Unit - 3

Hydrologic Cycle

Learning Objectives

- To understand the status of water on the earth
- To learn the basic concepts of Hydrologic cycle
- To study the different components of hydrologic cycle

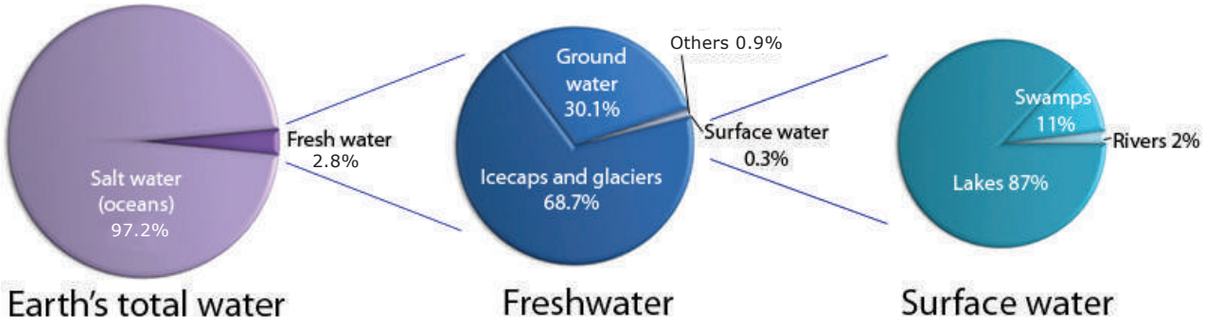
9DWYH8

Introduction

Water is one of the most important elements on the earth. All plants and animals need water for survival. Apart from drinking, water is required for domestic, agriculture, industrial purposes etc. Water is very essential for carrying out almost all economic activities. So, water is an indispensible element without which life form on the earth is not possible.

Water on the Earth

About 71% of the earth's surface is covered by water. The quantity of water present on the earth is about 326 million cubic miles. It is hard to visualise this massive quantity of water. Most of the water on the earth is saline and is found in seas and oceans. The salt water constitutes about 97.2% and the fresh water is only about 2.8%. Out of this 2.8%, about 2.2% is available as surface water and the remaining 0.6% as groundwater. From this 2.2% of surface water, 2.15% is available in the form of glaciers and icecaps, 0.01% in lakes and streams and the remaining 0.04% is in other forms. Only about 0.25% of the total ground water of 0.6% can be



Water on the Earth

economically extracted with the present drilling technology.

Water resources are useful or potentially useful to humans. Water in India is available in three sources. They are **precipitation, surface water** and **groundwater**.

Table 1: Estimated Volume of Water on the Earth's Surface

Water Source	Volume of water (Cubic Miles)	Percentage to Total Water
Oceans, Seas, & Bays	321,000,000	96.54
Ice caps, Glaciers, & Permanent Snow	5,773,000	1.74
Groundwater	5,614,000	1.69
Soil Moisture	3,959	0.001
Ground Ice & Permafrost	71,970	0.022
Lakes	42,320	0.013
Atmosphere	3,095	0.001
Swamp Water	2,752	0.0008
Rivers	509	0.0002
Biological Water	269	0.0001

(*Source: Shiklomanov, 1993*)

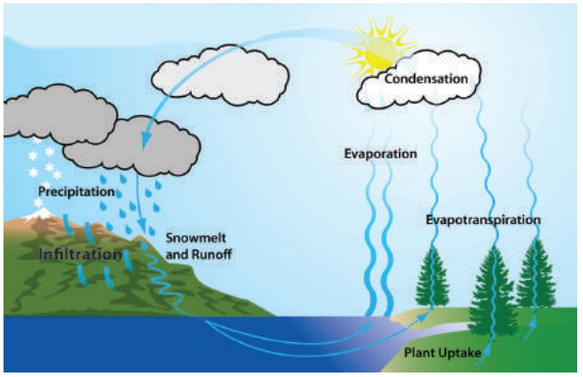
Hydrologic Cycle or Water Cycle

Hydrology is the science which deals with the various aspects of water such as its occurrence, distribution, movement and properties on the planet earth. Availability of water on the earth is not uniform. Some places are very rich and some places are poor in water resources.

Hydrologic cycle is a global sun-driven process where water is transported from oceans to atmosphere, from atmosphere to land and from land back to oceans. The water cycle can be considered as a closed system for the earth, as the quantity of water involved in the cycle is invariable, though its distribution varies over space and time.

Evaporation takes place from the surface water and transpiration from the plants. Water vapour gets condensed at higher altitudes by condensation nuclei and form clouds. The clouds melt and sometimes burst resulting in precipitation of different forms. A part of water from precipitation flows over the land is called runoff and the other part infiltrates into the soil which builds up the groundwater.

Hydrologic cycle is a circulation of water. It is a continuous process and takes place naturally. The three important phases of the hydrologic cycle are: **1) Evapotranspiration, 2) Precipitation** and **3) Runoff**.



Hydrologic Cycle

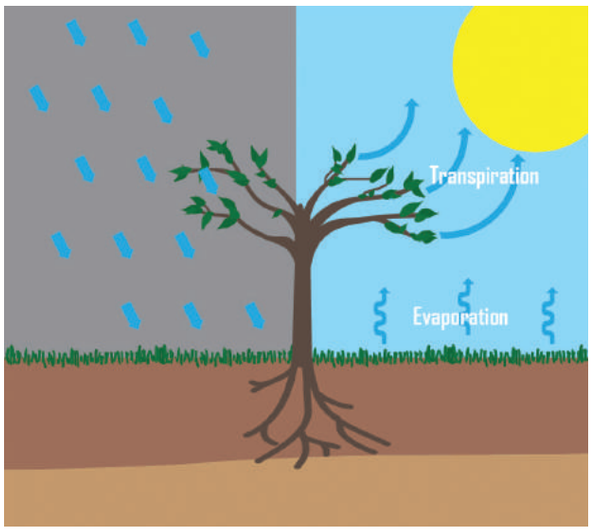
Components of Hydrologic Cycle

There are six main components in hydrologic cycle. They are: 1) Evapotranspiration, 2) Condensation, 3) Precipitation, 4) Infiltration, 5) Percolation, and 6) Runoff.

Evapotranspiration

It is defined as the total loss of water from the earth through evaporation from the surface water bodies and the transpiration from vegetation. In cropped area, it is difficult to determine the evaporation and transpiration separately. Therefore it is collectively called as evapotranspiration. The following part explains the process of evaporation and transpiration separately.

LAIT74



Evapotranspiration

(a) Evaporation

Evaporation refers to the process in which the liquid form of water changes into gaseous form. Water boils at 100°C (212°F) temperature but, it actually begins to evaporate at 0°C (32°F); and the process takes place very slowly. Temperature is the prime element which affects the rate of evaporation. There is a positive relationship between these two variables. Areal extent of surface water, wind and the atmospheric humidity are the other variables which affect the rate of evaporation.

The atmosphere gets nearly 90% of moisture from the oceans, seas, lakes and rivers through evaporation and 10% of the moisture from plants through transpiration.

On a global scale, the amount of water gets evaporated is about the same as the amount of water delivered to earth as precipitation. This process varies geographically, as the evaporation is more prevalent over the oceans than precipitation, while over the land, precipitation routinely exceeds evaporation. The rate of evaporation is low during the periods of calm winds than during windy times. When the air is calm, evaporated water tends to stay close to the water body. During windy, the water vapour is driven away and is replaced by dry air which facilitates additional evaporation.

DO YOU KNOW?

The rate of evaporation increases with

- Increase in wind speed
- Increase in temperature
- Decrease in humidity and
- Increase in areal extent of surface water bodies.

(b) Transpiration

Transpiration refers to the process by which the water content in the plants are released into the atmosphere in the form of water vapour. Much of the water taken up by plants is released through transpiration. The rate of transpiration is also affected by the temperature, wind and humidity. The rate of transpiration is also affected by nature of vegetation and the matheod of cultivation of crops

(c) Condensation

It refers to the process in which the gaseous form of water changes into liquid form. Condensation generally occurs in the atmosphere when warm air rises, cools and loses its capacity to hold water vapour. As a result, excess water vapour condenses to form cloud droplets. Condensation is responsible for the formation of clouds. These clouds produce precipitation which is the primary route for water to return to the earth's surface in the water cycle. Condensation is the opposite of evaporation.

Forms of Condensation

Dew, frost, fog, mist and clouds are the different forms of condensation.

a) **Dew:** It is a water droplet formed by the condensation of water vapour on a relatively cold surface of an object. It forms when the temperature of an object drops below the dew point temperature.

b) **Frost:** The ice crystals formed by deposition of water vapour on a relatively cold surface of an object is known as frost. It forms when the temperature of an object drops below the freezing point of temperature.

c) **Fog:** Fog is the suspended tiny water droplets or ice crystals in an air layer next to the earth's surface that reduces the visibility to 1,000 m or lower. For aviation purposes, the criterion for fog is 10 km or less.

d) **Mist:** Mist is the tiny droplets of water hanging in the air. These droplets form when the water vapour in the air is rapidly cooled, causing it to change from invisible gas to tiny visible water droplets. Mist is less dense than fog.

e) **Clouds:** Clouds consist of tiny water droplets/ice particles which are so small and light in weight. Clouds are formed by microscopic drops of water or by small ice crystals. The size of the droplets generally range from a couple of microns to 100 microns. When the size of the water droplets exceeds 100 microns, it becomes rain drops.

- Condensation occurs when the air get saturated.
- Warm air can hold more water vapour than the cool air.
- Saturation occurs when the temperature drops down.

Precipitation

Precipitation refers to all forms of water that fall from clouds and reaches the earth's surface. For the occurrence of precipitation, cloud droplets or ice crystals must grow heavy enough to fall through the air. When the droplets grow large in size, they tend to fall. While moving down, by collecting some small droplets, they become heavy enough to fall out of the cloud as raindrops.

Forms of Precipitation

The form of precipitation in a region depends on the kind of weather or the climate of the region. The precipitation in the warmer parts of the world is always in the form of rain or drizzle. In colder regions, precipitation may fall as snow or ice. Common types of precipitation are rain, sleet, freezing rain, hail and snow.

Rain: The most common kind of precipitation is rain. The precipitation in the form of water droplets is called rain. The precipitation in which the size of rain drops are <0.5 mm in diameter is known as drizzle and the rain drops with >0.5 mm in diameter is known as rain. Generally drizzle takes place from stratus clouds.

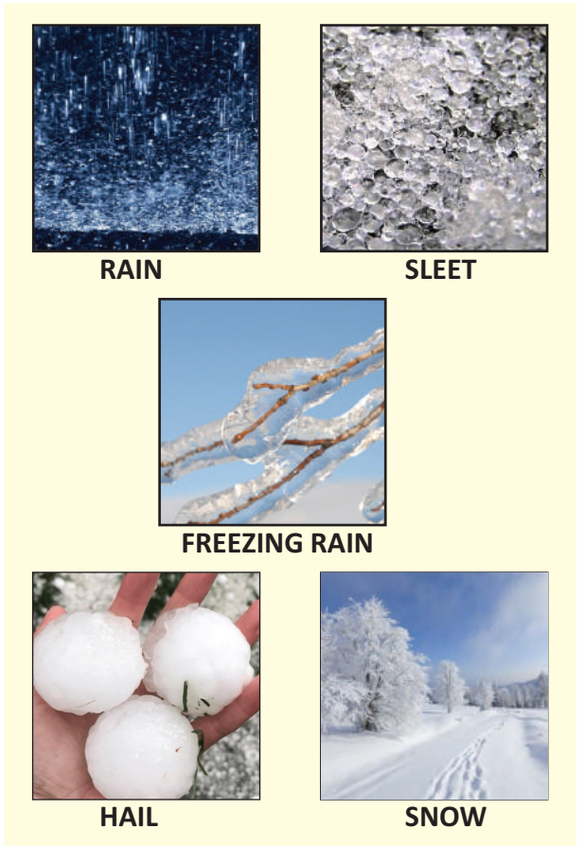
Sleet: The precipitation which takes place in the form of mixture of water droplets and tiny particles of ice(5mm in diameter) is known as sleet. Sometimes raindrops fall through a layer of air below 0°C, the freezing point of water. As they fall, the raindrops freeze into solid particles of ice. So, the mixture of water droplets and ice particles would fall on the earth surface.

Freezing Rain: Some times raindrops falling through cold air near the ground do not freeze in the air. Instead, the raindrops freeze when they touch a cold surface. This is called freezing rain and the drops of water are usually greater than 0.5 mm in diameter.

Hail: The precipitation which consists of round pellets of ice which are larger than 5 mm in diameter is called hail or hailstones. Hail forms only in cumulonimbus clouds during thunderstorms. A hailstone starts as an ice pellet inside a cold region of a cloud. Strong updrafts in the cloud carry the hailstone up and down through the cold region many times.

Snow: Often water vapour in a cloud is converted directly into snow pieces due to lowering of temperature. It appears like a

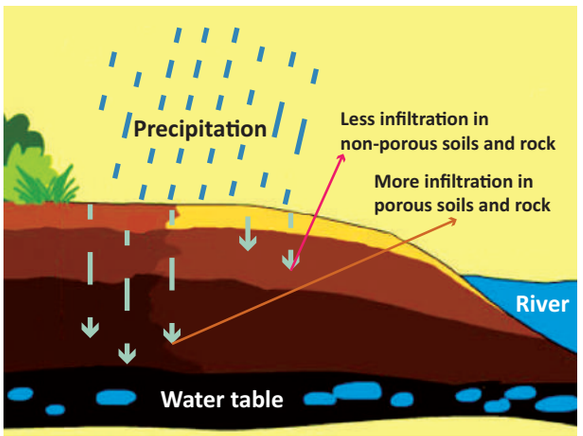
powdery mass of ice. The precipitation in the form of powdery mass of ice is known as snowfall. It is common in the polar and high mountainous regions.



Different forms of Precipitation

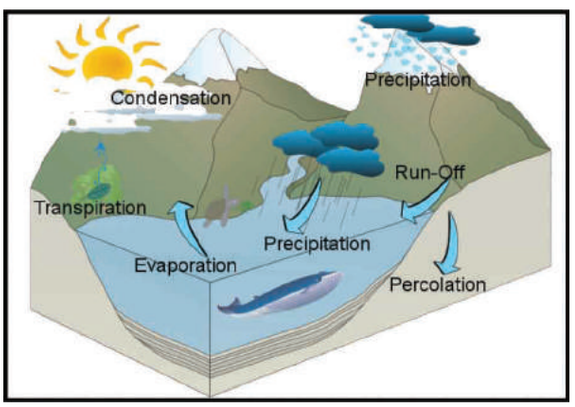
Infiltration

Water entering the soil at the surface of the ground is termed as infiltration. Infiltration allows the soil temporarily to store water, making it available for plants use and organisms in the soil. Infiltration is an important process where rain water soaks into the ground, through the soil and underlying rock layers. Some of this water ultimately returns to the surface through springs or low spots down hills. Some of the water remains underground and is called groundwater. The rate of infiltration is influenced by the physical characteristics of the soil, vegetative cover, moisture content of the soil, soil temperature and rainfall intensity. The terms infiltration and percolation are often used interchangeably.



Infiltration Process

Percolation



Percolation Process

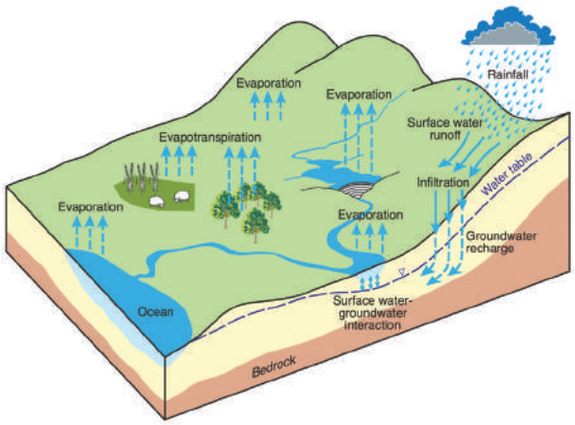
Percolation is the downward movement of infiltrated water through soil and rock layers. Infiltration occurs near the surface of the soil and delivers water from the surface into the soil and plant root zones. Percolation moves the infiltrated water through the soil profile and rock layers which leads to the formation of ground water or become a part of sub-surface run-off process. Thus, the percolation process represents the flow of water from unsaturated zone to the saturated zone.

Runoff

Runoff is the water that is pulled by gravity across land's surface. It replenishes groundwater and surface water as it percolates into an aquifer (it is an underground layer of water-bearing rock) or moves into a river, stream or watershed. It comes from unabsorbed water from rain, snowmelt,

irrigation or other sources, comprising a significant element in the water cycle as well as the water supply when it drains into a watershed.

Runoff is also a major contributor to the erosion which carves out canyons, gorges and related landforms. The rate of runoff that can happen depends on the amount of rainfall, porosity of soil, vegetation and slope. Only about 35% of precipitation ends up in the sea or ocean and the other 65% is absorbed into the soil.



Runoff Process

Types of Runoff

Based on the time interval between the instance of rainfall and generation of runoff, the runoff may be classified into following three types

i) **Surface Runoff:** It is the portion of rainfall, which enters the stream immediately after the rainfall. It occurs, when the rainfall is longer, heavier and exceeds the rate of infiltration. In this condition the excess water makes a head over the ground surface, which tends to move from one place to another following land gradient and is known as overland flow. When the overland flow joins the streams, channels or oceans, it is termed as surface runoff or surface flow.

ii) **Sub-Surface Runoff:** The water that has entered the subsoil and moves laterally without joining the water-table to the streams, rivers or oceans is known as sub-surface runoff. The sub-surface runoff is usually referred as interflow.

iii) **Base Flow:** It is a flow of underground water from a saturated ground water zone to a water channel. It usually appears at a downstream location where the channel elevation is lower than the groundwater table. Groundwater provides the stream flow during dry periods of small or no precipitation.

Units of the Measurement pertaining to Hydrology

- Evaporation /interception - inches (or) cm
- Infiltration - inches (or) cm / hour
- Precipitation - inches (or) mm (or) cm
- Run off - inches (or) mm (or) cm
- Run off rate - cubic feet per second
- Run off volume - acre feet (or) cubic feet
- Storage - cubic feet (or) acre feet

Recap

- Water is one of the most important elements on earth. All plants and animals need water for survival.
- About 71% of the earth's surface is covered by water. Out of this, only about 2.8% is fresh water and the remaining 97.2% is saltwater found in seas and oceans.
- Hydrological cycle is a global sun-driven process where water is transported from oceans to atmosphere, from atmosphere to land and from land back to oceans.
- There are six main components in hydrologic cycle. They are evapotranspiration, condensation, precipitation, infiltration, percolation, and runoff.
- The precipitation in the warmer parts of the world is in the form of rain or drizzle. The common types of precipitation include rain, sleet, freezing rain, hail, and snow.
- Infiltration occurs near the surface of the soil and delivers water from the surface into the soil and plant rooting zone. Percolation moves it through the soil profile and rock layers to form groundwater.

GLOSSARY		
Aquifer	It is an underground layer of water - bearing permeable rocks, rock fractures or unconsolidated materials (gravel, sand or silt)	நீர்கொள்பாறை
Evapotranspiration	It refers to the water lost through evaporation from the water bodies and transpiration from vegetation	ஆவியீர்ப்பு
Infiltration	the seepage of water into soil or rock	நீர் ஊடுருவல்
Percolation	the slow movement of water through the pores in soil	நீர் உட்கசிதல்
Precipitation	falling products of condensation in the atmosphere, as rain, snow, or hail	பொழிவு
Runoff	overflow	நீர் வழிந்தோடல்

Evaluation

I Choose the Correct answer

1. The process in which the water moves between the oceans, atmosphere and land is called
   a) River Cycle b) Hydrologic Cycle
   c) Rock Cycle d) Life Cycle
2. The percentage of fresh water on the earth is
   a) 71 b) 97
   c) 2.8 d) 0.6
3. The process of changing of water from gaseous to liquid form is known as
   a) Condensation b) Evaporation
   c) Sublimation d) Rainfall
4. Water that flows in the sub-soil or through the ground into the streams, rivers, lakes and oceans is termed as
   a) Condensation b) Evaporation
   c) Transpiration d) Runoff
5. The evaporation of water from the leaves of plants is called
   a) Transpiration b) Condensation
   c) Water vapour d) Precipitation
6. Water that is good enough to drink is called
   a) Groundwater b) Surface water
   c) Potable water d) Artesian water

II Fill in the blanks

1. The degree of water vapour present in the atmosphere is known as_____.
2. There are _____ phases in the water cycle.
3. The falling of water towards the earth surface from atmosphere in any form is known as _____.
4. The precipitation with the rain drop size of<0.5mm in diameter is known as _____.
5. Mist is denser than _____.

III Match the following

1.	Vegetation	Clouds
2.	Condensation	Sleet
3.	Snow and rain drops	At the surface
4.	Infiltration	Transpiration

IV Choose the correct statement

1. Evaporation refers to
   I. The process in which the gaseous form of water changes in to liquid form.

II. It refers to the process in which the liquid form of water changes into gaseous form.

III. Water boils at 100°C temperature but, it actually begins to evaporate at 0°C.

IV. It is responsible for the formation of clouds.

a) I and IV are correct

b) II only correct

c) II and III are correct

d) All are correct

V State whether the following statements are True or False

1. Water boils at 212°F temperature but, it begins to evaporate at 32°F.
2. Mist is not the tiny droplets of water hanging in the air.
3. The sub-surface runoff is usually referred as interflow.

VI Answer briefly

1. Write a short note on aquifer.
2. Define " hydrological cycle".
3. How is the dew formation takes place?
4. Write a short note on surface run-off.

VII Give reasons

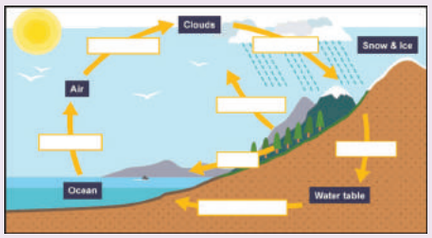
1. Infiltration of water is low in the region of non-porous soil.
2. Fresh water is less on the earth.
3. Snowfall is common in the polar region and mountainous regions.

VIII Answer in a paragraph

1. Explain the different stages involved in the hydrological cycle.
2. Distinguish between evaporation and transpiration.
3. Give a detailed explanation on different forms of precipitation.
4. Explain the run-off and its types.

ACTIVITY

Find out the missing components of hydrologic cycle in the given diagram and fill it up appropriately.



REFERENCES BOOK

1. Davie, T. (2008). *Fundamentals of Hydrology* (Second Edition – Routledge Fundamentals of Physical Geography Series). Routledge - Taylor & Francis Group, New York.
2. Musy, A. and Higy, C. (2011). *Hydrology: A Science of Nature Science* Publishers, Enfield.
3. Raghunath, H.M. (2006). *Hydrology – Principles, Analysis and Design* (Revised Second Edition). New Age International (P) Limited, Publishers, New Delhi.
4. Rakhecha, P.R. and Singh, V.P. (2009). *Applied Hydrometeorology,* Springer Publishing Company, Dordrecht and Capital Publishing Company, New Delhi.
5. Viessman, W. (Jr), Lewis, G.L. (2003). *Introduction to Hydrology* (Fifth Edition). Prentice-Hall of India Private Limited, New Delhi.

INTERNET RESOURCES

- http://www.fao.org/docrep/X0490E/x0490e04.htm.
- https://www.sciencelearn.org.nz (University of Waikato).
- https://cals.arizona.edu/azmet/etowhat1.pdf.
- https://pmm.nasa.gov/education/sites/default/files/lesson_plan_files/evaporation_investigation_lesson_plan.pdf.
- https://www.watereducation.org/aquapedia-background/runoff.