CHAPTER - 11

NOISE POLLUTION

Unwanted sound is called noise. The noises of modern society are profoundly annoying to the individual human being. One noisy motorcyclist or scooterist crossing a city can disturb the sleep of many people. The most important change which is evident in most places in this century, is the explosion of human population. This has exerted pressure on all available resources. One of them is significant rise of noise level. Not only raised human voices but also sound from various sources like construction sites, loudspeakers, radio, microphone, automobiles, aeroplanes, railway engines, irrigation pumps etc. break the silence of the environment. Noise has gained such an intensity that it grates on everyone's nerves. Surveys of complaints and physical measurements, all show noise pollution to be one of the major hazards of modern life, especially in urban areas - areas which are the most industrialized, urbanized and motorized.

Surveys show that noise is now perceived in many countries to be the major negative factor affecting the quality of life. In the United States, for example, noise is ranked second only to crime. In West Germany, a 1979 poll indicated that 45 percent of the population believed that the protection against noise is more important than building new roads. In Japan, there are currently more complaints about noise than about any other form of pollution. It is high time to realise the importance of protection against noise pollution on global basis. It will not be untrue to admit that Indians are noisy people. In India, every occasion or sentiment is manifested in a noisy manner-be it a religious

occasion, an election or a family celebration.

A decibel (dB) is the standard unit for the measurement of noise. The zero on a decibel scale is at the threshold of hearing, the lowest sound pressure that can be heard. On this scale, 20 dB is a whisper, 40 dB the noise in a quiet office, 60 dB normal conversation, 80 dB in a bus, 100 dB in a train, 120 dB in a loud thunder and 140 dB the level at which a sound becomes physically painful. As it is measured on a logarithmic scale, a noise of 10 decibels is 10 times more powerful than 1 dB and 20 dB are 100 times more powerful, 40 dB 10000 times more powerful and so on.

There are variety of noises such as domestic noise, traffic noise, aircraft noise, construction noise and industrial noise, all leading to discomfort to human beings. Traffic noise makes our lives most uncomfortable. To a great extent domestic noise can be easily controlled by rational use of radio and TV through use of earphones. Noise in house-hold can be minimised by using carpets, drapery and upholstered furniture. The noise of sirens can also be modulated. An attempt was made to create silent zones around educational institutes, hospitals etc. in India but it did not work although it was most successful in Britain. Traffic noise is due to cars, motorcycles, trucks and buses. For instance a car gives 60 dB, a bus gives 80 dB, whereas a truck gives 85 dB and motorcycles, scooters, mopeds produce noise of level 85-90 dB. These noises are bounced on the hard surfacess of buildings and are reflected back to the ears. Usually noise is produced by air turbulence around the body of moving cars and tyres especially on cement roads. In cold countries snow tyres make more noise. In India, motor cycles are the worst culprits, wherein the noise originates from exhaust and engine. It can give 110-120 dB noise. Mufflers are designed in motorbikes to reduce noise. Trees and bushes are planted on highways to reduce noise by dispersing it on leaves and branches. Usually in good town planning, the bedrooms in buildings are located away from roads to give peace and tranquility.

11.1 SOURCES OF NOISE

Sources of noise are mainly either industrial or non-industrial. Non-industrial sources of noise are mainly loud speakers, automobiles, aeroplanes, trains, construction works, radios, microphones, house-hold appliances etc. The noise levels in decibels from various sources are detailed in table 11.1. Sources may also be classified as indoor and outdoor noises.

Indoor Noises : The sources of indoor noises are moving people, crying of babies, playing of radios, banging of doors, traffic on staircase, movement of furniture, conversation of the occupants, operation of cisterns and water closets, noise of type writers, working of nearby machines etc.

Outdoor Noises : These noises are created from nearby streets and the largest source of outdoor noise is generally the automobile traffic on the road. The other sources of outdoor noises are railways, aeroplanes, loudspeakers, machines in nearby factories etc.

11.2 EFFECTS OF NOISE POLLUTION

After considerable research it was shown that the greatest amount of threat to human body comes from noise vibrations which are high pitched, loud, poor in tone and are long lasting. Another type of noise which can cause harm to human body is the sound due to explosion, which has a high amplitude but lasts for a very small duration. Various body systems affected by noise are auditory system, circulatory system and nervous system. The basic hearing mechanism is Cochlea, that is containing about 20,000 small hair cells. The temporarily damaged cells due to noise may be born again if ear is given rest. But prolonged exposure to noise may permanently damage them.

Auditory System: Medical research has confirmed that a certain type of noise is capable of affecting human auditory system and can result in loss of hearing. The effects on hearing mechanism can be in three forms:

Temporary threshold shift

Permanent threshold shift and

Acoustic trauma.

Noise Induced Temporary Threshold Shift (NITTS) : It is a measure of efficiency of hearing the auditory threshold, that is the sound pressure level at which one can just begin to detect a sound. Temporary threshold shift or auditory fatigue is a short term effect which follows exposure to a high noise level and from which the subject recovers after a few hours. The loss of hearing cannot be recovered completely.

TABLE 11.1 Noise Levels of Some Noisy Sources

S.No.	Noisy Sources / Areas	Noise Level dB(A)
1.	Threshold of audibility (inaudible)	0
2.	Breathing	10
3.	Rustling of leaves due to wind	20
4.	Quiet conversation	20-30
5.	Quiet garden	30
6.	Ticking clock	30
7.	House in quiet street	35
8.	Conversation at 1m	40

9.	Inside
10.	Radio
11.	Comp
12.	Loud
13.	Type
14.	Offic
15.	Class
16.	Child
17.	Home
18.	Hous
19.	Medi
20.	Freig
21.	Printi
22.	Morn
23.	Inside
24.	Vacu
25.	High
26.	Heav
27.	Inside
28.	Sport
29.	Inside
30.	Buses
31.	Freig
32.	Truck
33.	Prope
34.	Marri
35.	Nama
36.	Labor
37.	Concr
38.	Moto
39.	Weav
40.	Rail e
41.	Train
42.	Pneur
43.	Thun
44.	Jet tak
45.	Riveti

9.	Inside small shops	55
10.	Radio music	55-60
11.	Computer rooms	55-60
12.	Loud conversation	60
13.	Type institute	60
14.	Office noise	65
15.	Class room teaching	55-60
16.	Children playing	60-80
17.	Home appliances	65-75
18.	House hold generators	70-80
19.	Medium road traffic (main street)	70-80
20.	Freight train at (25-40 kmph) at 150 m	77
21.	Printing press	80
22.	Morning bhajans	75-90
23.	Inside concert halls during performance	85
24.	Vacuum cleaner	80
25.	High volume air sampler	80-85
26.	Heavy road traffic (highways)	80-90
27.	Inside jet aircraft	85
28.	Sports car	80-95
29.	Inside cinema theatre	85-95
30.	Buses and trucks (gross wt 3.5 tonne)	85-95
31.	Freight trains (at 65 kmph) at 7.5m	96
32.	Trucks (gross weight 3.5 - 12 tonne)	90-100
33.	Propeller type jet plane at 300 m	90-100
34.	Marriages	80-100
35.	Namaaz	90-105
36.	Laboratory machines (turbines)	90-100
37.	Concrete mixtures	90-105
38.	Motor cycles and cars (horns)	90-105
39.	Weaving springs	105
40.	Rail engine at 15 m	97-105
41.	Train whistle at 15 m	110
42.	Pneumatic drill	110
43.	Thunder storm	110
44.	Jet take off at 300 m	100-110
45.	Riveting steel plates	110-130

46.	Loud speakers	100-120
47.	Steel rolling	95-105
48.	Pile driving	110-130
49.	Threshold of pain	120
50.	Jet take off at 100 m	120
51.	Jet engine at 25 m	140
52.	Diwali crackers	125-160
53.	Firing hand gun	140-170
54.	Space vehicle launch - short distance	140-170
55.	Naval gun shooting	160-180
56.	Exploding bomb (major permanent damage in a short time)	190

TABLE 11.2 Acceptable Noise Levels, IS : 4954 - 1968

Acceptable Outdoor Noise in Residential Areas			Acceptable Indoor Noise Levels for Various Types of Buildings		
Sl No	Location	Noise Level dB (A)	Sl No	Location	Noise Level dB (A)
i	Rural	25-35	i	Radio & TV studio	25-30
ii	Suburban	30-40	ii	Music room	30-35
iii	Residential (urban)	40-50	iii	Hospitals, class room, auditorium	35-40
iv	Urban (residential & business)	40-50	iv	Apartments, hotels, homes, conference rooms, small offices	35-40
v	City	45-55			
vi	Industrial area	50-60	v	Court rooms, private offices, libraries	40-45
			vi	Large public offices, banks, stores etc.	45-50
			vii	Restaurants	50-55

TABLE 11.3

[Amendmen

Area Code	
A	
B	
C	
D	

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TABLE 11.3 Ambient Air Quality Standards in Respect of Noise

[Amendment of Environment (protection) act, 1986 (29 of 1986)]

Area Code	Category of Area	Limits in dB (A)	
		Day Time 6 am - 9 pm	Night Time 9 pm - 6 am
A	Industrial area	75	70
B	Commercial area	65	55
C	Residential area	55	45
D	Silence zone	50	40

NOTE: Silence zone is defined as area upto 100 meters around such premises as hospitals, educational institutions and courts. The silence zones are to be declared by the competent authority. Use of vehicular horns, loud speakers 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 authorities and the corresponding standards shall apply. These rules may be called the Environment (protection) act third amendment rules, 1989 (Dated 26-12-89). This shift has been observed in many factory workers by measuring the threshold on Monday morning and at the end of the day. This type of temporary damage is not immediately discernible to the individual.

Noise Induced Permanent Threshold Shift (NIPTS): This occurs gradually, over perhaps, a few years and is not obvious to the individual until it has reached an advanced stage. This is an irreversible damage to the nerves and the inner ear and results in loss of sensitivity at high frequencies most markedly at about 4000 Hz. Due to this shift sibilants are not clearly heard making the understanding of conversation very difficult. Thus it remains throughout the life time of the affected person.

The adverse effects of noise may be broadly classified as follows:

Annoyance, fatigue and boredom
Loss of hearing
Physiological effects
Masking
Effects on human performance

Annoyance: A noise is said to be annoying if an exposed individual or a group of individuals would reduce the noise, avoid or leave the noisy area if

possible. Both loudness and annoyance increase with increasing sound level. In general, noise whose sound level fluctuates is more annoying than the same average steady noise whose sound level is constant. An individual's activity during noise exposure may affect his reaction to noise, such as sleep interference. Noises which occur at random and unpredictable intervals are significantly more disturbing than noises which occur at predictable, periodic intervals. An individual annoyance due to noise is generally influenced by his experience or exposure to noise.

Physiological Effects: These are divided into short term and long term effects. Short term effects include changes in breathing amplitude, rate of saliva and gastric secretion, blood pressure, heart-beat rate and pulse rate, dilation of the eye pupil and varying gastro-intestinal problems. Long term effects include increased cardiac oxygen demand, plasma cortisol, blood cholesterol etc.

Masking: Masking is the process by which the threshold of audibility for one sound is raised by the presence of another (masking) sound. A particular noise is considered unwanted or annoying based on the degree to which it masks the hearing of certain wanted sounds such as speech and music. In mining environment, masking is certainly a critical safety issue, where noise may mask the sounds of shaft and haulage signals, warnings before blasting or the sound of approaching tabs.

Effects on Human Performance: The less variation in a strange noise, the less it will affect the performance adversely. For similar sounds and tasks, regular intermittent sounds are less likely to impair average performance than continuous ones are. In contrast, unpredictable intermittent sounds may be more harmful. Effects of noise on performance are more likely to be detrimental above sound pressure levels of 95 dB. High frequency sounds are likely to affect performance more seriously than low frequencies. Noise is relatively unimportant if the average rate of work is considered but it increases the accidents or errors caused by momentary inefficiency, which are of serious concern in any industrial environment. In general there is a risk of hostile behaviour during and after exposure to noise. Deliberate and intentional memory may be normal or even improved by noise, but the recollection of incidental features of the situation deteriorates. However there is a general depression or apathy which continues to persist for a time outside the situation in which noise has been experienced.

Acoustic Trauma: It is a condition of sudden permanent aural damage resulting from an intense-short-term exposure, which may be single exposure. This sound is capable of rupturing the eardrum that results in some degree of permanent hearing loss. However, when only the ear drum is

damaged without any damage to inner and middle ear the ear drum hears with time and full hearing is usually restored.

Effect on Circulatory System: Exposure to noise makes the blood vessels shrink. Also, blood supply to many parts of the body decreases on exposure to sound. The cause of headaches which result due to exposure to noise is also due to the decrease of blood supply to the brain. Some effect of vibrations on heart has also been reported when small blood vessels are subjected to the noise vibrations. They contract in spasm and this is accompanied by thickening and clotting of blood, which may very well cause heart attack. At 160 dB major permanent damage may be caused if sound is produced.

Effect on Nervous System: The various effects of noise pollution are :

(i) Trucks, buses and cars on the roads, the trains on their tracks, the jet aeroplanes in sky-they all are producing more and more of noise as their number is increasing. Haphazard growth of the cities, inspite of the efforts of the city planners, is bringing small and large industries beside or inside the residential areas. The transistors, the radios and the loudspeakers make their own contribution. Much noise came from people, a vast majority of whom are not aware that by speaking loudly they are being a nuisance. The presence of noise takes away the essence of music and speech.

(ii) Exposure to noise tells upon the health. Very loud noise of 150 decibels can cause a rash under the collar, in between the fingers and the thighs. Ear drums may get ruptured. It can cause giddiness and nausea. 130 - 135 dB sound produces dizziness and vomiting.

(iii) Exposure to over 100 decibel for a few hours lessens efficiency and makes one more prone to accidents. It makes one aggressive and quarrelsome. Even in those who are sleeping, exposure to loud noise causes a disturbance in their brain waves.

(iv) It can lead to irregular or faster pulse beats, enlarged hearts and increase in blood cholesterol. It causes mental fatigue, irritability and precipitates or aggravates mental tension and neurosis. Prolonged exposure to noise results in temporary deafness or nervous breakdowns.

(v) Most disturbing observation is that loud noise increases heart rate of the foetus inside the abdomen of a pregnant mother. This may cause irreparable damage to the unborn baby. Also, as ear is the first organ that develops fully after conception even the unborn may be badly affected by noise pollution.

(vi) Infrasonic waves cause motions and may be used to disperse mobs. Buildings may be demolished by them. Ultrasonic waves, which are often used as disinfectants, are harmful to life.

11.3 MEASUREMENT OF NOISE POLLUTION

The sounds vary in pitch, which is defined as the relative highness or lowness of a sound. Pitch is determined by the frequency of sound wave i.e. the rapidity with which it vibrates. A high pitched sound with its fast vibration is more penetrating than one with low pitch. The intensity of sound is measured in decibels (dB). This scale was devised to measure the smallest difference in sound which is detectable by the human ears. Its gradations move up not in simple arithmetic progression but in multiple progression based on logarithmic scale.

The subject of noise control is not an easy one to master. Part of the difficulty lies in interdisciplinary action it borrows generously from the fields of mathematics, dynamics, vibrations, fluid mechanics, thermodynamics, electronics, psychoacoustics, material science and engineering acoustics. Nomenclature and jargon are other obstacles to be overcome and noise control engineering, perhaps more than any other field, has an abundance of new terms which must be mastered while learning the subject. Also seemingly insidious nature of the way sound is generated and propagated often defies intuitional noise reduction solution which in other areas of engineering are based upon experience.

An understanding of the fundamentals of sound generation and propagation is essential to the engineer responsible for initiating and carrying out noise control programmes. Sound in the physiological sense is the result of pressure vibration in the air which acts on the surface of eardrum. The ear converts this pressure variation into electrical signals which are then interpreted by brain as sound.

Sound is a form of energy which is emitted by a vibrating body and on reaching the ear causes the sensation of hearing through nerves. Sounds produced by all vibrating bodies are not audible. In order to produce an audible effect, the frequency (i.e. number of vibrations per second) of the vibrating body should be greater than 20 Hz and less than 20,000 Hz. These are known as frequency limits of audibility. Sounds of frequencies less than 20 Hz are called infrasonic and greater than 20,000 Hz are called ultrasonic

Propagation of Sound : Due to vibrations of a body compressions and rarefactions are produced. These travel in air to the ear and produce sound. The particles of air vibrate about their mean positions and transmit momentum and energy through air to the receiver (ear).

Characteristics of Sound : Sound consists of wave motion in an elastic medium. These waves travel through the medium from the source of sound to the listener. Sound waves consist of vibrations in pressure on oscillations of the medium in which they travel. The rate of oscillation is called the frequency or pitch of the sound and is measured in cycles per second or Hertz. High pitched sounds have high frequencies and are more disturbing. Loudness may be described as 'Listeners' auditory impression of the strength of a sound' and is therefore a subjective judgement. It is expressed in units called 'Sones'. Sound is not electromagnetic radiation. It cannot be propagated through vacuum.

Sound Pressure N/m^2	Intensity $watt/m^2$	dB
2×10^{-5}	10^{-12}	0
2×10^{-4}	10^{-10}	20
2×10^{-3}	10^{-8}	40
2×10^{-4}	10^{-4}	80

In general 80 dB (10 sones, depending upon frequency) may be considered as the critical level for ear damage. The ear is able to analyse the sound into frequency component and the range of a young person with perfect hearing is from 20 - 20,000 Hz. Normally hearing is most acute in the frequency range of 2000 - 5000 Hz but is reduced rapidly below 200 Hz and above 10,000 Hz. The ear is potentially liable to damage if it receives high intensity noise. The human ear responds to a change in sound pressure in the range of 0.00002 Pa.

Effect of Distance from the Source: In a homogeneous and undisturbed environment a spherical point source emits sound equally in all directions. The sound pressure level decreases in inverse proportion to the distance from the source. If the sound pressure level L_1 in dB is measured at a distance of r_1 m then the level L_2 at a distance of r_2 m can be calculated by using the relationship.

$$L_2 = L_1 - 20 \log_{10} (r_2 / r_1)$$

Thus, the sound pressure level decreases 6 dB for each doubling of distance from the source and 20 dB for each increase in distance from the source by a factor of 10.

Sones: Loudness is also expressed in Sones. One sone is equal to the loudness of 40 dB sound pressure at 1000 Hz. The same 40 dB at 5000 Hz means twice as loud and it therefore is 2 sones. The receptivity of ears of

human beings are not same. Many animals (dogs) can hear sounds inaudible to human ear. So in psycho-acoustic terms, we have to consider both sound intensity and frequency which is called "Phone" or decibel at 1000 Hz. The relation between sones and phones is given by

$$\text{Log}_{10} S = 0.03 (P-40)$$

Description of Decibel Scales: The decibel is a mathematical scale similar in use to a logarithmic scale. It is used to describe the intensity or energy level of a physical quantity compressing the quantity into numbers that are convenient for data presentation. Fundamentally it is ten times the base ten logarithm of the ratio of a power or energy quantity with respect to a reference base of the same physical quantity.

$L_E = 10 \text{Log}_{10} E / E_{ref}$ dB where

L_E = Energy or power level in decibels

E = Energy or power quantity of interest in watts

E_{ref} = Reference energy or power quantity of interest in watts

Sound Pressure Level: A normal human ear is capable of functioning over a pressure range of about one million. Secondly, experiments have shown that the ear responds in a logarithmic manner to the perceived loudness of sound. The sound pressure level, L_p is given by

$$L_P = 10 \log_{10} [P / P_{ref}]^2 \text{ dB}$$

Addition of Sound Levels: Ambient noise in any industrial environment is due to several sources and thus, it is necessary to find the combined resultant sound level when there are more than one source. The combined sound level is not the sum of the individual levels, but is calculated as follows.

Addition of unequal sound levels L_1 and L_2 ($L_1 > L_2$)

Difference between dBs	Correction to be applied to L_1
0	3
1	2.5
2	2
3	2
4	1.5
5	1
6	1
7	1
8	0.5
9	0.5
≥ 10	0

To combine the sound levels of several sources (more than two) first combine the levels of first and second source which results in 'L' dB. Based on the difference between this combined level L and the level of third source, again calculate the new combined level L. Any number of sound levels may be combined in this manner.

Weighing Networks: The human ear is not equally sensitive to all frequencies and hence, though the sound pressure level of two different sounds may be the same the first may be judged to be louder than the second if the sound power of the first is concentrated in a frequency region where the ear is more sensitive. Thus, sound pressure level is not a measure of the loudness of a sound. To obtain levels which bear a closer relationship to loudness judgements than sound pressure level, "frequency weighing networks" are incorporated in the sound measuring instruments. These weighing networks (or filters) alter the sensitivity of the instruments with respect to frequency, so that the instrument is less sensitive at frequencies where the ear is less sensitive. Thus, all standard sound measuring instruments make allowance for frequency dependent response of the ear by using filters which attenuate the levels in the different frequencies and thereby give direct readings which reflect the sensitivity of the ear. Since the amount of attenuation is dependent upon the sound level, the three weighing networks (A, B and C) usually employed, have frequency characteristic response simulating 40, 70 and 100 dB equal loudness contours. Taking into account the fact that human ear is more responsible for high frequency sounds (1000 to 5000 Hz) than low frequency sounds, dB (A) is the unit of measurement used in regulations of noise measurements in industrial, commercial and residential environments. It is the universally used sound level.

11.4 CONTROL OF NOISE POLLUTION

It may not be possible to have a total elimination of annoying sounds but attempts should be directed to reduction at source, reduction of the duration of exposure etc.

The sounds generated and transmitted in air directly to human ears are known as air borne sounds. The air - borne noise possesses less power, continues for a long duration and is confined to places near its origin. It is transmitted to the receiving room in two ways: (1) by air path between two rooms such as doors, windows, ventilators, key holes, ducts, pipes etc. and (2) by forced vibration set up by the transmitting room to the walls, floors and ceiling of the receiving room.

The sounds which originate and progress on the building structure are known as structure borne sounds or impact sounds. The structure borne noise is powerful, propagates over long distances and persists for a very short

duration. It is developed in solid structures and is then transmitted as air-borne noise. The closing of doors, vibration of machines etc. set up vibrations in solid materials of the structure which result in transmission of noise to the receiving room.

Noise Reduction at Source: Reducing noise at the source itself is the most promising method, which is accomplished as follows :

(i) **Selection of Machinery:** Noise should be reduced as near the source as possible so that acoustical treatment is less expensive and a large number of people are protected from the noise. While the operational processes in a factory may be fixed and may have no quieter alternative, careful selection of the machine tools and equipment to be used may considerably help attaining lower noise levels in the machine shop. One make of machine tool may have noisy mechanical system compared with another of similar performance.

(ii) **Reducing Noise from Potential Sources :** Impact that is not essential to a process should be quietened. Noise from handling and dropping of materials on hard surfaces may be reduced by using soft resilient materials on containers, fixing rubber tyres on trucks, trolleys etc. Machine noise may be kept to a minimum by proper maintenance. Proper lubrication reduces noise by friction from conveyors, rollers etc.

(iii) **Noise from Radiating Surfaces:** This can be reduced by reducing the radiating area. For example, if the area is halved, the noise intensity will be reduced by three dB and at low frequencies the reduction will be much greater. Supporting structures for vibrating machines and other equipment should be frames rather than cabinets or sheeted enclosures. If an enclosure is used, precaution should be taken to isolate it and line it on the inside with sound-absorbent material. The noise radiated by machinery guards can be minimized by making them of perforated sheet or of wire mesh.

(iv) **Reducing Transmission of Mechanical Vibrations:** A vibrating source does not usually contain a large radiating surface but the vibration is conducted along mechanically rigid paths to surfaces that can act as effective radiator. If the rigid connecting paths are interrupted by resilient material, the transmission of vibration and consequently the noise radiated may be greatly reduced. The reduction depends on the ratio of the driving (forcing) frequency of the source to the natural frequency of the resilient system.

(v) **Material for Isolators:** Vibration isolators are usually made of resilient materials like steel in the form of springs, rubber, cork and felt.

Because of the large range of deflections obtainable in coil springs, they may isolate vibrations over a large spectrum of low frequencies. Metal springs transmit high frequencies (from about two hundred to several thousand c/s) very readily. Transmission of these frequencies can be reduced by eliminating direct contact between the spring and the supporting structure. Rubber or felt pads may be inserted between the ends of the spring and the surfaces to which it is fastened.

Rubber pads may be used to isolate very effectively, relatively small machinery, engines, motors etc. It may be used in compression or in shear. Some rubber mountings use rubber in shear as the primary elastic elements and rubber in compression as a secondary element which furnishes snubbing action if the mounting is subjected to an overload. Felt or cork or both may be used as resilient mats or pads under machine bases.

Large press droppers which create serious impact vibration in heavy mac-hine shops, may be mounted rigidly on massive blocks of concrete having weights many times greater than the weights of the supported machines. The inertia blocks may, in turn, be isolated from the building structure by large wooden block and with thick pads of cork.

In critical installations, attempt should be made to locate the resilient mounts in a plane which contains the centre of gravity of the mounted assembly. It is also preferable to locate the mounts laterally as far away as possible from the centre of the machine.

Rigid mechanical ties between vibrating machine and building structure short circuit or reduce the effectiveness of isolators. Loose and flexible connection should be inserted in all pipes and conduits leading from the vibrating machine. Where flexible connections are impracticable, bends should be inserted into the pipes or the pipes themselves should be supp-orted on vibration mounts for a considerable distance from the source.

(vi) **Noise Reduction by Enclosures and Barriers:** Air borne noise generated by a machine may be reduced by placing the machine in an enclosure or behind a barrier. Much larger noise reduction can be achieved with complete enclosures. The enclosure may be in the form of close - fitting acoustic box around the machine such that the operator performs his normal work outside the box and thus is not subjected to the high noise levels of the machine. The enclosure may also be made of sheet metal lined inside with an acoustical material.

Where size of the machine, working area and the operation do not permit close - fitting enclosures, the machine may be housed in a room

of its own. The inside of the enclosure should be lined with sound-absorbing materials to reduce the noise level of the contained sound. The walls of the enclosures shall also have adequate transmission loss to provide proper sound insulation.

A partial elimination of noise in certain directions may be obtained by barriers or partial enclosures. Two sided or three sided barrier, with acoustic absorption material may affect appreciable noise reduction. Where it is possible, the opening should face a wall covered with sound absorbing material. If the top of the enclosure is open, the reduction may be increased by placing the sound-absorbing material on the ceiling overhead.

(vii) **Acoustical Absorption Devices:** In order to reduce the general reverberant noise level in machine shops, acoustical material may be placed on the ceiling and side walls. With this treatment three to eight dB reduction of middle and high frequency noise may be achieved. This would bring down the general reverberation noise level and as a consequence, the noise conditions may become less confusing.

For efficient noise reduction functional sound absorbers may be clustered as near the machine as possible. These units may be suspended and distributed in any pattern to obtain lower noise levels within the machine shop. Compared on the basis of equal total exposed surface areas, functional sound absorbers have slightly higher noise reduction coefficients.

Ear Protection Aids: For noisy industries, the workers should be provided with ear protection aids like earplugs, headphones or noise helmets. A unique form of operational modification is employing deaf persons to handle noisy equipment, wherever possible, subject to suitable safe guards. The noise levels must be reduced to a point where the noise hazard will be reduced to a condition of acceptability.

Design of Doors and Windows: For reducing noise, it is necessary to design carefully the doors and windows of the room. The sound travels through very thin cracks between the door and wall. Excellent sound insulation is obtained by constructing glazed windows with double or triple panes of glass. The air space at the edges of such panes is filled with sound absorbing material.

Treatment of Floors, Ceilings and Floorings: It is known that floating floors and suspended ceilings help considerably in reducing noise. Suitable sound absorbing materials like hair, felt, acoustical tiles and perforated plywood and specially made porous materials are available and can be fixed on walls, floors and ceilings to have reduction in noise. It is suggested to use

a few suspended absorbers from the ceiling for reducing deflections from the ceiling and for absorbing the machine noise. These absorbers may be suspended on the top of the machine and as close as possible to it.

Planting of Trees: A new concept gaining acceptance is the planting of trees like Neem, Tamarind, Coconut etc. near schools, hospitals, public offices and such sites. The presence of trees is likely to reduce the noise to the extent of about 8 - 10 dB. Similarly indoor plants are helpful to reduce noise in a house by 8 to 10 dB. Belts of trees or shrubs may also be used as barriers of sound. It has been found that in dense evergreen woods, the attenuation of sound is about 18 dB per 300 m at 500 c/s. This is due to absorption by the foliage on one hand and multiple scattering on the other. Obviously, denser the barrier, greater is the attenuation.

Use of Silencers or Filters: This method is applicable to the control of noise from ducts, exhausts or convey systems, the ends of which must be open to the atmosphere. For this purpose glass wool or mineral wool covered with a sheet of perforations may be used.

Vibration Damping: This arrangement is attempted to reduce vibration. A layer of damping material in the form of resilient pads made of rubber, neoprene, cork and plastic may be adopted for high frequency vibrations. It is desirable to make massive base for a vibrating machine.

Noise Control by Locations: Another practical method of reducing noise is by increasing the distance between the source and work vicinity. Machines, processes and work areas which are approximately equally noisy should be located together. Areas that are particularly noisy should be segregated from quiet areas. The office space in a factory should be as far as possible segregated from the production area and preferably be located in a separate building. If a common wall is unavoidable it should be heavy with minimum connecting doors and no permanent openings.

Noise control by Absorption of Reflected Sound

Ceiling: The absorptivity of the ceiling can be increased by introducing large absorbing area without interference with other operations. Two methods are commonly employed (1) by suspended grid system, using lay-in or concealed grid type panels or tiles and (2) by verticaly suspending panels of absorbent material. If ceiling treatment does not give required attenuation, reflections from the walls should be reduced by applying absorptive treatment to them.

Screens: After the above treatments if the noise is to be reduced further, it is advisable to use screens around the noisy machines. Sound reduction of the

order of 10 dB (A) to 15 dB(A) may be achieved by using screens in an already treated area. The various other absorbing materials are acoustic plaster (a plaster of granulated insulating material and cement), compressed cane or wooden boards, perforated asbestos, teak plywood packed by wire etc.

Noise Control by Town Planning and Legislations: Vibrations from external sources such as railways, cars, traffic, factories etc. create structure borne sound. The most effective method of reducing such noise is to have a rational town planning. The city is divided into suitable zones and residential zones are placed away from railways, workshops, factories and main streets.

A vigorous pursuit of the existing legislative measures, especially during the festivals and marriage functions should be made to control noise pollution.

Good mental and physical health requires that exposure to loud noise should be minimised on the roads, inside the factories, at construction sites and inside residential buildings. Noise produced inside the factories is very harmful for the workers as they are continuously exposed to it for years together. It is detrimental to the interests of the owners as well as it lessens efficiency of the workers and makes them accident prone.

It is the duty of the town - planners to segregate industries from residential areas. If this is not done there is not only the nuisance from noise but also from air - pollution. Inside the houses one can lessen noise by using carpets or rubber on the floor. Heavy curtains also lessen the propagation of noise. Fans and other electrical equipments need care so that they make the least noise. The most important thing is to make people aware that noise is bad for physical and mental health. Many people yet do not know it!

Noise Pollution

Sound is a normal feature of our life. It is a main mean of communication and entertainment. Sound is also one of the effective alarm system in many animals. A loud, unwanted or unpleasant sound that causes discomfort is called **noise**. A given sound may appear music to someone and noise to others. It depends upon loudness, duration, rhythm and mood of a person. *'The release of unwanted sound in the atmosphere is called noise pollution'*.

Sound travels in pressure waves and affects our eardrums. The intensity of a sound wave is the average rate per unit area at which energy is transferred by the wave onto the surface (expressed as weber per meter^2 or Wm^{-2}). The sound level is the logarithm of ratio of the ambient intensity to the reference intensity (usually considered 10^{-12} Wm^{-2}). The unit of sound level is **decibel** (dB), a name that was given to recognize the work of Alexander Graham Bell. When the ambient sound intensity is equal to the reference intensity, the sound or noise level is 0 dB. Noise level can range from 0 to more than 120 dB. Noise beyond 120 dB causes physical discomfort. In view of the logarithmic nature of scale, 10, 20 and 100 decibels represents 10 times, 100 times and 10^{10} times the threshold intensity, respectively. The intensity of normal conversation sound ranges between 35 dB to 60 dB. Prolonged exposure to noise of 80 dB or more may lead to impairment of hearing. A noise above 140 dB becomes painful. The workers of noisy factories and soldiers lose their ability to hear soft sounds.

Sources of Noise Pollution

Noise pollution is the result of industrialized urban life and congestion. The main sources of noise are various industries such as textile mills, engineering established, printing presses,

defence equipments and vehicles (tanks, artillery, rocket launching, explosions, practice firings), transport vehicles (trains, trucks, buses, cars, motor-cycles, scooters, jet planes), domestic gadgets (mixers, exhaust fans, desert coolers, air conditioners, vacuum cleaners), entertaining equipment (radios, record players, television sets), public address systems etc. (*Fig. 5.13 and 5.14*). The operations such as blasting, bulldozing, construction work, stone crushing etc. and use of crackers on festival occasions also contribute to noise pollution.

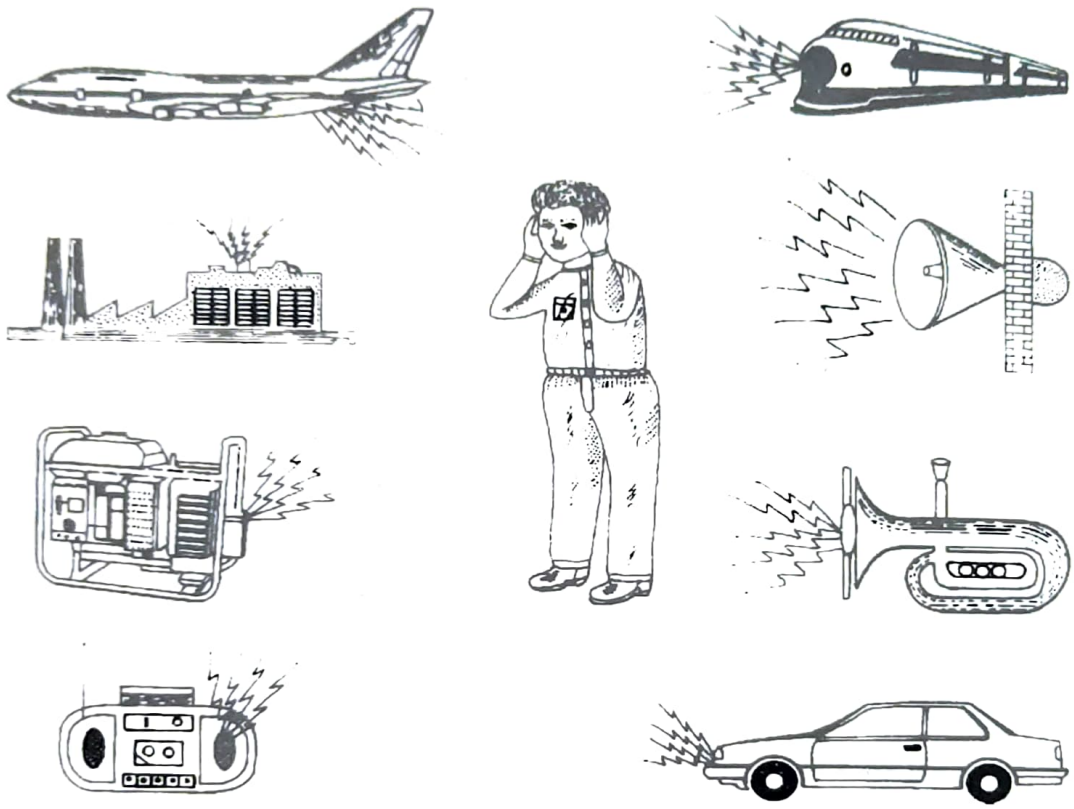

Fig. 5.13. Chief sources of noise pollution.

Fig. 5.14. Dance party with loud music.

The zone wise ambient noise levels as recommended by the Central Pollution Control Board is given in *Table 5.4*.

Table 5.4. Zone-Wise Permissible Ambient Noise Levels

Zones	Day (6.00—21.00 hr.)	Night (21.00—6.00 hr.)
Industry	75 dB	70 dB
Commercial	65 dB	55 dB
Residential	55 dB	45 dB
Silent zone	50 dB	40 dB

Effect of Noise Pollution

Noise pollution affects the power of hearing as well as general health of man.

(*a*) ***Effect on Hearing Ability.*** The most immediate and acute effect of noise pollution is impairment of hearing :

(*i*) Ear drum may be damaged by sudden loud noise or prolonged exposure to noise.

(*ii*) The sensory cells meant for hearing in our ears may be permanently damaged, if they are subjected to repeated sounds of high intensity before their recovery.

(*iii*) The noise in cities is often enough to deafen people gradually at least partially as they age.

(*b*) ***Effect on General Health.*** Following adverse effects on general health are caused by noise pollution :

(*i*) Noise cause anxiety and stress and in extreme cases may lead to fright.

(*ii*) Constant exposure to noise causes hormonal imbalance leading to several disorders such as increased rate of heart beat, constriction of blood vessels and increase in cholesterol level producing high blood pressure, hypertension and decreased heart output.

(*iii*) Noise causes digestive spasms and dilation of eye pupil, impairment of night vision and decrease in the rate of colour perception.

(*iv*) A sudden high intensity noise produces a startle reaction which may affect psychomotor performance of a person and even heart failure in a heart patient.

(*v*) Noise also detracts attention and causes emotional disturbance.

(*vi*) Damage to heart, brain and liver has been reported in animals due to prolonged noise pollution.

(*c*) ***Other Effects.*** Noise interferes with our conversation, disturb concentration and upsets mood.

Control of Noise Pollution

Following measures can be adopted to control noise pollution :

1. Proper lubrication and maintenance of machines can reduce noise.
2. Noisy machines should be installed in sound-proof chambers or quieter machines should be fabricated to replace the noisy ones.
3. Noise producing industries, railway stations, aerodromes should be located away from human settlements.
4. There should be silence zones around residential areas, educational institutions and hospitals.

5. Noise by motor vehicles on roads can be reduced by planting several rows of coniferous trees.

6. Occupational exposure to noise can be reduced using protective devices such as ear muffs or cotton plugs.

7. Use of loud-speakers and amplifiers should be restricted to a fixed intensity and fixed hours of the day.

8. Personal protection against noise can be done by stuffing a bit of cotton in the ears or holding hands over ears under noisy situations.