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A Study on Noise Characterization at Highway Crossing

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ABSTRACT

Noise is unwanted sound. Sound is a form of energy that is an inevitable consequence of mechanical processes. Sound may be defined as pressure variation that the human ear can detect. On the other hand it represents only a small fraction of the total energy involved in a mechanical process. In air, sound propagates at a speed of approximately 340 m/s. The normal hearing for a healthy young person frequency ranges from 20 Hz to 20000 Hz and sound pressure range is from 0 to 120 dB. The level of annoyance depends not only on the quality of sound, but also our attitude towards it. The sound of new jet aircraft taking off may be music to the ears of the design engineer, but will be ear–splitting agony for the people living near the end of the runway. While expressing sound or noise in terms of Pa we have to deal with the numbers as small as 20 and as large as 2,000,000,000. To avoid this inconvenience the sound or noise is expressed using decibel scale. The scale uses the hearing threshold of 20 µPa or 20 x 10-6 Pa as the reference level. This is defined as 0 dB. Sound pressure level, which is often abbreviated as SPL of Lp, is measured in decibels (dB) which is one tenth of bel (B). A bel is defined as a logarithm of the behavior of two readings of the same type (Bruel and Kjaer, 2000).

Key Words: *FHWA, Amplitude.*

The frequency of a sound wave refers to the number of vibrations per second, measured in unit of hertz (Hz) (Bruel and Kjaer, 2000). The frequency analysis allows separating the main components of the signals by dividing the frequency range of interest into smaller frequency bands using a set of filters. Human ear is a non linear device i.e., input and output amplitude do not necessarily have same ratio at all signal levels. The simplest periodic sound is a pure tone i.e., a pressure disturbance that fluctuates sinusoidal at a particular frequency. The lower the frequency, the longer is the wave length (wavelength = velocity of sound/frequency). According to the document of U.S. Federal Highway Administration (FHWA), “Measurement of highway-related noise”, most modern sound level meters used in highway studies will accurately measure levels in the frequencies that human ear can hear, from 20 to 20,000 Hz. Our ears are most sensitive to mid range frequencies, from about 1000 to 6300 Hz. Such frequency analysis are often done in bands of octaves or 1/3 octaves. An octave band is a frequency band with upper and lower cut off frequencies having a ratio of 2. For example the cut off frequencies of 707 Hz and 1414 Hz define an octave band, whose centre frequency is 1000 Hz octave band.

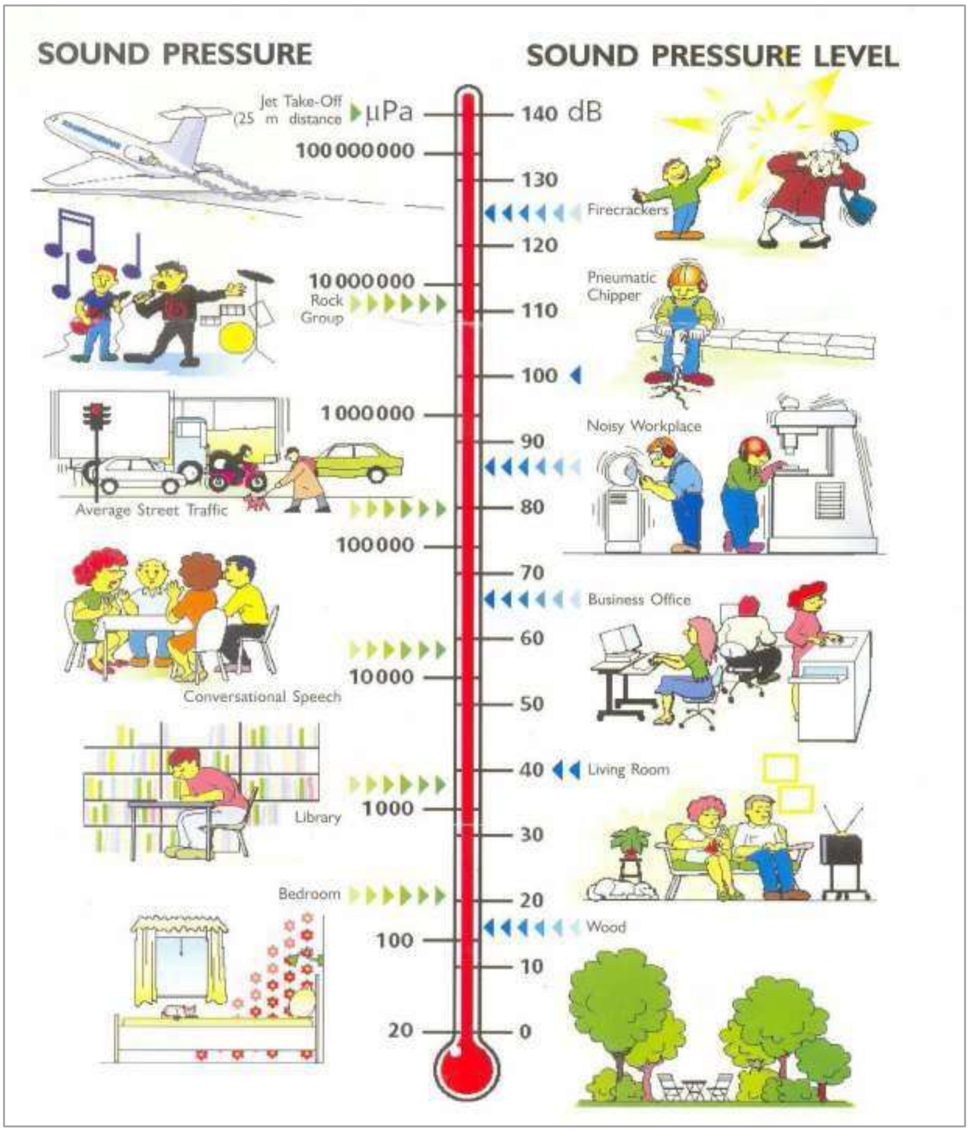

Figure 1: Typical Noise Levels (dB) with Static Air Pressure

Human hearing is not equally sensitive at all frequencies. Furthermore, the variation of sensitivity with frequency is a function of level. Therefore, several weighting scales have been developed to simulate the various sensitivities. These are categorized as A-, B-, C-, D- or Lin- frequency weightings (Figure 2). A- Weighting started with the work by Fletcher and Munson, 1933 of a set of equal loudness contours. After three years these curves were used by American standards for sound level meters. The B- weighting network corresponds to a contour at medium Sound Pressure Levels (SPLs) and the C- weighting network to an equal loudness contour at high SPLs. A specialized characteristic, the D- weighting has also been standardized for aircraft noise measurements. Z or ZERO frequency - weighting was introduced in the international standard IEC 61672 in 2003 and was later known as Linear (Lin) frequency weighting. This does not weight the signal but enables the signal to pass through unmodified (Bias and Hansen, 2009).

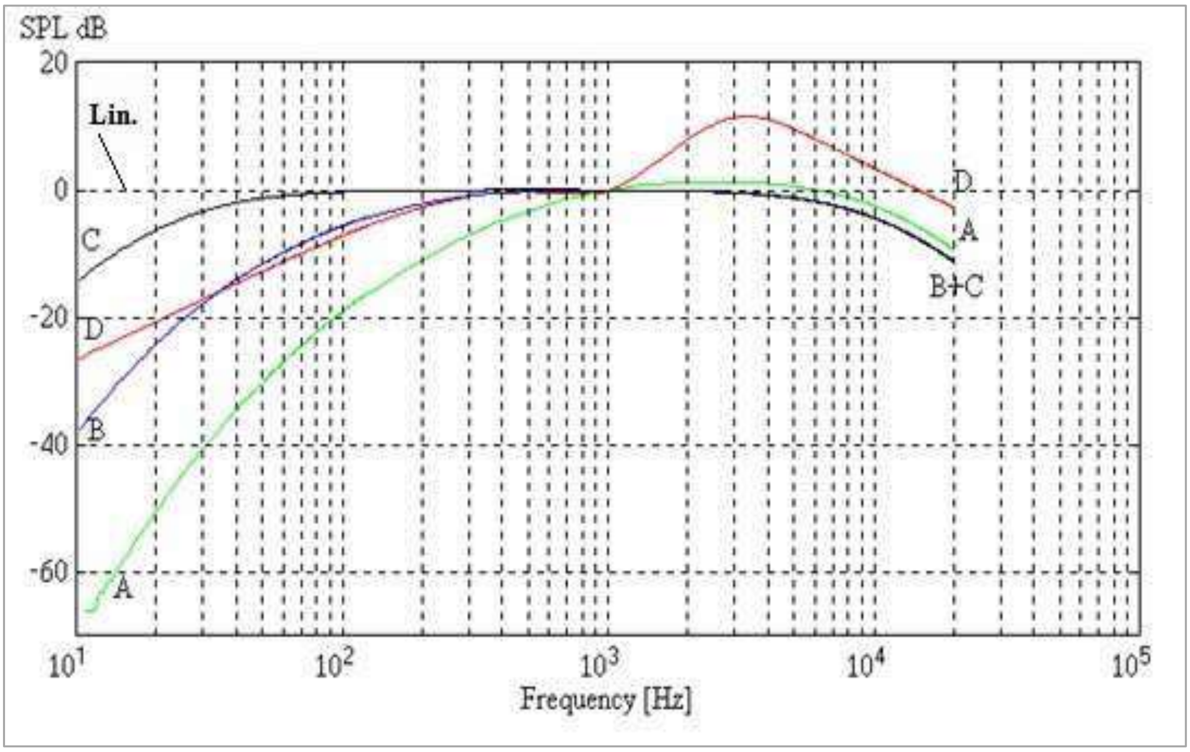

Figure 2: A-, B-, C-, D- and Lin-frequency Weightings Across the Range 10 Hz – 20 kHz

Different internationally recognized meter damping characteristics are available on sound level measuring instruments: 'Slow' (S), 'Fast' (F) and 'Impulse' (I) (IEC 651, 1979; BS 5969, 1983). The 'Fast' characteristic gives an effective averaging time of approximately 0.125 second, whereas 'Slow' characteristic gives an effective averaging time of approximately 1 second. The 'Slow' characteristic is mainly used in situations where the reading with the 'Fast' response fluctuates too much (more than about 4 dB) to give a reasonably well-defined value. The 'Impulse' characteristic is about four times faster than the 'Fast' response. It has a very fast rising time constant (approximately 35 milliseconds) and a very slow falling time constant.

Noise has become a major concern for the population residing near the highways as it has an inauspicious impact over their physical and mental well being. In recent years rapid urbanization and industrialization has enhanced noise pollution all over the world. Road traffic comes next to the industrialization for destroying the environment (Banerjee et al., 2009). Traffic noise varies with the type of vehicle, its speed and the condition of the roads (Cho and Mun, 2007). Noise has several adverse impacts on the population such as sleeplessness, headache, high blood pressure, dizziness, fatigue and cardiovascular diseases (Pathak et. al., 2007; Fyhri and Aasvang, 2010). The nature of adverse impact on population health varies depending on the noise frequency. Low frequency noise results in annoyance and sleep deprivation, physiological effects, and perception thresholds (Waye et. al., 2002 and Leventhall, 2004); whereas high frequency noise may cause hearing impairments, hypertensions, high blood pressure, speech interface, annoyance and disturbance of daily activities (e.g., Ishiyama and Hashimoto, 2000). In present study, the adverse health impact will be forecasted on the basis of *Preferred Noise Criteria* (PNC) and *Noise Rating* (NR) curves. Recommended PNC levels and their equivalent dB (A) are given in Table 1.

Table 1: Recommended PNC Levels and Corresponding dB (A) Equivalents

S. No.	**Environmental Conditions**	**Acceptable level**	
		PNC	**dB (A)**
1	Excellent listening conditions	< 20	< 30
2	Sleeping, residential, private office, library & classroom spaces	25 – 40	34 - 47
3	Large offices, stores, cafeterias and restaurants	35 – 45	42 - 52
4	Lobbies, laboratory, engineering and secretarial spaces	40 – 50	47 - 56
5	Maintenance, equipment, kitchen and laundry rooms	45 – 55	52 - 61
6	Shops, garages, power-plant control rooms, etc.	50 – 60	56 - 66

From Table 2 and Figure 3, it can be seen that equivalent allowable sound level rises as the frequency decreases. However, at very low frequency these levels allow exposure which leads towards various physical and psychological disorders. As a verification of their criteria, the author reports that measurements in auditoria and offices which the occupants find satisfactory fall in the appropriate PNC range. Therefore, PNC type criteria provide no protection for low frequency sound exposure, and further tend to rely on the public's increasing toleration of background noise and what seems to be decreasing auditory skills.

Table 2: PNC Value at Centre Frequency (Hz)

PNC Range	**Frequency**								
	31.5	63.0	125	250	500	1000	2000	4000	8000
PNC – 15	58	43	35	28	21	15	10	8	8
PNC – 20	59	46	39	32	26	20	15	13	13
PNC – 25	60	49	43	37	31	25	20	18	18
PNC – 30	61	52	46	41	35	30	25	23	23
PNC – 35	62	55	50	45	40	35	30	28	28
PNC – 40	64	59	54	50	45	40	35	33	33
PNC – 45	67	63	58	54	50	45	41	38	38
PNC – 50	70	66	62	58	54	50	46	43	43
PNC – 55	73	70	66	62	59	55	51	48	48
PNC – 60	76	73	69	66	63	59	56	53	53
PNC – 65	79	76	73	70	67	64	61	58	58

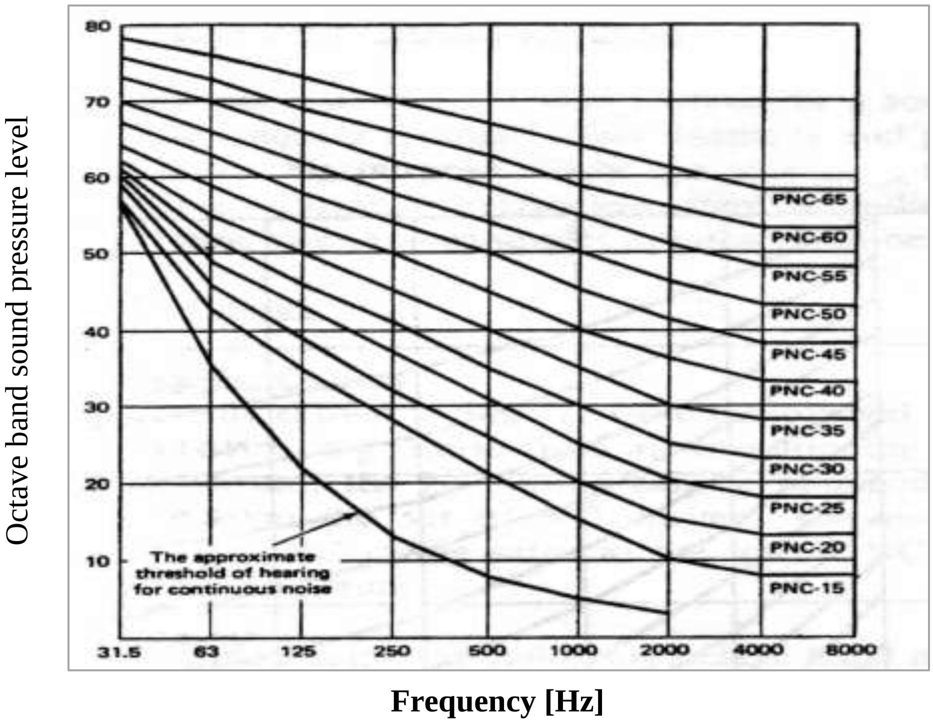

Figure 3: Preferred Noise Criteria Curve

It will be seen from NR curves (Figure 4), that higher frequencies (where the ear is more sensitive) are given heavier noise ratings than lower ones, information not taken into consideration in strict decibel measurements. Permissible noise levels for residential, commercial, industrial and silence zone of India are given in Table 3 and Table 4.

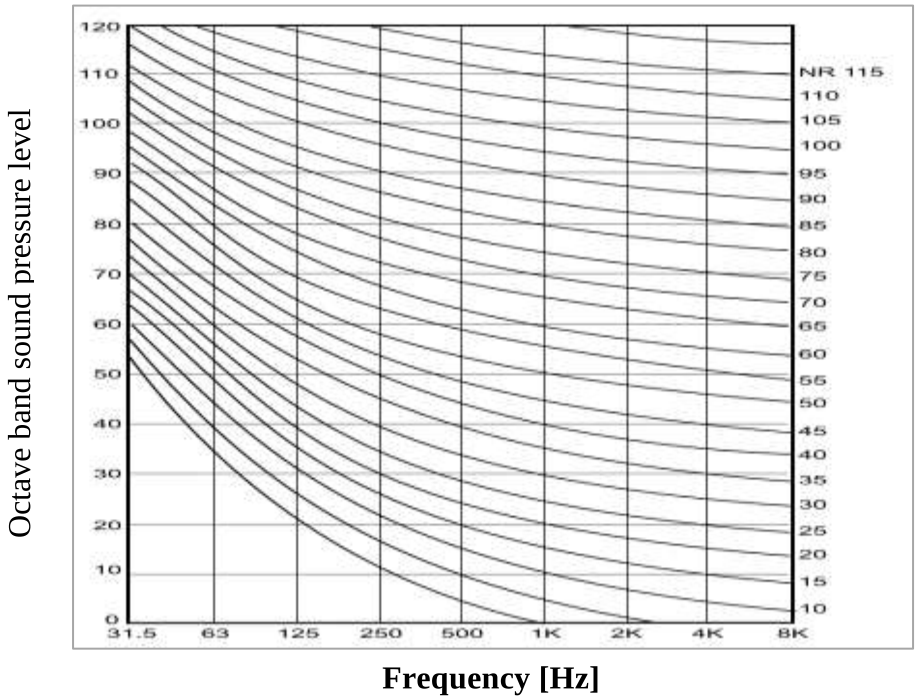

Figure 4: Noise Rating Curves

Table 3: Ambient Noise Standards in India as Per CPCB

S.N.	Area	L_{eq} in dB(A)	
		Daytime*	Nighttime**
1	Industrial Area	75	70
2	Commercial Area	65	55
3	Residential	55	45
4	Silence Zone***	50	40

* Daytime- 6.00 am -10.00 pm, ** Nighttime- 10.00 pm - 6.00 am,
*** Area up to 100m, around certain premise like hospital, educational institutes and court may be declared as silence zone.

Table 4: Acceptable Noise Level Standards for Residential Area as Per IS: 4954-1968 in India

S. No.	Location	Acceptable Noise Level in dB(A)
1	Rural	25-35
2	Suburban	30-40
3	Residential	30-45
4	Urban (residential and business)	40-45
5	City	45-50
6	Industrial area	50-60

The study area is situated in Lucknow city, which is the capital of Uttar Pradesh spread in 2528 sq. km. and attracts population from other areas due to better infrastructure, better employment opportunities, education facilities and law & order situation. This has resulted in rapid increase in growth of residential and commercial units as well as increase in number of vehicles. As per the 2011 census, total population of Lucknow city is 4,588,455 indicating an increase of 25.79 percent compared to 2001 census. In year 1999-2000 the total number of vehicles was 41,734 whereas by year 2008-09 it touched the figure of 666,068 (Figure 5).

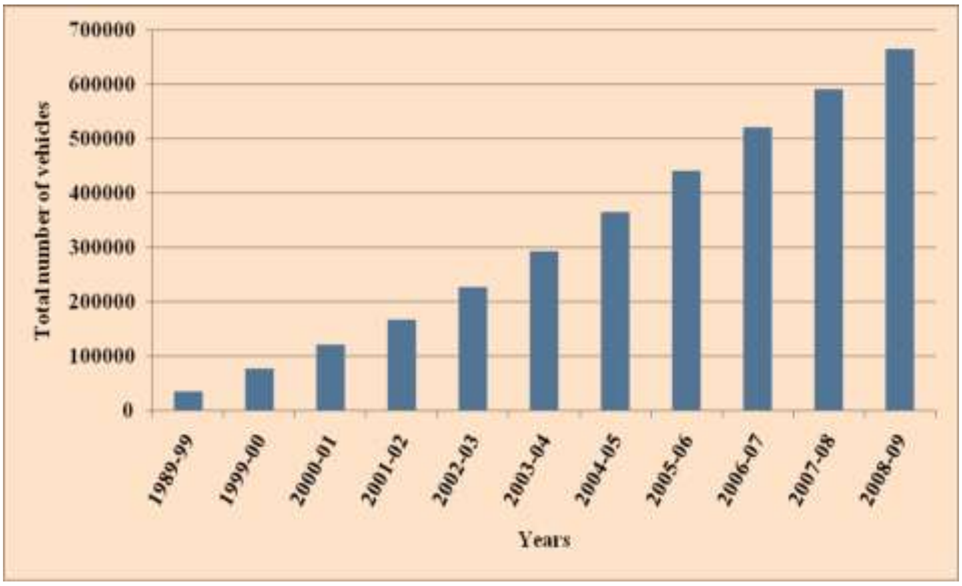

Figure 5: Vehicular growth in Lucknow (Barman and Daftardar, 2010)

The average sound pressure level (SPL) is determined by the equation:

$$L_p = 10 \times \log_{10} \frac{1}{N} \sum_{1}^{n} 10^{\frac{L.n}{10}} \qquad \textbf{(1)}$$

where, n =number of measurements in particular octave frequency

L_n = nth observed L_{eq} (L) value in particular octave frequency

n = 1, 2, 3,.......n

Since the distances of traffic noise sampling locations vary from the center line of the road, it can be made uniform using the following formula (Chakrabarty et al., 1997):

$$Leq,d\ (dBA) = Leq,r - 20\ log10\ (d/r) \qquad (2)$$

where, r = distance from center line of the road at which noise level is known

d = distance from center line of the road at which noise level to known

Variation of noise level will be observed at all the 1/3 octave band frequencies available with the noise level meter (model: 1900, make: Quest) equipped with filter unit (model: OB-300, make: Quest). SPL will be recorded on working days under suitable climatic conditions (i.e., no storm and rain) as per the sampling plan. Further care will be taken that there is no other major noise (such as loudspeakers, marriage band etc.) during measurements. Measurements will be discarded if such an event occurred during sampling slots. After recording the noise data, Quest software (supplied with the sound level meter) will be used for the retrieval of data to computer for further analysis. Noise measurement parameters (L_{eq}, L_{90}, L_{max}, ER-3 dB, frequency response, L_{in} weighting, time response in fast mode and 1 second logging rate interval, Threshold-off) will be monitored using sound level meter. Sound level meter will be calibrated daily using sound level Calibrator (Model QC-20).

Present study will focus on the spatial and temporal distribution of frequency based noise in the study area, identifying the sources contributing to overall noise, and forecasting adverse health impact of noise in the study area.

The noise standards are different in different countries and adopt different techniques and methods for its measurement and protection. The present study can be utilized in:

1. Knowledge of frequency wise spatial and temporal variation in traffic noise on a highway crossing.
2. Assessment of possible adverse health impacts on the population residing in vicinity of highways.
3. Identifying the noise pollution sources which will help in policy making in reducing noise pollution.

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