA recommended value of 85 dBA. The $L_{10}$ values show that they are much above the OSHA recommended value (85 dBA). However all $L_{90}$ values are within the OSHA prescribed limit [11]. Table-2, Table-3 and Table-4 represent the equivalent continuous noise exposure in dB(A) as well as Traffic Noise Index (TNI) and Equivalent Noise Pollution ($L_{np}$) at twelve different runs in running condition of auto rickshaws during winter, summer and monsoon seasons. Threshold level and criterion level are always kept in 80 dB and 90 dB respectively.

TABLE IV: Traffic Noise Index & Equivalent Noise Pollution in Monsoon

| No of runs | $L_{eq}$dBA | $L_{10}$ dBA | $L_{90}$ dBA | TNI (Traffic Noise Index) dBA | $L_{np}$(Equivalent Noise Pollution) dBA |
|---|---|---|---|---|---|
| 1 | 83.32 | 95.20 | 72.84 | 132.28 | 105.66 |
| 2 | 83.10 | 90.31 | 70.21 | 120.57 | 103.14 |
| 3 | 84.50 | 98.63 | 74.42 | 141.14 | 108.68 |
| 4 | 85.41 | 98.11 | 74.01 | 139.00 | 109.49 |
| 5 | 83.03 | 94.90 | 72.64 | 131.68 | 105.29 |
| 6 | 82.23 | 90.11 | 70.14 | 119.98 | 102.16 |
| 7 | 83.41 | 91.24 | 70.95 | 121.95 | 103.65 |
| 8 | 84.27 | 98.27 | 74.92 | 138.04 | 107.48 |
| 9 | 87.31 | 95.56 | 73.34 | 131.98 | 109.76 |
| 10 | 83.02 | 91.40 | 70.54 | 123.98 | 103.38 |
| 11 | 83.00 | 91.70 | 70.42 | 124.04 | 130.78 |
| 12 | 83.00 | 90.01 | 70.26 | 119.26 | 102.75 |

From Table-4, it is seen that, maximum Traffic Noise Index is 141.14 dBA, whereas minimum is 119.26 dBA. Maximum Equivalent Noise Pollution is 130.78 dBA and minimum is 102.16 dBA.

Now Exceedance times (the amount of time the recorded value exceeded the noise limit set by OSHA for % of runs from 70 dB - 140 dB as depicted by the dosimeter) and Time weighted Average (TWA) are shown in Table-5. Table-6 shows the break-up percentage of noise in each 5 dB interval.

TABLE V: Noise Dose From 70 Db to 140 Db and Corresponding Time Weighted Average

| No. of Runs | 70 dB | 85 dB | 90 dB | 100 dB | 115 dB | 140 dB | TWA dBA |
|---|---|---|---|---|---|---|---|
| 1 | 92.61 | 17.61 | 3.22 | 0.10 | 0.00 | 0.00 | 62.7 |
| 2 | 97.79 | 18.81 | 2.62 | 0.08 | 0.00 | 0.00 | 62.7 |
| 3 | 100 | 16.96 | 6.60 | 0.15 | 0.00 | 0.00 | 63.1 |
| 4 | 99.19 | 47.37 | 12.38 | 0.00 | 0.00 | 0.00 | 62.3 |
| 5 | 100 | 38.60 | 6.60 | 0.28 | 0.00 | 0.00 | 48.2 |
| 6 | 99.74 | 35.50 | 5.89 | 0.03 | 0.00 | 0.00 | 61.6 |
| 7 | 100 | 39.26 | 4.69 | 0.03 | 0.00 | 0.00 | 64.0 |
| 8 | 100 | 56.65 | 3.74 | 0.04 | 0.00 | 0.00 | 52.6 |
| 9 | 96.80 | 67.14 | 26.21 | 0.16 | 0.00 | 0.00 | 52.8 |
| 10 | 93.01 | 52.31 | 5.99 | 0.22 | 0.00 | 0.00 | 61.6 |
| 11 | 96.22 | 37.01 | 13.30 | 0.02 | 0.00 | 0.00 | 64.5 |
| 12 | 99.18 | 17.99 | 4.62 | 0.31 | 0.00 | 0.00 | 49.7 |

TABLE VI:-Intermediate Noise Dose (%)

| No. of Runs | 70dB-85dB | 85dB-90dB | 90dB-100dB | 100dB-115dB | 115dB-140dB |
|---|---|---|---|---|---|
| 1 | 75.08 | 14.39 | 3.12 | 0.10 | 0.00 |
| 2 | 79.61 | 15.56 | 2.54 | 0.08 | 0.00 |
| 3 | 83.04 | 10.36 | 6.45 | 0.15 | 0.00 |
| 4 | 51.82 | 34.99 | 12.38 | 0.00 | 0.00 |
| 5 | 61.40 | 32.00 | 6.32 | 0.28 | 0.00 |
| 6 | 64.24 | 29.61 | 5.86 | 0.03 | 0.00 |
| 7 | 60.74 | 34.57 | 4.66 | 0.03 | 0.00 |
| 8 | 43.34 | 52.91 | 3.70 | 0.04 | 0.00 |
| 9 | 29.66 | 40.93 | 26.05 | 0.16 | 0.00 |
| 10 | 40.70 | 46.32 | 5.77 | 0.22 | 0.00 |
| 11 | 59.21 | 23.71 | 13.28 | 0.02 | 0.00 |
| 12 | 81.19 | 13.37 | 4.31 | 0.31 | 0.00 |

*A. Correlation coefficient for different data set*

Applying Statistical Regression for $L_{Aeq}$ and $L_{90}$ for different seasons the regression equations are as follows:

$y = 0.491x + 31.14$ ……...(14) (winter)

$y = 0.378\ x + 41.28$ ……...(15) (summer)

$y = 0.491x + 31.14$ ……(16) (monsoon)

Again regression equations for TNI and $L_{np}$ are:

$y = -0.006\ x^2 + 1.864\ x – 27.37$ …….(17) (winter)

$y = -0.003\ x^2 + 0.985\ x + 29.61$ ……..(18) (summer)

$y = 0.132\ x + 90.60$ …….(19) (monsoon)

From different data set for $L_{Aeq}$ and $L_{90}$ in different seasons, it is found from the correlation coefficient data, the winter data set is almost linearly correlated ($r^2 = 0.490$) and summer data set is least linearly correlated ($r^2 = 0.222$). Again from the different data set for different routes plotting for TNI and $L_{np}$ the summer ($r^2 = 0.750$) and winter ($r^2 = 0.451$), data follow polynomial trend line of order two. Also monsoon data shows very poor linear correlation value such as $r^2 = 0.018$. Fig. 1 to Fig. 6 shows regression graphs in different seasons.

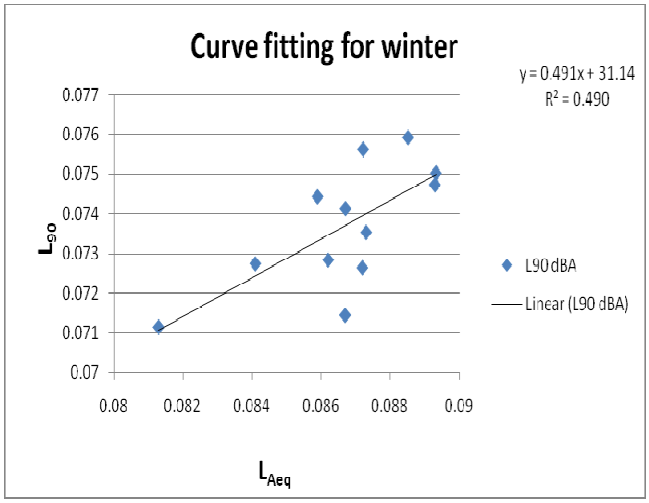


Fig. 1. Curve fitting for $L_{Aeq}$ and $L_{90}$ in winter

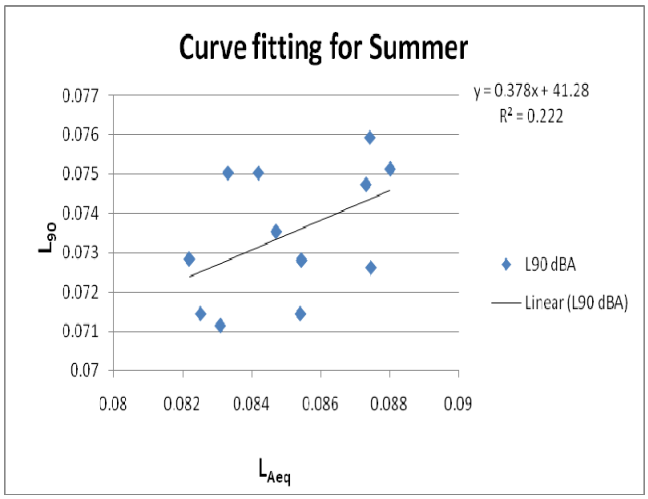


Fig. 2. Curve fitting for $L_{Aeq}$ and $L_{90}$ in summer

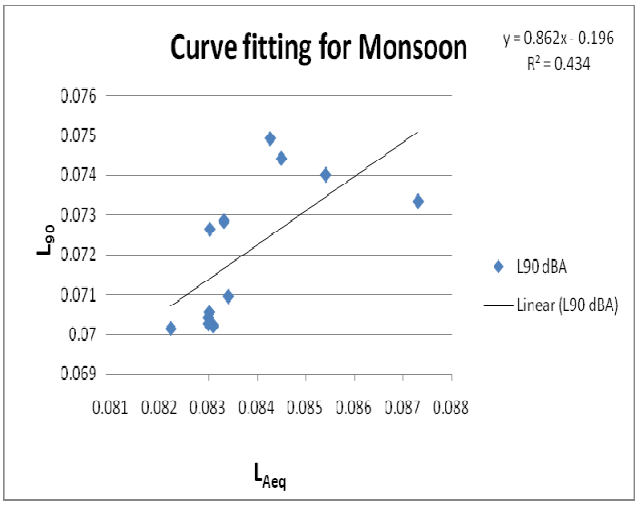


Fig. 3. Curve fitting for $L_{Aeq}$ and $L_{90}$ in monsoon

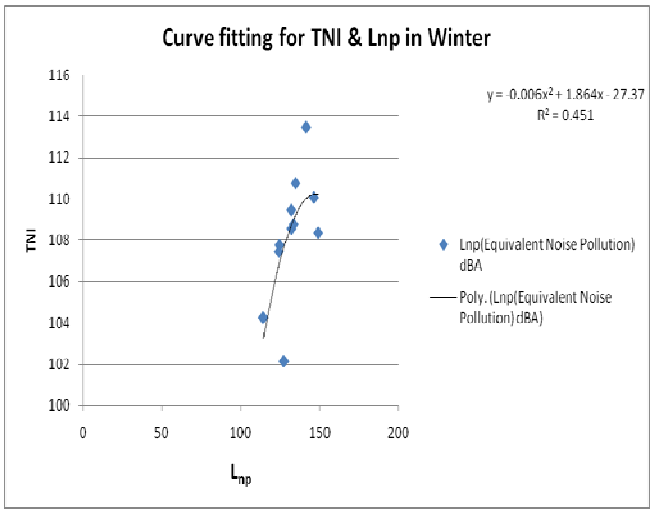


Fig. 4. Curve fitting for TNI and $L_{np}$ in winter

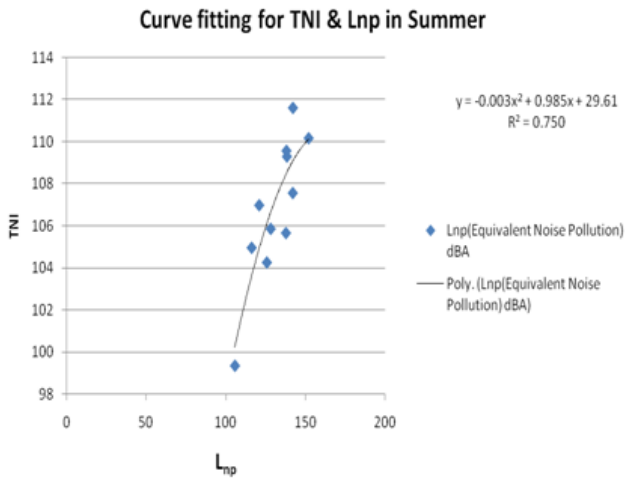


Fig. 5. Curve fitting for TNI and $L_{np}$ in summer

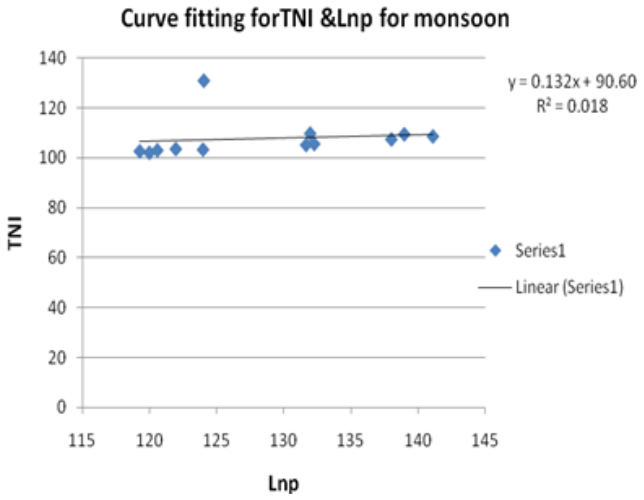


Fig. 6. Curve fitting for TNI and $L_{np}$ in monsoon

## IV. Discussion

From above it is found that TNI (Traffic Noise Index) is maximum in summer, i.e., 152.08 dBA and $L_{np}$ (Equivalent Noise Pollution) is maximum in monsoon, i.e., 130.78 dBA. Mean Time Weighted Average (TWA) is 58.81 dBA considering all seasons. It is observed that different auto rickshaw drivers have different categories of sensitivity of hearing. This is concluded after analyzing the answers given by the auto drivers in response to the questionnaires offered.

## V. Conclusion

This study suggests that the noise exposure for auto rickshaw drivers is interfered with the safety of driver daily life, since disturbance in the form of noise is a major cause of not hearing warning signals or horns from other vehicles in the roads. Actual data is not yet presented on noise induced hearing loss or what noise levels would have caused it. It has been earlier found in previous studies that working in such places where daily noise dose exceeds 89 dBA, is more dangerous even for those suffering from mild noise related hearing loss. If noise exposure can be reduced, then it will decrease the tendency of drivers to cause accident and injury, because inability to hear auditory warning signals, or too uncertain about their presence, appropriate action cannot be taken in time from the part of the auto rickshaw drivers. Apart from this, the long exposure to this level of noise is surely produce short term and long term hearing disorders. Though this study is done only with auto rickshaws, this study can be easily extended to other types of vehicles. The results indicate how much the auto rickshaw drivers of Kolkata, in particular, and all drivers, in general, are exposed to high intensity of noise pollution. For prevention measure, the usage of Ear Plug or Ear Muff can reduce the problem. Unless there are strong regulations to prevent noise pollution in roads, it is very hard to remove the problem at all. This research work can be further extended in other modes of transportations like buses, trucks, motor cars etc. moving throughout the world.

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