MANAGEMENT OF NOISE INDUCED HEARING LOSS: A REVIEW

Reg. No. M0116

Independent Project as a part fulfilment of
First Year M.Sc, (Speech and Hearing),
Submitted to the University of Mysore,
Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MYSORE - 570 006

May, 2002

DEDICATED TO

My dearest Amma

Certificate

This is to certify that this Independent Project entitled ***"MANAGEMENT OF NOISE INDUCED HEARING LOSS : A REVIEW"*** *is the bonafide work in part fulfilment for the degree of Master of Science (Speech and Hearing) of the student with* ***Register No. M0116.***

Mysore
May, 2002

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Certificate

This is to certify that this Independent Project entitled ***"MANAGEMENT OF NOISE INDUCED HEARING LOSS : A REVIEW"*** *has been prepared under my Supervision and Guidance.*

Mysore
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DECLARATION

This is to certify that this Independent Project entitled **"MANAGEMENT OF NOISE INDUCED HEARING LOSS : A REVIEW"** is the result of my own study under the guidance of **Mrs. P. Manjula,** Lecturer in Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other diploma or degree.

Mysore
May, 2002

Reg. No. M0116

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PROLOGUE

The word 'Noise' is derived from the Latin word 'Nausea' meaning annoyance. It is defined as any unwanted sound and has been a recognised annoyance for centuries. Julius Caeser once issued an edict forbidding chariot driving on Rome's cobbled streets at night, since the rumble and clatter disturbed the slumber of the Metropolis. In 600 B.C, the Greeks were not allowed to do metal work within their city limits since it produced noise (Ward, 1980, cited in Canlon, B., 1987). Thus, even during those days noise control measures were in practice.

Noise is a major environmental pollutant which poses a threat to our health and economy. An increasingly urban, industrial and mechanised society is the prime contributor for this Evidence shows that exposure to excess noise over prolonged periods can produce physiological as well as psychological changes in human beings. Noise has been found to interfere with our activities at three levels: (Trivedi and Raj, 1992), audiological level - interfering with the satisfactory performance of the hearing mechanism, biological level interfering with the biological functioning of the body and behavioural level affecting the social behaviour of the individuals.

Studies on occupational health hazards have demonstrated that noise exposure causes hearing loss (Morata, 1999, Ward, 1993, cited in Soames Job, R.F., and Hatfield, J., 2000) and may have a detrimental impact on cardiovascular health. (Talbott, Brink, Burks, Palmer, Engberg, Cioletti and Ingman, 1996, cited in Soames Job, R.F., and Hatfield, J., 2000). Noise also has been found to impair performance both in occupational (Smith, 1989, cited in Soames Job, R.F., and Hatfield, J., 2000) and educational settings (Haines, Stansfield, Job and Berglund, 1998, Hygge, Evans and Bulinger, 1998, cited in Soames Job, R.F., and Hatfield, J., 2000). Community noise surveys have demonstrated negative reactions (Fields, 1994, Hatfield and Job, 1998, Job, 1988, cited in Soames Job, R.F., and Hatfield, J., 2000) and sleep disturbances (Griefhan, 1992, Griefhan, Deppe, Menhert, Moog, Mohler and Schumer - Khors 1998, Ohrstrom, Bjorkman and Rylander, 1990, Pearsons, Barber, Tabachnick and Fidell, 1995, cited in Soames Job, R.F., and Hatfield, J., 2000) resulting from noise exposure.

Apart from occupational health hazards, it has also been found that noise associated with entertainment (eg : loud music) has deleterious effects on hearing (Axelsson and Prasher, 1999, cited in Soames Job, R.F., and Hatfield, J., 2000). Thus it is a well documented fact that noise has adverse effect on hearing. In 1989, a committee of the American College of Occupational Medicine (ACOM) published a position statement on noise induced hearing loss, which is reproduced below.

"Occupational noise induced hearing loss (NIHL), as opposed to acoustic trauma is a slowly developing hearing loss over a long period (several years) as the result of exposure to continuous or intermittent noise" (cited in Dobie, A.R., 1995).

Exposure to hazardous noise levels initially result in temporary threshold shift in which the threshold returns to the pre-exposure level. However, with continued exposure to noise, the threshold shift becomes permanent. The magnitude of permanent threshold shift depends on the acoustic characteristics of noise (such as intensity, duration, spectrum and temporal aspects) and individual susceptibility. The area which is most vulnerable to damage as a result of noise exposure is the organ of Corti within the inner ear. A variety of anatomical changes have been observed. These include alterations to the outer and inner hair cell stereocilia, cell bodies, cuticular plate, nerve endings, nerve fibres and supporting cells (Canlon, 1987).

The individuals are usually unaware of the problems in the early stages because initially frequencies outside the critical speech frequency bands are affected. In the later stages, hearing in other frequencies also deteriorates. Unlike many other conditions that produce sensorineural hearing loss, noise induced hearing loss can be prevented if we identify the problem early and employ preventive measures. Such measures shall also reduce the non-auditory effects of noise. Noise level should be maintained at satisfactory levels in the residential areas of the community by installing noise insulation, glazing windows. In the occupational settings, engineering and administrative controls can be employed. When engineering and / or administrative interventions to reduce exposure are not feasible or cannot reduce exposures to non-hazardous levels, primary prevention relies on the use of personal hearing protective devices. The employees should be given education about hearing loss and hearing conservation. They should be made aware of the auditory and non auditory effects of noise. For this orientation programmes should be carried out. There should be posters at places of high noise levels. The employees should be motivated to institute preventive measures. When engineering and / or administrative interventions to reduce exposure are not feasible, the preventive measure relies on the use of hearing protective devices (HPDs). But these are temporary till engineering and administrative controls are instituted. Properly selected, maintained and consistently worn HPDs will reduce exposures to safe levels and prevent NIHL. There are two main types of HPDs : earmuffs, which fit over the ears while earplugs and canal caps fit in the ear canal. It is essential to select and keep in stock a sufficient choice of HPDs appropriate to work environment and the wearers' needs. The factors that should be kept in mind are comfort, convenience, communication needs, cost, correct fit, attenuation, durability, etc (Royster and Royster, 1990).

However, therapeutic measures for the prevention of hair cell loss are limited and interventions for reversing the hair cell loss are presently unavailable. Hence, it is important to develop therapies that may enhance survival and recovery of structure and function in the injured cells. Several studies have been conducted in animals, such as use of gene therapy, magnesium therapy, calcium channel blockers, etc which may throw light into the mechanism of noise induced hearing loss and may help in the development of therapeutic measures for the prevention of noise induced hearing loss.

With increasing noise levels in public places, it is necessary to regulate and control noise. The noise pollution rules, 2000 was notified with the objective of maintaining the ambient air quality standards in the areas / zones such as industrial, commercial, residential and silence zones during day time and night time. Inorder to comply with the ambient air quality standards, cooperation between planners and environmental authorities is very important.

Much of the information regarding the management of noise induced hearing loss is scattered in various sources like journal articles, books and on internet. So it is difficult for a student or an audiologist to get a consolidated and complied information regarding the same. Hence this project aims to collect and compile information regarding the management of NIHL from all the possible sources and thereby make it easier for a student or an audiologist to get comprehensive information about the same.

METHOD

Information on noise control and the management of NIHL was collected from books, journal articles and through surfing the internet. The information thus obtained were compiled and categorised under the following categories:

I. Noise control from the different sources and the legal aspects concerning it.

   a. Industries
   b. Transportation
      i. Road traffic
      ii. Rail
      iii. Air
      iv. Water ---- /Surface
                      \Underwater
   c. Recreational vehicles
   d. Music
   e. Military
   f. Construction
   g. Domestic noise
   h. Recreational toys
   i. Hospital noise
   j. Noise in the Schools

II. Recent researches on animals for the reduction of the effect of noise exposure:

a. Gene therapy
b. Magnesium therapy
c. Calcium channel blockers
d. Hyperbaric oxygen treatment
e. Carbogen inhalation
f. Conditioning
g. Middle ear action

REVIEW OF LITERATURE

INDUSTRIAL NOISE

No environmental factors have caused so much confusion regarding its effect on worker's efficiency and worker's health as industrial noise. Noises in industry originate from processes causing impact, vibration or reciprocation movements, friction and turbulence in air or gas streams. Numerous studies and surveys have confirmed the fact that exposure to high levels of industrial noise causes some degree of hearing loss. It is essential to find out ways and means to control the noise pollution. It is also relevant in the sense that if we know the ways and means for its control, framing of various laws for the same would be an easy job for a legislature.

In every city an environmental authority should be constituted. The planners and authority have to devise certain methods by which noise produced by industries, construction work and traffic be controlled, They should plan in such a way that source of noise are away from noise free zones or silence zones (Trivedi and Raj, 1992). Noise control can be done at source, in the transmission path and at the receiver.

1. Noise control at the source

The most efficient way of controlling noise is at the design stage. This principle not only applies to noise source but also to industrial plants and office /

residential buildings. In many situations noise control is done by the manufacturer, where machines must be labeled with their noise output, thus giving the purchaser the option of acquiring quieter machines. In some situations simple modification of the peripheral devices may reduce the noise significantly such as attaching a silencer to the exhaust (Trivedi and Raj, 1992).

Given below are certain steps that can be easily performed and will significantly reduce the noise emission of equipment already in use (Behar, Chasin and Cheesman, 2000).

- Periodic balancing of rotating parts as improper balance leads to vibrations and increase in noise levels.
- Proper lubrication of moving parts. Use of right cutting oil is essential for reducing the cutting noise associated with machining.
- Substitution of a noisy process by a quieter one. Eg : Grinding instead of chopping, welding instead of riveting.

  Noise level can be lowered if the noise source is screened by thick walls and other noise absorbing materials. Rubberised material and anti-vibration pads can be used.
- Noise from portable air compressors can be reduced by external design techniques. Vibration damping must be applied to the large, flat panels and engine must be mounted on vibration isolations. Air must be brought in through acoustically treated ducts and there must be an adequate silencer

on the engine. This treatment reduces the noise from about 110 dBA to 85 dBA at a distance of one meter.

- Silencers either reactive or absorptive type can be used. Most reactive silencers for industrial applications have been high pass filters which attenuate low frequency noise only. Absorptive type is basically a section of pipe or duct which is lined with an acoustically absorbent material such as material wool or glass fibre. This is used for the mid and high frequency applications associated with high fluid flow velocities including intake and discharge silencers for gas turbines, fans, blowers and also discharge silencers for steam and gas vents and control valves.
- Vibration isolation in which a vibrating machine could be isolated from the surrounding structure by supporting it on resilient mountings.
- Noise caused by gas streams can be attenuated by the use of suitable ducts and by correct design and positioning of inlets and outlets.
- Attention should be paid during the construction of the factory. The noisiest part of the factory should be placed as far as possible from the boundary of the site and from parts of the works where as much quiet as possible is required (Trivedi and Raj, 1992).

2. Noise control in the path

Once the possibility of controlling the noise at the source has been exhausted, the next stage is to try to eliminate or reduce the transmission of the noise energy from the source to the receiver. Structure - borne vibration require specific materials for their control. But in most situations noise is transmitted through the air. If we are dealing with external noise, then the choice is the use of barriers and if both the source and the receiver are inside the same building, then acoustical enclosure has to be used for either of them. The barrier effectiveness is related to its height and the distances to the source and to the receiver. The higher the barrier and the closer the distances, the better the protection offered by the barrier. In an enclosure the reflected sounds are reduced by using high sound absorption on the limiting surfaces. Some of the sound absorbing materials are acoustic tiles, heavy carpet, unpainted concrete blocks, curtains, window glass, plaster etc. Landscaping, i.e, planting of evergreen trees, shrubs and bushes also help to reduce noise (Behar, Chasin and Cheesman, 2000).

3. Noise reduction at the receiver

This can be achieved by administrative techniques. It is possible to control both the exposure time and level for workers by arranging their work pattern in a way which would limit the amount of time that they spend in certain noise level environments. The opportunities for noise control at the receiver are limited in practice.

The employees should be given education about hearing loss and hearing conservation. They should be made aware of the auditory and non auditory effects of noise. For this orientation programmes should be carried out.

There should be posters at places of high noise levels. The employees should be motivated to institute preventive measures. When engineering and / or administrative interventions to reduce exposure are not feasible, the preventive measure relies on the use of hearing protective devices (HPDs). But these are temporary till engineering and administrative controls are instituted. Properly selected, maintained and consistently worn HPDs will reduce exposures to safe levels and prevent NIHL. There are two main types of HPDs : earmuffs, which fit over the ears while earplugs and canal caps fit in the ear canal. It is essential to select and keep in stock a sufficient choice of HPDs appropriate to work environment and the wearers' needs. The factors that should be kept in mind are comfort, convenience, communication needs, cost, correct fit, attenuation, durability, etc (Royster and Royster, 1990).

Infra and Ultrasound

Well fitted insert ear plugs provide attenuation at infrasonic frequencies (i.e., below about 20 Hz) that is about equal to those in the 125 Hz one-third octave band (OB). However, at those same frequencies, earmuffs provide very little protection and may even amplify sound (Nixon, Helle and Kettler, 1967, Paakkohen and Tikkanen, 1991, cited in Berger, E.H. and Casali, J.G. 1997). Conventional ear plugs and ear muffs generally provide adequate proteciton at ultrasonic frequencies (i.e., above about 20,000 Hz) with attenuation exceeding 30 dB for frequencies from about 10,000 to 30,000 Hz. (Behar and Crabtree, 1997, Berger, 1983, cited in Berger, E.H. and Casali, J.G. 1997).

Active noise reduction (ANR)

ANR reduces the overall level of noise by employing the technique of wave addition or wave cancellation (destructive interference). A miniature microphone placed inside the ear cup (of most ANR headset designs) measures the noise field inside the ear cup and sends a copy of the noise to an electronic circuit. The ANR system electronics invert the noise signal and send it back to the earphone inside the ear cup. If there were no time delays in the electronics and the earphone and microphone were perfectly matched and were in the same physical location, the noise signal from the earphone would be exactly 180° out of phase with the original noise signal and the cancellation would be perfect. However, the microphone and earphone cannot occupy the same location in space. Also all the elements of the ANR system add delays that limit the performance both in maximum frequency of active attenuation and in the achieved levels of attenuation (McKinley, Steuver and Nixon, 1996).

Frequency selective hearing protection devices

Efforts to improve communications under earplugs have involved the use of apertures or channels through an earplug body, sometimes opening into an air-filled cavity encapsulated by the earplug walls. This creates an air-leak that produces a low-pass filter characteristic. Attenuation is negligible below about 1000 Hz, increasing upto about 30 dB at 8000 Hz. Because most of the speech frequencies critical to intelligibility lie in the range from 1000 to 4000 Hz, the communication benefit potential of the low-pass feature may be small. Further more the attenuation may be insufficient for many industrial noise environments (Bergerand Casali, 1997).

Amplitude sensitive HPDs

Amplitude sensitive or level dependent HPDs provide reduced attenuation at low sound levels, with increasing protection at high levels. These use a non-linear component such as a valve, diaphragm or sharp-edged orifice opening into a duct to effect the change in attenuation. The low intensity sound waves exhibit laminar airflow and pass relatively unimpeded through the aperture, whereas high-intensity waves involve turbulent flow and are attenuated because of increasing acoustic resistance (Allen and Berger, 1990, cited in Berger, E.H. and Casali, J. G, 1997).

Refuge Devices : Similar t amplitude sensitive device, this device attenuates high level sounds while low level sounds are yet audible. Thus this device expands the dynamic range of its user. It's a low threshold WDRC amplifier with input stage compression. There have been standards set to limit the noise exposure. The permissible exposure is in Table -1

Exposure time (in hr/day)	Limit in dB/A
8	90
4	93
2	96
1	99
$^{1}/_{2}$	102
¼	105
1/8	108
1/16	111
1/32 (2 minutes or less)	114

Table -1 : Permissible continuous noise exposure limits.

Exposure to continuous or intermittent noise louder than 115 dB(A) should not be permitted. Exposure to pulse or impact noise should not exceed 140 dB (peak acoustic pressure).

TRANSPORTATION NOISE

Transportation noise will include noise from road, rail, air and water transport.

Road Noise control

In modern life, cars, buses, cycles and trucks have become an integral part of our transportation system. These vehicles are source of noise in several ways. Basically traffic noises have been of two types - noise generated by individual vehicles and noises generated by a continuous flow of vehicles of all types.

Sources of noise from individual vehicles are given below

- Engine noise
- Exhaust noise
- Slamming of vehicle doors
- Brake squeal
- Use of Horn
- Cooling fan noise
- Gear noise
- Tyre tread noise
- Wind flutter
- Others (speed of the vehicles condition of the road etc)

Not all vehicles make the same amount of noise. Measurements carried out by using test procedure gave the following results (Trivedi and Raj, 1992).

Luxury limousine	77 dB
Small passenger car	79 dB
Miniature Passenger car	84 dB
Sports Car	91 dB
Motor cycle (2 cylinder - 4 stroke)	94 dB
Motor Cycle (1 cylinder -2 stroke)	80 dB

Motor cycles, with their exposed engines and inadequate silencing arrangements are notorious noise producers with a sound level roughly 30 times higher than that of a saloon car. Diesel engines operate at considerably higher peak combustion pressures and higher rates of pressure rise and thus result in greater noise and vibration.

It has been found that in trucks having a high ground clearance, the engine gets more exposed and hence the vehicle provides little attenuation of noise. In cars and vans, the vehicle body provides considerable shielding of engine noise and the ground clearance is considerably smaller.

Structure borne sound and vibration of the engine are held under control by the use of rubber engine mounts. The air-borne engine noise is held under control, by the use of

1. Acoustical absorption blankets under the hood
2. Adequate firewall attenuation (dash mats)
3. Toe and floor-board mats with adequate attenuation and vibration damping properties.
4. Acoustical material in the car interior which is composed of the floor mat, the door and side trim, the headlining, the seat cushions and the seat back (Apps, 1957).

Exhaust Noise has been attenuated through the use of chambered mufflers having reactive and resistive elements that decrease the amplitude of the transmitted gas pressure pulses. Other alternative is to split the exhaust gas flow and to install a second muffler. But this dual system add weight and cost.

Vibration produced during the application of *brakes* resonates within the brake structure, and is then further magnified by the body of the car. It appears that little could be done about brake squeal, except by introduction of some damping devices into the vehicle.

All motor cars must be fitted with *horns* by law. However, they must be used only when required. It has been found that a visual stimulus like the flashing of headlights or flashing lights on the top is more effective than an audible one in attracting attention (Trivedi and Raj, 2000). Multitoned horns and continuous use of horns is banned.

Horns (Central motor vehicle rules, 1989) :

1. Every motor vehicle shall be fitted with an electric horn or other device (confirming to the specifications of the Bureau of Indian standards) for use by the driver of the vehicle and capable of giving audible and sufficient warning of the approach or position of the vehicle.
2. No motor vehicle shall be fitted with any multitoned horn giving a succession of different notes or with any other sound-producing device giving an unduly harsh, shrill, loud or alarming noise.

Nothing contained in sub-rule (2) shall prevent the use on vehicles used as ambulance or for fire-fighting or salvage purposes or on vehicles used by police officers or officers of motor vehicles department in the course of their duties of such sound signals as may be approved by the registering authority in whose jurisdiction such vehicles are kept.

The direct approach to reducing the *fan noise* is to lower the tip speed by reducing the rotary speed. The total airflow may be maintained by increasing the number of blades or by providing a shroud to channel the airflow through the radiator.

The *gear noise* in the vehicle can be controlled by

1. Modification and control of tooth profiles
2. Introduce damping in the casing.
3. Use of absorbsers attached to the casing.

The *tread* elements in the tyres are made of different lengths so that the sound radiated is more or less scrambled in such a fashion as to be easily obscured by noise already present in the vehicle. Tyre noise increase as the vehicle gets operated at higher speeds. More aggressive tread design such as cross leg type has been noisier than a rib-type design tyre.

Wind flutter: Is a low frequency disturbance which is heard inside a car when one of the front windows is partially or totally open and the airstream is free to impinge on the rear edge of the window frame. This can be prevented by closing the window.

Slamming of vehicle doors : This is a problem which can be soled at the design stage and will be done only when there is legislation forcing motor manufacturers to produce noiseless door shutting devices.

The *multiplicity* of high types of vehicles and the failure to segregate fast and slow moving traffic results in high noise emission as vehicles brake and then accelerate frequently.

However, the noise made by the vehicle is largely controlled by its user. Every possible means, should be employed to educate the drivers in careful considerate use and maintenance of these vehicles.

Noise control manners for highways include construction of barriers to dissipate or obstruct sound emissions, elevated or depressed highways, flyovers, re-routing of traffic, segregation of fast and slow moving traffic, landscaping maintenance of proper road surface repairs etc.

Table - 2 depicts the noise emission limits of automobiles

Category of automobiles	Limits in dB (A)
a. Motor cycle, Scooters and Three wheelers	80
b. Passenger cars	82
c. Passenger or commercial vehicles of upto 4 MT	85
d. Passenger or commercial vehicles of above 4 MT and upto 12 MT	89
e. Passenger or commercial vehicles exceeding 12 MT	91

Table-2 : Noise limits for automobiles.

Silencers

1. Every motor vehicle shall be fitted with a device (referred to as a silencer) which by means of an expansion chamber or otherwise reduces as far as practicable, the noise mat would otherwise be made by the escape of exhaust gases from the engine.
2. Noise standards - every motor vehicle shall be constructed and maintained as to conform to noise standards as indicated in the Table-2.

Rail Noise Control

A person inside a passenger car may hear an external source of noise because of sound waves which strike the walls of the car and set them into vibration. These vibrating walls then become secondary sources and generate noise inside. Furthermore, alternating mechanical forces acting directly on the car structure also set the walls into vibration. The noise level within the car depends on the magnitude of these external disturbances, on the surface area over which their resulting forces act, the transmission loss of the car walls and floor, on the location and size of holes and openings which permit air-borne noise to leak inside directly, and on the amount of sound absorption inside the car.

Inorder to achieve an environment free from rattles, squeaks, hisses and sudden noise, contributing noise sources must be reduced to an acceptable level. Some of the noise control measures are :

1. Vibration isolation

Where it is practicable to do so, substantial reductions in noise level within a railroad car can be obtained by making use of vibration isolation.

2. Partitions

The contribution to the noise level inside a car which is caused by airborne noise striking the outside of the car can be reduced by providing a more effective enclosure.

3. *Ventillating duct treatment*

4. Sound absorptive materials

The perforated metal-facing type, with a mineral fiber blanket acting as the sound absorber, has been used effectively.

Train noise at a distance can be decreased by reducing the noise generated underneath the railroad car. This can be accomplished by reducing the unsprung weight, using well-maintained or welded rail, and providing resilient bumpers in the track system. A skirt enclosure can reduce the airbrone sound radiated outward, thus lessening the noise heard at some distance from the tracks. The trains on elevated steels structures set the steel work into vibration, this becoming a large secondary source radiating into the air. Adequate control of this problem requires vibration isolation between roadbed and steel structure or use of noise control techniques on the structure or both (Jack, 1957).

Code of practice for controlling noise

Railway operations

Erection of acoustic barrier, reducing speed and avoiding whistling within and along municipal limits and habitation zones are recommended for adoption to the extent possible.

AIR CRAFT NOISE CONTROL

Air craft has been probably the most dramatic of the man-made noise sources which are heard by the general community, especially in the vicinity of an airport. This source of noise pollution is increasing steadily during recent years and especially to those close to international airports constitutes a serious problem. Noise made by jet planes has been intrinsically more disturbing than that of propeller driven aircraft because it is of far higher pitch (Trivedi and Raj, 1992).

Aircraft noise originates from both the propulsion system and the airframe, of which the propulsion system constitutes the major noise source. The propulsion systems of aircraft has been taken several forms - piston or gas turbine driven propellers and gas turbine engines. The major noise sources from these are core engine, fan exhaust stream, compressor, fan blades, fan exhaust nozzle, turbine blades, combustor, etc

Airframe noise is the noise generated in flight from sources other than the engine, auxiliary power units and other mechanical accessories. This noise is produced by the aerodynamic boundary layers or the turbulence created by air passing over and around the wings flaps, landing gear, wheel wells, door, windows, etc.

The first step in the battle against aircraft noise is the installation of sound-measuring equipment at individual recording points as widely dispersed as possible. With this, different zones subjected to different levels of noise stress can be mapped out. By this means it is possible for air-traffic control to lay down departure routes by which only thinly populated areas in the vicinity of the airfield have to be traversed (Von Gierke, 1957).

Protection of public health and welfare from aircraft noise has been accomplished most effectively by exercising four noise-control options taken together as a system.

1. Control at the source : Involve the application of basic design principles or special hardware to the engine / air frame combination, which will minimize the generation and radiation of noise.

Jet noise reduction involve the use of exhaust noise supressor or reduce the jet volocity but maintain thrust by increasing the mass flow. Another, method is to increase the bypass ratio.

2. Control in the Path : Involving the application of flight procedures that minimize generator and propagation of noise. It consists of modification of flight operational procedures such as changes or reorientation of flight patterns and the time of the day when the aircraft are operated. The air craft should fly over unpopulated or sparsely populated areas. Preferential-runway utilization can be used and to its effectiveness crosswind landing gears case be used.

Land-use control, involving the development or modification of air port surroundings for maximum noise compatible usage.

Relocation of run-up areas to places farther removed from the community, taking advantage of any special meteorological and terrain conditions all other alternatives which may be practical. Another possible method of ground-noise reduction is by the use of the sound shadows of buildings. If air planes are run-up close to hangars or buildings, the shielding effect of hangar can reduce the noise radiated in the direction of the hangar by as much as 10 to 25 dB. Noise reduction can also be achieved with specially built shielding walls. One solution to the provision of swift transporation to and from the airport is the use of vertical take off and landing craft (VTOL) and short take off and landing plane (STOL) (Lipscomb, 1974).

3. *Control at the Receiver :* Involving the application of procedures such as restriction on the type and use of aircraft at the airport, which will minimize community noise exposure and use of HPDs.

HPDs

The primary function is the conservation of hearing capacity of the wearer. It is possible to obtain a reduction in the noise level at the ear by about 10 to 45 dB depending upon the type of protector and the frequency composition of the noise. The devices commonly used for protecting the ear from noise are ear plugs, ear muffs, semi-inserts and helmets. When the noise levels are high combinations of two types of ear protectors are sometimes used. The reduction in noise level afforded by these protectors is not much at the lower frequencies, being of the order of 10-15 dB. However, at higher frequencies, provide attenuation of 20-30 dB.

Amplitude sensitive or level dependent HPDs provide reduced attenuation at low sound levels, with increasing protection at high levels.

Code of practice for controlling noise from aircraft operations

- Aerodrome should be located away from the city and growth of the city should not be allowed to extend to the aerodrome.
- Aeroplanes should take off in a direction rapidly away from the city.
- During boarding and unboarding operations the plane should be sufficiently away from the airport buildings.
- Night-time operations of the aircraft should be minimised.

WATER TRAFFIC

The powerful engines in today's ships produce high noise levels, which, when added to the noise from air conditioning, ventilation equipment and auxiliary plants for electrical power, mean that people on board are frequently subjected to excessive noise for long periods, even during the hours of relaxation and sleep (Hines, 1996, cited in Williams, D, 1985). Since most of the noise aboard originates at the propulsion unit, the problem may be partly overcome by ensuring that crew's living quarters and passenger accommodation are remotely sited from the engine room and propulsion end. The acoustical environment in the working areas of the ship must be determined. It is desirable to limit the maximum permissible sound levels at watch-keeping and manoeuvring positions which would allow better communication when running in poor visibility or when manoeuvring (Richards and Middleton, 1976, cited in Williams, D, 1985). Their results showed that levels as high as 115 dB(A) occurred in engine rooms, although the average noise on the platform level works nearer to 105 dB(A), differing very little with engine power and size of ship, nor for that matter with the speed of the engine unit. Although the engine room noises were high, the levels in the control rooms were 30 dB(A) less than in the plant area. Reduction of 9 dB(A) in the engine room and 6 dB(A) on upper deck may be achieved by careful consideration to acoustic insulation. The long-term aims of achieving desirable noise levels on board ship will be assisted by the introduction of stringent specifications stimulated by regulations and codes of practice.

Mac Millan (1975), cited in Williams, D, (1985) reports that hovercraft are without doubt the noisiest from the surface transport but, since they are few in number and operate mostly away from built-up areas, the noise problem chiefly affects the passengers and crew. Inside the craft, transmission and engine noise are predominant and sound pressure around 83 dB(A) is typically constant at cruising speeds, with short peaks of 91 dB(A) on arrival and departure (Duerden, 1972, cited in Williams, D, 1985).

Continuing developments in underwater sound technology are converting the 'Silent world' to a rather noisy work environment (National Research Council, 1970, cited in Smith, P.F, 1985). Exposure of divers to intense noise in water is increasing. The development and use of acoustic means of tracking divers has resulted in additional noise exposure. Some tracking systems require divers to wear small but powerful sound transmitters which produces pulses at 124 dB SPL (Muller, 1966, cited in Smith, P.F, 1985).

Studies on underwater hearing in man have shown that hearing in water and air differ in the range of frequencies to which the ear is sensitive and also in dynamic range. Man's hearing is more sensitive in water than in air at frequencies below 125 Hz and above 16 kHz. So hearing conservation standards for divers ought to encompass a much wider frequency range, both at lower and higher frequencies, than do such standards for usual industrial situations.

Low frequency intense underwater sounds produced by exploration devices and hulls of moored vessels are not common now, but device that produce high frequencies are common and present a hearing hazard (National Research Council, 1970, Rooney, 1969, Smith and Hunter, 1969, cited in Smith, P.F, 1985).

Corso and Levine (1965a, cited in Smith, P.F, 1985) plotted equal-loudness contours (ELCs) for BC hearing at frequencies as high as 95 kHz and found that ELCs converge at 85 kHz. This indicates that high frequency content of broad band noise is important in water than in air. The cochlea is partially protected from intense high frequencies in air by the filtering action of the ear canal and middle ear system. This protection is not afforded in underwater exposure to noise. Not much information is available on the effects of broad-band underwater noise on divers hearing.

Gould and Wyman of the U.S. Naval Coastal systems centers (cited in Smith, P.F, 1985) have made extensive noise measurements on hand held tools and showed that divers using such tools are exposed to BBN in the 1-32 kHz region at SPLs ranging upto 160 dB and occasionally higher. Yet no experimental studies have been done on the effects of such exposures on hearing. The existing empirical evidence is too scant to predict what levels of underwater noise would be safe for drivers.

Some amount of acoustic attenuation is provided by divers' dress. Wet-suit hoods are fairly effective between hearing protectors (Montague and Strickland, 1961, Smith, 1969, Norman, Phelps and Wrightman, 1971, cited Smith, P.F, 1985). The amount of protection provided by hoods vary greatly with fit.

RECREATIONAL VEHICLES

The call of the wild has not dimmed in modern times. More recreational vehicles are descending on the mountain paths, trails and back roads which include motor cycles, snow mobiles, pleasure aircraft, pleasure boats, etc.

Under the guise of increasing power, cyclists have been inclined to strip the muffler - an act that does little more than increase the noise, which the rider senses to signal great power. One way of protecting the ear is through the use of crash helmets. For protection of ear from aircraft and boat noise, use ear protective devices or headgears.

Some of the general protective measures are given below :

- Acoustical insulation for noise control and vibration dampening.
- Reticulated foam for filtration
- Gaskets
- Seals
- Thermal insulation
- Comfort cushioning
- Drainage cushioning
- Molded trim

Noisy toys

Noise harms children's hearing, language acquisition, reading and learning skills and social interactions. The effects of noise on child's development has received too little focus. Parents must make it their business to lower the decibel level in their child's lives (www.lhh.org|noise|children|tips.htm).

Avoid

Certain rattles, squeaky toys, toy telephones and musical toys measure over 110 dB (comparable to power tools). Children play with these close to their ears and manufacturer do not warn parents that sound emitted from toys may be damaging to hearing. Parents should listen to toys before buying and if it sounds too loud, should not buy. Should avoid gifting children with noisy toys.

In video arcades, the noise levels exceed 110 dB (the level of factory machinery). Parents should limit their children's time at these arcades. Children should be cautioned to keep the volume down during computer games and while listening to music.

Encourage

Quiet times foster an environment where parents and children can spend time together. The league for the hard of hearing recommends

- Books
- Quiet movies
- Visits to libraries and museums
- Puzzles, card games, construction sets etc.

MUSIC

In recent years with the advent of powerful amplifiers and modifications in technique, music a previously benign sound source, has generated sound levels of astounding proportions (Lipsomb, 1974). Music system reproduce music and other sound levels above 120 dB. In 'Boom car', the sound levels exceed 140 dB. Activities like aerobic exercising and ice skating, as well as disco dancing are accompanied by amplified music played at high sound levels. Use of personal stereo systems such as the walkman could be used by children at above safe levels of exposure. So in the school curricula education regarding the harmful effect of noise must be included. Musicians are less subject to hearing loss than industrial workers. The rationale for this may be wood wind and brass musicians constantly blow against a resistance which causes the Valsalva maneuver to be performed. This creates a mild middle ear dysfunction which results in a slight 'earplug' - a benefit which industrial workers would not achieve.

However, music professionals should routinely wear appropriate ear protection whenever they are exposed to potentially unsafe levels of music. Commercially available, custom-made earplugs designed by Etymotic Research for musicians offer adequate attenuation of sound without sacrificing the quality of music. The ER musician earplugs have a relatively flat frequency response. Because they are custom-fit deep within the ear canal and include a passive filter device, the ER-15 (15 dB / flat attenuation) and ER-25 (25 dB / flat attenuation) ear plugs combine comfort with a more material sd. ER -20/HI-FI is a non-custom device which allows for about 20 dB attenuation and a slight high frequency roll off. Vented / tuned is a custom - made swimmer's ear plug with a tunable vent or select-A-vent drilled through the center. At its most open position (3 mm diameter), the earplug is acoustically transparent upto about 2 kHz but with upto 30 dB of high frequency attenuation. This is useful because for some instruments only the very high frequency energy is intense enough to damage hearing. For live music performance, In-ear monitors are used. Musicians control the volume and frequency response of their own voice and instrument by wearing high fidelity, miniature speakers in deep insertion custom earmolds. One such is prophonics IV in-ear monitor (Hall, J.W. and Santucci, M, 1995). Some music systems have automatic volume limiters to control the excessively loud music.

Although many musicians discretely use ear plugs, often it consists only of cotton wool which is relatively ineffective. It is also aesthetically undesirable for members of an orchestra to be seen wearing earplugs, although many ear plugs are flesh colored. However, ear plugs would lead to problems in rehearsals where communication between conductor and players could be impaired. Also with the ordinary earplugs, as they do not produce same amount of attenuation at different frequencies, tuning of the musical instruments becomes a problem.

Raising the percussion and brass sections to a higher level serves to lessen the SPL reaching the ears of players seated infront. Since sound energy obeys an inverse-square law, increasing the distance between performers is beneficial but impracticable in confined conditions. Decreasing the reflective properties of the stage and auditorium helps to some extent (Westmore and Eversden, 1981). Wide range of instruments are used by musicians. Some of them are given below (Chasin and Chong, 1991).

1. Reeded wood winds - Levels do not exceed 100 dBSPL. The auditory damage is from the brass section to the rear. Because of the high frequency energy content of the brass, ER-15 ear plug is the attenuator of choice. If these musicians are sufficiently isolated from the brass section, vented / tuned earplugs may be optimal.
2. Flutes : Generate levels in excess of 105 dB SPL. The earplug recommended is the ER-15 with a long canal inorder to obliterate the occlusion effect.
3. Small strings : Include both violin and viola. Generate levels in excess of 110 dB SPL with peaks at 126 dB SPL. The earplug selected is ER-15, with the ear canal portion not overly long, as some occlusion is acceptable for these musicians.
4. Largestrings : Include bass, cello and harp. Generate levels in excesses of 90 dB SPL. The earplug recommended is vented / tuned ear plug with a 2000 Hz cut-off frequency (3 mm vent).

5. Brass instruments : Generate levels in excess of 115 dB SPL. The earplug to choose is the vented/ tuned earplug.
6. Vocalists : Levels up to 115 dB SPL. If performing solo, vented / tuned earplugs are the choice. If singing with other instruments, ER-15 earplugs with short ear canal are the choice.
7. Percussion : Damaging element is the high hat cymbal. The custom version of ER-20 / HI-FI yield the correct balance for ear protection.
8. Amplified instruments : The auditory damage is related to the close proximity of the amplifiers. Moving the amplifiers to a position further away from or infront of the performers would lessen the potential damage. ER-15 earplug is recommended.

MILITARY

Military service has always presented a risk to hearing from impulse noise in addition to noise from small arms, with a typical peak pressure of 160 dB at the users ear; a number of weapon systems in current service give peak pressures upto 185 dB in crew positions. To an increasing extent, soldiers are also exposed to continuous noise in vehicles or in workshops; these levels can exceed 100 dBA at the ear, even where hearing protection is used. The problem is becoming more acute, since the quest for more power from equipment of reduced size and weight tends to increase noise at the user's position. The types of exposure to loud noises encountered within the military cover a wide range of auditory stresses. Some exposures are so intense that a single event for an unprotective person could result in severe, permanent noise induced hearing loss (Ades, 1955, cited in Gasaway, D.C. 1994). The gamut of noise types include construction, repair, refurbishing, retrofitting and refitting of ships, tanks, armored vehicles, aircraft, rockets, missiles, ballistic weapons and the myriad support systems associated with military hardware and devices.

Risk criteria

The Army (Hearing conservation, 1980, cited in Gasaway, D.C. 1994) currently uses a risk criterion for intermittent and /or steady-state noises which differ from that employed by the Air Fore and Navy (Hazardous noise exposure, 1982; Hearing conservation and noise abatement, 1983, cited in Gasaway, D.C.

1994). Although all three services employ a 'trading' relationship of 4 dBA for each halving or doubling of allowable durations of exposures, the starting point or boundary for 8 hrs/ day assessments is 85 dBA for the Army and 84 dBA for the Navy and Air Force.

This may not appear to be a significant difference, however, the duration of allowable exposure existing between these two criteria becomes dramatically different for noise levels in the lower range of exposure risks (especially at and below 90 dB). For example, whereas the Army criterion for 90 dBA would allow an exposure duration of 202 minutes / day, the Navy/Air Force criterion would permit an exposure duration of 170 minutes/day for the same sound. This represents a difference of 32 minutes / day between the two.

Noise control measure

Reducing noise exposures to relatively safe levels of unprotected exposure may be facilitated by using noise-control engineering and administrative approaches, either during the initial procurement or by altering and changing the noise emitted by existing machinery, equipment or vehicles. Although all three services can and do have existing military standards and specifications for new equipment, this approach may not be rigorously adopted and enforced. Many vehicles such as tanks and armored vehicles, ships and aircraft, already have limited acceptable noise exposure standards, (Van Cott and Kinkade, 1972, cited in Gasaway, D.C. 1994) which, if obtained during initial procurements would help reduce the noise associated with their operation. However, many procurements receive waivers for noise since it is believed that strict adherences to lower noise levels exceed technological and / or economic feasibilities.

Hence, dependence on personal hearing protection is the main line of defense against overexposure to noise. Most hearing protection devices (HPDs) used by the military services are obtained from federal supply channels where large quantities are purchased periodically and made available through world-wide networks. Each type of HPD procured is assigned a specific alpha/ numeric code called Federal supply number (FSN). The basic type of devices included as hearing protectors are inserts, semi-inserts (earcaps), circumaural muffs, headsets and noise-attenuating communication devices (used alone as headsets or fitted in helmets). Insert devices include pre-molded types such as the single-flange (V-51R) and the 3-flange plugs and a few types of user molded devices, such as the Silaflex (Flents), wax-impregnated cotton stopples (Flents) and expandable vinyl foam plugs. Hearing protection devices that accommodate alterations in barometric pressures associated with hypobaric environments are a common requirement within the military. Expandable vinyl foam plugs accommodate such changes and have improved the ease with which alternations in environmental pressure changes can be tolerated (Stork and Gasaway, 1977, cited in Gasaway, D.C. 1994). Thus the use of HPDs assumes critical importance. Ensure that the protectors can attenuate the noise sufficiently and that they do not interfere with military tasks or military equipment (such as ballistic helmets or sights), that any adverse effect on communication is minimised and that the soldier is prepared to use them effectively on all occassions of noise exposure (Forrest, 1985).

Amplitude sensitive devices for impulse type noise

These attenuate high level sounds but amplify low-level sounds. Hearing protectors that incorporate active noise cancellation (ANC) was first developed by the military for use in tanks. ANC utilizes a very fast computer that samples the noise and generates a mirror image of it which is then played along with the source noise, thus cancelling it. These systems are very expensive.

Combined use of ear plugs and muffs in association with a safe distances of over five meters from the noise source gives adequate protection against acute acoustic trauma from impulse noise (arms and fire shots).

Human TTS data suggest that damage risk for impulse noise can be predicted on the basis of the A-weighted energy contained in the impulses. Animal experiments suggest that damage risk for large caliber weapons may be overrated after the inclusion of A-weighting in the energy measure. Damage risk cannot be based on the peak level alone, but duration is important. Practice has shown that light-caliber weapon shooting in enclosed (reverberating) shooting ranges and large-caliber shooting from trenches may be relatively hazardous (Smoorenberg, 1982).

Noise from field guns produced in the low frequency band of 186 dB peak, has not been found to cause physical injury to the hearing system of a man at a distance of six meters. An upper safe limit for exposure to impulsive noise from gunfire of 155-160 dB (linear, peak) has been recommended to minimise the incidence of hearing loss amongst the gunners and other workers exposed to noisy environments.

CONSTRUCTION NOISE

Noise from construction sites has been generally far worse than noise originating from factories. The reasons are that construction occurs anywhere where the erection of roads, bridges and buildings become necessary. Also the equipment is inherently noisy. Construction noise has been generally excused as a 'temporary nuisance', even though in most large cities it continues day after day, year after year (Trivedi and Raj, 1992).

The noise from construction machinery may be reduced by internal design changes and by external design procedures. Some machines respond fairly easily to noise reduction procedures, while others do not. The technique of noise control is given below :

1. Paving breakers and Rock drills

The major component of paving breaker noise is exhaust noise which can be reduced from about 108 dBA at one meter to about 102 dBA by a strap-on muffler. Breakers with integral mufflers have been slightly more effective and reduce the noise to about 100 dBA at one meter. Another component of paving breaker noise is the ringing of the steel which can be reduced by damping techniques.

2. Large drills

Exhaust mufflers have been used to reduce the noise of large crawler drills. For locations that must comply with street noise control codes, large drills could be totally enclosed.

3. Erecting sheds

To reduce noise from construction equipment, erect sheds around sites, with or without absorbent linings.

4. Piling

Vibratory pile drivers could replace impact drivers. Quiet running electric motors can be used instead of diesels. Enclosing the hammer head and top of the pile in an acoustic screen reduces the operating noise of a pile driver considerably.

5. Compressor

Use of few large compressors in place of several small ones.

Different countries are having different regulations concerning noise emission. Certain countries allow noise emission upto a certain level during a specific part of the working day. Other governments specify maximum emission outside the nearest building. It has been suggested that the noise limit for construction sites should be 70 dB in rural, suburban and urban areas away from traffic and industry, and 75 dB close to main roads and industrial areas -

measured outside the nearest window to the site. It has been important that individuals and local authorities maintain the pressure on construction companies to see that what is technically possible actually happens.

Code of practice for controlling noise from construction activities

- acoustic barriers should be placed near construction sites.
- The maximum noise levels near the construction site should be limited to 75 dB(A) Leq (5 min) in industrial areas and to 65 dBA Leq (5 min) in other areas.
- There should be fencing around the construction site to prevent people coming near the site.
- Materials need to be stockpiled and unused equipment to be placed between noisy operating equipments and other areas.
- Constructing temporary earth bund around the site using soil which normally is hauled away from the construction site.

NOISE FROM DOMESTIC APPLIANCES

There are a number of noise sources in and around the house. Attention must be paid to control the noise exposures from these domestic appliances. The levels of some of the appliances are as follows :

	Domestic appliances	Limits in dB(A) sound pressure level at one meter distance from the operating appliances
a)	Window air conditioners of 1 ton to 1.5 ton	68
b)	Air cooler	60
c)	Refrigerators	46

Indoor noise in apartments and houses can be reduced by

1. Reducing sounds at their sources or seeking quieter appliances to replace old ones. While procuring, select less noisy gadgets.
2. By using foam / rubber pads / mats under noisy appliances such as blenders mixers.
3. By using sound absorbent materials. If noise is a bothersome part of household activities and some of the noise sources cannot be silenced, ear plugs offer a type of solution.
4. Routine care and maintenance of home appliances can reduce the sound levels they create.
5. Use of cupboard doors with magnetic notches, mat and pads on work surface, cork tile on the surface, acoustic tile on the ceiling, carpet on the

floor, draperies along atleast one wall and, well-upholstered furniture not only enhance the appearance of the room but sound treat at them as well.

6. Poorly fitted and / or thin doors are best replaced by heavy, well-located ones.
7. Most telephone bells can be adjusted by means of a volume control on the bottom of the telephone.

SCHOOLS

It is critically important that noise levels in schools be controlled if optimal listening in classrooms is to be possible. The noise level for an unoccupied classroom during school time should not exceed 35 to 40 dBA, and for an occupied classroom 40 to 50 dBA. The direct solution to the noise problem is to isolate or remove specific noise sources that contribute to excessive noise level in a classroom (Berg, 1993).

There are three types of classroom noise : background, intruding and internally generated. Background noise is steady state and comes from vehicular traffic; heating ventilating and cooling systems; gymnasiums and cafeterias; and classroom projectors and fans. Intruding noise is more sudden or temporary. This include jet plane overhead, yells on the playground, footsteps in the hallway or a school buzzer. Internally generated noise includes students' and teachers' talking, chairs and tables sliding and shoes shuffling. The intensity and spectral composition of these noises vary constantly within each classroom situation. Heating, ventilating and air-conditioning (HVAC) system include large centrifugal fans, refrigeration compressors, boilers, cooling towers, water pumps and transformers. To prevent and absorb vibrations of these mechanical equipment components, rigid supports, flexible connections, expansion joints and mufflers could be used. Water pipe hammering and air duct vibration can be kept out of a building structure by using ceiling hangers, pipe clamps with glass fiber or floor-mounted supports. Air outlets and diffusers in classrooms must also be aligned correctly.

Noises exceeding 80 dBA may exist throughout cafeterias, gymnasiums, mechanical equipment rooms, etc. These noises enter classrooms by vibration of building elements, by pathways under doors and through leaks or flanking paths. Hence, the sound leaks should be sealed. Also doors should be solid-core wood or fiber - filled hollow metal and be gasketed around the entire perimeter for airtightness when closed. Double glass windows with wide spacing between panes of different thickness is also useful.

'Clicks' from footsteps can be cushioned with carpeting and resilient rubber floors. Thuds' from things dropped may require elaborate constructions such as concrete slabs with suspended ceiling and floors (floating floors). A noisy projector should be repaired and replaced.

Schools can establish policies restricting the use of motor cycles, power mowers and similar noisy equipment to before and after school hours. A wall barrier can provide a noise barrier between a heavily travelled road and a nearby school. Communities can monitor noise levels to determine if sound conforms to existing airline standards aimed at reducing jet aircraft while on take-off. Trees and shrubs help provide a noise barrier to a lesser extent. Also the parking lot should be away from classrooms.

Finally, class discipline and co-operation procedures for increasing student on-task behaviour, reducing student off-task behaviour and decreasing overall noise in the classroom should be established by the teacher. Decreasing the class population size also helps to decrease noise levels. Thus a proper noise control plan should be set up in each school to identify, measure and isolate or reduce noises (Berg, 1993).

HOSPITALS

The problem of noise in hospitals has been appreciated for many years and there is no doubt that it can be particularly tiring to both the staff and patients. Certain criteria already exists which recommend levels of continuous noise acceptable within hospitals. Beranek proposed that a noise criteria (NC) rating of 30 would be appropriate. It appears from surveys that internally generated noise is often more disturbing than noise from outside sources. If the hospital is air conditioned noise levels can be as high as 60 dB(A) and in situations where there is no air-conditioning, the noise levels can be as low as 30-40 dBA. Noise level must be of a level that will prevent the disturbance to a recovering patient. Noise also interferes with speech, diagnosis and surgery (Walker, J.G., 1978).

Acceptable noise levels are given below :

Hospital wards	40 dBA
Consulting room	45 dBA
Diagnostic and examination room	35 dBA
Operation theatre	40 dBA

Care should be taken to keep the noise level at permissible limits. Enclosures must be provided for noisy equipments. The sole of shoes must have rubber pads.

FIRE CRACKERS

Blasting of fire crackers is a health hazard since it is responsible for both air pollution and noise pollution. During the process of bursting, the chemical energy of the reaction is converted into mechanical energy and is accompanied with air pollutants and intense impulse sound. The sound lasts for a very short time and is so sudden that it impinges on the human ear before its own protective system is aroused whereby the impact can damage hearing temporarily or permanently depending upon the energy of the impact.

In India damage risk criterion for impulsive sounds was studied for army weapons in the past and has been recently studied for fire crackers also.

Noise standards for fire crackers

(Notification issued by the Ministry of Environment and Forests, 1999)

- No bursting of fire crackers during 10 pm and 6 am.
- The manufacturers of fire crackers are required not to produce any cracker having noise level greater than 125 dB at four meter distance.
- The manufacture, sale or use of fire crackers generating noise levels exceeding 125 dB (AI) or 145 dB (C) peak, at four meter distance from the point of bursting jshail be prohibited.

- For individual fire crackers consisting the series (conjoined fire crackers) the above mentioned limit be reduced by 5 log 10(N) dB, where N-Number of crackers joined together.

RECENT RESEARCH STUDIES

1. CARBOGEN INHALATION

Pharmacological agents with a possible vasodilating influence on inner ear blood vessels would at least theoretically be able to counteract a vasoconstrictive effect from noise and prevent NIHL However, there is very little evidence in literature on these matters. One of the agents which appears to have some protective effect against noise is carbogen (90-95% O_2 + 5-10% CO_2). Studies on inhalation of carbogen have shown that carbogen inhalation raise oxygen tension in the endolymph (Prazma, Fischer, Biggers and Ascher, 1978, cited in Brown, J.J., Vernon, J.A., and Fenwick, A., 1982) and in perilymph (First, Murata and Hesli, 1976, cited in Brown, J.J., Vernon, J.A., and Fenwick, A., 1982). It has also been shown to reduce pure tone induced temporary threshold shift in humans and chinchillas (Joglekar, Lipscomb and Shambaugh, 1977, Brown, Meikle and Lee, 1985; Witter, Deka, Lipscomb and Shambaugh 1980, cited in Brown, J.J., Vernon, J.A., and Fenwick, A., 1982).

These studies have confirmed the beneficial effect of carbogen inhalation on acoustically - induced permanent auditary impairment and that carbogen inhalation during high intensity result in statistically significant reduction in pathologic elevation of 1 μv isopotential function of the a.c. cochlear potential and reduced the loss of IHCs and OHCs. The protection was most pronounced below 1.5 kHz. However, carbogen inhalation combined with low intensity exposure was not found to lead to any changes in the a.c. cochlear potential or in the number of missing hair cells. Carbogen inhalation increased blood flow and to some extent caused vasodilation. Thus the increased blood flow effects of carbogen may counteract the reduced blood supply effects of noise (Dengerink, Axelsson, Miller and Wright, 1984).

Hyperbaric oxygen (HBO) treatment

HBO treatment for acute acoustic trauma and NIHL has become increasingly common. The study was conducted in rats in a pressure chamber with 100% oxygen and the pressure was held for 90 minutes. Results showed less hearing impairment, particularly at high frequencies. It has been reported that oxygen tension in the cochlea reduces during acoustic stimulation. HBO treatment increases oxygen tension in endolymph and perilymph and might in this way help the hypoxic cells to survive (Kuokkanen, Virkkala, Zhai and Ylikoski, 1997).

Transcutaneous electrostimulation

Recently it has been shown that electrical stimulation of the coehlea at the round window reduced TTS in animals. Since it is not practical to electrically stimulate the cochlea directly at the round window in humans, transcutaneous electrostimulation was performed as an alternative (Tachibana, Kiyoshita, Senuma, Nakanishi Sasaki, 1992). The study was conducted in 26 volunteers. Results indicated that electrostimulation caused a reduction of TTS after loud sound exposure. This may be of clinical importance since it may be used for the prevention and treatment of noise induced hearing loss or acoustic trauma.

Magnesium (Mg) therapy

A study was conducted by Scheibe, Haupt, Mazurek and Konig, 2001, to examine the therapeutic effect of magnesium on noise trauma in anaesthetised guinea pigs exposed to impulse noise. The animals received subcutaneous injections of different magnesium doses. Also the therapeutic efficacy as a function of the post-exposure time of onset of the magnesium treatment was tested.

Results showed that 0.29 mmol magnesium has proved to be most effective and resulted in a significant reduction by 13 to 20 dB at all frequencies tested. Also PTS was found to be clearly dependent on the post exposure time of the onset of treatment. The therapeutic effect decreased with the length of time elapsed between the end of exposure and the beginning of treatment. This emphasizes the need that any kind of magnesium therapy in noise trauma should be started as soon as possible after exposure.

Magnesium as a natural and cheap agent, being practically without any side effects should more often be considered when it comes to developing both preventive and therapeutic strategies for protection against noise trauma. (Scheibe, Haupt, Mazurek and Konig, 2001).

Calcium channel blockers

Animal studies were conducted to look at the potential protective effect of calcium channel blocker (diltiazem) on the OHCs following exposure to noise. (Henrich, Maurer, and Mann, 1999). Guinea pigs were subjected to various patterns of noise exposure with or without prior treatment with systemic diltiazem and then sacrificed. Ultra structural examination revealed that diltiazem reduces the morphological changes on the OHC's that occur secondary to intense noise exposure. The authors postulate that a possible mechanism of noise induced hearing loss is the formation of temporary holes in the lipid bilayer of the cell membrane which allows calcium ion influx into OHC. This alters the osmotic balance of the cytoplasm and leads to cell damage, a sequence that may be interrupted by calcium channel blocker. There are several types of calcium channels in cells and intracellular spaces. But only one type modified by diltiazem ('L' type). They are numerous in baso lateral cell membrane and the intracellular space between IHC and neighbouring cells.

Gene therapy

Genes that regulate ontogeny of the inner ear and its response to insults are rapidly being identified and characterized (Fekete, 1999, Steel and Bussoli, 1999, cited in Kawamoto, et. al., 2001). The gene products of many of these genes have the potential to provide prevention or cure for inner ear disease such as acoustic trauma. (Shoji, Yamasoba, Magal, Dolan. Altschuler and Miller 2000, Staecker, Dazert, Malgrange, Lefebvre, Ryan and Vandewater, 1997, Van de Water, Staecker, Ernfoms, Moonen and Lefebvre 1996, cited in Kawamoto, etal., 2001).

The main disadvantage of this is the transient effectiveness due to their degradation. So if the genes that encode the therapeutic agents can be introduced into the cells and lead to production of the gene product , a more stable type of therapy can be accomplished. Thus to utilise the genetic information for designing therapies, it is necessary to develop gene based therapy which involves the delivery and expression of a gene, and thereby the availability of gene product to the cells in the lesion, where it can exert its protective or therapeutic effect. (Anderson 2000, Nabel, Simari, Yang San and Nabel, 1997, Nabel, 1998, cited in Kawamoto, et al., 2001). A variety of vectors are available for delivering transgenes into cells. Non-viral vectors are safe but their efficiency is limited and in most cases insufficient for obtaining therapeutic levels of gene expression. (Kabanov and Kabanov, 1995, Qin, Pahud, Ding, Bielinska, Kukowska-Lataloo, Baker and Bromberg, 1998, cited in Kawamoto, et al., 2001). Viral vectors are currently the most efficient vectors, but each of them have some limiting disadvantages. Experiments were conducted to assess the protective capability of the human GDNF transgene against noise trauma in the guinea pig cochlea. The left ears of guinea pigs were inoculated with a recombinant adenovirus with a human GDNF insert (Ad. GDNF). Later animals were sacrificed and hair cells counted in the left and right ears. Auditory brainstem threshold were measured before the inoculation and just prior to sacrifice. Control groups included inoculation with a reported gene vector (Ad. lacZ) and Ad. GDNF in normal ears with no noise exposure. Results showed that both Ad. GDNF and Ad. lacZ vectors can protect the cochlear hair cells and hearing from noise insult. The authors speculate that the protection is due to the presence of viral vector which leads to cytokinine expression and signalling, causing a mild immune response, which, in turn, increases the resistance of the tissue to trauma. There is evidence that cytokinines can play protective roles by enhancing secretion of neurotrophins and other growth factors (Appel, Kolman, Kazimirsky, Blumberg and Brodie, 1997, Ebadi, Bashir, Heidrick, Hamada, Refacy, Hamed, Helal, Baxi, Cerutis and Lassi, 1997, Lindsay and Yancopoulos, 1996, cited in Kawamoto, et al., 2001). Moreover, the lack of toxicity of Ad. GDNF in normal ears is of importance to the on-going efforts to pursue inner ear gene therapy technology. Rapid progress in vector technology is likely to yield vectors that are non toxic and non-immunogenic and are likely to make gene therapy for environmental and genetic inner ear disease a reality.

Conditioning

It has been known that prior exposure to low level noise protects hearing from subsequent traumatic noise. This phenomenon is called conditioning or toughening. Sound conditioning provides 20 dB protection against a traumatizing stimulus (Canlon and Dagli, 1996). It has been shown to occur with sound pressure levels (SPLs) from 81 to 95 dB and with frequencies ranging between 0.5 and 4.0 kHz (Canlon, Barg and Flock, 1988, Subramaniam, Henderson, Campo and Spongr, 1992, Subramaniam, Henderson and Spongr, 1993, cited in Pukkila, M., Zhai, S., Virkkala, J., Pirvola, U., and Ylikoski, J., 1997).

The conditioning procedure lasted between 6 hours / day for only 2 days periodically and for 24 days continuously. The mechanisms proposed to be involved in conditioning phenomenon are the middle ear muscles, the efferent innervation system of the inner ear, changes in the inner hair cells of the inner ear and most recently, specific protective proteins namely heat shock proteins (HSPs) and growth factors (GF). Three kinds of HSPs were evaluated (HSP 72, HSP 90, HSP 27) (Lim, Miller, Dolan, Raphael and Altschuler, 1996).

Noise induces expression of HSP 72 and HSP 27 in outer hair cells and modulates the levels of HSP 90. HSP 90 has a constitutive expression in inner and outer hair cells and HSP 27 has constitutive levels in stereocilia Constitutive HSPs could help stabilize proteins against the initial stress caused by noise and induced HSPs could provide further stabilisation of proteins, renaturation of affected proteins and stabilization of receptors and cell processing. HSPs have been reported to bind to and affect cytoskeletal proteins including actin and spectrin, that have important role in hair cell functioning.

Noise Protection Effect of Middle Ear

To estimate the attenuation and protection effect of the acoustic stapedius reflex on the inner ear, extratympanic manometry (ETM) was used. ETM is the measurement of air pressure changes in the sealed external ear canal. This method was used, as it is able to distinguish between the stapedius and tensor reflex. Patients with unilateral Bell's palsy were investigated during palsy time and after recovery. The amplitude of the contralateral acoustic stapedius reflex was used as a relative measure of the excitation of the cochlea on the affected side. After ETM investigation, a TTS was shown on the affected side and the hearing threshold on healthy side was unchanged. Thus, the attenuation effect of the acoustic stapedius reflex protects the inner ear from an acoustic damage. Protection effect of the tensor tympani was not demonstrated (Brask, 1979).

In normal operation, with normal intensity sounds, the ossicles vibrate in such a way to push and pull the stapes and thus via the footplate in the oval window, push and pull on the perilymph in the upper gallery of the cochlea. For sound intensity above 140 dB, the whole mode of oscillation of the ossicles changes and they rock from side to side. Thus the footplate is no longer pushed or pulled, but rocks to and fro and pushes the perilymph from side to side of the oval window instead of up and down the cochlea. As a result, the pressure fluctuations in the perilymph are greatly reduced and the effect is a sudden drop in loudness as the second mode of oscillation come into action.

Hair Cell Regeneration

Recent research shows that hair cells and supporting cells in the avian ear could regenerate and repair themselves. A few days after the original hair cell population is destroyed, the supporting cells rapidly divide and presumably differentiate into new hair cells. One structure that is severely damaged by acoustic over stimulation is the tectorial membrane. Both the upper and lower layer of the tectorial membrane are destroyed along the abneural edge of the basilar papilla. Lower layer regenerates in concert with the hair cells; however, the upper layer fails to regenerate. The absence of the upper layer could alter the mechanical response of the cochlea by changing its mass or stiffness, but whether this has any significant effect on various functional measures of hearing is not yet fully understood.

If the hair cells do regenerate, the peripheral processes of each afferent and efferent neuron must reestablish synaptic contact with the appropriate hair cells (s) in order to maintain the proper tonotopic organization. Afferent and efferent synapses have been observed on regenerating hair cells. However, the pattern of afferent innervation could conceivably be altered, because the number of cochlear ganglion neurons is reduced after acoustic trauma. What effect this has on the cochlear frequency-place map is not yet known.

The degree of recovery following acoustic overstimulation appears to be highly variable. Some reports suggest that there is complete recovery of function, while others have found permanent behavioral and physiological deficits. The incomplete recovery of function following acoustic overstimulation could be due to residual damage to hair cells that survive the traumatizing exposure. In some cases, permanent hair cell lesions have been observed after high level sound exposures. The lack of regeneration presumably occurs because the supporting cells, which divide and differentiate into hair cells, are destroyed (Chen, Trautwein, Shero and Salvi, 1996).

Although advances are being made toward identifying stem cells, little is known about the intercellular signals that induce stem cells to re-enter the mitotic cycle. Damage to the epithelium by noise or drugs is a sufficient stimulus to trigger these events, but the subsequent chain of cellular events remains to be discovered. The fact that all vertebrate classes, with the exception of mammals have this capacity suggests that proliferation in mammals is actively suppressed. Discovery of the signals that trigger regeneration in birds and elucidation of the chain of cellular events will provide critical information. It may then be feasible to identify the steps that are blocked in mammals. Such steps may someday lead to ability to stimulate hair cell regeneration in humans (Rubel, 1992).

EPILOGUE

The twenty first century has witnessed the continual increase and spread of industrialisation throughout the world. Accompanying this development has been a growing increase in noise levels and also the number of individuals exposed to hazardous levels. The levels of noise now common in our environment place an excessive burden on the auditory system in the form of auditory and non-auditory effects. The primary impact of these effects in daily life is its interference with speech communication. Apart from this, it has an effect on the economy. Compensation claims as a result of permanent hearing damage are now in the courts. Also there is effect on property values, i.e, the value comes down. Since the hearing damage increase insidiously over the years, the individuals may be unaware of the problem in the initial stages and the affected patients often experience social isolation and withdrawal. Individuals tend to leave their job which inturn affect the production. Hence it is desirable to reduce the noise exposure below hazardous levels and employ noise control measures. In India, there exists no law exclusively which deals with the problem of noise whereas developed countries of the world have already enacted specific laws to control the noise menace. Hence, it is of great necessity to make new laws and revise the existing laws. Apart from the noise control measures, strict implementation of the existing and adding new act, with regard to noise control is mandatory.

The control measures can be either engineering or administrative control. If both are not feasible or cannot reduce exposures to non hazardous levels, then personal hearing protective devices can be used. Now in the present century, with the advancement in science and technology, there is great excitement and optimism at the prospect of inducing the regeneration of sensory cells destroyed by noise; use of chemicals such as calcium channel blockers, magnesium etc. for reducing the effects of noise on auditory and thus on non-auditory structures.

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