



Noise Pollution and Impact on Children Health

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Abstract

With rapid urbanization and life style changes, loud noise is omnipresent and has become a part of life. Indoor and outdoor environmental noise pollution have been documented as a serious health hazard with increasing adverse effects on fetus, infants, children, adolescents and adults. Noise induced hearing loss and non-auditory adverse effects due to noise pollution, are being increasingly diagnosed in all age groups including the fetus. Outdated motorized vehicles, machinery, increasing traffic, congested residential areas, crowded educational institutions and workplaces, unregulated commercial and industrial noise have become a source of noise pollution with long-term disability. Areas of noise pollution must be identified and corrective measures be taken. Toys, personal, domestic, commercial, industrial equipment should be within the safe sound intensity. Loudspeakers and vehicular horns should be banned except in emergencies. Nocturnal noise pollution must be avoided near residential areas as sleep disturbances have serious long-term health consequences. Pregnant women, fetus, newborns, infants and children are most susceptible to noise induced health hazards and should be given utmost protection. Educational institutions, workplaces, commercial and industrial areas should be regularly monitored for noise levels and protective ear muffs and plugs be used. Public be educated repeatedly regarding health hazards of noise. Traffic noise should be regulated to be within safe limits. Bus-stands, railway stations and airports should be moved away from residential areas. Houses should be sound proofed suitably. Long term studies should be conducted in pregnant women, newborn children and adults to have more data on hazards of noise pollution.

Keywords Environment · Noise pollution · Hearing loss · Health hazard

Abbreviations

AF	Audio frequency
Hz	Hertz – frequency of sound waves
dB	Decibel – unit of sound
dB(A)	Relative loudness of sound in air
μPa	Sound pressure
NIHL	Noise induced hearing loss

Introduction

Noise is any sound which is unpleasant, unwanted or so loud that it causes or can cause disturbance or irritation [1]. Noise pollution is that sound present in the environment, for a duration which causes or can cause temporary or permanent harm to the human beings or animals [2, 3]. Total or partial hearing loss renders the individual to uncomfortable living and becomes a handicap.

The ears are the primary organs of hearing the sounds produced usually outside and perceived inside the body by the brain of animals and human beings. The human ear has three main parts.

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1. **Outer Ear:** It includes the pinna, the ear canal and the tympanic membrane, which transmits the received sound to middle ear [4, 5].
2. **Middle Ear:** This small air-filled chamber located inside the tympanic membrane contains three ossicles which are the smallest of all the human bones. Lateral to medial, the Malleus (hammer), the Incus (anvil) and the Stapes (stirrup) help in transmission of sound received as

vibrations from the tympanic membrane to the inner ear. The middle ear bones and muscles dampen or augment the sound vibrations suitably and forward them to the highly sensitive and delicate inner ear through the oval window, a thin membrane separating the middle ear to the inner ear (fluid filled). The other thin membrane, the round window, helps the sound waves to smoothly displace the fluid in the inner ear [4, 5].

3. **Inner Ear:** This consists of spiral fluid filled tube, the cochlea. The cochlea is divided by organ of Corti lengthwise, which are very complex and are the main organ of conversion of mechanical to neural signals. The highly specialized and sensitive basilar membrane, endolymph and the hair cells in the organ of Corti convert the high and low mechanical sound vibrations to action potentials of similar pattern and transmits them to auditory nerve and to the CNS [4, 5].

Audio Frequencies (AF) are the frequency range where humans can hear sounds. This is between 20 and 20,000 Hz. The frequencies above the audible range are known as ultrasonic while the lower range is called as infrasonic.

Disruption, as in stroke or injury at any level from the ear to the brain leads to problems in hearing which may be minor loss of some frequencies, major hearing loss or even complex problems as tinnitus, hallucinations *etc.*

Classification of Hearing Loss [6, 7]

Types of Hearing Loss

1. Conductive: Outer and middle ear involvement
2. Sensorineural (SNHL): Inner ear, auditory nerve or brain involvement
3. Mixed: Due to both above

Degree of Hearing Loss (Hearing Loss Range dBHL) [7]:

1. Slight (16–25)
2. Mild (26–40)
3. Moderate (41–55)
4. Moderately Severe (56–70)
5. Severe (71–90)
6. Profound (91+)

Etiology of Hearing Loss

1. Hereditary
2. Congenital
3. Presbycusis or aging
4. Acquired

- a. Noise induced
- b. Ototoxic drugs and chemicals
- c. Infections

Places of Noise Pollution

- I. Residences, educational institutes and offices
- II. Social, religious, public and entertainment areas
- III. Transportation
- IV. Commercial and Industrial areas
- V. Others like war zones, combat-training zones, sports arena, playgrounds, noisy neighborhood, unruly pets, slums, call centers, telephone exchanges *etc.*

Sources of Noises

1. Toys and Play stations.
2. Mechanical home, kitchen, office, educational appliances.
3. Entertainment: Radio, TV, music systems, bands, loud speakers, movie theaters, personal audio systems like earphones, headphones, Bluetooth appliances.
4. Communication devices like cell phones *etc.*
5. Transport vehicles: Motorized wheelers personally used to commute, public transport vehicles as buses, trains, airplanes, cargo transport vehicles as trucks, goods trains, cargo planes.
6. Mechanical equipment: Hammers, grinders, mowers, mixers, fans, air-coolers, air-conditioners *etc.*
7. Large machines: Land movers, drills, machines and vehicles used in construction and maintenance of houses, apartments, office blocks, schools, colleges, factories *etc.*
8. Deforestation or urbanization: This is an indirect contributor to noise. Deforestation leads to increase in construction of houses, commercial areas, industries, roads, traffic *etc.* which ultimately leads to more noise in the previously quiet area.

All animals are affected by loud sounds or noise pollution and respond by increasing their own sounds or by becoming quieter. They become irritable, lose concentration and move away from the noise temporarily or permanently as the situation demands [8].

Noise pollution affects the physical and mental health of human beings. Noise exposure leads to psychomotor effects by increasing stress, causing sleep disturbance, difficulty in normal conversation, lack of concentration, irritability, violent behavior, increased heart rate commonly observed with loud drum beats, tachyarrhythmia, vasoconstriction, hypertension and associated diseases [9].

Long term exposure to noise may lead to tinnitus and Noise Induced Hearing Loss (NIHL). This is seen more with traffic, occupational and entertainment noise where the exposed persons were found to have significant NIHL than the non-exposed [9].

Prolonged exposure of loud sounds in pregnant women and children accompanying adults to construction sites, factories *etc.* may all lead to temporary and permanent hearing loss depending on the loudness and duration of exposure. The earlier a child is exposed to noise, earlier will be the Noise Induced Hearing Loss (NIHL) and other non-auditory problems [10].

We usually test for hearing in a newborn at birth, which if normal, forget about hearing and associated problems that may occur as the child grows. It is detected only after some alert parent or teacher observes delayed development, poor grades or when brought to notice by the child or adolescent about some hearing difficulty. By that time, the hearing loss is usually permanent, which will increase with cumulative effect of exposure to even low level of noise and aging process.

Hazard Recognition

Till few years back noise pollution was a totally neglected area. Only now it is being recognized as an Environmental Pollutant and a Health Hazard [11]. Earlier only VIP areas and Hospitals had a customary sign of 'No Horn Zone' or a 'Silent Zone'. People have begun to value silence and concerns are being raised. Metros and bigger cities follow 'silence hours' from 10 pm to 5–6 am for loudspeakers and music only. However heavy, noisy vehicles can run during that time. Young children too have begun to be aware of harmful environmental factors and recognize noise pollution as an environmental hazard [12].

No Horn Day/International Noise Awareness Day

On last Wednesday of April 1996, Center of Hearing and Communication (CHC) started internationally, awareness in public regarding effect of noise on health of people. Every year on this day irritation caused by noise, NIHL and deafness *etc.* are discussed and debated in public and professional forums.

Health Effects of Noise Pollution

Auditory Health Effects of Noise Pollution

1. *Tinnitus* is an abnormal ringing sound arising mainly inside the body. It may be whistling, grinding, hissing, buzzing or similar sounds. When frequent or continuous, it becomes irritating and affects routine activities as

sleeping, working, studying *etc.* Exposure to loud noise and aging are important causes of tinnitus and is sensorineural in origin.

2. *Noise Induced Hearing Loss (NIHL)* – About 5% of the population globally is affected by NIHL. Nearly 50% of the cases of hearing loss are due to Noise exposure. WHO estimates that in children and adults between 12 and 35 y, having personal hearing devices, 50% are at risk of hearing loss, if the volume is loud or exposure prolonged. NIHL causes mostly SNHL affecting the inner ear, nerves and the neuronal tissues. Acute exposure to very loud noise may lead to tympanitis or perforation of ear drum causing severe pain and hearing loss [13].

In USA, 12.5% children of age 6–19 y have permanent hearing loss of varying degree due to increased noise exposure [14].

NIHL may be:

- *Temporary*: This is due to very loud but brief exposure to noise like airplane engine or a loud firecracker or ammunition exploding nearby or to loud but prolonged exposure of a few hours to sound as in a disco or a music party. The hearing loss is over a wide range of frequency but recovery generally occurs in few hours or a week.
- *Permanent*: One-time exposure to sound above 120 dB(A) or constant exposure to sounds above 85 dB(A) may lead to permanent irreversible hearing loss.

70 dB(A) has been labeled as cutoff level of sound by US Environment Protection Agency. Exposure to sounds above this level for 24 h or more will lead to NIHL and associated mental and later physical problems. Higher dB sound will produce NIHL in lesser duration of exposure. Table 1 shows approximate sound levels as observed by different sources [14–16].

Non-auditory Health Effects of Noise Pollution

1. Sleep disturbances
2. Mental disturbances such as stress, mood changes, emotional imbalance, mental fatigue, decreased concentration, intolerance, communication problems, irritability, aggressiveness, hostility *etc.*
3. Physical effects as easy fatigability, headaches, unexplained aches, loss or increased appetite *etc.*
4. Cognitive and learning disorders
5. Cardiovascular effects
6. Unfavorable pregnancy outcome

In a study of impact of noise in a residential area in Brazil, vehicle traffic was found to be the principle source of noise [15, 17].

Table 1 Average sound levels of some activities in decibel dB

Activity	Decibel (dB)
Space shuttle launch	220
Aircraft take off (25 m distance)	140
Discotheque	110–120
Construction site	100
Average street traffic	80–90
Noisy workplace	80
Normal conversation	60
Library	30–40
Bed room	20–30
Space	0

Two thousand eight hundred forty four children of 9–10 y attending 77 schools of the Netherlands, 27 in Spain, and 30 in the UK located around three major airports were studied. The results indicated that airplane noise, a chronic environmental stressor, impaired cognitive development in children, specifically reading comprehension. Therefore, schools exposed to high levels of aircraft noise are unhealthy educational environments [18].

Another study in the United Kingdom analysed a sample of 719 children of 9–10 y of age from 22 schools around London's Heathrow airport under the 2001–2003 Road Traffic and Aircraft Noise Exposure and Children's Cognition and Health (RANCH) project. Aircraft noise exposure at school was significantly associated with poorer recognition memory, conceptual recall memory, poorer reading comprehension and information recall memory [19].

A longitudinal study over 15-y period (1992 to 2006) showed that living near petrochemical industries in Sweden implies a higher long-term risk (25%) of being annoyed by industrial noise. Industrial noise annoyances were also related to annoyance by road traffic noise in adolescents and adults above the age of 18 y, which probably had started at an earlier age [20].

The fetus and infant are very prone to the effects of environmental factors that influence their developmental processes because through the mother, they are subjected to:

- a) critical windows of vulnerability during the fast growth and development of fetal organs.
- b) immature metabolism and
- c) greater effect of toxic agents relative to their weight.

Mother's exposure to physical, biological and chemical environmental hazards including traffic noise during pregnancy may lead to serious health problems in herself as well as fetus and the newborn like premature birth, low birth weight, congenital anomalies, hearing loss, learning disabilities, behavioral problems, respiratory diseases, cardiovascular

diseases like hypertension, diabetes, childhood cancer and obesity (Table 2). The economic and social burden of a child with compromised health and development are substantial. The effects of early exposure to environmental pollutants may manifest throughout life and even generations. Certain physical and mental illnesses in adults have their origin in early life [13].

Noise pollution concerns inside the Hospitals, ICU's, PICU's, NICU's have been noticed and studies underway. Though the Hospital area itself is a 'Silent Zone', silence is rare inside. Preterm, LBW's, new-borns, mothers and critical patients are affected by noise inside wards and in OPD's [13, 21].

According to the Recommended Standards for Newborn ICU Design, Eighth edition, the sound in the infant care area should not exceed hourly Leq (Equivalent or average Continuous Sound Level) of 45 dB. The transient sounds or Lmax (maximum sound level) should not exceed 65 dB. Soundlevel in the staff working area, lounge and family area, should not exceed hourly Leq of 50 dB with Lmax of 70 dB [22].

Diagnosis of NIHL [23]

The person will complain of sudden onset or gradually increasing tinnitus, difficulty in following a conversation especially in a crowded, noisy place, meeting or a party. Ear examination is followed by Weber's and Rhine's test, Pure Tone Audiometry, Auditory Brainstem Response (ABR) or Brainstem Auditory Evoked Response (BAER) test, Otoacoustic Emissions (OAE) and Behaviour Audiometry Evaluation depending on the age and other factors. These will define the exact problem and its extent.

Treatment of NIHL [24, 25]

As of now no medical or surgical option is available for treatment or reversal of NIHL. Undergoing research may bring remedy in form of pharmacological agents, neuro-trophins, gene and stem cell therapies.

Acute NIHL

1. Placing the person in a quiet room.
2. Hyperbaric Oxygen and antioxidants can minimize the damage.
3. Counseling to avoid future exposure to noise.
4. Hearing protection like earmuffs and ear buds (decrease sound by 15–30 dB and 25–45 dB when used together)

Table 2 Health hazards of noise in different age groups [13]

Timing of insult	Sound (dB)	Effects
Intrauterine	>80 for >8 h at stretch	High frequency hearing loss; Prematurity, Low birth weight, birth defects
Newborn	>45	Damage to the cilia of the cochlea leading to hearing loss; Increased blood pressure, heart rate, respiratory rate, and decreased oxygen saturation; Increased need in oxygen and energy consumption. Changed behavioral and physiological responses of infants. Enhanced pain perception.
Child	>70 for prolonged period or sudden exposure to >100	Learning disabilities, attention disabilities. Ruptured ear drum.

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Chronic NIHL

1. Avoid future exposure to loud noise and hearing protection.
2. Use of Hearing-aids and Cochlear implants may help.

Hazards of Headphones and Earbuds [26, 27]

Individuals constantly using Personal Audio Device (PAD) at high intensities with headphones or earbuds are at risk of developing a temporary or permanent threshold shift especially when such listening habits persist for some years. Constant use of PADs for more than five years can lead to changes in high-frequency hearing (4 kHz) [28]. This hearing loss can be detected by Pure Tone Audiometry [29]. The audiogram displays a sharp reduction in hearing at frequencies between 3 and 6 kHz. With continued exposure, the hearing loss extends to higher and lower frequencies and is generally bilateral and symmetrical.

The highest safe exposure level is 85 dB for up to a maximum of 8 h. The permissible time for safe listening decreases as sound levels increase. Therefore, the safe duration of exposure to sound level of 100 dB is only 15 min per day. Output of PAD ranges from 75 dB to 136 dB. Maximum output levels vary with the regulations in different parts of the world. Typically, users of PAD set the volume between 75 and 105 dB [27, 29–31].

The effect on the auditory system of exposure to loud sounds or noise is cumulative and irreversible and effective treatment is limited. However, NIHL is completely avoidable. Prevention is thus paramount and efforts to preserve hearing and prevent tinnitus should be made wherever hazardous noise is present.

Due to lack of Indian data of early life exposure to environmental risk factors and their effect on health in birth

cohorts, studies should be a part of long term data collection and interpretation [11, 13, 32, 33].

Prevention of Harmful Effects of Noise

I. Personal

1. Avoid exposure to loud sound for long durations. Use ear plugs and muffs.
2. Avoid loud music, radio and TV. Keep the volume to lowest possible.
3. Avoid toys, appliances, entertainment audio systems, machines with loud sound and for long duration.
4. Avoid home industry with loud sound production like cereal grinders, gem stone cutting and polishing, fabrication *etc.*
5. Avoid living in noisy areas as near highways, congested traffic areas, railway station and railway tracks, bus stands, airports, industrial areas *etc.*
6. Avoid use of Headphones, earbuds, Bluetooth and other PADs applied in or near the ear.
7. Use speaker phone for telephonic conversation whenever possible.
8. Set the volume to a comfortable level in a quiet environment and avoid raising it in noisy environments; the volume should be not more than 60% of maximum.
9. Smartphone apps can be used to monitor the output levels of PADs and ensure that they are below 85 dB.
10. Listening breaks can help to reduce exposure.
11. Limiting headphones/earphones use to less than 1 h a day is ideal.

II. Community

1. Factories, industries, bus stands, railway stations, airports should be away from residential areas.

2. Industrial machinery should be within permissible limits and ear muff/plugs be used compulsorily.
3. Use of loud speakers should be banned in religious, public and residential places except in emergencies.
4. Music concerts *etc.* should be in closed spaces and with information to those attending that such activities are of risk of developing temporary or permanent NIHL.
5. Vehicular horns and sirens should be strictly prohibited except in emergencies.
6. Traffic noise should be restricted to under 70 dB(A) in residential areas.
7. Traffic noise should be minimized by constructing smooth roads, limiting speeds and heavy vehicles, smoothly running traffic with signals which are so timed that they reduce halting at junctions.
8. Sound barriers should be constructed to reduce traffic noise.
9. All light, medium and heavy vehicles, trains, aircrafts should have more quieter engines. Their movement be restricted during night hours near residential areas and during day hours near educational areas.
10. Hospital noise pollution should be addressed as a priority.

Conclusions

To summarize, the environmental noise pollution causes temporary and permanent hearing loss. Motorized vehicles are a significant cause of sleep disturbance. Poor sleep causes endocrine and metabolic disturbances, several cardio-metabolic and psychiatric problems and anti-social behavior, both in children and adults. Nocturnal environmental noise cause biological effects like stress, altered sleep pattern and quality of sleep which are like those seen in endogenous sleep disorders. Apart from these subjective feelings and measurable effects of disturbed sleep, people affected by nocturnal environmental noise suffer the next day from daytime sleepiness, tiredness, annoyance, mood changes, decreased well-being and cognitive performance. Nocturnal environmental noise affecting normal sleep is most concerned form of noise pollution having adverse health consequences due to its synergistic direct and indirect influence on biological system. Duration and quality of sleep are risk factors or markers significantly affected by the environment but amenable to modification through awareness and counseling and through measures of public health. Avoidance, at all costs, of sleep disruptions caused by environmental noise is essential [8, 34, 35].

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Compliance with Ethical Standards

Conflict of Interest None.

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