UNIT 1   NOISE IMPACT ANALYSIS

Structure

1.0   INTRODUCTION

Sound is propagated through a medium. Geometric spreading and surface effects are the factors which affects the sound propagation. There are various rating methods like instrumental methods, numerical modeling and scale for the prediction of noise. In this unit we will also study about the internal combustion engine noise in addition to exhaust and intake noise. Human health is widely affected by the noise or we can say transportation noise. Stress on hormones, sleep disturbance and psychological health disturbances are some of the consequences due to excessive noise exposure. Therefore, guidelines have been drafted for noise impact assessment in jet engines, commercial/public buildings and metallurgical industries.

1.1   OBJECTIVES

After reading this unit, you should be able to:

● understand the concept of noise;

● list the various methods used for Prediction and Rating of Noise; and

● describe the impacts of noise on human health.

1.2   NOISE PREDICTION AND RATING METHODS

Dear Learners, let us now read about noise prediction and rating methods in the following sentences:

1.2.1   Noise Propagation

Acoustic Energy transmission through a medium via a sound wave is referred as the propagation of sound. We can say that Sound is basically a sequence of pressure waves; it propagates through compressible media like solid, water or air (Figure 1.1). When sound propagates, medium refracts attenuates or reflects the waves passing through them. When medium is air, transmission of sound from its source to the surroundings is done by pressure variations. The level of sound decreases, as it gets far away from the source. Sound absorption by air and distance plays important factors which are responsible for the sound weakening. This reduction in sound is known as Attenuation. The sound or noise encountered in day to day life is from point or line sources. There is a decrease in level of noise by 6dB per doubling of distance from point source while in line source; there is a decrease in the level of noise by 3dB per doubling of distance from the source.
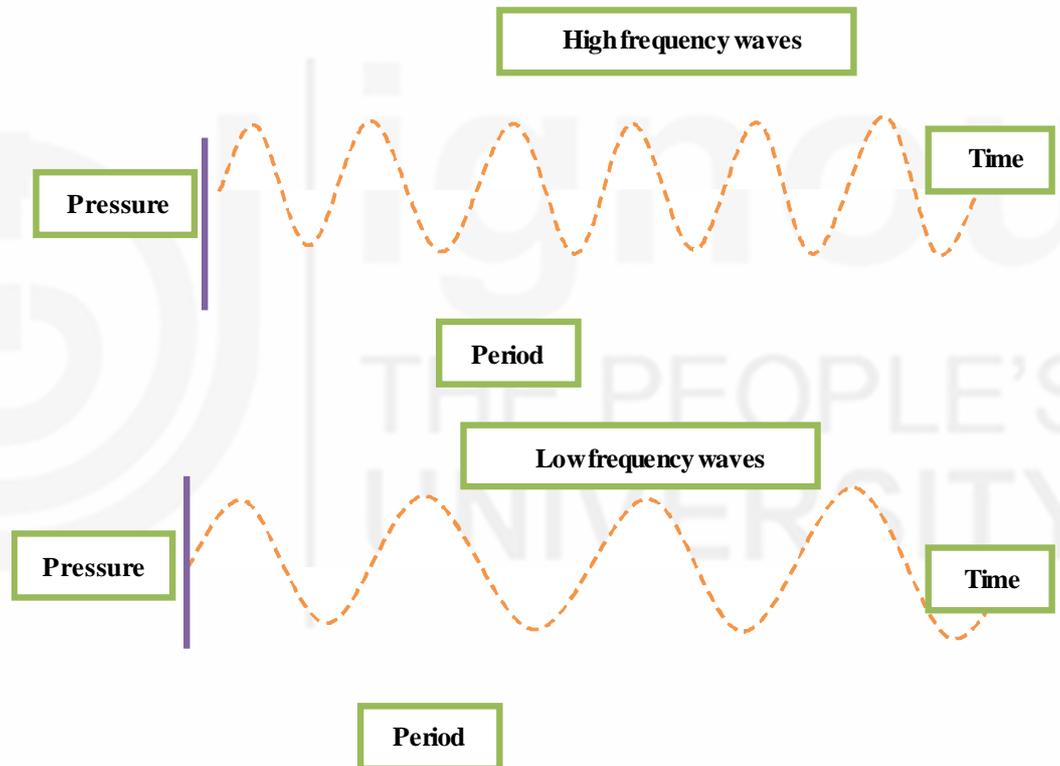
Fig. 1.1: Propagation of sound

Factors affecting propagation of sound

Geometric spreading and surface effects are considered to be the important factors which affects the propagation of sound. These factors are explained below;

Geometric Spreading

When the wave front expands and sound energy spreads, this spreading of energy is referred as geometric spreading. Geometric spreading affects all situations of sound propagation and it is independent of frequency. The types of geometric spreading

can be further divided into cylindrical and spherical spreading. Losses due to the spreading of sound propagation are generally expressed in x dB as the distance doubles from the source.

Surface Effects

(a) Ground Absorption: If the propagation of sound is above the ground, acoustic energy losses on reflection results into attenuation. The loss due to ground absorption depends on the type of surface. Smooth or hard surface produce less absorption.
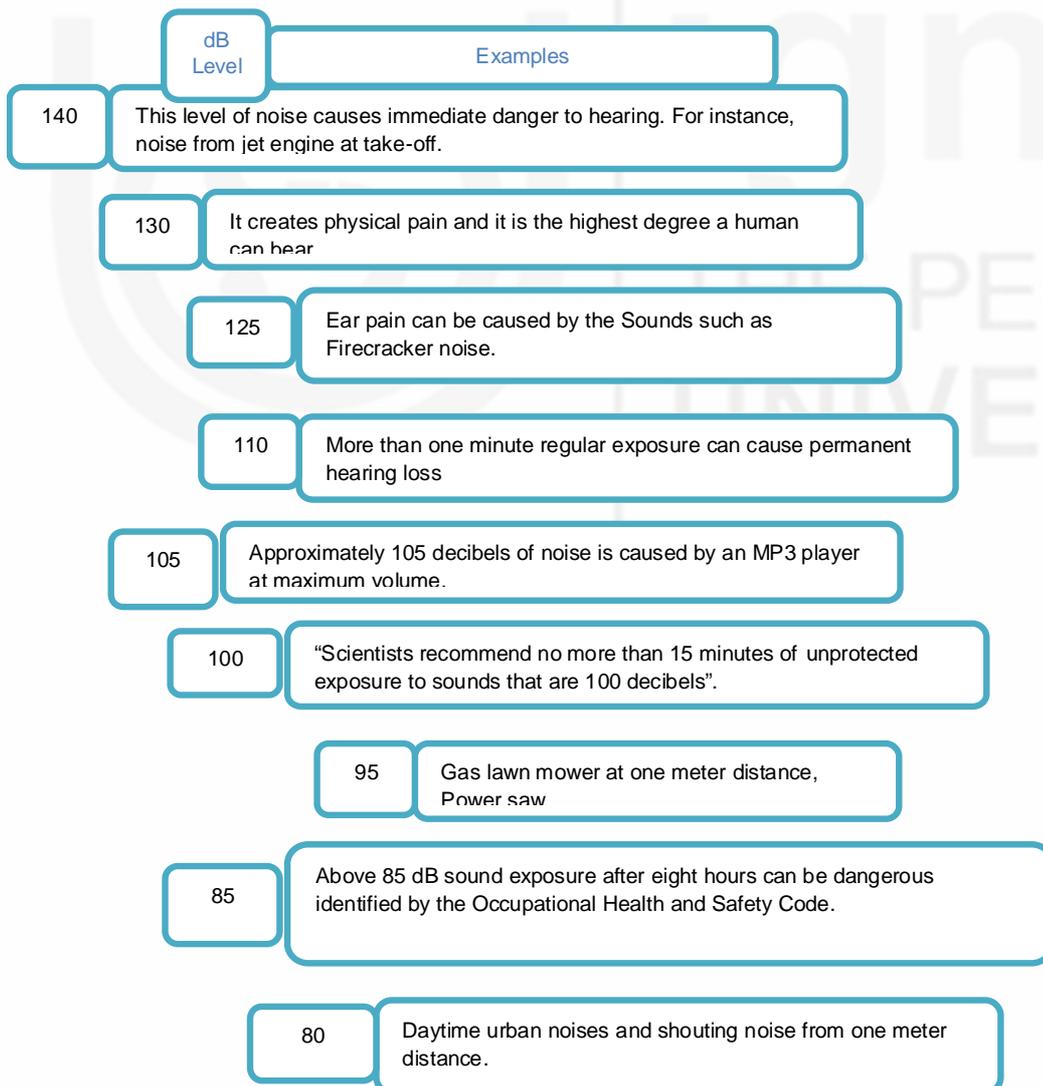
(b) Attenuation due to Barriers and Trees: For significant attenuation, solid barriers or a band of trees with several feet depth is required. Low frequencies get easily diffracted from the edge of a barrier while high frequencies are more effective for a barrier. Due to the scattering by atmosphere, 40dB is the maximum performance of barrier.

1.2.2 Noise Scale and Rating

Noise scale

Decibel (dB) is the unit for measuring sound. Sound to the human ear is related to the decibel scale. The threshold of human hearing is between 0 dB and 130 dB. Noise creates physical pain on reaching the top of scale (Figure 1.2)

dB Level	Examples
140	This level of noise causes immediate danger to hearing. For instance, noise from jet engine at take-off.
130	It creates physical pain and it is the highest degree a human can bear.
125	Ear pain can be caused by the Sounds such as Firecracker noise.
110	More than one minute regular exposure can cause permanent hearing loss
105	Approximately 105 decibels of noise is caused by an MP3 player at maximum volume.
100	"Scientists recommend no more than 15 minutes of unprotected exposure to sounds that are 100 decibels".
95	Gas lawn mower at one meter distance, Power saw
85	Above 85 dB sound exposure after eight hours can be dangerous identified by the Occupational Health and Safety Code.
80	Daytime urban noises and shouting noise from one meter distance.

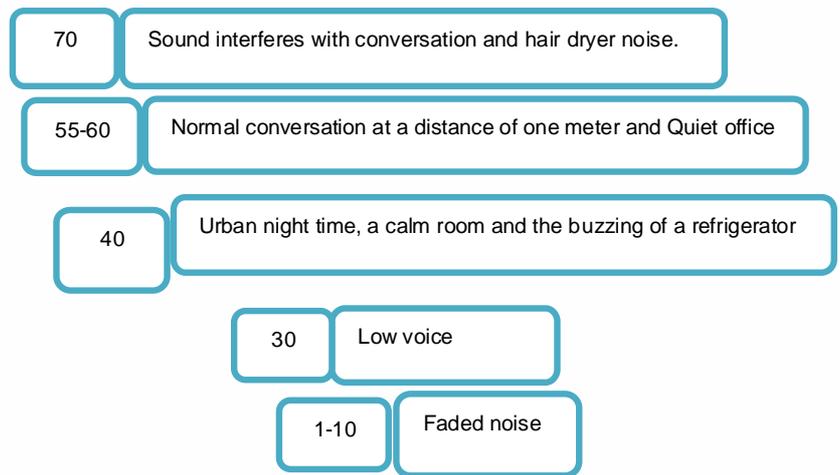| 70 | Sound interferes with conversation and hair dryer noise. |
55-60	Normal conversation at a distance of one meter and Quiet office
40	Urban night time, a calm room and the buzzing of a refrigerator
30	Low voice
1-10	Faded noise

Fig. 1.2: Noise Scale

Noise Rating

Four rating methods were used by Comair Rotron (company established in 1947 in Woodstock New York by James Van Ryan) for the description of levels of noise:

PSIL–PSIL stands for Preferred Speech Interference Level and it is the first rating system used. The PSIL is determined at center frequencies of 500, 1000 and 2000 Hz with arithmetic average of the sound pressure level in the three octave bands. Effects of noise on spoken communication can be rated using PSIL.

dBA– dBA is the 'A' weighed sound pressure level and second system for rating. It is used to determine in fulfillment with regulations such as Occupational Safety and Health Act (OSHA) by the government agencies. High and low frequency portions of audible spectrum can be de-emphasized by a sound level meter which is equipped by a filtering system and can directly determine dBA. At a distance of 3 feet from the source, this measurement can be recorded.

NPEL– It is the third system of rating which is "A" weighted sound power level reference to a 1 picowatt and expressed in Bels. It can be abbreviated as Noise Power Emission Level (NEPL). NEPL was adopted as a preferred unit of measurement by the Institute of Noise Control Engineering (INCE). The INCE "Recommended Practice for Measurement of Noise Emitted by Air Moving Devices (AMDs) for Computer and Business Equipment" is the guideline for the illustration and management of noise emitted by components. In INCE, practical application procedures are now included in the ANSI S12.11. It is the most recent and technically thorough acoustic test procedure which is available. Comair Rotron does all acoustical testing as per INCE and ANSI S12.11-1987.

Freely Suspended–This is the fourth system of rating. According to this method, the middle of Calibrated Reverberate Room has a suspended fan with springs. The fan runs at a distance of 1 meter with nominal voltage and free delivery. The sound pressure level (dBA) is recorded. For the measurement of noise, transportation agencies have different standards. For instance, the day-night sound level (DNL) standard is used by Federal Aviation Administration (FAA).

1.2.3 Instrumental Methods

Acoustic instruments such as Octave band analyzers, Sound level meter, noise average meter, noise dose meter, recorders (magnetic tape, cassette, and pen), noise survey

meter, acoustic calibrator, sound scope meter and statistical analyzers are used to quantify and classify the physical properties of sound on the basis of physical parameters such as duration and amplitude. In sound level meters, A, B, and C are the different weighting networks adopted. Scales other than A are rarely used as they do not provide a good approximation to the human ear frequency response. For the measurement and analysis of steady noise, the cheapest and simplest instrument is the noise survey meter. The combination of octave band analyzer and sound level meter results into sound scope meter. Intermittent noise is measured by Noise integrator giving an average or intermittent noise level when used in combination with a noise survey meter. Noise dose meter is used to automatically integrate the sound energy received with respect to its duration and intensity. There are various measuring instruments of different specifications available in the market, but B and K make instruments are mostly preferred due to their reliability and accuracy.

1.2.4 Numerical/Computational Modelling

Noise impact prediction, sound quality assessment (such as echo or reverberation), speech intelligibility and determination of acoustic construction requirements can be done using computational noise modeling. A range of scenarios, meteorological influences and operating conditions allows analysis in combination with monitoring of existing or representative existing noise sources to complete computational modelling. For the design of acoustic control measures and accurate prediction, sophisticated computer modelling tools are used. A variety of acoustic software packages includes "Cadna /A and ENM for environmental and source noise prediction, INM (aircraft noise modelling) and Odeon for internal noise modelling of sound quality, speech intelligibility and noise breakout".

Check Your Progress 1

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

1) What is noise propagation?

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2) Abbreviate NPEL.

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1.3 ESTIMATING TRANSPORTATION NOISE

Dear Learners, let us now read about estimating transportation noise in the following sentences:

1.3.1 Internal Combustion Engine Noise Prediction

Due to its own inertia, the crank mechanism (bearings, crankshaft, connecting rods, and pistons) experiences externally applied forces via internally generated forces

and gas forces. Due to noise-generating mechanism, mechanical noise is produced by the reaction of the engine structure to the sum of these forces. In gasoline engines, "piston/liner clearances are rather small, and mechanical noise tends to be dominated by impacts in the crankshaft bearings made through the oil film". Fuel injection equipment, timing drives and valve train are the other sources of mechanical noise. There are two sets of noise characterization in Gasoline engines: Gasoline engines with slight speed dependence and modest load dependence. Due to increasing load, there is an increase of about 5dB in noise level at low speed (say up to 2500 rev min1). There is greater speed dependence (50 dB per decade) and little load dependence at higher speeds as mechanical noise is affected by inertial forces. This is the reason for the commonly experienced abrupt start of roaring engine noise as gasoline engine's running speed becomes hard. For the measurement of noise emission from any source (including the engine), sound power is the universal parameter. Another method is to compute sound pressure level at particular locations around the engine and apply this for rating engine noise. SAE J1074 is widely used standard method for the prediction of engine noise.

1.3.2 Exhaust and Intake Noise Prediction

Intake and exhaust noise are the most significant sources of exterior vehicle noise. The intake and exhaust operating noise systems are classified as follows:

Primary noise sources - Pressure fluctuations in the manifold and its propagation to the exhaust tailpipe or intake orifice is radiated as noise which is caused by the primary noise sources being the unsteady mass flow through the valves. The system which is responsible for engine breathing or primary noise is similar as it is suitably harnessed to progress the volumetric efficiency of the NA engine by wave action tuning.

Secondary noise sources – Flow motion through the intake and exhaust systems are responsible for secondary noise sources. This self-induced noise is generally known as flow noise. The structure-radiated sound i.e. shell noise from the intake or exhaust tailpipes are energized by either primary or secondary noise sources. Aerodynamic noise consists of both the classes i.e. breathing and flow noise.

1.3.3 Tire/Road Noise Prediction

The recognition of road noise is considered as one of the major environment pollution. Consequently it leads to the advancement in accurate noise prediction model that enables to predict traffic noise using common variables such as traffic flow in requisites of vehicle per hour, traffic speed and composition in terms of fraction of heavy vehicle, road gradient, traffic etc.

1.3.4 Aerodynamic Noise Prediction

The function of ratio of pressure (p_1/p_2) and mass flow rate across the valve is aerodynamic noise generation. "The point at which sonic speed is reached in the valve vena contracta is a function of the valve design and its pressure recovery coefficient, FL, combined with the ratio of upstream to downstream absolute pressure (p_1/p_2)". The valves are said to be choked when sonic velocity reaches at the vena contracta. By keeping upstream pressure constant, if the ratio of pressure increases there is no increase in their capacity. Subsonic flows produce high noise levels but usually highest noise level sources are choked valves. Considerable noise starting at pipe velocities of approximately Mach 0.4 to Mach 1.0 (sonic) is generated by the velocity of the flow in downstream pipe. Vapor control or noisy gas valves can have

trim wear and control instabilities with acoustically induced and turbulence-induced vibration damage. At very high cycle rates i.e. 1,000–10,000 cps, vibration-related stresses can be produced by high intensity noise. While valve service life can be drastically reduced by noise-induced damage, and in certain cases, it may be responsible for valve or piping failures quickly in minutes or hours.

1.3.5 Brake Noise Prediction

From decades, Brake noise has been considered to be the major concern to the manufacturers of vehicle has been an issue of concern to vehicle manufacturers. Brake noise can be categorized into various distinct categories (Figure 1.3):
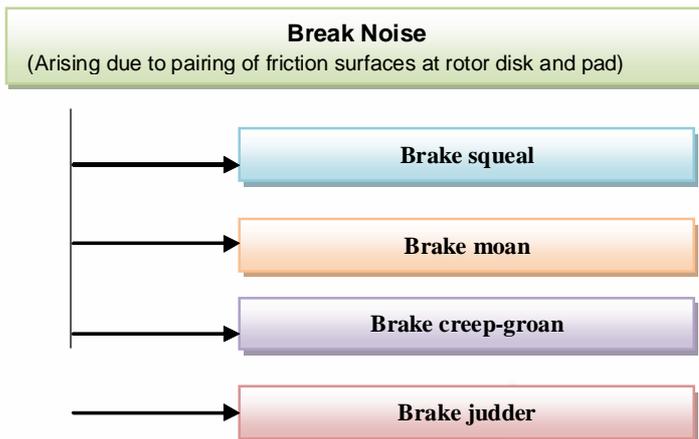
Fig. 1.3: Categories of Brake Noise

- *Brake squeal* has a tonal character which has components above 1000 Hz at higher speeds.

- *Brake moan* occurs at moderate speed and it is characterized by the 100 Hz frequency components.

- *Brake creep-groan* is characterized by frequency components of approximately 100 Hz and it occurs at speed less than walking pace.

- *Brake judder* is characterized by frequency components of about 10 Hz which is speed less than walking pace.

The above four categories of brake noise arises due to the pairing of friction surfaces at the rotor disk and pad. The disk, the pads and the caliper assembly are the brake components which radiates brake squeal noise. In the case of brake judder, moan and creep-groan, the resonant frequencies of the brake components are usually so high (rarely less than 1000–2000 Hz) that the vehicle suspension acts as the resonant system.

Check Your Progress 2

Note: a) Write your answer in about 50 words.

b) Check your progress with possible answers given at the end of the unit.

1) What is Brake creep groan?

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2)   What is flow noise?

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1.4   ESTIMATING THE IMPACT OF TRANSPORTATION NOISE ON HUMAN HEALTH

Sound which is undesirable confirmed as noise. It has been a topic of debate among researchers in recent years. Noise that's continuous or lasts for a brief period can equally be harmful to our health. Transportation is the key contributor of noise pollution and major cause of human exposure to noise is road traffic. Ambient sound levels have steadily increased because of growing number of road visits, higher speed in motor vehicles and increase in frequency of flying and use of aircraft. Growing demand for air and road travel reflects that more people are being exposed to noise. Noise might indirectly result in poor health in numerous ways. Initially, short term contact with sharp noise causes variety of short-term physiological responses i.e. increased heart rate, blood pressure and endocrine outputs. Constant noise exposure can cause long term activation in lien of these responses. Transportation noise arises from traffic on roads, railways and airways. If we tend to exclude airways, transportation noise can be reduced by following three measures:

● Protecting citizens from traffic noise by arrangement of different kind of noise barriers.

● Taking actions to amend the traffic in sensitive areas.

● Reducing noise at the point of supply by altering the design of vehicles on road.

Noise generating from vehicles depend on type of vehicle and operating conditions. In general the following sources can be identified:

● Power train noise

● Rolling noise

● Structure-born noise

● Aerodynamic noise

According to the experts from the European Union, near by 20% of the European Union population suffers from unacceptable noise levels which might have long-term impact on the health. Recent studies have highlighted the medical impact of environmental noise. Detailed impact of transportation noise on human health is given below:

Annoyance: It is a multifarious psychological theory including both evaluative and behavioral components (Guski *et al.,* 1999), which is used to determine the negative impacts of noise. Annoyance is a very important health effect of noise (WHO, 2000). Numerous studies reveal the exposure-effect association due to different noise sources

on annoyance (Miedema and Vos, 1998; Miedema and Oudshoorn, 2001). It is observed that aircraft noise produces greater annoyance than road traffic noise at the same level of exposure. Impacts of traffic are shown in Figure 1.4.
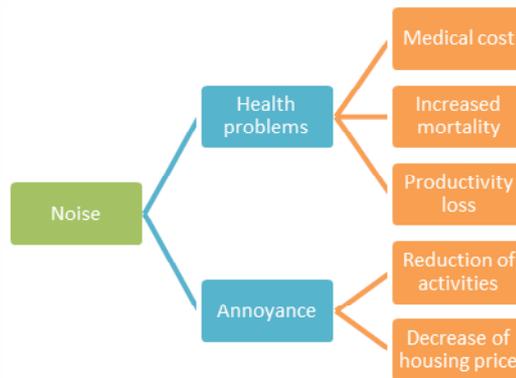
Fig. 1.4: Impacts of traffic noise

*Stress hormones***:** The studies related to endocrine markers of noise exposure have given differing results. Cortisol, adrenaline and noradrenaline are released by the adrenal glands in the situation of stress. The difficulty in analyzing these hormones is that the salivary and urinary measures of hormones are biased due to unmeasured factors. For instance, Cortisol is difficult to examine, as it has diurnal variation and is usually high in morning and low in evening, making it difficult to measure effectively.

*Sleep disturbance***:** The exposure to night-time noise may potentially disturb the sleep, shorten sleep duration, cause awakenings and reduce perceived quality of sleep (Michaud *et al.,* 2007) and could affect health in two ways. Firstly, by their impact on biological response, such as increasing heart rate, awakenings and sleep quality, as the individual respond to stimuli in environment. Secondly, sleep disturbance can have impact on well being causing annoyance, irritation, mood fluctuation, fatigue and impaired performance of doing task (Clark and Stansfeld, 2004).

*Psychological health and Cardio-vascular issues***:**

Noise exposure relates to an increase in number of psychological symptoms such as symptoms which includes anxiety and depression. Blood pressure, cardio-vascular disease and stress related to heart problems are increased as the noise pollution gets increased which might disturbs the normal blood flow.

*Effect on wildlife***:** Wildlife faces far more problems than humans because they are more dependent on sound. Animals develop a better sense of hearing than human since their survival mainly depends on it. Ill effects of excessive noise begin at home. Pets react more aggressively in households where there is constant noise.

*Cognitive development***:** Exposure throughout critical duration of schooling may potentially impair development and have a long term effect on educational skill. Most convincing result observed are deficits in memory and reading comprehension developed in children above 2 years who were near the airport.

Draft Guidelines for Noise Impact (2002)

A joint working party of the Institute of Acoustics and Institute of Environment Management and Assessment had generated a draft guidance document on noise impact assessment called Guidelines for Noise Impact Assessment. Impact description of sound and its level (dB) is shown in table 1.1.

Table 1.1: Sound Level and their impacts

Sound Level Change dB(A)	Subjective Response	Impact Description
0.0	No change	None
0.1 – 2.9	Imperceptible change in loudness	Slight
3.0 – 4.9	Perceptible change in loudness	Moderate
5.0 – 9.9	Up to a doubling or halving of loudness	Substantial
10.0 or more	More than doubling or halving in loudness	Severe

1.5 EXAMPLES OF NOISE IMPACT ASSESSMENT

Dear Learners, let us now read about examples of noise impact assessment in the following sentences:

1.5.1 Jet engines

Performance of turbojet engines determines the sound which have severe problem due to intensity of both ecological and order constructive danger caused by fatigue acoustic integrity of aircraft. Noise has become an important parameter to be taken into account in design of aircraft, so restrictive noise with all consequences becomes a necessity. Aircraft noise outfitted with turbojet engines has major reason which includes mixing of gases leaving the engine with ambient air; pulsations in fuel system of engine which produce variations in output speed of blades; density jumps (shock waves) of supersonic flight by which airflows interacts with engine-exhaust turbulent jet flow generates noise; blade vibrations of components (fan, compressor and turbine) which causes disturbance of airflow and gas. The principle of operation depends upon chemical transformation of potential energy of fuel into mechanical energy. The operating step consists of:

● Aspiration of atmospheric air through the intake device;

● compressing air by compressor (centrifugal or axial);

● burning chemical fuel;

● Air mixture in combustion chamber;

● expanding gases of combustion turbine that drive the compressor;

● Expanding gases in outlet device (the exhaust nozzle) as a spray reagent.

1.5.2 Noise in commercial and public Building

Noise created by construction work includes the following:

● Demolition work, site preparation work and building maintenance or repair;

● Operation of vehicles within, leaving or entering a construction site and

● Activities carried out near immediate vicinity of construction site and citizens who execute work at the site, or activity associated with work at site.

Obstruction to construction noise is valid for activities on a site that requires development authorization under the Development Act, 1993 in respect of any of the activities undertaken at the site. Construction noise does not include the use of machinery for minor maintenance or other activities on domestic premises or other minor activities on commercial or industrial premises which do not require authorization under the Development Act 1993 as these activities are regulated under other sections of the Environment Protection (Noise) Policy, 2007.

1.5.3 Metallurgical industries

Metallurgical industry is categorized into primary and secondary metal production operations. Primary operation includes the production of metal from ore. Secondary metal production includes production of alloys from ingots and recovery of metal from salvage and scrap. Power system includes vehicle and vehicle speed. Non-power system mainly includes car horns etc. Attenuation of noise in industry is difficult work because the machines and enclosures are very diverse in nature and their acoustic characterization is not simple. Noise produced by electric arc furnace causes severe health and amenity problems for the people working in steel melting shops. Effects mainly depends on intensity and frequency of noise, time duration of a particular exposure, total exposure for long time, age and most importantly individual susceptibility and tolerance limits. Hearing impairment either temporary or permanent is probably the most common physiological effect of noise.

Check Tour Progress 3

Note: a) Write your answer in about 50 words.

   b) Check your progress with possible answers given at the end of the unit.

1) How does noise affect the psychological and cardio-vascular health in humans?

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2) Briefly write about primary and secondary operations in metallurgical industries?

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1.6   LET US SUM UP

Let's wind up the chapter by studying the basics of noise, rating methods and scale of noise, prediction and estimation of transportation noise. After studying above chapter, you will be able to understand noise and their effects on environment and human health. By understanding the noise prediction and estimation methods you will be able to know that how road transportation and noise plays vital role in daily life. You will be able to discuss about intake and exhaust engine noise. Sound plays basic role in our routine life but excessive exposure to noise can lead to the hindrance in human health. Psychological health is greatly affected by noise pollution. So by understanding the noise scale you will be able to interpret suitable noise exposure.

1.7 KEY WORDS

Noise	:	Is as an unwanted sound which is unpleasant, loud or disruptive to hearing.
Noise annoyance	:	Is defined as a feeling of displeasure or an emotional and attitudinal reaction from a person exposed to noise.
Energy	:	It is the power derived from the utilization of physical or chemical resources, especially to provide light and heat or machines to work.
Brake Noise	:	Low frequency disc brake noise is a problem that typically occurs in the frequency range between 100 and 1000 Hz.
Medium	:	Is the intervening substance through which sensory impressions are conveyed or physical forces are transmitted.
Frequency	:	Is defined as the rate per second of a vibration constituting a wave, either in a material, or in an electromagnetic field.
Vibration	:	May be defined as an oscillation of the parts of a fluid or an elastic solid whose equilibrium has been disturbed.
Pressure	:	Is defined as the force per unit area exerted by the fluid against a surface with which it is in contact.

1.8 REFERENCES AND SUGGESTED FURTHER READINGS

Babisch, W. (2002). The noise/stress concept, risk assessment and research needs. *Noise and health*, *4* (16), 1.

Clark, C., &Stansfeld, S. A. (2007). The effect of transportation noise on health and cognitive development: A review of recent evidence. *International Journal of Comparative Psychology*, *20* (2).

Guski, R., Felscher-Suhr, U., &Schuemer, R. (1999). The concept of noise annoyance: how international experts see it. *Journal of sound and vibration*, *223* (4), 513-527.

Michaud, D. S., Fidell, S., Pearsons, K., Campbell, K. C., & Keith, S. E. (2007). Review of field studies of aircraft noise-induced sleep disturbance. *The Journal of the Acoustical Society of America*, *121*(1), 32-41.

Miedema, H. M., & Oudshoorn, C. G. (2001). Annoyance from transportation noise: relationships with exposure metrics DNL and DENL and their confidence intervals. *Environmental health perspectives*, *109*(4), 409.

Miedema, H. M., &Vos, H. (2007). Associations between self-reported sleep disturbance and environmental noise based on reanalyses of pooled data from 24 studies. *Behavioral sleep medicine*, *5*(1), 1-20.

1.9 ANSWERS TO CHECK YOUR PROGRESS

Your answers should include the following points:

Check Your Progress 1

1. When an acoustic energy transmits through a sound wave via any medium i.e. air, water or solid, then it is referred as noise propagation.

2. NEPL can be abbreviated as Noise Power Emission Level.

Check Your Progress 2

1. It occurs at speeds less than walking speed and it is characterized by frequency components of around 100 Hz.

2. The flow motion through the intake and exhaust systems is responsible for secondary noise sources and this self-induced noise is generally known as flow noise.

Check Your Progress 3

1. Excessive noise exposure leads to the increase in psychological symptoms such as anxiety and depression. Blood pressure, cardio-vascular diseases and stress related heart problems due to noise pollution consequently hinders the normal blood flow.

2. In metallurgical industries, primary operation includes production of metal from ore while secondary operation includes production of alloys from ingots and recovery of metal from salvage and scrap.

First the noise filters must be applied and then the compression methods. In the case of classification the instances that are really needed to determine the decision boundaries between classes are those situated close to the decision boundaries. As in classification the definition of "similarity to k nearest neighbors" can be in practice reduced to "being of the same class as k nearest neighbors", almost all the instances situated far from the decision boundaries will have the same class as their neighbors and thus will be removed by the condensation methods.Â As it might be expected, combining input and output noise in the training data, had the largest impact on network learning. 1. Noise control. I. Hansen, Colin H., 1951– II. Title.Â Figure 1.1 Impact noise reduction: (a) variable height collector; (b) interrupted fall. Substitution of parts of equipment includes modification of gear teeth, by replacing spur gears with helical gears—generally resulting in 10 dB of noise reduction, replacement of straight edged cutters with spiral cutters (for example, in wood working machines a 10 dB(A) reduction may be achieved), replacement of gear drives with belt drives, replacement of metal gears with plastic gears. • The impact of environmental noise is likely to be greatest at locations where humans are associated with noise sensitive situations. Thus noise levels are generally reported in dB(A) which includes the A-weighting frequency response that corresponds to the sensitivity of the human ear. • The main concerns of environmental noise generally relate to interference of such activities as sleep, relaxation and conversation.Â These units are fairly robust, can be left outdoors and have the capability to record for several weeks without attention. The problems alluded to above regarding the influence of extraneous sources of noise can be severe for a noise logger because there may be no valid identification of the actual noise sources that lead to any of the measured results. Section 4: Noise Impact Analysis. Section 5: Transit Vibration. Section 6: Vibration Impact Analysis. Section 7: Noise and Vibration during. Section 8: Documentation of Noise and.Â Work unit number. 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Department of Transportation Volpe National Transportation Systems Center 55 Broadway. Cambridge, MA 02142.Â 15. SUBJECT TERMS Transit noise and vibration analysis, noise and vibration impact criteria, noise and vibration mitigation measures, environmental impact assessment, Nation Environmental Policy Act compliance. 16. security classification of: a. REPORT Unclassified. In this paper, a static "noise impact analysis" methodology is developed to estimate the circuit vulnerability. First, both the circuit elements and the transient noise are abstracted in the format of matrices. Then the circuit-noise interaction is modeled by a series of matrix transformations, which jointly considers three masking effects that can potentially prevent transient noise from causing observable errors.Â @article{Zhao2005ASN, title={A static noise impact analysis methodology for evaluating transient error effects in digital VLSI circuits}, author={Chong Zhao and Xiaoliang Bai and S. Dey}, journal={IEEE International Conference on Test, 2005.}, year={2005}, pages={10 pp.-1058} }. Chong Zhao, Xiaoliang Bai, S. Dey.