UNIT 4 WATER RESOURCES

Structure

4.1 INTRODUCTION

Availability of water and, to a great extent, its proper usage contributes significantly to national economy. It is for this reason that substantial financial allocation is made for water resources sector while deciding the details of five year plans. In fact, during the First Five Year Plan (1951-56), agriculture, irrigation and power projects were accorded the highest priority with 44.6% fund allotment. In our country, agriculture generates 26% of national income and about 64% of the employment. At present, India has the largest irrigated area among all the countries of the world. This has greatly contributed to the increase in food grains production by four times between the period, 1950 and 1997. It is worth comparing the quantitative requirement of water across different production activities. The studies indicate that one acre of paddy crop requires 47.5 lakh litres of water. A steel plant requires 83600 litres of water for every ton of steel produced. A car coming out of the factory consumes 1.14 lakh litres of water in its manufacture. For refining a 200 litres barrel of petrol, 3000 litres of water are required. For producing one ton of synthetic rubber, 22.8 lakh litres of water are required. In short, location of an industry depends on the availability of water as a raw material. All these are mentioned to illustrate the fact that water is an important resource for national development.

In this unit, we shall make a brief reference to the global distribution of water and the water resources of our country. We shall indicate how there is regional imbalance in water availability. The hydrological cycle and hydrodynamics of fresh water ecosystems will be explained. Knowledge of these features could help us in optimising the available water resources for the best possible use. We shall have a detailed discussion on the need and methods for conservation and management of water resources. The aim is to focus on the remedial measures to be undertaken to overcome the problems that arise due to scarcity of water.

Objectives

After studying this unit, you should be able to:

- list the reasons for considering water as a resource,
- state the quantitative aspects of water availability at the global and national levels,
- discuss the various stages and importance of the hydrological cycle,
- indicate the basic features of the hydrodynamics of fresh water ecosystems,
- justify the need for conservation and management of water resources, and
- explain the methods that could be employed for water conservation and management.

4.2 UNITS FOR LAND AREA AND RAINFALL

Before we proceed to next section, we must be aware of some units used in describing land area (irrigated) and volume of water obtained through rainfall, snowfall or from ground sources.

Units for land area

1 Hectare = 2.47 acres = 10^4 metre^2
(*i.e.*, 1 ha = 10^4 m^2)
100 hectares = 10^6 metre^2 = 1 kilometre^2
(*i.e.*, 100 ha = 10^6 m^2 = 1 km^2)
Also, 1 million hectare (1 mha) = 10^{10} m^2 ….. (4.1)

Units for volume of water arising due to rainfall, snowfall or groundwater facility

1000 litres = 1m^3
1 hectare metre = 10^4m^3
(1 ha m)
1 million hectare metre = 10^{10} m^3 = 10 km^3 = 10^{13} litres ….. (4.2)
(*i.e.*, 1 mha m)

Calculation of volume of water arising due to rainfall

Keeping the area in m^2 unit and the rainfall in m unit, the volume of water arising due to rainfall is obtained in m^3 unit using Eq. 4.3.

$$\left.\begin{array}{l}\text{Volume of water arising}\\ \text{annually due to rainfall}\\ \text{in m}^3\text{ unit}\end{array}\right\} = \begin{pmatrix}\text{Surface area}\\ \text{in m}^2\text{ unit}\end{pmatrix} \times \begin{pmatrix}\text{average annual}\\ \text{rainfall in m unit}\end{pmatrix} \qquad \text{….. (4.3)}$$

The volume of water due to rainfall can also be calculated in mha m units as per Eq. 4.4.

$$\left.\begin{array}{l}\text{Volume of water arising}\\ \text{annually due to rainfall}\\ \text{in mha m units}\end{array}\right\} = \begin{pmatrix}\text{Land area in}\\ \text{mha unit}\end{pmatrix} \times \begin{pmatrix}\text{average annual}\\ \text{rainfall in m unit}\end{pmatrix} \qquad \text{..… (4.4)}$$

Example 1

Let us calculate the volume of water arising annually due to rainfall over only the land area of our country that is equal to 304 mha. The average rainfall is 110 cm (*i.e.* 1.10 m). Let us express the answer in mha m, m^3 and litre units.

Using Eq. 4.4,

$$\left.\begin{array}{l}\text{volume of water arising}\\ \text{annually due to rainfall}\\ \text{over the land area of our}\\ \text{country}\end{array}\right\} \begin{array}{l} = 304 \times 1.10 \text{ mha m}\\ = 334.4 \text{ mha m}\\ = 3.344 \times 10^{12} \text{ m}^3 \qquad \text{(Using Eq. 4.2)}\\ = 3.344 \times 10^{15} \text{ litres}\end{array}$$

SAQ 1

The area of a location is 1483 km^2. The average annual rainfall is 60 cm. Calculate the volume of rainwater that falls over the location annually in m^3, mha m and litre units.

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4.3 GLOBAL DISTRIBUTION OF WATER

Water covers about three quarters of the earth's surface. The total amount of water has been estimated to be more than 1.400×10^9 km^3, which is enough to cover the earth with a layer of water of 300 m depth. About 97.2% of this water is in the oceans. Of the 2.8% that is fresh, 2.15% is frozen as glaciers and in ice caps. Thus, all the water in the lakes and rivers, all the moisture in the atmosphere, soil and vegetation and all the water underground amounts to about 0.65% of the total; again out of this, major portion is in the form of groundwater half of which may lie more than 1000 m below the surface. Around 0.017% is in rivers, fresh water lakes *etc.*

If earth's total water content is 100 litres, only 17 cc is present as fresh water in rivers, lakes *etc*.

4.4 WATER RESOURCES OF INDIA

In this section, we shall discuss the availability of water in India from all sources.

4.4.1 Annual Rainfall

The Indian economy depends to a great extent on the rainfall that occurs through two monsoons, the southwest and the northeast. The average annual rainfall in India is 110 cm whereas the global mean is 99.1 cm. India has the highest rainfall when comparison is made among countries of similar size. But it is variable in space and time. The heaviest rains occur along the north-eastern states and along the west coast (from Trivandrum to Bombay). Mawsynram, near Cherrapunji, has the highest annual rainfall of 900 cm – sometimes even 1140 cm in a year with as much as 104 cm in a day. In contrast, the areas receiving less than 40 cm rainfall in a year include (i) the Thar Desert areas of Western Rajasthan that extend up to Kachchh in Gujarat and (ii) most of Jammu and Kashmir. Rajasthan has the least rainfall among the major states. Most of the rainfall occurs in our country in about three months period, especially over 200 hours and, half of it in 30 hours. Consequently, the run off is high. Rainfall during monsoon is also not certain. In Sec 4.2, we calculated rainfall over only the land area of our country as 334.4 mha m. Over the entire country, there is 395 mha m from rainfall and 5 mha m from snowfall making a total of 400 mha m of fresh water. The whole of it cannot be put to use due to reasons given under Subsec. 4.7.1.

The flow of rainwater over the land surface along the natural slope is called run off.

4.4.2 River Systems in Our Country

The rivers in India may be classified into four types as follows:

i) The Himalayan rivers
ii) The Deccan rivers
iii) The Coastal rivers
iv) Rivers of the inland drainage basin

The Himalayan rivers are fed both by snow and rain and, have a continuous flow throughout the year. During the monsoon months, the Himalayas receive heavy rainfall resulting in frequent flood. The main Himalayan rivers are:

i) The Indus and its tributaries (such as the Jhelum, the Chenab, the Ravi, the Beas, and the Satluj *etc.*)
ii) The Brahmaputra and Barak (the latter also known as Meghna)
iii) The Ganga and its tributaries (such as the Yamuna, the Ram Ganga *etc.*)

Drainage:

An area into which surface water flows.

Among the deccan rivers, the Godavari, the Krishna, the Pennar and the Cauvery are the major ones. Among the coastal rivers, mainly there are four on the west coast (the Sabarmati, the Mahi, the Narmada and the Tapi) and three on the east coast (the Subarnarekha, the Brahmani and the Mahanadi).

Arid Area:
A land area getting less than 25 cm rainfall, which is insufficient to support agriculture. Because of low moisture content in air (*i.e.*, low humidity) evaporation rate will be high.

The rivers of the inland drainage basins are also known as desert rivers. They flow for some distance and get lost in deserts. They flow through arid areas where evaporation equals rainfall and hence, there is no surface flow. A typical example is the Luni river which rises in the Nagaur District of Rajasthan and, after running for a total length of 482 km finally disappears in the Great Rann of Kachchh.

4.4.3 River Basins

Three divisions based on drainage are accepted for Indian rivers as shown in Table 4.1. The major river basins cater to the needs of 80% of the country's population. The names of major rivers, their catchment areas and the states falling under their river basins are given in Table 4.2. Each river basin shown in Table 4.2 includes the main rivers and their tributaries also. The medium and minor river basins cover 17% of the total drainage area and provide 15% of flow contribution. The Brahmaputra, the Ganga and the Indus basins along with that of the Godavari cover more than half of the country. The whole of the west coast stretching 1500 km between Surat in Gujarat and Kanyakumari in Tamilnadu are fed by fourteen medium and eighteen minor river basins. But important cities like Bombay, Panaji, Cochin and Trivandrum are left out of these basins.

Table 4.1: Classification of River Basins of India.

Category	Basin area/km^2	Number of basins	% of total drainage area	% of flow contribution
Major	More than 20,000	14	83	85
Medium	Between 20,000 and 2000	44	8	7
Minor and Desert	Less then 2000	55	9	8

Table 4.2: The Catchment Areas and the States Involved in Major Basins.

S.No.	River basin	Catchment area/km^2	States in which the catchment area falls
1.	Indus	3,28,000	Jammu & Kashmir, H.P., Punjab, Haryana, Rajasthan
2.	Ganga	8,60,000	Uttaranchal, U.P., H.P., West Bengal, Jharkhand, Haryana, Rajasthan, M.P., Bihar, Delhi
3.	Brahmaputra	1,87,000	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, West Bengal
4.	Sabarmati	20,000	Gujarat, Rajasthan
5.	Mahi	30,000	Gujarat, M.P., Rajasthan
6.	Narmada	98,000	Gujarat, M.P., Maharashtra
7.	Tapi	60,000	Gujarat, M.P., Maharashtra
8.	Subarnarekha	19,000	Bihar, Orissa, West Bengal
9.	Brahmani	39,000	Bihar, M.P., Orissa
10.	Mahanadi	1,40,000	Bihar, Chhatisgarh, M.P., Maharashtra, Orissa
11.	Godavari	3,10,000	A.P., Karnataka, M.P., Maharashtra, Orissa
12.	Krishna	2,58,000	A.P., Karnataka, Maharashtra
13.	Pennar	55,000	A.P., Karnataka
14.	Cauvery	87,000	Karnataka, Kerala, Tamilnadu

Each river basin shown in Table 4.2 includes the main rivers and their tributaries also.

Catchment area:

The area served by a river system.

On the east coast of peninsular India, the following three pockets are not covered under any major river basins:

i) The area between the Mahanadi and the Godavari basins in Orissa coast
ii) The area between the Pennar and the Cauvery basin wherein Chennai and Pondicherry are located
iii) The area south of the Cauvery i.e., from Madurai to Kanyakumari.

Based on volume of water flow along the rivers, the following aspects are worth noting:

- Our Country has fourteen major, fortyfour medium and fifty-five minor river basins. Evidently, there is tremendous variation in the quantity of discharge from a major basin to the minor one and, also in the quality of discharge from region to region.
- The northern and eastern regions have much better water resources than southern and western parts. Among the fourteen major river basins, only four have perennial flow of water due to heavy rainfall *i.e.*, in the Brahmputra, the Ganga, the Mahanadi and the Brahmani. Six basins (the Krishna, the Indus, the Godavari, the Narmada, the Tapi and the Subernarekha) have medium rainfall. The

Water flow variation of a river through different seasons has a direct influence on its efficiency to flush out and dilute sewage let into it.

remaining four (the Cauvery, the Mahi, the Sabarmati and the Pennar) occupy the area of low rainfall. The seasonal variation in water flow in the Ganga and the Brahmaputra is of the order 50:1, whereas in Cauvery and Mahi, the same is of the order 1000:1.

- The (treated or untreated) industrial waste and domestic waste can be flushed out when the rainwater flows through the rivers. During dry seasons, there is not enough flowing water to carry the waste materials. Thus, waste management need to be given a serious thought, where dumping is done into monsoon fed rivers.

4.4.4 Groundwater Availability

Groundwater is the water that occurs below the surface of the earth. Groundwater is that part of the precipitation which soaks into the soil through the openings and keeps moving underground. It is generally found in geological formations commonly referred to as aquifers. Rainfall characterised by seasonal, annual and locational variation is not a very reliable source of water supply in most parts of the country. Availability of groundwater is a major asset that can greatly influence agricultural and industrial sectors. The contribution of groundwater resource to agriculture is as high as 50%. Nearly 80% of rural water supply and over 50% of urban and industrial water supply demand is met from groundwater resource. It has been estimated that at a depth of 300 m, the groundwater reserves of the country are 3700 mha m, more than nine times the annual rainfall. But the usable portion of groundwater is only 43.2 mha m. Just as in rainfall pattern, usable groundwater availability also varies from region to region.

The groundwater is abundant in the Indo-Gangetic plain but scarce in the western and southern regions. The groundwater withdrawal needs to be replenished through rainfall. But from the point of view of its utilisation, there is unevenness. The groundwater under utilisation and over utilisation exist side by side in different parts of the country. Under utilisation occurs in areas where cheap canal water is available. Over utilisation remains a major problem in areas with no or uncertain canal water supply and, where more water-intensive agricultural production system is practised. The over use leads to deterioration of water quality due to (i) the lowering of water level thereby reaching saline water layers below or (ii) passage of sea water into the groundwater source (where the source is near a sea). Usage of such poor quality water can have adverse effect on living beings and agriculture.

SAQ 2

From the fact that the average annual rainfall in India is significantly higher than the global mean, it looks India is fairly rich in water resources. Examine this statement in the light of variability of rainfall with respect to space and time.

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SAQ 3

State the problems arising out of over utilisation of groundwater.

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4.5 HYDROLOGICAL CYCLE

Hydrological cycle is defined as the cyclic process of evaporation, cloud formation, rainfall, snowfall and refilling of water bodies. The evaporation takes place from oceans and other water sources due to solar heat. As a result of this, clouds are formed, which float around in gaseous form or in liquid droplet form along with tiny crystals. Eventually, the water returns to the earth in the form of rain or snow known as precipitation. When it reaches the earth, some of it runs across the ground into the rivers and finally flows into the ocean again. Some portion of rainwater gets absorbed into the soil and even percolates deep to form groundwater. A portion of the rainwater also immediately evaporates back into the sky.

4.5.1 Stages in Hydrological Cycle

The sun and wind control the entire hydrological cycle. During the hydrological cycle, there is transfer of heat around the earth, thereby moderating extreme conditions of temperatures. The stages of the cycle are given below.

i) Evaporation

Water from soil surface, ponds, lakes, rivers and oceans gets transferred as moisture. The factors which affect evaporation are: temperature, relative humidity, wind velocity, amount of rainfall or snowfall, quality of water, surface area of the water source, sunshine *etc*.

ii) Transpiration

Transpiration refers to loss of water in vapour form from plant leaves. The water taken into the roots of the plants from the soil replaces the transpired water. In a way, transpiration is like the action of a pump absorbing water from the soil and leaving the vapour into the atmosphere. Water loss from a vegetated area takes place both by evaporation and transpiration and it is termed, evapotranspiration.

iii) Interception

Interception is the retention of precipitation by thick vegetation (of trees and plants) or by shrubs that is evaporated back to atmosphere. Because of interception in densely vegetated areas, very little rain reaches the soil directly. Interception is to be particularly noted in low rainfall areas.

iv) Precipitation

Water returns to the land and sea from the atmosphere by means of condensation, deposition and precipitation. Condensation is the process of conversion of water vapour into liquid state (in the form of dew droplets). Deposition is the process by which water vapour changes into ice crystals. In the atmosphere, tiny droplets of water and ice crystals form clouds. Precipitation signifies rainfall and snowfall.

v) Run off

Some of the rainfall is soaked into the soil as ground water. The excess water flows over the land surface along the natural slope of the area and is known as run off. Run off is the main source of water for lakes, streams and rivers. The rainwater ultimately drains into the sea. Soil characteristics such as smoothness and steepness of the slope influence the rate and the magnitude of the run off.

The vapour pressure exerted by the water vapour when its concentration is maximum that can remain in a sample of air at a particular temperature is called its saturation vapour pressure. The saturation vapour pressure increases as the air temperature increases. Relative humidity, expressed as a percentage, is related to saturation vapour pressure by the following equation:

$$\text{Percent relative humidity} = \frac{\text{Vapour pressure}}{\text{Saturation vapour pressure}} \times 100$$

For cloud formation and precipitation to occur, relative humidity must have a high value. Also when relative humidity increases, water evaporation rate decreases.

The movement of water through trees standing even to a height of 200 feet or more is aided by an anomalous property of water namely, high surface tension value. Compared to many liquids, water has high surface tension. The surface tension of water is high due to strong cohesive forces caused by intermolecular hydrogen bonding. These forces help in the upward movement of water through capillary rise.

It has also been estimated that hydrological cycle uses more energy in a day than man has generated throughout history by burning all types of fuels.

Water table:

The upper limit of the portion of the ground wholly saturated with water.

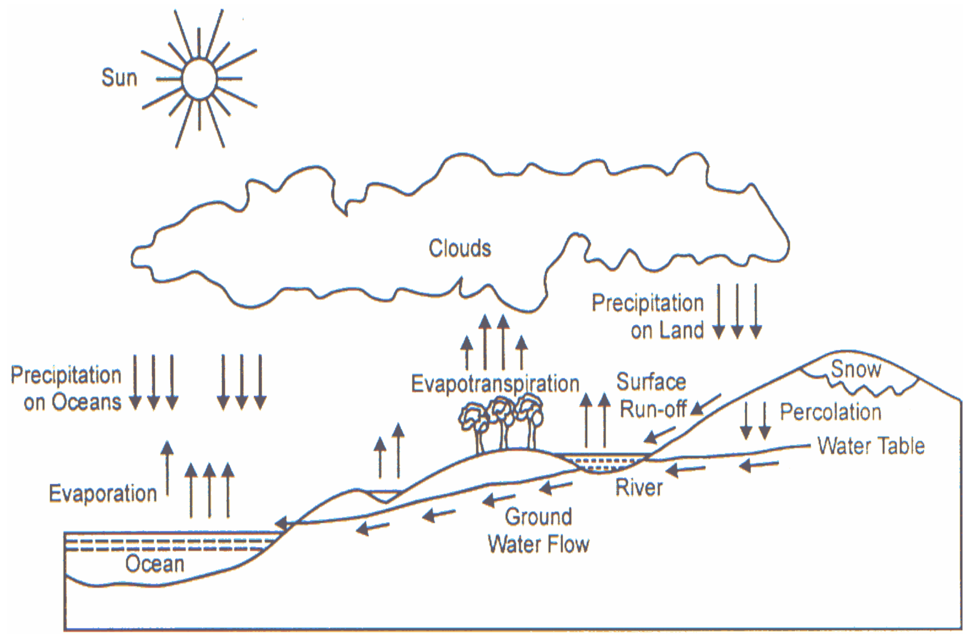

Fig. 4.1: Hydrological cycle.

vi) Infiltration

Infiltration is the absorption of part of the precipitation by the surface layers of soil. During infiltration, water moves downward vertically through various layers finally forming groundwater. The amount of water that undergoes infiltration depends on intensity of rainfall, surface conditions of the soil, vegetation cover and available storage capacity.

The entire cyclic process is represented through Fig. 4.1.

4.5.2 Abnormal Properties of Water Helping the Operations of Hydrological Cycle

Water has high heat capacity value. It signifies that water requires/releases large heat energy while being heated/cooled. This particular quality of water helps in regulating the temperature conditions in our planet as also in plants, animals and human beings. But for this property of water, our planet might have experienced extreme conditions of heat and cold. It is reported that in the industrial side also, 90% of water is used in cooling operation, while 10% alone is used as a reactant or a solvent.

Silt consists of the following:

- fine particles of weathered rock
- dirt and
- organic matter.

It is worth mentioning that water has

- higher melting point, boiling point and heat of vaporisation than most other common liquids of comparable molecular weight
- lower density in the solid state than in the liquid state
- high heat capacity, and
- high surface tension.

Its high melting point helps in maintaining ice caps at polar regions. The lower density of ice facilitates its floatation on water surface. This enables lower layers in ocean and other water systems to remain in the liquid state, although the surface may be covered with ice. It facilitates aquatic life even in cold regions. Further, once spring sets in, surface ice begins to melt. In short, there is constant mobility of solid and liquid forms of water. But for the lower density of ice, much of the portions of deep oceans would have remained solidified forever. Also, intolerable extremes of cold and heat would have been present in the world. Further, the high heat capacity of water helps to regulate temperature conditions both during winter and summer. High surface tension helps in movement of water through plants and trees due to capillary rise. The last feature enables constant replacement of water lost by the plants and trees through evapotranspiration.

4.5.3 Importance of Hydrological Cycle

Let us see how the phase transformation of water and the run off during hydrological cycle affect human life favourably and unfavourably.

i) Climate and monsoon are directly related to the hydrological cycle. The dynamic flow of water vapour in the atmosphere contributes to climatic conditions in a place.

It is estimated that the rivers and streams carry around 2.7 billion tons of silt into the oceans every year.

ii) The physical disintegration and the chemical decomposition of the materials on the surface of the earth due to various operations of the hydrological cycle are known as weathering reactions. Water has a prominent role in weathering reactions. The rainwater trapped in the crevices of rocks solidifies during winter. Due to lower density of ice than water, it expands and helps in breaking the rocks and mountains. The rain that falls uses part of its energy over the rocks and mountains causing erosion. The run off carries lot of silt so formed from the rocks causing valleys. The silt is colloidal in nature. A part of it coagulates when coming into contact with saline water near the sea, resulting in the formation of deltas, a rich deposition of fertile soil. The silt that is still carried finally gets deposited into the oceans. In other words, hydrological cycle breaks the mountains and rocks in a slow way and fills up the oceans with the silt so formed – a process of surface leveling. Thus, the weathering reactions help in shaping the earth. Further, weathering reactions play a prominent role in the formation of minerals. You are advised to refer to Unit 1 of Block 1 to understand this aspect. In Sec 5.3 of the next unit, you shall study how minerals are formed through the weathering reactions carried out by water with rock materials.

Crevices: Small narrow cracks within rocks.

If you want to know about coagulation of colloids, go through Subsec. 20.6.5 of Unit 20 of Physical Chemistry (CHE-04) Course.

iii) The flow of water down the steep slopes could yield considerable hydroelectric power. Also the run off aided by the gravity on the plains enables navigation through water bodies.

iv) An excess of rainfall within a short time may bring floods. A long interval between successive rainfalls causes drought conditions. Floods and drought are instances to show how hydrological cycle operation could adversely affect living conditions.

In this subsection, we have studied how through hydrological cycle, all the water bodies – oceans, rivers, atmosphere and glaciers – are interconnected. Next, let us study the hydrodynamic features of three major types of fresh water ecosystems.

Eco system:
A community of animals, plants and bacteria and, interrelated physical and chemical environment.

SAQ 4

Explain the terms, evapotranspiration and interception.

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Hydrodynamics:
The branch of Physics dealing with motion of water and its related characteristics.

4.6 HYDRODYNAMICS OF FRESH WATER ECOSYSTEMS

Under hydrodynamics, we shall examine the flow velocity of water, vertical mixing and stratification. First, we examine the effect of **flow velocity** on aquatic systems. The fast moving aquatic systems experience turbulence to a great extent and, agitate water layers. This process helps in enhancing dissolved oxygen content. As an analogy, remember the laboratory practice of stirring the contents of a beaker vigorously to dissolve maximum amount of a solute in a solvent. You can now understand as to why turbulent rivers have high dissolved oxygen content; slow moving rivers may have oxygen well below saturation conditions. The two terms, vertical mixing and stratification are related to each other. Due to water current and

Flow velocity:
It is the speed with which water flows through the water system.

turbulence, mixing of water layers from top to bottom takes place, which is known **as vertical mixing**. Vertical mixing leads to uniformity of temperature and chemical composition (with respect to dissolved materials such as dissolved oxygen *etc.*) Lack of vertical mixing leads to stratification. **Stratification** refers to formation of distinct horizontal layers differing in temperature, chemical composition and biological properties. The difference in biological characteristics of various layers is due mainly to the difference in nutrient content and dissolved oxygen. You may go through the portion written under temperature in Sec. 5.2 of the next unit to understand the significance of the term, stratification. We explain the flow velocity, vertical mixing and stratification of three of the fresh water ecosystems.

Rivers

Lateral mixing:

Mixing of water along sideways, usually at same height from the river bed.

The rivers are characterised by unidirectional current with a relatively high, average flow ranging from 0.1 m s^{-1} to 1 m s^{-1}. The river flow is highly variable with time depending on climatic situation and the drainage pattern. In general, thorough and continuous vertical mixing is achieved in rivers due to prevailing currents and turbulence. Lateral mixing may take place only over considerable distance downstream of major confluence.

Lakes

Confluence:

Merging of two or more aquatic systems.

The lakes are characterised by low average current velocity of 0.001 m s^{-1} to 0.01 m s^{-1} (surface value). Therefore, water residence times, ranging from one month to several hundreds of years, are often used to quantify mass movement of material. Current within lakes are multidirectional. Many lakes have alternating period of stratification and vertical mixing, periodicity of which is regulated by the climatic conditions and depth.

Groundwater

The groundwaters are characterised by a rather steady flow pattern in terms of direction and velocity. The average flow velocities commonly found in aquifers (groundwater reservoirs) are in the range 10^{-10} m s^{-1} – 10^{-3} m s^{-1}; these are largely governed by the porosity and the permeability of the geological material As a consequence, mixing is rather poor. Depending on local geological features, the groundwater dynamics can be highly diverse.

There are also several transitional forms of water bodies, which demonstrate features of more than one of those described above. We shall not go into these details.

As a consequence of the range of flow velocities noted above, large variations in water residence times occur in different types of inland water bodies. The hydrodynamic characteristics of each type of water body are highly dependent on the size of the water body and on the climatic conditions in the drainage basin. The governing factor for rivers is their discharge variability. Lakes are classified by their water residence time and stratification. Groundwaters greatly depend upon infiltration, which allows for the renewal of the groundwater body.

SAQ 5

Name two important hydrodynamic characteristics that are studied for fresh water ecosystems. State the reason for their importance.

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4.7 CRUCIAL ISSUES ASSOCIATED WITH CONSERVATION AND MANAGEMENT OF WATER RESOURCES

Conservation of water refers to the issues of development and protection of the water resources in such a way that the present and future needs for water are satisfied. The conservation aspect deals with the problems related to

- the storage of water
- retention of moisture in the soil and
- maintenance of withdrawal-recharge ratio of water bodies.

The management of water resources specifies measures to be taken to maximise the efficiency of water use. In view of huge investments to be made in increasing quantum of water supply, an efficient use of the available water is advocated by water management concept. Under water management, issues related to

- maximising production in relation to consumption and
- minimising wastage

will be considered.

We shall first examine in detail the aspects that have to be taken into consideration while thinking of solution for the problems associated with water conservation and management.

4.7.1 Features Related to Water Availability and Usage

We shall discuss the following features in this regard.

a) Regional imbalance in the availability of water resources

We have already explained that among the various regions of our country, there is

- variation in rainfall (in Subsec. 4.4.1),
- imbalance in river water availability (in Subsec. 4.4.3), and
- imbalance both with respect to availability and utilisation of groundwater (in Subsec. 4.4.4).

b) Limited availability of usable water

As mentioned earlier, our country gets around 400 mha m of fresh water both from rainfall and snowfall. The whole of it cannot be put to use due to the following reasons:

i) Loss due to evaporation, plant transpiration, percolation into soil and interception
ii) Constraints due to the following topographical and hydrological features:

   - rain along the hill slopes mostly get washed away (as along western ghats)
   - absence of proper storage systems like tanks results in flow of rainwater into drainage
   - capacity of dams built so far are enough only to hold around 20% of rainwater while 80% is let off.

As per the Nineth Five Year Plan document, only 69 mha m of surface water can be put to beneficial use every year. Also out of groundwater, only 43.2 mha m is usable every year. Hence a total of 112.2 mha m is the total usable water.

c) Population increase and decreasing annual per capita availability of water

The population in our country has increased from 36.11 crores in 1951 to 84.34 crores in 1991 and to 102.7 crores in 2001.The direct result of population increase is the decrease in annual per capita availability of water. It is possible to calculate annual per capita availability of water as follows:

The annual run off in the river system of the country has been assessed as 1869 km^3 and it is to be divided by the population to get the above parameter.

$$\left(\begin{array}{c}\text{Annual per capita}\\ \text{availability of water}\end{array}\right) = \frac{\text{Annual run off in the river system}}{\text{Population}}$$

$$= \frac{1869 \times 10^9 m^3}{\text{Population}} \; [1 km^3 = 10^9 m^3] \qquad \text{..... (4.5)}$$

Accordingly the annual per capita availability of water in our country has decreased from 5176 m^3 in 1951 to 2216 m^3 in 1991 and to 1820 m^3 in 2001. You check these values using Eq. 4.5 and the population data given above. As per 1991 data, the global annual per capita availability was 9231 m^3. It has been assessed that a per capita water supply of 2000 m^3 is minimum and 1000 m^3 is very low. India is likely to reach a condition known as 'water stress' from 2007 onwards. The water stress condition will affect the economic development besides leading to ecological degradation. In 1990, India was ranked at the 42nd position among 100 countries in relation to per capita annual water availability.

d) Problems associated with construction of big dams

The construction of big dams is considered beneficial due to the following aspects:

a) generation of hydroelectricity
b) increased irrigation facility and control of floods
c) improved municipal and industrial water supply.

At the same time, the big dams have many adverse ecological and socio-economic implications also as given below:

- deforestation, soil erosion and landslides (due to clearance of site for the dam)
- seismic activity (i.e. being more susceptible to earth quakes)
- sedimentation (i.e. deposition of large amount of silts in the dam)
- water logging and salinisation
- displacement of inhabitants (along with loss of their main occupation related to agriculture, and local resources)
- epidemic eruption of water-borne diseases.

We shall explain the terms, water logging and salinisation, in Subsec. 4.7.2.

Paradoxically, it has been mentioned that as a result of construction of major dams, the total flood - prone area of India has doubled from 20 mha to 40 mha in recent times. Further, there is a substantial increase in the cost of construction of big dams due to corrective action to be taken in relation to adverse factors mentioned above.

4.7.2 Need for Conservation and Management of Water Resources

We now explain the need for conservation and management of water resources.

a) Increase in demand for water for irrigation, domestic, industrial and other uses

The increase in population evidently results in increased demand for more drinking water, food, buildings, consumer articles *etc*. These demands call for more facilities for agricultural production, industry *etc.* all of which again require huge amount of water supply as mentioned in Sec 4.1. Based on population data, total fresh water demand for irrigation, domestic, industrial, cattle and other purposes is estimated to be 105 mha m in the year 2025. It denotes that more than 90% of utilisable potential of water resources (of 112.2 mha m) of the country has to be put to use.

b) Water scarcity, women illiteracy and rural backwardness

Water supply pattern for public consumption is highly nonuniform when we compare urban and rural sectors. In cities like Delhi and Bombay, per capita water supply is much higher as compared to many towns and villages.

Further, the anomaly is that those who live in cities or near the canal system get water mostly on government subsidy; on the other hand, others have to pay heavily for obtaining water for irrigation or for domestic use. Or else, they have to spend considerable time in fetching water. It must be mentioned that consequent to scarcity of drinking water supply, the rural women starting from girlhood have to spend considerable time in fetching water. In some cases, they have to walk even for a few kilometers to bring water. It has been identified as one of the causes, apart from other socio-cultural reasons, for illiteracy and backwardness of rural women, in particular. It is also mentioned that assured water supply could improve school attendance especially with reference to girl children. It is stressed that greater access to water supply can improve the living conditions in rural areas.

c) Need to enhance hydroelectric power production

We are generating 30% only out of the estimated hydroelectric potential of 75,400 MW. There is a huge untapped potential for hydroelectric power generation.

d) Need for control of floods and drought

Flood plain: Level land that may be submerged by floodwaters.

The extreme variation in water availability with respect to seasons and locations is illustrated by the occurrence of droughts and floods in different parts of the country during every year. A total area of 40 mha is prone to floods. Besides crop losses, floods cause considerable damage to houses and property as also loss of human and cattle lives. During the last 25 years, on an average, 9.3 lakh houses were damaged every year along with loss of 1240 human lives and 77,000 cattle. Floods occur due to intervention in the path of rivers, obstruction of the natural drainage and invasion of the flood plain as a result of population growth. Besides the direct losses, floods destabilise economic activity also. The agricultural activities for the subsequent seasons are also affected. Note that Brahmaputra basin is particularly prone to floods.

Droughts are periods over which precipitation is much below normal level. Wherever rain water is the major source of water, lack of rainfall even for a few months could be disastrous. Agricultural drought arises when soil moisture gets much depleted and the yields are significantly reduced. In our country, nearly 16% of the total area of our country is drought - prone and it directly affects 12% of the population.

e) Development of fisheries, inland water transport and tourism

The fish resources of India are extremely rich. Over 1200 species are found in river and coastal water systems; one third of them is commercial. Poor maintenance of the country's water resources leads to depletion of fish catches. Our country has about 14,500 km of navigable waterways, which comprises of rivers, canals, backwaters *etc.* Only 3000 km stretch is used for transport purposes now. The river navigation is particularly a cheap mode of transport for moving cargo in bulk. It is one of the areas having high potential of development, which again depends on maintenance of water resources. In the development of tourism, the water bodies have a vital role to play.

Water use efficiency =

$$\frac{\text{(Mass of dry matter produced via photosynthesis)}}{\text{(Mass of water used during its growth)}}$$

In Subsec. 5.5.3 of the next unit, you will study in detail the adverse effects of algal growth on water systems.

f) Need to optimise use of water

As in the case of money, water saved is water procured. We can optimise the use of water by

i) minimising loss due to evapotranspiration and
ii) minimising wastage in agricultural and domestic sectors.

Let us discuss the second aspect in detail. In agricultural sector, the water use efficiency by conventional irrigation (known as flood irrigation) is not more than 45%. Studies indicate that India uses about three times as much water per acre as Japan and, produces only one-third as much rice. Also excess seepage leads to water logging and salinity, which we shall discuss shortly. The water losses in domestic supply system in the cities of developing countries are generally 50% and above. The wastage of water occurs due to

- faulty supply lines
- unplanned plumbing
- usage of flushing system, washing machines, shower heads, taps *etc*. that are not designed keeping in view the economic usage of water.

We must bear in mind the cost involved in procuring precious water from distant sources and also in purifying it. Further, excess water going though the drains requires further expenditure in sewage disposal. There is a need for taking measures for recycling of wastewater.

g) Need to protect the environment and ecosystems

Proper handling of the water resources is quite essential for maintaining clean environment. The environmental impacts of excess use of groundwater and construction of big dams have been mentioned earlier. Proper measures need to be taken in relation to these aspects.

- For providing water supply to cities, water is drawn from river systems in distant location. Protective action must be taken to ensure that ecosystem is not affected due to usage of paths other than natural routes followed by the river systems.

- Let us explain the bad effects of water logging and salinisation.
  - ➢ Excess stagnant water leads to accumulation of water around the roots of plants. Also underground water level may rise. The airflow to the root system of plants may get affected. The condition may be conducive for the growth of algae too that could spoil water quality. These aspects are collectively known as water logging.
  - ➢ In dry climate, water near the surface evaporates causing deposition of damaging layers of salts on the soil. This process is known as salinisation and it affects growth of crops.

- Regarding the health hazards arising out of mixing of untreated domestic sewage and industrial effluents with river systems and, the protective measures to be taken in this regard, you shall study in Units 6 and 14 of this course.

SAQ 6

What are the adverse socioeconomic implications of constructing big dams?

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4.8 METHODS OF WATER CONSERVATION AND MANAGEMENT

Now we shall discuss the methods of water conservation and management.

1) Conservation of surface water

In order to conserve the surface run off, the following methods are suggested.

a) Construction of dams with due concern for environment

You have studied in Subsec. 4.7.1, the environmental hazards associated with the construction of big dams. As protective measures, Govt. of India has come up with legislations such as Environmental (Protection) Act, 1986 and Environmental Impact Assessment Notification, 1994. Under these provisions, any project needs to be begun only after getting environmental clearance from the concerned government agencies. Also environmental safeguards are to be undertaken. Taking the help of Botanical Survey of India, steps are to be undertaken to develop botanical garden to conserve rich biodiversity. Biological measures such as plantation, pasture development *etc.* are to be undertaken as measures of compensatory afforestation. Special care is to be taken towards fish breeding facilitating upstream and downstream migration of fish. Socioeconomic survey of the people likely to be affected by the projects is to be carried out. The resettlement and rehabilitation plan is to be prepared in consultation with the representatives of the local people. Special care is to be taken towards housing, employment, reconstruction of culturally important places, vocational training, water supply, community facility, fuel arrangement *etc.* It must be mentioned that all these result in huge expenditure.

Considering the disadvantages of constructing big dams, it is suggested that smaller dams and mini-hydroelectric projects could be constructed for water supply and power generation at various locations. These are to be built and managed by the user groups. A cluster of small reservoirs could permit longer periods of flow of water. Due to spread of reservoir system, flood control could also be more effective.

b) Rainwater harvesting

Rainwater harvesting is the deliberate collection and storage of rainwater on natural or man made catchment areas. The catchment includes
i) artificially prepared land surface
ii) hill slopes or rocky surfaces
iii) roof tops of buildings.

The first two types will be taken up here and the third will be discussed shortly under groundwater conservation.

i) Catchment on artificially prepared land area

The rainwater harvesting structures such as ponds, lakes *etc.* built in historical times on artificially prepared land surfaces exist even now in many parts of the country. Along with the British rule started the neglect of pond irrigation system. The British Government abolished the system of local tax collection for tank repair and maintenance. Without adequate funds and powers, the local communities lost interest in water resource management. The damage caused is quite high such that even now the system is not effectively reactivated. The pond irrigation needs to be properly nurtured by

- removal of silt
- ensuring water quality by preventing excess growth of algae, water hyacinth *etc.*
- preventing construction activities and encroachments on the pond sites
- putting a legal ban on discharge of domestic waste, effluent *etc*. into the ponds.

Silt gradually gets deposited on the ponds over a period of time and causes water to spill over the banks. It shortens the useful life of a pond system.

ii) Rainwater harvesting for hill area

In hills, a contour of steps could be arranged so that each step could store rainwater. Fig. 4.2 is a snap from Indian Council of Agricultural Research Centre Unit at Barha Pani, Meghalaya, in which contour trenches and bench terraces are illustrated. Contour trenches are successive pits made for storing water. The bench terraces are stepwise cut in the slope of the hill such that considerable landspace is left in each step for retaining rainwater. This technique is especially suitable for areas having rainfall of considerable intensity spread over a large part as in Himalayan areas, North-eastern States and Andaman and Nicobar Islands. The benefits of rainwater harvesting structures are given below:

- improves groundwater level and its quality
- helps in avoiding droughts
- reduces soil erosion in rocky areas as the surface run off is reduced
- decreases the flooding of roads which generally happens during rainy days
- saves electrical energy in lifting groundwater from deeper levels
- helps in increasing the extent of cultivable land area, agricultural yield, fodder production, cattle breed capacity and, in short, improves rural economy.

Fig. 4.2: Catchment on hill slopes – note a contour trench and bench terraces.

The voluntary organisations like *Tarun Bharat Sangh* of Alwar have been doing remarkable work in Rajasthan reviving traditional methods of rainwater harvesting. Their efforts have helped in improving water availability for human consumption, agricultural activities and cattle breeding. Rainwater harvesting has resulted in rebuilding rural economy and developing self reliance in many villages of Rajasthan.

2) Groundwater conservation

In Subsec. 4.4.4, we have explained the need to conserve groundwater. Some of the techniques of groundwater management and conservation are given below.

a) Artificial recharge

Artificial recharging is done by digging recharge pits or wells; these wells admit water from surface to fresh water aquifer. In order to recharge groundwater, government recently has made rainwater harvesting as a legal requirement. The Central Groundwater Board and other government organisations have come up with models for replenishing the groundwater in rural and urban areas through rainwater harvesting.

While taking steps for rainwater harvesting, its limitations given below must also be taken into consideration:

- breeding of mosquitoes is a common problem
- studies indicate that rainwater stored for a long time could develop bacterial growth
- rainwater harvesting arrangement needs capital investment.

Monthly application of chlorine or bleaching power is considered sufficient to deal with mosquito and bacterial growth problems. The stagnation of water need to be avoided by providing proper slope towards the recharge wells. It must be borne in mind that recurring costs of maintenance are quite low. Using Eq. 4.6, you can calculate rainwater volume that can be collected.

$$\left.\begin{array}{l}\text{Volume of rainwater}\\\text{that can be collected}\end{array}\right\} = \left\{\begin{array}{l}\text{Rainwater}\\\text{volume}\end{array}\right\} \times \left\{\begin{array}{l}\text{water}\\\text{collecting}\\\text{efficiency}\end{array}\right\} \quad \ldots\ldots (4.6)$$

Usually rainwater collecting efficiency is a fraction with value less than 1. By multiplying rainwater collecting efficiency by 100, we can get rainwater collecting efficiency as percentage.

Example 2

Calculate the volume of rainwater that can be collected annually due to rainfall over only the land area of our country. Use the data given in Example 1 in Sec 4.2. Assume that water-collecting efficiency is ½.

Using Eq. 4.6 and the data mentioned above, annually 167.2 mha m or 1.672×10^{12} m^3 rainwater can be collected.

b) Percolation tank method

Percolation tanks are constructed across the watercourse for artificial recharge. Many states like Maharashtra, Rajasthan, Andhra Pradesh and Karnataka have used percolation tanks. The studies conducted in Maharashtra indicates that on an average each percolation tank

- exerted influence over an area of 1.2 km^2,
- caused a rise of 2.5 m in groundwater level and
- led to annual artificial recharge of 1.5 ha m.

Conjunctive use of groundwater and surface water

It is emphasised that both surface and groundwater resources can be viewed as an integral resource. Their development and usage must be done in a coordinated way to prevent water logging and soil salinity and to provide adequate and assured water supply for crops. The Central Water Commission and the Central Groundwater Board have prepared guidelines for the conjunctive use of both the resources.

3. Catchment area protection

Catchment area protection plans are usually called watershed protection plans. These are adopted as an important measure to conserve and protect the quality and quantity of water in a watershed. The run off water is withheld in the hilly area. This will delay the run off so that greater time is available for water to seep underground. Such methods are used in northeastern states. Afforestation in the catchment area is also adopted for water and soil conservation.

Watershed:

An area of high ground which divides two or more river systems so that all streams on one side flow into one river and those on the other side flow into a different river.

4. Interbasin transfer of water

In Subsec 4.4.3, we have discussed in detail how northern and eastern regions are water-rich and, southern and western regions have comparatively low water resources. It is realised that interlinking of river basins is a necessary step towards equitable distribution of water resources. The Ministry of Water Resources has formulated a National Perspective for Water Development in 1980 comprising of two components.

a) Himalayan rivers component

The main features are given below:

i) Conserving the monsoon flow for flood control, hydroelectric power generation and irrigation
ii) Interlinking of Brahmaputra, Ganga and Mahanadi systems
i) Providing additional irrigation facilities to Haryana, Rajasthan, Punjab and Gujarat
ii) Providing additional flow to Kolkatta Port and facilitate inland navigation facilities.

b) Peninsular rivers component

Under this scheme, it is proposed to transfer the surplus waters from the Himalayan rivers through the interlinking of Mahanadi – Godavari – Krishna – Pennar – Cauvery. This will provide additional irrigation facilities to Maharashtra, Karnataka, Andhra Pradesh and Tamil Nadu. Further, interlinking of west and east flowing rivers in Kerala is also planned to bring additional irrigation to Kerala and Tamil Nadu. It is proposed to interlink a few small rivers flowing along the west coast north of Bombay and south of Tapi and, the southern tributaries of the Yamuna like the Chambal and the Ken.

A few basic challenges in implementing interbasin transfer are given below:

i) Serious political issues arising out of regional consideration need to be resolved
ii) Heavy financial investments are needed
iii) Pooling of technical expertise is to be done.

It is often said that due to delayed decisions in the interstate sharing of waters, crops in approximately 20 mha of cultivable land are heavily affected. Special tribunals are appointed to decide the sharing of river waters among the states.

River water sharing with the neighbouring countries

Regarding the need for cooperation at the international level, we shall throw some more light using the following observations made by B.G. Verghese in his book, *Waters of Hope:* "The Ganga, Brahmaputra and Barak share a large interlinked basin spread over five nations -India, Bhutan, Nepal, Bangladesh and China's Tibet. In spite of the fact that these river systems carry 214 mha m of water to the sea and, possess a hydroelectric potential of 2,50,000 MW, it is ironical that the people living in this basin represent the single largest concentration of one of the poorest beings living amidst the plenty of natural resources. Proper management of water resources in this region could result in improvement of standard of life in this region**.** In short, water is a resource to this part of the world in the same sense that petroleum is to the middle east." In order to settle water disputes in this region, international bodies like Indo-Bangladesh Joint Rivers Commission have been set up. For sharing the Indus river water, India and Pakistan have created the Permanent Indus Commission.

a)

b)

Fig. 4.3: a) Drip irrigation through well-laid out hose pipes along the field
b) Sprinkler irrigation.

5. Methods based on modifications in agricultural practices

By making suitable changes in agricultural practices, water can be used more efficiently. The following are some of the suggested measures.

a) Adoption of drip and sprinkler irrigation

Surface irrigation method, which is traditionally used in our country, is unsuitable for water scarce areas, as large amount of water is lost through evaporation and percolation in this method. Drip irrigation and sprinkler irrigation are superior to surface irrigation. In drip irrigation, water pipes running through the land contain small holes which emit the water directly to the soil adjacent to the root system. This method is particularly useful in arid zones. In sprinkler method, water is sprinkled using water jets moving in different directions in the field. It has been estimated that water use efficiency is 95% for drip irrigation, 45% for surface irrigation and 75% for sprinkler irrigation. Drip irrigation facility can be done even using poor quality water or saline water since direct contact between water and leaves is avoided. Certain crops like cotton, tomato and melon tolerate salinity equivalent to 0.47% NaCl. The only condition is that cultivation is to be done in sandy or loamy sandy soils. The constant flushing of the roots helps in removal of salts from root system. Drip irrigation allows the use of minimally treated sewage water since water is delivered to the ground minimising health risks. In Figs. 4.3 (a) and (b), drip irrigation and sprinkler irrigation are illustrated; the former pertains to a field in Israel treated by drip irrigation.

Loamy sandy soil: A sandy soil having decayed vegetable matter that makes it better than sand for growing crops. Also refer to Unit 2 of Block 1.

b) Management of growing pattern and selection of crop varieties

In water scarce areas, the crop selection should be based on the efficiency of a crop to utilise water. Some of the plants suitable for water scarce areas are (i) plants having shorter growth period (ii) high yielding plants that require no increase in water supply (iii) plants with deep roots and (iv) plants which cannot tolerate surface irrigation. In water scarce areas, crops such as wheat, paddy and sugarcane are to be avoided. Instead, low water requiring crops (dry land crops) such as coarse grains, millets, edible oil seeds and pulses have to be cultivated. Certain crops, which adopt to dry or desert conditions have a tendency to reduce the water loss in transpiration.

Dry land crops have low transpiration rate.

D
lc
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c) Nutritional management

Adjustments in plant nutrients can play a vital role in improving water efficiency. For instance, potassium helps in increasing the water use efficiency. Experiments conducted at the Water Technology Centre, Coimbatore, indicated that foliar application of 0.5% potassium chloride can reduce the moisture stress in soyabeen, sorghum and groundnut.

d) Reducing evapotranspiration

By reducing the evaporation from soil surface and transpiration from the plants, evapotranspiration loss can be reduced. In arid zones, where low humidity prevails, considerable amount of water is lost in evaporation from soil surface. This can be prevented by spreading leaves, straw *etc.* on the ground around the plants. Nonporous materials like papers, plastic foils or metal foils can also be spread over the fields for preventing loss due to evapotranspiration. Further, using windbreaks, air movement over a crop can be reduced. Other methods are given below:

- application of chemicals that reduce transpiration
- destroying the unwanted plants from the farm
- removing unproductive leaves from the crop
- enclosing crops in such structures so that the transpired water can be collected and reused
- applying monomolecular films over water bodies

Whenever chemical methods are used for reducing evapotranspiration, their environmental impact is also to be carefully analysed.

6. Methods based on modifications in domestic and industrial uses

We shall discuss three methods in this context.

a) Recycling of wastewater from domestic and industrial sources

The wastewater from industrial and domestic sources can be reused after proper treatment for irrigation and recharging groundwater. While using recycled water, water quality should be appropriate for the purpose for which it is to be used. If recycled water is of high quality, it can be used for industrial or even municipal supply. The parks and nearby agricultural lands can be irrigated using treated municipal wastewater. Many industrial units are already using the wastewater after proper treatment.

b) Conservation of water in domestic usage

The municipal and panchayat administration units must try to create public awareness about the need for economic usage of water. Water saving plumbing devices like air-assisted showerheads, flow-limiting faucets (taps), front loading washing machines and air assisted toilet cisterns are available for use.

Israel utilises modern technology to locate, conserve and manage its limited water resources:

1) For location of water resources, neutron scattering devices are used, which emit high speed neutrons into the soil. Any neutron that comes into contact with hydrogen atom, one of the constituents of water molecule – shows up signals in the special device used giving a measure of the soil moisture content.
2) Irrigation is controlled by computers, which are programmed to operate drip and sprinkler lines.

c) Incentives for water conservation

There is lack of incentive for efforts taken to conserve water. It also leads to overuse of water. Observance of conservation measures for irrigation and domestic water use should be encouraged through tax concession.

7. Introduction of modern technology

Some of the methods of modern technology used towards water conservation and management are given below.

a) Locating aquifers using satellites

The satellites can give us wealth of information regarding location of new aquifers, accumulation of winter snow in mountains, soil erosion detection, pollution levels in water bodies *etc.* Using these data, it is also possible to provide early warning about floods and drought conditions.

b) Fresh water from brackish water and seawater

Brackish water: Water containing considerable dissolved salts.

Many desalination methods are being used for converting brackish water into drinking water. We shall discuss the principles of only three methods.

i) Multiple effect distillation

The principle used is that boiling point of a liquid is lowered, if pressure is lowered. Several condensers – evaporators are arranged in series and the vapour from one is used to boil water in the evaporator at the next lower pressure by its condensation. Successive distillation leads to production of pure water. To bring down the cost, this plant is operated in conjunction with low pressure steam obtained from a thermal power station or an industrial process.

ii) Reverse osmosis

In reverse osmosis, water moves through semipermeable membrane leaving the dissolved ions behind. In electrodialysis, the cations and anions move through the selectively permeable membranes leaving pure water behind.

During osmosis, water passes into a concentrated solution from a dilute solution when separated by a semipermeable membrane. In reverse osmosis, water passes through a plastic membrane from the concentrated solution to a dilute solution due to application of pressure. Specially treated cellulose acetate, polymethacrylate *etc.* membranes are used. The running cost for a reverse osmosis plant is low due to low energy consumed, membrane durability *etc.* It is advantageous, since it can remove ionisable and nonionsiable matter as also colloidal and high molecular weight organic matter.

iii) Electrodialysis

Low electrical conductivity of pure water and the migration of ions of dissolved solids in presence of an applied electric current are made use of in electrodialysis. It is also a membrane technology used for pulling out the ions from the brackish water. Two types of membranes are used – one permeable only to cations and another permeable to anions. Two types of membranes are kept alternatively for large-scale purification of brackish water. A polystyrene polymer with sulphonic acid group is used as cation selective membrane while anion selective membrane has quaternary ammonium group. The seawater gets desalinated due to movement of cations and anions through the membranes selective to them.

SAQ 7

State some measures to safeguard the socioeconomic aspects during construction of big dams.

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4.9 SUMMARY

Water is one of the resources of a country. Agricultural production, industrial growth and public heath - all these depend on availability of water in good quantity and quality. In this unit, we have discussed in detail the river water and groundwater resources of our country. A short description of hydrological cycle is provided highlighting the interaction of sunlight and wind with water bodies. The constant interchange of water among its three phases and its effect on climate, mineral formation, carving out of valleys and the delta, power production and occurrence of floods and drought are explained. The crucial issues related to water conservation and management are examined from the point of view of population growth and economic development. The aspects associated with interstate and international sharing of water are indicated. The sociological aspect of rural water scarcity as a contributing factor for women illiteracy and rural backwardness is stated. The methods that could be followed for water conservation and management are explained in detail.

In this unit, we gave a dominant place to the quantitative aspects of water resources. In the next two units of this block, we shall examine quality aspects of water resources.

4.10 TERMINAL QUESTIONS

1. In what way does the low quantity water flow in a river affect the environment?
2. State the importance of weathering reactions.
3. Explain how water helps in regulating the temperature conditions in the earth.
4. Can there be stratification in a flowing river? Explain.
5. The Indian population was 68.63 crores in 1981. Calculate annual per capita water availability during that year.

   Annual run off = 1869×10^9 m^3.
6. State the adverse effects of water scarcity in the rural areas that are not served by a canal system.
7. Explain the terms, water logging and salinisation.
8. What protective measures are needed to reactivate the ponds?
9. What are the main health problems associated with rainwater harvesting? What remedial measure can be adopted for the same?
10. State the difference between reverse osmosis and electrodialysis.

4.11 ANSWERS

Self-Assessment Questions

1. Area = 1483 km^2 = 1.483×10^9 m^2

$$\left.\begin{array}{l}\text{Using Eq.4.3,}\\ \text{the volume of}\\ \text{rainwater that falls}\\ \text{annually}\end{array}\right\} \begin{array}{l} = 1.483 \times 10^9 \times \dfrac{60}{100}\ m^3 \\ = 8.9 \times 10^8\ m^3 \\ = 8.9 \times 10^{-2}\ \text{mha m} \qquad \text{(Using Eq. 4.2)} \\ = 8.9 \times 10^{11}\ \text{litres}\end{array}$$

2. The heaviest rains occur along north-eastern states and along the west coast. In contrast, many other parts of the country like Western Rajasthan, part of Gujarat, most of Jammu and Kashmir have much less rainfall. Most of the rainfall occurs in our country in around 200 hours and, half of it in 30 hours. Consequently, the run-off is high.

3. Over utilisation leads to deterioration of water quality due to lowering of water level and passage of seawater into the groundwater source (where the source is near the sea). Usage of poor quality water can have adverse effect on living beings and agriculture.

4. Water loss from a vegetated area takes place both by evaporation and transpiration. It is termed evapotranspiration. Interception is the retention of precipitation by thick vegetation or by shrubs that is evaporated back to atmosphere.

5. Flow velocity and stratification are the two important factors. The flow velocity decides the solubility of gases like oxygen. Stratification indicates changes in temperature, chemical composition and biological properties down the layers.

6. The inhabitants are displaced. They have to lose their main occupation related to agriculture and local resources.

7. Socioeconomic survey of the people likely to be affected by the project is to be carried out. In consultation with the representatives of the local people, resettlement and rehabilitation plans are to be prepared. Special care is to be taken towards housing, employment, vocational training, water supply, community facility, fuel arrangement *etc.*

Terminal Questions

1. During dry seasons, there is not enough flowing water to carry the waste materials. The waste management need to be given a serious thought where dumping is done into monsoon fed rivers.

2. The weathering reactions are responsible for the formation of valleys and deltas and, for surface leveling of the seas through silt deposit. The minerals are formed by the chemical decomposition of rock materials by water.

3. The high heat capacity of water ensures that a large amount of heat is involved in heating or cooling process. So, intolerable extremes of cold and hot conditions are avoided in the earth.

4. A flowing river experiences thorough and continuous vertical mixing due to prevailing current and turbulence. Hence, stratification is not to be seen in such a river.

5. As per Eq. 4.5, annual per capita water availability must be 2723 m^3.

6. The rural people who are away from the canal system have to pay heavily for obtaining water for irrigation or domestic use. Alternatively, the rural people, especially womenfolk, have to spend considerable time in fetching water. The water scarcity is cited as one of the reasons for illiteracy and backwardness of rural women.

7. The accumulation of stagnant water prevents airflow to the root system. It results in algal growth and spoils water quality. These are collectively known as water logging. In dry climate, water near the surface evaporates causing deposition of

damaging layers of salts on the soil. This process is known as salinisation and it affects growth of crops.

8. The silt should be removed periodically. Measures must be taken to protect water quality by preventing the excess growth of algae, water hyacinth *etc*. The pond sites must be kept clear of encroachments. Domestic waste and effluents must not be discharged into the ponds.

9. Breeding of mosquitoes is a common problem. The rainwater could develop bacterial growth. Monthly application of chlorine or bleaching powder is considered sufficient to deal with these problems.

10. In reverse osmosis, water passes through the membrane leaving the ions behind; in electrodialysis, the ions are pulled out from the brackish water through the membranes leaving pure water behind.