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Noise Pollution: A Review

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Abstract Noise pollution is the excessive noise that may harm the activity or balance of human being. The source of most noise worldwide is mainly caused by atmospheric noise/environmental noise/occupational noise such as industrial machines, transportation systems and indoor noise generated by machines (particularly in some workplaces), building activities, domestic appliances and music performances etc. The construction and industrial machineries frequently exposes its employees to hazardous noise levels and at the same time adds greatly to community noise. Noise may not be high enough to damage hearing (within buildings) and however the same have an adverse effect on general human health. Transportation contributes largely to environmental noise. The government of different countries has rules & regulations against the hazardous noise sources, but enforcement seems to be lenient. Noise laws and ordinances vary widely across the globe.

Keywords: *atmospheric noise, environmental noise, occupational noise*

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1. Introduction

Noise pollution is defined as the distressing noise that may harm the physical/mental activity of human being as well as animal life. Now days the matter of noise pollution is of prime concern. The objective of the presented paper is to create social awareness among the educated people and spread the knowledgeable information about the noise pollution. Noise is found almost everywhere. Some industrial locations have even louder continuous noise. Community noise is chiefly produced by transportation sources, most often airplanes and highway vehicles. Noise sources are also in public buildings and residences. Physically, there is no dissimilarity between sound and noise. Noise corresponds to undesired sound and any needless disturbance within a useful frequency band. The generation of most of the outdoor/ environmental noise in the world is mainly caused by industrial machines, transportation systems etc. as well as indoor noise generated by machines (especially in some workplaces), building activities, domestic appliances and music performances etc. The different countries have rules & regulation bodies against the harmful noise sources, but implementation seems to be indulgent. Noise laws and ordinances vary widely across the world. The presented article includes the comprehensive study of various aspects of noise pollution. The various classes of noise contributing to noise pollution, is covered in section II. Some important noise pollution related technical terms and details are elaborated in section III. The annoying noise level standards and limits are summarized in section IV. The noise monitoring as well as the hazardous effects of noise pollution and their consequences on human life are covered in section V. The selected code books on noise pollution by Bureau of Indian Standards (BIS) and noise pollution control are elaborated in Section VI and finally conclusions are covered in section VII.

2. Classes of Noise Related to Noise Pollution

Noise is unwanted sound and unnecessary form of energy which is emitted by a vibrating body and on reaching the human ear causes the feeling of hearing through nerves. Sounds produced by all vibrating bodies are not audible. The limits of audibility are from 20 Hz to 20 kHz. Sounds of frequencies less than 20 Hz are called infrasonics and greater than 20kHz are called ultrasonics. Noise may be continuous or intermittent as well as may be of high frequency or of low frequency which is undesired for a normal human hearing. The discrimination between sound and noise also depends upon the tendency and interest of the person receiving it, the ambient conditions and impact of the sound generated during that particular duration of time. Since noise is also a sound, the terms noise and sound are synonymously used and are followed in the presented article. Its pressure is used measured in logarithmic unit (dB) as the logarithmic scale permits a range of pressures to be described without using large numbers as well as it also represents the nonlinear behavior of the ear more convincingly.

It is observed that noise can be perceived either physiologically or psychologically. When noise is perceived physiologically, human subconsciously sense the vibrations of the noise (sound) waves in our physical body whereas psychological perception of noise refers to the event when conscious awareness of a person shifts attention to that noise rather than letting it filter through intuitive where it goes ignored [1].

(i) Atmospheric noise: It is a kind of radio noise caused by natural atmospheric processes, chiefly

lightning discharges in thunderstorms. It is primarily due to cloud-to-ground flashes as the current is much stronger than that of cloud-to-cloud flashes. On a worldwide scale, 3.5 million lightning flashes occur daily. This is around 40 lightning flashes per second [2]. The addition of all these lightning flashes constitutes atmospheric noise. At very low frequency(VLF) and low frequency(LF), atmospheric noise often dominates, while at high frequency(HF), man-made noise dominates mainly in urban areas. From 1960s to 1980s, a universal effort was made to measure the atmospheric noise and its variations [3,4,5].

(ii) Environmental noise: It is the abstract of noise pollution from outside sources, caused mainly by transport systems which includes a wheeled passenger vehicle that carries its own motor like buses, trains, trucks, cars, two/three wheelers, helicopters, watercraft, spacecraft and aircraft, and various recreational activities like sports, music performances [6,7,8]. This class of noise is generally present in some form in all areas of human activity. The effects in humans of exposure to environmental noise may vary from emotional to physiological and psychological [9]. The effects of environmental noise in humans may vary from emotional to physiological and psychological. Low level noise is not necessarily harmful. However, the undesirable effects of noise exposure could include annoyance, sleep disturbance, nervousness, hearing loss and stress-related problems [10]. Noise from transportation is generated by the engine/exhaust and aerodynamic noise (compression and friction in the air around the body during motion. Recreational noise could be generated by a large number of different sources and processes. The background noise like alarms, people talking, bioacoustic noise from animals or birds also constitute the environmental noise.

(iii) Occupational noise: Noise which affects workers in the course of their jobs and is due to the work environment and/or to the machinery which they must operate. Industrial noise varies in loudness, frequency components, and uniformity. It may be roughly uniform in frequency response and constant in level. Many machines in simultaneous operation are often like this. Other industrial or working place noise shows continuous background noise at relatively low levels with intermittently occurring periods of higher noise levels.

3. Technical Terms and Details Related with Noise Pollution

The definition of some important technical terms related with noise pollution measuring parameters and indicators is quoted from American National Standards Institute (ANSI) standard, ANSI S1.1-1994[ANSI 1994] or ANSI S3.20-1995[ANSI 1995] according to the terms used in that standard [11].

(i). Audiogram: Graph of hearing threshold level as a function of frequency. Sounds of frequencies less than 20 Hz are called infrasonics and greater than 20,000 Hz are called ultrasonics.

(ii). Baseline Audiogram: It is the audiogram against which subsequent audiograms will be compared for the estimate of significant threshold shift. It is obtained from an audiometric examination administered before employment or within the first 30 days of employment that is preceded by a period of at least 12 hours of silence.

(iii). Continuous Noise: Noise with negligibly small fluctuations of level within the period of observation.

(iv). Crest factor: 10 times the logarithm to the base 10 of the square of wideband peak amplitude of a signal to the time-mean-square amplitude over a stated time period.

(v). Decible, A-weighted (dBA): The sound level measured with the A-weighting network on a sound level meter.

(vi). Decibel, C-weighted (dBC): The sound level measured with the C-weighting network on a sound level meter.

(vii). Noise reduction rating (NRR): It indicates a hearing protector's noise reduction capabilities (in dB), is a single number rating that is required by law to be shown on the label of each hearing protector sold in the USA.

(viii). Derate: To use a fraction of a hearing protector's NRR to calculate the noise exposure of the worker wearing that protector.

(ix). Dose: The amount of actual exposure relative to the amount of allowable exposure, and for which 100% and above represents exposures that are hazardous. The dose of noise is calculated according to the following formula;

$$D = \left[\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots + \frac{C_n}{T_n}\right] \times 100 \quad (1)$$

where C_n =total time of exposure at a specific noise level, T_n =exposure/reference time [12] at which noise for this level becomes hazardous (in hour)

$$= \frac{8}{2^{(L-90)/5}} \quad (2)$$

and L =A-weighted sound level in dB(A).

(x). Effective noise level: The estimated A-weighted noise level at the ear when wearing hearing protector. Effective noise level is computed by (i) subtracting derated NRRs from C-weighted noise exposure levels, or (ii) subtracting derated NRRs minus 7dB from Aweighted noise exposure levels. Its unit is in dB.

(xi). Equal-Energy hypothesis: A hypothesis stating that equal amount of sound energy will produce equal amounts of hearing impairment, regardless of sound energy is distributed in time.

(xii). Equivalent continuous sound level: 10 times the log to the base 10 of the ratio of time-mean-square instantaneous A-weighted sound pressure,

during a stated time interval T, to the square of the standard reference sound pressure.

(xiii). Excess risk: percentage with material impairment of hearing in an occupational-noise-exposed population after subtracting the percentage who would normally acquire such impairment from other causes in a population not exposed to occupational noise.

(xiv). Exchange rate: An increment of decibels that require the halving of exposure time or a decrement of decibels that requires the doubling of exposure time.

(xv). Hearing Threshold Level (HTL): For a specified signal, amount in decibels by which the hearing threshold for a listener, for one or both ears, exceeds a specified reference equivalent threshold level.

(xvi). Emission level: A descriptor for noise exposure (in dB) representing the total sound energy incident on the ear over a specified period of time.

(xvii). Impulsive noise: Impulsive noise is characterized by a sharp rise and rapid decay in sound levels and is less than 1 sec in duration.

(xviii). Intermittent noise: Noise levels that are interrupted by intervals of relatively low sound levels.

(xix). Permanent threshold shift (PTS): Permanent increase in the threshold of audibility for an ear (unit in dB).

(xx). Significant threshold shift (STS): A shift in hearing threshold, outside the range of audiometric testing variability (±5dB), that warrants follow-up action to prevent further hearing loss.

(xxi). Sound intensity (in W/m^2): Average rate of sound energy transmitted in a specified direction at a point through a unit area normal to this direction at the point considered.

(xxii). Sound intensity level (in dB): 10 times the log to the base 10 of the ratio of the intensity of a given sound in a stated direction to the reference sound intensity of $1pW/m^2$.

(xxiii). Sound pressure (in Pa): Root- mean-square instantaneous sound pressure at a point during a given time interval.

(xxiv). Sound pressure level (in dB): 10 times the log to the base 10 of the ratio of the time-mean-square pressure of a sound, in a particular frequency band, to the square of reference sound pressure in gases of 20μPa.

(xxv). Temporary threshold shift (in dB): temporary increase in the threshold of audibility for an ear caused by exposure to high intensity acoustic stimuli.

(xxvi). Time-weighted average (TWA) in dB(A): The averaging of different exposure levels during an exposure period [13].

$$TWA = 10\log\left(\frac{D}{100}\right) + 85 \tag{3}$$

where, D =Dose

(xxvii). Day-night equivalent noise levels (L_{dn}): The day night equivalent noise levels of a society is expressed as [13];

$$L_{dn} in\ dB(A) = 10 \times \log\left[\frac{15}{24}\left(10^{L_d/10}\right) + \frac{9}{24}\left(10^{(L_d+10)/10}\right)\right] \tag{4}$$

where, L_d = day-equivalent noise levels (from 6AM - 9 PM i.e.15hours), in dB (A)

L_n = night equivalent noise levels (from 9 PM - 6 AM i.e. 9 hours), in dB (A)

A sound level of 10 dB is added to L_n due to the low ambient sound levels during night.

Sounds of frequencies from 800 to 3000 HZ are covered by the A - weighted scale. If the sound pressure level, L_1 in dB is measured at d_1 meters, then the sound pressure level, L_2 in dB at d_2 meters is given by [13],

$$L_2 = L_1 - 20\log 10\left(\frac{d_2}{d_1}\right). \tag{5}$$

If the sound levels are measured in terms of pressure, then, sound pressure level, L_p in dB (A), is given by [13],

$$L_p = 20\log 10\left(\frac{P}{P_0}\right) \tag{6}$$

where the L_p is measured against a standard reference pressure, $P_0 = 2\times10^{-5}\,N/m^2$ which is equivalent to zero decibels. The sound pressure is the pressure exerted at a point due to a sound/noise source [13]. The effective noise/sound levels of two or more sources cannot be simply added algebraically. For example, the effective sound level from two sources of 50 dB(A) each, say is not 50 + 50 = 100 dB (A) but 50 + 3 = 53 dB(A).

4. Noise Level Standards and Limits

Variation in noise levels is wide. Noise levels from various sources/areas are displayed in Table 1 [14,15].

Table 1. Noise levels from various sources/areas

Noise Sources	Noise levels, in dB(A)
Air compressors	95-104
Quiet garden	30
110 KVA diesel generator	95
Ticking clock	30
Lathe Machine	87
Computer rooms	55-60
Milling machine	112
Type institute	60
Oxy-acetylene cutting	96
Printing press	80
Pulveriser	92
Sports car	80-95
Riveting	95
Trains	96
Power operated portable saw	108
Trucks	90-100
Steam turbine (12,500 kW)	91
Car horns	90-105
Pneumatic Chiseling	118
Jet takeoff	120

Table 2 represents the permissible exposure limits and exchange rates used by various countries [16].

Table 2. Permissible exposure limits and exchange rates used by different countries

Countries	Permissible Exposure Limit (PEL), 8-hour average dB(A)	Exchange Rate, dB(A)
Argentina, 2003	85	3
Australia, 2000	85	3
Brazil, 1992	85	5
Canada, 1991	87	3
Chile, 2000	85	3
China, 1985	85	3
Colombia, 1990	85	5
EU, 2003	87	3
Finland, 1982	85	3
France, 1990	85	3
Germany, 1990	85	3
Hungary	85	3
India, 1989	90	-
Israel, 1984	85	5
Italy, 1990	85	3
Mexico, 2001	85	3
Netherlands, 1987	80	3
New Zealand, 1995	85	3
Norway, 1982	85	3
Spain, 1989	85	3
Sweden, 1992	85	3
U.K., 1989	85	3
United States, 1983	90	5
Uruguay, 1988	85	3
Venezuela	85	3

The Ministry of Environment & Forests, Govt. of India, has notified noise limits in the Noise Pollution (Regulation and Control) rules, 2000 [17]. The corresponding data are mentioned in Table 3. The Principal Rules were published in the Gazette of India, vide S.O. 123(E), dated 14.2.2000 and subsequently amended vide S.O. 1046(E), dated 22.11.2000, S.O. 1088(E), dated 11.10.2002, S.O. 1569 (E), dated 19.09.2006 and S.O. 50 (E) dated 11.01.2010 under the Environment (Protection) Act, 1986.

Table 3. SCHEDULE

Area Code dB(A)	Category of Area / Zone	Time-weighted average of the sound level limits in	
Time		Day Time	Night
(A)	Industrial area	75	70
(B)	Commercial area	65	55
(C)	Residential area	55	45
(D)	Silence Zone	50	40

Note:-
1. Day time shall mean from 6.00 a.m. to 10.00 p.m.
2. Night time shall mean from 10.00 p.m. to 6.00 a.m.
3. Silence zone is an area comprising not less than 100 meters around hospitals, educational institutions, courts, religious places or any other area which is declared as such by the competent authority
4. Mixed categories of areas may be declared as one of the four above mentioned categories by the competent authority.

As per the Noise Pollution (Regulation and Control) rules, 2000, the noise level at the boundary of the public place, where loudspeaker or public address system or any other noise source is being used shall not exceed 10 dB (A) above the ambient noise standards for the area or 75 dB (A) whichever is lower [17]. The peripheral noise level of a privately owned sound system or a sound producing instrument shall not, at the boundary of the private place, exceed by more than 5 dB (A) the ambient noise standards specified for the area in which it is used.

5. Noise Monitoring and Effects of Noise Pollution on Human Health

(i) Noise monitoring

It should be carried out on routine basis or to address the public complaints. The objective is to monitor the noise level at a particular site or as mentioned in the complaints. The weakest sound pressure disturbance that can be detected by an “average” person at 1,000Hz has been found to be 20μN/m2 and the largest 107μN/m^2. The noise monitoring should be based on the following steps [17];

(1) Site selection criteria
(2) Selection of noise level meter
(3) Calibration
(4) Monitoring time
(5) Monitoring parameters
(6) Monitoring protocols
(7) Monitoring records
(8) Monitoring data submission
(9) Monitoring Inferences

(ii) Effects of noise pollution on human health

Health effects related to environmental noise result in a cost for society. Presently, the European Commission (EC) is committed to meeting demanding targets on noise reduction through the 7th Environment Action Programme (EAP) [18]. The World Health Organization (W.H.O.) is revising the Community Noise Guidelines for the region [19]. Exposure to noise may lead to changes in the normal way the body functions. The body reacts to acute noise exposure by releasing stress hormones, such as adrenaline [20]. The severe effects occur not only at high sound levels in workplace settings, but also at relatively low environmental noise levels when concentration, relaxation, or sleep is disturbed [20]. Night-time noise may have more of an impact on cardiovascular health than day-time noise, because sleep is disturbed. The W.H.O. considers night-time noise levels of less than 55 dB(A) to be necessary to prevent adverse health effects from noise in the short term, although the long-term goal is 40 dB(A). The most common effects of noise pollution on the vulnerable identified by the research are as follows [20]:

a) Annoyance
b) Sleep disturbance
c) Heart and circulation problem
d) Quality of life
e) Cognitive processes
f) Hearing loss

Exposure to continuous noise of 85–90 dB(A), particularly over a lifetime in industrial settings, can lead to a progressive loss of hearing, with an increase in the threshold of hearing sensitivity. Hearing impairments due to noise are a direct consequence of the effects of sound energy on the inner ear [21]. Hearing impairment has been defined as an increase in the threshold of hearing. The affected person is unable to understand speech in day-to-day life. Noise-induced hearing impairment mainly occurs in the frequency range of 3kHz-6kHz, and with increased exposure, at lower frequencies. Speech intelligibility can

be reduced even at 10 dB, averaged over 2kHz-4kHz, over both ears [22]. Above 30 dB hearing impairment (averaged over 2 kHz -4 kHz, over both ears) a social hearing handicap is noticeable. Significant hearing impairment occurs on extended exposure to noise levels of 70-85 dB [22]. Noise may influence health directly and not through annoyance. The response to noise may depend on characteristics of the sound, including intensity, frequency, complexity of sound and duration [23].

6. Selected Code Books on Noise Pollution by BIS and Noise Pollution Control

(i) Selected code books on noise pollution by BIS

A range of code books for sampling, analysis and guidelines for control of noise pollution from domestic and industrial sources, are published by Bureau of Indian Standards (BIS) [24]. A few of them are listed in Table 4 [24].

Table 4. Selected code books on noise pollution by BIS

BIS code	Description
IS-1950-1962	Sound insulation of non-industrial buildings, code of practice for
IS-3483-1965	Noise reduction in industrial buildings, code of practice for
IS-4758-1968	Noise emitted by machines, methods of measurements of
IS-4954-1968	Noise abatement in town planning recommendations
IS-6098-1971	Air borne noise emitted by rotating electrical machinery, method of measurement of
IS-9167-1979	Ear protectors
IS-3098-1980	Noise emitted by moving road vehicles, measurement
IS-10399-1982	Noise emitted by stationary road vehicles, methods of measurement of

(ii) Noise pollution control

Noise pollution control techniques are broadly classified in three categories which are discussed below.

(a) Noise control at generation end

The noise pollution can be controlled at the generation end by employing following techniques:

- The domestic noise coming from different sources like radio, television sets, kitchen appliances, washing machines etc., can be reduced by their careful and sensible operation.
- Regular servicing and maintenance of vehicles will decrease the harmful noise levels. Proper fixing of silencers to automobiles, two wheelers etc., will reduce the noise levels.
- Speaking at low voices adequate for communication reduces the excess noise levels.
- Prohibition on usage of loud speakers except for important meetings / functions.
- Selection of certain machinery/equipment which generates less noise due to its superior technology etc. is also an important factor in noise minimization. Proper handling and regular maintenance is essential for noise pollution control in industries.

(b) Noise control during the transmission path

- Setting up of barriers between noise source point and receiver point can attenuate the noise levels. It should be close to either of the source or receiver.
- By incorporating the use of suitable noise absorbing material for wall/door/window/ceiling in the building will reduce the noise levels.
- A sound source may be enclosed within a paneled structure to reduce the noise levels at the receiver.
- Development of green belt can attenuate the sound levels. The statutory regulations direct the industries to develop greenbelt around four times the built-up area for minimizing different pollutants, including noise.

(c) Noise control by using protective devices

- Noise protection devices like earmuffs, ear plugs etc. are the commonly used for hearing protection. Ear-muffs provide the attenuation which varies widely in respect to their size, shape, seal material etc. Study shows that, average noise attenuation up to 32 dB can be achieved using these devices like earmuffs.

7. Conclusions

Now days, every one of us are adding to noise pollution as most of our routine activities generate some noise. Noise pollution damagingly affects the human being leading to loss of hearing as well as mental stress. Efforts are made through this review article to make the person aware about the preliminaries of noise pollution and its hazardous effect. The statutory bodies have defined the noise level exposure limits for human being. It is desirable that suitable noise control measures be taken and reduces the interference of statutory bodies. The technical terminology is useful to analyze and understand the noise pollution in the form of data. In the last, a brief discussion is made on the control of noise pollution.

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