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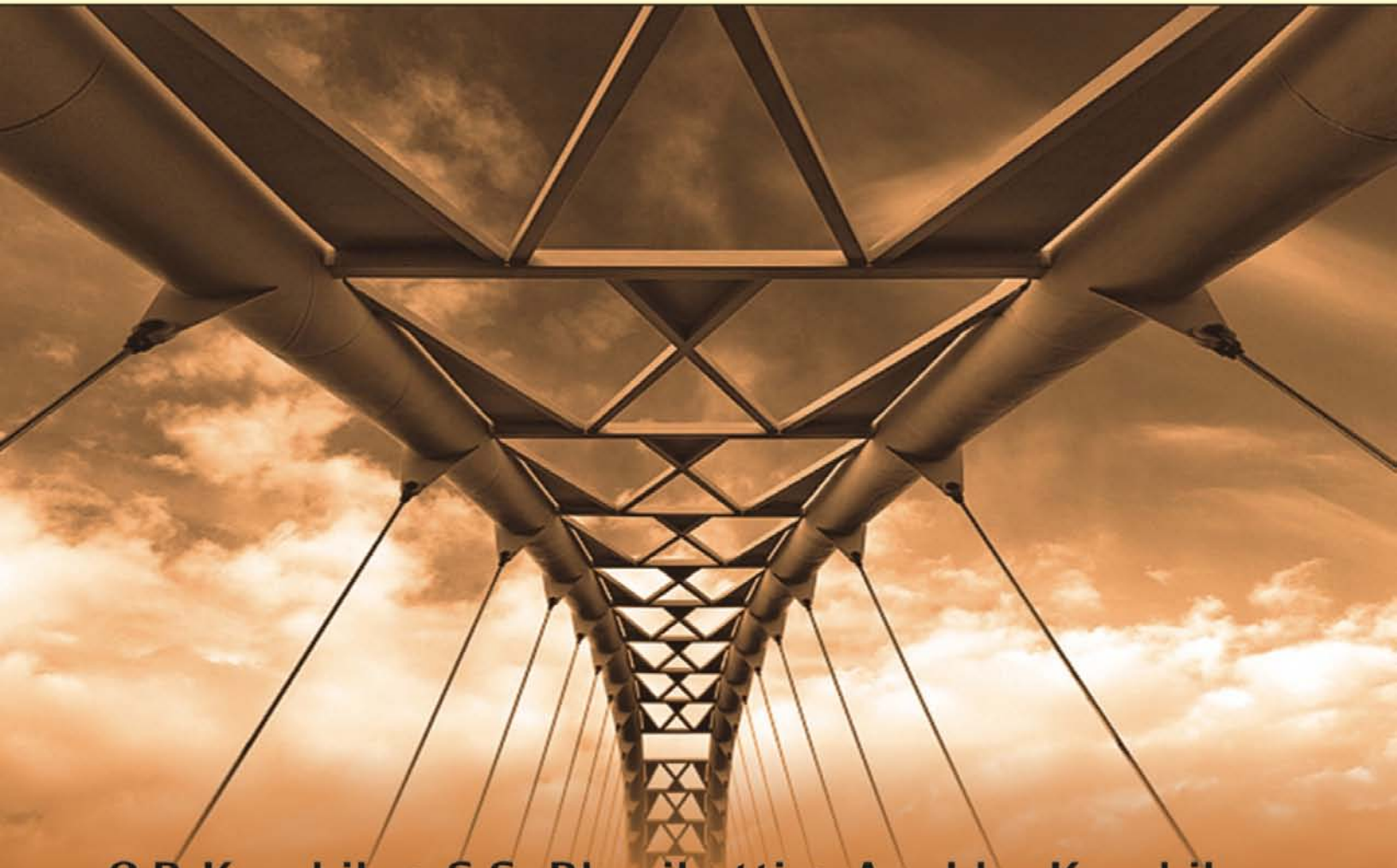
Basic Civil and Environmental Engineering



C.P. Kaushik • S.S. Bhavikatti • Anubha Kaushik

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Preface

Ever increasing human population, rapid industrialization and changing life style have caused degradation of the environment. Every component of the environment is polluted, threatening the life support system. Global efforts are underway to prevent or reduce environmental degradation and to protect biodiversity.

In this book the principles of basic civil engineering and environmental engineering are discussed. In the first section introduction to civil engineering is given. Use of basic as well as modern materials including their recycling is explained. Construction of substructure, superstructure and automation in construction is dealt with. This section also covers principles of survey including use of modern survey equipments and application of GIS. In the second section chapters dealing with environmental engineering have been covered. Topics related to ecology and ecosystem, human impacts on environment, environmental pollution, energy resources, various techniques of harnessing energy, environmental impact assessment and built environment have ben discussed.

Attempt has been made to use simple language to make the book reader friendly. Illustrations have been included to make the subject interesting and easy to grasp. The authors solicit constructive criticism and suggestions for improvement of this book.

The authors thank New Age International (P) Ltd., Publishers, New Delhi for their efforts to bring out the book in the present form.

—AUTHORS

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SECTION I

BASIC CIVIL ENGINEERING

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CHAPTER 1

Introduction to Civil Engineering

Civil Engineering is the oldest branch of engineering which is growing right from the stone-age civilization. American Society of Civil Engineering defines *civil engineering as the profession in which knowledge of the mathematical and physical sciences gained by study, experience and practice is applied with judgement to develop ways to utilize economically the materials and forces of the nature for the progressive well-being of man.*

In this chapter various civil engineering infrastructure projects for 21st century are listed and the role of civil engineer are presented. Apart from civil engineering there are other infrastructural facilities required by the public which need coordination with other engineers. Importance of this interdisciplinary approach in engineering is also presented in this chapter.

1.1 CIVIL ENGINEERING INFRASTRUCTURE PROJECTS

The world has realised that a government should not involve itself in production and distribution but develop infrastructure to create an atmosphere for economical development. Civil Engineering activities in the infrastructure development are as under:

1. A good planning of towns and extension areas in the cities is required. Each extension area should be self-sufficient in accommodating offices, educational institutions, markets, hospitals, recreational facility and residential accommodations.

2. Fast rate of urbanization and increase in the cost of land has forced civil engineers to go for vertical growth in cities. In metropolitan cities, 25 storey buildings have become common. Even in small towns multi-storey buildings have become necessity. These requirements have brought in new building technologies and sophisticated analysis methods. Civil Engineers have to solve the problems of rural areas and poor people also. Low cost housing is the need of the day to make poor people afford their own houses.

3. Water is an important need for all living beings. Civil engineers have to exploit various water resources and ensure water supply to urban areas throughout the year. Rural areas need water for agriculture also. Hence civil engineers have to build dams and tanks and bring water to houses through pipes, and to fields through canals and distributories.

4. Another important amenity that public require is good roads. Design of appropriate base course thickness, finishing surfaces, cross drainage, design of horizontal and vertical curves are the duties of civil engineers. Proper design of intersection of roads is necessary. Construction of

culverts, bridges and tunnels became part of road works. Railway is an important long distance facility. Construction of railway lines and railway station is an important infrastructure activity. Globalization has resulted in need for building airports and harbours also.

5. Other important infrastructural activities of civil engineering are controlling air pollution, noise pollution and land pollution.

1.2 ROLE OF CIVIL ENGINEERS

A civil engineer has to conceive, plan, estimate, get approval, create and maintain all civil engineering infrastructure activities. Civil engineer has a very important role in the development of the following infrastructures:

1. Measure and map the earth's surface.
2. Plan and develop extensions of towns and cities.
3. Build the suitable structures for the rural and urban areas for various utilities.
4. Build the tanks and dams to exploit water resources.
5. Build river navigation and flood control projects.
6. Build canals and distributories to take water to agricultural fields.
7. Purify and supply water to needy areas like houses, schools, offices etc.
8. Provide and maintain communication systems like roads, railways, harbours and airports.
9. Devise systems for control and efficient flow of traffic.
10. Provide, build and maintain drainage and waste water disposal system.
11. Monitor land, water and air pollution, and take measures to control them. Fast growing industrialization has put heavy responsibilities on civil engineers to preserve and protect environment.

1.3 IMPORTANCE OF AN INTERDISCIPLINARY APPROACH

Infrastructure facility includes suitable electricity supply. Internet and telephones are also desirable features.

Educational facility also forms part of infrastructure. The proximity of good primary and secondary schools to residential areas is desirable. Collegiate and professional education also form part of infrastructure of a city.

Good health care is a necessity. Good primary health centres, specialized hospitals and clinical facilities add to the infrastructure facilities.

If a city/town has good infrastructure, it satisfies a citizen and he contributes to the development activity of the nation well. Many private entrepreneurs start industries and other economical activities. Employment opportunities increase and there is all round development.

Hence there is need for civil engineers to interact with the following people and plan the civil engineering infrastructure facilities.

1. Architects and town planners.
2. Electrical engineers.
3. Electronic engineers.

4. Mechanical and automobile engineers.
5. Doctors and health care officers.
6. Educationalists.
7. Municipal officers.
8. Taluka and district administrators.

Thus civil engineers should understand importance of an interdisciplinary approach in their planning and construction activities so that there is no complaints from any corner of the society. It should be noted that correcting mistakes is always costly and time consuming. A little bit extra care will avoid such mistakes.

Questions

1. What is Civil Engineering ? Discuss various civil engineering infrastructures required.

2. Write short notes on:

(*i*) Role of Civil Engineers.

(*ii*) Importance of interdisciplinary approach in the development of infrastructures.

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CHAPTER II

Basic Areas in Civil Engineering

Civil engineering is a very vast field. It can be classified into:

1. Surveying
2. Construction engineering
3. Structural engineering
4. Earthquake engineering
5. Geotechnical and foundation engineering
6. Quantity surveying
7. Fluid mechanics
8. Irrigation engineering
9. Transportation engineering
10. Environmental engineering
11. Town planning
12. Infrastructural development
13. Project management
14. Remote sensing

Scope of each of these is presented in this chapter.

2.1 SURVEYING

Surveying is the science of map making. To start any development activity, the relative positions of various objects in the area with respect to horizontal and vertical axes through a reference point is required. This is achieved by surveying the area. Earlier, the conventional instruments like chain, tape and levelling instruments were used. In this electronic era, modern electronic equipments like electronic distance meters (EDM) and total stations are used, to get more accurate results easily.

Preparing topo maps of talukas, districts, states and countries and showing all important features like rivers, hills, forests, lakes, towns and cities in plan and elevation (by contour lines) also forms part of surveying. When maps of large areas are to be made corrections for earth curvature are to be made for all measurements. Such survey is called geodetic surveying also.

2.2 CONSTRUCTION ENGINEERING

Construction is the major activity of civil engineering. Hence civil engineer must know properties and uses of basic materials of construction like stone, bricks, tiles, cement, sand, jelly, steel, glass, glazed tiles, plaster of paris, paints and varnishes. Behaviour of reinforced cement concrete (R.C.C.) and prestressed concrete should be understood properly. Improved versions of many flooring materials, bath room fittings keep on appearing in the market. Construction engineer should study their advantages, disadvantages and cost effectiveness.

Construction technology should keep pace with the need of modern trend. In cities building tall structures in shortest possible period is the requirement while in rural areas and poor need the low cost housing technology. Construction engineer should know quantity of materials and man power requirement. He has to plan and execute the work in proper sequence without wasting man power, material and time of construction equipments.

2.3 STRUCTURAL ENGINEERING

Load acting any structure is ultimately transferred to ground. In doing so, various components of the structure are subjected to internal stresses. For example, in a building, load acting on a slab is transferred by slab to ground through structural components like beams, columns and footings. Assessing various types of internal stresses in the components of a structure is known as structural analysis and finding suitable size of the structural component is known as structural design. The structures to be designed may be of masonry, R.C.C., prestressed concrete or of steel. Structural engineering involves analysis of various structures like buildings, water tanks, chimneys, bridges etc. and designing them using suitable materials like masonry, R.C.C., prestressed concrete or steel. A structural engineer has not only to give a safe structure but he has to give economical structure. To get economical sections, mathematical optimization techniques are to be used.

2.4 EARTHQUAKE ENGINEERING

About 50 years ago it was thought, in India, only north-east region and some parts of north India are earthquake prone areas. But Koyna earthquake, Latur earthquake and Gujarat earthquake have brought lot of changes in earthquake engineering. India's map of earthquake zones showing intensity of earthquake forces to be considered in different parts of the country has been redrawn. Behaviour of the structures to earthquake forces is dealt in earthquake engineering. Design of earthquake resistant structure is attracting lot of research. Studying magnitude, behaviour of structures and designing the structure for earthquake forces constitute earthquake engineering branch of civil engineering.

2.5 GEOTECHNICAL AND FOUNDATION ENGINEERING

Soil property changes from place to place. Even in the same place if may not be uniform at various depth. The soil property may vary from season to season due to varying moisture content. The loads from all structures are to be safely transferred to soil. Hence, safe bearing capacity of the soil is to be properly assessed.

Apart from finding safe bearing capacity for the foundations of building, geotechnical engineering involves various studies required for the design of pavements, tunnels, earthen dams,

canals and earth retaining structures. It involves study of ground improvement techniques also. Since stability of every structure depends on how safely load is transferred to ground, this branch of civil engineering is very important.

2.6 QUANTITY SURVEYING

This is the branch of civil engineering which deals with estimating the quantity of various materials required for a project work. For example in a building project the quantity of earth work in foundations, quantity of stones required for the foundation, quantity of bricks, cement, jelly, sand and steel requirements are to be assessed for various stages of construction. Estimated cost of the work depends upon the quantity of various materials required. At the planning stage itself one should have the idea of requirement of construction materials so that estimated cost is known. Main criteria for selecting any project is its estimated cost. Hence quantity surveying is an important branch in civil engineering.

How to make deduction for quantity of plastering for various types of openings in the wall, calculating area of painting for various types of doors and windows etc. also form important aspect of quantity surveying.

Labour requirement for various activities of construction also forms part of quantity surveying.

2.7 FLUID MECHANICS

Water is an important fluid required for all living beings. For the design and construction of hydraulic structure study of mechanics of water and its flow characteristics is very much essential. This is important field in civil engineering and it is known as fluid mechanics/hydraulics; fluid mechanics being the general term applicable to all type of fluids.

2.8 IRRIGATION ENGINEERING

Water is to be supplied to agricultural field. Hence suitable water resources are to be identified and water retaining structures are to be built. Identifying, planning and building water retaining structures like tanks and dams and carrying stored water to fields is known as water resources and irrigation engineering. Constructing canals, distributories aquaducts and regulators form part of irrigation engineering.

2.9 TRANSPORTATION ENGINEERING

Another important amenity that public requires is good roads. Design of good road involves the design of base courses, surface finishes, cross drainage works, road intersections, culverts, bridges and tunnels. Roads need suitable design of horizontal and vertical curves also. Railway is another important long way transport facility. Design construction and maintenance of railway lines and signal systems are part of transportation engineering. Design, construction and maintenance of harbours and airports are also the need of globalization era. For proper planning of these transport facilities traffic survey is to be carried out. All these activities constitute the transportation engineering.

2.10 ENVIRONMENTAL ENGINEERING

Supplying potable water to rural areas, towns and cities and disposal of waste water and solid waste is another field of civil engineering. Solid waste management and disposal of electronic waste systematically is the need for maintaining good environment. Study of sources, causes, effects and remedial measures associated with air pollution, water pollution, land pollution and noise pollution forms environmental engineering branch of civil engineering.

2.11 TOWN PLANNING

New towns and cities and extension areas of existing cities are to be planned properly so that suitable communication system, educational facilities medical facilities, shopping centres are provided along with residential areas. Growing industrialisation of country has brought importance to 'Town Planning' aspect of civil engineering.

2.12 INFRASTRUCTURAL DEVELOPMENT

Importance of an interdisciplinary approach to total infrastructural development is necessary. Any new area developed should have proper approach roads, electricity and water supply, telecommunication facility. Proximity of primary schools, high schools, health care and market facility should be provided. Civil engineers have to work with other organisation and government agencies for suitable infrastructure developments for the new as well as existing localities of the towns and cities.

2.13 PROJECT MANAGEMENT

Planning, scheduling and management forms the basis for taking up a project.

Planning

Planning is the decision-making process about What, Where, Who and How (WWWH) to start a project work.

What: An individual or a group of enterprising people or a government/public sector agency plan to start a project. They form a group of high level managers. They identify goals, form the objective and identify the opportunities of the project. This type of planning is called as strategic planning.

Where: The next step the strategic planners takes is where to start the project work.

Who: The strategic planners identifying the middle level and operational level managers to carry out the task. The middle level management deals with financial management and coordinates with the operational planners and strategic planners.

How: The operational planners have to work at minute details of the work assigned, find the requirement of machinery and work force and plan day to day activities. They should be ready with alternative plans, if uncertainties creep in at any stage.

The planning is key to success of a project. If the planning is good and work is executed as per the plan, a project can make a good profit and the organisation becomes competent for obtaining more work.

Scheduling

Scheduling is the process of dividing the project into various stages, various events and identifying time, machinery and human resources required for each event. For example, the construction of a building may be divided into the following stages:

1. Mobilizing
2. Laying foundation
3. Building superstructure
4. Finishing.

Laying the foundation may be divided into the following events:

1. Digging
2. Laying bed concrete
3. Constructing stone masonry for foundation
4. Providing coping concrete
5. Pointing the joints and
6. Filling the trenches

Like this all other stages involve a number of events. For each event, scheduled date of commencement and completion are to be fixed. Material, equipment and human resources requirement should be identified. For this bar chart or network representation of events is done. Critical activities are identified, the delay of which will delay the entire project. All efforts are concentrated to execute these events as per schedule.

Scheduling is necessary for the successful implementation of the project.

Construction Management

Management is the science and art of planning, organising, staffing, scheduling and executing the work. Achieving coordination among various people involved in the work is art of management. A manager not only directs his subordinates but motivates them to do the work. Communication skill and leadership qualities are to be developed for good construction management.

Planning, scheduling and construction management constitute project management branch of civil engineering.

2.14 REMOTE SENSING

Remote sensing is science and art of acquiring information about an object without physical contact with it. Though human sights and photographs are common examples of remote sensing, in civil engineering we restrict its meaning to sensing of the objects on the earth from satellites using electromagnetic energy. Most of the remote sensing methods make use of the reflected microwaves, infrared rays and visible light waves in the electromagnetic spectrum. When the electromagnetic waves sent from satellites strike the earth surface, its characters change due to transmission, absorption, emission, scattering and reflection. Since each feature on the earth has different characters, it is possible to identify the feature on the earth with satellite pictures. Remote sensing is mostly qualitative in nature. Data obtained from satellite is to be analysed by user and correctly identify the objects. This is called image processing. India has its own remote sensing satellites such as INSAT series, PSLV series etc.

Major area of application of remote sensing is for the following:

1. Resource exploration
2. Environmental study
3. Land use identification and
4. For assessing and predicting natural hazards.

Nowadays this area of civil engineering is fast developing and many engineers are employed for this work.

Questions

1. Briefly explain scope of any four of the following branches of civil engineering.
   (*a*) Structural engineering
   (*b*) Geotechnical engineering
   (*c*) Fluid mechanics
   (*d*) Irrigation engineering
   (*e*) Transportation engineering and
   (*f*) Environmental engineering

2. Explain the terms 'Planning, Scheduling and Management' as applied to project management, emphasizing their importance.

3. Write short note on 'Remote Sensing'.

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CHAPTER III

Materials of Construction

Various materials are used for constructing buildings, bridges, roads, retaining walls and dams. Use of the following materials of construction is presented in this chapter.

1. Stones
2. Bricks
3. Sand
4. Reinforcing steel
5. Cement
6. Plain cement concrete (PCC)
7. Reinforced cement concrete (RCC)
8. Prestressed concrete (PSC)
9. Precast concrete and

An introduction to smart materials is presented and need for recycling of materials is discussed.

3.1 STONE

Stone is a naturally available building material, which has been used from the early age of civilization. It is available in the form of rock, which is cut to the required size and shape and used as building block. Stone has been used to build small residential buildings to larges palaces, forts, temples and monuments. Rashtrapathi Bhavan, Jaipur Palace, Red Fort, Birla Mandirs at Delhi, Banaras and Hyderabad, Taj Mahal, Gateway of India and India Gate etc. are the world famous stone buildings.

The following is the list of uses of stone:

1. Stone masonry is used for constructing foundations, walls, columns and arches in a building.

2. Stones are used as flooring materials. Marble which is having good appearance is used as flooring material in luxurious buildings.

3. Stone slabs are used as damp proof courses, lintels and sometimes even as roofing material.

4. Stones with good appearance are used for the face works of buildings. Polished marble and granite are commonly used materials for the face works.

5. Stones are used for paving of roads, foot path and open spaces around the buildings.

6. Crushed stones with murram are used to provide base course for roads. When very smaller pieces of stones are mixed with tar, it forms finishing coat of roads.

7. Crushed stones are used for the following:

(*i*) As a basic inert material (jelly/coarse aggregate) in concrete.

(*ii*) As railway ballast.

(*iii*) For making artificial stones and hollow building blocks.

8. Stones are also used in construction of piers and abutments of bridges.

9. Stone is commonly used as basic construction material in buildings, retaining walls and dams. However it is worth noting that the popularity of stones as building material is going down due to the following reasons:

1. Availability of stones within a reasonable distance from the cities is becoming scare. As a result of it, the cost of the stone at construction sites in cities is increasing.

2. Labour cost for handling and dressing of stones is high.

3. As the surfaces of stones are not uniform, mortar consumed in stone masonry is high.

4. Mortar bricks and hollow concrete blocks which are easy to handle and consume less mortar are becoming more popular.

5. R.C.C. and steel are more dependable materials for their uniformity of strength and hence designers prefer to use them for all important and big buildings.

3.2 BRICKS

Bricks are obtained by moulding good clay into blocks, which are dried and then burnt. This is the oldest building block to replace stone. Manufacture of bricks was started with hand moulding, sun drying and burning in clamps. A considerable amount of technological development has taken place with better knowledge of the properties of raw materials, use of better machineries and techniques of handling, drying and burning. Bricks are used for the following construction works:

1. As building blocks.

2. For lining of ovens, furnaces and chimneys.

3. To encase steel columns to protect them from fire.

4. For providing water proofing course to R.C.C. roofs.

5. For making footpaths and cycle tracks in cities.

3.3 SAND

Sand is used as a base course to place flooring tiles so as to get level surface. In construction works sand is mainly used as inert material in mortar and concrete.

Sand is a natural product which is obtained as river sand, nalla sand and pit sand. Sea sand should not be used in making mortar and concrete for the following reasons:

1. It contains salt and hence structure remains damp. The mortar is affected by efflorescence and then blisters appear.

2. It contains shells and organic matter, which decompose after some time and reduce the strength and life of mortar and concrete.

Sand can be obtained artificially by crushing stones also. In crushing stones to get coarse aggregates, it is obtained as a by-product. The minute particles of crushed stones form artificial sand for construction activities. In constructing dams and bridges, artificial sand is very commonly used.

Sand is used in mortar and concrete for the following purpose:

1. It subdivides the paste of binding material into thin films and allows it to adhere and spread.

2. It fills up the gap between the two building blocks and spreads the binding material.

3. It adds to the density of mortars and concrete.

4. It prevents shrinkage of cementing material.

5. It allows carbon dioxide from the atmosphere to reach some depth and thereby improves there by setting power.

6. The cost of cementing material per unit volume is reduced as this low cost material increases the volume of cementing material.

7. Silica of sand contributes to formation of silicates resulting into hardened mass.

3.4 REINFORCING STEEL

Steel is an alloy of ferrous metal with 0.25 to 1.5 per cent of carbon. Higher the carbon content, harder is the steel. Steel bars of circular cross sections are mainly used as reinforcement to strengthen concrete structures. There are three types of reinforcing steel:

1. Mild steel
2. High Yield Strength Deformed bars (HYSD)/TOR steel and
3. High tensile steel.

3.4.1 Mild Steel

It contains carbon upto 0.23 to 0.25%. Higher value is permitted for bars of 20 mm and above diameter. It is available in diameters of 6, 10, 12, 16, 20, 25 and 32 mm. Its yield strength is 250 N/mm^2 and young's modulus 2×10^5 N/mm^2. It was very commonly used reinforcement in concrete. But nowadays TOR steel is replacing it. It is used as window bars, for grills and for making steel gates.

3.4.2 HYSD Bars/TOR Steel

Two types of TOR steel bars are available. They are Fe-415 and Fe-500. The number associated with the designation indicates the tensile strength of bar in N/mm^2. These bars are provided with ribs deformation on surface so that bond between concrete and steel improves. These bars are available in diameters 8, 10, 12, 16, 20, 22, 25, 28 and 32 mm. Nowadays these bars are replacing mild steel bars as reinforcement since their strength in tension and bond is higher. These are also used as wind bars.

3.4.3 High Tensile Bars

High tensile steel bars are made with 0.8 % carbon and 0.6 % manganese apart from small percentages of silicon, sulphur and phosphorous. The process of making these wires involve cold drawing and tempering. They are usually available in 2, 3, 4, 5, 6, 7 mm diameters. They may be bundled with number of them to form a strand.

These bars are having tensile strength as high as 1400 N/mm^2 to 1900 N/mm^2. The young's modulus of steels is also same as that of mild steel.

High tensile bars are used as reinforcement in prestressed concrete.

3.5 CEMENT

Cement is manufactured by calcifying calcarious material (lime) and argillaceous material (shale and clay) and then clinker so formed is ground to fine powder. Use of cement alone is limited to filling small cracks with its paste. It is mainly used as binding material in mortar and concrete.

3.6 PLAIN CEMENT CONCRETE

The intimate mixture of cement, sand, coarse aggregate (jelly) and water is known as plain cement concrete. A small quantities of admixtures like air entraining agents, water proofing agents, workability agents may also be added to impart special properties to the plain cement concrete. Uses of plain cement concrete is listed below:

1. As bed concrete below the wall footings, column footings and on walls below beams.
2. As sill concrete to get a hard and even surface at window and ventilator sills.
3. As coping concrete over the parapet and compound walls.
4. For flagging the area around the buildings.
5. For making pavements.
6. For making tennis courts, basket ball courts etc.

3.7 REINFORCED CEMENT CONCRETE

Concrete is good in resisting compressive stress but is very weak in resiting tensile stresses. Hence reinforcement is provided in the concrete wherever tensile stress is expected. The best reinforcing material is steel, since its tensile strength is high and bond between steel and concrete is good. Since elastic modulus of steel is quite high compared to concrete, the force developed in steel is high. A cage of reinforcements is prepared as per the design requirements, kept in the form work and then green concrete is poured. After the concrete hardens, the form work is removed. The composite material of steel and concrete, now called R.C.C. acts as a structural member and can resist tensile as well as compressive forces efficiently.

Uses of R.C.C.

1. R.C.C. is used as a structural member wherever bending of the member is expected. The common structural elements in a building where R.C.C. is used are:

(*a*) Footing

(*b*) Columns

(*c*) Beams, lintels

(*d*) Chejjas, roof slabs

(*e*) Stairs.

2. R.C.C. is used for the construction of storage structures like:

(*a*) Water tanks

(*b*) Dams

(*c*) Silos, bunkers

3. They are used for the construction of

(*a*) Bridges

(*b*) Retaining walls

(*c*) Docks and harbours

(*d*) Under water structures

4. R.C.C. is used for building tall structures like

(*a*) Multistorey buildings

(*b*) Chimneys

(*c*) Towers.

5. R.C.C. is used for paving

(*a*) High ways

(*b*) City roads

(*c*) Airports.

6. R.C.C. is used in atomic plants to prevent radiation. For this purpose R.C.C. walls built are as thick as 1.5 m to 2.0 m.

3.8 PRESTRESSED CONCRETE (PSC)

In prestressed concrete elements, calculated compressive stresses are introduced in the zone wherever tensile stresses are expected when the element is put to use. Thus in bridge girders, bottom side of beam tensile stresses develop when deck slab is placed and vehicles start moving on the bridge. Hence before girder is placed in its position compressive stresses are introduced at bottom side. This is achieved by pulling the high tensile wires before concrete is poured in the form work of beam and releasing the pull only after concrete hardens (pretensioned prestress concrete). In another method, it may be achieved by providing a duct from end to end in the beam while casting the beam. Then high tensile wire is passed through the duct and after stretching, it is anchored to the ends of beams. This is called post-tensioning prestress beam. ACI committee defines prestressed concrete as the one in which internal stresses have been introduced such that the stresses resulting from given external loadings are counter-acted to a desired degree. Prestressed concrete is commonly used in making the following structural elements.

1. Beams and girders.
2. Slabs and grid floors.
3. Pipes and tanks
4. Poles, piles, sleepers and pavements.
5. Shell and folded plate roofs.

3.9 PRECAST CONCRETE

Usually concrete structures are built by casting them in their final position in the site by providing form work, pouring concrete and then removing the form work. It is called as cast-in-situ construction. If concrete elements are cast in factories or elsewhere and transported to their final destination, they are called precast elements.

Since the elements are cast in factories where controls are better, they are superior to cast in situ elements. However, the disadvantage is cost of transportation and achieving desired connections on site. Precast concrete is used in the following:

1. Pipes and tanks
2. Poles, piles, sleepers and pavement
3. Lintel beams
4. Beams and girders
5. Building blocks
6. Wall panels
7. Manhole covers

3.10 INTRODUCTION TO SMART MATERIALS

These are the materials which exhibit considerable changes in their mechanical properties like strain (Deformation) and viscosity, when subjected to changes in thermal, electrical or magnetic field changes. These properties can be exploited to develop sensors and devices which can respond to changes automatically. Hence such materials are called as intelligent/active/adaptive materials also. Currently available smart materials are:

1. Shape Memory Alloy (SMA)
2. Magnetostrictive Materials
3. Piezoelectric Materials
4. Electrostrictive Materials and
5. Electro-rheological Fluids.

Shape Memory Alloy (SMA)

These are the metallic materials which demonstrate the ability to return to some previously defined shape or size when subjected to appropriate thermal change. Materials that exhibit shape memory only upon heating are referred to as having one way shape memory. Some materials undergo a change in shape upon cooling also. These materials are said to have two way shape memory.

There are wide variety of alloys which exhibit shape memory. However for commercial exploitation only Niti (Nickel alloys) and the copper base alloys such as CuZn Al (Copper-Zinc-Aluminium) alloys are found useful.

Niti alloys have greater shape memory (up to 8%) compared to copper base alloys (4-5%). The Niti alloys are thermally stable and have excellent corrosion resistance also. Copper based alloys have medium corrosion resistance and susceptive to stress corrosion cracking. However the advantage of copper based alloys is that they are cheap and they can be melted and intruded with ease.

Magnetostrictive Materials

These materials undergo deformation when subjected to magnetic field. Most ferromagnetic materials exhibit some measurable magnetostriction. The higher known magnetostriction are those of iron alloys containing rare earth elements Dysposium (Dy Fe2) or Terbium (TbFe2).

Piezoelectric Materials

Piezoelectrical materials are the most widely used smart materials. These materials undergo surface elongation when an electrical field is applied across them and produce voltage when surface strain is introduced. Figure 3.1 and 3.2 show these phenomenon. The materials which

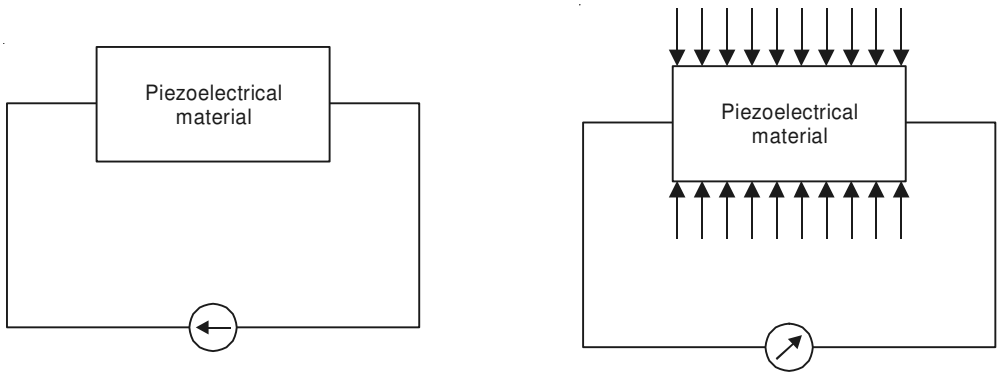


Fig. 3.1. *Generation of electricity on application of pressure*

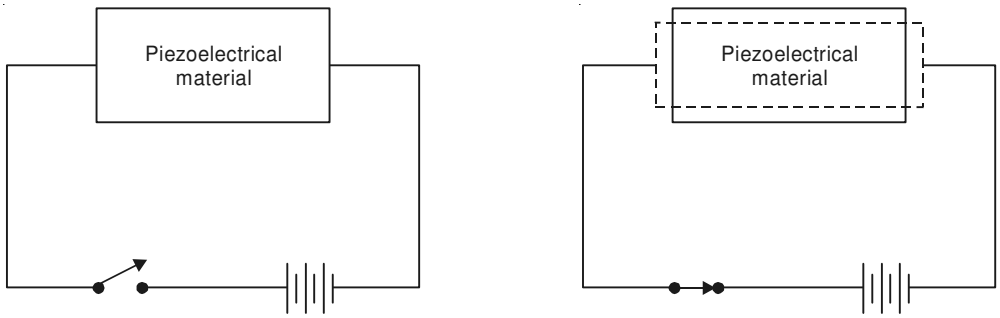


Fig. 3.2. *Change in the dimensions of material on application of electricity.*

exhibit piezoelectrical property are non-metallic materials such as quartz, Rochelle salt. Polyvinylidene fluid (PVDF), which can be easily formed into very thin sheet (film) and adhered to any surface is very commonly used smart material.

Electrostrictive Materials

These materials are identical to piezoelectric materials, with better strain capacity but very sensitive to temperature.

Electrorheological Fluids

Electrorheological fluids are colloidal suspensions that exhibit reversible change in viscosity when subjected to an electric field. The property of electrorheological fluids of reversible transition from liquid to solid state has been utilised in many engineering applications. These changes could be reversed in time intervals of the order of milliseconds.

Applications

1. Aircrafts and space crafts are large structures which have to float in air. Hence they should be as light as possible. When weight reduction is made from the consideration of only primary forces, the problem of structural instability, excessive deflection and excessive vibration result. The sensors and actuators are used to dampen the vibration and to reduce deflections. They are fixed at optimum positions to control vibrations. The instabilities are sensed using sensors made of smart materials. Signals are processed in computers and corrective forces are developed through actuators which are made of smart materials. Figure 3.3 shows the method of building a structure (plate or beam) so that they can sense and react to lateral instability.

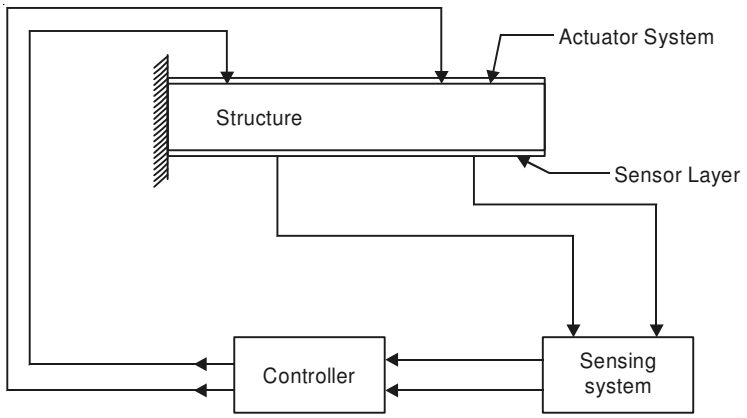


Fig. 3.3. *Sensors and actuators*

2. Smart concrete is obtained by reinforcing the concrete with carbon fibres as much as 0.2% to 0.5% of volume of concrete. Carbon fibres increase the electrical resistance to deformation. Strain is detected through measurement of electrical resistance. Hence warning system can be developed to detect flaws in concrete structure following the changes in intercondition following an earthquake. This method of producing smart material is cheaper than the method of attaching or embedding the sensors and actuators.

3. By providing highway with smart concrete it is possible to find the weight and speed of vehicle moving on it.

4. Smart concrete is used to dampen vibration or reduce earthquake damage.

5. Smart concrete is useful in studying soundness of bridge structures.

6. Electrorheological fluids are used in clutches, values and engines.

7. Smart materials are used to develop safety, security and emergency control systems in buildings and cars.

8. Smart windows having impact on heating, ventilation and air conditioning loads are developed for use in buildings and automobiles.

3.11 RECYCLING OF MATERIALS

To effectively face rising ecological and environmental threat from waste concrete and from some of the industrial wastes, recycling has become need of the modern civilization. In this article recycling of the following waste materials is discussed.

1. Concrete Rubble
2. Crusher Dust

3. Fly Ash
4. Silica Fume
5. Spent Foundry Sand
6. Blast Furnace Slag
7. Red mud
8. Polythene

3.11.1 Recycling Waste Concrete

Every year millions of tonnes of concrete rubble is generated in this world due to various reasons such as:

(*a*) Distructions of cities during the wars and earthquakes.

(*b*) Rejected precast concrete elements.

(*c*) Testing of concrete cubes.

(*d*) Concrete pavements reaching the end of their useful life.

It is estimated that in USA itself approximately 150 million tonnes of concrete rubble is generated annually. Earlier disposal of concrete rubble was for filling land fills like borrow pits of soils or depleted quarries. But environmental consciousness, depletion of quarry aggregate and economical consideration have made it necessary to reuse concrete rubble.

The research in this field started immediately after second world war in Europe. Nowadays from many concrete laboratories in India also encouraging results have been reported.

Concrete rubble is mainly recycled as aggregate for new concrete. The recycle aggregate has slightly less specific gravity and has more absorption value. Impact value and crushing values are also reduced.

The strength of recycled aggregate concrete is about 10 to 15 per cent less as compared to concrete with fresh aggregate. However suitable mix designs may be made and reliable results obtained. The mix requires slightly higher quantity of cement or using admixtures to reduce water requirement.

Recycled aggregate concrete can be safely used as plain concrete. With proper corrections in mix design, it can be used for R.C.C. works also.

3.11.2 Recycling Crusher Dust

Crusher dust is the by-product of crushing of rock to obtain coarse aggregates/jelly for concrete. The disposal of this dust is a serious environmental problem. If it is possible to use this crusher dust in production of concrete and mortar by partial or full replacement of natural sand, then this will not only save the cost of construction but at the same time it will solve the problem of disposal of the crushed dust.

The researchers have reported that replacement of natural sand with crusher dust results into reduction in workability which can be compensated by using chemical admixtures. The test results reveal:

1. Replacement of natural sand by crusher dust is not detrimental upto 50%.

2. Concrete with 100% crusher dust can be used with greater precaution. In such concrete durability requirement is not met in stipulated 28 days. However, incorporating fly ash can enhance the durability characteristics.

3. Combination of crusher dust and fly ash is beneficial in cost and durability aspects.

3.11.3 Use of Fly Ash

Fly ash is the by-product from thermal plants. The thermal plant owners take all care to prevent it from flying in the air and dump it in wet ponds. Till 15-20 years ago it was treated as a waste and disposal as a serious problem. This gave rise to research to utilise fly ash. Now it is found that it is a useful material in the following works:

1. It is a dependable resource material for brick production. 40 to 50 per cent fly ash can be used with 25 to 30 per cent sand, 10 to 15 per cent lime and 10-15 per cent gypsum to produce strong and durable bricks.

2. Adding 15 to 30 per cent fly ash in cement, blended cement is produced. The blended cement has got very good weather resisting capacity and hence it is more durable than ordinary portland cement. Hence use of blended cement is becoming more popular than ordinary portland cement.

3. In recent years high performance high volume fly ash concrete has emerged that incorporates a large volume of fly ash (HVFA) into conventional portland cement. Fly ash used is 40 to 50% . Use of fly ash reduces heat generation during setting of cement. Use of HVFA makes concrete pavements cost effective. This concrete takes more time to gain full strength (120 days compared to 28 days by ordinary concrete) and needs small quantity of superplasticizer (chemical to improve workability).

Nowadays demand for fly ash has increased so much that there is no problem of disposing but thermal power stations can sell it to nominal price.

3.11.4 Silica Fume

Silica fume is a by-product from the silicon, ferrow-silicon manufacturing process from quartz and carbon in electric furnace. It is in the form of extremely fine spherical particles. Before 1990 it was viewed as factory waste. But in 1987, silica fume concrete was used for Deepak Fertilisers. It was discovered that it has beneficiary effect on concrete, including increase in strength and durability. Now nearly all major projects are using High Performance Silica Fume concrete. Some of the important projects where silica fume is used are Tehri Dam, Bandra Worli Sea Link, Nuclear Power Station, Kaiga, Karwar, Mumbai to Poona express way. Replacing cement by 12.5 per cent silica fume has the maximum advantage in increasing the strength.

As a result of increase in its demand, now silica fume is expensive. However when analysed against the cost of an alternative concrete of similar performance it is found to be economical also. This conclusion has been drawn from the cost analysis of Mumbai-Poona express way.

3.11.5 Spent Foundry Sand

The most common type of casting process in the foundry industry is known as sand casting. The sand used for preparing the moulds is known as foundry sand. Molten metal is passed into the mould and allowed to cool. After cooling, the mould is broken away from the metal piece in a process called shake out. These broken pieces of mould which consists of slag, wastes etc. is called spent foundry sand. This spent foundry sand is posing a threat to the environment and needs safe disposal. To reduce this environmental pollution, this spent foundry sand can be used as part of concrete.

It has been found that if 10% of natural sand is replaced with spent foundry sand compressive strength of concrete increases by 3%. More than 10% replacement result into reduction in concrete strength.

3.11.6 Blast Furnace Slag

The blast furnace slag which is a by-product in the manufacture of pig iron is converted into foamed/expanded slag by tripping steam while cooling process is on. Industries have come up near the steel mills to manufacture readymade building blocks and partition wall panels using blast furnace slag.

Ground Granulated Blast Furnace Slag (GGBFS) from cement industries are used as replacement of cement. It is found that only 5% of strength is lost, if 40% of cement is replaced by GGBFS. However, in this case strength gained is slow. It takes about 60 days to get almost full strength compared to 28 days taken by ordinary cement concrete. However it is the best means of recycling this industrial waste.

3.11.7 Red Mud

Red mud is a waste material obtained from aluminium plants causing environmental pollution and disposal problems. For every tonne of alumina produced equal quantity of hazardous, highly alkaline red mud is produced, which mainly consists of hydrous hydrated oxides of alumina, titanium, silica and alkalies.

A process has been developed by CBRI Roorkee utilising red mud and fly ash to manufacture bricks of various colours and texture. Compressive strength achieved is 40 N/mm^2 (minimum compressive strength required being 3.1 N/mm^2). Water absorption of such bricks is only 12%. It has been reported that in mortars 10% and in concrete 5% of cement may be replaced to get better strength. In Taiwan red mud is used with PVC to produce red mud plastics (RMP). The corrugated roofing sheets manufactured have shown highly improved properties over PVC in terms of weather resistance.

3.11.8 Polythene

Polythene is the environmental hazardous materials, since it is not getting dissolved in nature. While chemical engineers are busy in finding methods of dissolving it using chemical technology and reusing the polythene, civil engineers are trying to recycle it as building materials.

Some success has been reported in using polythene as damp proof material in building low cost houses. Major breakthrough is likely in using it as a useful material in road works. Polythene cleaned and cut into small pieces is mixed with tar and is used in about 600 km of roads in and around Bangalore. Results are encouraging. Roads laid in 2002 are showing good performance. It is expected that durability of such roads is twice that of tar roads without using polythene.

Questions

1. What are the various uses of stones and bricks in construction ? Why nowadays popularity of stone as building material is going down ?

2. Why sand is used in making mortars and concrete ?

What are the different sources of sand ?

Why sea sand should not be used in making mortars and concrete ?

3. Distinguish among 'mild steel torsteel and high tensile steel'. Highlight use of each one of them in the building construction.

4. Explain the following materials and list their various uses in building construction:
   (*a*) Plain concrete
   (*b*) Reinforced cement concrete and
   (*c*) Prestressed concrete.

5. Write short notes on
   (*a*) Precast concrete
   (*b*) Smart materials

6. Discuss whether concrete rubble and crusher dust can be used in making fresh concrete. Highlight their advantages and disadvantages.

7. Write short notes on recycling the following industrial wastes:
   (*a*) Fly ash
   (*b*) Silica fume
   (*c*) Blast furnace slag and
   (*d*) Red mud.

8. Why polythene is environmental hazardous material? Discuss possible ways of recycling the polythene.

❐❐❐

CHAPTER IV

Construction of Substructures

The structure that we see above ground surface may be called as superstructure. The load carried by the superstructure is to be suitably distributed to the ground so that it is safely carried. The structure that is built below ground level to distribute the load from superstructure on wider area of ground is known as sub-structure. Foundation is the lowest part of sub-structure that transfer the load directly to the ground. In this chapter functions of foundations and types of shallow foundations are presented.

4.1 FUNCTIONS OF FOUNDATION

The functions of foundation are:

1. To distribute the weight of the structure over a large area so as to avoid exceeding load bearing capacity of the soil. Masonry walls R.C.C. or steel columns can carry considerable load per unit area where as soil can carry quite less load per unit area. Hence there is need to gradually increase the area for load transfer and finally provide sufficient area. This is the main purpose of foundation.

2. Incidentally by providing foundation load on soil is evenly distributed and hence unequal settlement of parts of superstructure prevented.

3. Foundation takes the structure deep into the ground and anchors it. The overturning and sliding of structures is prevented. Thus foundation gives stability to the structure.

4. Foundation provides a level surface for building operations.

4.2 BEARING CAPACITY

Bearing capacity of the soil means the load carrying capacity of the subsoil. This value is determined using the formulae developed in soil mechanics. It depends upon the cohesiveness, frictional properties and unit weight of subsoil. It can be determined by directly by a test known as plate load test. In this test a 300 × 300 mm × 18 mm thick or 450 × 450 mm × 18 mm thick steel plate is kept directly on the subsoil. A short steel column is connected to it and at ground level a platform is built. This platform is loaded with an increment of 5 kN at a time and the settlement is observed through a level. This process of loading and observing settlement is continued till the

subsoil yields and sudden sinking is observed. Load settlement curve is plotted and load corresponding to yielding is taken as ultimate bearing capacity of the soil. This value is divided by a factor of safety of 2 to 3 depending upon the reliability of the soil and the value thus obtained is known as safe bearing capacity (SBC) of soil. Figure 4.1 shows the typical arrangement of plate load test.

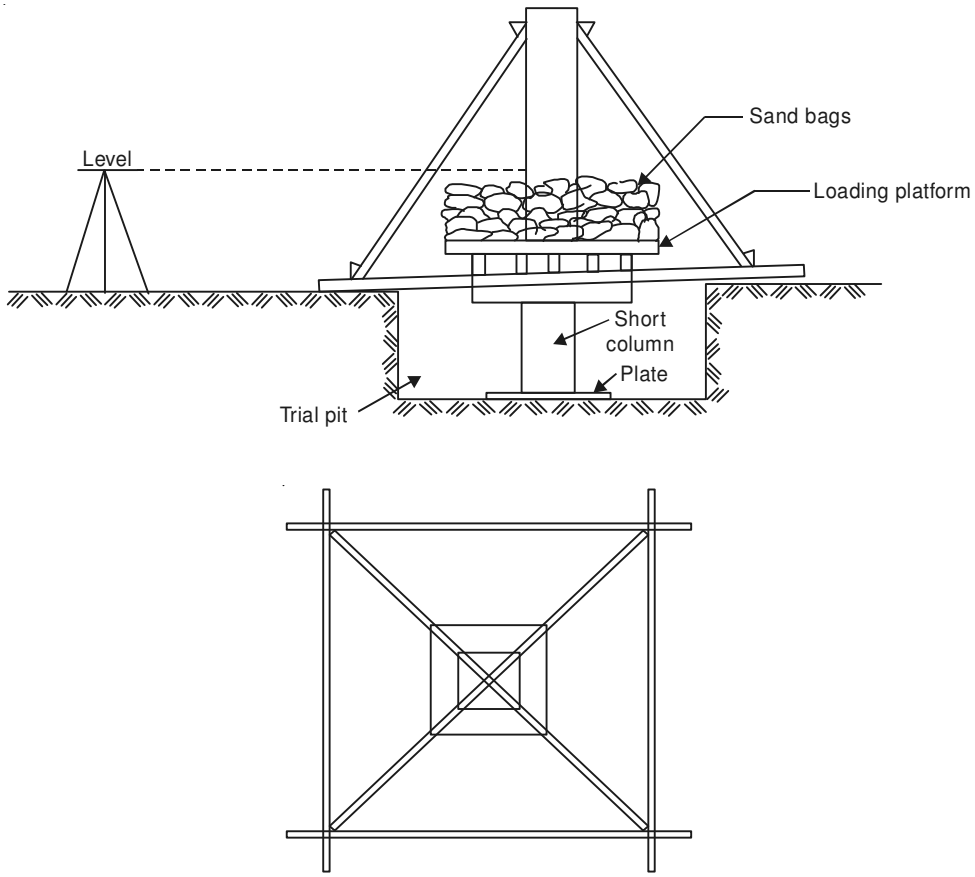


Fig. 4.1. *Arrangement for plate load test*

Bearing capacity of soil may be increased by

1. Increasing the depth of foundation, since the lower strata or ground has natural campaction.
2. Putting granular materials like sand and gravel on the natural soil and then compacting well.
3. By combining the soil in an enclosed area by driving sheet piles or sand piles.
4. Draining out the area, if it is a marshy land.
5. Attempts have been made to improve bearing capacity of soil by chemical treatment also.

Table 4.1 shows the safe bearing capacities of some common soils according to National Building Code of India (1983).

TABLE 4.1. Safe Bearing Capacity
[Table 2 of NBC, Clause 7.1.2.2]

Sl. No.	*Type of Rocks/Soils*	*Safe Bearing Capacity*	*Remarks*
(1)	*(2)*	*(3)*	*(4)*
	(*a*) Rocks	kN/m²	
(1)	Rocks (hard) without lamination and defects, for example, granite, trap and diorite	3240	–
(2)	Laminated rocks, for example, stone and limestone in sound condition	1620	–
(3)	Residual deposits of shattered and broken bed rock and hard shale, cemented material	880	–
(4)	Soft rock	440	–
	(*b*) Non-cohesive soils		
(5)	Gravel, sand and gravel, compact and offering high resistance to penetration when excavated by tools	440	(*See* Note 2)
(6)	Coarse sand, compact and dry	440	Dry means that the ground water level is at a depth not less than the width of foundation below the base of the foundation
(7)	Medium sand, compact and dry	245	–
(8)	Fine sand, silt (dry lumps easily pulverized by the fingers)	150	–
(9)	Loose gravel or sand-gravel mixture, loose coarse to medium sand, dry	245	(*See* Note 2)
(10)	Fine sand, loose and dry	100	–
	(*c*) Cohesive soils		
(11)	Soft shale, hard or stiff clay in deep bed, dry	440	This group is susceptible to long term consolidation settlement
(12)	Medium clay, readily indented with a thumb nail	245	–
(13)	Moist clay and sand clay mixture which can be indented with strong thumb pressure	150	–
(14)	Soft clay indented with moderate thumb pressure	100	–
(15)	Very soft clay which can be penetrated several centimetres with the thumb	50	–
(16)	Black cotton soil or other shrinkable or expansive clay in dry condition (50 per cent saturation)	–	*See* Note 3. To be determined after investigation
	(*d*) Peat		
(17)	Peat	–	*See* Notes 3 and 4. To be determined after investigation
	(*e*) Make-up ground		
(18)	Fills or made-up ground	–	*See* Notes 2 and 4. To be determined after investigation

NOTE 1: Values listed in the table are from shear consideration only.

NOTE 2: Values are very much rough for the following reasons:

(*a*) Effect of characteristics of foundations (that is, effect of depth, width, shape, roughness, etc.) has not been considered.

(*b*) Effect of range of soil properties (that is, angle of frictional resistance, cohesion, water table, density, etc.) has not been considered.

(*c*) Effect of eccentricity and indication of loads has not been considered.

NOTE 3: For non-cohesive soils, the values listed in the table shall be reduced by 50 per cent if the water table is above or near the base of footing.

NOTE 4: Compactness of non-cohesive soils may be determined by driving a cone of 65 mm dia and 60 apex angle by a hammer of 65 kg falling from 75 cm. If corrected number of blows (N) for 30 cm penetration is less than 10, the soil is called loose; if N lies between 10 and 30, it is medium, and if more than 30, the soil is called dense.

4.3 TYPES OF SHALLOW FOUNDATIONS

Shallow foundations are usually spread foundations in which load is spread to wider area and then transferred safety to soil. Different types of shallow foundations used may be classified into

1. Wall foundation
2. Foundation for Brick Pillars
3. Foundation for R.C.C. columns and
4. Foundation for steel columns.

In all these cases depth of footing is calculated using Rankine's formula:

$$H = \frac{p}{w}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

where p = Safe bearing capacity of soil

w = Unit weight of soil

ϕ = Angle of repose of the soil

However a minimum depth of 0.9 m is provided in all cases.

4.3.1 Wall Foundation

Figure 4.2 shows a typical footing for the wall of a permanent building. The load from wall is transferred to stone masonry through plinth concrete. It is gradually spread with different courses of stone masonry. The projection from course to course is 75 mm on either side. Finally about 150 mm to 200 mm plain concrete bed transfers the load to the ground. Number of courses and depth of each course may be suitably varied depending upon the depth of foundation required. For temporary structures instead of stone masonry brick masonry itself may be taken upto plain concrete bed spreading by 50 mm on each side in each course.

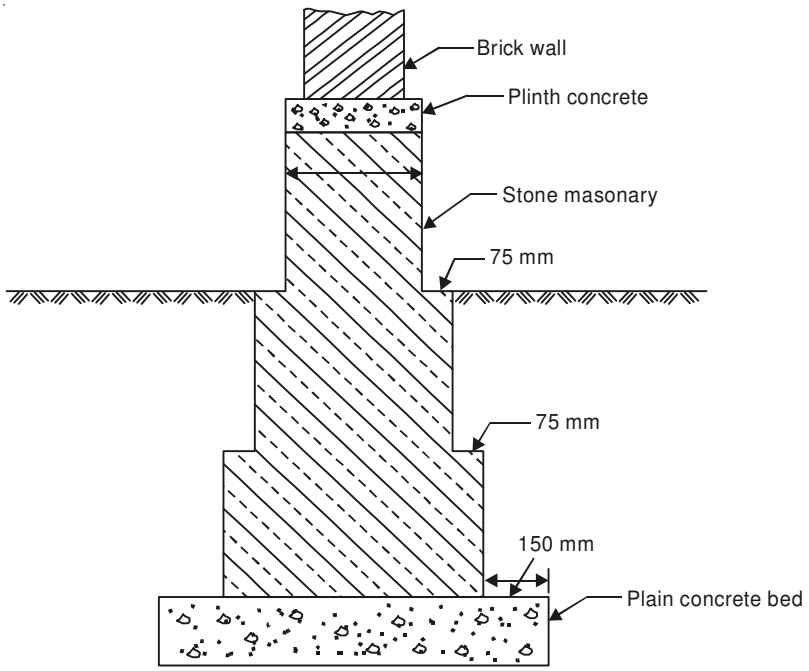


Fig. 4.2. *Wall footing*

4.3.2 Foundation for Brick Pillars

Knowing the load from pillars and SBC (safe bearing capacity) of soil, area of footing required is calculated. Plain concrete bed of 150 to 200 mm is laid. Then courses of brick masonry are laid giving offsets of 50 mm on all sides and the finally reducing it to brick pillar size. Figure 4.3 shows a typical foundation for a brick pillar.

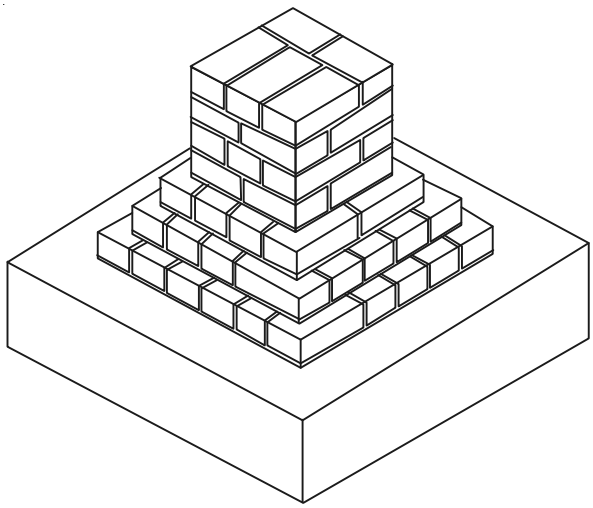


Fig. 4.3. *Foundation for a brick pillar*

Earlier inverted arch footings [Fig. 4.4] were tried for a series of columns. But due to problem of providing abutment for last column this is given up now.

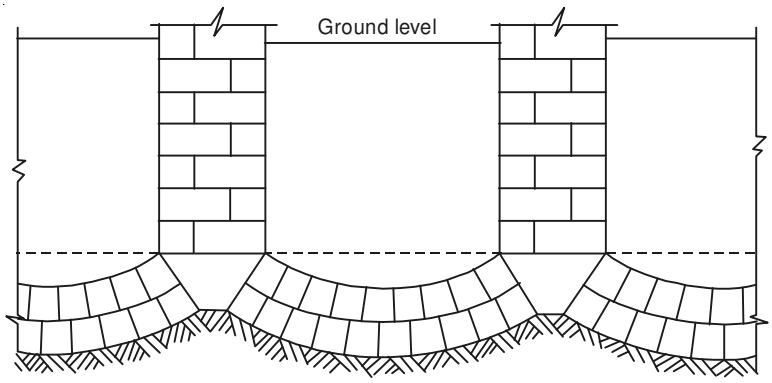


Fig. 4.4. *Inverted arch footings for brick pillars*

4.3.3 Foundations For R.C.C. Columns

R.C.C. columns carry considerable load per unit area and hence it needs spreading the load over larger areas on ground. R.C.C. column footings are provided which are subjected to bending and shear.

The various R.C.C. footings provided may be broadly classified as

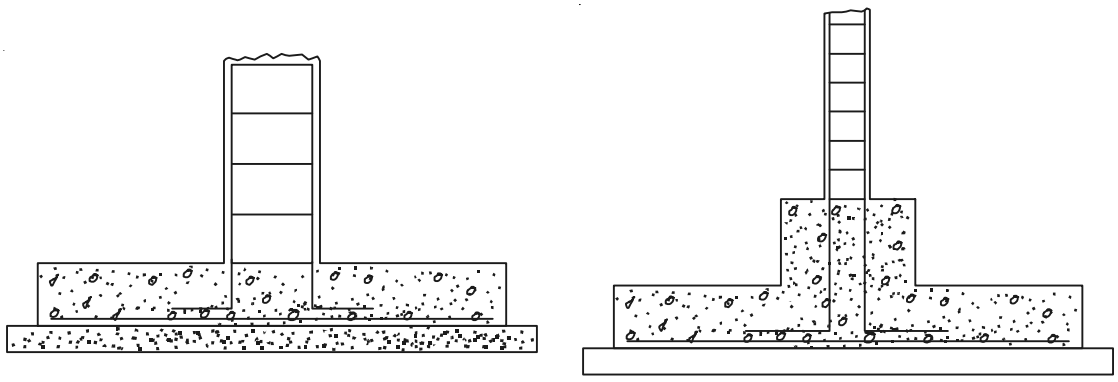
(*i*) Isolated Footing

(*ii*) Combined Footing for two columns

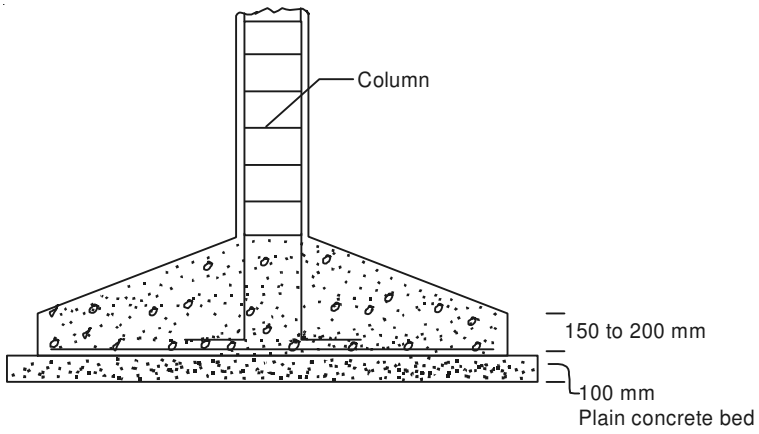
(*iii*) Combined Footing for multiple columns.

Isolated column footings

For each column when separate footing is provided, it is called isolated column footing. Reinforcements are provided on lower side of footing in both directions. The thickness and reinforcement required are designed. Figure 4.5. shows three types of isolated footings commonly used.



(*a*) Simple Spread Footing (*b*) Stepped Footing



(*c*) Sloping footing

Fig. 4.5. *Isolated column footing*

Combined footing for two columns

Combined footing are provided for two columns in the following situations:

1. The two columns are close by and if isolated column footings are designed they may overlap.

2. One column is almost on property line and hence it is not permitted to have projection on the other's or public property.

In such situations the following types of footings may be provided.

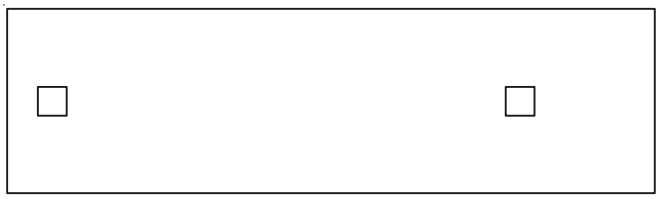
(*i*) Rectangular slab type

(*ii*) Trapezoidal slab type

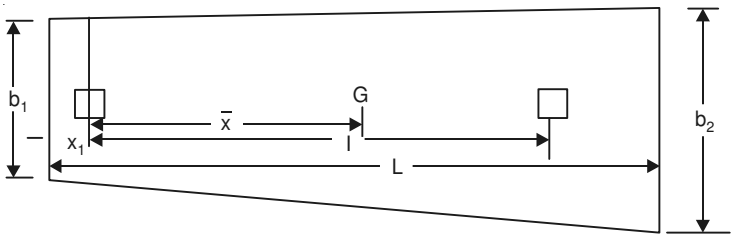
(*iii*) Beam and slab type and

(*iv*) Strap or cantilever footings.

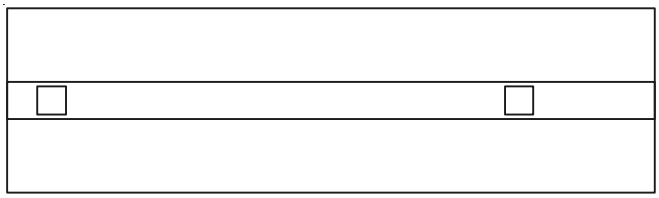
These footings are shown in Fig. 4.6.



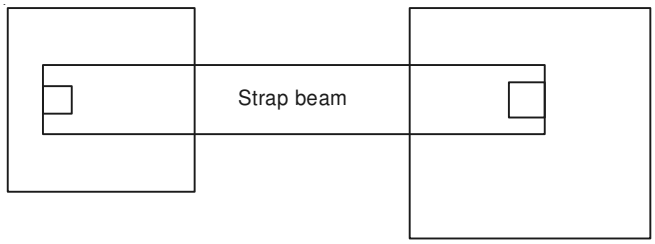
(*a*) Rectangular slab type



(*b*) Trapezoidal slab type



(*c*) Beam and slab type

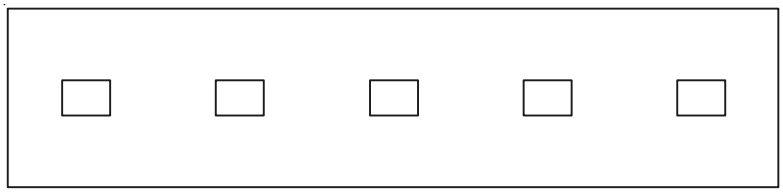


(*d*) Strap or cantilever footing

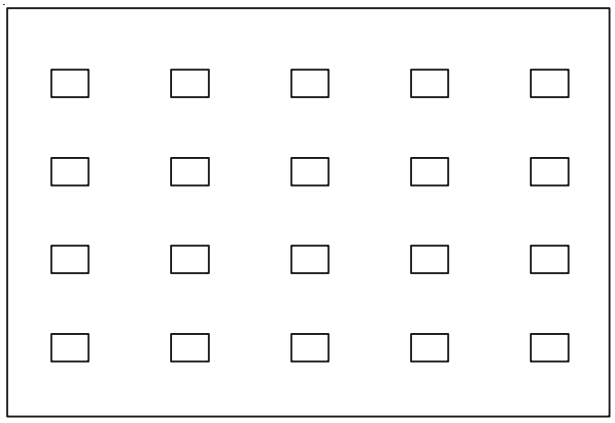
Fig. 4.6. *Combined footing for two columns*

Combined footings for multiple columns

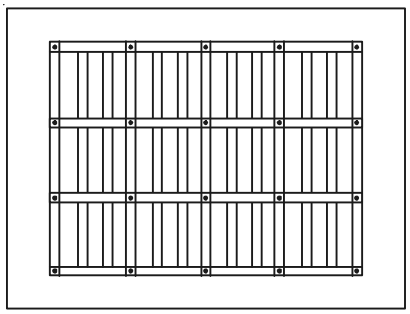
Combined footings supporting a row of columns is called strip footing and it is shown in Fig. 4.6. In multistorey framed structures a number of columns in a number of rows are to be supported by single footing since isolated or strip footings overlap adjoining footing. By providing raft/mat footing or grid footing this situation can be taken care. This type of footing prevents unequal settlement of columns also. Figure 4.7 shows these footings.



(*a*) Strip footing



(*b*) Mat/raft footing

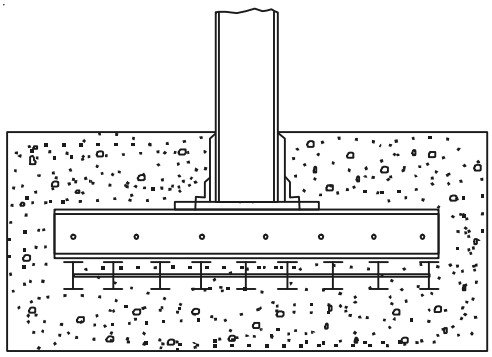


(*c*) Grid footing

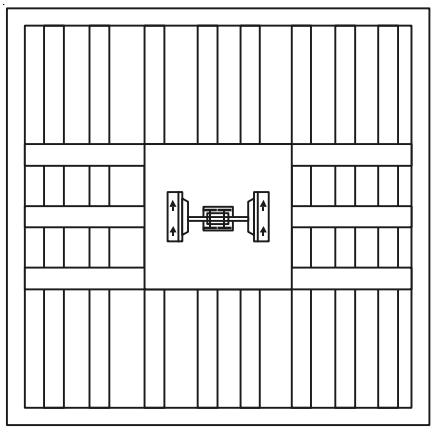
Fig. 4.7. *Combined footings for multiple columns*

4.3.4 Footings for Steel Columns

Load carried by steel columns per unit area is very high. Steel columns transfer the load to R.C.C. footing which in turn transfer the land to soil. Steel columns are either directly connected to R.C.C. footings or they are provided with grillage foundation. Figure 4.8 shows a typical grillage foundation, which consists of two layers of I-sections placed on concrete bed and fully encased in concrete.



(*a*) Sectional elevation



(*b*) Plan

Fig. 4.8. *Grillage foundation*

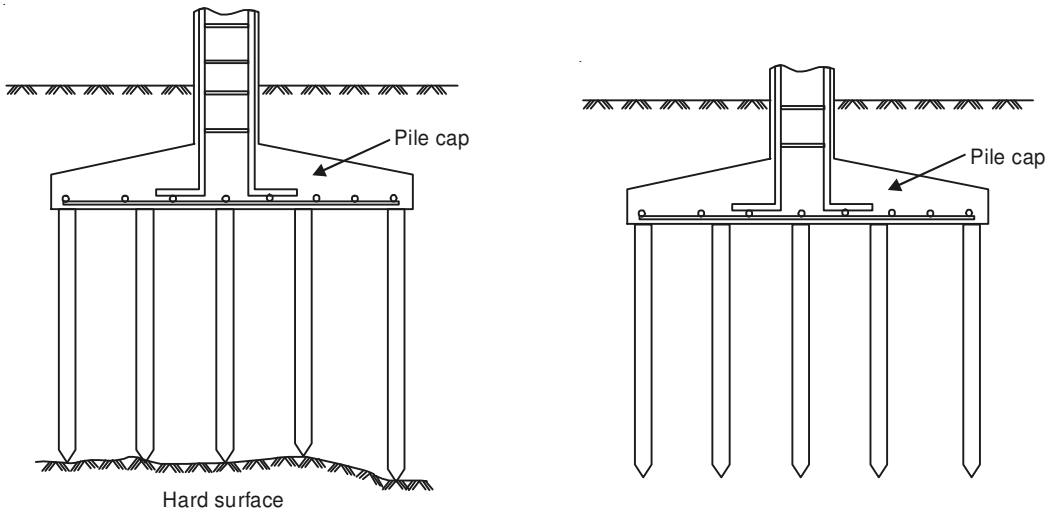
4.4 FOUNDATIONS USING PILES

If suitable hard soil is not available at reasonable depth, it is economical and safe to go for pile foundations instead of spread footings. In water logged soil like black cotton soil this situation is common.

There are two types of piles used for foundations *viz.,* Bearing Piles and Friction Piles.

Bearing Piles: Piles are the poles made of timber, plain concrete, R.C.C. or steel. These piles are hammered down to rest on hard surface. On top of a number of piles a concrete cap is cast and over that construction activity of building starts. Thus bearing piles transfer the load to hard surface directly.

Friction Piles: When hard surface is not met at reasonable depth, the frictional resistance between the adjoining soil and pile is checked and the pile length is kept sufficient enough to transfer the load by friction. Figure 4.9 shows typical pile foundations.



(*a*) Bearing pile foundation (*b*) Friction pile foundation

Fig. 4.9. *Pile foundation*

Questions

1. What is substructure ? Discuss various functions of foundations.

2. (*a*) Explain the term 'safe bearing capacity of soil'. What are the different methods of improving it ?

(*b*) Give values of safe bearing capacities of any four soils.

3. Explain Rankine's Formula for finding depth of foundation.

4. Give neat sketches for the foundations of

(*a*) Wall (*b*) Brick pillar (*c*) Isolated R.C.C. column.

5. Write short notes on

(*a*) Combined footings for R.C. columns (*b*) Grillage foundation

(*c*) Pile foundations.

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CHAPTER V

Superstructures

As already defined superstructure is the part of structure above ground level which is visible easily. In a building columns, walls, beams, slabs, doors, window etc. form the superstructure while in bridges piers and deck form superstructure. The visible part of dams and water tank are superstructures of dam and water tank respectively. In this chapter various loads acting on superstructure are discussed and types of construction discussed.

5.1 TYPES OF LOADS ON SUPERSTRUCTURES

To get safe structures at the same time without ignoring economy of the structure, it is necessary to estimate the various loads acting suitably. Indian standard code IS: 875–1987 specifies various design loads for buildings and structures. They have grouped various loads as under:

1. Dead loads
2. Imposed loads
3. Wind loads
4. Snow loads
5. Earthquake loads
6. Special loads

Details of earthquake load is covered in IS: 1893 – 1984 which should be considered along with other types of loads given in IS-875. The code also gives various load combinations to be considered in the design.

5.2 DEAD LOADS

The dead load in a building comprises the weight of roofs, floors, beams, columns, walls, partition walls etc. which form permanent part of the building. It is to be found by working out volume of each part and then multiplying with unit weight. Unit weight of various materials are listed in part-I of IS: 875. Unit weights of some of the common materials are presented in Table 5.1.

TABLE 5.1. Unit Weight of Common Building Materials

Sl. No.	*Material*		*Weight*
1.	Brick Masonry		18.8 kN/m^3
2.	Stone Masonry		20.4 – 26.5 kN/m^3
3.	Plain cement concrete		24.0 kN/m^3
4.	Reinforced cement concrete		25.0 kN/m^3
5.	Timber		5 to 8 kN/m^3
6.	Wooden floors hard wood	16 mm thick	160 kN/m^3
		28 mm thick	200 N/m^3
7.	Terrazo paving		240 N/m^3
8.	Country Tiles (single) including battens		700 N/m^3
9.	Mangalore Tiles with battens		650 N/m^3
10.	Mangalore tiles with flat tiles		785 N/m^3
11.	A.C. Sheets	6 mm thick	170 N/m^3
12.	A.C. Sheet	5 mm plain	110 N/m^3

5.3 IMPOSED LOADS (IL)

The loads which keep on changing from time to time are called as imposed loads. Common examples of such loads in a building are the weight of the persons, weights of movable partition, dust loads and weight of furnitures. These loads were formerly known as live loads. These loads are to be suitably assumed by the designer. It is one of the major load in the design. The minimum values to be assumed are given in IS 875 (part 2)–1987. It depends upon the intended use of the building. These values are presented for square metre of floor area. The code gives the values of loads for the following occupancy classification:

(*i*) Residential buildings–dwelling houses, hotels, hostels, boiler rooms and plant rooms, garages.

(*ii*) Educational buildings

(*iii*) Institutional buildings

(*iv*) Assembly buildings

(*v*) Business and office buildings

(*vi*) Mercantine buildings

(*vii*) Industrial buildings, and

(*viii*) Storage rooms.

The code gives uniformly distributed load as well as concentrated loads. The floors are to be investigated for both uniformly distributed and worst position of concentrated loads. The one which gives worst effect is to be considered for the design but both should not be considered to act simultaneously.

In a particular building, imposed load may change from room to room. For example in a hotel or a hostel building the loads specified are,

	udl	Concentrated load
(*a*) Living rooms and bed rooms	2 kN/m^2	1.8 kN
(*b*) Kitchen	3 kN/m^2	4.5 kN
(*c*) Dining rooms	4 kN/m^2	2.7 kN
(*d*) Office rooms	2.5 kN/m^2	2.7 kN
(*e*) Store rooms	5 kN/m^2	4.5 kN
(*f*) Rooms for indoor games	3 kN/m^2	1.8 kN
(*g*) Bath rooms and toilets	2 kN/m^2	–
(*h*) Corridors, passages, stair cases etc.		
and (*i*) Balconies	4 kN/m^2	1.5 kN concentrated at outer edge.

Some of the important values are presented in table 5.2 which are the minimum values and wherever necessary more than these values are to be assumed.

TABLE 5.2. Minimum Imposed Load to be Considered

Sl. No.	***Occupancy***	***UDL Load***	***Concentrated***
1.	Bath rooms and toilets in all types of building	2 kN/m^2	1.8 kN
2.	Living and bed rooms	2 kN/m^2	1.8 kN
3.	Office rooms in		
	(*i*) Hostels, hotels, hospitals and business building with separate store	2.5 kN/m^2	2.7 kN
	(*ii*) In assembly buildings	3 kN/m^2	4.5 kN
4.	Kitchens in (*i*) Dwelling houses	2 kN/m^2	1.8 kN
	(*ii*) Hostels, hotels and hospitals	3 kN/m^2	4.5 kN
5.	Banking halls, class rooms, x-ray rooms, operation rooms	3 kN/m^2	4.5 kN
6.	Dining rooms in (*i*) educational buildings, institutional and mercantine buildings	3 kN/m^2	2.7 kN
	(*ii*) hostels and hotels	4 kN/m^2	2.7 kN
7.	Corridors, passages, stair cases in		
	(*i*) Dwelling houses, hostels and hotels	3 kN/m^2	4.5 kN
	(*ii*) Educational institutional and assembly buildings	4 kN/m^2	4.5 kN
	(*iii*) Marcantine buildings	5 kN/m^2	4.5 kN
8.	Reading rooms in libraries		
	(*i*) With separate storage	3 kN/m^2	4.5 kN
	(*ii*) Without separate storage	4 kN/m^2	4.5 kN
9.	Assembly areas in assembly buildings		
	(*i*) With fixed seats	5 kN/m^2	..
	(*ii*) Without fixed seats	5 kN/m^2	3.6 kN
10.	Store rooms in educational buildings	5 kN/m^2	4.5 kN
11.	Store room in libraries	6 kN/m^2 for a height of 2.24 + 2 kN/m^2 for every 1 m additional height	4.5 kN

12.	Boiler rooms and plant rooms in (*i*) hostels, hotels, hospitals, mercantine and industrial buildings (*ii*) Assembly & storage buildings	 5 kN/m² 7.5 kN/m²	 4.5 kN 4.5 kN

Imposed loads to be considered on various roofs are presented in table 5.3

TABLE 5.3. Imposed Loads on Various Types of Roofs (Table 2 of National Building Code – 1983)

Sl. No.	*Type of Roof*	*Imposed Load Measured on Plan Area*	*Minimum Imposed Load Measured on Plan*
(*i*)	Flat, sloping or curved roof with slopes up to and including 10 degrees		
	(*a*) Access provided	1.5 kN/m²	3.75 kN uniformly distributed over any span of one metre width of the roof slab and 9 kN uniformly distributed over the span of any beam or truss or wall.
	(*b*) Access not provided except for maintenance.	0.75 kN/m²	1.9 kN uniformly distributed over any span of one metre width of the roof slab and 4.5 kN uniformly distributed over the span of any beam of truss or wall.
(*ii*)	Sloping roof with slope greater than 10 degrees.	For roof membrane sheet or purlins – 0.75 kN/m² less 0.02 kN/m² for every degree increase in slope over 10 degrees.	Subject to a minimum of 0.4 kN/m²
(*iii*)	Curved roof with slope of line obtained by joining springing point to the crown with the horizontal, greater than 10 degrees.	$(0.75 - 0.52\ \alpha^2)$ kN/m² where $\alpha = h/l$ h = height of the highest point of the structure measured from its springing: and l = chord width of the roof if singly curved and shorter of the two sides if doubly curved. Alternatively, where structural analysis can be carried out for curved roofs of all slopes in a simple manner applying the laws of statistics, the curved roofs shall be divided into minimum 6 equal segments and for each segment imposed load shall be calculated appropriate of each segment as given in (*i*) and (*ii*)	Subject to a minimum of 0.4 kN/m²

NOTE 1. The loads given above do not include loads due to snow, rain, dust collection, etc. The roof shall be designed for imposed loads given above or snow/rain load, whichever is greater.

NOTE 2. For special types of roofs with highly permeable and absorbent material, the contingency of roof material increasing in weight due to absorption of moisture shall be provided for.

However in a multi-storeyed buildings chances of full imposed loads acting simultaneously on all floors is very rare. Hence the code makes provision for reduction of loads in designing columns, load bearing walls, their supports and foundations as shown in table 5.4.

TABLE 5.4. Reductions in Imposed Loads on Floors in Design of Supporting Structural Elements

Number of Floors (including the roof) to be carried by Member Under Consideration	*Reduction in Total Distributed Imposed Load in Per cent*
1	0
2	10
3	20
4	30
5 to 10	40
Over 10	50

5.4 WIND LOADS

The force exerted by the horizontal component of wind is to be considered in the design of buildings. It depends upon the velocity of wind and shape and size of the building. Complete details of calculating wind load on structures are given in IS-875 (Part 3) -1987. Brief idea of these provisions are given below:

(*i*) Using colour code, basic wind pressure 'V_b' is shown in a map of India. Designer can pickup the value of V_b depending upon the locality of the building.

(*ii*) To get the design wind velocity V_z the following expression shall be used:

$$V_z = k_1 k_2 k_3 V_b$$

Where k_1 = Risk coefficient

k_2 = Coefficient based on terrain, height and structure size.

k_3 = Topography factor

(*iii*) The design wind pressure is given by

$$p_z = 0.6\ V^2_z$$

where p_z is in N/m^2 at height Z and V_z is in m/sec. Up to a height of 30 m, the wind pressure is considered to act uniformly. Above 30 m height, the wind pressure increases.

5.5 SNOW LOADS

IS 875 (part 4) – 1987 deals with snow loads on roofs of the building. For the building to be located in the regions wherever snow is likely to fall, this load is to be considered. The snow load acts vertically and may be expressed in kN/m^2 or N/m^2. The minimum snow load on a roof area

or any other area above ground which is subjected to snow accumulation is obtained by the expression

$$S = \mu S_0$$

Where S = Design snow load on plan area of roof.

μ = Shape coefficient, and

S_0 = Ground snow load.

Ground snow load at any place depends on the critical combination of the maximum depth of undisturbed aggregate cumulative snow fall and its average density. These values for different regions may be obtained from Snow and Avalanches Study Establishment Manali (HP) or Indian Meteorological Department Pune. The shape coefficient depends on the shape of roofs and for some of the common shapes the code gives these coefficients. When the slope of roof is more than 60° this load is not considered.

It may be noted that roofs should be designed for the actual load due to snow or for the imposed load, whichever is more sever.

5.6 EARTHQUAKE FORCES

Earthquake shocks cause movement of foundation of structures. Due to inertia additional forces develop on super structure. The total vibration caused by earthquake may be resolved into three mutually perpendicular directions, usually taken as vertical and two horizontal directions. The movement in vertical direction do not cause forces in superstructure to any significant extent. But movement in vertical direction do not cause forces in superstructure to any significant extent. But movement in horizontal directions cause considerable forces.

The intensity of vibration of ground expected at any location depends upon the magnitude of earthquake, the depth of focus, the distance from the epicenter and the strata on which the structure stands.

The response of the structure to the ground vibration is a function of the nature of foundation soil, size and mode of construction and the duration and intensity of ground motion. IS: 1893–1984 gives the details of such calculations for structures standing on soils which will not considerably settle or slide appreciably due to earthquake. The seismic accelerations for the design may be arrived at from **seismic coefficients,** which is defined as the ratio of acceleration due to earthquake and acceleration due to gravity. For the purpose of determining the seismic forces, India is divided into five zones. Depending on the problem, one of the following two methods may be used for computing the seismic forces:

(*a*) Seismic coefficient method

(*b*) Response spectrum method

The details of these methods are presented in IS 1983 code and also in National Building Code of India. After the Gujarat earthquake (2000) Government of India has realized the importance of structural designs based on considering seismic forces and has initiated training of the teachers of technical institution on a large scale (NPEEE).

There are large number of cases of less importance and relatively small structures for which no analysis be made for earthquake forces provided certain simple precautions are taken in the

construction. For example

(*a*) Providing bracings in the vertical panels of steel and R.C.C. frames.

(*b*) Avoiding mud and rubble masonry and going for light materials and well braced timber framed structures.

5.7 OTHER FORCES AND EFFECTS

As per the clause 19.6 of IS 456 – 2000, in addition to above load discussed, account shall be taken of the following forces and effects if they are liable to affect materially the safety and serviceability of the structure:

(*a*) Foundation movement (See IS 1904)

(*b*) Elastic axial shortening

(*c*) Soil and fluid pressure (See IS 875, Part 5)

(*d*) Vibration

(*e*) Fatigue

(*f*) Impact (See IS 875, Part 5)

(*g*) Erection loads (See IS 875, Part 2) and

(*h*) Stress concentration effect due to point load and the like.

5.8 LOAD COMBINATIONS

A judicious combination of the loads is necessary to ensure the required safety and economy in the design keeping in view the probability of

(*a*) Their acting together

(*b*) Their disposition in relation to other loads and severity of stresses or deformations caused by the combination of various loads.

The Recommended Load Combinations by National Building Codes

1.	DL	7.	DL + IL + EL
2.	DL + IL	8.	DL + IL + TL
3.	DL + WL	9.	DL + WL + TL
4.	DL + EL	10.	DL + EL + TL
5.	DL + TL	11.	DL + IL + WL + TL
6.	DL + IL + WL	12.	DL + IL + EL +TI

where DL = dead load IL = imposed load

WL = wind load EL = earthquake load

and TL = temperature load.

NOTE: When snow load is present on roofs, replace imposed load by snow load for the purpose of above load combinations.

5.9 TYPES OF CONSTRUCTION

Wall are important part of superstructure. They are commonly constructed with stones, bricks or hollow concrete blocks. Walls enclose and divide the space in the building. In addition to it if they are made to carry load from roof/floor apart from self weight it is called **load bearing construction.**

If reinforced cement concrete or steel frame consisting of columns, beams, slabs are built first and walls are built only to enclose the area, the load transfer is mainly by beams and columns walls carry only self weight. These walls serve as filler material. Such structures are called **framed structures.**

Load bearing construction

Load bearing walls are built with stone, brick or concrete blocks joined together by cement mortar of 1 cement to 6 sand (1: 6). The walls are built course by course. Height of a course in stone masonry, brick masonry and hollow concrete block masonry is 150 mm, 100 mm and 200 mm (or 100 mm) respectively. In load bearing walls verticality of wall should be strictly ensured and vertical joints should be broken. The thickness of wall should be sufficient to transfer the load safely, without exceeding permissible stress. The critical portions in masonry from consideration of stresses are near the openings for doors and windows and the portion where concrete beams rest.

Minimum thicknesses used are 375 mm, 200 mm and 200 mm in case of stone, brick and hollow block constructions respectively. It is also recommended that slenderness ratio of wall defined as ratio of effective length or effective height to thickness should not be more than 27. National building code of India (NBC – 1983) defines effective height and effective length as given in table 5.5 and 5.6 [for full details refer NBC – 1983.]

TABLE 5.5. Effective Height of Walls in Terms of Actual Height H

Sl. No.	*End Condition*	*Effective Height*
1.	Lateral as well as rotational restraint	0.75 H
2.	Lateral as well as rotational restraint at one end and only lateral restraint at other	0.85 H
3.	Lateral restraint but no rotational restraint at both ends	1.0 H
4.	Lateral and rotational restraint at one end and no restraint at other ends (Compound walls, parapets etc.)	1.5 H

TABLE 5.6. Effective Length of Walls of Length L

Sl. No.	*Condition of support*	*Effective Length*
1.	Continuous and supported by cross walls	0.8 L
2.	Continuous at one end and supported by cross wall at other end	0.9 L
3.	Wall supported by cross walls of each end	1.0 L
4.	Free at one end and continuous at other end	1.5 L
5.	Free at one end and supported by cross wall at other end	2.0 L

Comparison between stone masonry and brick masonry

The merits and demerits of stone masonry and brick masonry are compared in table 5.7.

TABLE 5.7. Merits and Demerits of Stone Masonry and Brick Masonry

Description	*Stone Masonry*	*Brick Masonry*
1. Strength	High	Much Less
2. Durability	Excellent	Less
3. Appearance	Beautiful. No treatment is necessary with age.	Not so good. Needs plastering and colour washing.
4. Danger from dampness	No danger	May disintegrate.
5. Skill	Skilled Labour required for dressing and placing stones.	Ordinary skill is enough.
6. Handling	Heavy. Hence handling cost is more.	Easy to handle. Hence handling cost is less.
7. Fire resistance	Less	More.
8. Moulding to desired shape	Needs skilled labour	Convenient
9. Uses	For foundations, walls in building, dams, piers and abutment.	For building load bearing and position walls.

Framed constructions

Framed construction starts with foundations for columns. Columns are then raised. Beams and floors are built simultaneously in case of R.C.C. Construction goes floor by floor. After skeleton of second floors are ready construction of walls is taken up. Construction of multistorey buildings are possible in this type of construction.

Advantage of framed construction is interior alteration of rooms is possible by removing or by constructing additional walls.

In factories steel frame structures are also used. In these cases flooring is by R.C.C. and roofing is usually with trusses supporting A.C. sheets.

5.9 COMPOSITE CONSTRUCTION

If facing and backing of walls are made using different materials it is called composite wall construction. Facing material used is always good in appearance.

The following types of composite constructions are used:

1. Stone slabs facing with brick masonry backing.
2. Dressed stone facing and brick masonry backing.
3. Brick facing with rubble stone masonry.
4. Tile facing and brick backing.
5. Brick facing and concrete backing.
6. Stone facing and concrete backing.

In all these constructions proper bond between facing and backing should be achieved. For this purpose GI or aluminium clamps may be used. In case of brick facing alternate courses of bricks are projected inside backing. Rich plaster is used between facing and backing materials.

Figure 5.1 shows stone slab facing with brick masonry backing.

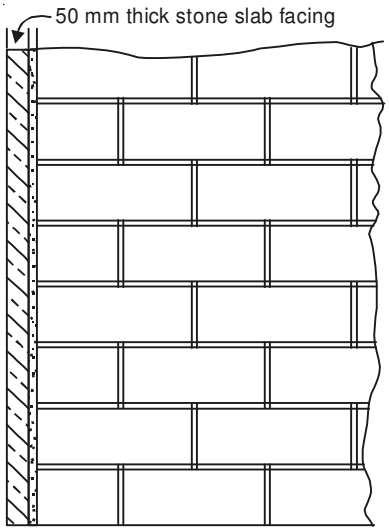

Fig. 5.1. *Composite masonry—stone facing with brick masonry backing*

Questions

1. Distinguish between dead load and imposed load in a building. How their values are assessed 1 ?

Why and how much reduction in imposed load is suggested in design of supporting structural elements ?

2. Write short notes on

(*a*) Wind loads

(*b*) Snow loads

(*c*) Earthquake forces

3. Distinguish between load bearing and framed construction. Discuss the advantages and disadvantages of them.

4. Write short note on 'composite construction'.

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CHAPTER VI

Introduction to Automation in Construction

Huge amount of money is invested in the construction of buildings bridges and roads. Economical consideration needs earliest use of the investment and hence present day demand is automation in construction. To meet this challenge lot of research has gone into and a number of techniques are developed. In this chapter the automation in buildings, dams, bridges and road constructions are briefly discussed.

6.1 AUTOMATION IN BUILDING CONSTRUCTION

6.1.1 Digging for Foundation

Any construction work starts with digging for foundation. Nowadays manual digging for foundation is almost given up in all cities and towns. JCB is used for this purpose which can finish digging work for most of the buildings in a day or two.

6.1.2 Mining, Lifting, Transporting and Placing of Concrete

Labour oriented method of mixing, lifting, transporting and placing of concrete needs to be changed to mechanisation of concreting. Without it speed and economy cannot be achieved in construction.

Batching and mixing plants

In *large projects* like dam construction or in ready mixed concrete plants large batching and mixing plants are used. Ready mixed concreting is new concept in which concrete mixing is done in large plants and then transported to needy places in the city. The capacity of such plants varies from 120-150 cubic metre per hour. These concrete production plant comprise of:

1. Silos, containers and bins for storage of raw materials.
2. Batching arrangement.
3. Measuring and recording equipment.
4. Mixing equipment.

5. Control system.

6. Electrical, hydraulic and pneumatic drives.

7. Conveying systems like belt/screw conveyors.

Cement is generally stored in silos. The silos are loaded with cement with the help of pneumatic blowers. If bagged cement is used then tree cement is loaded using compressed air loader and a splitter unit.

Water is generally stored in tanks located close to the plant.

Aggregates are stored in silos. A storage capacity of 1500 m^3 is possible.

Cement silos are provided with weigh hoppers which use knife edge balance principle. Larger plants use electromechanical system. For measuring water a water meter or a water batch is used. The aggregates weighers are generally identical to the cement weighers in the plant.

The aggregates and cement are first dry mixed in hoppers using scrappers.

Provision is made upto four types of concrete admixtures to be added with required quantity.

Free fall or power mixers are used for thorough mixing of concrete.

Fully automatic plant control systems with multiple inputs are based in a container or control room.

Figure 6.1 shows a typical batching plant and Fig. 6.2 shows a microprocessor control system in a mining plant.

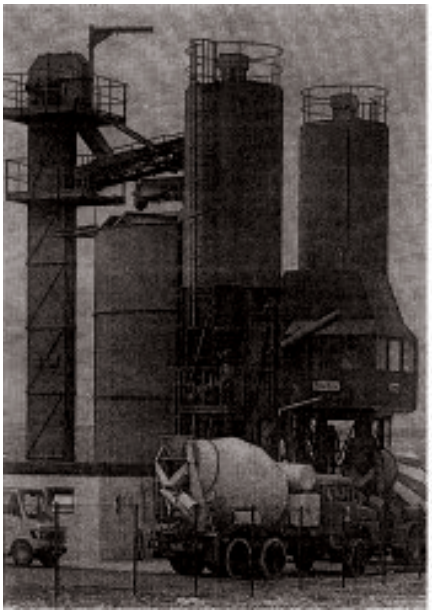

Fig. 6.1. *Concrete batching plant*

Fig. 6.2. *Microprocessor control system in concrete batching mixing plant.*

Transportation and Placing

Various modes of transporting concrete are truck agitators, truck miners, cranes, buckets, elevators, belt conveyors, concrete pumps, chutes etc. The suitability of method of mechanical transportation varies from job site to job sites. Often combination of various methods is also used. It may be noted that truck agitators, truck miners are useful for horizontal transport, while cranes, buckets,

elevators, belt conveyors and pumps are useful for vertical transport. Chutes are useful for dropping concrete in intricate portions.

Minibatching plants are suitable for projects like national highways, flyover, mass housing and industrial projects. They have the capacity of 15 to 20 m^3 per hour. The plant includes:

1. In built weighing system for fine and coarse aggregates.
2. Automated loading system for aggregates.
3. Cement hopper with weighing system.
4. Automatic admixture dozing system.
5. Print out system giving details of batching and mixing.

Figure 6.3 shows a mini batching plant.

Fig. 6.3. *Mini batching plant*

6.1.3 Self Compacting Concrete (SCC)

Self compacting concrete (SCC) as the name signifies should be able to compact itself without any additional vibrations or compaction. It was first developed in late 1980s. It is highly flowable within the form work and fills it without any external vibration. This is used to ensure the filling of congested sections. It includes the high amount of super plasticizers and cement to increase flowability. Viscosity agents are also added. The mix may incorporate steel or polypropylene fibres also. The sand can be finer.

In Sweden bridges are built with SCC. In Japan two anchor blocks were constructed in Akashi-Kailro bridge. In France SCC is preferred in cities as noise free concreting. Since there is no vibrations in compacting, form works can be reused several time. Use of SCC is becoming popular in precast industries also.

6.1.4 Prefabricated Structural Elements

Use of prefabricated structural elements increases construction speed and quality of structural element. It saves time because casting of these elements can start much early in factories much before they are to be put in the building. For building activity requirement of time is only for putting them in the structure. Some of the commonly used prefabricated structural elements are :

1. **Precast concrete portions:** Precast concrete posts and panels of sizes 1000 × 400 × 40 mm are as shown in Fig 6.4.

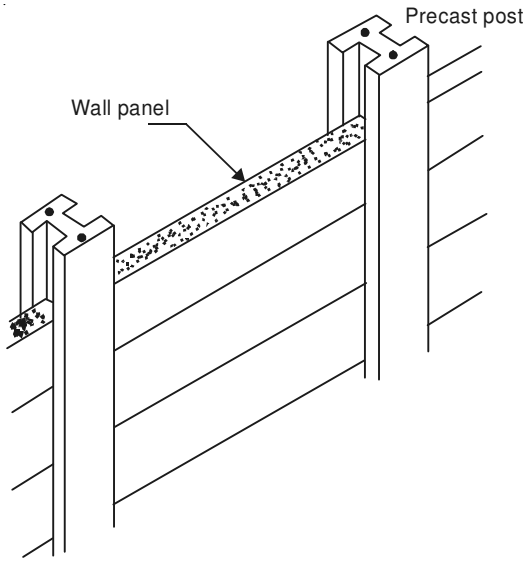

Fig. 6.4. *Precast concrete posts and panels.*

Fig. 6.5. *Prefabricated roof truss and reapers for Mangalore tiled roof*

2. **Precast roofing units:** In Pune, universal temple of Ramakrishna was built with suitable elements to form required geometric forms of Shikharas. The technique of using precast elements has saved construction time by at least 6 to 8 months. After erecting shell units the outer surface of roofs and domes are covered with Glass Mosaic Tiles laid in polymer modified tile adhesive, giving excellent aesthetic view and weather proofing.

3. **Lift slab construction:** In this constructions, slabs are cast at ground level one over the other with separators in between. Then slabs are lifted along columns to their positions using cranes or jacks and clamped. This process has been applied on a two storeyed building built at Roorkee by Central Building Research Institute. It is possible to extend the technique to multistoreyed structures with several floors. In America this has been tried successfully.

6.1.5 Form Works

Providing form works takes of considerable time in building construction. Convention method of providing wooden form work needs modernisation. Steel form works consisting of steel plates, rods and pipes is gradually replacing conventional wooden form work. Steel form work is speedy; give good finished surface and safe too.

In the construction of silos and chimneys slip forms are used. The form work is clamped to already built portion of the structure with about 1 to 1.5 m protection. As the upper portion is built, form work is slided up and fixed to newly cast portion. It saves cost of form work and speeds up the construction activity.

6.1.6 Application of Robots for Building Automation

It is desirable to have robots for building automation to reduce hazards at work sites, improve quality and reduce the cost of construction. However there are many problems in the development of robots for construction industry such as:

1. Large loads.
2. Components of variable sizes to be handled.
3. Adverse weather conditions such as variable humidity and temperature.
4. Dust and dirt.
5. Need for three dimensional movement.
6. Each site having different size and shape.

Some of the robotic applications developed are

1. For inspection of interiors of pipes and drainage conduits.
2. To detects voids around sewers and offshore pipes.
3. For excavation for slurry filled foundations.
4. Human-machine inferface semi automated earth movers.
5. Concrete cutters and crushers to dismantle concrete structures without creating noise and air pollution.
6. For plastering : An encouraging result has been achieved in this area. Robots that can plaster 1.0 m^2 area with 15 mm plaster in only one minute have been developed. Manually the same work needs 30 minute. Sri. B. Srinivas Rao, associate professor, Department of Civil Enginneering, University College of Engg. Osmania Unversity, Hyderabad reports that for external plastering of 15050 m^2 area in 11 storey complex with 15 mm thick 1: 4 plaster total cost with robot plastering worked out Rs. 2,46,988 = 00 whereas it would have cost Rs. 7,09,700 = 00 if conventional method was used. The whole work was completed in 9 days only whereas conventional plastering would have taken 54 days.

Lot of research and development is required to develop robots for construction works since nowadays good number of multistorey buildings are coming up.

6.2 AUTOMATION IN DAM CONSTRUCTION

Dam construction is highly mechanised. In earthen dam constructions heavy machineries are used for digging, transporting, placing and consolidating required soil. Concreting is also highly mechanised.

6.3 AUTOMATION IN BRIDGE CONSTRUCTION

Modern trend in bridge construction is to use precast construction. Superstructure of bridge is cast in parts and erected on the site.

Noida bridge connecting Delhi and Noida provides an eight lane link of 552 m across river Yamuna. The superstructure was cast in 13 spans of 42.5 m. Maximum weight of precast segment was 100 tonnes. Erection was done using launching truss.

JJ hospital flyover in Mumbai is the most elegant and longest elevated road in India. For this casting yard could be located at 20 km away from the site. To facilitate transportation and erection it was cast in several segments and connected at site.

120 m arch foot bridge across river Seonyce in Seoul, South Korea was built in six precast segment and erected at site. Ultra strength concrete (compressive strength 200 N/mm^2) was used for casting segments.

In Panval Nadi viaduct precast box girders were erected using launching girders and pushing the girder by jacks.

6.4 AUTOMATION IN ROAD CONSTRUCTION

A number of machines are used to mix, transport, place, compact and level the asphalt on super highways. Concreting is also mechanised in these construction.

Questions

1. Why there is need for automation in construction?
2. Explain the automation achieved in batching, mixing, transporting and placing of concrete.
3. Write short notes on:
   (*a*) Self compacting concrete.
   (*b*) Prefabricated structural elements.
   (*c*) Application of Robots in building automation.
   (*d*) Automation in bridge constructions.

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CHAPTER VII

Introduction to Surveying

Surveying is an art of making measurements of objects on, above or beneath the ground to show their relative positions on paper. The relative position required is either horizontal or vertical or both.

Less precisely, the term 'surveying' is used to the operations directed to the measurements of objects in their horizontal position. Art of measurements to determine their relative vertical position is known as levelling.

7.1 MAPS

A map may be defined as the graphical representation of the features on, near or below the surface of the earth as projected on a horizontal plane to a suitable scale. However, since the surface of the earth is curved and that of paper is plane, no part of the earth can be represented on such maps without distortion. If the area to be represented is small, the distortion is less and large scale can be used. Such representations are called plans. If the area to be represented is large, small scales are to be used and distortion is large. Representation of larger areas are called maps. Representation of a campus, a locality in a municipal area are plans while representation of a district/state/country are maps. There is no exact demarkating line between a plan and a map.

Map showing details of natural features like rivers, streams, lakes, hills and forest as well as man-made features like roads, railways, dams, canals, villages and towns are called topo maps or topographical maps. They also show contour lines and positions of Great Trignometric Survey (GTS) bench marks. One can purchase these maps of various parts of India from the department known as 'Survey of India' by contacting Surveyor General's office, PB No. 37, Dehradun-248001. This is the department which has prepared the topo maps and keeps on updating them regularly as and when new features are added.

7.2 USES OF MAPS

Various uses of maps are listed below.

1. Maps prepared to show countries, states, districts etc. avoid disputes.
2. Plans prepared to record the property lines of private, public and governments (land records) help in avoiding unnecessary controversies.

3. Topo maps showing natural and man-made features help in planning irrigation projects, flood control measures, road and railway routes, and other engineering projects.
4. Road maps help travellers to plan their programmes.
5. Locality plans helps in identifying houses and office locations.
6. Plans prepared after mine surveys help in systematically exploring mineral wealth.
7. Geological maps showing different strata in the earth crust help in selecting sites for man-made reservoirs.
8. Archaeological maps are prepared for unearthing relics of antiquity.
9. Military plans help in strategic planning.

Thus, the maps prepared for various purposes are the basis for many engineering projects and useful in day-to-day life.

7.3 METHODS OF LOCATING A POINT WITH RESPECT TO TWO REFERENCE POINTS

Two points are selected in the field and distance between them is measured. Using suitable scale those two points are plotted on the paper. With respect to those two points any other point in the field may be located by linear measurements only or by linear and angular measurements or only by angular measurements as shown in Fig 7.1.

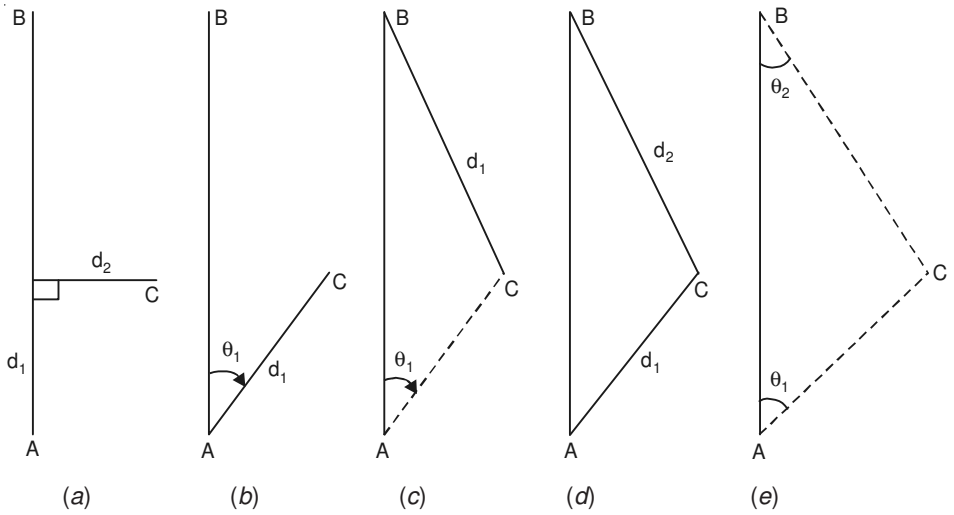


Fig. 7.1. *Locating point C w.r.t. AB*

7.4 PRINCIPLE OF SURVEYING

To get accurate results one should follow the two basic principles explained below:

1. Working from Whole to Part

In surveying large areas, a set of control points are identified and they are located with the highest precision. Then secondary control points are located using less precise methods. With respect to lines connecting secondary control points, the details of localised areas are measured and plotted.

This is called working from whole to part. This principle helps in localising the errors. If the surveying is carried out by adding localised areas one to other, the errors accumulate and the maps will be erroneous.

2. Fixing Positions of New Control Points

For fixing new control points (stations) with respect to already fixed points, at least two independent processes should be followed. If A and B are two already located control points and with respect to them a new control point C is to be located, apart from the minimum measurements required as shown in Fig. 7.1, one more reading should be taken. Fixing of check lines and tie lines will also serve this process (Ref. Fig. 7.2)

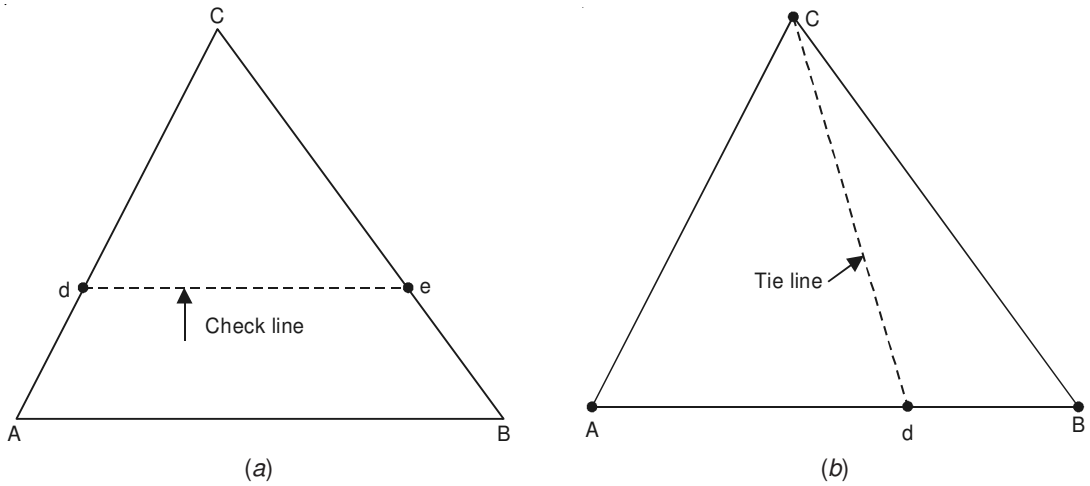


Fig. 7.2. *Check line and tie line*

7.5 MODERN SURVEY METHODS

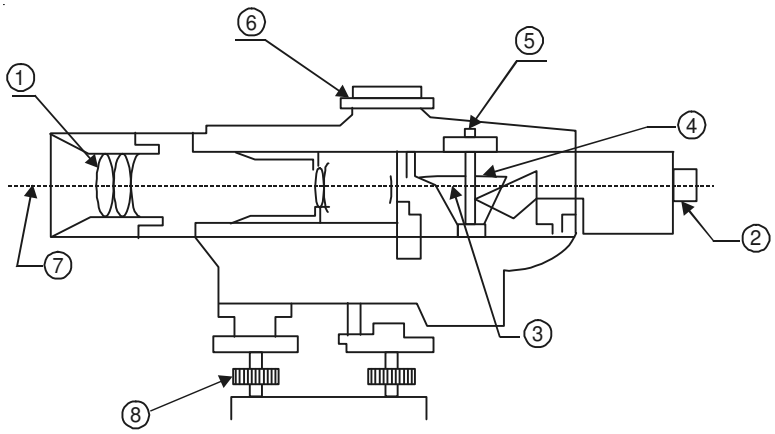
Earlier, chain and tapes were used for measurement of distances and compass for measuring the direction of survey lines. These methods are still used in surveying small areas. There are number of difficulties in measurement in difficult terrain. Bushes, ponds and rivers are some of the obstacles for chaining and taping. Steel structures and objects attract compass needles and distort angle measurements. Magnetic declination at a site varies from time to time. In compass survey, this correction is required. To overcome these difficulties many survey equipments are developed and surveying is made more accurate and fast. Some of these methods are presented in this article.

7.5.1 Use of Modern Levels

Earlier, dumpy levels which consists of a telescope, a level tube and levelling head was used for finding the difference between horizontal sight from level to the ground point where graduated staff is held. The axis of level tube and line of sight through telescope are fixed parallel to each other. Levelling head consist of two parallel plates with three or four foot screws. Lower plate is screwed on to a tripod stand. By operating foot screws, top plate to which telescope is fitted, is tilted till level tube is centered. In this position, horizontal line of sight is obtained.

Nowadays auto levels have been developed. Levelling of the instrument is simplified. Within a certain tilt range automatic levelling is achieved by an inclination compensating device. This

device is called tilt compensator which is suspended like a pendulum and inserted in the path of light rays through the telescope [Ref. Fig 7.3]. The operation comfort, high speed and precision are the advantages of this instruments. The plate 7.1 shows a dumpy level and plate 7.2 shows a typical auto level.



1. Objective Lens
2. Eye Piece
3. Compensator Object
4. Compensator Suspension
5. Magnetic Dampening System
6. Sighting Collimator
7. Line of Sight
8. Foot Screws

Fig. 7.3. *Auto Level—Cross Sectional View.*

Plate 7.1

Plate 7.2

Next modernisation of levels is introduction of precise levels. In this centering of the bubble can be checked simultaneously while taking staff reading since by an arrangement known as coincidence system the split image of the ends of bubble of level tube appear in a portion of line of sight. When the bubble is centered the split ends appears to coincide and form a U-shaped curve as shown in Fig. 7.4.

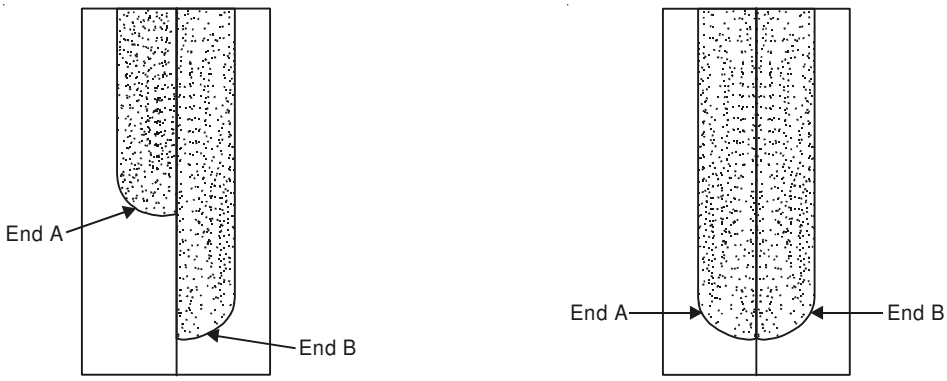


Fig. 7.4

In precise levels fraction of a levelling staff also can be read accurately since optical micrometers are provided. Optical micrometer is a device which can be built into the instrument itself or it may be attached to the instrument externally. It consists of a thick glass plate the rotation of which deviates the line of sight and hence enables fractional reading of levelling staff minimum graduation.

Precise level is used with precise staff, which can be held to the ground firmly with the help of metal shoe and the verticality of which can be checked with a circular bubble tube attached.

7.5.2 Theodolites

Theodolite is a commonly used instrument for measuring horizontal and vertical angles. Plate 7.3 shows a typical theodolite.

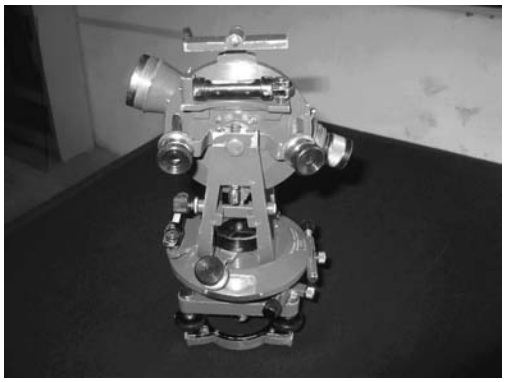


Plate 7.3

It consists of levelling head, two horizontal plates, a telescope and a vertical circle. Levelling head is similar to that of a level and is used to fix the instrument to the stand and level it by operating foot screws. Lower plate carries a graduated circle at its bevelled edge. The graduations

are divided into 360° and each degree is further divided into 20′ intervals. Upper plate carries two verniers fixed diametrically opposite to each other. They are provided with clamps. With the help of clamps both plates can be clamped together or only lower plate can be clamped. If a horizontal angle PAQ [Fig. 7.5] is to be measured with instrument at A, the following procedure may be followed.

1. Clamp both plates with vernier reading zero.
2. Direct the telescope to sight P and then clamp the lower plate.
3. Release the upper plate clamp, and direct telescope to sight *Q*. Then clamp the plate.
4. Take reading on graduated circle with the help of verniers. It gives angle *PAQ*.

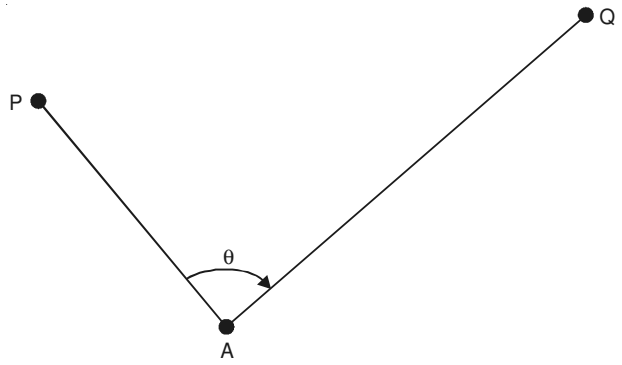


Fig. 7.5.

Vertical graduation circle rigidly connected to telescope. The circle is graduated up to an accuracy of 20′. The graduations are from 0 to +90° and 0 to –90°. Zero-zero graduation represents horizontal sight. Plus graduations correspond to upward angles while minus graduations correspond to downward angles. With the help of verniers provided on the frame accurate readings can be taken up to 20″.

In precise, theodolites optical micrometers are provided which help in reading angles to an accuracy of even 1″. Such theodolites are provided with optical plummet to precisely set the instrument on the selected ground point.

Electronic digital theodolites are having all the features of optical theodolites. In addition to them they are having digital display using light emitating diodes (LEDs) or liquid crystal diodes (LCDs). The digital display is automatically read and recorded in a solid state memory device which can be processed by a computer. The reading can be switched over from one circle to another by using push over switch.

7.5.3 Electro Magnetic Distance Measurement (EDM)

In these instruments distance measurement is based on propagation, reflection and reception of either radio or visible light or infrared waves. In these instruments, radio or light waves are generated and then propagated. They are reflected at the point up to which distance is to be measured from the instrument stations and again received by the instrument. Earlier, attempts was to measure time taken to travel this length of 2*x* and find the distance, since the velocity of wave is known. Since time taken is only a fraction of second not much success is reported in this method. The improved technique uses phase difference method in which the length of the wave is modulated and the number of completed and a fraction of incompleted wavelength is measured.

Then the distance travelled is calculated. EDM instruments have built-in microprocessors which provide horizontal and vertical distances.

EDM instruments may be broadly classified into the following three types :

1. Infrared wave instruments
2. Visible light wave instruments
3. Microwave instruments.

Infrared Wave Instruments: In these instruments amplitude modulated infrared waves are used. At the end of the line, prisms are used to reflect the waves. These instruments are light and economical and can be mounted on theodolite. With these instruments, accuracy achieved is ± 10 mm per kilometre. The range is up to 3 km. These instruments are useful for most of the civil engineering projects. Wild Heerburg Company manufactures these instruments under the trade names DISTOMAT DI 1000 and DISTOMAT DI 15.

Visible Light Wave Instruments: These instruments rely on propagation of modulated light waves of 5×10^{14} Hz frequency. This was developed in Sweden and is called Geodimeter. The EDM instruments in this category are having a range of 25 km at an accuracy of ± 0.2 mm to ± 1.0 mm.

Microwave Instruments: These instruments make use of high frequency (microwave) radio waves of 3 to 300 GHz. These instruments were invented as early as 1950 in South Africa by Dr. T.L. Wadley and they were called as Tellurometers. The instrument needs only 12 or 24 volt batteries. Hence, they are light and portable. The range of these instruments are 100 km with an accuracy of 5 to 15 mm/km. Tellurometer consists of two identical units. One instrument is used as master unit and the other as remote unit. By pressing a button, a master unit can be converted to a remote unit and a remote unit can be converted to a master unit. It needs two skilled persons to operate. A speech facility is provided to each operator to interact during measurement.

7.5.4 Laser Instruments

Laser theodolites and laser alignment instruments are also available for surveyors. The laser adaptor enables observer to centre the laser beam very accurately on the target Laser (Light Amplification by Simulated Emission of Radiation) alignment instruments produce a laser beam which is a visible straight line. They have wide range applications in alignment and setting out works of roads, railways, pipe lines, tunnelling, mining and base line surveys. Laser attachments mounted on the telescope of theodolites are called as laser theodolite.

7.5.5 Total Station

Electronic theodolite combined with electromagnetic distance meter (EDM), microprocessor, electronic data collector and storage system form a total station. The instrument can be used to measure vertical and horizontal angles as well as to measure distances. Microprocessor in the total station reduces the observed data to horizontal distance, vertical distance, horizontal angle, vertical angle and difference in elevation and coordinates. The data is collected on an electronic book which can be used for downloading the data to computers and reused. Using suitable software, the data downloaded on computer can be used for plotting. A typical total station is shown in plate 7.4.

Plate 7.4.

Presently, the total stations are costly but looking at their usefulness in quick processing and accuracy they are becoming popular. Similar to any other electronic equipments, their prices are coming down and hence the day may not be far off when total stations will replace all other survey instruments.

7.5.6 Global Positioning System

The station points used in surveying are to be identified before any project work is undertaken. For this surveyor used permanent objects like building corners, culvert edges, electric poles etc. as reference points. Navigators used sun and stars. Sometimes so-called permanent objects may not exist when the execution of project work is taken up or weather conditions may obstruct the observations. Nowadays, this problem is overcome by using an instrument called Global Positioning System (GPS). This was doveloped by United States defence department and was called as Navigational System with Time and Ranging Global Positioning System (NAVSTARGPS) or simply GPS.

There are 24 satellites positioned around the earth by U.S. air force. These satellites are used as reference points to locate a point on the earth. These satellites are at an altitude of 20200 km above the earth. The 24 satellites are positioned such that, from any point on earth a minimum of 4 satellites are visible.

The users needs only GPS receiver. The receiver measures the travel time of the signals from satellites and calculates position (latitude and longitude) and elevation with respect to a selected datum. The uses of GPS are in:

1. Marine navigation
2. Airborne aviation
3. Surveying of lands
4. Sports such as yatching and hiking.
5. Guiding automobile drivers to their destination.

The advantages of using GPS are

1. Can be used in day as well as in nights.
2. Intervisibility of station points on land not required.
3. Time required is much less.
4. Man power required is less.
5. High accuracy is achieved. GPS provides accuracies within a centimeter.

7.6 INTRODUCTION TO DIGITAL MAPPING

Maps are pictorial presentation of spatial objects on or near earths surface on a flat surface to a suitable scale. The scale selected is such that the map can be shown on a paper of convenient size. Digital mapping involves storing, analysing and presenting spatial data.

Maps may be classified on the basis of their thematic content and scale. The thematic content of map may be land use, nature of soils, roads, railways, layout of cities or location of hotels etc. The map depicting natural objects like rivers, mountains, forest, lakes as well as man-made objects like roads, railways, dams etc. are called as topographic maps. The scale represents unit distance on paper to the distance on field. For example, a scale of 1:1000 means 1 cm on paper represents 1000 cm (= 10 m) on field. Based on scale maps are classified as

(*i*) large if greater than 1 : 1000

(*ii*) intermediate if between 1 : 1000 to 1 : 10,000 and

(*iii*) small if more than 1 : 10,000.

After deciding the thematic content and scale, the features (spatial entities) are selected which are to be shown on map. Then method of showing the features as points, lines or as areas is decided.

The data collected about the features are to be projected for placing them on to flat piece of paper. There are hundreds of different map projections. Most commonly used projections are

(*i*) Cylindrical projection

(*ii*) Azimuthal projection, and

(*iii*) Conic projections.

The computer carries out all these calculations and readies the data for projecting on flat surface.

To this data storage spatial reference system is applied to locate the features relative to each other. The usual reference system is latitudes and longitudes of the earths surface.

Then the digital data is annotated with legends and texts to facilitate use of the map.

The Relational Database Management Scheme (RDBMS) of storing these data help in viewing more than one theme at a time on computer scheme or to get printed on paper with the help of plotter. Some of the advantage of digital mapping are listed below :

1. Map making is quick.
2. Scales of map can be easily changed and viewed.
3. Maps can be made as per users need by clubbing only required theme of data.
4. Updating the existing map with latest information is neat and easy.
5. Creating maps like 3-Dimension type is easy.

7.7 DIGITAL PLANIMETER FOR MEASURING AREAS FROM MAPS

Planimeters are devices used to measure areas on maps, drawings or blueprints.

The mechanical (non-digital) planimeters were first to be developed [Fig. 7.6]. They consist of pole arm and tracer arms hinged together and a recording wheel. The recording wheel consists of a hard steel graduated roller and a disc.

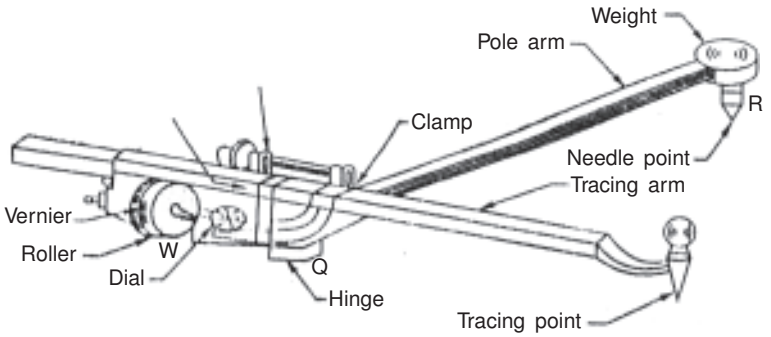


Fig. 7.6. *Non-digital planimeter*

A suitable gear system moves a pointer on disc by one division for every one revolution of the roller. The vernier helps in reading fraction of revolutions made. As tracer point provided at the end of tracer arm is moved along the boundary of map to be measured roller makes revolutions. Since the plane of the wheel is perpendicular to the plane of tracer arm, the wheel measures only normal displacement. This movement can be calibrated to measure the area of the map.

Now, digital planimeters have been developed which directly display the area measured. There is no need to read verniers and calibrate the planimeter manually. There is provision for selecting units like cm^2, m^2, km^2 or in^2, ft^2, acres. For this, scale of map is to be set. If the value of area measured exceeds the capacity of planimeter, it automatically switches over to higher units and continue to record measurement.

To measure the area of map the outline of the map is to be traced completely with the tracer point. The revolutions of the measuring wheel to either direction is sensed by the electroshaft encoder which generates pulses to be processed by the built in processor. The area measured is displayed. 6 to 8 digit planimeters are available.

The displayed area may be held by operating held button and retraced to measure the area again. The average of the area measured can be automatically obtained. By pressing release button zero setting can be obtained.

There are two types of digital planimeters—roller type and fixed type [plate 7.5 and 7.6]. Roller type digital planimeters can be used to measure areas of larger maps while in the other one map is to be divided in different parts and measurements can be made. Of course, the measured values of parts can be automatically added.

Plate 7.5

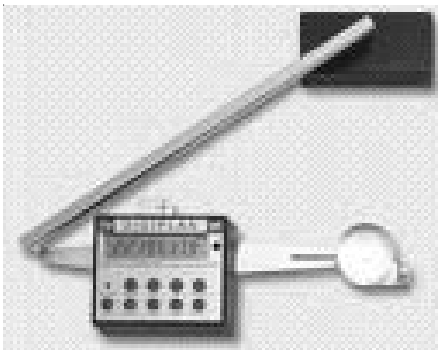


Plate 7.6

Best results are obtained if the map is smooth but not glossy. Photos or laminated maps increase the chances of the measuring wheel slipping, which will result in inaccurate measurements. Folds on the maps cause problems in getting correct measurements.

All digital planimeters are provided with 24 to 30 hour battery back-ups. If necessary, they can be directly connected to power supply.

The advantages of digital planimeters are

1. Choice of metric or English unit is available.
2. No need for calibration each time.
3. Digital display which is easy to read.
4. Automatic averaging, if used repeatedly to get more accurate results. (Hold buttons is to be pressed after each reading is taken).
5. Zero setting by push button.
6. Higher accuracy.
7. Downloading the area measured to computers for further processing.

Questions

1. Differentiate between plan and map.
2. List various uses of maps.
3. Explain the principles of surveying.
4. Write short notes on
   (*a*) Auto levels
   (*b*) Precise levels
5. Briefly explain main parts of theodolite.
6. What is meant by EDM? Briefly explain different types of EDMs.
7. Write short notes on
   (*a*) Total Station
   (*b*) Global Positioning System
8. What is digital mapping ? What are its advantages over ordinary mapping?
9. Write short note on 'Digital Planimeter'.

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CHAPTER VIII

Introduction to Levelling

Levelling is an art and science of determining the elevations of given points or establishing given points at required height above or below a datum line. It involves measurements in vertical plane. Some of the applications of levelling are to fix the plinth levels of a building, to align road, canal and sewage or to determine the capacity of tanks.

In this chapter, some of the definitions used in levelling are explained and introduction is given to simple and differential levelling for setting out various benchmarks, determining the elevations of different points and for preparation of contour maps.

8.1 DEFINITIONS OF BASIC TERMS USED IN LEVELLING

1. Level Surface

Any surface parallel to the mean spheroid of the earth is called a level surface and the line drawn on the level surface is known as a level line. Figure 8.1 shows a level surface. Thus a level surface is a curved surface, which is equidistant from the centre of the earth.

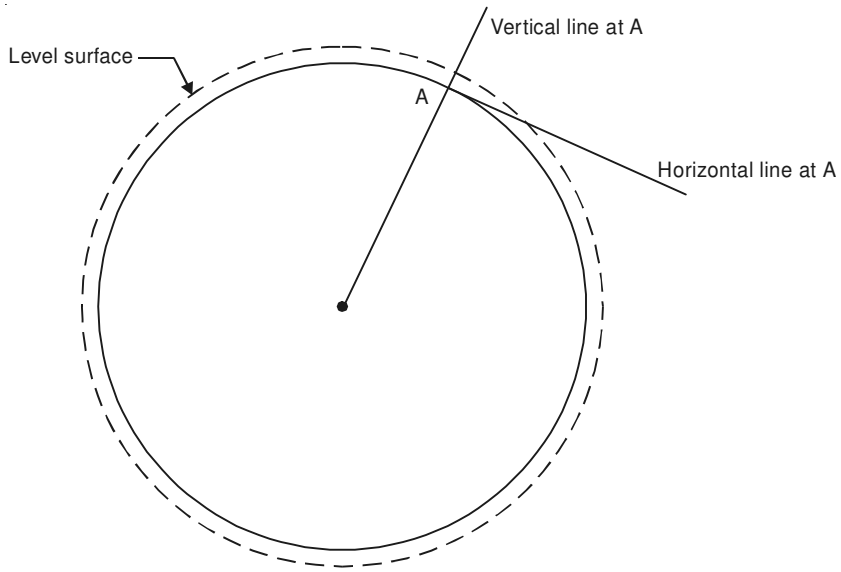


Fig. 8.1.

2. Horizontal Surface

Surface tangential to level surface at a given point is called horizontal surface at that point. When levelling is involved in small areas, there may not be much difference in horizontal and level surface but when large areas are involved there is considerable difference.

3. Vertical Line

It is the line connecting centre of the earth and the point. At any point, it is easily located by a freely suspended plumb-bob.

4. Datum

The point or the surface with respect to which levels of other points are determined is called datum or datum surface. In preparing maps of large areas like a country mean sea level is taken as datum while in local projects level of some permanent objects are taken as datum.

5. Reduced Levels (RL)

The levels of various points taken as heights above or below the datum surfaces are known as reduced levels.

6. Benchmark

It is a relatively permanent point of reference whose elevation with respect to some assumed datum is known. It is a starting and ending point in levelling. The following four types of bench-marks are commonly used :

(*i*) GTS benchmarks

(*ii*) Permanent benchmarks

(*iii*) Arbitrary benchmarks, and

(*iv*) Temporary benchmarks.

(i) GTS Benchmarks: The long form of GTS benchmark is Great Trigonometric Survey benchmark. They are established by national agencies such as survey of India. They are established with the highest accuracy at several locations all over the country, with respect to mean sea level. Survey of India has used mean sea level of Karachi (Pakistan) as datum. These benchmarks are indicated on a brass plate fixed on a concrete pedestal with well-protected wall around it.

(ii) Permanent Benchmarks: These are fixed points of reference, established with respect to GTS benchmarks. State Government agencies like public works department fix such bench marks.

(iii) Arbitrary Benchmarks: In many engineering projects, the difference in elevation is more important than reduced level with respect to mean sea level. In such cases, the elevation of a permanent structure like corner of plinth of a building may be assumed to have arbitrary reduced level such as 100.00 m or 200.00 m. These benchmarks are quite useful in small projects.

(iv) Temporary Benchmarks: These benchmarks are established at the end of the days work, so that the work can be continued next day from that point onward.

8.2 PRINCIPLE OF DIRECT LEVELLING

In direct levelling, it is assumed that when an instrument is properly levelled, line of sight is truly horizontal and the vertical axis is truly vertical. The graduated staff is held vertically on a bench mark and the reading is taken. This is the difference in the elevations of bench mark and the line

of sight. Hence, by adding this reading to the reduced level of benchmark, level of line of sight is obtained. Then staff is moved and held at the point, the elevation of which is required and the reading is taken from the levelling instrument without disturbing its height of line of sight. Hence, by subtracting their reading in the level of sight, elevation of the place where staff is held, is obtained.

If distances are small compared to the radius of the earth, there is hardly any difference in horizontal surface and level surface. Hence horizontal lines are considered as level lines.

8.3 TYPES OF LEVELLING

The following are some of the types of levelling:

1. Simple levelling
2. Differential levelling
3. Fly levelling
4. Profile levelling
5. Cross sectioning, and
6. Reciprocal levelling

First two types of levelling are explained in this article. Before that the reader should understand the following terms:

1. Back sight
2. Fore sight
3. Intermediate sight, and
4. Change point.

1. Back Sight : It is the sight taken on a level staff, held at a point of known elevation with an intention of determining the plane of collimation (elevation of line of sight). It is always the first reading after setting the instrument. When this reading is added to the reduced level of the staff point, plane of collimation is obtained.

2. Fore Sight : This is the last reading taken from an instrument. After this reading is taken the instrument is shifted. When this reading is subtracted from the plane of collimation, the R.L. of point where staff is held, is obtained.

3. Intermediate Sight : Excluding back sight and fore sight all other readings taken from an instrument stations are called intermediate sights. When these readings are subtracted from plane of collimation, the R.L. of points where staff is held, are obtained.

4. Change Point : This is also known as turning point. This is the point on which fore sight is taken and then instrument is shifted to new position and then back sight is taken. Thus, it facilitates shifting of the instrument maintaining continuity in the levelling.

8.3.1 Simple Levelling

When difference in levels of two nearby points are required, it is obtained by simple levelling. Two points are so near that with one setting of the level, the reading on both points can be obtained.

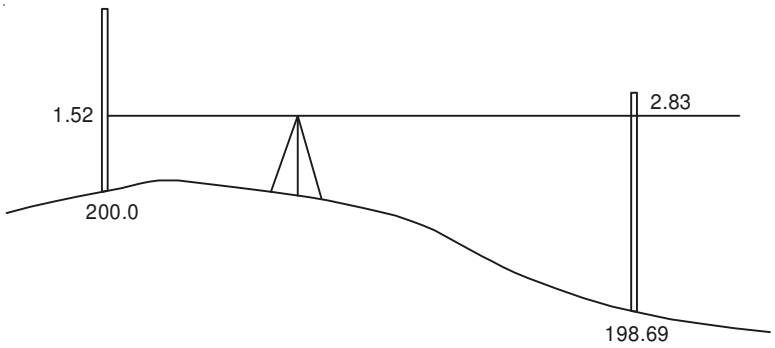


Fig. 8.2. *Simple levelling*

Figure 8.2 shows one such case. Let the reduced level of point A be 200.0m and R.L. of point B is required.

Back sight is = 1.52 m

∴ Plane of collimation = R.L. of A + Back sight on A

= 200.00 + 1.52 = 201.52 m

Fore sight on B is 2.83 m.

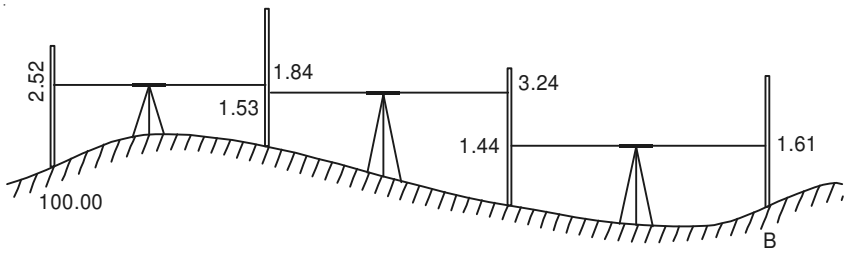
∴ R.L. of B = Plane of collimation – Fore sight on B

= 201.52 – 2.83 = 198.69 m.

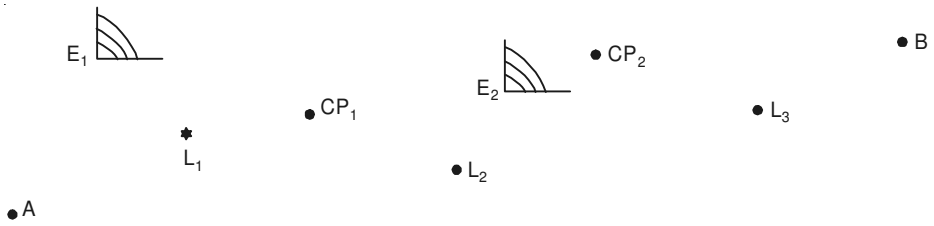
It may be noted that the instrument position need not be along the line AB (in plan) and the R.L of instrument position do not appear in the calculations.

8.3.2 Differential Levelling

If the distance between the two points A and B is too large, it will not be possible to take the readings from a single setting of the instrument. In such situations, differential levelling may be carried out. This method needs setting of instrument at more than one point, each shifting facilitated by a change point. Figure 8.3 shows a scheme of such levelling.



(*a*) Elevation



(*b*) Plan

Fig. 8.3. *Differential levelling*

In this case, instrument is first set at L_1 and back sight is taken on A. Then change point CP_1 is selected and fore sight is taken from L_1. Now instrument is shifted to L_2 and back sight is taken on CP_1. Next staff is shifted to CP_2 and fore sight is taken from instrument at L_2. After this instrument is shifted to L_3 and set. Back sight is taken to staff held at CP_2 and then fore sight is taken to point B. If RL of A is 100.00 m, R.L. of B can be found as follows :

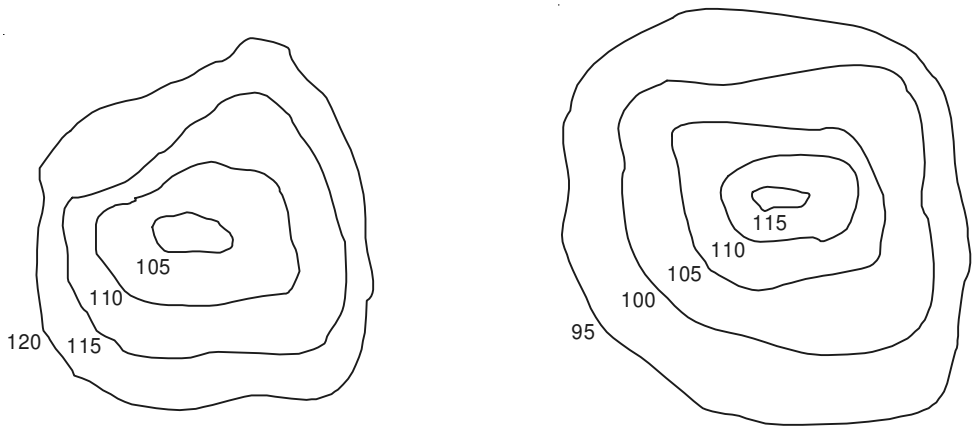
R.L of A = 100.00 m.
Back sight on A = 2.52 m.
∴ Plane of collimation at L_1 = 100 + 2.52 = 102.52 m.
Fore sight to CP_1 = 1.82 m.
∴ R.L of CP_1 = 102.52 – 1.84 = 100.68 m.
Back sight to CP_1 from L_2 = 1.53 m.
∴ Plane of collimation at L_2 = 100.68 + 1.53 = 102.21 m.
Fore sight to CP_2 from L_2 = 3.24 m.
∴ R.L of CP_2 = 102.21 – 3.24 = 98.97 m.
Back sight to CP_2 from L_3 = 1.44 m.
∴ Plane of collimation at L_3 = 98.97 + 1.44 = 100.41 m.
Fore sight to B = 1.61 m.
∴ R.L of B = 100.41 – 1.61 = 98.80 m.

If there are intermediate sights to E_1, E_2 etc., the RL of those points can be obtained by subtracting intermediate sight on them from the corresponding plane of collimation of observations.

Differential levelling is used for setting out various benchmarks and for determining elevation of different points.

8.4 PREPARATION OF CONTOUR MAPS

A contour line is the imaginary line which connects points of equal elevations. These lines are drawn on the plan of an area keeping vertical distance between two consecutive contour lines constant. This constant vertical distance is called contour interval. Figure 8.4 shows typical contour lines. Figure 8.4 (*a*) shows a pond and Fig. 8.4 (*b*) shows a hill. From contours nature of terrain can be observed.



(*a*) Contours of a pond (*b*) Contours of a hill

Fig. 8.4.

To prepare contour map of an area, three coordinates of various points are required. The two horizontal coordinates fix the position of points in plan while vertical coordinate obtained by levelling gives the elevation of point. After fixing horizontal positions and vertical coordinates of several points contour lines can be drawn connecting points of equal elevations. Points on contour lines are located by observation or by mathematical interpolation.

In small areas horizontal control is established by plane table surveys. In larger areas it may be by block levelling or by cross sectional levelling or by radial lines surveying. Figure 8.5 shows such schemes of establishing horizontal control in contouring.

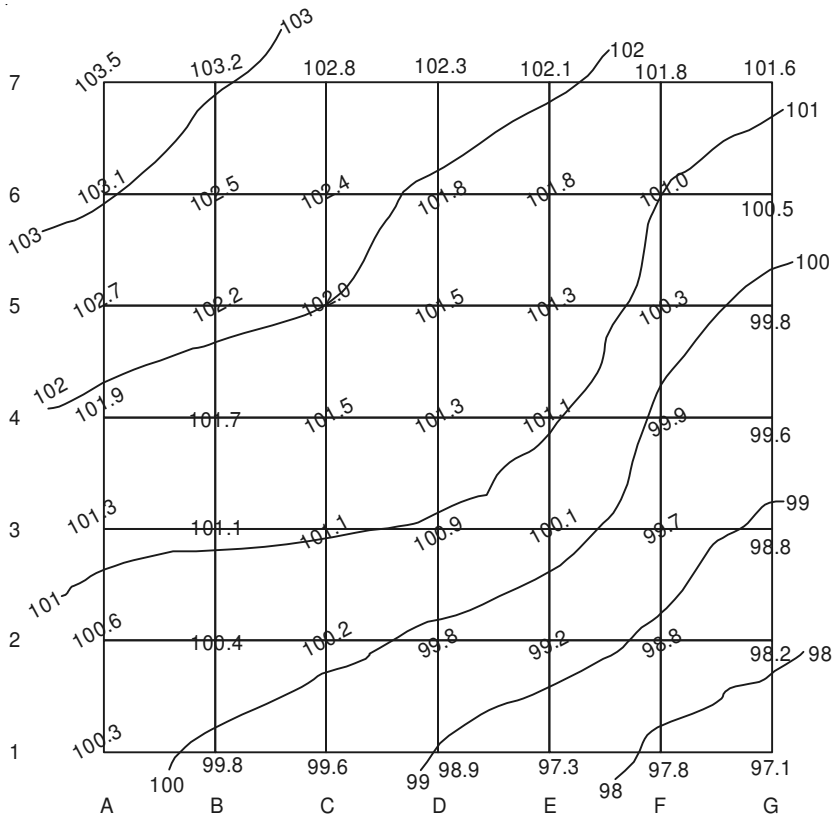


Fig. 8.5. *(a) Block levelling to get contours*

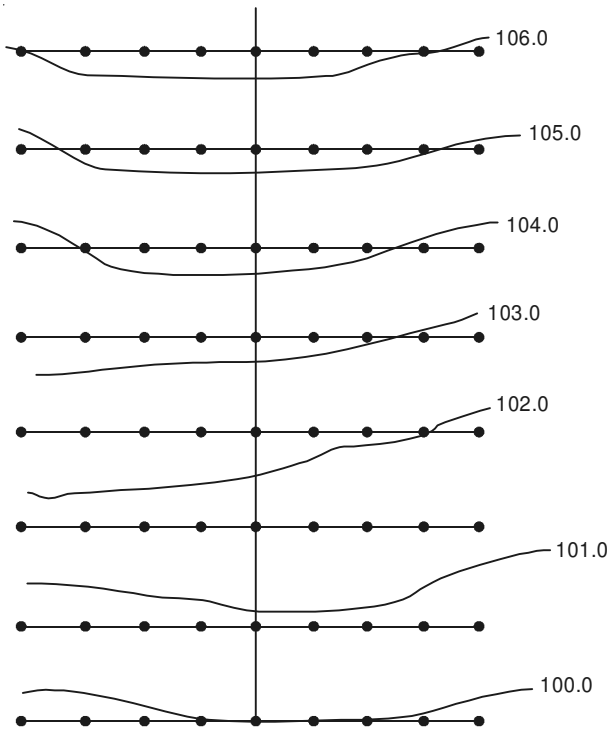


Fig. 8.5. *(b) Cross sectioning for contouring*

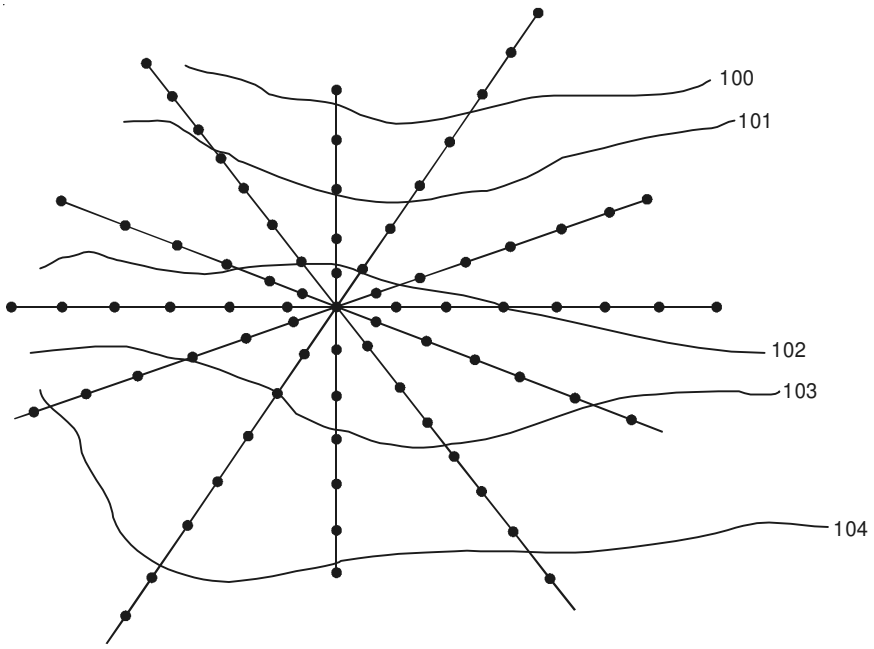


Fig. 8.5. *(c) Radial survey for contouring*

Questions

1. Explain the terms
   (*a*) Level Surface
   (*b*) Datum
   (*c*) Reduced Level
2. What is bench mark ? Briefly explain different types of benchmarks used in surveying.
3. Explain principles of direct levelling.
4. Explain the terms:
   (*a*) Back Sight
   (*b*) Fore Sight
   (*c*) Intermediate Sight and
   (*d*) Change Point
5. Differentiate between simple levelling and differential levelling.
6. With a neat sketch explain differential levelling.
7. Write short note on contours and contouring.

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CHAPTER IX

Introduction to GIS and Other Survey Softwares

Earlier, surveyor went all round the land to prepare maps. All countries established national institutions to prepare maps. Topographical maps are available for all places in India. Maps are used as the language of simple geography. Separate maps are used to show different attributes like roads, railways, crop data etc. The process of map making and updating the information on maps by conventional methods is laborious and is prone to errors. Searching a required map is a time consuming process.

The technological development and the progress of geographical world is taking place at a very fast rate. In this modern era of computers, geographical information is digitized and stored. At the press of key, any map and the required information of that area can be obtained. Geographical Information System (GIS) may be defined as a computer based information system which attempts to capture, store, manipulate, analyse and display spatially referenced and associated data.

9.1 DATA FOR GIS

The GIS data consists of two-different data, namely, spatial and attribute. Spatial data is in the form of vector used for map making. Attribute data is in the form of charts, tables or descriptive text about the places located in the map.

Data for a GIS can be derived from many alternative sources. It can be gathered directly in the field by conducting survey using total station. But it is very costly and time consuming process. Generally, data is derived from already available source, such as topographic maps, aerial photographs. Nowadays, data is collected from remote sensing using satellite pictures. For any GIS data, the files created are topological data, coordinate files and files with attribute data. Once GIS is developed, the user may receive information easily at the click on computer.

9.2 AREAS OF GIS APPLICATIONS

Some of the area of GIS applications are

1. Layout of residential areas
2. Location of market, industrial, cultural centres and other utilities.

3. Roads
4. Rail routes
5. Land use of different crops
6. Drainage systems
7. Streams and river basins
8. Lakes
9. Dams and canals
10. Risk assessment

9.3 GIS BASED SOFTWARES

Many GIS based softwares are commercially available which can operate on Window, Unix and Macintosh platforms. The most of the data for GIS packages are from remote sensing systems, mounted in aircrafts and satellites. This data is to be processed and held along with geographical data. The spatial and non-spatial data along with vectorial data are to be processed for developing application capabilities. Applications involve analysing and producing output information. Hence, a GIS based software has several modules integrated to produce desired output. Various modules required are for

1. Interface with remote sensing.
2. Image processing.
3. Vector based package capable of holding both spatial and non-spatial data.
4. Digitising and editing capability.
5. Capability to manage tabular data.
6. Analysis module.
7. Capability for editing so as to add legends, free texts and logos etc.
8. Modelling capabilities like calculation of slopes, curve and contour fittings.
9. Provision for Geo-coding.

Some of the GIS software packages available are listed below :

1. Arc/Info—developed by Environmental Systems Research Institute (ESRI), Redlands, California, USA
2. PAMAP GIS—a product of PAMAP Graphics Limited, Canada
3. GENAMAP—marketed by Genasys, an international developers.
4. SPANS—Spatial Analysis System developed by TYDAC Technologies, Canada
5. INTERGRAPH MGE
6. ISRO GIS—developed by Indian Space Research Organization
7. Idrisi GIS—developed by Clark University, USA.

9.4 OTHER SURVEYING SOFTWARE

Auto-Civil is a software having several modules to handle many civil engineering analysis and designs. One of these modules is surveying. It has capability to develop contours when the levels of various points in an area are given. The contour interval can be easily changed. The input can

be by keying or from total station data recording. The software is capable of giving earthwork (volume of earthwork) involved in a project work, if formation level information is supplied.

Auto plotter is the advanced version of Auto-civil. It is having advanced facilities and to get information plotted. It is quite useful for roads, railways and canal alignment projects.

Questions

1. Briefly explain what is GIS.

2. List areas of GIS applications.

3. Write short notes on.

(*a*) GIS based software.

(*b*) Other surveying software.

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SECTION II

ENVIRONMENTAL ENGINEERING

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CHAPTER X

Ecology and Ecosystem

10.1 CONCEPT OF ENVIRONMENT

'Environment' is derived from the French word *Environner,* which means to encircle or surround. All the biological and non-biological entities surrounding us are included in environment. As per Environment (Protection) Act, 1986, environment includes all the physical and biological surroundings of an organism along with their interactions. **Environment** is thus defined as **"the sum total of water, air and land and the inter-relationships that exist among them and with the human beings, other living organisms and materials."** The concept of environment can be clearly understood from Fig. 10.1.

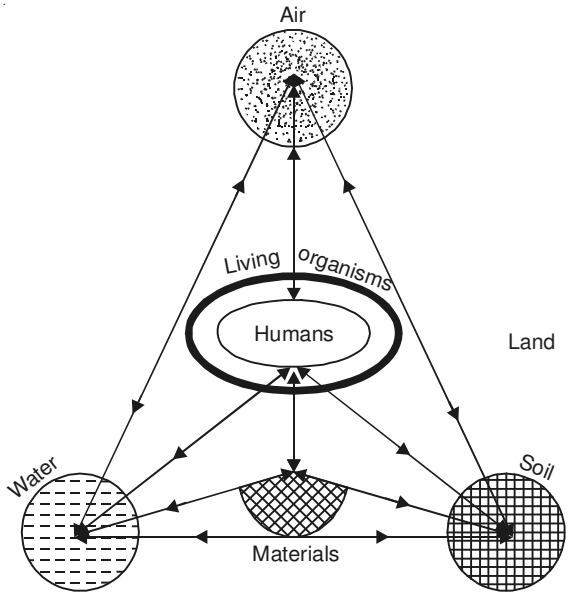


Fig. 10.1. *Concept of Environment: air, water, land, living organisms and materials surrounding us and their interactions together constitute environment*

Figure 10.1 depicts the environment of human beings. Air, water and land surrounding us constitute our environment, and influence us directly. At the same time we too have an influence on our environment due to overuse or over-exploitation of resources or due to discharge of

pollutants in the air, water and land. The flora, fauna and micro-organisms as well as the man-made structures in our surroundings have a bi-directional interaction with us directly or indirectly. The totality of all these components and their interactions constitute the environment.

Urban environment is somewhat different from rural environment. In urban environment we can see profound influence of human beings. Most of the natural landscapes in cities have been changed and modified by man-made artificial structures like multi-storeyed buildings, commercial complexes, factories, transportation networks and so on. Urban air, water and soil are loaded with various types of chemicals and wastes. Diversity of plants and animals is much less as compared to rural environment. Urban population is more dense and has greater energy demands.

10.2 CONCEPT OF ECOLOGY AND ECOSYSTEM

Various kinds of life supporting systems like the forests, grasslands, oceans, lakes, rivers, mountains, deserts and estuaries show wide variations in their structural composition and functions. However, they all are alike in the fact that they consist of living entities interacting with their surroundings exchanging matter and energy. How do these different units like a hot desert, a dense evergreen forest, the Antarctic Sea or a shallow pond differ in the type of their flora and fauna, how do they derive their energy and nutrients to live together, how do they influence each other and regulate their stability are the questions that are answered by Ecology.

The term Ecology was coined by Earnst Haeckel in 1869. It is derived from the Greek words *Oikos*- home + *logos*- study. So **ecology deals with the study of organisms in their natural home interacting with their surroundings.** The surroundings or environment consists of other living organisms (biotic) and physical (abiotic) components. Modern ecologists believe that an adequate definition of ecology must specify some unit of study and one such basic unit described by Tansley (1935) was ecosystem. **An ecosystem is a self-regulating group of biotic communities of species interacting with one another and with their non-living environment exchanging energy and matter. Now ecology is often defined as "the study of ecosystems"**.

An ecosystem is an integrated unit consisting of interacting plants, animals and microorganisms whose survival depends upon the maintenance and regulation of their biotic and abiotic structures and functions. The ecosystem is thus, a unit or a system which is composed of a number of sub-units, that are all directly or indirectly linked with each other. They may be freely exchanging energy and matter from outside—an *open ecosystem* or may be isolated from outside in term of exchange of matter—a *closed ecosystem*.

10.3 BIOTIC AND ABIOTIC FACTORS

Ecosystems show large variations in their size, structure, composition etc. However, all the ecosystems are characterized by certain basic structural and functional features which are common. Composition and organization of biological communities and abiotic components constitute the structure of an ecosystem. Thus, ecosystems have basically two types of factors, the biotic and abiotic factors, as described below:

10.3.1 Biotic Factors

A. Biotic Components

The plants, animals and microorganisms present in an ecosystem form the biotic component. These organisms have different nutritional behaviour and status in the ecosystems and are accordingly known as *Producers* or *Consumers,* based on how do they get their food.

(*i*) Producers

They are mainly the green plants, which can synthesize their food themselves by making use of carbondioxide present in the air and water in the presence of sunlight by involving chlorophyll, the green pigment present in the leaves, through the process of **photosynthesis**. They are also known as **photo autotrophs** (auto=self; troph=food, photo=light).

There are some microorganisms also which can produce organic matter to some extent through oxidation of certain chemicals in the absence of sunlight. They are known as **chemosynthetic** organisms or **chemo-autotrophs**. For instance in the ocean depths, where there is no sunlight, chemoautotrophic sulphur bacteria make use of the heat generated by the decay of radioactive elements present in the earth's core and released in ocean's depths. They use this heat to convert dissolved hydrogen sulphide (H_2S) and carbon dioxide (CO_2) into organic compounds.

(*ii*) Consumers

All organisms which get their organic food by feeding upon other organisms are called consumers, which are of the following types:

- ***Herbivores*** (plant eaters): They feed directly on producers and hence also known as *primary consumers*. *e.g.,* rabbit, insect, some birds.
- ***Carnivores*** (meat eaters): They feed on other consumers. If they feed on herbivores they are called *secondary consumers* (*e.g.,* frog) and if they feed on other carnivores they are known as *tertiary carnivores/consumers* (*e.g.,* snake, big fish etc.).
- ***Omnivores:*** They feed on both plants and animals. *e.g.,* humans, rat, fox, many birds.
- ***Detritivores (Detritus feeders or Saprotrophs):*** They feed on the parts of dead organisms, wastes of living organisms, their cast-offs and partially decomposed matter *e.g.,* beetles, termites, ants, crabs, earthworms etc.

(*iii*) Decomposers

They derive their nutrition by breaking down the complex organic molecules to simpler organic compounds and ultimately into inorganic nutrients. Various bacteria and fungi are decomposers.

In all the ecosystems this biotic structure prevails. However, in some, it is the primary producers which predominate (*e.g.,* in forests, agroecosystems) while in others the decomposers predominate (*e.g.,* deep ocean).

B. Biotic Structure

The biotic components of an ecosystem are interlinked and interdependent in the form of foodchain. The flow of energy is mediated through a series of feeding relationships in a definite sequence or pattern which is known as **food chain**. Nutrients too move along the food chain. The producers and consumers are arranged in the ecosystem in a definite manner and their interaction along with population size are expressed together as **trophic structure**. Each food level is known as **trophic level** and the amount of living matter at each trophic level at a given time is known as **standing crop** or **standing biomass.**

Before we study about energy flow or nutrient cycling, we must learn about the food-chains that provide the path through which the flow of energy and matter take place in an ecosystem.

The sequence of eating and being eaten in an ecosystem is known as food chain. All organisms, living or dead, are potential food for some other organism and thus, there is essentially no waste in the functioning of a natural ecosystem. A caterpillar eats a plant leaf, a sparrow eats the caterpillar, a cat or a hawk eats the sparrow and when they all die, they are all consumed by microorganisms like bacteria or fungi (decomposers) which break down the organic matter and convert it into simple inorganic substances that can again be used by the plants— the primary producers.

Some common examples of simple food chains are:

- Grass → grasshopper → Frog → Snake → Hawk (Grassland ecosystem)
- Phytoplanktons → water fleas → small fish → Tuna (Pond ecosystem)
- Lichens → reindeer → Man (Arctic tundra ecosystem)

Each organism in the ecosystem is assigned a feeding level or trophic level depending on its nutritional status. Thus, in the grassland food chain, grasshopper occupies the Ist trophic level, frog the IInd and snake and hawk occupy the IIIrd and the IVth trophic levels, respectively. The decomposers consume the dead matter of all these trophic levels. In nature, we come across two major types of food chains:

(*i*) Grazing Food Chain

It starts with green plants (primary producers) and culminates in carnivores. All the examples cited above show this type of food chain.

Grazing food chain of a shallow pond ecosystem shows that floating small plants (Phytoplanktons) are the primary producers, which are eaten by floating small animals (zooplanktons), which are the herbivores. These are in turn, consumed by small fish and then big fish which are carnivores.

Phytoplanktons (algae, diatoms) ⟶ Zooplanktons (insects, larvae, rotifers) ⟶ Small fish ⟶ Large carnivorous fish

(*ii*) Detritus Food Chain

It starts with dead organic matter which the detritivores and decomposers consume. Partially decomposed dead organic matter and even the decomposers are consumed by detritivores and their predators. An example of the detritus food chain is seen in a Mangrove (estuary) ecosystem.

Here, a large quantity of leaf material falls in the form of litter into the water. The leaf fragments are eaten by **saprotrophs** or **detritus feeders**. (Saprotrophs are those organisms which feed on dead organic matter). These fallen leaves are colonized by small algae, which are also consumed by the saprotrophs or detritivores consisting of crabs, mollusks, shrimps, insect larvae, nematodes and fishes. The detritivores are eaten by small carnivorous fishes, which in turn are eaten by large carnivorous fishes.

Leaf litter → algae → crabs → small carnivorous fish → large carnivorous fish (Mangrove ecosystem)

Dead organic matter → fungi → bacteria (Forest ecosystem)

Thus, the grazing food chain derives its energy basically from plant energy while in the detritus food chain it is obtained primarily from plant biomass, secondarily from microbial biomass

and tertiarily from carnivores. Both the food chains occur together in natural ecosystems, but grazing food chain usually predominates.

Food Web: A Network of Food Chains

Food chains in ecosystems are rarely found to operate as isolated linear sequences. Rather, they are found to be interconnected and usually form a complex network with several linkages and are known as food webs. Thus, **food web is a network of food chains where different types of organisms are connected at different trophic levels, so that there are a number of options of eating and being eaten at each trophic level.**

Why nature has evolved food webs in ecosystems instead of simple linear food chains? This is because food webs give greater stability to the ecosystem. In a linear food chain, if one species becomes extinct or one species suffers then the species in the subsequent trophic levels are also affected. In a food web, on the other hand, there are a number of options available at each trophic level. So if one species is affected, it does not affect other trophic levels so seriously.

Significance of food chains and food webs

- Food chains and food webs play a very significant role in the ecosystem because the two most important functions of *energy flow and nutrient cycling take place through them.*
- The food chains also help in maintaining and regulating the population size of different animals and thus, help maintain the *ecological balance*.
- Food chains show a unique property of *biological magnification* of some chemicals. There are several pesticides, heavy metals and other chemicals which are non-biodegradable in nature. Such chemicals are not decomposed by microorganisms and they keep on passing from one trophic level to another. And, at each successive trophic level, they keep on increasing in concentration. This phenomenon is known as biomagnification or biological magnification.

Biomagnification of DDT: A striking case of biomagnification of DDT (a broad range insecticide) was observed when some birds like Osprey were found to suffer a sharp decline in their population. The young ones of these birds were found to hatch out in premature condition leading to their death. This was later found to be due to bio-magnification of DDT through the food chain. DDT sprayed for pest control was in very low concentration, but its concentration increased along the food chain through phytoplanktons to zooplanktons and then to fish which was eaten by the birds. The concentration of DDT was magnified several thousand times in the birds which caused thinning of shells in the birds' eggs, causing death of the young ones.

It becomes very clear from the above instance that the animals occupying the higher trophic levels are at a greater risk of biomagnification of toxic chemicals. Human beings consuming milk, eggs and meat are at a higher trophic level. So, we have to stop indiscriminate use of pesticides and heavy metals if we wish to save ourselves from their biologically magnified toxic levels.

10.3.2 Abiotic Factors

The physical and chemical components of an ecosystem constitute its abiotic structure. It includes climatic factors, edaphic (soil) factors, geographical or topographic factors, energy, nutrients and toxic substances. All these factors can be broadly classified into two groups of factors *i.e.*, physical and chemical factors.

A. *Physical factors:* The sunlight and shade, intensity of solar flux, duration of sun hours, average temperature, maximum-minimum temperature, annual rainfall, wind, latitude and altitude, soil type, water availability, water currents etc. are some of the important physical features which have a strong influence on the ecosystem.

We can clearly see the striking differences in solar flux, temperature and precipitation (rainfall, snow etc.) pattern in a desert ecosystem, in a tropical rainforest and in tundra ecosystem.

B. *Chemical factors:* Availability of major essential nutrients like carbon, nitrogen, phosphorus, potassium, hydrogen, oxygen and sulphur, level of toxic substances, salts causing salinity and various organic substances present in the soil or water are the factors that influence the functioning of the ecosystem.

Let us now discuss some important climatic, topographic and edaphic factors briefly.

- **Climatic Factors:** Various meteorological factors such as temperature, light, relative humidity, precipitation and wind influence the climate of a region and are important abiotic factors.

  Light and temperature influence basic metabolic processes of plants like photosynthesis, seed germination, flowering, fruiting and seed ripening. Availability of light is also influenced by other abiotic factors like presence of gases and particulate matter in the atmosphere and water, which in turn have a significant effect on plant productivity. Different plants are adapted to different light conditions. **Heliophytes** grow best is full sunlight whereas **sciophytes** grow best in shade conditions or diffused sunlight.

  The duration or length of day and night known as **photoperiodism** is also a very important factor influencing plants and many animals, particularly in their reproductive stages. Temperature too has a very important impact on plant as well as animal growth and development. Both low and high temperature can lead to serious freezing or thermal injury.

  Precipitation refers to all moisture that reaches earth in the form of rain, snow, hail or dew. Rainfall pattern and magnitude determines the type of vegetation and the distribution of animal species in an area. Striking differences in precipitation leads to wide variations in flora and fauna of a tropical rain forest and a dry desert.

  Wind as a factor may cause abrasion of soil and ice, soil erosion and sand dune formation, salt spray along sea coast, lodging of vegetation, churning of oceans and desiccation in plants through increased evapo-transpiration.

- **Topographic Factors:** Physical geography of the area influences the flora and fauna by influencing indirectly through climatic factors. The altitude, latitude and longitude of an area affects temperature, pressure, wind velocity, solar intensity and humidity, which affect the vegetation and animal life. Steepness of the slope influences flow of water, soil erosion, siltation, wind speed etc. The windward and leeward side of a mountain influence rainfall in the region.

- **Edaphic Factors:** Soil is a complex matrix consisting of weathered superficial rock material in which organic matter, inorganic gases and minerals along with soil biota exist.

  Soil texture, soil pH, soil porosity, soil water, soil salinity, soil organic matter, soil mineral matter etc. are important soil characteristics that largely influence plant and animal life.

  Different ecological groups of plants have evolved with distinct adaptive features on different types of soils. Thus, halophytes growing in saline soils, oxalophytes growing in acidic soils, psammophytes growing on sands, lithophytes growing on rocks and calcicoles growing on calcareous soils have varied characters and adaptations.

Thus, all the biotic components of an ecosystem are influenced by the abiotic components and vice versa, and they are linked together through energy flow and matter cycling as shown diagrammatically in Fig. 10.2.

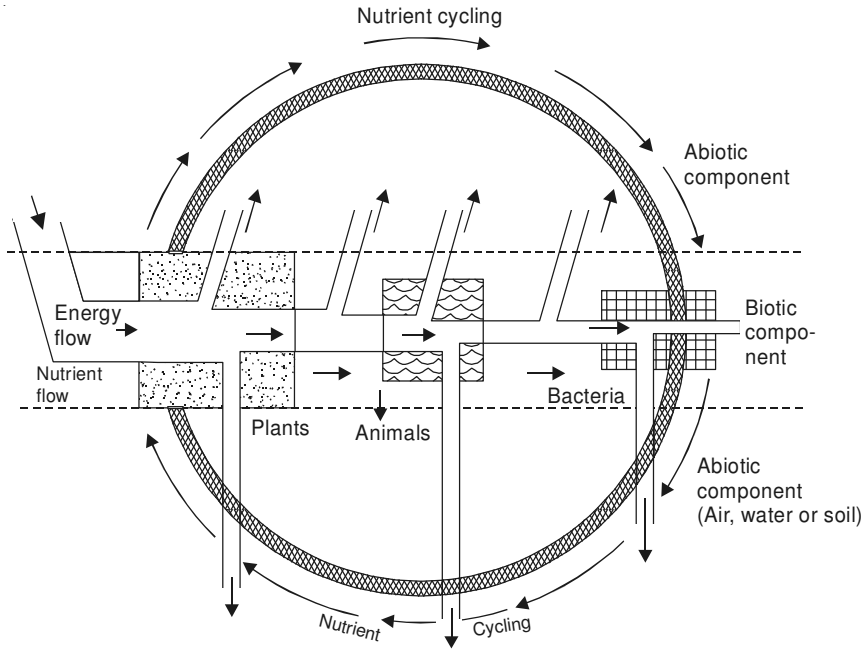


Fig. 10.2. *Nutrient cycling and energy flow mediated through food-chain. The flow of energy is unidirectional while the nutrients move in a cyclic manner from the abiotic to biotic (food chain) to abiotic and so on*

10.4 ECOLOGICAL CYCLES (Biogeochemical Cycles)

Besides energy flow, the other important functional attribute of an ecosystem is nutrient cycling. Nutrients like carbon, nitrogen, sulphur, oxygen, hydrogen, phosphorus etc. move in circular paths through biotic and abiotic components and are therefore known as **biogeochemical cycles.** Water also moves in a cycle, known as hydrological cycle. The nutrients too move through the food chain and ultimately reach the detritus compartment (containing dead organic matter) where various micro-organisms carry out decomposition. Various organically bound nutrients of dead plants and animals are converted into inorganic substances by microbial decomposition that are readily used up by plants (primary producers) and the cycle starts afresh.

10.4.1 Nitrogen Cycle

Cycling of one such important nutrient nitrogen is shown in Fig. 10.3. Nitrogen is present in the atmosphere as N_2 in large amount (78%) and it is fixed either by the physical process of lightening or biologically by some bacteria and/or cyanobacteria (blue green algae). The nitrogen is taken up by plants and used in metabolism for biosynthesis of amino acids, proteins, vitamins etc. and passes through the food chain. After death of the plants and animals, the organic nitrogen in dead tissues is decomposed by several groups of ammonifying bacteria converting organic -N into ammonia and nitrifying bacteria like *Nitrosomonas* and *Nitrobacter* which convert them into nitrites and nitrates respectively, which are again used by plants. Some bacteria like *Pseudomonas* convert nitrates, into molecular nitrogen or N_2 by denitrification which is released back into the atmosphere and the cycle goes on.

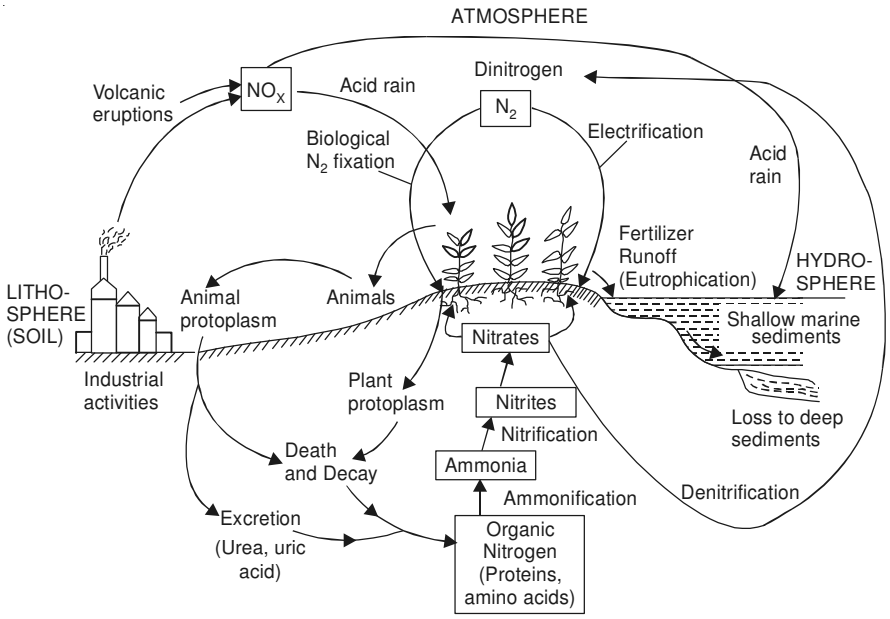


Fig. 10.3. *Nitrogen cycle—a gaseous cycle with major reserve as N_2 (78%) in the atmosphere. Circulation of N- between living components and soil/atmosphere is mediated by a group of micro-organisms which convert one form of N into another*

10.4.2 Carbon Cycle

Sometimes human interferences disturb the normal cycling of nutrients and create ecosystem imbalance. For example, nature has a very balanced carbon cycle (Fig. 10.4). Carbon, in the form of carbon dioxide is taken up by green plants as a raw material for photosynthesis, through which a variety of carbohydrates and other organic substances are produced. It moves through the food chain and ultimately organic carbon present in the dead matter is returned to the atmosphere as carbon dioxide by microorganisms. Respiration by all organisms produces carbon dioxide, while the latter is used up by plants.

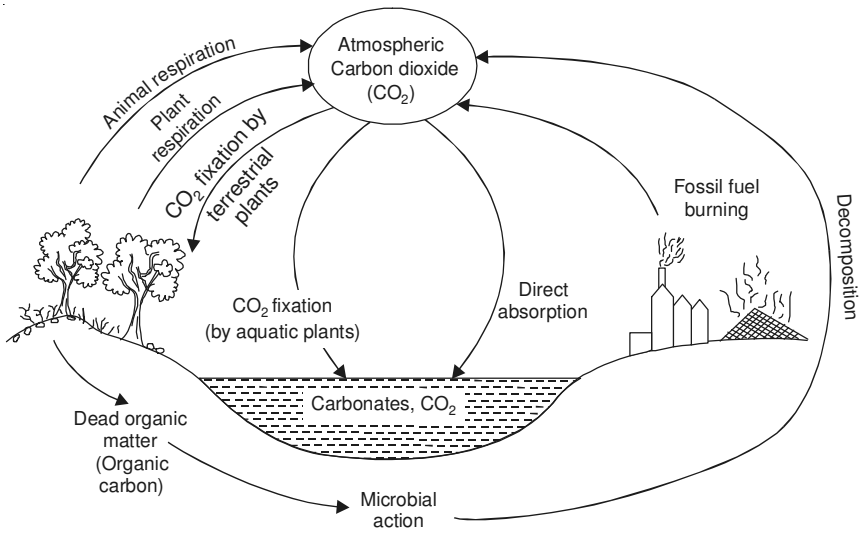


Fig. 10.4. *Carbon cycle*

In the recent years carbon dioxide levels have increased in the atmosphere due to burning of fossil fuels etc. which has caused an imbalance in the natural carbon cycle and the world today is facing the serious problem of global warming due to enhanced carbon dioxide emissions. There is a need to reduce carbon dioxide emissions and increase its fixation by planting more trees.

10.4.3 Phosphorus Cycle

Phosphorous cycle is another important nutrient cycle, which is shown in Fig. 10.5. The reservoir of phosphorus (P) lies in rocks, fossils etc. which is excavated by man for using it as a fertilizer. Farmers use the phosphate fertilizers indiscriminately and as a result excess phosphates are lost as run-off, which causes the problem of **eutrophication** *i.e.,* over-nourishment of lakes leading to algal blooms.

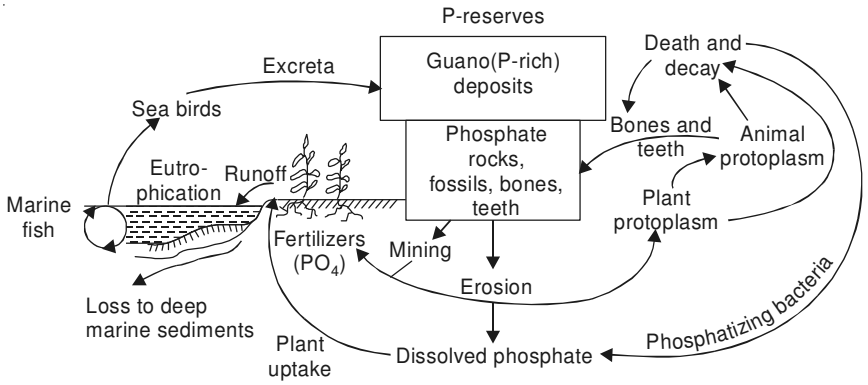


Fig. 10.5. *Phosphorus cycle—a sedimentary cycle with major reserves of phosphorus in the sediments*

A good proportion of phosphates moving with surface run-off reaches the oceans and are lost into the deep sediments. Our limited supply of phosphorus lying in the phosphate rocks of this earth are thus over-exploited by man and a large part is taken out of the normal cycle due to loss into oceans. So human beings are making the phosphorous cycle acyclic. Sea birds, on the other hand, are playing an important role in phosphorus cycling. They eat sea-fishes which are phosphorus rich and the droppings or excreta of the birds return the phosphorus on the land. The Guano deposits on the coasts of Peru are a rich source of phosphorus.

10.5 HUMAN (ANTHROPOGENIC) IMPACTS ON ENVIRONMENT

Human beings evolved about 40,000 years ago on the 10.6 billion year old earth. In the initial one thousand years, when human population was small and man was basically a hunter gatherer with limited requirements, his interference with natural cylces and harmony was negligible. However, with development of agricultural activities followed by industrial revolution, there were tremendous changes in the population size of human beings along with rise is quality and standards of living. Due to technological development and rapid economic growth our civilisation has reached its zenith, but at the same time it has let to serious environmental degradation. Development has changed the attitude of human beings towards nature, which has further aggravated the problems.

Let us see how our life style, consumerism, agriculture developmental activities and industrialisation have affected our environment including air, water, land materials, biological diversity and also human beings.

10.5.1 Impact of Changing Human Behaviour on Environment

While early human societies used to consume much less resources, with the dawn of industrial era, consumerism has shown an exponential rise. It has been related both to the increase in the population size as well as increase in our demands due to change in lifestyle. Earlier we used to live a much simpler life and used to have fewer wants. In the modern society our needs have multiplied and so consumerism of resources has also multiplied.

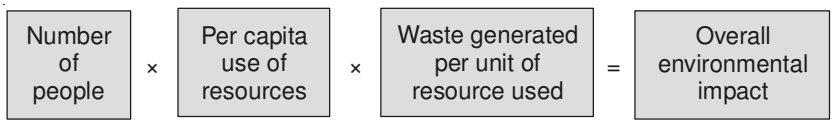
Our population was less than 1 million for thousands of years ever since we evolved on this earth. Today we have crossed the six billion mark and are likely to reach 11 billion by 2045 as per World Bank estimates. Let us see how the changing population trends influence consumerism of natural resources and generation of wastes. Two types of conditions of population and consumerism exist.

(*i*) **People over-population:** It occurs when there are more people than available supplies of food, water and other important resources in the area. Excessive population pressure causes degradation of the limited resources, and there is absolute poverty, under-nourishment and premature deaths.

This occurs in less developed countries (LDCs). Here due to large number of people, adequate resources are not available for all. So there is less per capita consumption although overall consumption is high.

(*ii*) **Consumption over-population:** This occurs in the more developed countries (MDCs). Here population size is smaller while resources are in abundance and due to luxurious lifestyle, per capita consumption of resources is very high. More the consumption of resources more is the waste generation and greater is the degradation of the environment.

This concept can be explained by using the model of Paul Ehrlich and John Hodlren (1972):



In LDC's - No. of people is very high, but per capita use of resources and waste generated are less.

In MDC's - No. of people is low, but per capita use of resources and wastes generated are very high.

The overall environmental impact of these two types of consumerism may be same or even greater in case of MDC's.

This concept has been illustrated diagramatically in Fig. 10.6.

Thus, consumerism varies from country to country and USA is known to show maximum consumerism. The throw-away attitude and luxurious lifestyle of the West results in very high resource exploitation as compared to less developed countries. With every unit of energy, mineral or any resource used there is lot of waste generation and pollution in the environment.

A comparison of consumerism pattern of USA and India can illustrate this point more clearly (Table 10.1).

TABLE 10.1. Comparison of Consumerism and Waste Generation

Consumerism Parameter	*Per cent global values*	
	USA	*India*
Population	4.7%	16%
Production of goods	21%	1%
Energy use	25%	3%
Pollutant/waste generation	25%	3%
CFC's production	22%	0.7%

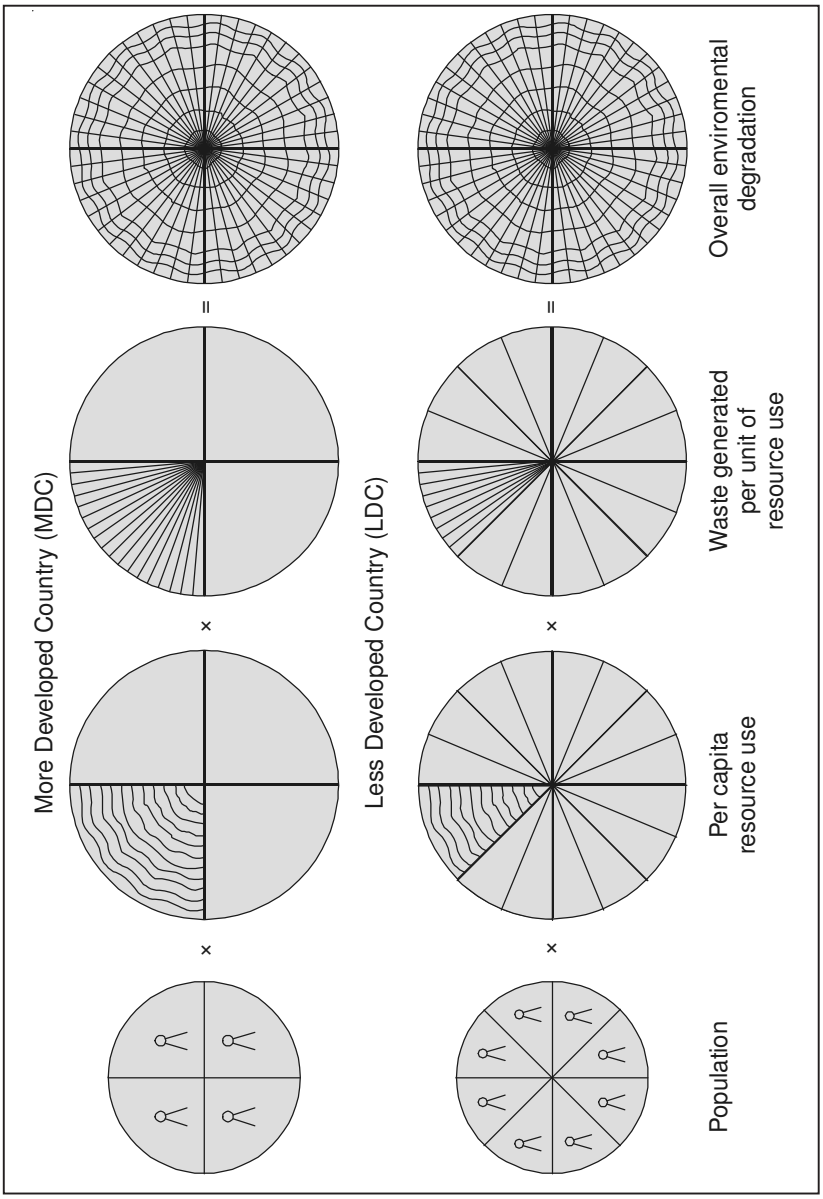


Fig. 10.6. *Relationship of population, consumerism waste production and environmental impacts*

The table shows that although the population of India is 3.4 times more than that of U.S.A. its overall energy use and waste generation are less than 1/8th that of USA. Thus, more consumerism leads to more waste production.

10.5.2 Impacts of Intensive Food Production (Agricultural Practices and Overgrazing)

For about 75 per cent duration of their existence on this earth, human beings have acted as hunter-gatherers. It was about 10,000 to 12,000 years ago, when a cultural shift known as 'Agricultural revolution' took place in several regions of the world, which changed the life style of humans from wandering nomadic life to a settled life. People started domesticating animals and cultivating the plant species that were useful. Gradually, population increased and so did the demands for more food production. There was a need to increase the cropped land area and increase crop yield by using technological advancements. In order to feed the livestock there was increasing demand for more grazing land. Intensive agricultural practices and overgrazing led to several offshoots that influenced our environment. In the present section we would discuss about these impacts.

A. Impacts of Agriculture

In primitive times human beings used the practice **Slash and burn cultivation or shifting cultivation,** which is still prevalent in many tribal areas, as in the North East Hills of India. The type of agriculture practiced these days is very different from the traditional ones and their outputs in terms of yield as well as their impacts on the environment show lots of differences, as discussed below:

(*a*) Traditional Agriculture and its Impacts: It usually involves a small plot, simple tools, naturally available water, organic fertilizer and a mix of crops. It is more near to natural conditions and usually it results in low production. It is still practiced by about half the global population.

The main impacts of this type of agriculture are as follows:

(*i*) **Deforestation:** The slash and burn of trees in forests to clear the land for cultivation and frequent shifting result in loss of forest cover.

(*ii*) **Soil erosion:** Clearing of forest cover exposes the soil to wind, rain and storms, thereby resulting in loss of top fertile layer of soil.

(*iii*) **Depletion of nutrients:** During slash and burn the organic matter in the soil gets destroyed and most of the nutrients are taken up by the crops within a short period, thus making the soil nutrient poor which forces the cultivators shift to another area.

(*b*) Modern Agriculture and its Impacts: It makes use of hybrid seeds of selected and single crop variety, high-tech equipments and lots of energy subsidies in the form of fertilizers, pesticides and irrigation water. The food production has increased tremendously, evidenced by "green revolution". However, it has also given rise to several problematic off-shoots as discussed below:

(*i*) Impacts related to high yielding varieties (HYV): The uses of HYVs encourage monoculture *i.e.,* the same genotype (variety) is grown over vast areas. In case of an attack by some pathogen, there is total devastation of the crop by the disease due to exactly uniform conditions, which help in rapid spread of the disease.

(*ii*) Fertilizer related problems:

- **Micronutrient imbalance:** Most of the chemical fertilizers used in modern agriculture have nitrogen, phosphorus and potassium (N, P, K) which are essential macronutrients. Farmers usually use these fertilizers indiscriminately to boost up crop growth. Excessive

use of fertilizers cause *micronutrient imbalance*. For example, excessive fertilizer use in Punjab and Haryana has caused deficiency of the micronutrient zinc in the soils, which is affecting productivity of the soil.

- **Nitrate pollution:** Nitrogenous fertilizers applied in the fields often leach deep into the soil and ultimately contaminate the ground water. The nitrates get concentrated in the water and when their concentration exceeds 25 mg/L, they become the cause of a serious health hazard called **"Blue Baby Syndrome"** or methaemoglobinemia. This disease affects the infants to the maximum extent causing even death. In Denmark, England, France, Germany and Netherlands this problem has been faced frequently. In India also, problem of nitrate pollution exists in many areas.
- **Eutrophication:** Excessive use of N and P fertilizers in the agricultural fields leads to another problem, which is not related to the soil, but relates to water bodies like lakes. A large proportion of nitrogen and phosphorus used in crop fields is washed off and along with runoff water reach the water bodies causing over nourishment of the lakes, a process known as **Eutrophication** (eu = more, trophic = nutrition).

  Due to eutrophication the lakes get invaded by algal blooms. These algal species grow very fast by rapidly using up the nutrients. They are often toxic and badly affect the food chain. The algal species quickly complete their life cycle and die thereby adding a lot of dead organic matter. The fishes are also killed and there is a lot of dead matter that starts getting decomposed. Oxygen is consumed in the process of decomposition and very soon the water gets depleted of dissolved oxygen. This further affects aquatic fauna and ultimately anaerobic conditions are created where only anaerobic bacteria can survive many of which are known to be pathogenic. Thus, due to excessive use of fertilizers in the agricultural fields the lake ecosystem gets degraded. This shows how an unmindful action can have far reaching consequences.

(*iii*) Pesticide related problems: Thousands of types of pesticides are used in agriculture. The first generation pesticides include chemicals like sulphur, arsenic, lead or mercury to kill the pests. DDT (Dichlorodiphenyl trichloroethane) whose insecticidal properties were discovered by Paul Mueller in 1939 belongs to the second generation pesticides. After 1940, a large number of synthetic pesticides came into use. Although these pesticides have gone a long way in protecting our crops from huge losses occurring due to pests, yet they have a number of side-effects, as discussed below:

- **Creating resistance in pests and producing new pests:** Some individuals of the pest species usually survive even after pesticide spray. The survivors give rise to highly resistant generations. About 20 species of pests are now known which have become immune to all types of pesticides and are known as **"Super pests".**
- **Death of non-target organisms:** Many insecticides are broad spectrum poisons which not only kill the target species but also several non-target species that are useful to us.
- **Biological magnification:** Many of the pesticides are non-biodegradable and keep on accumulating in the food chain, a process called biological magnification. Since human beings occupy a high trophic level in the food chain, they get the pesticides in a bio-magnified form which is very harmful.

(*iv*) Waterlogging: Over irrigation of croplands by farmers for good growth of their crop usually leads to waterlogging. Inadequate drainage causes excess water to accumulate underground and gradually forms a continuous column with the water table. Under water-logged conditions, pore-spaces in the soil get fully drenched with water and the soil-air gets depleted. The water table rises while the roots of plants do not get adequate air for respiration. Mechanical strength of the soil declines, the crop plants get lodged and crop yield falls.

In Punjab, extensive areas have become water-logged where adequate canal water supply or tube-well water encouraged the farmers to use it over-enthusiastically leading to water-logging problem.

Preventing excessive irrigation, sub-surface drainage technology and bio-drainage with trees like Eucalyptus are some of the remedial measures to prevent water-logging.

(*v*) Salinity problem: At present one third of the total cultivable land area of the world is affected by salts. In India about seven million hectares of land are estimated to be salt-affected which may be saline or sodic. Saline soils are characterized by the accumulation of soluble salts like sodium chloride, sodium sulphate, calcium chloride, magnesium chloride etc. in the soil profile. Their electrical conductivity is more than 4 dS/m. Sodic soils have carbonates and bicarbonates of sodium, the pH usually exceeds 8.0 and the exchangeable sodium percentage (ESP) is more than 15%.

A major cause of salinization of soil is excessive irrigation. About 20% of the world's croplands receive irrigation with canal water or ground water which unlike rainwater often contains dissolved salts. Under dry climates, the water evaporates leaving behind salts in the upper soil profile (Fig. 10.7).

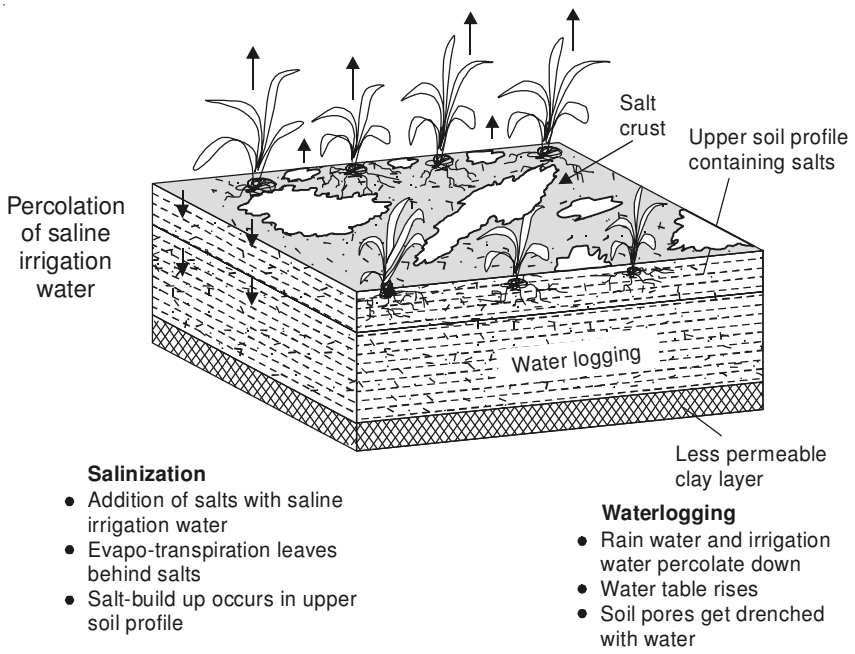


Fig. 10.7. *Salinization and water logging*

Thousands of hectares of land area in Haryana and Punjab are affected by soil salinity and alkalinity. Salinity causes stunted plant growth and lowers crop yield. Most of the crops cannot tolerate high salinity.

The most common method for getting rid of salts is to flush them out by applying more good quality water to such soils. Another method is laying underground network of perforated drainage pipes for flushing out the salts slowly known as subsurface drainage.

B. Impacts of Overgrazing

Livestock wealth plays a crucial role in the rural life of our country. India leads in livestock population in the world. The huge population of livestock needs to be fed and the grazing lands or pasture areas are not adequate. Very often we find that the livestock grazing on a particular piece of grassland or pasture surpass the carrying capacity. **Carrying capacity** of any system is the maximum population that can be supported by it on a sustainable basis. However, most often, the grazing pressure is so high that its carrying capacity is crossed and the sustainability of the grazing lands fails. Let us see what are the impacts of overgrazing.

(*i*) **Land degradation:** Overgrazing removes the vegetal cover over the soil and the exposed soil gets compacted due to which the operative soil depth declines. So the roots cannot go much deep into the soil and adequate soil moisture is not available. Organic recycling also declines in the ecosystem because not enough detritus or litter remains on the soil to be decomposed. The humus content of the soil decreases and overgrazing leads to organically poor, dry, compacted soil. Due to trampling by cattle the soil loses infiltration capacity, which reduces percolation of water into the soil and as a result of this more water gets lost from the ecosystem along with surface run off. Thus overgrazing leads to multiple actions resulting in loss of soil structure, hydraulic conductivity and soil fertility.

(*ii*) **Soil erosion:** Due to overgrazing by cattle, the cover of vegetation almost gets removed from the land. The soil becomes exposed and gets eroded by the action of strong wind, rainfall etc. The grass roots are very good binders of soil. When the grasses are removed, the soil becomes loose and susceptible to the action of wind and water.

(*iii*) **Loss of useful species:** Overgrazing adversely affects the composition of plant population and their regeneration capacity. The original grassland consists of good quality grasses and herbs with high nutritive value. When the livestock graze upon them heavily, even the root stocks which carry the reserve food for regeneration get destroyed. Now some other species appear in their place. These secondary species are hardier and are less nutritive in nature. Some livestock keep on overgrazing on these species also. Ultimately the nutritious, juicy fodder giving species are replaced by unpalatable and sometimes thorny plants. These species do not have a good capacity of binding the soil particles and, therefore, the soil becomes more prone to soil erosion.

As a result of overgrazing vast areas in Arunachal Pradesh and Meghalaya are getting invaded by thorny bushes, weeds etc. of low fodder value. Thus, overgrazing makes the grazing land lose its regenerating capacity and once good quality pasture land gets converted into an ecosystem with poor quality thorny vegetation.

The impacts of agricultural practices and overgrazing are summarized in Fig. 10.8.

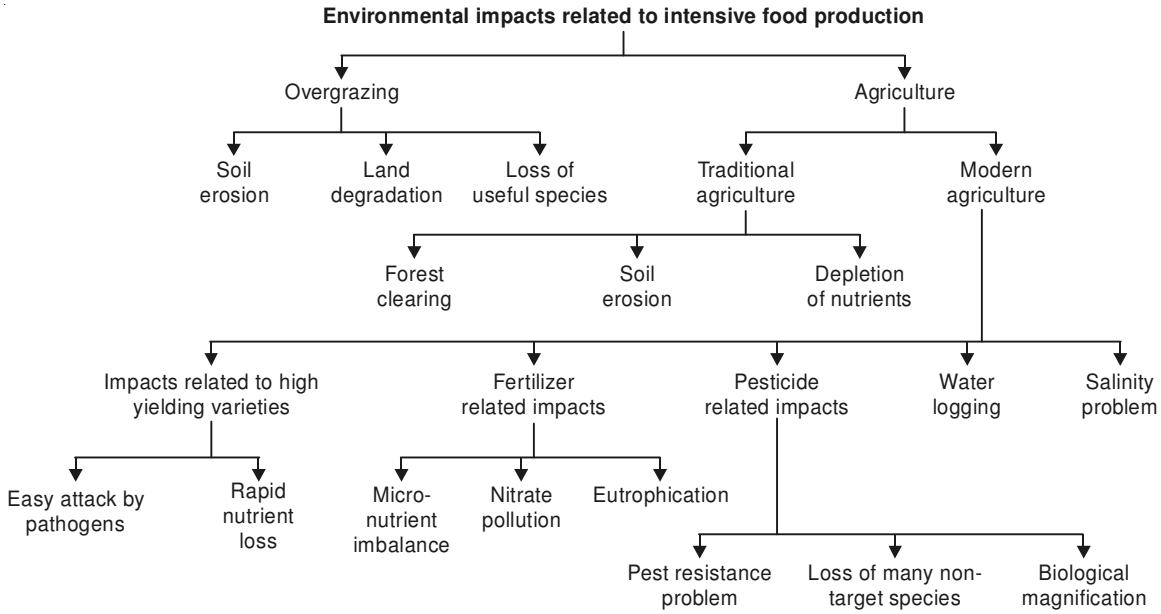


Fig. 10.8. *Chain of side effects on environment due to intensive practices for increased food production*

10.5.3 Impact of Development Activities on Environment

Rapid development activities have been associated with more and more exploitation of various natural resources. Technological development has resulted in fast depletion of non-renewable energy resources, mainly coal and petroleum, and also various minerals. Mining activities, dam building, urbanisation and industrialisation have all interfered with the ecological balance of nature due to large scale impacts.

A. Environmental Impact of Mining

The fact that reserves of mineral resources in our earth's crust or in the ocean are limited is not so significant as compared to the environmental concern arising from the impacts of extraction and processing of these minerals during mining and smelting.

Mining is done to extract minerals (or fossil fuels) from deep deposits in soil by using **sub-surface mining** or from shallow deposits by **surface mining**. The former method is more destructive, dangerous and expensive including risks of occupational hazards and accidents.

Surface mining can make use of any of the following three types:

(*a*) *Open-pit mining* in which machines dig holes and remove the ores (*e.g.,* copper, iron, gravel, limestone, sandstone, marble, granite).

(*b*) *Dredging* in which chained buckets and draglines are used which scrap up the minerals from under-water mineral deposits.

(*c*) *Strip mining* in which the ore is stripped off by using bulldozers, power shovels and stripping wheels (*e.g.,* phosphate rocks).

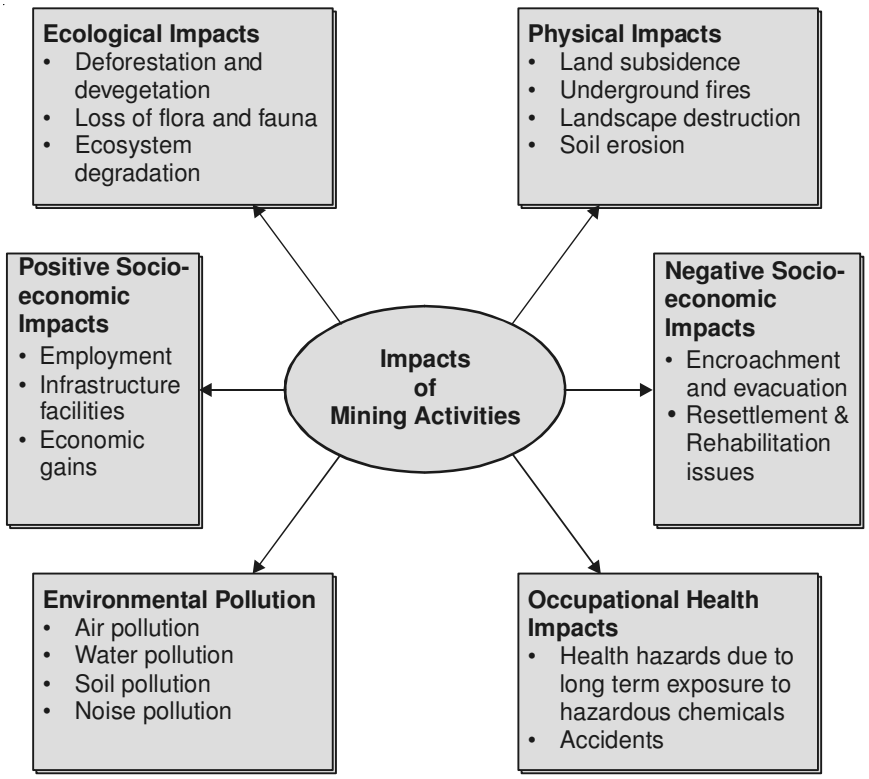


Fig. 10.9. *Impacts of mining activities*

The environmental damage caused by mining activities depicted in Fig. 10.9 are discussed below:

(*i*) **Devegetation and defacing of landscape:** The topsoil as well as the vegetation are removed from the mining area to get access to the deposit. While large scale deforestation or devegetation leads to several ecological losses, the landscape also gets badly affected. Huge quantities of debris and tailings alongwith big scars and disruptions spoil the aesthetic value of the region and make it prone to soil erosion.

(*ii*) **Subsidence of land:** This is mainly associated with underground mining. Subsidence of mining areas often results in tilting of buildings, cracks in houses, buckling of roads, bending of rail tracks and leaking of gas from cracked pipe-lines leading to serious disasters.

(*iii*) **Groundwater contamination:** Mining disturbs the natural hydrological processes and also pollutes the groundwater. Sulphur, usually present as an impurity in many ores is known to get converted into sulphuric acid through microbial action, thereby making the water acidic. Some heavy metals also get leached into the groundwater and contaminate it posing health hazards.

(*iv*) **Surface water pollution:** The acid mine drainage often contaminates the nearby streams and lakes. The acidic water is detrimental to many forms of aquatic life. Sometimes radioactive substances like uranium also contaminate the water bodies through uranium mine wastes and kill aquatic animals. Heavy metal pollution of water bodies near the mining areas is a common feature creating health hazards.

(*v*) **Air pollution:** In order to separate and purify the metal from other impurities in the ore, smelting is done which emits enormous quantities of air pollutants damaging the vegetation nearby and has serious environmental health impacts. The suspended particulate matter (SPM), SOx, soot, arsenic particles, cadmium, lead etc. shoot up in the atmosphere near the smelters and the public suffers from several health problems.

(*vi*) **Occupational health hazards:** Most of the miners suffer from various respiratory and skin diseases due to constant exposure to the suspended particulate matter and toxic substances. Miners working in different types of mines suffer from asbestosis, silicosis, black lung disease etc.

Statistical data show that, on an average, there are 30 non-fatal but disabling accidents per ton of mineral produced and one death per 2.5 tons of mineral produced.

In order to minimize the adverse impacts of mining it is desirable to adopt eco-friendly mining technology. The low-grade ores can be better utilized by using **microbial leaching technique.** The bacterium *Thiobacillus ferroxidans* has been successfully and economically used for extracting gold embedded in iron sulphide ore. The ores are inoculated with the desired strains of bacteria, which remove the impurities (like sulphur) and leave the pure mineral. This biological method is helpful from economic as well as environmental point of view.

Restoration of mined areas by re-vegetating them with appropriate plant species, stabilization of the mined lands, gradual restoration of flora, prevention of toxic drainage discharge and conforming to the standards of air emissions are essential for minimizing environmental impacts of mining.

B. Impacts of Big Dams

Big dams and river valley projects have multi-purpose uses and have been referred to as *"Temples of modern India"*. However, these dams are also responsible for the destruction of vast areas of forests.

India has more than 1550 large dams, the maximum being in the state of Maharashtra (more than 600), followed by Gujarat (more than 250) and Madhya Pradesh (130). The highest one is *Tehri dam*, on river Bhagirathi in Uttarakhand and the largest in terms of capacity is Bhakra dam on river Satluj in Himachal Pradesh.

Big dams have been in sharp focus of various environmental groups all over the world which is mainly because of several ecological problems including deforestation and socio-economic problems related to tribal or native people associated with them. The *Silent Valley* hydroelectric project was one of the first such projects situated in the tropical rain forest area of Western Ghats which attracted much concern of the people and was abandoned keeping in view its ecological implications.

For building big dams, large scale devastation of forests takes place which breaks the natural ecological balance of the region. Floods, droughts and landslides become more prevalent in such areas. Forests are the repositories of invaluable gifts of nature in the form of biodiversity and by destroying these (particularly, the tropical rain forests) we are going to lose these species even before knowing them. These species could be having marvellous economic or medicinal value. This storehouse of species which have evolved over millions of years get lost due to deforestation in a single stroke.

Big dams are often regarded as a symbol of national development. However, there are several other issues and problems related to these. Figure 10.10 depicts various aspects associated with big dams.

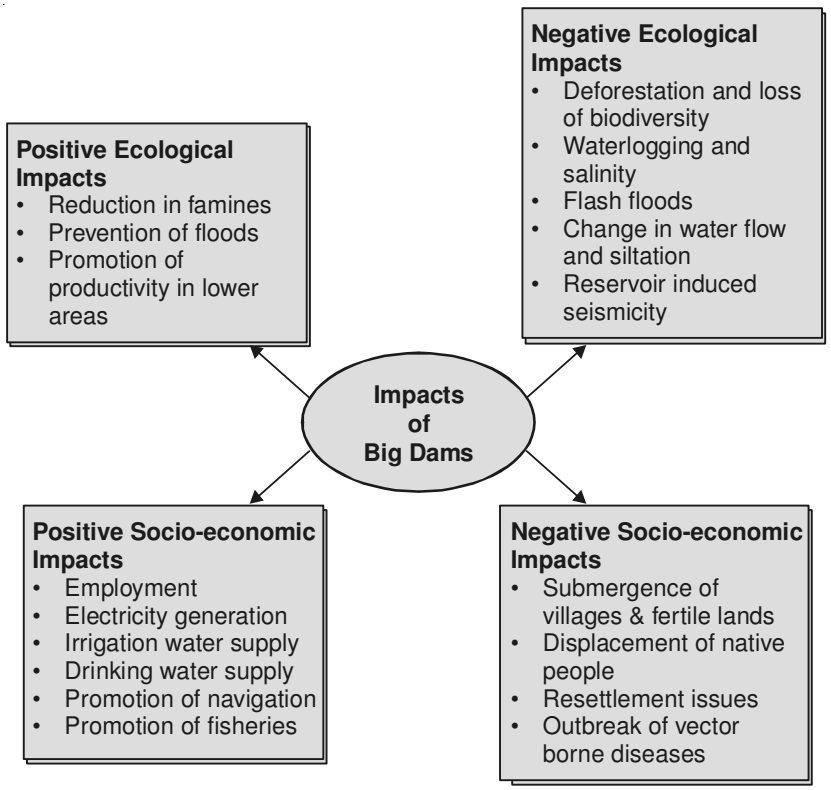


Fig. 10.10. *Impacts of big dams*

Benefits

River valley projects with big dams have usually been considered to play a key role in the development process due to their multiple uses. India has the distinction of having the largest number of river-valley projects. The tribals living in the area pin big hopes on these projects as they aim at providing employment and raising the standard and quality of life. The dams have tremendous potential for economic upliftment and growth. They can help in checking floods and famines, generate electricity and reduce water and power shortage, provide irrigation water to lower areas, provide drinking water in remote areas and promote navigation, fishery etc.

Environmental Problems

The environmental impacts of big-dams are also too many due to which very often the big dams become a subject of controversy. The impacts can be at the upstream as well as downstream levels.

(A) The upstream problems include the following:

(*i*) Displacement of tribal people

(*ii*) Loss of forests, flora and fauna

(*iii*) Changes in fisheries and the spawning grounds

(*iv*) Siltation and sedimentation of reservoirs

(*v*) Loss of non-forest land

(*vi*) Stagnation and waterlogging near reservoir

(*vii*) Breeding of vectors and spread of vector-borne diseases

(*viii*) Reservoir induced seismicity (RIS) causing earthquakes

(*ix*) Growth of aquatic weeds.

(*x*) Microclimatic changes.

(B) The downstream impacts include the following:

(*i*) Water logging and salinity due to over irrigation

(*ii*) Micro-climatic changes

(*iii*) Reduced water flow and silt deposition in river

(*iv*) Flash floods

(*v*) Salt water intrusion at river mouth

(*vi*) Loss of land fertility along the river since the sediments carrying nutrients get deposited in the reservoir

(*vii*) Outbreak of vector-borne diseases like malaria

Thus, although dams are built to serve the society with multiple uses, but it has several side-effects. That is why now construction of small dams or mini-hydel projects are being considered.

10.5.4 Some Major Impacts due to Human Activities

There are some major consequences of development activities that have occurred due to several activities linked together. Deforestation, desertification, biodiversity loss, landslides land degradation, pollution, acid rain and global climate change are some such impacts, which will be discussed here.

A. Over-exploitation of Forests, Deforestation and its Impact

Forests have been known to possess huge potential for human use and they have been exploited since early times for their vast potential. Exploitation of forests has taken place to meet human demands in the following ways:

- Wood cutting and large scale logging for raw materials like timber, pulp wood, fuel wood, gum, rubber, drugs, etc.
- Deforestation due to road construction
- Clearing of forests to create more agricultural lands to meet the food demands of growing population
- Encroachment of forests leading to its destruction
- Heavy grazing by livestock.
- Mining activities leading to clearing of forests
- Big hydropower projects resulting in large scale destruction of forests.

As a result of over-exploitation, the tropical forest cover in India is now reduced to the Coastal Western Ghats and Northeast India, which is still suffering degradation.

The potential of forests must be tapped and nurtured, but we must stop over-exploitation. A recent World Bank study (2004) shows that if we unlock the opportunities for the people of India from its forests, there will be a boost in economy from the current 222 million US dollars to 2 billion US dollars in the next 15 years. However, the exploitation needs to be balanced with conservation efforts.

Deforestation has far reaching consequences, which may be outlined as follows:

(*i*) It threatens the existence of many wildlife species due to destruction of their natural habitat (home).

(*ii*) Biodiversity is lost and along with that genetic diversity is eroded.

(*iii*) Hydrological cycle gets affected, thereby influencing rainfall.

(*iv*) Problems of soil erosion and loss of soil fertility increase.

(*v*) In hilly areas it often leads to landslides.

(*vi*) More carbon is added to the atmosphere and global warming is enhanced.

B. Loss of Biodiversity

Biodiversity refers to the variety and variability among all groups of living organisms and the ecosystem complexes in which they occur. From the driest deserts to the dense tropical rainforests and from the high snow-clad mountain peaks to the deepest of ocean trenches, life occurs in a marvellous spectrum of forms, size, colour and shape, each with unique ecological inter-relationships. Just imagine how monotonous and dull the world would have been had there been only a few species of living organisms that could be counted on fingertips!

The value of biodiversity in terms of its commercial utility, ecological services, social and aesthetic value is enormous. We get benefits from other organisms in innumerable ways. Sometimes we realize and appreciate the value of the organism only after it is lost from this earth. Very small, insignificant, useless looking organism may play a crucial role in the ecological balance of the ecosystem or may be a potential source of some invaluable drug for dreaded diseases like cancer or AIDS.

Extinction or elimination of a species is a natural process of evolution and in the geologic past the earth has experienced mass extinctions. Over the last 150 years the rate of extinction has escalated more dramatically. If the present trend continues we would lose 1/3rd to 2/3rd of our current biodiversity by the middle of twenty first century.

Some of the major man-made causes related to biodiversity loss are as follows:

(*i*) Habitat loss and habitat fragmentation

Destruction and loss of natural habitat is the single largest cause of biodiversity loss. Billions of hectares of forests and grasslands have been cleared by man over the past 10,000 years for conversion into agriculture lands, pastures, settlement areas or development projects. These natural forests and grasslands were the natural homes of thousands of species which perished due to loss of their natural habitat.

Sometimes the loss of habitat is in instalments so that the habitat is divided into small and scattered patches, a phenomenon known as **habitat fragmentation**. Due to habitat fragmentation many song birds and wild animals like bears and large cats are vanishing.

(*ii*) Poaching

Illegal trade of wildlife products by killing prohibited endangered animals *i.e.*, poaching is another threat to wildlife. Despite international ban on trade in products from endangered species, smuggling of wildlife items like furs, hides, horns, tusks, live specimens and herbal products worth millions of dollars per year continues.

C. Landslides

Various anthropogenic activities like hydroelectric projects, large dams, reservoirs, construction of roads and railway lines, construction of buildings, mining etc. are responsible for clearing of large forested areas. During construction of roads, mining activities etc. huge portions of fragile mountainous areas are cut or destroyed by dynamite and thrown into adjacent valleys and streams.

These land masses weaken the already fragile mountain slopes and lead to landslides. They also increase the turbidity of various nearby streams, thereby reducing their productivity.

D. Desertification

Desertification is a process whereby the productive potential of arid or semi-arid lands falls. Moderate desertification causes 10–25% drop in productivity, severe desertification causes 25–50% drop while very severe desertification results in more than 50% drop in productivity and usually creates huge gullies and sand dunes. Desertification leads to the conversion of rangelands or irrigated croplands to desert like conditions in which agricultural productivity falls. Desertification is not the literal invasion of desert into a non-desert area. It includes degradation of the ecosystems within as well as outside the natural deserts.

While formation of deserts may take place due to natural phenomena like climate change, yet major anthropogenic activities responsible for desertification are as follows:

(*i*) Deforestation: The process of denuding and degrading a forested land initiates a desert producing cycle that feeds on itself. Since there is no vegetation to hold back the surface run-off, water drains off quickly before it can soak into the soil to nourish the plants or to replenish the groundwater. This increases soil erosion, loss of fertility and loss of water.

(*ii*) Overgrazing: The regions most seriously affected by desertification are the cattle producing areas of the world. This is because the increasing cattle population heavily graze in grasslands or forests and as a result denude the land area. The dry barren land becomes loose and more prone to soil erosion. It reflects more of the sun's heat, changing wind patterns, driving away moisture laden clouds leading to further desertification.

(*iii*) Mining and quarrying: These activities are also responsible for loss of vegetal cover and denudation of extensive land areas leading to desertification.

E. Environmental Pollution

The most serious impact of industrialization is environmental pollution that has affected our land, water and air. Major rivers of the world have suffered colossal losses due to water pollution. Many important rivers have been converted into open severs. Even the groundwater is getting polluted due to illegal drilling of industrial waste water. Toxic gases and particulate matter from industrial emissions and vehicular exhaust have polluted the atmosphere. Release of greenhouse gases into the atmosphere has caused enhanced global warming. Release of CFC's has been responsible for depletion of protective ozone layer in the stratosphere, which makes our earth more prone to exposure to harmful uv radiations.

Release of oxides of nitrogen and sulphur from power plants and industries is responsible for causing acid rain in many regions of the world. Contamination of the land with toxic heavy metals is rendering it unproductive. Movement of heavy metals and pesticides through food chain has become a major cause of alarm for human health as well. All pollution aspects are being discussed separately in Chapter XII.

Human behaviour and the technological advances have not only caused regional (localized) impacts as discussed in the preceding section but have also resulted in global environmental disturbances. Technological advancement coupled with improved life style has resulted in production and emission of undesirable substances into the environment which are causing global environmental problems such as acid rain, Ozone layer depletion, global warming and climate change.

F. Acid Rain

Oxides of sulphur and nitrogen originating from industrial operations and fossil fuel combustion are the major acid forming gases. Acid forming gases are oxidised over several days by which time they travel several thousand kilometers. In the atmosphere these gases are ultimately converted into sulphuric and nitric acids. Hydrogen chloride emission forms hydrochloric acid. These acids cause acidic rain. Acid rain is only one component of acidic deposition. Acidic deposition is the total of wet acidic deposition (acid rain) and dry deposition.

Rain water is turned into acid rain when its pH falls below 5.6 (Fig. 10.18). In fact clean or natural rain water has a pH of 5.6 at 20°C because of formation of carbonic acid due to dissolution of atmospheric CO_2 in rain water.

The strong acids like sulphuric acid (H_2SO_4) and nitric acid (HNO_3) dissolved or formed in rainwater dissociate or release hydrogen ions thereby increasing the acidity in rain drops.

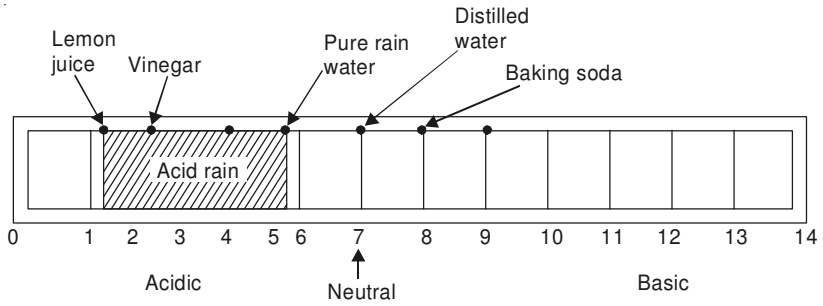


Fig. 10.11. *The pH scale of common substances*

Generally sulphuric acid forms a major fraction of acid rain, followed by nitric acid and a very small fraction of other acids. However, in urban areas Calcium (Ca^{2+}), Magnesium (Mg^{2+}) and ammonium (NH_4^+) ions help to neutralize the rain drops shifting the overall H^+ towards basic

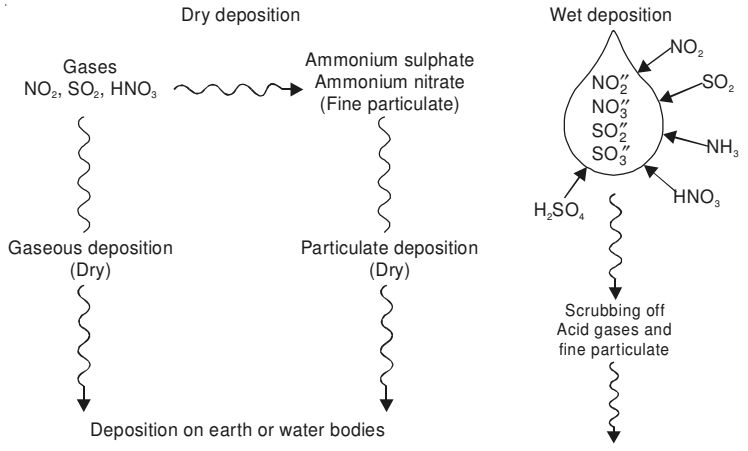


Fig. 10.12. *Acid deposition (dry deposition and wet deposition)*

scale. The overall pH of any raindrop is due to the net effect of carbonic acid, sulphuric acid, nitric acid and other acidic constituents or any neutralizers such as ammonia.

In the absence of rain, dry deposition of acid may occur. Acid forming gases like oxides of sulphur and nitrogen and acid aerosols get deposited on the surface of water bodies, vegetation, soil and other materials. On moist surfaces or in liquids these acid forming gases can dissolve and form acids similar to that formed in acid rain. If the oxidizers are present on the liquid surfaces then these gases undergo oxidation to form acids. Fine particles or acid droplets can act as nuclei for water to condense to form rain droplets. By such process sulphuric acid is incorporated into the droplets. In the clouds additional SO_2 and NO_2 contact the droplets and get absorbed which can be oxidized by the dissolved hydrogen peroxide (H_2O_2) or other oxidizers. In the droplets falling from the clouds additional acidic gases and aerosol particles get incorporated, further decreasing their pH. A unit decrease in pH value causes 10 times increase in acidity. Average pH in rainfall over eastern United States from April 1979 to March 1980 was less than 5.0. In India acid rain is recorded from certain places:

Name of place	**pH of rainwater**
Kodaikanal	5.18
Minicoy	5.52
Mohanbari	5.50

Effects of Acid Rain

Acid rain causes a number of harmful effects below pH 5.1. The effects are visible in the aquatic system even at pH less than 5.5.

- It causes deterioration of buildings especially made of marble *e.g.* monuments like Taj Mahal. Crystals of calcium and magnesium sulphate are formed as a result of corrosion caused by acid rain.
- It damages stone statues. Priceless stone statues in Greece and Italy have been partially dissolved by acid rain.
- It damages metals and car finishes.
- It causes release of lead from water pipes used for drinking water.
- Aquatic life especially fish are badly affected by lake acidification.
- Aquatic animals suffer from toxicity of metals such as aluminium, mercury, manganese, zinc and lead which leak from the surrounding rocks due to acid rain.
- It results in reproductive failure, and killing of fish.
- Many lakes of Sweden, Norway, Canada have become fishless due to acid rain. The Adirondack Lakes located in the state of New York are known to be worst affected by atmospheric acid rains.
- It damages foliage and weakens trees.
- It makes trees more susceptible to stresses like cold temperature, drought, etc. Many insects and fungi are more tolerant to acidic conditions and hence they can attack the susceptible trees and cause diseases.

Control of Acid Rain

- Emission of SO_2 and NO_2 from industries and power plants should be reduced by using pollution control equipments.
- Liming of lakes and soils should be done to correct the adverse effects of acid rain.
- A coating of protective layer of inert polymer should be given in the interior of water pipes for drinking water.

G. Ozone Layer Depletion

For the last 450 million years the earth has had a natural sunscreen in the stratosphere called the ozone layer. This layer filters out harmful ultraviolet radiations from the sunlight and thus protects various life forms on the earth.

Ozone is a form of oxygen. The molecule of oxygen contains two atoms (O_2) whereas that of ozone contains three (O_3). In the stratosphere ozone is continuously being created by the absorption of short wavelength ultraviolet (UV) radiations. Ultraviolet radiations less than 242 nanometers decompose molecular oxygen into atomic oxygen (O) by photolytic decomposition.

$$O_2 + h\nu \longrightarrow O + O$$

The atomic oxygen rapidly reacts with molecular oxygen to form ozone.

$$O + O_2 + M \longrightarrow O_3 + M$$

(M is a third body necessary to carry away the energy released in the reaction).

Ozone thus formed distributes itself in the stratosphere and absorbs harmful ultraviolet radiations (200 to 320 nm) and is continuously being converted back to molecular oxygen.

$$O_3 + h\nu \longrightarrow O_2 + O$$

Absorption of UV radiations results in heating of the stratosphere.

The net result of the above reactions is an equilibrium concentration of stratospheric ozone. Ozone concentration in about 24 km of the stratosphere *i.e.,* from 16 km to 40 km away from earth is about 10 ppm (as compared to 0.05 ppm concentration of harmful tropospheric ozone). This equilibrium is disturbed by reactive atoms of chlorine, bromine etc. which destroy ozone molecules and result is thinning of ozone layer generally called ozone hole.

The amount of atmospheric ozone is measured by 'Dobson Spectrometer' and is expressed in **Dobson units (DU)**. One DU is equivalent to 0.01 mm thickness of pure ozone at the density it would possess if it were brought to ground level (1atm) pressure. Normally over temperate latitude its concentration is about 350 DU, over tropics it is 250 DU whereas at subpolar regions (except when ozone thinning occurs) it is on an average 450 DU. It is because of the stratospheric winds which transport ozone from tropical towards polar regions.

Thinning of Ozone Layer

The Antarctic ozone hole was discovered by Dr. Joe C. Farman and his colleagues in the British Antarctic Survey who had been recording ozone levels over this region since 1957. During spring season of south pole *i.e.* September to November each year ozone depletion is observed. Steep decline has been observed since mid 1970s with a record low concentration of 90 DU in early October of 1993.

Chlorofluorocarbons (CFC) are mainly responsible for ozone depletion in the stratosphere. CFCs are a group of synthetic chemicals first discovered by Thomas Midgley Jr. in 1930. CFC-11 and CFC-12 are the CFCs most commonly used. CFCs are used as coolants in refrigerators and air conditioners, as propellants, cleaning solvents, sterilant and in styrofoam etc. CFCs released in the troposphere reach the stratosphere and remain there for 65–110 years destroying O_3 molecules. In 1974, Rowland and Molina warned that CFCs are lowering the concentration of ozone in the stratosphere and predicted severe consequences. It was however, in 1985 that scientists for the first time discovered that 50% (98% in some areas) of upper stratospheric ozone over Antarctica was destroyed during the Antarctic spring and early summer (September-December). At Antarctic region the temperature during winter drops to – 90°C. The winds blowing in a circular pattern over earth's poles create polar vortices. Water droplets in clouds when they enter these vortices form ice crystals. CFCs get collected on the surfaces of these ice crystals and destroy ozone much

faster. Similar destruction of ozone over North Pole occurs during Arctic spring and early summer (February-June). The depletion is 10–25% and it is less than that observed at south pole.

Nitrous oxide emitted by supersonic aircrafts, during combustion of fossil fuel, and use of nitrogen fertilizers breaks ozone molecules. Chlorine liberated from chlorofluorocarbons also break ozone molecules. The chain reaction started in Antarctic spring *i.e.* August/September continues till nitrogen dioxide is liberated from nitric acid formed in the stratosphere by photolysis (breakdown by sunlight). Nitrogen dioxide combines with chlorine and stops further destruction of ozone.

Effects of Ozone Depletion

- Ozone depletion in the stratosphere will result in more UV radiation reaching the earth especially UV-B (290–320 nm). The UV-B radiations affect DNA and the photosynthetic chemicals. Any change in DNA can result in mutation and cancer. Cases of skin cancer (basal and squamous cell carcinoma) which do not cause death but cause disfigurement will increase.
- Easy absorption of UV rays by the lens and cornea of eye will result in increase in incidents of cataract.
- Melanin producing cells of the epidermis (important for human immune system) will be destroyed by UV-rays resulting in immuno-suppression. Fair people (who cannot produce enough melanin) will be at a greater risk of UV exposure.
- Phytoplanktons are sensitive to UV exposure. Ozone depletion will result in decrease in their population thereby affecting the population of zooplankton, fish, marine animals, in fact the whole aquatic food chain.
- Yield of vital crops like corn, rice, soybean, cotton, bean, pea, sorghum and wheat will decrease.
- Degradation of paints, plastics and other polymer material will result in economic loss due to effects of UV radiation resulting from ozone depletion.

H. Global Warming

Troposphere, the lowermost layer of the atmosphere traps heat by a natural process due to the presence of certain gases. This effect is called **Greenhouse Effect** as it is similar to the warming effect observed in the horticultural greenhouse made of glass. The amount of heat trapped in the atmosphere depends mostly on the concentrations of "heat trapping" or "greenhouse" gases and the length of time they stay in the atmosphere. The major greenhouse gases are carbon dioxide, ozone, methane, nitrous oxide, chlorofluorocarbons (CFCs) and water vapours.

The average global temperature is 15°C. In the absence of greenhouse gases this temperature would have been –18°C. Therefore, Greenhouse Effect contributes a temperature rise to the tune of 33°C. Heat trapped by greenhouse gases in the atmosphere keeps the planet warm enough to allow us and other species to exist. The two predominant greenhouse gases are water vapours, which are controlled by hydrological cycle, and carbon dioxide, which is controlled mostly by the global carbon cycle. While the levels of water vapour in the troposphere have relatively remained constant, the levels of carbon dioxide have increased. Other gases whose levels have increased due to human activities are methane, nitrous oxide and chlorofluorocarbons. Deforestation has further resulted in elevated levels of carbon dioxide due to non-removal of carbon dioxide by plants through photosynthesis.

Warming or cooling by more than 2°C over the past few decades may prove to be disastrous for various ecosystems on the earth including humans, as it would alter the conditions faster than some species could adapt or migrate. Some areas will become inhabitable because of drought or floods following a rise in average sea level.

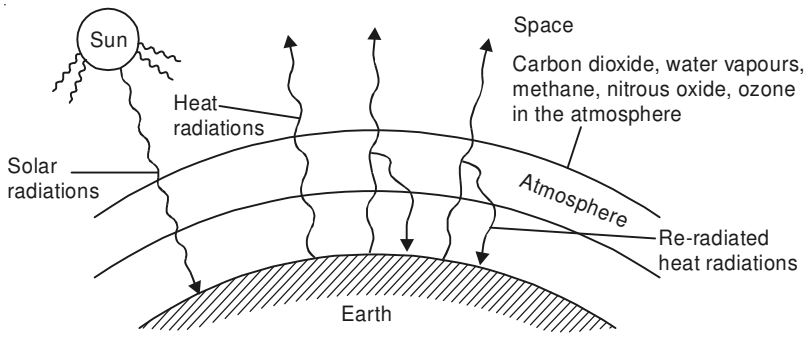


Fig. 10.13. *The greenhouse effect*

The phenomenon that worries the environmental scientists is that due to anthropogenic activities there is an increase in the concentration of the greenhouse gases in the air that absorb infra-red light containing heat and results in the re-radiation of even more of the outgoing thermal infra-red energy, thereby increasing the average surface temperature beyond 15°C. The phenomenon is referred to as the **enhanced greenhouse effect** to distinguish its effect from the one that has been operating naturally for millennia.

Impacts of Enhanced Greenhouse Effect

The enhanced greenhouse effect will not only cause global warming but will also affect various other climatic and natural processes.

(*i*) **Global temperature increase:** It is estimated that the earth's mean temperature will rise between 1.5 to 5.5°C by 2050 if input of greenhouse gases continues to rise at the present rate. Even at the lower value, earth would be warmer than it has been for the past 10,000 years.

(*ii*) **Rise in sea level**: With increase in global temperature sea water will expand. Heating will melt the polar ice sheets and glaciers resulting in further rise in sea level. Current models indicate that an increase in the average atmospheric temperature of 3°C would raise the average global sea level by 0.2–1.5 meters over the next 50–100 years.

One meter rise in sea level will inundate low lying areas of cities like Shanghai, Cairo, Bangkok, Sydney, Hamburg and Venice as well as agricultural lowlands and deltas in Egypt, Bangladesh, India and China, and will affect rice productivity. This will also disturb many commercially important spawning grounds, and would probably increase the frequency of storm damage to lagoons, estuaries and coral reefs.

In India, the Lakshadweep Islands with a maximum height of 4 meters above the sea level may be vulnerable. Some of the most beautiful cities like Mumbai may be saved by heavy investment on embankment to prevent inundation.

Life of millions of people will be affected by the sea level rise who have built homes in the deltas of the Ganges, the Nile, the Mekong, the Yangtze and the Mississippi rivers.

(*iii*) **Effects on human health**: Global warming will lead to changes in the rainfall pattern in many areas, thereby affecting the distribution of vector-borne diseases like malaria, filariasis, elephantiasis etc.

Areas which are presently free from diseases like malaria, schistosomiasis etc. may become the breeding grounds for the vectors of such diseases. The areas likely to be affected in this manner are Ethiopia, Kenya and Indonesia. Warmer temperature and more water stagnation would favour the breeding of mosquitoes, snails and some insects, which are the vectors of such diseases.

Higher temperature and humidity will increase or aggravate respiratory and skin diseases.

(*iv*) **Effects on agriculture:** There are different views regarding the effect of global warming on agriculture. It may show positive or negative effects on various types of crops in different regions of the world. Tropical and subtropical regions will be more affected since the average temperature in these regions is already on the higher side. Even a rise of 2°C may be quite harmful to crops. Soil moisture will decrease and evapo-transpiration will increase, which may drastically affect wheat and maize production.

Increase in temperature and humidity will increase pest growth like the growth of vectors of various diseases. Pests will adapt to such changes better than the crops.

To cope up with the changing situation, drought resistant, heat resistant and pest resistant varieties of crops have to be developed.

Measures to Check Global Warming

To slow down enhanced global warming the following steps will be important:

(*i*) Cut down the current rate of use of CFCs and fossil fuel.
(*ii*) Use energy more efficiently.
(*iii*) Shift to renewable energy resources.
(*iv*) Increase Nuclear Power Plants for electricity production.
(*v*) Shift from coal to natural gas.
(*vi*) Trap and use methane as a fuel.
(*vii*) Reduce beef production.
(*viii*) Adopt sustainable agriculture. Reduce dependence on chemical fertilizers.
(*ix*) Stabilize population growth.
(*x*) Efficiently remove CO_2 from smoke stacks.
(*xi*) Plant more trees.
(*xii*) Remove atmospheric CO_2 by utilizing photosynthetic algae.

Climate Change

Climate is the average weather of an area. It is the general weather conditions, seasonal variations and extremes of weather in a region. Such conditions which average over a long period, at least 30 years, is called climate.

The **Intergovernmental Panel on Climate Change (IPCC)** in 1990 and 1992 published the best available evidence about past climate change, the green house effect and recent changes in global temperature. It is observed that earth's temperature has changed considerably during the geological times. It has experienced several glacial and interglacial periods. However, during the

past 10,000 years of the current interglacial period the mean average temperature has fluctuated by 0.5–1°C over 100 to 200 year period. We have relatively stable climate for thousands of years due to which we have practised agriculture and increased in population. Even small changes in climatic conditions may disturb agriculture that would lead to migration of animals including humans.

Anthropogenic (man-made) activities are upsetting the delicate balance that has established between various components of the environment. Greenhouse gases are increasing in the atmosphere resulting in increase in the average global temperature.

This may upset the hydrological cycle, result in floods and droughts in different regions of the world, cause sea level rise, changes in agriculture productivity, famines and death of humans as well as livestock.

The global change in temperature will not be uniform everywhere and will fluctuate in different regions. The places at higher latitudes will be warmed up more during late autumn and winter than the places in tropics. Poles may experience 2 to 3 times more warming than the global average, while warming in the tropics may be only 50 to 100% on an average. The increased warming at poles will reduce the thermal gradient between the equator and high latitude regions decreasing the energy available to the heat engine that drives the global weather machine. This will disturb the global pattern of winds and ocean currents as well as the timing and distribution of rainfall. Shifting of ocean currents may change the climate of Iceland and Britain and may result in cooling at a time when rest of the world warms. By a temperature increase of 1.5 to 4.5°C the global hydrological cycle is expected to intensify by 5 to 10%. Disturbed rainfall will result in some areas becoming wetter and the others drier. Although rainfall may increase, higher temperatures will result in more evapo-transpiration leading to annual water deficit in crop fields.

IPCC Report, 2007

The fourth Assessment Report (AR4) of the United Nations Intergovernmental Panel on Climate Change (IPCC), 2007 has been prepared by more than 2500 scientific expert researchers from more than 130 countries during 6 years efforts. The report released on April 6, 2007 highlights the unequal availability of water *i.e.,* excess or lack of water leading to increase in droughts and floods. Glaciers in Himalayas will melt and the size and number of glacial lakes will increase. The mid latitude and semi arid regions of the world will experience drier years. Africa will experience water stress. There will be increased availability of water in moist tropics and high latitudes. Rain dependent agricultural produce will get a boost in North America. Sea level and human activities together will contribute to loss of coastal wetlands. Fresh water availability will decrease by 2050. More than a billion people will be at greater risk. The report assesses that 40 per cent species will become extinct. Human health will be affected. There will be increase in number of deaths, diseases like diarrhoea, cardiovascular diseases, etc. The work done by IPCC has been internationally acclaimed. The Nobel Prize for Peace (2007) was awarded jointly to IPCC (headed by Dr. R.K. Pachauri) and Al-Gore (the then Vice-President of the USA).

In sum, we can say that agricultural revolution that took place over 10,000 years ago and industrial revolution that took-place over 200 years ago have together brought enormous changes in our environment. Our social, economic and cultural systems have changed. Now there is a need for 'Environmental revolution' so that the planet earth and the mankind can survive.

10.6 NEED TO CONSERVE NATURAL RESOURCES

Life on this planet earth depends upon a variety of goods and services provided by the nature, which are known as natural resources. Thus water, air, soil, minerals, coal, forests, crops and wildlife are all examples of natural resources. Any stock or reserve that can be drawn from nature is a natural resource.

All living organisms are able to grow, develop and live by utilising various natural resources, that are of two types:

- **Renewable resources** which are inexhaustive and can be regenerated within a given span of time *e.g.,* forests, wildlife, wind energy, biomass energy, tidal energy, hydro power etc. Solar energy is also a renewable form of energy as it is an inexhaustible source of energy.
- **Non-renewable resources** which cannot be regenerated *e.g.,* Fossil fuels like coal, petroleum, minerals etc. Once we exhaust these reserves, the same cannot be replenished.

Even our renewable resources can become non-renewable if we exploit them to such extent that their rate of consumption exceeds their rate of regeneration. For example, if a species is exploited so much that its population size declines below the threshold level then it is not able to sustain itself and gradually the species becomes endangered or extinct.

It is very important to protect and conserve our natural resources and use them in a judicious manner so that we do not exhaust them. It does not mean that we should stop using most of the natural resources. Rather, we should use the resources in such a way that we always save enough of them for our future generations. Let us see what is the value of these natural resources and why should we conserve the same:

A. Water—A Precious Natural Resource

Although water is very abundant on this earth, yet it is very precious. Out of the total water reserves of the world, about 97.4% is salty water (marine) and only 2.6% is fresh water. Even this small fraction of fresh water is not available to us as most of it is locked up in polar ice caps (1.98%) and just 0.6% is readily available to us in the form of groundwater and surface water.

Overuse of groundwater for drinking, irrigation and domestic purposes has resulted in rapid depletion of groundwater in various regions leading to lowering of water table and drying of wells. Pollution of many of the groundwater aquifers has made many of these wells unfit for consumption.

Rivers and streams have long been used for discharging the wastes. Most of the civilizations have grown and flourished on the banks of rivers, but unfortunately, growth in turn, has been responsible for pollution of the rivers.

As per the United Nations estimates (2002), at least 1.1 billion people do not even have access to safe drinking water and 2.4 billion do not have adequate sanitation facilities. Increasing population and expanding development would further increase the demand for water. It is estimated that by 2024, two-thirds of the world population would be suffering from acute water shortage.

B. Land—A Finite and Valuable Resource

Land is a finite and very important resource upon which we depend for our food, fibre and fuel wood, the basic amenities of life. Soil, especially the top soil, is classified as a renewable resource because it is continuously regenerated by natural process though at a very slow rate. About 200-1000 years are needed for the formation of one inch or 2.5 cm soil, depending upon the climate and the soil type. But, when rate of erosion is faster than rate of renewal, then the soil becomes a non-renewable resource.

Hence, there is a need to conserve the land and prevent its degradation.

C. Biodiversity—A Multi-valued Resource

The value of biodiversity in terms of its commercial utility, ecological services, social and aesthetic value is enormous. The multiple uses of biodiversity or biodiversity value has been classified by McNeely *et al* (1990) as follows:

(*i*) **Consumptive use value:** These are direct use values where the biodiversity product can be harvested and consumed directly *e.g.,* fuel, food, drugs, fibre etc.

A large number of wild plants are consumed by human beings as food. About 80,000 edible plant species have been reported from wild. About 90% of present day food crops have been domesticated from wild tropical plants. A large number of wild animals also are source of food.

About 75% of the world's population depends upon plants or plant extracts for medicines. The wonder drug Penicillin used as an antibiotic is derived from a fungus called *Penicillium*. Likewise, we get Tetracyclin from a bacterium. Quinine, the cure for malaria is obtained from the bark of Cinchona tree, while Digitalin is obtained from foxglove (*Digitalis*) which is an effective cure for heart ailments. Recently vinblastin and vincristine, two anti-cancer drugs, have been obtained from Periwinkle (*Catharanthus*) plant, which possesses anti-cancer alkaloids. A large number of marine animals are supposed to possess anti-cancer properties which are yet to be explored systematically.

(*ii*) **Productive use values:** These are the commercially usable values where the product is marketed and sold including animal products like tusks of elephants, musk from musk deer, silk from silk-worm, wool from sheep, fur of many animals, lac from lac insects etc. Many industries are dependent upon the productive use values of biodiversity *e.g.,*- the paper and pulp industry, plywood industry, railway sleeper industry, silk industry, textile industry, ivory-works, leather industry and pearl industry.

(*iii*) **Social value:** These are the values associated with the social life, customs, religion and psycho-spiritual aspects of the people like Tulsi (holy basil), Peepal, Mango, Lotus, Bael etc, the leaves, fruits or flowers of which are used in worship. Many animals like cow, snake, bull, peacock and owl also have significant status in our psycho-spiritual arena showing distinct social value.

(*iv*) **Ethical value (Existence value):** The ethical value means that we may or may not use a species, but knowing the very fact that this species exists in nature gives us pleasure. We all feel sorry when we learn that "passenger pigeon" or "dodo" is no more on this earth. We are not deriving anything direct from kangaroo, zebra or giraffe, but we all strongly feel that these species should exist in nature. This means, there is an ethical value or existence value attached to each species.

(*v*) **Aesthetic value:** Great aesthetic value is attached to biodiversity. People from far and wide spend a lot of time and money to visit wilderness areas where they can enjoy the aesthetic value of biodiversity and this type of tourism is now known as ***eco-tourism***.

(*vi*) **Option values:** These values include the potentials of biodiversity that are presently unknown and need to be explored. There is a possibility that we may have some potential cure for AIDS or cancer existing within the depths of a marine ecosystem, or a tropical rainforest.

(*vii*) **Ecosystem service value:** Recently, a non-consumptive use value related to ecosystem services has been recognized, which refers to the services provided by ecosystems consisting of biodiversity. These are prevention of soil erosion, prevention of floods, maintenance of soil fertility, cycling of nutrients, fixation of nitrogen, cycling of water, their role as carbon sinks, pollutant absorption and reduction of the threat of global warming etc.

Different categories of biodiversity value clearly indicate that ecosystem, species and genetic diversity all have enormous potential and a decline in biodiversity will lead to huge economic, ecological and socio-cultural losses. Hence, every effort should be made to preserve the biodiversity.

D. Economic and Environmental Value of Forest Resources

Forests are one of the most important natural resources on this earth. Covering the earth like a green blanket these forests not only produce innumerable material goods, but also provide several environmental services which are essential for life.

Forests are of immense value to us. They are not only useful for industry but also for rural economic growth. They offer huge potential for reducing poverty while also conserving their valuable key resources.

Figure 10.14 compares the value of forests in terms of economic products and environmental services.

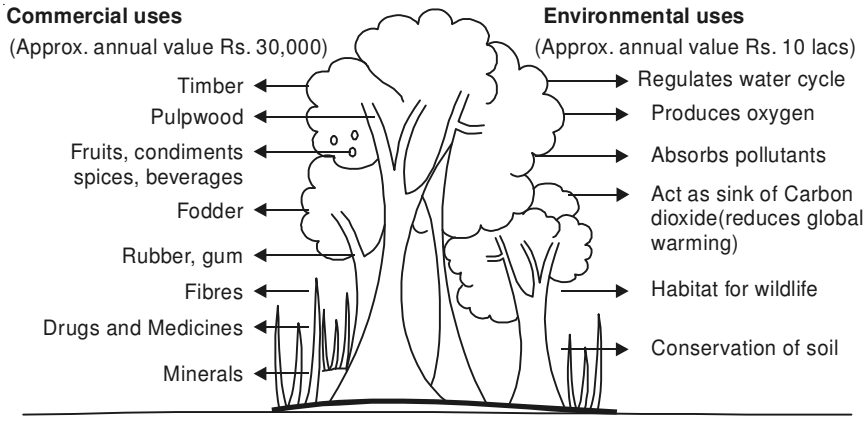


Fig. 10.14. *Economic vs. Environmental value of forests*

Economic uses: Forests provide us a large number of commercial goods which include timber, firewood, pulpwood, food items, gum, resins, non-edible oils, rubber, fibers, lac, bamboo canes, fodder, medicine, drugs and many more items.

Half of the timber cut each year is used as fuel for heating and cooking. One third of the wood harvest is used for building materials as lumber, plywood and hardwood, particle board and chipboard. One sixth of the wood harvest is converted into pulp and used in paper industry. Many forest lands are used for mining, agriculture, grazing, and recreation and for development of dams.

Ecological Uses: The ecological services provided by our forests may be summed up as follows:

- **Production of oxygen:** The trees produce oxygen by photosynthesis which is vital for life on this earth. They are rightly called as earth's lungs.
- **Reducing global warming:** The main greenhouse gas carbon dioxide (CO_2) is absorbed by the forests as a raw material for photosynthesis. Thus forest canopy acts as a sink for CO_2 thereby reducing the problem of global warming caused by greenhouse gas CO_2.
- **Wildlife habitat:** Forests are the homes of millions of wild animals and plants. About 7 million species are found in the tropical forests alone.
- **Regulation of hydrological cycle**: Forested watersheds act like giant sponges, absorbing the rainfall, slowing down the runoff and slowly releasing the water for recharge of springs. About 50–80 % of the moisture in the air above tropical forests comes from their transpiration which helps in bringing rains.
- **Soil conservation:** Forests bind the soil particles tightly in their roots and prevent soil erosion. They also act as wind-breaks.
- **Pollution moderators:** Forests can absorb many toxic gases and can help in keeping the air pure. They have also been reported to absorb noise and thus help in preventing air and noise pollution.

While a typical tree produces annually commercial goods worth about Rs. 30,000 it provides environmental services worth nearly Rs. one lakh.

10.7 RESOURCE CONSERVATION PRACTICES

There are various types of conservation practices for different natural resources.

A. Water Conservation

Water being one of the most precious and indispensable resources needs to be conserved. The following strategies can be adopted for conservation of water.

(*i*) **Decreasing run-off losses:** Huge water-loss occurs due to run-off on most of the soils, which can be reduced by allowing most of the water to infiltrate into the soil. This can be achieved by using contour cultivation, terrace farming, water spreading, chemical treatment or improved water-storage system.

- **Contour cultivation** on small furrows and ridges across the slopes trap rainwater and allow more time for infiltration. Terracing constructed on deep soils have large water-storage capacity. On gentle slopes trapped run-off is spread over a large area for better infiltration.
- **Conservation-bench terracing** involves construction of a series of benches for catching the run-off water.

- **Water spreading** is done by channeling or lagoon-levelling. In channeling, the water-flow is controlled by a series of diversions with vertical intervals. In lagoon leveling, small depressions are dug in the area so that there is temporary storage of water.
- **Chemical wetting agents (Surfactants)** increase the water intake rates when added to normal irrigated soils.
- **Surface crop residues** including tillage, mulch, animal residues etc. help in reducing run-off by allowing more time for water to penetrate into the land.
- **Chemical conditioners** like gypsum ($CaSO_4.2H_2O$) when applied to sodic soils improve soil permeability and reduce run-off. Another useful conditioner is HPAN (hydrolysed polyacrylonitrile).
- **Water-storage structures** like farm ponds, dug-outs etc. built by individual farmers can be useful measures for conserving water through reduction of run-off.

(*ii*) **Reducing evaporation losses:** Horizontal barriers of asphalt placed below the soil surface increase water availability particularly in sandy soil.

A co-polymer of starch and acrylonitrile called 'super slurper', which has been reported to absorb water upto 1400 times its weight is also useful.

(*iii*) **Storing water in soil**: Storage of water takes place in the soil root zone when the soil is wetted to field capacity. By leaving the soil fallow for one season water can be made available for the crop grown in next season.

(*iv*) **Reducing irrigation losses:** This can be achieved by:

- Use of lined or covered canals to reduce seepage.
- Irrigation in early morning or late evening to reduce evaporation losses.
- Sprinkling irrigation and drip irrigation to conserve water by 30–50%.
- Growing hybrid crop varieties with less water requirements and tolerance to saline water helps conserve water.

(*v*) **Re-use of water**

- Treated wastewater can be used for ferti-irrigation.
- Using grey water from washings, bath-tubs etc. for watering gardens, washing cars or paths help in saving fresh water.

(*vi*) **Preventing wastage of water:** This can be done in households, commercial buildings and public places.

- Closing taps when not in use
- Repairing any leakage from pipes
- Using small capacity flush in toilets.

(*vii*) **Increasing block pricing** so that the consumer pays a proportionately higher bill for greater use of water, thereby encouraging economised water use.

B. Rainwater Harvesting

Rainwater harvesting is a technique of increasing the recharge of groundwater by capturing and storing rainwater. This is done by constructing special water-harvesting structures like dug wells, percolation pits, lagoons, check dams etc. Rainwater, wherever it falls, is captured and pollution of this water is prevented. Rainwater harvesting is not only proving useful for poor and scanty rainfall regions but also for the rich ones.

The annual average rainfall in India is 1200 mm, however, in most places it is concentrated over the rainy season, from June to September. It is an astonishing fact that Cherapunji, the place receiving the second highest annual rainfall as 11000 mm still suffers from water scarcity. The water flows with run-off and there is little vegetation to check the run-off and allow infiltration. Till now there is hardly any rain-water harvesting being done in this region, thereby losing all the water that comes through rainfall.

Rainwater harvesting has the following objectives:

(*i*) to reduce run-off loss

(*ii*) to avoid flooding of roads

(*iii*) to meet the increasing demands of water

(*iv*) to raise the water table by recharging ground water

(*v*) to reduce groundwater contamination

(*vi*) to supplement groundwater supplies during lean season.

Rainwater can be mainly harvested by any one of the following methods:

(*i*) by storing in tanks or reservoirs above or below ground.

(*ii*) by constructing pits, dug-wells, lagoons, trench or check-dams on small rivulets

(*iii*) by recharging the groundwater.

Before adopting a rain-water harvesting system, the soil characteristics, topography, rainfall pattern and climatic conditions should be understood.

Traditional Rain Water Harvesting

In India, it is an old practice in high rainfall areas to collect rainwater from roof-tops into storage tanks. In foot hills, water flowing from springs is collected by embankment. In Himalayan foot-hills people use the hollow bamboos as pipelines to transport the water of natural springs. Rajasthan is known for its *'tankas'* (underground tanks) and *khadins* (embankments) for harvesting rainwater. In ancient times we had adequate *Talaabs*, *Baawaris*, *Johars, Hauz* etc. in every city, village and capital cities of our kings and lords, which were used to collect rain-water to ensure adequate water supply in dry periods.

Modern Techniques of Rain Water Harvesting

In arid and semi-arid regions artificial ground water recharging is done by constructing shallow percolation tanks. Check-dams made of any suitable native material (brush, poles, rocks, plants, loose rocks, wire-nets, stones, slabs, sacks etc.) are constructed for harvesting run-off from large catchment areas. Rajendra Singh of Rajasthan popularly known as "water man" has been doing a commendable job for harvesting rain-water by building checkdams in Rajasthan and he was honoured with the prestigious Magsaysay Award for his work.

Groundwater flow can be intercepted by building groundwater dams for storing water underground. As compared to surface dams, groundwater dams have several advantages like minimum evaporation loss, reduced chances of contamination etc.

In roof top rainwater harvesting, which is a low cost and effective technique for urban houses and buildings, the rain-water from the top of the roofs is diverted to some surface tank or pit through a delivery system which can be later used for several purposes. Also, it can be used to recharge underground aquifers by diverting the stored water to some abandoned dug-well or by using a hand pump (Fig. 10.15).

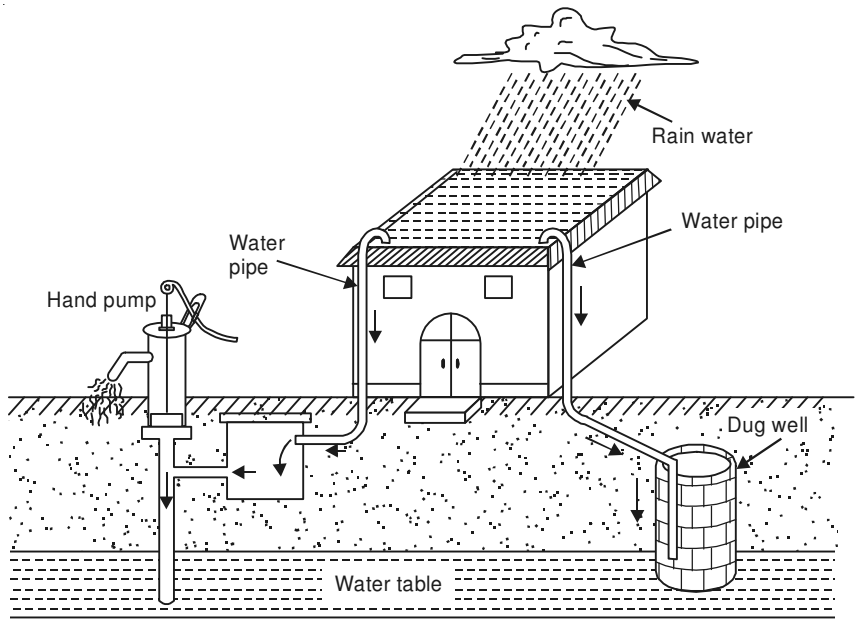


Fig. 10.15. *Roof-top rainwater harvesting by recharging (i) through hand pump or (ii) through abandoned dugwell*

All the above techniques of rainwater harvesting are low-cost methods with little maintenance expenses. Rainwater harvesting helps in recharging the aquifers, improves groundwater quality by dilution, improves soil moisture and reduces soil erosion by minimizing run-off water.

C. Watershed Management

The land area drained by a river is known as the river basin. The **watershed is defined as the land area from which water drains under gravity to a common drainage channel. Thus, watershed is a delineated area with a well-defined topographic boundary and one water outlet**. The watershed can range from a few square kilometers to few thousand square kilometers in size. In the watershed the hydrological conditions are such that water becomes concentrated within a particular location like a river or a reservoir, by which the watershed is drained. The watershed comprises complex interactions of soil, landform, vegetation, land use activities and water. People and animals are an integral part of a watershed having mutual impacts on each other. We may live anywhere, we would be living in some watershed.

A watershed influences us as it is directly involved in sustained food production, water supply for irrigation, power generation, transportation as well as for influencing sedimentation and erosion, vegetation growth, floods and droughts. Thus, management of watersheds, treating them as a basic functional unit, is extremely important and the first such Integrated Watershed Management was adopted in 1949 by the Damodar Valley Corporation.

Watershed degradation: The watersheds are very often found to be degraded due to uncontrolled, unplanned and unscientific land use activities. Overgrazing, deforestation, mining, construction activities, industrialization, shifting cultivation, natural and artificial fires, soil erosion and ignorance of local people have been responsible for degradation of various watersheds.

Objectives of Watershed Management: Rational utilization of land and water resources for optimum production causing minimum damage to the natural resources is known as watershed management. The objectives of watershed management are as follows:

(*i*) To rehabilitate the watershed through proper land use, adopting conservation strategies for minimizing soil erosion and moisture retention so as to ensure good productivity of land for the farmers.

(*ii*) To manage the watershed for beneficial developmental activities like domestic water supply, irrigation, hydropower generation etc.

(*iii*) To minimize the risks of floods, droughts and landslides.

(*iv*) To develop rural areas in the region with clear plans for improving the economy of the region.

Watershed Management Practices

In the Fifth Five Year Plan, watershed management approach was included with a number of programmes for it and a national policy was developed. In watershed management, the aspects of development are considered with regard to the availability of resources.

The practices of conservation and development of land and water are taken up with respect to their suitability for peoples' benefit as well as sustainability. Various measures taken up for management include the following:

(*i*) **Water harvesting:** Proper storage of water is done with provision for use in dry seasons in low rainfall areas. It also helps in moderation of floods.

(*ii*) **Afforestation and agroforestry:** In watershed development, afforestation and crop plantation play a very important role. They help to prevent soil erosion and retention of moisture. In high rainfall areas woody trees are grown in between crops to substantially reduce the runoff and loss of fertile soil. In Dehradun, trees like *Eucalyptus* and *Leucaena* and grasses like *Chrysopogon* are grown along with maize or wheat to achieve the above objectives. Woody trees grown successfully in such agroforestry programmes include *Dalbergia sissoo* (Sheesham), *Tectona grandis* (Teak) and *Acacia nilotica* (Keekar) which have been used in watershed areas of river Yamuna.

(*iii*) **Mechanical measures for reducing soil erosion and runoff losses:** Several mechanical measures like terracing, bunding, bench terracing, no-till farming, contour cropping, strip cropping etc. are used to minimize run-off and soil erosion particularly on the slopes of watersheds. Bunding has proved to be a very useful method in reducing run-off, peak discharge and soil loss in Dehradun and Siwaliks.

(*iv*) **Scientific mining and quarrying:** Due to improper mining, the hills lose stability and get disturbed resulting in landslides, rapid erosion etc. Contour trenching at an interval of 1 meter on overburden dump, planting some soil-binding plants like *Ipomoea* and *Vitex* and draining of water courses in the mined area are recommended for minimizing the destructive effects of mining in watershed areas.

(*v*) **Public participation:** People's involvement including the farmers and tribals is the key to the success of any watershed management programme, particularly the soil and water conservation. People's cooperation as well as participation has to be ensured for the same. The communities are to be motivated for protecting a freshly planted area and maintaining a water harvesting structure implemented by the government or some external agency (NGO) independently or by involving the local people. Properly educating the people about the campaign and its benefits or sometimes paying certain incentives to them can help in effective people's participation.

Successful watershed management has been done at Sukhomajri Panchkula, Haryana through active participation of the local people.

Watershed management in Himalayan region is of vital importance since most of the watersheds of our country lie here. Several anthropogenic activities accelerate its slope instability which need to be prevented and efforts should be made to protect the watershed by preventing overgrazing, terracing and contour farming to check run-off and erosion etc. On steeper slopes with sliding faces, straw mulching tied with thin wires and ropes helps in establishing the vegetation and stabilizing the slopes.

D. Soil Conservation Practices

In order to prevent soil erosion and conserve the soil the following conservation practices are employed:

(*i*) **Conservational till farming:** In traditional method the land is ploughed and the soil is broken up and smoothed to make a planting surface. However, this disturbs the soil and makes it susceptible to erosion when fallow (*i.e.*, without crop cover). Conservational till farming, popularly known as **no-till-farming** causes minimum disturbance to the top soil. Here special tillers break up and loosen the subsurface soil without turning over the topsoil. The tilling machines make slits in the unploughed soil and inject seeds, fertilizers, herbicides and a little water in the slit, so that the seed germinates and the crop grows successfully without competition with weeds.

(*ii*) **Contour farming:** On gentle slopes, crops are grown in rows across, rather than up and down, a practice known as contour farming. Each row planted horizontally along the slope of the land acts as a small dam to help hold soil and slow down loss of soil through run-off water.

(*iii*) **Terrace farming:** It is used on still steeper slopes which are converted into a series of broad terraces that run across the contour. Terracing retains water for crops at all levels and cuts down soil erosion by controlling run-off. In high rainfall areas, ditches are also provided behind the terrace to permit adequate drainage (Plate I, *a*).

(*iv*) **Strip cropping:** Here strips of crops are alternated with strips of soil saving covercrops like grasses or grass-legume mixture. Whatever run-off comes from the cropped soil is retained by the strip of cover-crop and this reduces soil erosion. Nitrogen fixing legumes also help in restoring soil fertility (Plate I, *b*).

Plate I(a) Terrace farming

Plate I(b) Strip cropping

(*v*) **Alley cropping:** It is a form of inter-cropping in which crops are planted between rows of trees or shrubs. This is also called **Agro forestry.** Even when the crop is harvested, the soil is not fallow because trees and shrubs still remain on the soil holding the soil particles and prevent soil erosion (Plate I, *c*).

(*vi*) **Wind breaks or shelterbelts:** They help in reducing erosion caused by strong winds.

The trees are planted in long rows along the cultivated land boundary so that wind is blocked. The wind speed is substantially reduced which helps in preventing wind erosion of soil (Plate I, *d*).

Plate I(c) Alley cropping

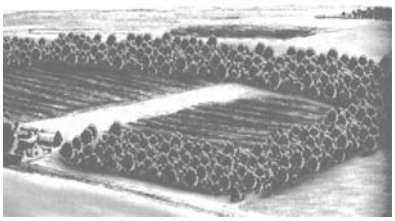


Plate I(d) Shelter belt

Thus, soil erosion is one of the world's most critical problems and, if not slowed, will seriously reduce agricultural and forestry production, and degrade the quality of aquatic ecosystems as well due to increased siltation. Soil erosion, is in fact, a gradual process and very often the cumulative effects become visible only when the damage has already become irreversible. The best way to control soil erosion is to maintain adequate vegetational cover over the soil.

E. Conservation of Biodiversity

The enormous value of biodiversity due to its genetic, commercial, medical, aesthetic, ecological and optional importance emphasizes the need to conserve it. Gradually, we are coming to realize that wildlife is not just 'a game to be hunted', rather it is a 'gift of nature' to be nurtured and enjoyed. A number of measures are now being taken the world over to conserve biodiversity consisting of plants and wildlife.

There are two approaches of biodiversity conservation:

(*a*) *In-situ* conservation (within habitat): This is achieved by protection of wild flora and fauna in nature itself. *e.g.,* Biosphere Reserves, National Parks, Sanctuaries, Reserve Forests etc.

(*b*) *Ex-situ* conservation (outside habitats): This is done by establishment of gene banks, seed banks, zoos, botanical gardens, culture collections etc.

In-situ Conservation

The ***Biosphere Reserves*** conserve some representative ecosystems as a whole for long-term *in-situ* conservation.

A **National Park** is an area dedicated for the conservation of wildlife along with its environment. It is also meant for enjoyment through tourism but without impairing the environment. Grazing of domestic animals, all private rights and forestry activities are prohibited within a National Park. Each National Park usually aims at conservation specifically of some particular species of wildlife along with others.

Wildlife sanctuaries are also protected areas where killing, hunting, shooting or capturing of wildlife is prohibited except under the control of highest authority. However, private ownership rights are permissible and forestry operations are also permitted to an extent that they do not affect the wildlife adversely.

At present we have 7 major Biosphere reserves, 80 National Parks, 420 wildlife sanctuaries and 120 Botanical gardens in our country covering 4% of the geographic area.

For plants, there is one gene sanctuary for Citrus (Lemon family) and one for pitcher plant (an insect eating plant) in Northeast India. For the protection and conservation of certain animals, there have been specific projects in our country *e.g.,* Project Tiger, Gir Lion Project, Crocodile Breeding Project, Project Elephant, Snow Leopard Project.

Ex-situ Conservation

This type of conservation is mainly done for conservation of crop varieties, the wild relatives of crops and all the local varieties with the main objective of conserving the total genetic variability of the crop species for future crop improvement or afforestation programmes. In India, we have the following important **gene bank/seed bank** facilities:

(*i*) National Bureau of Plant Genetic Resources (NBPGR) is located in New Delhi. Here agricultural and horticultural crops and their wild relatives are preserved by ***cryo-preservation*** of seeds, pollen etc. by using liquid nitrogen at a temperature as low as –196°C. Varieties of rice, pearl millet, Brassica, turnip, radish, tomato, onion, carrot, chilli, tobacco, poppy etc. have been preserved successfully in liquid nitrogen for several years without losing seed viability.

(*ii*) National Bureau of Animal Genetic Resources (NBAGR) located at Karnal, Haryana. It preserves the semen of domesticated bovine animals.

(*iii*) National Facility for Plant Tissue Culture Repository (NFPTCR) for the development of a facility of conservation of varieties of crop plants/trees by tissue culture. This facility has been created within the NBPGR.

The G-15 countries have also resolved to set up a network of gene banks to facilitate the conservation of various varieties of aromatic and medicinal plants for which India is the networking coordinator country.

10.8 ENVIRONMENTAL IMPACT ASSESSMENT (EIA)

For a nation to progress socially and economically, developmental in different fields is essential. While development helps in raising the standards of life, it also has some side effects which are mainly responsible for environmental deterioration.

In post-independence period, India went ahead with several development projects and showed rapid industrial growth. However, we did not pay much attention to the pollution problem at that time. The total insensitivity on ecological and environmental aspects on the part of our government and policy makers until recently has put a huge backlog of negative environmental impacts, which have to be set right.

It is very important, therefore, to know the environmental impacts of various types of developmental activities. The cause and effect relationships of the projects and their impact analysis need to be done systematically.

Environmental Impact Assessment (EIA) is a procedure to plan some developmental activity with well-defined environmental goals so that damage due to the activity both during developmental stage and production stage have minimum impact on the natural system and the population in the area.

The National Environmental Protection Agency (NEPA) U.S.A. in 1969 first of all provided the guidelines for environmental impact assessment through Council for Environmental Quality (CEQ).

In India, the gazette notification on EIA was issued in 1994 vide which the Ministry of Environment and Forests provided guidelines for project proponents to have EIA and prepare an Environmental Impact Statement prior to clearance the project.

10.8.1 Goals of EIA

(*i*) To fulfill the responsibilities towards the coming generations as trustees of environment.

(*ii*) To assure safe, healthy, productive, aesthetically as well as culturally pleasing surroundings.

(*iii*) To provide widest range of beneficial uses of environment without degradation or risk to health.

(*iv*) To preserve historical, cultural and natural heritage.

(*v*) To achieve a balance between population and resource use for a good standard of living.

(*vi*) To ensure sustainable development with minimal environmental degradation.

The following points are usually incorporated while preparing the Environmental Impact Statement (EIS):

- Effect on land including land degradation and subsistence.
- Deforestation and compensatory afforestation.
- Air pollution and dispersion along with possible health effects.
- Water pollution including surface water and ground water pollution.
- Noise pollution.
- Loss of flora and fauna.
- Socio-economic impacts including human displacement, cultural loss and health aspect.
- Risk analysis and disaster management.
- Recycling and reduction of waste.
- Efficient use of inputs including energy and matter.

EIA is done with an aim to select the best alternative through which adverse impact on the environment can be nullified or minimized without compromising with the economic and social benefits of the developmental project.

The alternatives can be in three ways:

(*i*) Alternative technologies providing options with maximum energy efficiency and minimal wastage.

(*ii*) Alternative mitigating or controlling mechanisms through which recycling of by-products or reduction of emissions can take place.

(*iii*) Alternate phasing to work out if phasing of the project is possible instead of one stroke development to avoid drastic impact.

However, besides these alternatives, the most important alternative taken into consideration in EIA is the impact assessment at alternative sites *i.e.,* which of the site I or II or III located in different natural area would have the least impact of the development project, and that site is selected for the development project.

Thus, the main purpose of EIA is precisely to estimate the type and level of damage caused to natural environment in a well-defined time scale so that remedial measures can be initiated on those aspects requiring action at the right time.

10.8.2 Methodology

The basic steps followed in EIA are screening, scoping, base line data, impact identification, prediction, evaluation, mitigation, EIS preparation, review and environment audit.

(*i*) **Screening** is done to see whether the project needs an EIA for clearance or not. Further, there are some prohibited areas where no development project is allowed.

(*ii*) **Scoping** involves determination of the extent of EIA required for the project.

(*iii*) **Baseline data** gives a holistic picture of the overall environmental setting of the project location showing any significant environmental items prior to initiation of the action; any potentially critical environmental changes and information about the site to the decision makers and reviewers, who might be unfamiliar with the general location of the project area.

The following environmental parameters are usually considered while preparing the base-line data:

(*a*) Site location and topography.

(*b*) Regional demography - population distribution within 10 and 50 kilometer radius; land-use and water-use pattern.

(*c*) Regional landmarks like historical and cultural heritage in the area. For this archaeological or state register can be checked.

(*d*) Geology – Groundwater and surface water resources are quantified; water, quality, pollution sources etc are studied.

(*e*) Hydrology – Groundwater and surface water resources are quantified; water, quality, pollution sources etc are studied.

(*f*) Meteorology – Temperature extremes, wind speed and direction, dew point, atmospheric stability, rainfall, storms etc. are recorded.

(*g*) Ecology – The flora, fauna, endangered species, successional stage etc. are enlisted.

For a particular project, some of the parameters may be important while for others, some other parameters could be important.

(*iv*) **Impact Identification.** It includes the details of project characterization and base-line environmental characteristics to ensure the identification of full range of environmental impacts.

During identification process, the positive and negative, direct and indirect significant and insignificant impacts are considered.

Various methods employed for impact identification are as follows:

(*a*) ***Checklists:*** These are based on enlisting of specific environmental, social, biological and economic factors affecting the environment. Checklists can be simple, descriptive or questionnaire based.

(*b*) ***Matrices:*** This is most common type of impact identification method. Here the impacts are arranged in rows and columns *i.e.,* like a matrix.

A **Simple Matrix** is 2-dimensional in nature with environmental component on one axis and developmental actions on the other axis. In a **time Dependent Matrix** time-scale of impacts is taken whereas in **Magnitude Matrix,** the magnitude of impact is also denoted in the matrix by putting symbols.

Leopold Matrix is a well known matrix which consists of a hoziontal list of 100 project actions and a vertical list of 88 environmental components. Thus, theoretically

8,800 possible interactions exist. However, in practice, about 25–30 interactions occur for each project. Magnitude of the impact and importance of the impact are shown on a scale varying from 1 to 10.

We determine the impact of the proposed project for each parameter and the degree of impact ranges from 0 (for very adverse) to I (for very good). It is referred to as environmental quality.

(*c*) ***Quantitative Method:*** It compares the relative importance of all impacts by weighting, standardizing and aggregating the impacts. The best known method here is Battelle Environmental Evaluation System (BEES) which consists of Environmental, Social and Economic parameters.

Here numerical values are given to the parameters to study the changes by comparing the value with the standard values *e.g.,* a water body with Dissolved Oxygen (D.O) exceeding 10 ppm is of high quality (Score 1) while a stream with less than 4 ppm D.O. has a low quality (Say Score 0.35)

This is usually employed for River Valley Projects. 78 environmental parameters are considered which are grouped into 4 categories: ecology, environmental pollution, aesthetics, and human interest. Each parameter is assigned a specific value, known as Parameter Importance Unit (PIU) and sum total of all these is equal to 1000.

(*v*) **Impact Prediction:** Here the magnitude and other dimensions of changes associated with the project are identified in comparison with a situation without the project. In other words, prediction involves identification of potential change in the indicators of various environmental factors.

The two important models of impact prediction are:

(*a*) ***Mathematical Model:*** The cause and effect relationships are expressed in the form of a flow chart or mathematical function.

(*b*) ***Mass Balance Model:*** This is usually adopted where physical changes are involved. Here all inputs are balanced by the outputs.

(*vi*) **Impact Evaluation:** After prediction of the impacts, their relative significance is assessed by evaluation. The methods of evaluation can be qualitative or quantitative to determine magnitude of the impact, temporal and spatial extent of the impact, recovery (resilience) of the affected environment, and the value of the affected environment.

One of the most important methods used to evaluate impact of a project is **cost benefit analysis.** This method takes into consideration a long view of the project and also the side-effects. Net social benefit is considered including all costs and benefits. It takes into account all tangible annual benefits and costs in monetary terms. However, it is very difficult to identify the intangibles like environmental parameters. The intangible category includes loss of a rare species, urbanization of a beautiful natural landscape, loss of human health etc.

Lately, some techniques for monetary valuation of environmental factors have also been evolved.

Environmental Valuation Techniques

(*i*) **Direct Household Production Function**

Here it is estimated that how much would be the expenditure on commodities which can act as substitutes for a particular environmental change.

(*a*) ***Avertive Expenditure:*** The estimate of value of peace and quietness can be obtained by observing the expenditure on noise insulation.

(*b*) ***Travel Cost Method:*** the cost of travelling and time spent for visit to a site of recreation can be taken as an estimate of the value of the scenic beauty of a natural site.

(*ii*) **Direct Hedonic Price Method**

In this method, the real markets where these attributes are traded are examined *e.g.,* by comparing the house price in different localities *i.e.,* in a quiet place with clean air and a polluted and noisy place, we can get an estimate of clean and quiet environment.

(*iii*) **Direct Experimental Market**

In this method, survey is done to find individual values for non-market goods. Here, experimental markets are created to discover how people would value certain environmental changes:

(*a*) ***Contingent Valuation Method:*** In this method people are asked what they are willing to pay (WTP) for keeping some desirable factor (like a good piece of landscape, a historic building etc.) or for preventing some loss.

Also, what they are willing to accept (WTA) for losing some factor (native vegetation) or tolerating some factor (foul smell).

(*b*) ***Contingent Ranking Method:*** People are asked to rank their preferences for various environmental goods.

(*iv*) **Indirect Market Price Approach**

If a stone bridge is eroded by pollution, then the cost of replacement or restoration of the bridge is taken as the cost of pollution.

Multi-Criteria Approach

This method involving scoring and weighting overcomes the drawback of cost-benefit analysis. Quantitative scales are used according to the availability of the information about the environmental impact. Relative importance of the factor (parameter) is taken on a scale of 10 and given a weighting.

For example, we can use this method for impact evaluation of a project in two alternative situations A & B.

Impact Type	*Weight (W)*	*Alternative A*		*Alternative B*	
		Score(b)	*Impact (aw)*	*Score(b)*	*Impact (bw)*
Noise	3	5	15	1	3
Loss of flora	4	1	4	3	12
Air pollution	3	2	6	2	6
Total	10		25		21

Based on the above evaluation of impacts we can say that alternative A is going to cause more severe impact (25) as compared to that of B (21). So, alternative B is preferred to alternative A.

(*vii*) **Mitigation:** After assessing the possible impacts of the proposed project, mitigation measures are to be suggested in order to avoid, reduce and if possible, remedy the significant adverse change. Various mitigation measures could be as follows:

(*a*) ***Avoidance of Impacts***

This could be achieved by control of solid/liquid wastes by recycling them or by removing them from the site for treatment elsewhere.

(*b*) ***Ruduction of adverse effects***

This is done by using sensitive building designs, using colour matching with the local environment to reduce visual impact of the project, using silt-traps and planting of crop-covers.

(*c*) ***Repair or restoration***

The agricultural land used for storage of materials during construction may be fully rehabilitated. Land used for gravel extraction may be restored for agricultural use. Any diversion in stream flow during construction by a road project must be re-established.

(*d*) ***Compensation for adverse effect***

If there is loss of a public recreational space or wildlife habitat, then provision must be made for creation of a spot with afforestation or plantation of the type of native plants. If there is lot of noise produced during the project operation, sound insulation must be done.

(*viii*) **Decision Analysis:** After going through the various steps of impact identification, prediction and evaluation, decision analysis is done. Individual decision or group response are used for arriving at a decision. In order to have minimum bias, group response is usually taken. The most commonly used approach is the multi-step questionnaire based Delphi approach.

(*ix*) **Environmental Impact Statement (EIS):** It should include the following five major aspects

(*a*) The environmental impact of the proposed action.

(*b*) The adverse impact that cannot be avoided if the development occurs.

(*c*) Alternatives to the proposed action.

(*d*) Relation between the local short-term use of human environment and maintenance of long-term production.

(*e*) Irreversible changes in resources.

EIS is to be written in the format provided by the MOEF or CEQ as per their guidelines.

(*x*) **Environmental Audit:** EIA must be followed by a suitable environmental audit or environmental management system (EMS). Environmental impact auditing involves comparison of the impacts predicted in the EIS with those actually occurring after implementation to assess whether the impact prediction performs satisfactorily.

In order to maximize optimal utilization of natural resources and minimization of emission/discharge of pollutants/waste products in environment and reuse/recycling measures, environmental auditing has been introduced by Ministry of Environment & Forests and the Pollution Control Boards. An annual statement is required to be submitted by Project Authorities to the Pollution Control Board reflecting their achievements made during the year on above mentioned aspects.

In industries like chemical industries, raw materials are used in excess, quite often due to operational deficiencies. The excess usage of raw materials is to be checked. If these excess materials are not recycled or recovered, they find their way to environment causing pollution.

Environmental auditing thus helps to safeguard the environment and assists in complying with local, regional and national laws and regulations, with the company's policy and with the environmental standards.

Projects that are being assessed for environmental impact by the Ministry include Industry and mining, Irrigation and power, Transport & communication.

Under the Environmental Protection Act (1986) the following ecologically sensitive (fragile) areas cannot be used for developmental projects:

(*a*) Doon valley & Arawalli ranges

(*b*) Some coastal areas as per coastal regulation zone notification.

(*c*) Wildlife sanctuaries, Biosphere reserves, national parks and wetlands.

Thus EIA is a methodology through which efforts are being made to provide suitable site from the point of view of environment for locating a project through formulation of guidelines and rules. However, in India till now the exact procedure of EIA for selecting the best site among 3–4 alternatives is not followed. Environmental clearance from the MoEF, Govt. of India is, however, mandatory for certain projects/industries under certain conditions. The implementation of these conditions is monitored at field level by regional offices of Ministry of Environment and Forests. Some industries which do not fall within the ambit of MoEF have to approach State Pollution Control Board for seeking no objection certificate and permission to commission the project on the basis of assessment of quantity and quality of pollutants and control measures adopted by the investor to meet the prescribed standards.

10.9 SOLID WASTE MANAGEMENT

Higher standards of living of ever increasing population has resulted in an increase in the quantity and variety of waste generated. It is now realized that if waste generation continues indiscriminately then very soon it would be beyond rectification. Management of solid waste has, therefore, become very important in order to minimize the adverse effects of solid wastes. Solid waste (waste other than liquid or gaseous) can be classified as municipal, industrial, agricultural, medical, mining waste and sewage sludge.

A. Sources of Urban and Industrial Wastes

Urban waste consists of medical waste from hospitals; municipal solid wastes from homes, offices, markets (commercial waste) small cottage units, and horticulture waste from parks, gardens, orchards etc.

- **Waste from homes (Domestic waste)** contains a variety of discarded materials like polyethylene bags, empty metal and aluminium cans, scrap metals, glass bottles, waste paper, diapers, cloth/rags, food waste etc.
- **Waste from shops** mainly consists of waste paper, packaging material, cans, bottles, polyethylene bags, peanut shells, eggshells, tea leaves etc.
- **Biomedical waste or Hospital waste** includes anatomical wastes, pathological wastes, infectious wastes etc.
- **Construction/demolition waste** includes debris and rubbles, wood, concrete etc.
- **Horticulture waste and waste from slaughter houses** include vegetable parts, residues and remains of slaughtered animals, respectively.

The urban solid waste materials that can be degraded by micro-organisms are called **biodegradable wastes**. Examples of this type of waste are vegetable wastes, stale food, tea leaves, egg shells, peanut shells, dry leaves etc. Wastes that cannot be degraded by micro-organisms are called **non-biodegradable wastes**. For example, polyethylene bags, scrap metal, glass bottles etc.

- **Industrial waste:** Industrial waste consists of a large number of materials including factory rubbish, packaging material, organic wastes, acids, alkalis and metals etc. During some industrial processing large quantities of hazardous and toxic materials are also produced. The main sources of industrial wastes are chemical industries, metal and mineral processing industries. Radioactive wastes are generated by nuclear power plants. Thermal power plants produce fly ash in large quantities. Solid wastes from other types of industries include scrap metal, rubber, plastic, paper, glass, wood, oils, paints, asphalt, tars, dyes, scrap leather, ceramics, abrasives, slag, heavy metals, asbestos, batteries. A new type of waste being generated these days is electronic waste.

  In Europe and North America the environmental laws and safety laws are becoming more stringent due to which disposal of hazardous wastes is becoming a problem. Cost of disposal of such wastes is increasing. Therefore, these wastes are being exported to developing countries which do not even have sufficient knowledge or technique for their disposal.

B. Effects of Solid Wastes

Municipal solid wastes heap up on the roads due to improper disposal system. People clean their own houses and litter their immediate surroundings which affects the community including themselves. This type of dumping allows biodegradable materials to decompose under uncontrolled and unhygienic conditions. This produces foul smell and breeds various types of insects and infectious organisms besides spoiling the aesthetics of the site.

Industrial solid wastes are sources of toxic metals and hazardous wastes, which may spread on land and can cause changes in physico-chemical and biological characteristics thereby affecting productivity of soils. Toxic substances may leach or percolate to contaminate the ground water. Toxic chemicals are also taken up by crops or leafy vegetables from where they enter human body through food.

In refuse mixing the hazardous wastes are mixed with garbage and other combustible waste. This makes segregation and disposal all the more difficult and risky. Various types of wastes like cans, pesticides, cleaning solvents, batteries (zinc, lead or mercury) radioactive materials, plastics are mixed up with paper, scraps and other non-toxic materials which could be recycled. Burning of some of these materials produce dioxins, furans and polychlorinated biphenyls, which have the potential to cause various types of ailments including cancer.

C. Management of Solid Waste

For waste management we stress on 'three R's'-Reduce, reuse and recycle before destruction and safe storage of wastes.

(*i*) **Reduction in use of raw materials:** Reduction in the use of raw materials correspondingly decreases the production of waste. Reduced demand for any metallic product decreases its mining, hence less production of waste.

(*ii*) **Reuse of waste materials:** The refillable containers, and plastic bags which are discarded after use should be reused. In Villages casseroles and silos are made from waste paper and rubber rings from discarded cycle tubes. Such practices reduce waste generation.

(*iii*) **Recycling of materials:** Recycling is the reprocessing of discarded materials into new useful products.

Formation of some old type products *e.g.,* old aluminium cans and glass bottles are melted and recast into new cans and bottles.

Formation of new products: Preparation of cellulose insulation from paper, preparation of fuel pellets from kitchen waste. Preparation of automobiles and construction materials from steel cans.

The process of reducing, reusing and recycling saves money, energy, raw materials, land space and also reduces pollution. Recycling of paper will reduce cutting of trees for making fresh paper. Reuse of metals will reduce mining and melting of ores for recovery of metals from ores and prevent pollution.

(*iv*) **Waste disposal:**

For discarding wastes the following disposal methods can be adopted:

- **Sanitary landfill**: In a sanitary landfill, garbage is spread out in thin layers, compacted and covered with clay or plastic foam.

  In the modern landfills the bottom is covered with an impermeable liner, usually several layers of clay, thick plastic and sand. The liner protects the ground water from being contaminated due to percolation of leachate. Leachate from bottom is pumped and sent for treatment. When landfill is full it is covered with clay, sand, gravel and top soil to prevent seepage of water. Several wells are drilled near the landfill site to monitor if any leakage is contaminating ground water. Methane produced by anaerobic decomposition is collected and burnt to produce electricity or heat.

- **Composting**: Due to shortage of space for landfill in bigger cities, the biodegradable yard waste (kept separate from the municipal waste) is allowed to degrade or decompose in an oxygen rich medium. A good quality nutrient rich and environmental friendly manure is formed which improves the soil conditions and fertility. Vermi-technology, using earthworms can further help in converting solid organic waste into good quality compost.

- **Incineration**: Solid wastes can be brunt in large amounts at high temperature (around 1800°C) in incinerator. Incinerator is a high temperature furnace used for burning solid wastes. Earlier incinerators used to be made of simple brick lining, but the modern ones are rotary. Kiln incinerators having a long inclined passage through which the waste is constantly moved. There is about 75% reduction in waste mass and 90% reduction in volume. The incinerators in which the waste to be burnt is not segregated are known as **mass burn incinerators**. There are special incinerators where potentially harmful or hazardous wastes are destroyed. These are known as **Hazardous waste Incinerators.**

  Incinerators help in substantially reducing the quantity of wastes prior to their final disposal along with electricity generation. It also helps in safely destroying hospital wastes. However, during incineration high levels of dioxins, furans, lead and cadmium may be emitted with the fly ash of incinerator. For incineration of materials, it is better to remove batteries containing heavy metals and plastic containing chlorine before burning the material. Prior removal of plastics will reduce emissions of dioxins and polychlorinated biphenyls (PCBs).

10.10 ELECTRONIC WASTE (E-WASTE) AND ITS DISPOSAL

Electronic waste or E-waste is a new type of waste that has emerged in the recent years due to fast developments in the field of electronics, which keeps on changing the configuration and technology and as a result of that older models of electronic devices become obsolete in a short span of time. E-waste consists of obsolete telecommunication devices, reprograhic devices, security devices, automobile devices besides refrigerators, air conditioners, microwaves and a myriad of other electrical and electronic gadgets which add to the waste stream.

In India, the electronic waste management assumes greater significance not only due to the generation of our own waste but also dumping of e-waste, particularly computer waste from the developed countries. Manufactures and assemblers are estimated to produce around 1200 tons of electronic scrap annually. India being a developing country needs to adopt low cost technology with maximum resource recovery in an environment friendly manner.

IT industry has emerged as the fastest growing segment of Indian industry and its growth rate is almost double the growth rate of IT industries in many of the developed countries. In the IT action plan, the government has targeted to increase the present level, from 5 per 500 people to 1 for 50 people, by 2008.

Out of the nearly five million PCs presently in India, about 1.38 million are either of the old configuration (486) or even below. So a vast amount of equipment is soon going to be added to the waste stream, because upgradation beyond a point would not be feasible. Besides this, huge import of junk computers from other countries in the form of donations or gifts or low cost reusable PCs are going to create a big solid waste management problem in India. PC scrap in the form of monitors, printers, keyboards, CPUs, floppies, CDs, typewriters, PVC wires have already started piling up that are going to increase enormously in the coming years.

E-waste, which on the face of it seems quite clean and safe is not so. Its qualitative characterisation shows it to be very complex consisting of several hazardous constituents that can play havoc with our health. These toxic and hazardous substances are as follows:

(*i*) Lead and cadmium in circuit boards.

(*ii*) Lead oxide and cadmium in monitor cathode ray tubes (CRTs).

(*iii*) Mercury in switches and flat screen monitors.

(*iv*) Cadmium in computer batteries.

(*v*) Polychlorinated biphenyls (PCBs) in older capacitors and transformers.

(*vi*) And brominated flame retardants on printed circuit boards.

(*vii*) Plastic casings, cables and polyvinyl chloride (PVC) cable insulation that release highly toxic dioxins and furans when burned to recover copper from the wires. After separating all remaining components, motherboards are put for open pit burning to extract the thin layer of copper foils laminated in the circuit board.

Disposal and recycling of E-waste: It has serious legal and environmental implications due to the toxic nature of the waste. These materials are complex and difficult to recycle in a safe manner even in developed countries. The recycling of computer waste requires sophisticated technology and processes, which are not only very expensive, but also needs specific skills and training for operation.

Unlike many other countries there are no specific governmental legislations on e-waste, standards for disposal and proper procedures outlined for handling these toxic hi-tech products. Consequently, the electronic wastes in our country mostly end up in landfills or are partly recycled in most unhygienic conditions and partly thrown into waste streams.

In India, most of the recyclers currently engaged in recycling activities are poor people, mostly women and children, ignorant about the hazardous materials they are handling and have no access to the expensive technology to handle the waste.

Computer scrap in our country is managed through product reuse, conventional disposal in landfills, incineration and recycling. However, the disposal and recycling of computer waste in our country are still not safe and pose grave environmental and health hazards.

The management of electronic waste has to be assessed in the broad framework of *Extended Producer Responsibility* and the *Precautionary Principle*, so that in future policies the producers should own the responsibility of dealing with the waste management by taking back such wastes and recycle or reuse them in a safe manner. At present, management options for e-waste are extremely polluting and hence a cause of grave concern.

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CHAPTER XI

Planning for the Built Environment

11.0 BUILT ENVIRONMENT

Built Environment refers to man-made environment encompassing ecology—environment—human settlements in urban/rural areas and their interrelationships.

The built environment is defined as man-made structures built to fulfil human needs and values by modifying the environment and thus affecting it. The six components of built environment include:

(*i*) **Products—**include materials used to create the tasks of building (wood, bricks, mortar, concrete, steel, plastic, iron marble, glass etc.

(*ii*) **Interiors—**created by arranged grouping of materials enclosed within a structure to fulfill activity needs (living room, stadium, assembly halls etc.).

(*iii*) **Structures—**planned grouping of spaces where generally related activities are combined into a composite unit (*e.g.,* schools, factories, official complexes, housing, bridges etc.).

(*iv*) **Landscapes—**exterior areas around structures (*e.g.,* parks, gardens, forests etc.).

(*v*) **Cities—**groupings of structures and landscapes of different sizes clustered together.

(*vi*) **Regions—**grouping of cities.

Different regions all over the world together give rise to the highest artifact, the earth. Thus, each component is related to the other and the term built environment is a holistic concept encompassing integration of various designed components.

With increasing population there is tremendous pressure on our finite land resources, which are used for agricultural and horticultural production, forestry, development of industries or commercial complexes, and for housing. Both overcrowded unplanned urban settlements and unhygienic, underdeveloped rural settlements pose big challenges for the present and future generations. Settlements have been found to have serious impacts on nature and there is an urgent need to apply the principles of sustainability to built environment, which is possible by integrating inputs from various fields of ecology, architecture, engineering, science, technology and economics. Built environment should not just be viewed as structures created by human beings merely for providing shelter and space for various human-centred activities, rather these

are to be viewed as a dynamic interplay of spaces with judicious utilisation for multiple purposes, providing physical comfort and psychological satisfaction to the occupants along with balanced ecological elements.

Fast depletion of natural resources, shrinking land, rising pollution levels and associated health problems have forced the architects to re-look at the structure and design of buildings by replacing the 'structural approach' by 'environmental approach'.

The concept of Built-environment was envisaged by Rabindranath Tagore in planning Vishva Bharati University, which is based on futuristic ecological considerations and has made use of environment-friendly building materials, showing maximum possible harmony with nature. Planning of Chandigarh, the city beautiful, by Le Corbusier was done by considering the city as a living system, where the four functional elements *viz.*, living, working, care of body & spirit, and circulation have been beautifully integrated. This is visible in the form of planned city centre, open green spaces, road networks, industrial areas, educational and cultural centres in the city.

It is becoming absolutely essential to pay due attention to intangible functions like clean, pleasant, aesthetic environment along with good quality building parameters that can be evaluated in monetary terms. Thus, the concept of *Integrated Built Environment* has become the necessity of the age to ensure sustainability, which takes into consideration ecologically sound landscaping, architecture and designing, ensuring occupational comfort, functional utility, psychological comfort, aesthetics, healthy surroundings, energy economy and eco-friendly materials.

11.1 NATURAL AND MAN-MADE ENVIRONMENT

Nature has provided dwelling place to millions of species of living organisms including small and big animals, birds, insects, microfauna and microflora. Most of the species build some sort of a protective structure or find some natural shelter for living and to protect themselves from their predators, enemies and vagaries of nature. But they generally live in harmony with nature, whereas man transforms the surroundings of his dwelling place causing large-scale impacts on environment.

The design of built environment depends a lot upon the type of the natural environment. For example, settlements developed on hills, slopes, plains, on the banks of rivers, and in deserts show basic difference in construction lay outs. Cultural aspects also play an important role in designing built environment.

Habitat development on this earth has largely taken place within about 5% of land area, which supports more than half of global population. **Environmental compatibility** is an important factor that determines habitat development. Indicators like altitude, slope, temperature, relative humidity, rainfall, soil fertility, forest cover, population density and pollution level determine environmental compatability for development of settlements. The design and planning of built environment is influenced by such parameters.

In the modern era of fast urbanisation and industrialisation along with explosive population growth, there has been unchecked encroachment of human settlements into forest areas and degradation of environment due to dumping of wastes and depletion of natural resources. Man is moving away from nature and converting natural areas into concrete jungles. These built environments are usually overcrowded, afflicted by vehicular and industrial pollution, noise, and devoid of natural greenery. Such built environments cause stress and health problems to the

inhabitants. Development of poor quality housing in the slums in cities are the worst built environments where the inhabitants suffer from various diseases due to unhygienic living conditions and being cut-off from nature, are deprived of the environmental benefits of nature.

11.2 ENVIRONMENTAL APPROACH OF BUILT ENVIRONMENT

Environment, as already explained earlier, is the sum total of all living organisms, air, water, soil and materials along with their interactions. We human beings are a part of the environment. But, unfortunately all our activities on this earth are human-centric, which means, we are transforming the earth to suit and meet our needs, ignoring other components of environment, and in this process we have already resulted in large scale ecological degradation.

Nature has its own ecological balance, mediated by intricate network, links and feedback loops, which regulate its functioning within certain ecological limits, known as **homeostasis.** But, beyond these limits, its negative feedback mechanisms are taken over by positive feedback mechanisms, which lead to further deviations in the system, ultimately leading to collapse of the system. So, we should try not to cause too many deviations that would trigger ecological imbalance.

Nature has developed different types of ecosystems that provide us a large number of benefits, referred to as **ecosystem services.** They (forest cover/vegetation cover) act as 'green lungs', purifying the air by producing life-supporting oxygen and acting as a sink for toxic gases. They use carbon dioxide (CO_2) as a raw material for synthesizing carbohydrates. Since increasing concentrations of CO_2 in the environment is a major cause of global warming, the role of green plant cover in sequestering CO_2 is considered important. The green plants also help attenuate noise. They regulate the hydrological cycle and protect the soil cover. They also support a variety of wildlife.

Rivers, springs and oceans support enormous biodiversity and help in providing several services for supporting life. Wetlands are also useful ecosystems that support biodiversity and also act as natural waste water treatment systems.

Urban/rural towns and buildings are generally referred to as **'environmental filters'**. Desired types of controls in micro-environment are to be achieved in such built environments by carefully planning and designing ecological and environmental elements into it. Development of green belts of different types, flowering plants, open spaces, water bodies, serene spots and provisions for cultural, social, intellectual and spiritual fulfilment have to be integrated therein.

Green vegetation cover and water bodies purify the atmosphere, cool down temperature, provide natural habitat to many birds and wildlife, add to the aesthetics of the place and provide us mental solace. While planning community built-environment, these elements are to be included in the design.

Mechanical and structural controls can also be achieved for proper built environment in various ways:

(*i*) Proper orientation of the building
(*ii*) Proper ventilation and shading
(*iii*) Moisture control and water proofing
(*iv*) Thermal insulation
(*v*) Acoustics and noise controls.
(*vi*) Provision for rain water harvesting.

11.3 PRINCIPLES OF PLANNING

A house or a building is not merely constructed for providing shelter or for creating an enclosed space for some definite activities. Creation of a desired environment inside as well as outside the building, keeping in view **utility, form** and **aesthetics** is the main concern of an architect and a civil engineer. Basic materials used for several buildings may be the same, but there are certain buildings which please every observer because of their design, liveliness, beauty and utility. Planning of a building is of utmost importance which should be based on a holistic approach considering the building, its form, colour, texture, material and looks in harmony with the site and its surrounding environment. The design should be such that the building should appear as an integral part of that environment. A great deal of vision, creativity and basic knowledge of civil engineering is required for a well planned building.

Planning of a building broadly depends upon:

(*i*) Its geographical and climate conditions.

(*ii*) Purpose for which it is to be used.

The longitude and latitude of a site provide useful information to us regarding its location in northern or southern hemisphere and whether it lies in hot tropics or cold temperate zone. Similarly, altitude provides information about the height of the site with respect to sea level. These parameters are important because they help us to know whether we should seek a design facilitating a breezy environment inside the building or a design to curtail such an influence.

Basically the planning would vary with the type of climatic conditions, as discussed here for different regions :

(i) Hot and Dry Climatic Conditions

Here the day temperatures are high almost for the whole of the year while night temperatures show a sharp drop. Dry air facilitates high night radiations leading to greater cooling. Here, we should plan for designs that

(*a*) prevent too much heating during day time.

(*b*) conserve might temperature.

This might be achieved by sealing off the interior from exterior by cutting off ventilation, which would, however, not be advisable. So other methods need to be adopted including the following:

- Using heat resistant materials that could delay the heat inflow during day time.
- Creating highly reflective surfaces that could keep out the heat at day time.
- Providing small openings for ventilation that could be closed when required.
- Constructing the roof in a way so as to throw open to sky for a short while in the evening to cool down the interior. But, this is possible only in single storeyed buildings.
- By creating day and night areas with proper design and materials.

(ii) Hot and Wet Climatic Conditions

These regions show less variations in day and night temperatures. Due to small cooling at night, it is not useful to utilise night air for cooling day temperature. Due to humidity, evaporative cooling effect is also not possible. Only option is to have maximum air movement inside the

building. Such areas should have buildings with maximum openings to the prevailing direction of the breeze. A shallow plan, having principal spaces arranged in a linear pattern at right angles to the direction of the breeze is desirable. Some subsidiary spaces arranged under the linear pattern forming a funnel shape can also be useful.

In regions having hot dry climate alternating with warm wet climate, the best way to design a building is to have season-wise distribution of utility space.

(iii) Cold Climatic Conditions

The major aim here is to conserve any heat received during day time. This is achieved by providing some heat adsorbent finish to exterior of the building surface and let the sun's rays penetrate deep into the interior by providing large glazed surfaces to the walls that catch sun's rays. However, these would also be the vulnerable spots for night time heat loss and cooling. The structures should be more deep with less exterior surface area to interior volume to reduce heat loss. Wind breaks are useful while no shading structures are required.

A building may be used for various purposes, public or private, and accordingly its functional requirements and planning would vary. While preparing a plan for a building three points need to be integrated *i.e.*, utility, form and aesthetics.

All these points need to be visualized considering three-dimensional aspect of the building structure, knowledge regarding the type of the people, their density and type of activities to be undertaken by them in these buildings are important before planning a building.

11.3.1 Aspect and Prospect

Proper placement of plan unit of a building with respect to sun, wind, topography, outlook, access outward to backyard as well as front street together fall under orientation. Since different purposes are associated with different rooms in a building, therefore, the requirement of sun and air also vary, both spatially and temporally.

Bedrooms generally should face east, so that enough sunshine enters the room in the morning, particularly in cold climates. The main window of the kitchen should face eastwards and others towards north. The openings of living room should be one eastwards and one northwards to make it comfortable throughout the day. Thus orientation helps to create comfortable and congenial environment inside the buildings. In case of non-square buildings, orientation is taken as the direction of normal to the long-axis. If the length of a building is north-south, its normal to long axis would be east-west, hence its orientation would be stated to be east-west.

Aspect: It is the placement of various rooms of a building in accordance with various activities meant to be performed there at different times of the day. Since ladies spend a sufficiently long time in kitchen, it is desirable to have an eastern or north-east aspect for comfortable stay in the kitchen. Amount of sunlight and air entering a room vary with the aspect of the room. Windows are provided to fulfil these requirements in a building through which air and sunlight enter. There are separate norms for window size in different climates. In hot and dry climates the requisite size of a window is $\frac{1}{10}$ th the floor area, whereas for hot humid climates it is $\frac{1}{7}$ th the floor area. Windows may be placed on one, two or even three sides of a room, at same height, even though their width may vary.

In many plans it is preferred to give kitchen at the back or side of the building and the second living room at near the entrance. Proper aspects are to be given to meet these desires, but the access to road would be an important factor deciding the plan. Main rooms and kitchen should get enough sunshine for at least part of the day while stores etc. can do without sunshine

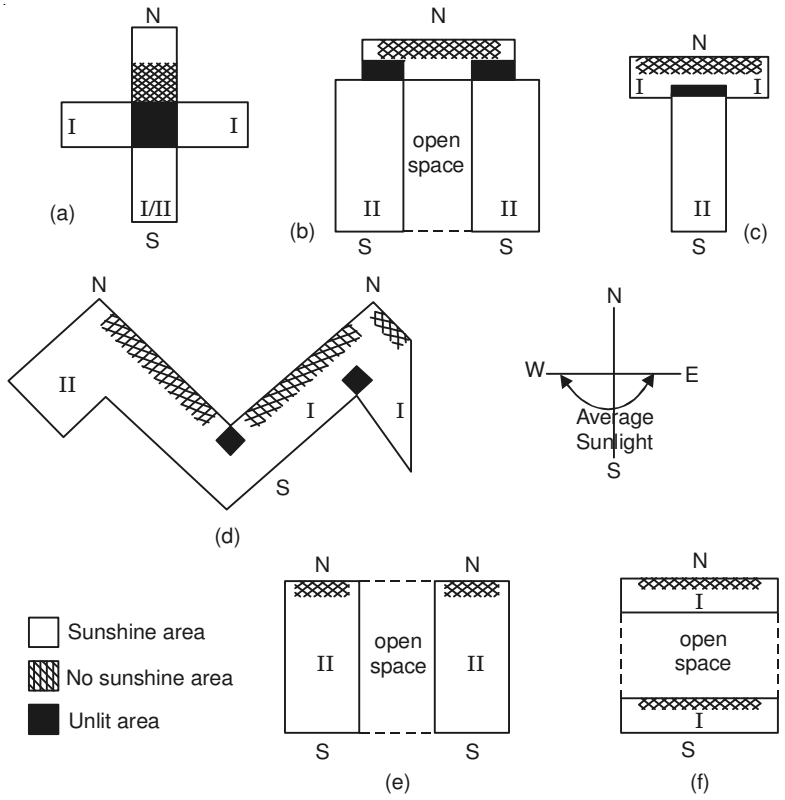

Fig. 11.1 *Some common shapes of blocks with respect to aspect (I-single storeyed, II-double storeyed)*

In large blocks of flats, main axis is usually North-south, so that sunshine reaches all the flats at least for some time during the day. Although aspect of a site is not so important for flats, but the shape of block are influenced by aspect.

Figure 11.1 (*a*—*f*) shows certain possible flat shapes with respect to aspect, with both sunlight and economy considerations. We see that in type–*a* there is no direct availability of sunlight to almost complete northern wing and substantial floor area is devoid of light (shown as dark area). The type *b*-is better with two-storeyed southern blocks getting sunlight throughout the day and a smaller part of I-storeyed northern block is sun-less, even small open space between the two southern blocks would allow enough sunlight to reach the windows of northern block. Thus, this type is economical as well. Type *C* is also similar, as far as sunlight availability to different wings and rooms is concerned, and it is more economical.

Another pattern possible is as shown in type-*d*, where little area is unlit, but all northward sides won't receive sunlight and here northward walls are quite large. Southern sides of both single and II-storeyed blocks get good sunlight. However, it requires more land area and involves higher cost.

Two other types (*e, f*), have two blocks separated by open space, one showing north-south and the other showing East-west aspect. The type-*e* is more economical, however, kitchens are likely to get sunny aspect. For type-*f* more land is needed as the space to be given in between the two blocks should be large enough to allow the sun to reach the lower windows of each block. Both these types are, however, well accessible to sunlight.

Prospect signifies the outside view of the building as seen from the windows and doors in external walls. It is to be decided which outside view is to be given more importance and which could be or preferably should be avoided. A balance has to be achieved between the aspect and prospect considerations, which may sometimes be at variance with each other. For example, the view of a hill top, a monument, a nearby lake or garden outside is preferred and prospect is to be decided accordingly, whereas view of some drain or slum is to be avoided and accordingly certain aspect considerations are to be modified.

11.3.2 Roominess

The space for every unit in a building is to be planned keeping in view its function. Once the space is decided for a unit, the next is planning of length, width and height of various structures items and fittings in the noon so as to facilitate maximum utility with adequate space for movement and function, referred to as roominess.

The height of window, top level of doors, windows and lofts etc. should be planned keeping in view the height of an average height person. A square room is less favourable than a rectangular room with length: width ratio of 1.2:1 or 1.5: 1. Less width with greater length will have a tunnel effect. Rooms with same area may differ in their roominess due to cramp effect, tunnel effect or because of non-availability of space to pull out your arms or bend your body, which may be due to improper planning. Space or roominess is greatly influenced by the number and positioning of windows, doors, lofts and cupboards. It is also affected by the type of the furniture, flooring, wall and even colour scheme of the room. Even the type of curtains can influence roominess effect.

Dark colours make the rooms look small, whereas light shades give the rooms a bigger look. Keeping into consideration the space effect needed we can chose a combination of light and dark colours for different walls in the same room.

Roominess with regard to head space would also vary for different functions. A feeling of close association amongst people would be achieved by keeping the ceiling height somewhat low as in case of a meeting room. But, in a court or in a place of worship, the ceiling in the main area is usually kept high to give it a feeling of supremacy. Along with roominess, it is important to plan for flexibility. This is because we cannot be static and are bound to have dynamism in the form of additions, modifications and expansion.

11.3.3 Grouping

Arrangement of various rooms with reference to their relatedness of functions is called grouping. For instance dining room or dining space should be close to the kitchen. Bedroom should have sanitary arrangements nearby. The corridor area in a house should be minimum and well ventilated. Grouping in different types of buildings vary due to different nature of functions. Groupings would thus be very different in a school, hastle, hospital, library a metro or a mall. Arrange-

ments for sanitation, staircase, subsidiary entrance etc., are to be considered very carefully for each type of the building.

Within a large complex, we may have buildings of very different functions, for each of which separate type of grouping is required. Yet some sort of cohesiveness is also sought within the complex, which needs careful consultation and considerations.

In flats considerable attention should be paid to the grouping of services, connection of drainage and plumbing. Corridor reduction helps in space saving but reduces privacy and comfort.

11.3.4 Privacy

The degree to which a built environment controls inputs from others and output to others is referred to as privacy. Privacy is required for several types of functions, individually or in groups. Various factors that influence privacy include the way rooms are arranged, placement of windows and doors, use of sound attenuating walls, floors and ceilings, placement of the room with respect to stairs etc. Privacy is not just confined to inside, but case an extend to exteriors like in parks or some public place, where special structures can be planned to provide privacy. Privacy is also required for specific counselling centres, hospitals etc. Consideration of all such elements is basic to planning principles.

11.3.5 Circulation

The external an internal movement of persons, vehicles and good in and around a building is referred to as circulation. It depends upon the function of the building and on the way the spaces are arranged, along which movement of person or vehicles or both takes place. It usually follows a regular and recurring pattern.

In terms of architecture, the pattern of circulation actually represents movement between masses and spaces. In other words we can say that the former follows the latter and the latter represents the former. So these can be referred to as mirror images, creating a system of masses—spaces and circulation for each other in a building. Different circulation patterns have been observed for different buildings:

(*i*) **Horizontal Circulation Pattern:** Here movement occurs on a horizontal plane. It can again be of various types—Linear, bilinear, peripheral, trilinear, peripheral, tetralinear peripheral, linear spiral, bilinear spinal, trilinear and tetralinear spiral, centrifugal spinal or circular pattern as shown in Fig. 11.2 (*a–l*).

When there is spacing in one live only, masses would move in linear pattern (*a*). When main space shows 1, 2, 3 or 4 side branchings to one side only, circulation would be linear, bilinear trilinear or tetralinear peripheral (*b, c, d, e,*) respectively. If main space branches once or twice on two sides then circulation would be linear spinal or bilinear spinal (*f, g*) and if on three or four sides, then it would be tri or quadrilinear spinal (*h,i*). When spaces are present centrifugally and branches are on both sides, then centrifugal spinal circulation occurs (*j*). If the spacing is provided in a circular manner and branching occurs only on one side, it is peripheral circular (*k*) and if on both sides, it is circular bispinal (*l*).

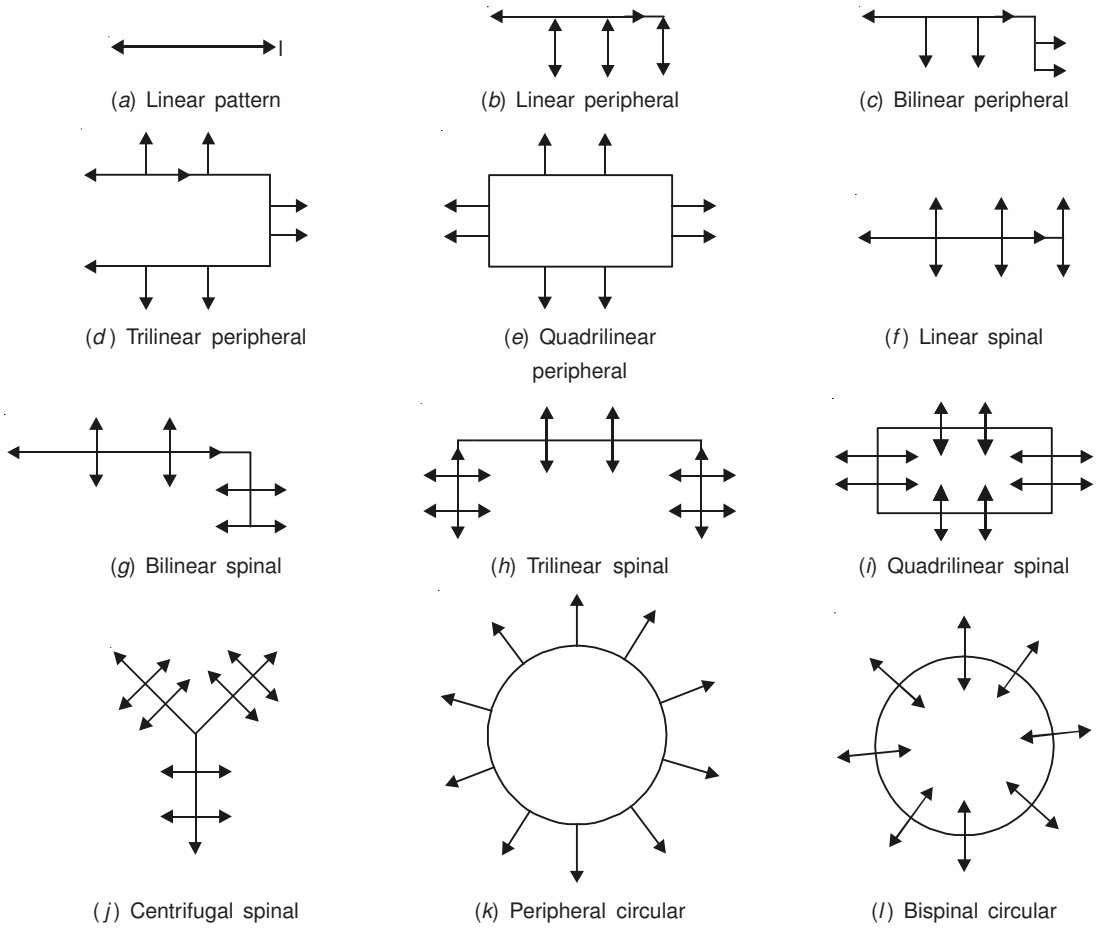

Fig. 11.2. *Horizontal circulation patterns in buildings*

(*ii*) **Vertical Circulation Pattern:** This refers to the mass movements taking place through stairs, lifts or other mechanized means in multi-storeyed buildings. In contrast to horizontal circulation pattern, here a third dimension of height is added.

It must be made clear here that true vertical circulation pattern would follow only in some tower like building, say Qutab Minar. In others it is a hybrid pattern is a combination of horizontal pattern repeated at certain vertical interval.

(*iii*) **Multistoreyed Circulation Pattern**

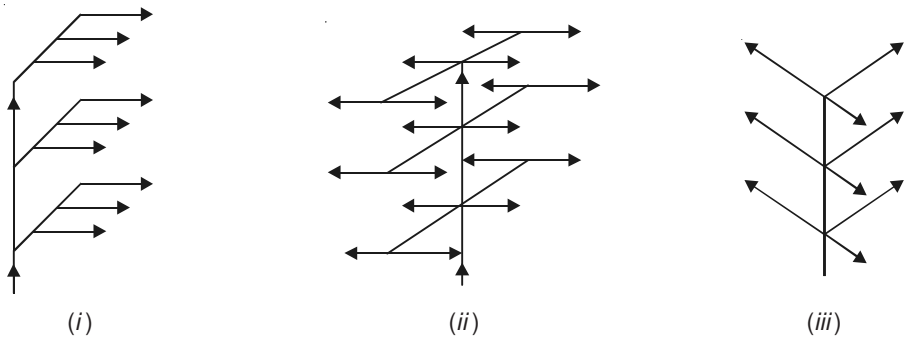

Fig. 11.3. *Multistoreyed circulation patterns*

As evident from the Fig. 11.3, these circulation patterns are basically horizontal circulation patterns superimposed upon itself and the whole unit is connected by a vertical pattern at one or several points.

(*iv*) **Miscellaneous Circulation Pattern:** These are combinations of certains circulation patterns grouped together. These are used rarely or in unique situations *i.e.*, in some museums, concert halls, auditorium *etc*.,

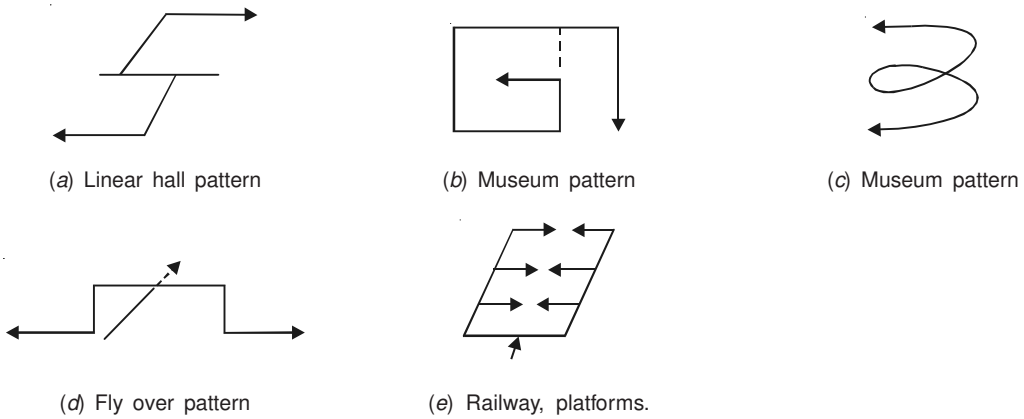

Fig. 11.4. *Miscellaneous circulation patterns*

11.3.6 Sanitation

Planning for proper sanitation includes consideration for lighting, ventilation and cleanliness taken together.

(*i*) **Lighting Facilities:** Proper lighting in various rooms of the building needs to be planned, which depends on the aspect. Natural light in the form of sunlight not only helps in economising the cost, but also helps in destroying various germs. The minimum size of the window required in dry and humid climatic regions vary, being $1/10^{th}$ of the floor area, respectively. Vertical windows help in better light inception. Light and soft shades for ceilings and walls of passages and rooms help in better reflection, hence improved lighting.

Artificial lighting is also required for illuminating different buildings and different units within a building. The intensity of illumination required for different functions may vary from 100 to 700 lux, or in some very intricate tasks upto 1500 lux. Minimum lighting (70 lux) is required in corridors, whereas reading places need 300-700 lux, while public areas, cinemas, banks, airport etc., may require 150-300 lux illumination.

Lighting should be pleasant and should not produce a glare. The amount of lighting allowed to enter the room through windows is decided on the basis of day light factor. 100 lux is equal to a day light factor of value 1.25%, based on 8000 lux as the external illumination in our country.

In a house, kitchen should get maximum day light factor of 2.5%, followed by study room (1.9%) and living room (0.625%). Direct and indirect sunlight both are useful for illuminating purposes. The number, size and placement of windows mainly control the entry of sunlight into the rooms.

(*ii*) **Ventilation:** The system of openings in a building that supplies as well as removes air by natural or mechanical means and creates circulation of air leading to comfortable conditions is called ventilation.

Orientation of the building and location of windows, ventilators and doors together create the ventilation system. Natural ventilation can be made use of by placing the windows and ventilators opposite to each other in a house or a flat. The openings should not be less than $1/4^{th}$ the surface area of that side of the room which faces an open space. In more densely populated buildings, artificial ventilation by means of exhaust or other mechanical means becomes a compulsion.

(*iii*) **Sanitary facilities and cleanliness:** Proper sanitary facilities, bathrooms, drainage and water proof tiles etc., should be provided along with precision for regular cleaning. Requirements of water for different urinals and bathrooms should be carefully followed. Manholes, rain water pipes, water supply, ventilation pipe etc., should be carefully planned and leakages on wall must be prevented.

11.3.7 Orientation

Orientation refers to the position and direction of a building or its part in relation to external climate or topographical factors. Different buildings need different orientations. The concepts of aspect and prospect related to orientation have already been discussed in this chapter.

We will discuss some examples to explain it further. While individual houses or flats have a requirement to provide maximum comfort and privacy, a big mall has a requirement to have an orientation for maximum publicity, thus facing the main road. Flats usually show different orientations with respect to climate and surroundings. Land use and economy are also important parameters.

In a school, college or university, orientation preference is given for the classrooms which should not face noisy roads and distracting surroundings. Light and ventilation should be the priority. In a hot climate orientation of class room in a school should be North-West so that mid-day diffused light is available from the north and west. By the time west sun becomes too hot, the classes would be over. But in a cold region, the orientation of classroom should be south and deep we can also artificially divert direct sunlight to avoid over heating by using baffles, inclined ceilings etc.

For hospitals, orientation required for different functions is very different. Patient's wards are always in use and need to be comfortable and should also have privacy. Operation theatres need maximum internal comfort, privacy and ideal light for precision work. Outdoor patient departments are public oriented, need less light and comfort. Besides these, there are other subsidiary spaces. In such cases, grouping is done and then orientation is decided.

Offices are also very densely crowded structures. Their orientation should vary depending upon the climate. There should be proper ventilation and prospect for relaxation. They also need publicity. So the orientation has to be based on all such considerations. Here, sometimes the block is divided into two parts to meet different requirements with different orientations.

11.3.8 Economy

While all other principle of planning are considered, the most limiting factor usually is the economic aspect. At the very outset, the architect should have a clear idea of the client's needs and budget. It is better to plan economically by providing minimum requirements and keeping options for expansion. Simple design, simple fixtures and materials and careful planning can cut down the costs. A knowledge about the principles of planning and creative imagination can together help meet every budget.

11.4 ROLE OF BYE-LAWS IN ENVIRONMENTAL REGULATION

Building bye-laws, 1983 introduced by the Ministry of Urban Development, have been modified from time to time by various states partly for providing guidelines to the builders in their respective states. The major aims of these bye-laws are as follows:

(*i*) To regulate construction activities.

(*ii*) To prevent haphazard growth of buildings.

(*iii*) To provide better civic amenities with hygienic conditions.

(*iv*) To regulate proper spacing between buildings in order to ensure access to sunlight etc.

Lately bye-laws for zonal regulation have also been implemented with the following objectives:

(*i*) To regulate land use.

(*ii*) To control population density.

(*iii*) To regulate planned development of a city.

(*iv*) To prevent damage to ecology of an area, particularly in ecologically sensitive areas.

Different countries have formulated different bye-laws based upon their climatic, geographic and population characteristics. Even within a country different states amend these laws depending upon their conditions and requirement, so as to regulate the kind of the building that may be put on a particular site. The bye-laws are sometimes based on aesthetics, so as to maintain aesthetic quality intact, but mostly these are based on hygienic conditions so as to prevent overcrowding and to ensure safe and clean water, adequate light and ventilation.

In the recent past bye-laws have also been added to promote environmental conservation by introducing bye-laws on solar energy capture, rain-water harvesting, solid waste disposal, energy efficiency and green space. Special bye-laws also relate to natural hazard prone areas like seismic zones or flood prone areas and prohibited areas. All such bye-laws play an important role in regulating and conserving the environment:

(*i*) For ensuring better environment (sunlight)

In cold climate, solar rays penetrating into the interior spaces of a building can prove to be very useful. The height of residential flats and the spacing regulated by bye-laws play a useful role in ensuring solar rays reaching the back side flats.

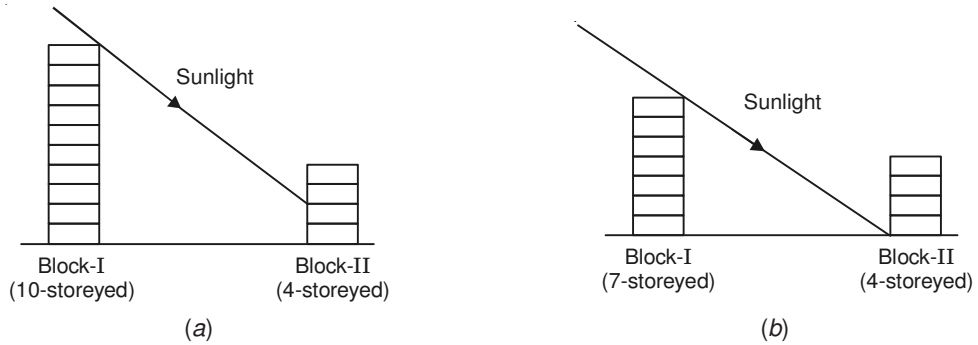

Fig. 11.5. *Sunlight is not available to groundfloor and Ist floor of Block-II almost throughout the day. Following the bye-laws, as height of Block-I is reduced from 10-storey to 7-storey, sunlight becomes available to even groundfloor in Block-II also*

(*ii*) Land-use zoning

Zoning regulations are legal tools for providing guidance for proper use of land ensuring public health, safety and welfare utilising both horizontal and vertical space. These bye-laws help improve the quality of life in urban areas and simultaneously protect and conserve environment.

In flood prone zones *e.g.,* building activity is restricted and the space is used as parks, play ground or gardens. Likewise along the drains, green belts should be planned. In hilly areas the major aim is to conserve forest cover and preserve green area while allowing any construction. In coastal regulation zone (CRZ) inland stretches influenced by tidal action along with their biodiversity are considered mainly for protection, thus limiting construction activities.

For seismic zones, a map has been prepared based on intensity scale and zone III, IV and V are considered to be seismically active and earthquake hazard prone areas.

If an active fault trace is identified by Geological Survey of India (GSI), a structure for human occupancy should not be constructed there and must be set back by a minimum of 15 meters on either side of the fault trace. Similarly, flood prone areas, land-slide prone areas and cyclone prone areas have been mapped for the country and zonation regulations exist for ensuring safety for any construction.

In flood prone areas, buildings of priority-I should be placed in a way that the area is above the levels corresponding to a 100-year flood level or maximum observed flood level, whichever is higher. Similarly, they should be above the levels corresponding to a 50-year rainfall flooding and the likely submersion due to drainage congestion. Buildings of priority-II should be placed outside the 25-year flood and 10-year rainfall contour, but their plinth level should be higher than 25-year flood mark with ground area left for unimportant uses. Priority-III activities like play ground, park etc. can to located in areas vulnerable to floods.

For hazard-prone zones special regulations for structural designs also exist. For cyclone-prone areas, code of practice for design loads, wind loads and guidelines for improving cyclonic resistance of low rise houses exist. Guidelines for earthquake resistant designs and structures are provided by various regulations. For protection from landslide hazard, guidelines for retaining wall in hilly areas are available.

(*iii*) Upgradation of poor urban settlements

With urban growth, the number of urban settlers has swelled up many fold in the last few decades, which has been associated with poor, unhygienic living conditions, unclean and unsafe drinking water availability and poor sanitation facilities. Thus these have become examples of degraded built-environment.

In the recent years the planners have realised the need for improving access to environment by providing household loans and help the slum dwellers to have access to basic services and amenities in the form of small houses. This type of regulation is playing a role in bringing sustainability.

Regulations were earlier thought to be just tools of planned development. Now, in the urban context, there bye-laws are considered as development standards. These standards embrace all development parameters and norms having bearing on spatial planning, intensity and pattern of development in different land use zones, norms and space standards and service infrastructure.

There are bye-laws regulating the provision of proper space for every function and amenity to be provided to the inhabitant, which varies in size depending upon the budget.

(*iv*) To promote solar energy utilisation

There are Energy Conservation Building Code (ECBC) norms which focus on reduction on energy use by providing design for natural light and use of solar energy. The Ministry of Non-conventional Energy Sources (Urban, Industrial and Commercial Group) has provided regulations for "Accelerated development and deployment of Solar Water Heating Systems in domestic, industrial and commercial sectors during 2008–10, with the main objective to promote wide spread use of solar water heaters in the country through a combination of financial and promotional incentives. Support will be provided to municipal corporations that adopt and notify the modifications to their building bye-laws for making installation of solar water heating systems mandatory in certain categories of buildings and/or provide rebate in property tax to the users of solar water heaters.

Such initiatives can go a long way in conserving energy.

(*v*) Water conservation/Rain water harvesting

The National Environment Policy, 2002 considered making it mandatory to have installation of water saving closets and taps in the building bye-laws of urban centres. Likewise water harvesting in all new constructions in relevant urban areas were made mandatory.

Water table is falling rapidly in recent decades in many regions due to withdrawal of excess amounts of water for various purposes that is in excess of annual recharge. In urban areas, apart from use in domestic and industrial use, housing and infrastructure like concrete floor, roads etc. prevent sufficient recharge. Rain water harvesting can play a significant role in preventing the loss of such water. Central Ground Water Authority (CGWA) regulates the use of ground water.

11.5 USE OF VARIOUS ECO-FRIENDLY MATERIALS IN CONSTRUCTION

Building design should be economic, socially appreciable, energy efficient and with minimal environmental impacts, following the principles of sustainable development. The present facilities in building design which are environmentally less acceptable should be upgraded in such a way that it puts less pressure on natural resources and minimises waste production.

Modern designers are adopting innovative approaches to satisfy client's choice at reasonable financial and environmental costs. Site selection and proper orientation to provide natural light and ventilation along with reduced energy requirements have been some of the major considerations in this regard.

Eco-friendly Materials

Production and usage of practically all types of building materials during construction and demolition have some impact on the environment in one way or the other. Extraction and processing of building material is associated with energy consumption and waste generation, which vary depending upon the type of the building. Local materials used for building have less environmental implications in terms of energy use and waste production. The quality of building material chosen for construction needs to be assessed from the point of view of environmental impacts. Production and use of building materials have the following environmental impacts:

(*i*) Energy consumption and related impacts.

(*ii*) Physical degradation of environment.

(*iii*) Depletion of natural resources and biodiversity.

(*iv*) Gaseous emissions causing global warming and acid rains.

(*v*) Toxic emissions and health effects.

(*vi*) Occupational health hazards.

Extraction and manufacturing of building materials cause physical degradation of surrounding areas, loss of top fertile layer, loss of forests including rainforests leading to destruction of wild life habitat of a large number of species, depletion of limited non-renewable energy reserves and environmental pollution.

Energy consumption is an important aspect of construction. Energy is required for extraction of minerals such as iron ores, bauxite etc. Energy is also required for transportation, processing, fabrication and installation during construction, refurbishment and demolition of buildings.

The most important measure of environmental impact of a building material is **'embodied energy'** or **'capital energy'**. **Embodied energy is defined as the amount of energy used to produce a unit weight of the material.**

Based upon the impacts, environmental profiles of various types of building materials are now available. In relative environmental performance rating system, simple grades like A, B, C... etc., are assigned based on their associated variety of environmental impacts like mineral and water extraction, fossil fuel depletion, emissions of pollutants, toxicity, role in climate change etc.

The embodied energy of a material increases with increase in the number of processes it undergoes. The associated waste production also increases accordingly. For this reason, the choice of such eco-friendly materials is necessary which are as close to nature as possible and also nearer to the construction site; so that energy consumption for transportation, processing and transforming is minimal. The cost and eco-friendliness could also be improved by using recycled material. For instance, embodied energy of an aluminium-framed window will be different if made from the recycled metal or from its ore. The type of the material used is also equally important. Embodied energy of an aluminium-framed window would be definitely higher than that of a timber-framed window, as the latter involves less processing and is natural. Also, the latter would be more eco-friendly as it does not give CO_2 emissions for processing.

Transportation of the building material from production to sale, and from market to construction site adds to the embodied energy of the material. Emissions arising from the use of fuels in vehicles add to global warming and various noxious gases emitted lead to serious health problems. Another important factor for consideration of eco-friendly material is the maintenance requirement and life-span of the building.

Building materials that contribute to embodied energy are cement, concrete, bricks, steel, aluminium, timber, glass, plaster etc., which are generally used in all types of buildings. Metals and plastics have very high embodied energy. Their use in small quantities like that in joints or fixtures may, however, be useful. Thus, selection of a proper building material must be given due consideration. The embodied energy of plastics is very high as these are derived from petroleum involving energy intensive processing. Their production is also associated with generation of the greenhouse gas namely, carbon dioxide (CO_2), volatile organic compounds (VOCs) and polyvinyl chloride (PVC), which are harmful because of global warming potential of CO_2 and health related problems of the latter two. Disposal of PVCs is a major problem. However, plastics have a positive aspect that these are derived from wastes of petroleum production.

Metals. Manufacturing of metals from their ores has several environmental impacts. In the recycling of metals harmful chemicals dioxins are produced, which are carcinegenic (cancer causing) in nature. Timber, on the other hand, is an eco-friendly material. But, indiscriminate cutting of

forests for timber production has far reaching environmental consequences. It is therefore necessary that timber production should be based on a sustainable strategy of forest management. Timber production based on 'selective cutting practice', ensuring replacement of cut trees by fresh plantations, can take care of forest sustainability. There should also be a scheme to certify that the wood being used for building has been obtained from a sustainable forest.

An important point worth mentioning here is that if timber is produced by cutting down rainforests, it would not be possible to substitute the cut trees by similar species. The tropical rainforests have evolved over a period of millions of years with complex biodiversity, which has intricate mechanism of ecosystem stability and regulation. Loss of biodiversity or replacement of a complex heterogeneous rainforest by some simple fast growing tree species will cause irrepairable damage to the ecosystem and the environment. While selecting an eco-friendly building material, like timber from a rainforest, such important issues must be considered.

Even when timber is otherwise obtained from a far-off place, its eco-friendliness diminishes because of the energy used in transportation, thereby enhancing its embodied energy. Many a times timber is treated with chemicals to prevent its rotting and decay. Use of such a timber as a building material will reduce its eco-friendliness due to toxic nature of the chemicals used in the treatment. Use of synthetic organic paints are environmentally more harmful. These can be substituted by water-based natural pigments, stains or waxes. Thermal insulators (like recycled paper, wool or cork), earth wall, straw bale construction should be preferred if space permits and rough finishes are not inhibitive. Glazed coatings too save energy.

Several building materials continue to affect the indoor air quality. These materials used as solvents, finishes and cleansers for maintenance and protection of building materials can cause 'sick building syndrome'.

Some insulating materials are made from non-renewable petroleum resources, while some use chlorofluorocarbons (CFCs). During demolition, their safe recovery is difficult. Release of CFCs in the atmosphere would enhance the global warming problem. Asbestos, which has been quite in use in buildings is now known to be very harmful for our health and not recommended now. Even during demolition of existing buildings, recovery of asbestos should be carried out very carefully.

11.6 CONCEPT OF GREEN BUILDING

Construction, maintenance and use of buildings have significant impact on environment. People's concern about environment and energy has necessitated the development of the concept of green building. A green building is broadly defined as the building which is sited, designed and operated to reduce negative environmental impacts and has a profound positive impact on natural environment, economy, health, productivity and society over its life cycle.

Green building at present constitutes about 5 per cent of the building market.

The green building is evaluated by holistic approach where each component is considered in context of the whole building and its social and environmental impacts. The important components of green building are as under:

Materials, Energy, Water, Health.

Materials: The materials to be used in the green building should be ecofriendly. These should be obtained from local renewable resources with minimum embodied energy and should be causing minimum waste during its use. These should be recyclable. Such materials will reduce green house gas emissions.

Green buildings use reclaimed materials *i.e.,* use of materials which have been used in previous buildings. Materials such as bricks, doors, windows, frames etc. can be used for another purpose depending on the size and strength, in the new building. This reduces the embodied energy and reduces environmental impacts.

Some toxic materials are used alongwith the construction materials. Paints for example used as coating material consist of pigments (heavy metals like cadmium, lead and chromium used in pigments), petrochemicals and solvents, benzene, formaldehyde and volatile organic compounds (VOCs) which are used as binder (to hold the paint) and carrier (to disperse the binder). Some preservatives, thickners, thinners and driers are also used. These toxic chemicals cause indoor pollution and are harmful to human health. These should be replaced by ecofriendly natural products.

Energy: The green buildings conform to energy efficient guidelines. Energy Conservation Building Code (ECBC) norms launched on 28 June, 2007 apply to all commercial buildings that are constructed in India and have electric connected load of 500 kW or more. ECBC provides design for natural and electrical system for reduction in energy use, 40–60% less energy than baseline building.

Solar panels can meet the hot water requirements and efficient lighting. Compact Fluorescent Lamps (CFLs) can reduce the electricity requirements. Natural day light reduces electricity requirement during day time.

Heating and cooling costs of such buildings can be reduced by passive solar designs. Use of insulating materials and glass windows play a major role in such designs. Low E glazed windows should be used.

The energy performance rating of windows, doors and skylights is done in terms of potential for gaining and loosing heat and transmitting sunlight into the building.

The non-solar heat flow conducted through a window, door or sunlight is measured in terms of *u*-factor which is reciprocal to their energy efficiency (*i.e.,* lower the *u*-factor more is the energy efficiency).

Insulation for heat is an important factor for energy efficient building. Traditional mud houses (consisting of soil mixed with water and straw) are generally found in the villages and this cob technique is also being used in modern construction to have stronger and thinner walls which provide insulation for heat and noise. During day time the material absorbs heat and the outer exposed side keeps the inside cool while during night time it radiates the absorbed heat to the interior. Stone bricks are also used in buildings which have less embodied energy than bricks from brick kilns although quarrying of stone has environmental impacts. Natural materials like lime, gypsum, clay etc. can be used for making strong and breathable walls.

A green building can have green roof system. E-rated reflective roof coating will reduce roof heating.

In an attempt to use renewable resources in ecofriendly buildings, the traditional biomass roofing (*i.e.,* thatch and wood tiles made from local renewable source) is preferred which forms a biodegradable, appealing and durable roofing.

The roof can provide natural substrate and processes for plant growth. A water proof layer (material for water retention) and proper drainage helps plant growth and at the same time protects the roof and building from damage. For green roofs small plants with fibrous roots and low water requirements are best suited. Green roof has the following advantages:

- Absorbs atmospheric CO_2.
- Improves energy efficiency.
- Causes cooling in summer and provides insulation in winter.
- Absorbs noxious pollutants, sound and noise from atmosphere.
- Absorbs rainwater which may otherwise flood the sewer lines.
- Preserves biodiversity, attracts butterflies, bees and local birds.
- Improves aesthetics of the building.

Reducing energy consumption and saving energy will reduce fossil fuel consumption and thereby reduce the threat of global climate change. In green building the use of ecofriendly construction material with low embodied energy helps in reducing carbon emission. This is an important consideration as the building sector contributes a substantial percentage of green house gases. Carbon emission can further be reduced by reducing energy consumption for heating, cooling and lighting and use of energy efficient gadgets.

Reduction in energy consumption in green building will not only reduce global warming and pollution but will also provide financial savings as the cost of fast depleting fuel will increase in near future.

Water: Water requirement in the green building is minimised. Water is used efficiently by employing water efficient appliances like low flush toilets, waterless urinals etc. The waste water is treated and used for gardening and flushing by the use of double plumbing system. Permeable pavements and rainwater harvesting technology help in recharging ground water.

Health: Indoor pollution is harmful to the health of residents. People who spend their time indoors with less ventilation get exposed to toxic materials, volatile organic compounds (VOCs) from paints, solvents, plastics and also mites, moulds, spores, microbes and many other indoor pollutants. They suffer from various types of diseases like asthma, headache, palpitation and chronic fatigue, nausea, eye irritation, skin disorders, liver and kidney damage and even cancer. Green building provides sufficient air circulation and the stale air is replaced by fresh one. The non-toxic materials and breathable walls help maintain good indoor air quality. Non-toxic materials like lead free paints *i.e.,* water soluble, natural or organic paints are used. Green buildings with proper ventilation for air circulation are good for health and well being. Natural day light while reduces electricity requirements, also improves productivity *e.g.,* students studying in day light classrooms are known to perform better (20–26% better) than those studying with least day light.

Buildings are evaluated on the basis of a number of parameters of environmental importance. Different ratings are given to such green buildings. "Platinum rating" is the highest rating for green buildings. LEED (Leadership in Energy and Environment Design) standards have been developed by USA and many countries have adopted by amending these suitably. A completed building may be rated with different levels as LEED certified, Silver, Gold or Platinum.

Indian Green Building Council (IGBC) and TERI (The Energy and Resource Institute) have developed rating systems for newly constructed buildings. IGBC has set up LEED India NC (LEED India Green Building Rating System for New Commercial Construction and Major Renovations) and TERI has its system called GRIHA (Green Rating for Integrated Habitat Assessment). The classification levels are as under:

Level	Points
Certified	26 to 32
Silver	33 to 38
Gold	39 to 51
Platinum	52 or more

Recently in 2009, Bureau of Energy Efficiency (BEE), taken off from Energy Conservation Building Code (ECBC) of 2007, has started rating office buildings on the basis of their energy consumption in kWh/sq. m./year over a minimum period of one year. The scheme is volantary and buildings at least one year old are rated on the basis of power consumption, from "one to five" in increasing order of the efficient building. Cities falling in three climatic zones namely, Composite (like Delhi), Hot and Dry (like Jaipur and Ahmedabad) and Hot and Humid (like Mumbai and Chennai) will be assessed on separate assessment parameters.

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CHAPTER XII

Energy and Environmental Pollution

Energy is the capacity to do work, produce motion or force or carry out transformations. It can be in different forms like thermal energy, electrical energy, mechanical energy or chemical energy. The raw form in which the energy resources occur in nature are the primary energy resources (coal, petroleum, natural gas, wind, solar) which are converted into some intermediate form (steam or chemicals) that are finally converted into usable or secondary energy (fuels, electricity etc.). Every development activity depends on energy. Therefore, energy resources and their usage directly influence national economy and growth of civilisation. While energy requirements of primitive man were limited, the energy needs in modern times have tremendously increased due to fast development, increasing transportation, industrialisation, raised standards of living and rapid population growth.

12.1 TYPES OF ENERGY RESOURCES

All energy resources are available in nature in their raw form, which are explored, extracted, processed and converted into final usable forms.

Based upon their usage over a long time, energy resources are generally classified as conventional and non-conventional. Demarcation between the two is not so rigid, because what is a non-conventional form today, may in due course of time, become conventional.

Conventional Energy Resources: Energy resources that are traditionally in use for all these years (particularly prior to the oil crisis of 1973) are known as conventional forms, e.g., coal, petroleum, natural gas, fire-wood, hydropower and even nuclear fission fuels.

Non-Conventional Energy Resources: These include the alternate resources of energy that are being considered and commercialised for large scale use after the oil crisis. These resources are going to have increased share of energy use in future. These alternate resources are generally renewable forms including solar, wind, geothermal, ocean wave, tidal, biomass, biogas, nuclear fusion energy etc.

A more appropriate categorisation of an energy resource is based on its durability and regenerating capacity, which classifies it as renewable or non-renewable.

Renewable resources are those which can be generated continuously in nature and are inexhaustible e.g., wood, solar energy, wind energy, tidal energy, hydropower, biomass energy, bio-fuels, geo-thermal energy and hydrogen. They are also known as non-conventional sources of energy and they can be used again and again in an endless manner.

Non-renewable resources which have accumulated in nature over a long span of time and cannot be quickly replenished when exhausted e.g., coal, petroleum, natural gas and nuclear fuels like uranium and thorium.

Wood is a renewable resource as we can get new wood by growing a sapling into a tree within 15–20 years but it has taken millions of years for the formation of coal from trees and cannot be regenerated in our life time, hence coal is not renewable. We will now discuss various forms of renewable and non-renewable energy resource.

12.1.1 Conventional Energy Resources

These are the fossil fuels like coal, petroleum, natural gas and nuclear fuels. These were formed by the decomposition of the remains of plants and animals buried under the earth millions of years ago. These fuels are very precious because they have taken such a long time to be formed and if we exhaust their reserves at such a fast rate as we have been doing, ever since we discovered them, then very soon we will lose these resources forever.

Coal

Coal was formed 255–350 million years ago in the hot, damp regions of the earth during the carboniferous age. The ancient plants along the banks of rivers and swamps were buried after death into the soil and due to the heat and pressure gradually got converted into peat and coal over millions of years. There are mainly three types of coal, namely ***anthracite*** (hard coal), ***bituminous*** (soft coal) and ***lignite*** (brown coal). Anthracite coal has maximum carbon (90%) and calorific value (8700 kcal/kg.). Bituminous, lignite and peat contain 80, 70 and 60% carbon, respectively. Coal is the most abundant fossil fuel in the world. ***At the present rate of usage, the coal reserves are likely to last for about 200 years and if its use increases by 2% per year, then it will last for another 65 years.***

India has about 5% of world's coal and Indian coal is not very good in terms of heat capacity. Major coal fields in India are Raniganj, Jharia, Bokaro, Singrauli and Godavari valley. The coal states of India are Jharkhand, Orissa, West Bengal, Madhya Pradesh, Andhra Pradesh and Maharashtra. Anthracite coal occurs only in J & K.

When coal is burnt it produces carbon dioxide, which is a greenhouse gas responsible for causing enhanced global warming. Coal also contains impurities like sulphur and as it burns the smoke contains toxic gases like oxides of sulphur and nitrogen.

Petroleum

It is the lifeline of global economy. There are 13 countries in the world having 67% of the petroleum reserves which together form the OPEC (Organization of Petroleum Exporting Countries). About 1/4th of the oil reserves are in Saudi Arabia.

At the present rate of usage, the world's crude oil reserves are estimated to get exhausted in just 40 years. Some optimists, however, believe that there are some yet undiscovered reserves. Even then the crude oil reserves will last for another 40 years or so. Crude petroleum is a complex mixture of alkane hydrocarbons. Hence, it has to be purified and refined by the process of **fractional distillation,** during which process different constituents separate out at different

temperatures. We get a large variety of products from this, namely, petroleum gas, kerosene, petrol, diesel, fuel oil, lubricating oil, paraffin wax, asphalt, plastic etc.

Petroleum is a cleaner fuel as compared to coal as it burns completely and leaves no residue. It is also easier to transport and use. That is the reason why petroleum is preferred amongst all the fossil fuels.

Liquefied Petroleum Gas (LPG): The main component of petroleum is butane, the other being propane and ethane. The petroleum gas is easily converted to liquid form under pressure as LPG. It is odourless, but the LPG in our domestic gas cylinders gives a foul smell. This is, in fact, due to ethyl mercaptan, a foul smelling gas, added to LPG so that any leakage of LPG from the cylinder can be detected instantaneously.

Oil fields in India are located at Digboi (Assam), Gujarat Plains and Bombay High, offshore areas in deltaic coasts of Godavari, Krishna, Kaveri and Mahanadi.

Natural Gas

It is mainly composed of methane (95%) with small amounts of propane and ethane. It is a fossil fuel. Natural gas deposits mostly accompany oil deposits because it has been formed by decomposing remains of dead animals and plants buried under the earth. **Natural gas is the cleanest fossil fuel.** It can be easily transported through pipelines. It has a high calorific value of about 50KJ/G and burns without any smoke.

Currently, the amount of natural gas deposits in the world are of the order of 80,450g m^{-3}. Russia has maximum reserves (40%), followed by Iran (14%) and USA(7%). Natural gas reserves are found in association with all the oil fields in India. Some new gas fields have been found in Tripura, Jaisalmer, off-shore area of Mumbai and the Krishna-Godavari Delta.

Natural gas is used as a domestic and industrial fuel. It is used as a fuel in thermal power plants for generating electricity. It is used as a source of hydrogen gas in fertilizer industry and as a source of carbon in tyre industry.

Compressed Natural Gas (CNG): It is being used as an alternative to petrol and diesel for transport of vehicles. Delhi has totally switched over to CNG where buses and auto-rickshaws run on this new fuel. CNG use has greatly reduced vehicular pollution in the city.

Synthetic Natural Gas (SNG): It is a mixture of carbon monoxide and hydrogen. It is a connecting link between a fossil fuel and substituted natural gas. Low grade coal is initially transformed into synthetic gas by gasification followed by catalytic conversion to methane.

Nuclear Energy

Nuclear energy is known for its high destructive power as evidenced from nuclear weapons. The nuclear energy can also be harnessed for providing commercial energy. Nuclear energy can be generated by two types of reactions:

(*i*) *Nuclear fission*: It is the nuclear change in which nucleus of certain isotopes with large mass numbers are split into lighter nuclei on bombardment by neutrons and a large amount of energy is released through a chain reaction as shown in Fig. 12.1

$$_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{36}Kr^{92} + {}_{56}Ba^{141} + 3\ {}_{0}n^{1} + \text{Energy}$$

Nuclear Reactors make use of nuclear chain reaction. In order to control the rate of fission, only 1 neutron released is allowed to strike for splitting another nucleus. Uranium-235 nuclei are most commonly used in nuclear reactors.

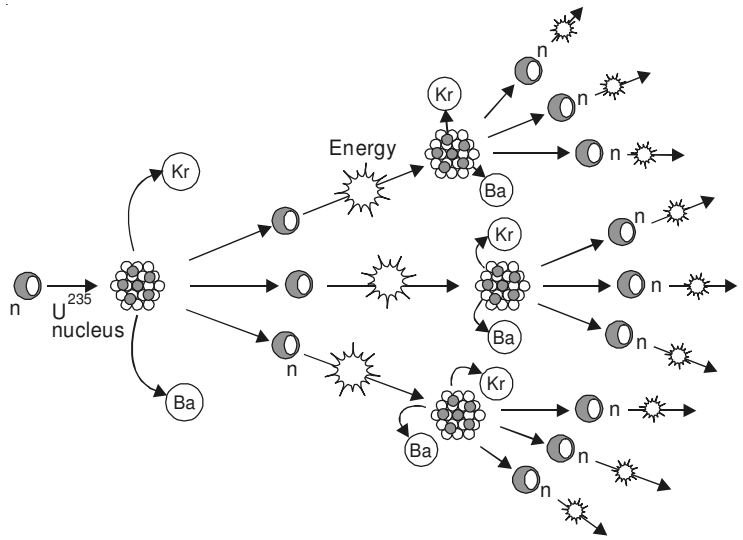

Fig. 12.1. *Nuclear fission—a chain reaction initiated by one neutron that bombards a Uranium (U^{235}) nucleus, releasing a huge quantity of energy, two smaller nuclei (Ba, Kr) and 3 neutrons*

(*ii*) *Nuclear fusion*: Here two isotopes of a light element are forced together at extremely high temperatures (1 billion ºC) until they fuse to form a heavier nucleus releasing enormous energy in the process. It is difficult to initiate the process but it releases more energy than nuclear fission (Fig. 12.2).

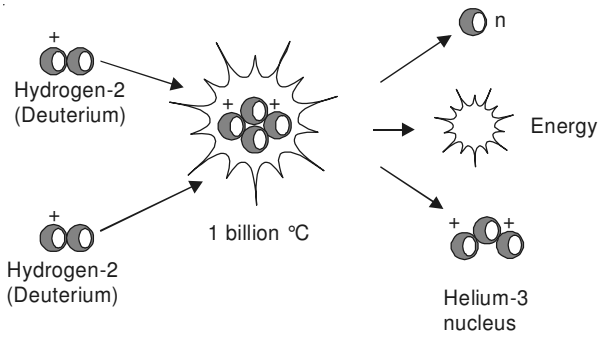

Fig. 12.2. *Nuclear fusion reaction between two hydrogen-2 nuclei, which takes place at a very high temperature of 1 billion °C; one neutron and one fusion nucleus of helium-3 is formed along with a huge amount of energy*

$$_1H^2 + {}_1H^2 \longrightarrow {}_3He^2 + {}_0n^1 + \text{Energy}$$

Two hydrogen-2 (Deuterium) atoms may fuse to form the nucleus of Helium at 1 billion ºC and release a huge amout of energy. Nuclear fusion reaction can also take place between one Hydrogen-2 (Deuterium) and one Hydrogen-3 (Tritium) nucleus at 100 million ºC forming Helium-4 nucleus, one neutron and a huge amount of energy.

Nuclear energy has tremendous potential but any leakage from the reactor may cause devastating nuclear pollution *e.g.,* 1986 Chernobyl nuclear disaster. Disposal of the nuclear waste is also a big problem.

Nuclear power in India is still not very well developed. There are six nuclear power stations with an installed capacity of 4120 MW.

These are located at Tarapur (Maharashtra), Rana Pratap Sagar near Kota (Rajasthan), Kalpakkam (Tamil Nadu), Narora (U.P), Kakrapar (Gujarat) and Kaiga (Karnataka). Four additional nuclear power stations are under construction.

12.1.2 Non-Conventional Energy Resources

Solar Energy

Sun is the ultimate source of energy, directly or indirectly for all other forms of energy. Nuclear fusion reactions occurring inside the sun release enormous quantities of energy in the form of heat and light.

Solar energy is diffused, variable and intermittent that varies with latitude, longitude, seasons day time and other physical factors like cloud cover, suspended dust, fog etc. The solar energy received by the near earth space is quite dilute, approximately 1.4 kW/m^2, known as **solar constant.**

Traditionally, we have been using solar energy for drying food grains, clothes, preservation of eatables, evaporating sea-water to obtain common salt and many such purposes. Solar energy is a clean, cheap and abundantly available form of renewable energy, which is also the ultimate source of energy for biomass energy, wind energy, geothermal energy, ocean thermal energy, tidal energy, wave energy and fossil fuels.

Wind Energy

Wind has energy owing to its motion. By using some device that can slow down a mass of moving air, a part of the energy of the moving wind can be extracted and converted into useful work. So, kinetic energy is converted into mechanical energy by the wind mills.

The technical wind power potential of our country is estimated to be about 20,000 MW, while at present we are generating about 5,400 MW. The largest wind farm of our country is near Kanyakumari in Tamil Nadu generating 380 MW electricity.

Wind energy is very useful as it does not cause any air pollution. After the initial installation cost, the wind energy is very cheap. It is believed that by the middle of the century wind power would supply more than 10% of world's electricity.

Tidal Energy, Tidal Current Energy and Wave Energy

Periodic rise and fall of ocean water level, twice in each lunar day is known as ocean tide. The rise and fall of tidal water is maximum near sea-shore and bays (river mouths), which are usually ideal for constructing tidal energy barrages. Tidal range is the difference in water level at high tide and low tide and difference in potential energy during high tide and low tide is called *tidal energy*.

Tidal currents are the flow of water during changing tidal level. The kinetic energy present in the tidal currents is known as *tidal current energy.*

Another type of energy is *ocean wave energy*. Waves are caused by surface winds in contrast to the tides that are caused by gravitational forces of moon and sun on ocean water.

Thus tidal energy and tidal current energy are hydro-power energy recurring with each tide and tidal current and hence renewable.

Ocean wave in the form of to and fro, up and down motion caused by surface winds possesses both potential and kinetic energy. The power contained in waves is usually in 10 to 70 kW/m, depending upon the amplitude of the wave.

Ocean Thermal Energy

It is acquired by ocean water from solar radiations, in the form of temperature rise. Total ocean thermal energy of the world is quite substantial, but the technology for conversion of ocean thermal energy to electric power is costly and difficult and yet to be properly commercialised.

Geothermal Energy

The enormous thermal energy present in the interior of the earth is called geothermal energy. It is going to last for millions of years and, therefore, referred to as renewable energy resource. These are apparent in the form of hot water springs/geysers, fumaroles (small vents in ground from where steam and gases are released) and volcanic erruptions. Geothermal energy resources are of two types—hydro and petro geothermal energy deposits. The former are deposits of hot water or steam at about 3000 m depth while the latter are hot dry rocks at 2000 m depth with temperature of about 200°C.

Biomass Energy

Biomass is the organic matter produced by the plants or animals which includes wood, crop residues, cattle dung, manure, sewage, agricultural wastes etc. Biomass energy is of the following types:

(*a*) **Energy plantations:** Solar energy is trapped by green plants through photosynthesis and converted into biomass energy. Fast growing trees like cottonwood, poplar and *Leucaena,* non-woody herbaceous grasses, crop plants like sugarcane, sweet sorghum and sugar beet, aquatic weeds like water hyacinth and sea-weeds and carbohydrate rich potato, cereal etc., are some of the important energy plantations. They may produce energy either by burning directly or by getting converted into burnable gas or may be converted into fuels by fermentation.

(*b*) **Petro-crops:** Certain latex-containing plants like Euphorbias and oil palms are rich in hydrocarbons and can yield an oil like substance under high temperature and pressure. This oily material may be burnt in diesel engines directly or may be refined to form gasoline. These plants are popularly known as petro-crops.

(*c*) **Agricultural and urban waste biomass:** Crop residues, bagasse (sugarcane residues), coconut shells, peanut hulls, cotton stalks etc. are some of the common agricultural wastes which produce energy by burning. Animal dung, fishery and poultry waste and even human refuse are examples of biomass energy. In Brazil 30% of electricity is obtained from burning bagasse. In rural India, animal dung cakes are burnt to produce heat. About 80% of rural heat energy requirements are met by burning agricultural wastes, wood and animal dung cakes.

In rural areas these forms of waste biomass are burned in open furnaces called **'Chulhas'** which usually produce smoke and are not so efficient (efficiency is <8%). Now improved Chulhas with tall chimney have been designed which have high efficiency and are smokeless.

The burning of plant residues or animal wastes cause air pollution and produce a lot of ash as waste residue. The burning of dung destroys essential nutrients like N and P. It is, therefore, more useful to convert the biomass into biogas or biofuels.

Biogas

Biogas is a mixture of methane, carbon dioxide, hydrogen and hydrogen sulphide, the major constituent being methane. Biogas is produced by anaerobic degradation of animal wastes (sometimes plant wastes) in the presence of water. Anaerobic degradation means breakdown of organic matter by bacteria in the absence of oxygen.

Biogas is a non-polluting, clean and low cost fuel which is very useful for rural areas where a lot of animal wastes and agricultural wastes are available. India has the largest cattle population in the world (240 million) and has tremendous potential for biogas production. From cattle dung alone, we can produce biogas of a magnitude of 22,500 Mm^3 annually. A sixty cubic feet gobar gas plant can serve the needs of one average family.

Biogas has the following main advantages: It is clean, non-polluting and cheap. There is direct supply of gas from the plant and there is no storage problem. The sludge left over is a rich fertilizer containing bacterial biomass with most of the nutrients preserved as such. Air-tight digestion/degradation of the animal wastes are safe as it eliminates health hazards which normally occur in case of direct use of dung due to direct exposure to faecal pathogens and parasites.

12.2 GROWING ENERGY DEMANDS AND NEED FOR ALTERNATE ENERGY RESOURCES

Energy consumption of a nation is usually considered as an index of its development. This is because almost all the developmental activities are directly or indirectly dependent upon energy. We find wide disparities in per capita energy use between the developed and the developing nations.

The first form of energy technology probably was the fire, which produced heat and the early man used it for cooking and heating purposes. Wind and hydropower have also been in use for the last 10,000 years. The invention of steam engines replaced the burning of wood by coal and coal was later replaced to a great extent by oil. In 1970's due to Iranian revolution and Arab oil embargo the prices of oil shot up. This ultimately led to exploration and use of several alternate sources of energy.

Development in different sectors relies largely upon energy. Energy is required for agriculture, industry, mining, transportation, lighting, cooling and heating in bulidings. With the demands of growing population the world is facing further energy deficit. The fossil fuels like coal, oil and natural gas, which at present are supplying 95% of the commercial energy are not going to last for many more years. Our life style is changing very fast and from a simple way of living we are shifting to a luxurious life style. If we just look at the number of electric gadgets in our homes and the number of private cars and scooters in our locality we will realise that in the last few years these have multiplied many fold and all of these consume energy.

Developed countries like U.S.A and Canada constitute about 5% of the world's population but consume one-fourth of global energy resources. An average person there consumes 300 GJ (Giga Joules, equal to 60 barrels of oils) per year. By contrast, an average man in a poor country like Bhutan, Nepal or Ethiopia consumes less than 1 GJ in a year. So a person in a rich country consumes almost as much energy in a single day as one person does in a whole year in a poor country. This shows that our life-style and standard of living are closely related to our energy needs.

Figure 12.3 show a strong correlation between per capita energy use and GNP (Gross National Product). Countries like U.S.A, Norway and Switzerland with high GNP show high energy use while India, China and Ethiopia have low GNP and low energy use. Bahrain and Quatar are oil rich states, hence, their energy consumption and GNP are more, although their development is not that high.

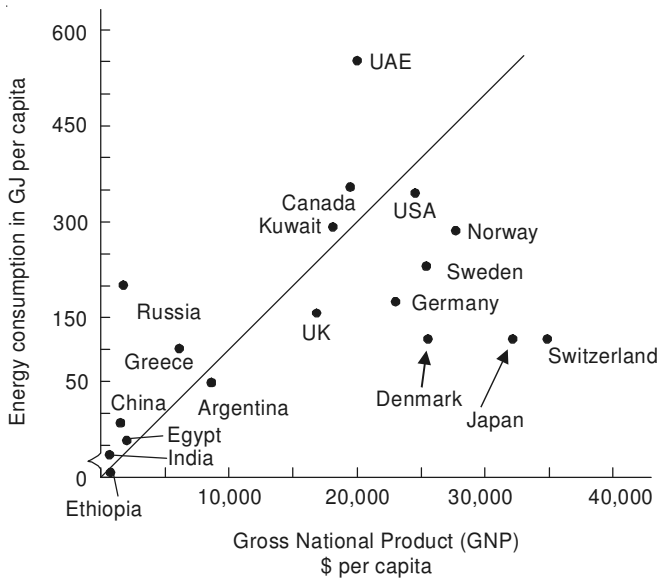

Fig. 12.3. *Per capita energy use and GNP (Data from World Resources Institute, 1997)*

The energy intensive standards of living already achieved in modern times have necessitated exploration of more and newer energy resources. Per capita energy consumptions vary widely, as discussed above, but considering the global demands, on a whole, projections are given by Energy Research Group (U.K.) that the annual global demands that have increased from 390 exajoules in 1985 to 590 exajoules in 2000, will reach 840 exajoules in the year 2020. (1 exajoule = 10^{18} joules; 1 joule = 1 Watt Second).

Energy consumption is increasing at an annual growth rate of 3 to 4%. During the 20th century, we have mainly relied upon fossil fuels as the major source of energy. The reserves of fossil fuels have thus depleted sharply and are not going to last for many more years. Soon after the oil crisis of 1970's, it was realised that we must look for some alternate sources of energy, because oil and coal reserves are certainly not going to last long. It was, however, only after the year 2000, that focus on alternate energy technology increased.

Not only our growing energy demands and limited fossil fuel reserves make it necessary to look for renewable energy resources, but there are several environmental problems as well that are associated with fossil fuels. Burning of fossil fuels have been responsible for large scale environmental pollution with far reaching consequences including acid rains, enhanced global warming and health problems.

It has therefore, become absolutely essential to harness alternative sources of energy so that we can meet the goals of sustainable development.

12.3 METHODS OF HARNESSING ENERGY

12.3.1 Coal

Coal production and processing involve exploration, mining, preparation, cleaning, storage, transportation and supply. Coal conversion technologies include coal gasification, coal liquefaction and coal carbonisation for coke and coal gas production.

- **Coal mining** is done either by surface mining, which is responsible for 75% of coal mining in India or lay underground mining for extraction of coal from beds that are more than 50 meters deep.
- **Coal preparation** involves removal of impurities, dirt and sulphur from the coal followed by sorting out, crushing, screening and cleaning. On burning coal releases oxides of sulphur, which are toxic in nature. About 70% of the sulphur present in coal as impurity is in organically bound form, which is difficult to remove.
- **Storage of coal** requires major precautions for preventing spontaneous fire due to heat, large storage bulk or accelerated oxidation.
- **Transportation** of coal may be land transport, river transport, ocean transport or pipeline transport.
- **Coal conversion technologies** involve conversion of coal from solid to liquid or gaseous form. Coal is converted from solid form to liquid or gaseous form. Various solid, and gaseous fuels have their specific applications. Direct burning of coal results in emission of particulates, smoke, SOx- NOx, CO and CO_2, whereas the gaseous or liquified fuels cause lesser pollution. Some important coal conversion technologies are discussed below:

Coal Gasification

It involves chemical reaction of coal, steam and air at high temperature. A coal water mixture called a Slurry is injected with oxygen into a heated furnace called gasifier, producing three combustible gases: Carbon monoxide, hydrogen and some methane. The heated gas is then cooled and purified. The resultant gas burns as cleanly as natural gas. The exhaust gas is used to spin one or two electric generators. The heat is also captured to generate steam, which operates another generator.

The generalised scheme of coal gasification is as shown below:

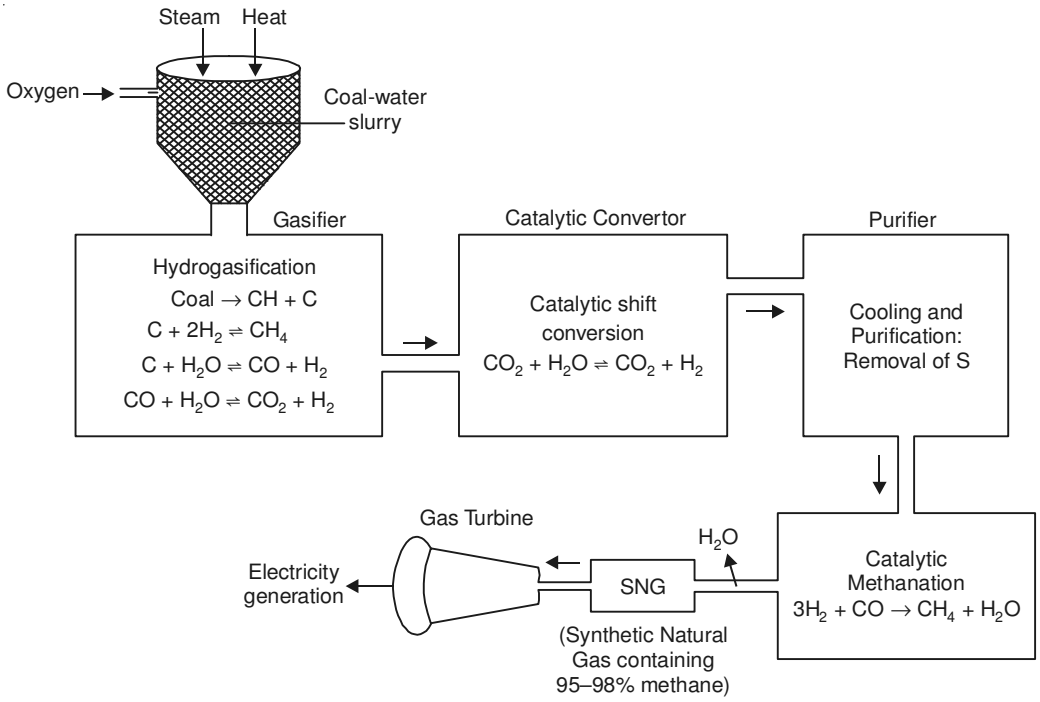

Fig. 12.4 *Generalised scheme of coal gasification*

Fluidized Bed Combustion

While burning coal, a lot of pollution occurs. So there is a need to burn coal in a cleaner way. Fluidized bed combustion is one such important technology, in while coal is crushed and mixed with bits of limestone and propelled into a furnace in strong current of air (Fig. 12.5). The particles mix turbulently in the combustion chamber ensuring very efficient combustion and therefore, low levels of carbon monoxide are produced. The furnace also operates at a much lower temperature than a conventional coal boiler, thus reducing nitrogen oxide emissions. The limestone reacts with sulphur oxides producing calcium sulphite or sulphate, thus reducing SO_x emissions from the stacks. Steam pipes in the furnace help maximise heat efficiency.

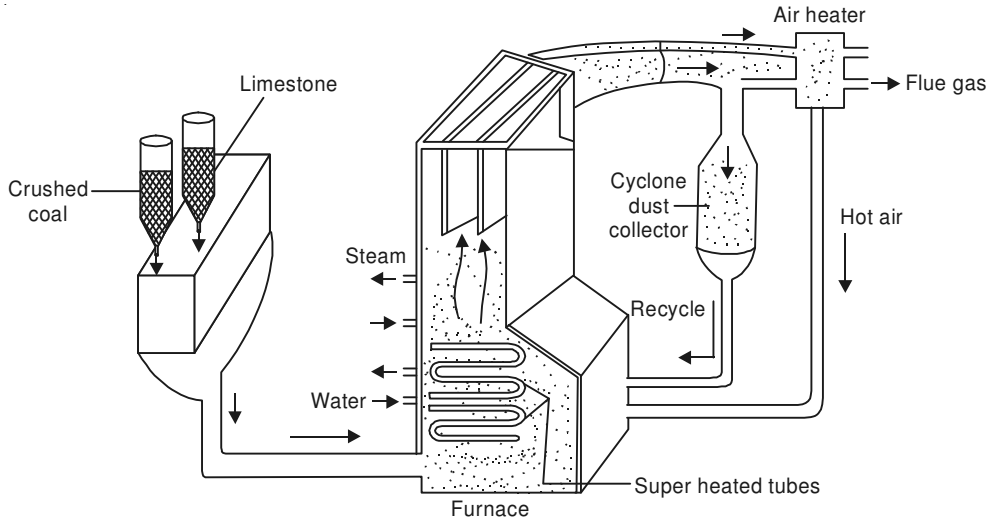

Fig. 12.5 *Fluidized bed combustion*

Coal Liquefaction

Coal can also be treated to produce a thick, oily substance by liquefaction. At least 4 major processes now exist which add hydrogen to coal to produce oil. The oil can then be refined like crude oil to produce a variety of products like jet fuel, gasoline, kerosene, many chemicals, drugs and plastics.

Coal liquefaction is a costly process and it generates pollutants like phenols. It also does not help in CO_2 emission reduction.

12.3.2 Petroleum

It differs from coal as the crude petroleum has to be refined and components separated before use, because it is a complex mixture of several types of oils, gaseous fuels, paraffin etc.

Basic steps in harnessing energy from petroleum include exploration of oil resources, drilling of wells, production, storage and transport of crude oil, refining of crude oil, storage and transportation of products.

Exploration is usually done in areas having sedimentary rocks, where petroleum deposits generally occur, which may be on-shore (land) or off-shore (sea) at shallow, medium or large depths.

Drilling is done from specifically formed drilling platforms. For enhanced extraction, the following techniques are used:

- By injecting fluid (air, gas, steam, water) into the well.
- By using chemical explosives to loosen tight formations.
- By adding chemicals to reduce viscosity of the crude oil.
- By allowing microbial growth inside to increase bulk, reduce viscosity and enhance recovery, known as Microbially Enhanced Oil Recovery (MEOR).
- By controlled underground burning to push up oil.

After extraction, crude oil is separated from natural gas and water, stored and transported through pipelines or tankers.

Crude oil is refined by the following processes:

- Separation – of some components by distillation.
- Chemical purification or removal of impurities by adsorption (on charcoal).
- Formation of hydrocarbons by cracking or hydrogenation.

During refining of crude oil, several products are obtained that are used in domestic, transport, industrial and electric power sectors.

12.3.3 Natural Gas

Natural gas is first made moisture-free by using ethylene glycol, which is regenerated by vacuum drying for re-use.

The heavy gases constituting the natural gas in dried conditions are removed by adsorption in poor oil under pressure, so that finally methane remains, with small proportions of some heavier hydrocarbons like ethylene, butane and propane.

Natural gas may be liquefied as Liquefied Natural Gas (LNG) and transported through pipelines.

12.3.4 Harnessing Nuclear Energy

(A) Nuclear Fission

The process of nuclear fission and energy generation has already been discussed in the previous section. The concept of harnessing nuclear energy for power generation emerged in 1950's, when the United States projected its ***'atoms for peace'*** plans to build nuclear powered electric generators, that would be cheap and non-polluting in terms of no CO_2 emission. The International Atomic Energy Agency (IAEA) projected global generation of nuclear power to the tune of 4.5 million MW (Megawatts) by the turn of 21st century. However, the much acclaimed nuclear power industry is yet to emerge as a major energy alternative, mainly because of its problems of reactor safety, waste storage and disposal.

Uranium isotope U^{235} is the most commonly used fuel in nuclear power plants. However, its concentration in the natural uranium ore is even less than one per cent (0.7%), hence it has to be mechanically and chemically purified and concentrated in order to sustain a chain reaction. As the concentration of U^{235} reaches near three per cent, it is formed into nearly 1.5 cm long cylindrical pellets weighing about 8.5 g and having an energy equivalent to a ton of coal. We will briefly discuss the working of different types of nuclear reactors here.

Pressurised Water Reactors (PWR): Water is circulated through the *reactor core*, which is a heavy steel vessel containing thousands of tightly bundled fuel assemblies each made up of hundreds of fuel pellets. From the tightly packed uranium, as a neutron is released it triggers the nuclear fission and huge amount of heat is released. The chain reaction is moderated by using a neutron-absorbing coolant circulating between the fuel rods. Control rods of graphite or boron are also used as moderators. The heat is absorbed by circulating water, which in turns gets heated up to 317°C and attains a pressure of 2235 psi. Then it is pumped to a steam generator that heats a secondary water-cooling loop and again produces steam, driving a turbine to generate electricity. The reactor vessel and steam generator are encased in thick-walled concrete and steel to withstand high temperature and pressure (Fig. 12.6). These are most commonly used in the United States.

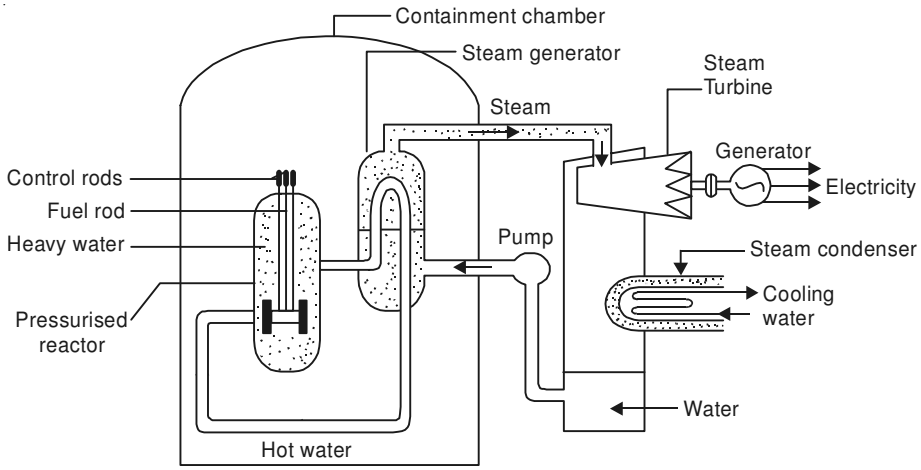

Fig. 12.6. *Pressurised heavy water reactor*

The coolant water used may be light water (H_2O) or heavy water (D_2O) and accordingly the reactor is known as Pressurised Light Water Reactor (PWR) or Pressurised Heavy Water Reactor (PHWR). In India, PHWR has been adopted as first generation reactor where deuterium is used both as a coolant and a moderator.

The simplest type of reactor is Boiling Water Reactor (BWR), in which light water is allowed to boil in the reactor core and steam is supplied directly to steam turbine.

Gas Cooled Reactor (GCR): In this type of reactor, the coolant is a gas like helium, which is circulated around the reactor core containing uranium pellets. It is safer and effective as a coolant, but has lower heat transfer capability. The reactor core is usually kept small, so that it does not generate too much heat to cause melt down in the event of coolant loss.

Breeder Reactors: These produce fuel rather than consuming it. Here fissionable plutonium or thorium isotopes are produced from uranium. The starting material is plutonium, obtained from spent fuel of fission reactors. (Fig. 12.7). After 10 years operation enough plutonium is produced to start a new reactor.

The major limitation of breeder reactor is the requirement of high density reactor core. Instead of water, liquid sodium is to be used as coolant, because heat capacity of water is not adequate to carry away the high heat flux in the core.

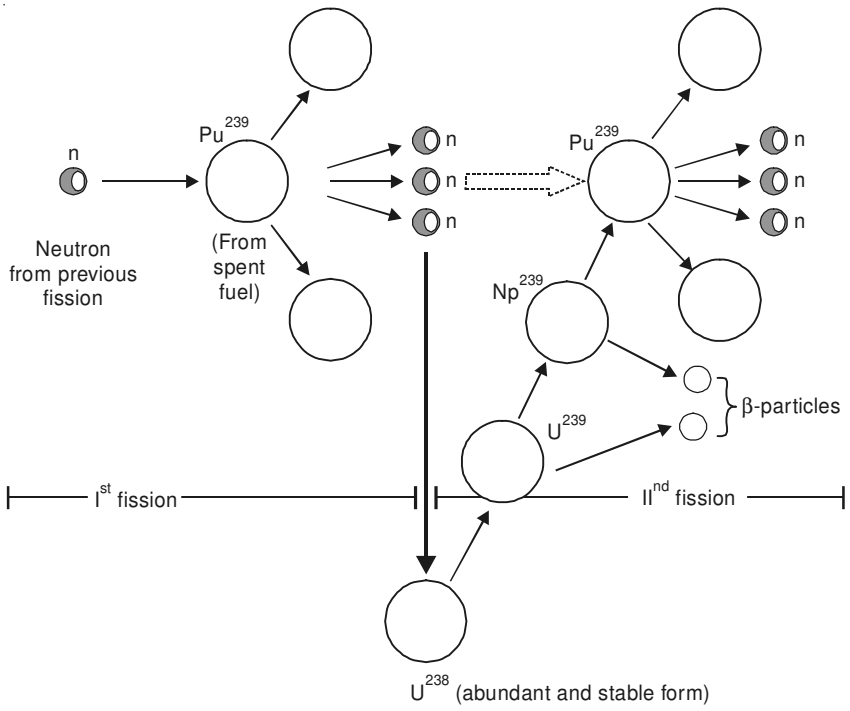

Fig. 12.7. *Nuclear fission reaction sequence in breeder reactor. Here plutonium (Pu^{239}) is used as well as produced in abundance*

Liquid sodium has certain drawbacks like its corrosive nature, intense flame when exposed to oxygen and explosive nature on coming in contact with water. Because of its own intense heat, a Liquid Metal Fast Breeder Reactor (LMFBR) may melt down and get self-destructed within a few seconds, if primary coolant gets exhausted or lost.

Excess of weapon-grade plutonium produced by breeder reactors also poses a danger of production of nuclear bombs, which would be a serious threat to global peace and humanity.

(B) Nuclear Fusion

Fusion of deuterium and tritium, the two radioactive isotopes of hydrogen can occur if temperature of the fuel mixture is raised to 100 million degrees celsius and pressure to several billion atmosphere. The forces keeping the nuclei apart are overcome under these conditions as the electrons strip away from the atoms. The two nuclei fuse and some of their mass is converted into energy. Two major nuclear fusion devices are discussed here.

(*i*) Magnetic Confinement: It involves containment of plasma, the fourth state of matter at very high temperature (10^8 °C), in which the electrons are stripped off their parent nuclei and electrically neutral gas of ions as free electrons is produced. Since, a metallic container cannot hold the plasma, hence compression of plasma is done by magnetic field confinement, so as to raise the temperature and pressure to the requisite levels. The following types of magnetic field confinement could be applied:

(*a*) Tokomak magnetic confinement, in which the vacuum chamber is shaped like a large doughnut (Fig. 12.8).

(*b*) Magnetic mirror confinement, in which plasma particles are reflected inwards by magnetic field envelope, acting like a mirror.

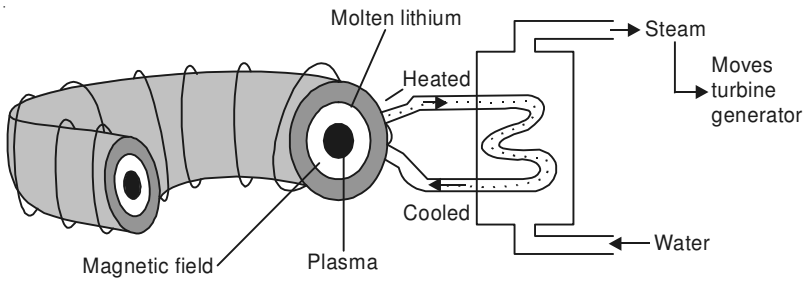

Fig. 12.8. *Magnetic field (tokomak) confinement – A nuclear fusion device*

(ii) Laser Inertial Confinement **:** Here extremely high intensity laser light is bombarded on small pellets from all sides simultaneously. Sudden absorption of energy results in collapse of the matter inwardly, a phenomenon called 'implosion', which increases the density and temperature to the threshold value. Such a condition exists for a fraction of a second before the pellets move apart in the form of a miniature hydrogen explosion. Enough reaction must occur as that some energy is harnessed.

The high energy neutrons escaping from the reaction are absorbed by molten lithium, which absorbs the neutrons and transfers heat to water forming steam, which drives turbine generator. (Fig. 12.9).

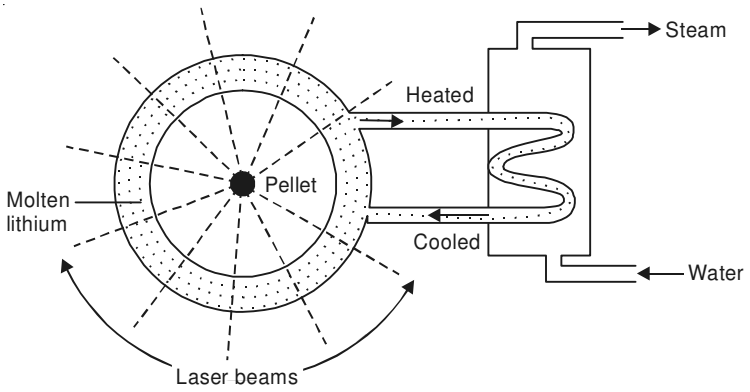

Fig. 12.9. *Internal confinement by laser beams – A nuclear fusion device*

Fusion reactions would reduce less radioactive wastes as compared to fission reactions. Laser beams with high power density and plasma generating 230×10^{6}°C temperature have already been created, that may sustain fusion reactors in future.

12.3.5 Harnessing Solar Energy

Solar energy can be harnessed and used broadly for the following applications:

(*i*) Passive heat collection without using any special conversion device. These are low temperature applications used mainly for heating water, buildings etc.

(*ii*) Direct conversion of solar radiations to electrical energy using photovoltaic cells (PV cells or solar cells) for low and medium power.

(*iii*) Conversion of solar energy to produce steam or electrical energy through a central receiver power plant. It has medium and high temperature applications.

(*iv*) Conversion of solar energy to produce thermal power in Mega watt range.

(*i*) Passive Heat Collection

Solar radiations are collected by passive collectors. Natural materials like stone, brick, glass etc., absorb heat of sun during day time and release the heat slowly at night time. The solar heat absorbed by the collectors placed at the top of a building is used for heating water during day time that is circulated through pipes to heat houses and commercial buildings during night time by making used of a pump.

Cost of the solar collector is an important factor for installation, hence, total surface area of the collector is kept as small as possible. Also with large surface area, higher collector temperature is obtained resulting in higher temperature difference leading to lower efficiency. Two types of collectors in use are discussed here:

(*a*) Simple Flat Plate Collector: It consists of a black coated flat heat absorbing plate with several channels for passage of working fluid, a liquid or a gas. Thermal loss is minimised by insulating the absorber plate with one or two transparent glass covers (Fig. 12.10). Heat absorbed by the plate is circulated by the fluid through channels. Temperatures between 85° to 120°C can be obtained with these collectors, depending upon the number of transparent insulating covers.

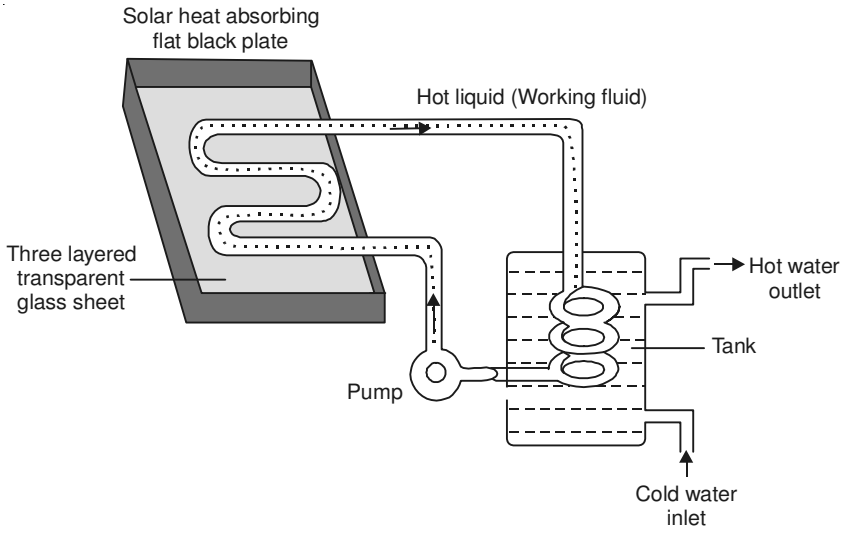

Fig. 12.10. *Flat plate solar collector for water heating system used on roof top.*

Efficiency of the collector is influenced by several factors like shadow factor, cosine loss factor, and reflective loss. Shadow effect is more near sun-rise and sun-set when the angle of elevation of the sun is < 15°. Cosine loss varies diurnally and reasonally. Solar power harnessed is proportional to cos θ, where θ is the angle between the perpendicular to collector surface and incident sun ray. Reflective losses from collector surface occur with passage of time due to dust, rusting, moisture, deformation etc.

(*b*) Parabolic Through (Trough) Collectors: Here much higher temperatures of 300°C can be achieved. Sun tracking is done in a single plane by parabolic through. Heat is absorbed by a pipe located along the central line and the heat is circulated by working fluid through the pipe (Fig. 12.11).

Another modification has been done in the form of paraboloid dish collectors that achieve still higher concentration ratios exceeding 1000, thereby attaining as high temperature as 1000°C. However, paraboloid dish collectors are much more difficult to make.

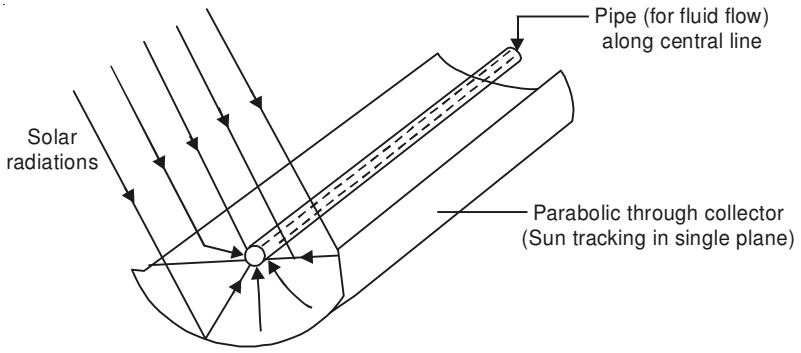

Fig. 12.11. *Parabolic through (trough) solar collector*

(*ii*) Photovoltaic cells (Solar cells) for direct conversion of solar radiations into electrical energy

Solar cell or PV cell is made of thin wafers of semiconductor material like silicon that forms the semi-conducting N–P junction, corresponding to negative and positive electrodes. The N–and P–type materials are obtained by doping silicon with N–type and P–type impurities.

There are two types of dopants used in doping the tetravalent silicon:

- Pentavalents like arsenic (As), antimony (Sb) or phosphorus (P)
- Trivalents like Indium (In), Boron (B) or Aluminium (AI).

When we dope Si with a pentavalent element, four of its electrons bond with four silicon neighbours, whereas the fifth excess electron is free to move due to loose bonding. Here, the number of conduction electrons are more than the number of holes. Hence the majority charge carriers are negatively charged electrons and therefore known as N–type semi-conductors.

On the other hand, when tetravalent silicon is doped with a trivalent element, the dopant has one outer electron less than Si. Therefore, this atom can form bonds on three sides with Si, but fails to form bond on one side. In order to hold the dopant atom (e.g. boron), tightly within the crystal lattice of Si, some of the electrons bond on outer side in the neighbouring area tend to slide into this vacant bond, leaving a 'hole' at its own site. This hole is available for conduction. Here the holes are the majority carriers while electrons are minority carriers.

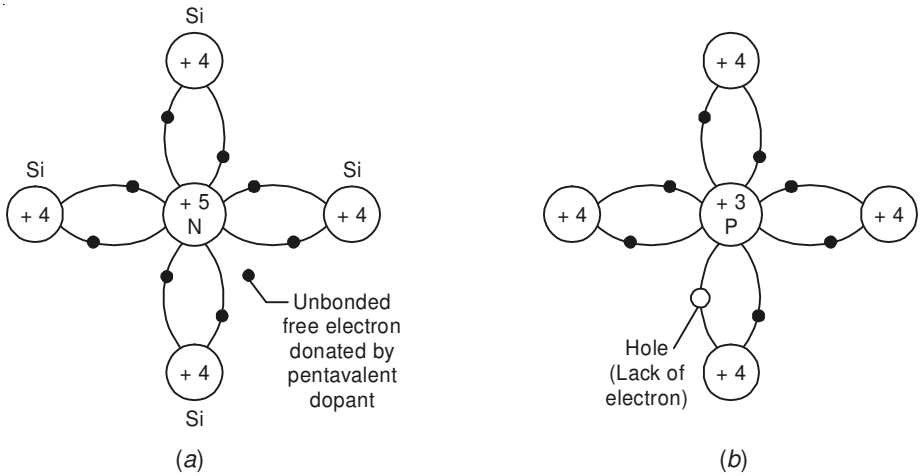

Fig. 12.12. *(a) Pentavalent donor atom doped for N–type semiconductor (b) trivalent acceptor atom doped for PN–type semiconductor*

As the solar radiations strike the thin transparent N–type layer, some of the radiations penetrate upto the thick P–type layer. Photons present in the light radiations result in liberation of electron-hole pairs in the P–N junction. Electrons (negative charge) are released from N–type semicouductor and holes (positive charge due to back of electrons) are created in the P–type semiconductor (Fig. 12.12). The potential difference causes flow of electrons, when the electric circuit is completed by connecting electrodes to the load. Thus, there is direct conversion of solar energy to electrical energy.

Silicon used in PV cells can be obtained from silica or sand, which is abundantly available and inexpensive. The potential difference produced by a single PV cell of 4 cm^2 size is about 0.4–0.5 volts, produces a current of 60–75 milli amperes, and has a rated power of about 0.3 watts. Figure 12.13 shows the structure of a solar cell.

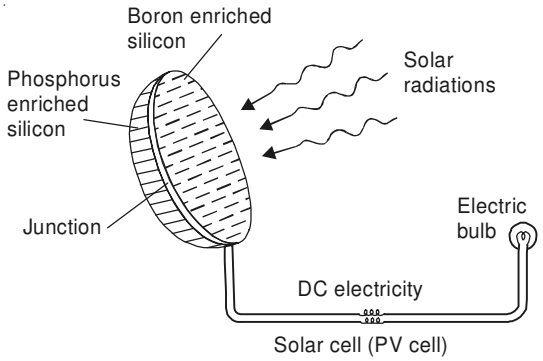

Fig. 12.13. *Solar cell*

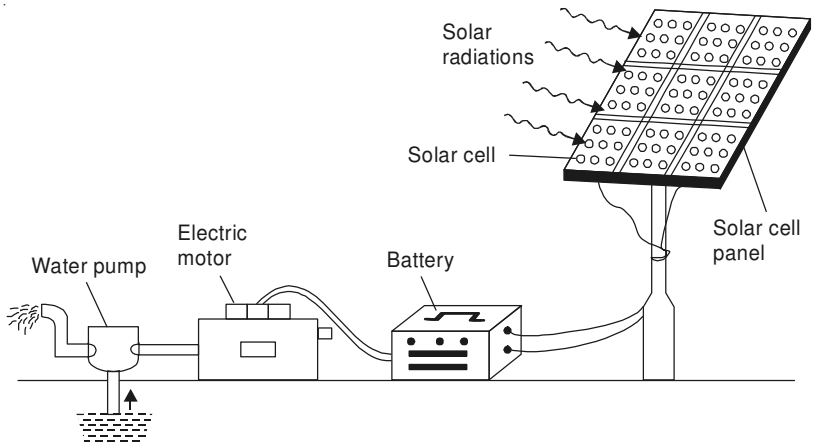

Fig. 12.14. *A solar pump run by electricity produced by solar cells*

A group of solar cells joined together in a definite pattern form a solar panel which can harness a large amount of solar energy and can produce electricity enough to run street-light, irrigation water pump etc. (Fig. 12.14).

Solar cells are widely used in calculators, electronic watches, street lighting, traffic signals, water pumps etc. They are also used in artificial satellites for electricity generation. Solar cells are used for running radio.

Merits and Demerits of Solar Cells

The merits of solar cell include clean, cheap, easy to use, renewable and safe form of energy that can be suitable for remote areas, away from main electricity networks or for mobile vehicles and aircrafts, little maintenance requirement and reliable service period of upto 10–15 years.

Intermittent and irregular solar radiations, need for storage battery and high capital cost due to large number requirement, low efficiency and low wattage are some of the demerits of solar cells.

- **Solar Central Receiver Thermal Power Plant:** These consist of nearly flat faced reflecting mirrors heliostats with provision of tracking the sun in two planes. Reflected rays from thousands of such heliostats, each with its own sun-tracking system are focussed on to the central receiver mounted on a tall tower. High temperatures are attained through this technique. Such solar electric power plants require large collection field expanding several square kilometer area. These plants are useful in areas having continuous bright sun light throughout the year.
- **Solar Distributed Collector Thermal Power Plant:** The heat transfer fluid from each collector is pumped to central heat storage. These days instead of flat plate collectors parabolic through collectors are preferred, because of low cost and simple single plane sun-tracking.
- **Solar Furnaces** can harness solar energy with large paraboloid reflector placed on some south facing tall building. The reflected rays are collected by a large central receiver placed on the focal point of the reflector.
- **Solar Pond:** These ponds also known as solar salt ponds are specially constructed shallow water reservoirs in which water gets heated by solar radiations. A salt gradient with lower concentration in upper layers and higher concentrations in lower layers of water is maintained to prevent convection currents. Hot upper layer remains of its place to provide thermal insulation. Heat from lower layers are transferred to a working fluid and then to heat exchanger.

12.3.6 Harnessing Wind Energy

Wind energy is harnessed in wind farms located in vast open spaces consisting of several wind turbine generator units along with electrical and mechanical auxiliaries. A wind-turbine generator unit consists of a wind turbine with a vertical or horizontal axis propellor (wheel), gear chain, synchronous or asynchronous electrical generator and some electro-mechanical auxiliaries and control panel.

The wind passes through the propellor of the wind turbine producing a rotory torque. The propellor rotates and converts the wind power into electric power. Power extracted from the wind by propellor type wind turbine is influenced by specific speed (tip speed)/wind speed ratio, which may range from 2 to 10. The minimum wind speed required for satisfactory working of a wind generator is 15 km/hr. Fig. 12.15 shows a typical wind farm with 3-blade windmill.

Two blade designs are more cost-effective as compared to three blade designs but suffer usually from vibrational problems. Earlier windmills used to be of vertical axis type, which are omnidirectional and can capture wind in any direction. Horizontal axis wind turbines are under high stress during storms and have more aerodynamic control problems. One of the most promising type is Darrieus Rotor with vertical axis (Fig. 12.16), which can produce electricity at relatively low wind speed also.

Fig. 12.15. *Wind farm*

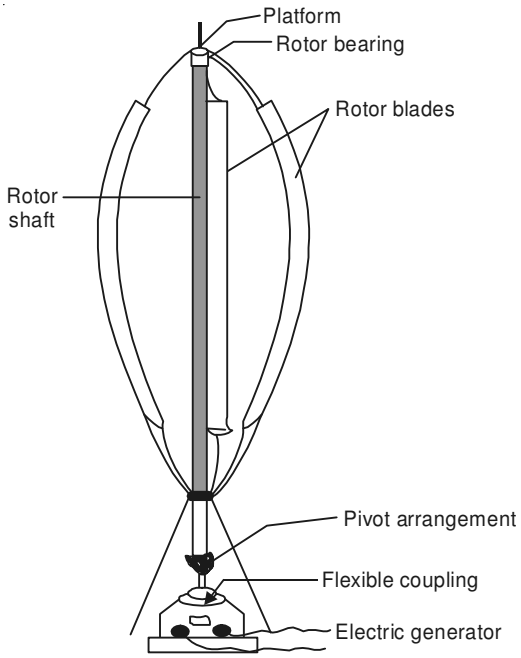

Fig. 12.16. *Darrieus (egg–beater type) Rotor wind turbine generator*

12.3.7 Hydropower

The water flowing in a river is collected by constructing a big dam where the water is stored and allowed to fall from a height. Potential energy stored in water reservoir at high head is converted into kinetic energy in the flowing water. The blades of the turbine located at the bottom of the dam move with the fast moving water which in turn rotate the generator and produce electricity. We can also construct mini or micro hydelpower plants on the rivers in hilly regions for harnessing

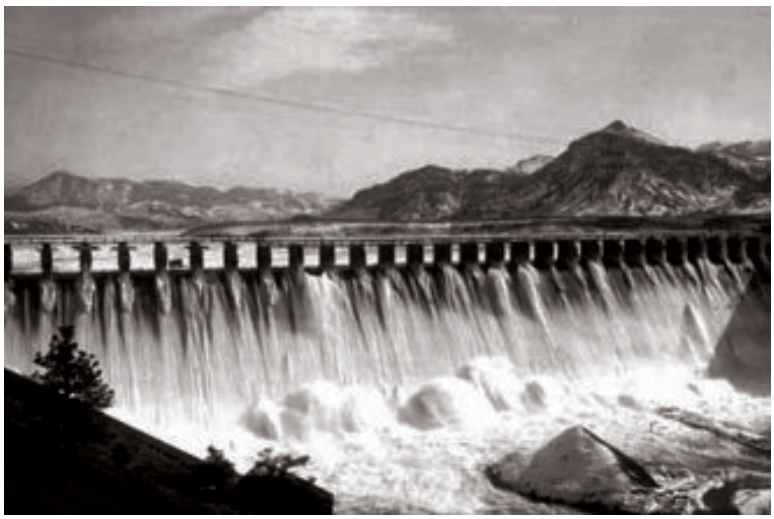

Fig. 12.17. *Hydroelectric power (Dam)*

the hydro energy on a small scale, but the minimum height of the waterfalls should be 10 metres. **The hydropower potential of India is estimated to be about 4×10^{11} kW-hours.** Till now we have utilised only a little more than 11% of this potential.

Hydropower does not cause any pollution, it is renewable and normally the hydropower projects are multi-purpose projects helping in controlling floods, used for irrigation, navigation etc. However, big dams are often associated with a number of environmental impacts.

12.3.8 Tidal Energy

Ocean tides produced by gravitational forces of sun and moon contain enormous amounts of energy. The 'high tide' and 'low tide' refer to the rise and fall of water in the oceans. A difference of several meters is required between the height of high and low tide to spin the turbines. The tidal energy can be harnessed by constructing a tidal barrage. During high tide, the sea-water flows into the reservoir of the barrage and turns the turbine, which in turn produces electricity by rotating the generators. During low tide, when the sea-level is low, the sea-water stored in the barrage reservoir flows out into the sea and again turns the turbines (Fig. 12.18).

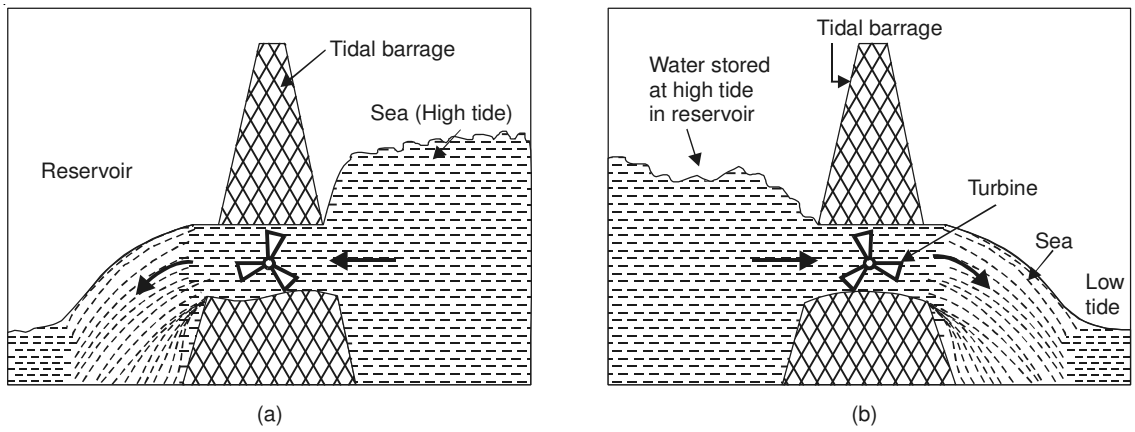

Fig. 12.18. *(a) Water flows into the reservoir to turn the turbine at high tide and (b) flows out from the reservoir to the sea again turning the turbine at low tide*

Tidal power is proportional to the square of tidal range, which is known to vary not only with geographic location, depth of ocean and distance from coast, but also with lunar days at the same location. A tidal range of above 2·5 m is essential for locating a tidal power plant.

There are only a few sites in the world where tidal energy can be suitably harnessed. The Bay of Fundy, Canada having 17–18 m high tides has a potential of 5,000 MW of power generation. The tidal mill at La Rance, France is one of the first modern tidal power mill. In India, Gulf of Cambay, Gulf of Kutch and the Sunderban deltas are the tidal power sites.

12.3.9 Ocean Thermal Energy Conversion (OTEC)

The energy available due to the difference in temperature of water at the surface of the tropical oceans and at deeper levels is called Ocean Thermal Energy. A difference of 20°C or more is required between surface water and deeper water of ocean for operating OTEC (Ocean Thermal Energy Conversion) power plants. Substantial amount of heat can be extracted from ocean water by Ocean Thermal Gradient Principle of thermodynamics. The warm surface water of oceans (24°C – 27°C) is used in two types of OTEC systems:

(*i*) **Steam turbine generator system:** The warm water is converted into steam in open cycle in an evaporator and electricity is generated.

(*ii*) **Vapour turbine generator system:** The warm water is used to boil a working fluid like ammonia or butane. The high pressure vapours of the liquid formed by boiling are then used to turn the turbine of the generator and produce electricity. The colder water from the deeper oceans (4ºC – 6ºC) is pumped to cool and condense the vapours into liquid. Thus the process keeps on going continuously for 24 hours a day.

Some limitations of OTEC include high cost, very large flow area, stress due to storms, corrosion by salts, algal obstruction and difficult maintenance.

First OTEC plant of India is in Kulasekharapatnam, Tamil Nadu.

12.3.10 Geothermal Energy

The energy harnessed from the hot rocks present inside the earth is called geothermal energy. High temperature and high pressure steam fields exist below the earth's surface in many places. This heat comes from the fission of radioactive material naturally present in the rocks. In some places, the steam or the hot water comes out of the ground naturally through cracks in the form of **natural geysers** as in Manikaran, Kullu and Sohana, Haryana and Tattapani, Chhattisgarh. About 340 geothermal springs have been identified by Geological Survey of India (GSI) in our country. Sometimes the steam or boiling water underneath the earth does not find any place to come out. We can artificially drill a hole up to the hot rocks and by putting a pipe in it make the steam or hot water gush out through the pipe at high pressure which turns the turbine of a generator to produce electricity Fig. 12.19 shows extraction of geothermal energy through hot dry rocks. In USA and New Zealand, there are several geothermal plants working successfully.

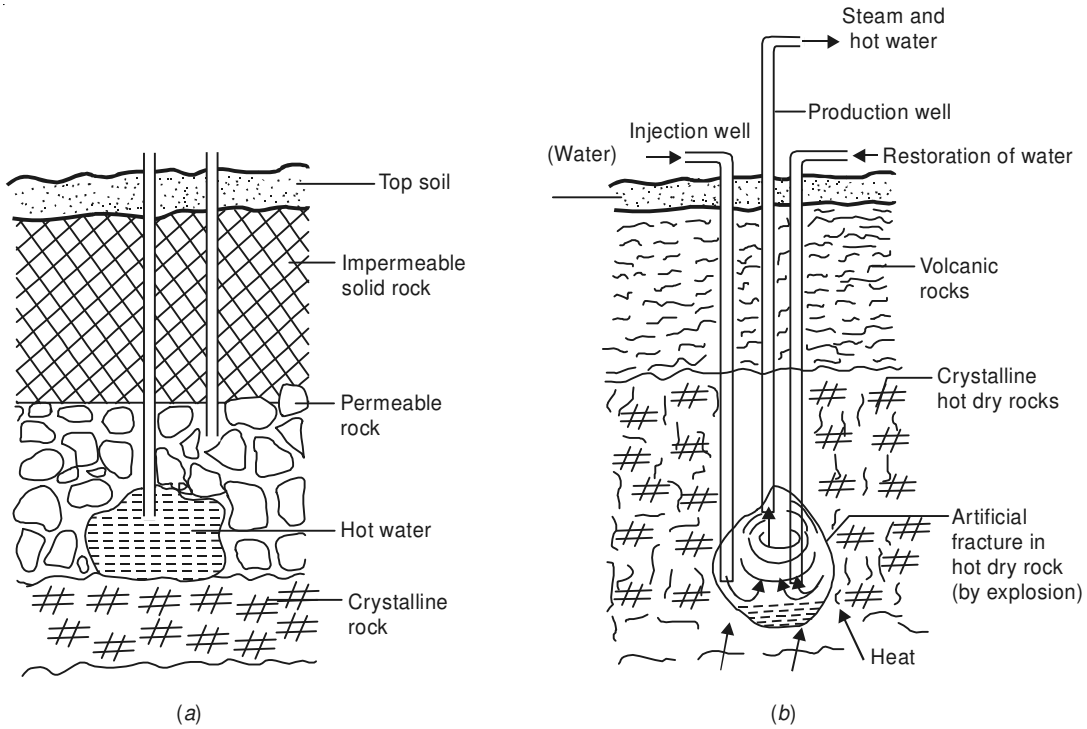

Fig. 12.19. *Extraction of geothermal energy (a) from liquid dominated geothermal resources (b) from petro geothermal resources in hot dry rock*

Biomass Conversion Processes

Energy locked in biomass can be converted into useful energy by following methods:

(*i*) **Incineration or direct combustion:** The organic matter like dry municipal waste, bagasse, farm waste, wood chips etc., are burnt at high temperature to produce heat, steam and electricity (cogeneration).

(*ii*) **Thermochemical conversion:** The organic matter is decomposed through thermochemical processes having different temperature and pressure combinations.

Biomass can be converted into gases, process called **gasification** by heating with limited air or heating at high temperature and pressure in the presence of steam and oxygen. Biomass can also be converted into gases, liquids or solids through **pyrolysis** at high temperature (500 – 900°C) in the absence of oxygen. A large variety of products can be obtained from biomass through pyrolytic destructive distillation.

(*iii*) **Biochemical conversion:** It may involve anaerobic digestion or fermentation of biomass using microbes to yield biogas and alcohols.

12.3.11 Biogas Production

Biogas plants used in our country are basically of two types:

1. Floating gas-holder type and 2. Fixed-dome type.

1. Floating gas holder type biogas plant: This type has a well-shaped digester tank which is placed under the ground and made up of bricks. In the digester tank, over the dung slurry an inverted steel drum floats to hold the bio-gas produced. The gas holder can move which is controlled by a pipe and the gas outlet is regulated by a valve. The digester tank has a partition wall and one side of it receives the dung-water mixture through inlet pipe while the other side discharges the spent slurry through outlet pipe. (Fig. 12.20).

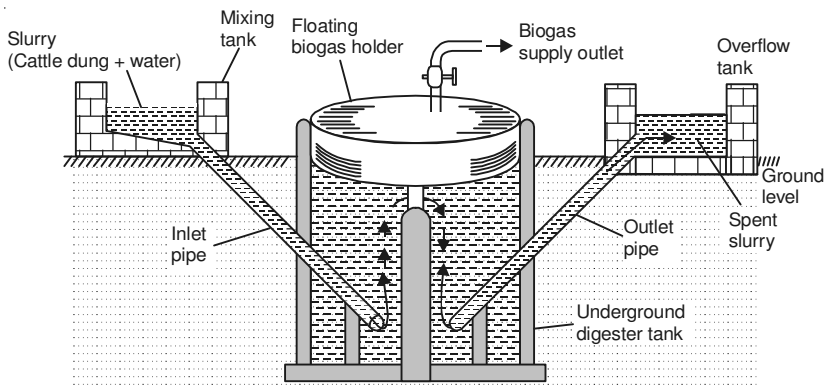

Fig. 12.20. *Floating gas holder type biogas plant*

Sometimes corrosion of steel gas-holder leads to leakage of biogas. The tank has to be painted time and again for maintenance which increases the cost. Hence, another type was designed as discussed below:

2. Fixed dome type biogas plant: The structure is almost similar to that of the previous type. However, instead of a steel gas-holder there is dome shaped roof made of cement and bricks. Instead of partitioning, here there is a single unit in the main digester but it has inlet and outlet chambers as shown in Fig. 12.21.

The Ministry of Non-Conventional Energy Sources (MNES) has been promoting the biogas programme in India. Out of the various models, the important ones used in rural set-up are KVIC Model (Floating drum type), Janta Model (Fixed dome type), Deenbandhu Model (Fixed dome type), Pragati Model (floating drum type), Ganesh Model (KVIC type but made of bamboo and polythene sheet) and Ferro-cement digester Model (KVIC type with ferro-cement digester).

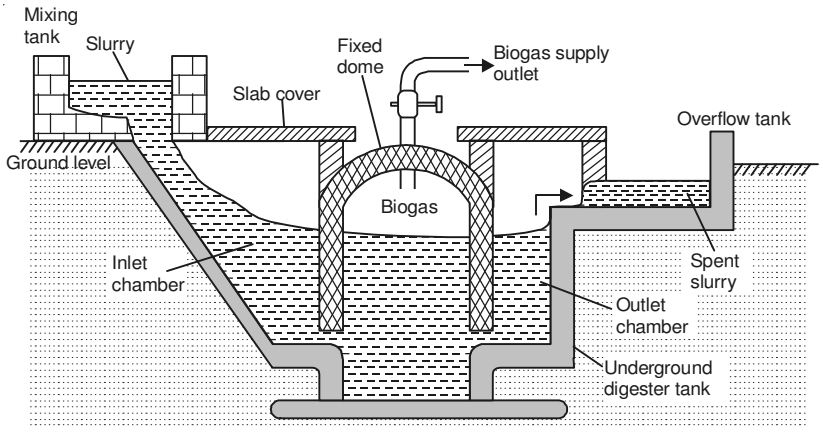

Fig. 12.21. *Fixed dome type biogas plant*

Biofuels

Biofuels can be obtained by fermenting biomass that produces alcohols like ethanol and methanol. **Ethanol** can be easily produced from carbohydrate rich substances like sugarcane, corn and sorghum (Jowar). It burns clean and is non-polluting. However, as compared to petrol its calorific value is less and therefore, produces much less heat than petrol. It is also considered to be an excellent substitute for kerosene and its combustion is as clean as LPG.

Gasohol is a common fuel used in Brazil and Zimbabwe for running cars and buses. In India too gasohol is planned to be used on trial basis in some parts of the country, to start with in Kanpur. Gasohol is a mixture of ethanol and gasoline.

Methanol is very useful since it burns at a lower temperature than gasoline or diesel. Thus the bulky radiator may be substituted by sleek designs in our cars. Methanol too is a clean, non-polluting fuel.

Methanol can be easily obtained from woody plants and ethanol from grain-based or sugar-containing plants.

Hydrogen as a Fuel

As hydrogen burns in air, it combines with oxygen to form water and a large amount of energy (150 kilojoules per gram) is released. Due to its high, rather the highest calorific value, hydrogen can serve as an excellent fuel. Moreover, it is non-polluting and can be easily produced.

Production of hydrogen is possible by thermal dissociation, photolysis or electrolysis of water:

(*i*) By thermal dissociation of water (at 3000°K or above) hydrogen (H_2) is produced.

(*ii*) Thermochemically, hydrogen is produced by chemical reaction of water with some other chemicals in 2–3 cycles so that we do not need the high temperatures as in direct thermal method and ultimately H_2 is produced.

(*iii*) Electrolytic method dissociates water into hydrogen (H_2) and oxygen by making a current flow through it.

(*iv*) Photolysis of water involves breakdown of water in the presence of sunlight to release hydrogen. Green plants and micro-algae also have photolysis of water during photosynthesis. Efforts are underway to trap hydrogen molecule which is produced during photosynthesis.

However, hydrogen is highly inflammable and explosive in nature. Hence, safe handling is required for using H_2 as a fuel. Also, it is difficult to store and transport. And being very light, it would have to be stored in bulk.

Presently, H_2 is used in the form of liquid hydrogen as a fuel in spaceships H_2 can be used in **fuel cell** to generate electricity. In fuel cell hydrogen is burnt in air or oxygen in the pressure of an electrolyte to produce electricity.

12.4 ENVIRONMENTAL POLLUTION

For normal and healthy living a conducive environment is required by all living beings, including humans, livestock, plants, micro-organisms and the wildlife. The favourable unpolluted environment has a specific composition. When this composition gets changed by addition of harmful substances, the environment is called polluted environment and the substances polluting it are called pollutants. **Environmental pollution can, therefore, be defined as any undesirable change in the physical, chemical or biological characteristics of any component of the environment (air, water, soil), which can cause harmful effects on various forms of life or property.** Environmental pollution could be of various types:

12.4.1 Air Pollution

It is an atmospheric condition in which certain substances (including the normal constituents in excess) are present in such concentrations which can cause undesirable effects on man and his environment. These substances include gases, particulate matter, radioactive substances etc.

Gaseous pollutants include oxides of sulphur (mostly SO_2, SO_3) oxides of nitrogen (mostly NO and NO_2 or NO_x), carbon monoxide (CO), volatile organic compounds (mostly hydrocarbons) etc. Particulate pollutants include smoke, dust, soot, fumes, aerosols, liquid droplets, pollen grains etc.

Radioactive pollutants include radon-222, iodine-131, strontium-90, plutonium-239 etc.

Classification of Air Pollutants

Air pollutants may occur in gaseous or particulate form and may be organic or inorganic in nature. On the basis of origin of pollutants they can be classified as primary or secondary pollutants.

Primary Pollutants: These are emitted directly from the point source (identifiable source) e.g. carbon monoxide (CO), oxides of nitrogen (NO_x), oxides of sulphur (SO_x), hydrocarbons, radioactive substances etc.

Secondary Pollutants: These are formed by interaction of primary pollutants (S) with other primary pollutants (s) or with some natural constituents of atmosphere, e.g. ozone (O_3), peroxyacetyl nitrate (PAN), Photochemical smog etc.

12.4.2 Causes/Sources of Air Pollutants

The sources of air pollution are natural and man-made (anthropogenic).

Natural Sources. The natural sources of air pollution are volcanic eruptions, forest fires, sea salt sprays, biological decay, photochemical oxidation of terpenes, marshes, extra terrestrial bodies, pollen grains of flowers, spores etc. Radioactive minerals present in the earth crust are the sources of radioactivity in the atmosphere.

Man-made: Man made sources include thermal power plants, industrial units, vehicular emissions, fossil fuel burning, agricultural activities etc. Thermal power plants have become the major sources for generating electricity in India as the nuclear power plants couldn't be installed as planned. The main pollutants emitted are fly ash and SO_2. Metallurgical plants also consume coal and produce similar pollutants. Fertilizer plants, smelters, textile mills, tanneries, refineries, chemical industries, paper and pulp mills are other sources of air pollution.

Automobile exhaust is another major source of air pollution. Automobiles release gases such as carbon monoxide (about 77%), oxides of nitrogen (about 8%) and hydrocarbons (about 14%). Heavy duty diesel vehicles spew more NO_x and suspended particulate matter (SPM) than petrol vehicles which produce more carbon monoxide and hydrocarbons.

12.4.3 Indoor Air Pollution

The most important indoor air pollutant is radon gas. Radon gas and its radioactive daughters are responsible for a large number of lung cancer deaths each year. Radon can be emitted from building materials like bricks, concrete, tiles etc., which are derived from soil containing radium. Radon is also present in groundwater and natural gas and is emitted indoors while using them.

Many houses in the under-developed and developing countries including India use fuels like coal, dung-cakes, wood and kerosene in their kitchens. Complete combustion of fuel produces carbon dioxide which may not be toxic. However, incomplete combustion produces the toxic gas carbon monoxide. Coal contains varying amounts of sulphur which on burning produces sulphur dioxide. Fossil fuel burning produces black soot. These pollutants i.e. CO, SO_2, soot and many others like formaldehyde, benzo-(*a*) pyrene (BAP) are toxic and harmful for health. BAP is also found in cigarette smoke and is considered to cause cancer. A housewife using wood as fuel for cooking inhales BAP equivalent to 20 packets of cigarette a day.

Effects of air pollution. Air pollution has adverse effects on living organisms and materials.

Effects on human health. Human respiratory system has a number of mechanisms for protection from air pollution. Bigger particles (> 10 μm) can be trapped by the hairs and sticky mucus in the lining of the nose. Smaller particles can reach tracheobronchial system and there get trapped in mucus. They are sent back to throat by beating of hair like cilia from where they can be removed by spitting or swallowing. Years of exposure to air pollutants (including cigarette smoke) adversely affect these natural defences and can result in lung cancer, asthma, chronic, bronchitis and emphysema (damage to air sacs leading to loss of lung elasticity and acute shortness of breath). Suspended particulates can cause damage to lung tissues and diseases like asthma, bronchitis and cancer especially when they bring with them cancer causing or toxic pollutants attached on their surface. Sulphur dioxide (SO_2) causes constriction of respiratory passage and can cause bronchitis like conditions. In the presence of suspended particulates, SO_2 can form acid sulphate particles, which can go deep into the lungs and affect them severely.

Oxides of nitrogen especially NO_2 can irritate the lungs and cause conditions like chronic bronchitis and emphysema. Carbon monoxide (CO) reaches lungs and combines with haemoglobin of blood to form carboxyhaemoglobin. CO has affinity for haemoglobin 210 times more than oxygen. Haemoglobin is, therefore, unable to transport oxygen to various parts of the body. This causes suffocation. Long exposure to CO may cause dizziness, unconsciousness and even death.

Many other air pollutants like benzene (from unleaded petrol), formaldehyde and particulates like polychlorinated biphenyls (PCBs), toxic metals and dioxins (from burning of polythene) can cause mutations, reproductive problems or even cancer.

Many other hazardous materials like asbestos, beryllium, mercury, arsenic and radioactive substances cause lung diseases and/or affect other vital organs like kidney, liver, spleen, brain and some may also cause cancer.

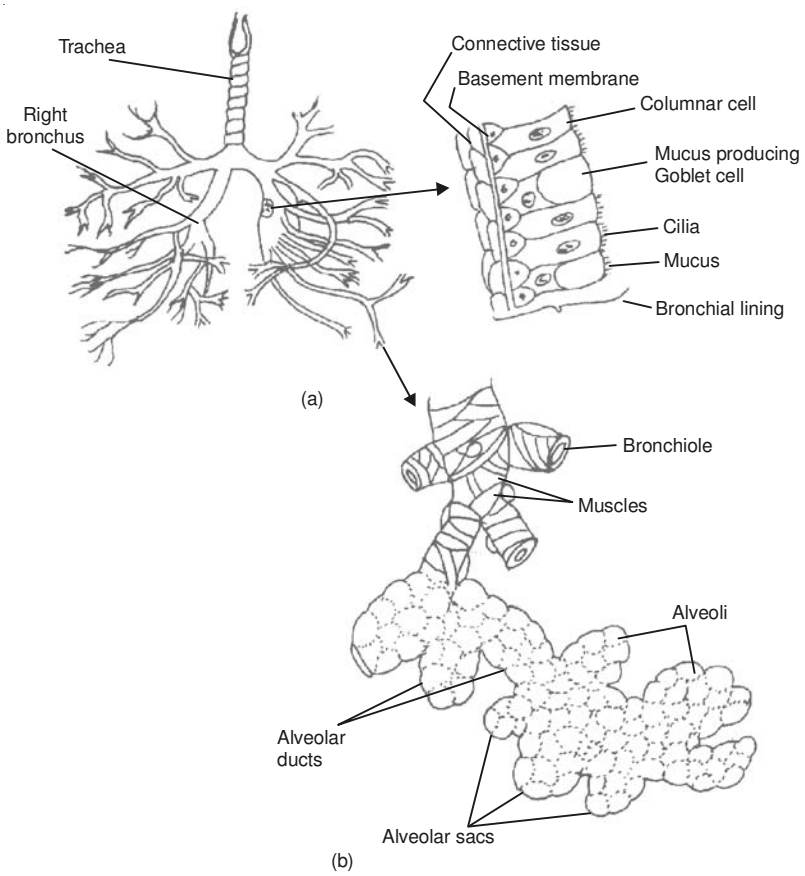

Fig. 12.22. *Lower respiratory system of human beings (a and b) and cross section of bronchial lining showing cilia and goblet cells*

Effects on plants: Air pollutants affect plants by entering through stomata (leaf pores through which gases diffuse), destroy chlorophyll and affect photosynthesis. During the day time the stomata are wide open to facilitate photosynthesis. Air pollutants during day time affect plants by entering the leaf through these stomata more than night. Pollutants also erode waxy coating of the leaves called cuticle. Cuticle prevents excessive water loss and damage from diseases, pests, drought and frost. Damage to leaf structure causes ***necrosis*** (dead areas of leaf), ***chlorosis*** (loss or reduction of chlorophyll causing yellowing of leaf) or ***epinasty*** (downward curling of leaf), and ***abscission*** (dropping do leaves). Particulates deposited on leaves can form encrustations and plug the stomata and also reduce the availability of sunlight. The damage can result in death of the plant.

SO_2 causes bleaching of leaves, chlorosis, injury and necrosis of leaves. NO_2 results in increased abscission and suppressed growth. O_3 causes fleacks on leaf surface, premature aging, necrosis and bleaching. Peroxyacetyl nitrate (PAN) causes silvering of lower surface of leaf, damage

to young and more sensitive leaves and suppressed growth. Fluorides cause necrosis of leaf-tip while ethylene results in epinasty, leaf abscission and dropping of flowers.

Effects on aquatic life: Air pollutants mixing up with rain can cause high acidity (lower pH) in fresh water lakes. This affects aquatic life especially fish. Some of the fresh water lakes have experienced total fish death.

Effects on materials: Because of their corrosiveness, particulates can cause damage to exposed surfaces. Presence of SO_2 and moisture can accelerate corrosion of metallic surfaces due to formation of sulfuric acid. Metal parts of buildings, vehicles, bridges, wires and metallic railway tracks are affected. Sulfuric acid also damages buildings and causes disfigurement of statues made up of marble and limestone. Sulfuric acid formed by the atmospheric SO_2 and water vapours damages the leather binding of books. The pages of the books also become brittle. SO_2 can affect fabric, leather, paint and paper. Ozone in the atmosphere can cause cracking of rubber. Nylon stockings are weakened and ultimately damaged. Tyres of various vehicles are also damaged. These days chemicals are added to prevent damage to tyre rubber by ozone. Oxides of nitrogen and ozone can also cause fading of cotton and rayon fibres.

Remedial Measures for Air Pollution (Control)

Air pollution can be minimised by the following methods:

- Siting of industries after proper environmental impact assessment studies.
- By dilution of emission. This can be done by increasing the stack height (though up to permissible height), beyond inversion layer. Wind currents will disperse the pollutants. But this results in interstate dispute and is not considered to be solution for air pollution problem.
- Minimise/modify activities which cause pollution like transportation and energy production.
- Modification of process and/or equipment.
- Use of appropriate material.
- Using low sulphur coal in industries.
- Removing sulphur from coal (by washing or with the help of bacteria).
- Removing NO_x during the combustion process and controlling the flow of air and fuel in industrial boilers.
- Vehicular pollution can be checked by regular tune-up of engines; replacement of more polluting old vehicles; installing catalytic converters; by engine modification to have fuel efficient (lean) mixtures to reduce CO and hydrocarbon emissions; and slow and cooler burning of fuels to reduce NO_x emission (Honda Technology).
- Using mass transport system, bicycles etc.
- Shifting to less polluting (clean) fuels (hydrogen gas).
- Using non-conventional sources of energy.
- Using biological filters and bio-scrubbers.
- Planting more trees.
- Reduction of pollution at source.

12.4.4 Reduction of Air Pollution at Source

Gaseous pollutants: Gaseous pollutants can be reduced by physical adsorption on porous solid materials like activated charcoal, silica gel, fuller's earth, etc. Effluent gases can be absorbed in

liquid absorbent, e.g., SO_2 absorbed in ammonia solution. They can be removed by condensation which is carried out by cooling medium in tubes where the gases in contact condense and can be collected thereafter. Combustion can be used to reduce pollution by burning the pollutants in combustion equipment at optimal conditions of oxygen and temperature.

Particulate matter: Many devices are available now-a-days, for control of particulate matter (Fig. 12.23), choice of which depends on characteristics of particulate, flow rate, collection efficiency, costs, etc.

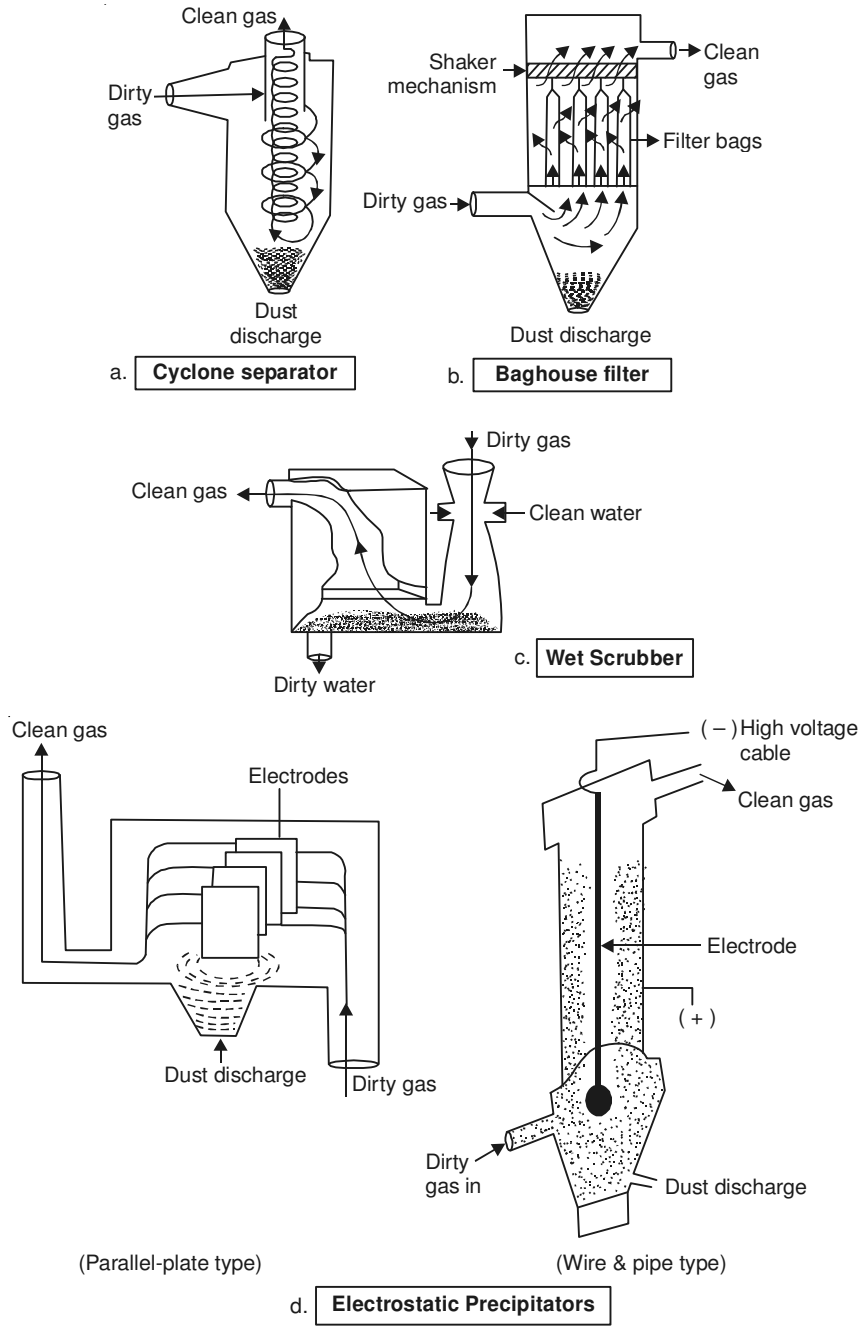

Fig. 12.23. *Control devices for control of particulate matter*

Cyclones: It consists of a cylinder with an inverted cone attached at the bottom. The gas with particles in it enters tangentially at the top of the cylinder and spins forming a vortex. Due to centrifugal force, the particles strike the wall of the cylinder. The particles then fall in the hopper due to gravity from where they are removed. The spinning gas forms an inner vortex and leaves from the top. The cyclone is very efficient for larger particles. However, smaller particles which pose human health problems are not removed efficiently. Therefore, cyclones are employed before the use of other costly devices.

Bag house filters: A bag house filter contains a large number of filter bags made of fabric. They are hung upside down in several compartments of bag house filter. Dirty gas is passed through the filter bags which leaves the bags through their pores. The dust particles get deposited on the inner surface of the bag filters and may form a cake which can be removed by shaking. The device is efficient for removal of very small particles and is preferred in various types of industries. The bag house filters are expensive and cannot be operated for moist gases. Corrosive gases may damage the material of the bags. Various types of materials, depending on the nature of the fuel gases to be cleaned, are used for making the filter bags.

Wet scrubbers: Dirty gases are passed through water in the chamber or water is sprayed on the gas. Particles are made wet and are removed from the gas stream which leaves from the top of the scrubber. Wet scrubbers are very efficient for removing the particulates. The scrubbers are very useful for removal of toxic and acidic gases also.

Electrostatic precipitators: The electrostatic precipitators may be plate type or cylinder type. Vertical wires are placed between the parallel plates or wire is hung along the axis of the cylinder. High negative voltage is applied to the wire. Dust particles while passing from the lower end get negatively charged (ionized) and are collected on the positively charged surface (plates/ cylindrical body) while the clean gas leaves from the top.

The deposited dust particles fall down in the dust collector or are removed by scrapping or by liquids. Electrostatic precipitators utilise electric energy and can efficiently remove even sub-microscopic particles.

12.5 NOISE POLLUTION

We hear various types of sounds everyday. Sound is mechanical energy from a vibrating source. A type of sound may be pleasant to someone and at the same time unpleasant to others. The unpleasant and unwanted sound is called noise.

Sound can propagate through a medium like air, liquid or solid. Sound wave is a pressure perturbation in the medium through which sound travels. Sound pressure alternately causes compression and rarefaction. The number of compressions and rarefaction of the molecules of the medium (for example, air) in a unit time is described as frequency. It is expressed in Hertz (Hz) and is equal to the number of cycles per second.

There is a wide range of sound pressures, which encounter human ear. Increase in sound pressure does not invoke linear response of human ear. A meaningful logarithmic scale has been devised. The noise measurements are expressed as Sound Pressure Level (SPL) which is logarithmic ratio of the sound pressure to a reference pressure. It is expressed as a dimensionless unit, decibel (dB). The international reference pressure of 2×10^{-5} Pa is the average threshold of hearing for

a healthy ear. Decibel scale is a measure of loudness. Noise can affect human ear because of its loudness and frequency (pitch).

The Central Pollution Control Board (CPCB) has recommended permissible noise levels for different location as given in Table 12.1.

TABLE 12.1. Noise Standards Recommended by CPCB Committee

Area Code	*Category of Area*	*Noise Level in dB(A) leq*	
		Day	*Night*
(A)	Industrial	75	70
(B)	Commercial	65	55
(C)	Residential	55	45
(D)	Silence zone	50	40

TABLE 12.2. Different Sounds and their Sound Levels on Decibel Scale

Sound Level (dB)		*Source of Sound*
180	—	Rocket engine
170		
160		
150	—	Jet plane take off
Threshold of pain — 140		
130	—	Maximum recorded rock music
120	—	Thunder cap
110	—	Autohorn 1m away
100	—	Jet fly over at 300 m, construction work, newspaper press
90	—	Motor cycle/8m away, food blender
80		
70	—	Vacuum cleaner, ordinary conversation
60	—	Air conditioning unit, 6 m away, light traffic noise, 30 m away
50	—	Average living room
40		
30	—	Library, soft whisper
20	—	Broadcasting studio
10	—	Rustling leaf
Threshold of hearing — 0		

Sources of Noise Pollution: The sources of noise can be classified as (*i*) Mobile sources and (*ii*) Stationary sources. (*i*) Mobile sources are various modes of transportation (like air, road, rail-transportation) and (*ii*) Stationary sources include industrial operations, construction activities and celebrations (social/religious functions, elections etc.), electric home appliances etc. Noise levels associated with various activities have been given in Table 12.2.

High levels of noise have been recorded in some of the cities of the world. In Nanjing (China) noise level of 105 dB has been recorded, while in some other cities of the world these levels are: Rome 90 dB, New York 88 dB, Kolkata 85 dB, Mumbai 82 dB, Delhi 80 dB, Kathmandu 75 dB.

Effects of Noise Pollution: Noise pollution causes the following effects.

***(i)* Interferes with man's communication:** In a noisy area communication is severely affected.

***(ii)* Hearing damage:** Noise can cause temporary or permanent hearing loss. It depends on intensity and duration of sound level. Auditory sensitivity is reduced with noise level for over 90 dB in the mid-high frequency for more than a few minutes.

***(iii)* Physiological and psychological changes:** Continuous exposure to noise affects the functioning of various systems of the body. It may result in hypertension, insomnia (sleeplessness), gastro-intestinal and digestive disorders, peptic ulcers, blood pressure changes, behavioural changes, emotional changes etc.

NOISE POLLUTION DURING DIWALI

Diwali is a festival of lights. Traditionally people of all ages enjoy firecrackers. Some accidents do occur every year claiming a few lives. Besides, noise generated by various firecrackers is beyond the permissible noise levels of 125 decibels as per the Environmental (Protection) (Second Amendment) Rules, 1999.

There has been a great concern over the noise levels generated during Diwali. Some measurements by certain group of researchers have also been made at various places during Diwali. It is recommended that the manufacturers of fireworks should mention the noise levels in decibels generated by individual items. The department of explosives of the Union Ministry of Commerce and Industry is entrusted with the task to ensure that the industry produces firecrackers conforming to permissible noise standards.

According to a test report on firecrackers produced by the National Physical Laboratory, New Delhi most of the firecrackers available in the market produce noise beyond the permissible levels of 125 decibels as per the Environment (Protection) (Second amendment) Rules, 1999. Some of them have been observed to produce noise near the threshold of pain. The details are given in Table 12.3.

TABLE 12.3. Noise Levels Generated by Firecrackers

Types of firecracker	*Manufacturer*	*Generated noise level in decibels*
Atom bomb (timing bomb)	Coronation Fireworks, Sivakasi	135 $\pm$ 2
Chinese crackers (a string of 1,000 in one piece)	Sri Kaliswari Fireworks, Sivakasi	128
Chinese crackers (a string of 600 in one piece)	Sri Kaliswari Fireworks, Sivakasi	132
Nazi (atom bomb)	Coronation Fireworks, Sivakasi	135 $\pm$ 0
Magic formula (flower bomb)	Rajan Fireworks, Sivakasi	136 $\pm$ 1

(Contd.)

Atom bomb (foiled)	Sri Kaliswari Fireworks, Sivakasi	131 ± 2
Hydrogen bomb	Sri Patrakali Fireworks, Sivakasi	134 ± 2
Rajan classic dhamaka (foiled bomb)	Rajan Fireworks, Sivakasi	136 ± 0
Samrat classic bomb (deluxe)	Venkateswara Fireworks, Sivakasi	136 ± 0
Hydro foiled (bomb)	Sri Kaliswari Fireworks, Sivakasi	132 ± 2
*Three sound (bomb)	Coronation Fireworks, Sivakasi	119 ± 7
Atom bomb	Local	136 ± 0

*Cracker meeting the noise pollution standards.

Source: Test report on firecrackers, National Physical Laboratory, New Delhi, April 21, 2003.

The noise levels were measured under standard conditions *i.e.,* in areas not having noise-reflecting surfaces within a 15 metre radius. Two gadgets, for measuring sound levels were installed at a height of 1.3 metres and at a distance of 4 metres from the source of sound.

Besides mentioning the sound levels on each of the types of firecrackers or banning the production of such firecrackers which produce noise above permissible levels, it is important to educate people about the harmful effects of noise during such festivals like Diwali. It can be done by giving public notices in the leading newspapers and messages through other mass media like radio and television.

Honourable Supreme Court in a Writ Petition (civil) of 1998 concerning noise pollution had passed the following directions as an interim measure.

The Union Government, The Union Territories as well as all the State Governments shall in particular comply with amended Rule 89 of the Environmental (Protection) Rules, 1986 framed under the Environmental (Protection) Act, 1986 which essentially reads as follows:

1. (*i*) The manufacture, sale or use of fire-crackers generating noise level exceeding 125 dB (AI) or 145 dB (C) pk at 4 meters distance from the point of bursting shall be prohibited.

   (*ii*) For individual fire-cracker constituting the series (joined fire-crackers), the above mentioned limit be reduced by 5 log 10 (N) dB, where N = Number of crackers joined together.

2. The use of fireworks or fire-crackers shall not be permitted except between 6.00 p.m. and 10.00 p.m. No fireworks or fire-crackers shall be used between 10.00 p.m. and 6.00 a.m.

3. Fire-crackers shall not be used at any time in silence zones, as defined by the Ministry of Environment and Forests. Silence Zone has been defined as:

"Silence Zone in an area comprising not less that 100 meters around hospitals, educational institutions, courts, religious places or any other area which is declared as such by the competent authority."

4. The State Education Resource Centres in all the States and Union Territories as well as the management/principals of schools in all the States and Union Territories shall take appropriate steps to educate students about the ill effects of air and noise pollution and apprise them of directions (1) to (3) above.

Remedial Measures for Noise Pollution (Control)

1. *Reduction in sources of noise*: Sources of noise pollution like heavy vehicles and old vehicles may not be allowed to ply in the populated areas.
2. Noise making machines should be kept in containers with sound absorbing media. The noise path will be in interrupted and will not reach the workers.
3. Proper oiling will reduce the noise from the machinery.
4. *Use of sound absorbing silencers*: Silencers can reduce noise by absorbing sound. For this purpose various types of fibrous material could be used.
5. Planting more trees having broad leaves.
6. *Through law*: Legislation can ensure that sound production is minimised at various social functions. Unnecessary horn blowing should be restricted especially in vehicle-congested areas.

12.6 WATER TREATMENT

More than 90% of the population in the United States as also many European countries don't even bother whether the drinking water is safe or not. However, in the developing countries the first question a visitor asks is whether the drinking water is safe to drink. We quite often see most of such people carrying their own mineral water bottles. It is estimated that 80 per cent of sickness in the world is due to improper quantity or quality of drinking water. The most affected areas in the world are in Asia, Africa, and Latin America. About 60% of babies born in the developing nations die of gastic disturbances. Millions of people are affected by schistosomiasis and filariasis. It is imperative to provide drinking water which is free from pathogens and other noxious substances which can cause sickness or disease.

Objective: The objective of water treatment is, therefore, is remove dissolved and undissolved substances and disease causing pathogens by standard water treatment methods. The treated water should meet the drinking water standards. Such standards are given by various international agencies like the World Health Organisation (WHO), US Public Health Standards (USPHS) as well as national agencies of various nations. In India agencies like Indian Council of Medical Research (ICMR), Bureau of Indian Standards (BIS) have also established such drinking water standards.

Water Treatment: The treatment of raw water is done by various unit operations (based on physical principles) and unit processes (based on chemical and biological principles) in order to produce water which is safe to drink and meets the safe drinking water standards.

Surface water generally needs to be filtered and disinfected while ground water needs removal of hardness (caused by calcium and magnesium) before disinfection. The following flowsheet will explain the water treatment methods.

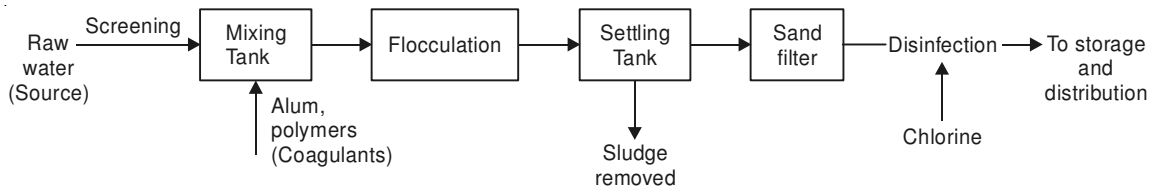

Fig. 12.24. *Flowsheet of a typical water treatment plant. For ground water, in addition softening by addition of lime/soda ash is required*

The raw water is screened by passing it through bar racks and screens to retain debris consisting of plant materials, plastics, rags and other floating materials. The raw water is then mixed with chemicals which help the suspended solids to coagulate into larger particles. Gentle mixing the coagulant with water encourages formation of floc, the process is called flocculation.

Water is moved slowly in a larger flow area to facilitate the floc to settle. This process is called sedimentation. The settled material called sludge is removed and disposed off. The water is passed through sand filter. After the whole process almost all the suspended solids are removed. Most of the colour is also removed. However, some pathogenic organisms like bacteria remain in water, which are killed by disinfection.

Disinfection is generally done by chlorination, by using chlorine gas, sodium hypochlorite or calcium hypochlorite. Chlorination although kills most of the bacteria is, however, less effective against *Giardia lamblia* (a pathogen). Another disadvantage of chlorination is that it forms cancer causing products when chlorine combines with organic matter in water.

Better methods of disinfection include use of UV-light or ozonation (use of ozone as a strong oxidizing agent).

12.6.1 Drinking Water Standards

Drinking Water – Specification (BIS 10500: 1991)

Sl. No.	***Substance or Characteristic***	***Requirement (Desirable limit)***	***Permissible limit in the absence of alternate source***
Essential Characteristics			
1.	Colour (Hazen units, Max)	5	25
2.	Odour	Unobjectonable	Unobjectionable
3.	Taste	Agreeable	Agreeable
4.	Turbidity (NTU. Max)	5	10
5.	pH Value	6.5 to 8.5	No Relaxation
6.	Total Hardness (as $CaCO_3$) mg/lit, Max	300	600
7.	lron (as Fe) mg/lit, Max	0.3	1.0
8.	Chlorides (as Cl) mg/lit, Max.	250	1000
9.	Residual free chlorine, mg/lit, Min.	0.2	--
10.	Fluoride (as F) mg/lit, Max	1.0	1.5
Desirable Characteristics			
11.	Dissolved solids mg/lit, Max	500	2000
12.	Calcium (as Ca) mg/lit, Max	75	200
13.	Magnesium (as Mg) mg/lit, Max	30	100
14.	Copper (as Cu) mg/lit, Max	0.05	1.5

15.	Manganese (as Mn) mg/lit, Max	0.10	0.3
16.	Sulfate (as SO_4) mg/lit, Max	200	400
17.	Nitrate (as NO_3) mg/lit, Max	45	No relaxation
18.	Phenolic Compounds (as C_6 H_5OH) mg/lit, Max	0.001	0.002
19.	Mercury (as Hg) mg/lit, Max	0.001	No relaxation
20.	Cadmium (as Cd) mg/lit, Max	0.01	No relaxation
21.	Selenium (as Se) mg/lit, Max	0.01	No relaxation
22.	Arsenic (as As) mg/lit, Max	0.01	No relaxation
23.	Cyanide (as CN) mg/lit, Max	0.05	No relaxation
24.	Lead (as Pb) mg/lit, Max	0.05	No relaxation
25.	Zinc (as Zn) mg/lit, Max	5	15
26.	Anionic detergents (as MBAS) mg/lit, Max	0.2	1.0
27.	Chromium (as Cr^{6+}) mg/lit, Max	0.05	No relaxation
28.	Polynuclear aromatic hydrocarbons (as PAH) g/lit, Max	--	--
29.	Mineral Oil mg/lit, Max	0.01	0.03
30.	Pesticides mg/lit. Max	Absent	0.001
31.	Radioactive Materials		
	(*i*) Alpha emitters Bq/lit. Max	--	0.1
	(*ii*) Beta emitters pci/lit. Max	--	1.0
32.	Alkalinity mg/lit, Max	200	600
33.	Aluminium (as Al) mg/lit, Max	0.03	0.2
34.	Boron mg/lit, Max	1	5

Bacteriological Examination

Water in Distribution System

Water in the distribution system, piped water, upto the consumer's level should have no coliform organisms. Since it is not ideally possible, therefore, the following standard in the water sample collected from distribution system is recommended (tested in accordance with IS 1622:1981)

(*a*) Throughout any year, 95 percent of samples should not contain any coliform organisms in 100 mL;

(*b*) No sample should contain *E. Coli* in 100 mL;

(*c*) No sample should contain more than 10 coliform organisms per 100 mL; and

(*d*) Coliform organisms should not be detectable in 100 mL of any two consecutive samples.

12.7 WATER POLLUTION

Water pollution can be defined as alteration in physical, chemical or biological characteristics of water making it unsuitable for designated use in its natural state.

Sources of water pollution: Water is an essential commodity for survival. We need water for drinking, cooking, bathing, washing, irrigation, and for industrial operations. Most of water for such uses comes from rivers, lakes or groundwater sources. Water has the property to dissolve many substances in it, therefore, it can easily get polluted. Pollution of water can be caused by point sources or non-point sources. Point sources are specific sites near water which directly discharge effluents into them. Major point sources of water pollution are industries, power plants, underground coal mines, offshore oil wells etc. The discharge from non-point sources is not at any particular site, rather, these sources are scattered, which individually or collectively pollute water. Surface run-off from agricultural fields, overflowing small drains, rain water sweeping roads and fields, atmospheric deposition etc., are the non-point sources of water pollution.

Ground water pollution: Ground water forms about 0.59% of the total water available on planet earth and is about 30 times more than surface water (streams, lakes and estuaries). Ground water seems to be less prone to pollution as the soil mantle through which water passes helps to retain various contaminants due to its cation exchange capacity. However, there are a number of potential sources of ground water pollution. Septic tanks, industry (textile, chemical, tanneries), deep well injection, mining etc., are mainly responsible for ground water pollution, which is irreversible. Ground water pollution with arsenic, fluoride and nitrate are posing serious health hazards.

Surface water pollution: The major sources of surface water pollution are:

1. **Sewage.** Emptying the drains and sewers in fresh water bodies causes water pollution. The problem is severe in cities.
2. **Industrial effluents.** Industrial wastes containing toxic chemicals, acids, alkalis, metallic salts, phenols, cyanides, ammonia, radioactive substances, etc., are sources of water pollution. They also cause thermal (heat) pollution of water.
3. **Synthetic detergents.** Synthetic detergents used in washing and cleaning produce foam and pollute water.
4. **Agrochemicals.** Agrochemicals like fertilizers (containing nitrates and phosphates) and pesticides (insecticides, fungicides, herbicides etc.) washed by rain-water and surface run-off pollute water.
5. **Oil.** Oil spillage into sea-water during drilling and shipment pollute it.
6. **Waste heat.** Waste heat from industrial discharges increases the temperature of water bodies and affects distribution and survival of sensitive species.

12.7.1 Effects of Water Pollution

Following are some important effects of various types of water pollutants:

Oxygen demanding wastes: Organic matter which reaches water bodies is decomposed by micro-organisms present in water. For this degradation, oxygen dissolved in water is consumed. Dissolved oxygen (DO) is the amount of oxygen dissolved in a given quantity of water at a

particular temperature and atmospheric pressure. Amount of dissolved oxygen depends on aeration, photosynthetic activity in water, respiration of animals and plants and ambient temperature.

The saturation value of DO varies from 8–15 mg/L. For active fish species (trout and Salmon) 5–8 mg/L of DO is required whereas less desirable species like carp can survive at 3.0 mg/L of DO.

Lower DO may be harmful to animals especially fish population. Oxygen depletion (deoxygenation) helps in release of phosphates from bottom sediments and causes eutrophication.

Nitrogen and Phosphorus compounds (nutrients): Addition of compounds containing nitrogen and phosphorus helps in the growth of algae and other plants which when die and decay consume oxygen of water. Under anaerobic conditions foul smelling gases are produced. Excess growth or decomposition of plant material will change the concentration of CO_2 which will further change pH of water. Changes in pH, oxygen and temperature will change many physico-chemical characteristics of water.

Pathogens: Many waste waters especially sewage contain many pathogenic (disease causing) and non-pathogenic micro-organisms and many viruses. Water borne diseases like cholera, dysentery, typhoid, jaundice etc. are spread by water contaminated with sewage.

Toxic compounds: Pollutants such as heavy metals, pesticides, cyanides and many other organic and inorganic compounds are harmful to aquatic organisms.

The demand of DO increases with addition of biodegradable organic matter which is expressed as biological oxygen demand (BOD). BOD is defined as the amount of DO required to aerobically decompose biodegradable organic matter of a given volume of water over a period of 5 days at 20°C. Higher BOD values of any water sample are associated with poor water quality. The non-biodegradable toxic compounds biomagnify in the food chain and cause toxic effects at various levels of food chain.

Some of these substances like pesticides, methyl mercury etc., move into the bodies of organisms from the medium in which these organisms live. Substances like DDT are not water soluble and have affinity for body lipids. These substances tend to accumulate in the organism's body. This process is called **bioaccumulation.** The concentration of these toxic substances builds up at successive levels of food chain. This process is called **biomagnification.** Following is the example of biomagnification of DDT in aquatic food chain:

Component	DDT concentration (ppm)
Birds	10.00
↑	↑
Needle fish	1.0
↑	↑
Minnows	0.1
↑	↑
Zooplankton	0.01
↑	↑
Water	0.000001

Toxic substances polluting the water ultimately affect human health. Some heavy metals like lead, mercury and cadmium cause various types of diseases. Mercury dumped into water is

transformed into water soluble methyl mercury by bacterial action. Methyl mercury accumulates in fish. In 1953, people in Japan suffered from numbness of body parts, vision and hearing problems and abnormal mental behaviour. This disease called **Minamata disease** occurred due to consumption of methyl mercury contaminated fish caught from Minamata Bay in Japan. The disease claimed 50 lives and permanently paralysed over 700 persons. Pollution by another heavy metal cadmium had caused the disease called **Itai-itai** in the people of Japan. The disease was caused by cadmium contaminated rice. The rice fields were irrigated with effluents of zinc smelters and drainage water from mines. In this disease bones, liver, kidney, lungs, pancreas and thyroid are affected.

Arsenic pollution of ground water in Bangladesh and West Bengal is causing various types of abnormalities.

Nitrate when present in excess in drinking water causes **blue baby syndrome** or **methaemoglobinemia.** The disease develops when a part of haemoglobin is converted into non-functional oxidized form.

Nitrate in stomach partly gets changed into nitrites which can produce cancer-causing products in the stomach.

Excess of fluoride in drinking water causes defects in teeth and bones called **fluorosis.**

Pesticides in drinking water ultimately reach humans and are known to cause various health problems. DDT, aldrin, dieldrin etc., have therefore, been banned. Recently, in Andhra Pradesh, people suffered from various abnormalities due to consumption of endosulphan contaminated cashew nuts.

Remedial Measures for Water Pollution (Control)

It is easy to reduce water pollution from point sources by legislation. However, due to absence of defined strategies it becomes difficult to prevent water pollution from non-point sources. The following points may help in reducing water pollution from non-point sources.

(*i*) Judicious use of agrochemicals like pesticides and fertilizers which will reduce their surface run-off and leaching. Use of these on sloped lands should be avoided.

(*ii*) Use of nitrogen fixing plants to supplement the use of fertilizers.

(*iii*) Adopting integrated pest management to reduce reliance on pesticides.

(*iv*) Prevent run-off of manure. Divert such run-off to basin for settlement. The nutrient rich water can be used as fertilizer in the fields.

(*v*) Separate drainage of sewage and rain water should be provided to prevent overflow of sewage with rain water.

(*vi*) Planting trees would reduce pollution by sediments and will also prevent soil erosion.

For controlling water pollution from point sources, treatment of waste waters is essential before being discharged. Parametres which are considered for reduction in such water are:

Total solids, biological oxygen demand (BOD), chemical oxygen demand (COD), nitrates and phosphates, oil and grease, toxic metals etc.

Waste waters should be properly treated by primary and secondary treatments to reduce the BOD, COD levels upto the permissible levels for discharge.

12.7.2 Waste Water Treatment

The composition of municipal waste water varies from place to place. Sometimes industrial wastes also mix with sewage. The type of treatment of waste water thus depends upon its characteristics

and the desired quality of water after treatment. The waste water treatment plants are generally primary, secondary or for advanced treatment.

The purpose of waste water treatments is to remove/reduce organic and inorganic substances, nutrients, toxic substances, kill pathogenic organisms, etc., so that the quality of discharged water is improved to meet the permissible level of water to be discharged in some water body, on land or agricultural field. Treatment of water thus aims at reduction of BOD, COD, eutrophication, etc. of receiving water bodies and prevention of bio-magnification of toxic substances in food chain and prevention of disease due to pathogenic organisms present in the waste water.

Various steps involved in treatment of waste water are shown in Fig. 12.25.

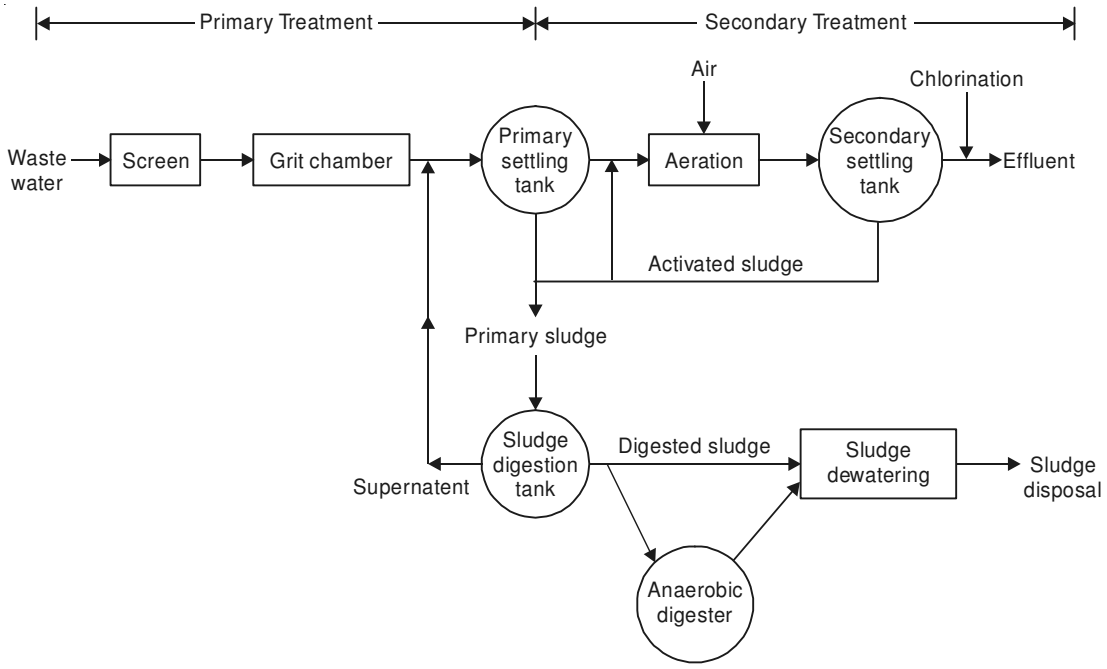

Fig. 12.25. *Flow diagram of sewage (waste water) treatment plant*

Primary treatment: It is a physical process for removal of debris, large particles with the help of screen. The waste water after screening is passed through grit chamber where sand, grit and other solids settle down. The water is then passed through the sedimentation tank or clarifier where most of the suspended solids settle down due to gravity. For better removal of suspended solids, sometimes chemically treated polymers are used. About 35% BOD and 60% of suspended solids are removed during primary treatment.

Secondary treatment: It is biological process which involves micro-organisms. It removes up to 90% of the BOD and 90% of suspended solids. Biodegradable oxygen demanding wastes are stabilised. Following are the various approaches adopted in secondary treatment.

Trickling filters: These consist of a bed of crushed stones/pebbles covered with slime which consists mainly of aerobic bacteria, algae, fungi, protozoa, worms and insect larvae. Sewage is degraded by the aerobic bacteria when it passes through the bed and is collected at the bottom of the filter. Some of the treated sewage may be recirculated along the influent. It helps in better removal of organic matter and also keeps the filter moist when the flow rate over the filter is slow.

Activated Sludge Process: The effluent from the primary clarifier goes to aeration tank. Aeration tank also receives micro-organisms from the secondary settling tank known as activated sludge. Oxygen is pumped into aeration tank for maintaining aerobic conditions. After few hours of agitation, the waste water goes to secondary settling tank where solids settle at the bottom. The sludge is produced, dewatered and disposed off. This can be used for landfills or disposed off in ocean or used in croplands, pastures, etc.

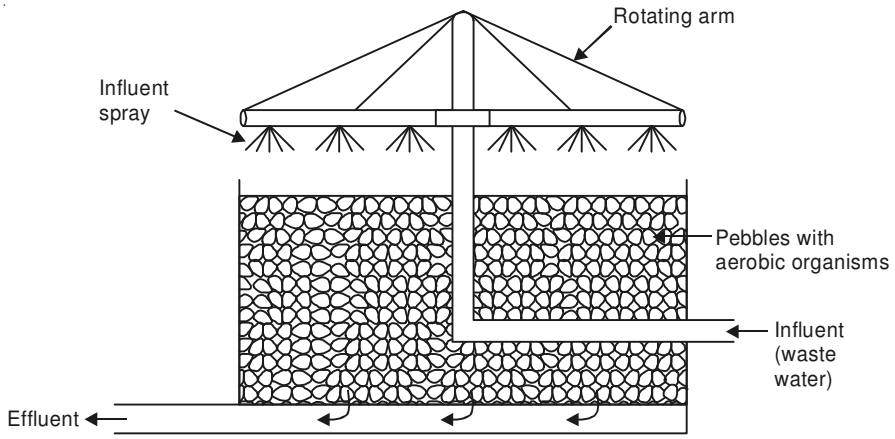

Fig. 12.26. *Cross section of a trickling filter*

Rotating Biological Contactor (RBC): It consists of circular plastic discs which are arranged on a rotating shaft. Circular discs have micro-organisms grown on them. The discs are contained in a waste water holding tank. About 40% area of the discs is submerged in the tank. The discs rotate in and out of water as the RBC rotates. The micro-organisms present on the discs absorb organic matter when they are in water and obtain the required oxygen when the discs are out of water. Thus a high degree of organic matter removal is achieved.

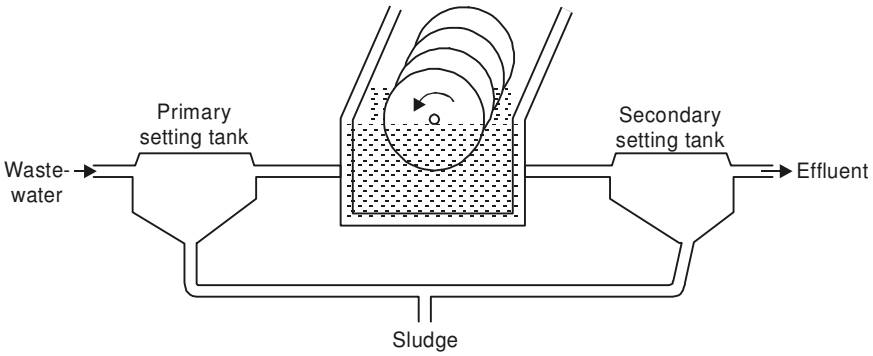

Fig. 12.27. *Rotating biological contactor*

Advanced Sewage Treatment: After the primary and secondary treatments many undesirable substances still remain in the effluent. Advanced water treatment involves the removal of such substances. The treatment, therefore, involves specific steps depending upon the type of substances to be removed. The materials to be removed in such treatments may include nitrates and phosphates (which cause eutrophication of receiving waters), colour, bacteria, viruses, pesticides, toxic metals, etc. Chlorination of water is generally done to kill harmful bacteria and some viruses. However,

chlorine can produce cancer-causing chlorinated hydrocarbons by reacting with organic matter. Other, but costly methods of disinfection are the use of ultraviolet light and ozone treatment. The sludge produced after such treatment is used as a fertilizer in the fields. However, there are chances of toxic metals and other untreated substances to build up in the food chain or leach to the ground water.

Upflow Anaerobic Sludge Blanket (UASB) Reactor: Anaerobic treatment is gaining importance as a method of waste water treatment due to its effectiveness in treating waste water and economic advantages. The UASB process consists of four stages of anaerobic digestion: hydrolysis, acidogenesis, acetogenesis and methanogenesis. A dense blanket of granular anaerobic biomass is used to convert organic compounds that are passed through the sludge blanket continuously. Biogas produced is collected at the top of the reactor. The waste water to be treated is fed into the reactor at the bottom. As the influent flows through the loops and enters the reactor chamber, hydrolysis occurs. The above mentioned four anaerobic processes convert the influent into H_2, CO_2, CH_4, acetate, new cell-matter etc. COD removal of up to 80% is achieved. Methane and CO_2 produced are separated from the reactor.

12.8 LAND POLLUTION

12.8.1 Sources of Land Pollution

Soil is the upper layer of the earth crust which is formed by weathering of rocks. Organic matter in the soil makes it suitable for living organisms. Dumping of various types of materials especially domestic and industrial wastes causes land pollution. Domestic wastes include garbages, rubbish material like glass, plastics, metallic cans, paper, fibres, cloth rags, containers, paints, varnishes etc. Leachates from dumping sites and sewage tanks are harmful and toxic, which pollute the soil.

Industrial wastes are the effluents discharged from chemical industries, paper and pulp mills, tanneries, textile mills, steel industries, distilleries, refineries, pesticides and fertilizer industries, pharmaceutical industries, food processing industries, cement industries, thermal and nuclear power plants, mining industries etc. Thermal power plants generate a large quantity of 'Fly ash'. Huge quantities of these wastes are dumped on land which cause land pollution.

Pesticides are used to kill pests that damage crops. These pesticides ultimately reach the soil and persist there for a long time. Pesticides which are persistent in nature are chlorinated hydrocarbon insecticides e.g., DDT, HCH, endrin, lindane, heptachlor, endosulfan etc. Residues of these pesticides in the soils have long term effects especially under the temperate conditions.

Industrial wastes also contain some organic and inorganic compounds that are refractory and non-biodegradable. Industrial sludge may contain various salts, toxic substances, metals like mercury, lead, cadmium, arsenic etc. Agrochemicals released with the wastes of pesticide and fertilizer factories or during agricultural practices also reach land and pollute it.

Land also receives excreta from animals and humans. The sewage sludge contains many pathogenic organisms, bacteria, viruses and intestinal worms which cause pollution in the land.

The sources of radioactive substances in soil are explosion of radioactive devices, radioactive wastes discharged from industries and laboratories, aerial fall out etc. Isotopes of radium, uranium, thorium, strontium, iodine, caesium and of many other elements reach land and persist there for a long time land keep on emitting radiations.

12.8.2 Effects of Land Pollution

Sewage and industrial effluents which pollute land ultimately affect human health. Various types of chemicals like acids, alkalis, pesticides, insecticides, weedicides, fungicides, heavy metals etc., in the industrial discharges affect soil fertility by causing changes in physical, chemical and biological properties.

Some of the persistent toxic chemicals inhibit the non-target organisms, soil flora and fauna and reduce soil productivity. These chemicals accumulate in food chain and ultimately affect human health. Indiscriminate use of pesticides specially is a matter of concern.

Sewage sludge has many types of pathogenic bacteria, viruses and intestinal worms which may cause various types of diseases. Decomposing organic matter in soil also produces toxic vapours.

Radioactive fallout on vegetation is the source of radio-isotopes which enter the food chain in the grazing animals. Some of these radio-isotopes replace essential elements in the body and cause abnormalities e.g., strontium-90 instead of calcium gets deposited in the bones and tissues. The bones become brittle and prone to fracture.

Radioisotopes which attach with the clay become a source of radiations in the environment.

Nitrogen and phosphorus from the fertilizers in land reach nearby water bodies with agricultural run-off and cause eutrophication. Chemicals or their degradations products from land may percolate and contaminate ground-water resources.

12.8.3 Control of Land Pollution

(*i*) Effluents should be properly treated before discharging them on land.

(*ii*) Solid wastes should be properly collected and disposed off by appropriate method.

(*iii*) From the wastes, recovery of useful products should be done.

(*iv*) Biodegradable organic waste should be used for generation of biogas.

(*v*) Cattle dung should be used for methane generation. Night-soil (human faeces) can also be used in the biogas plant to produce inflammable methane gas.

(*vi*) Microbial degradation of biodegradable substances is also one of the scientific approaches for reducing land pollution.

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