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Programme: M.Sc., Environmental Science

Course Title: Water, Soil Pollution and management

Course Code : CC04

Unit-I

Sources of Water and Pollution

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Hydrological cycle

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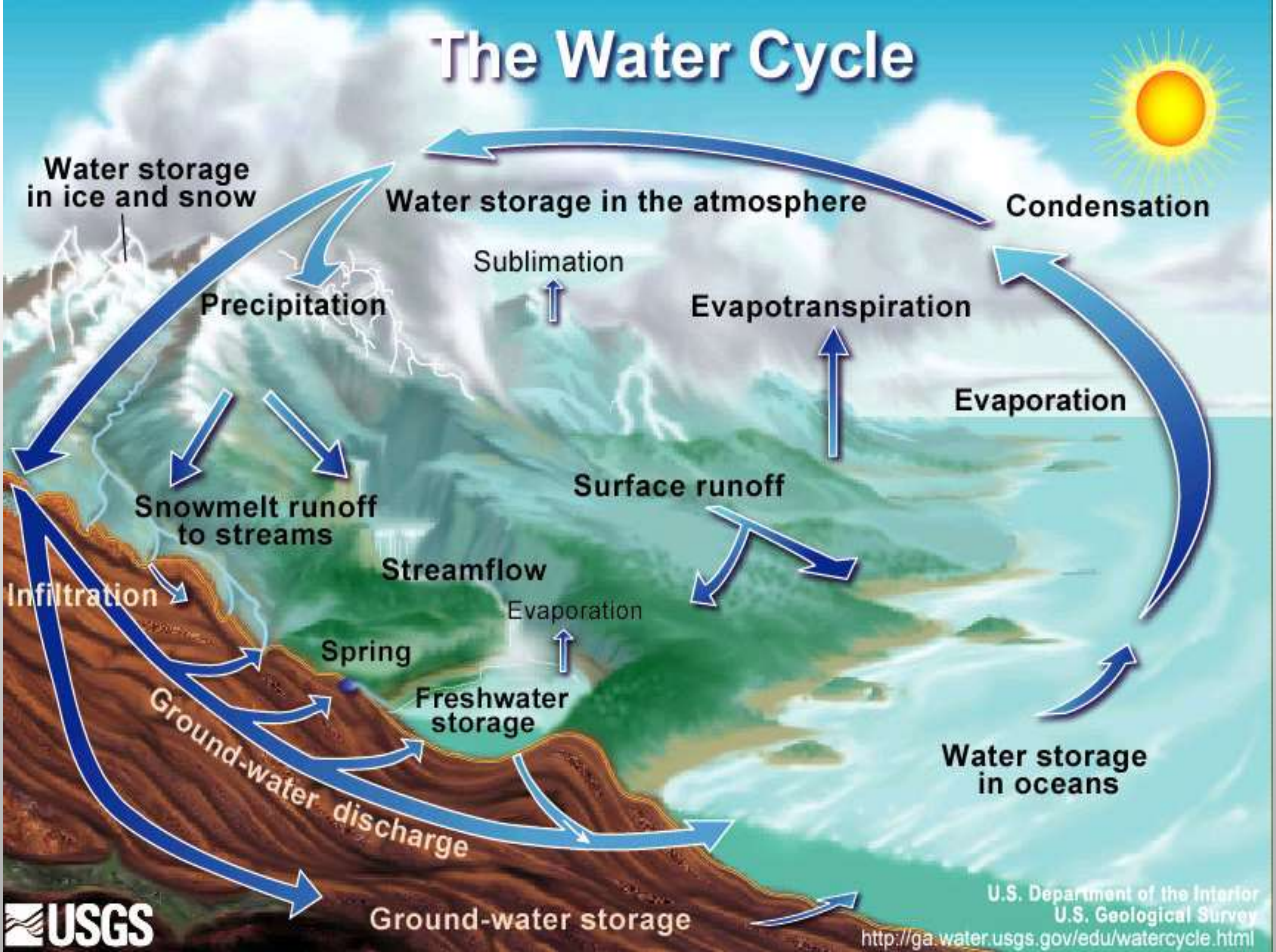

The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Sublimation
Precipitation
Evapotranspiration
Evaporation
Surface runoff
Snowmelt runoff to streams
Streamflow
Infiltration
Evaporation
Spring
Freshwater storage
Ground-water discharge
Water storage in oceans
Ground-water storage
USGS
U.S. Department of the Interior
U.S. Geological Survey
http://ga.water.usgs.gov/edu/watercycle.html

- The global water cycle can be described with nine major physical processes which form a continuum of water movement.
- Complex pathways include the passage of water from the gaseous envelope around the planet called the atmosphere, through the bodies of water on the surface of earth such as the oceans, glaciers and lakes, and at the same time (or more slowly) passing through the soil and rock layers underground.
- Later, the water is returned to the atmosphere. A fundamental characteristic of the hydrologic cycle is that it includes the following processes: evaporation, condensation, precipitation, interception, infiltration, percolation, transpiration, runoff and storage.

EVAPORATION

- Evaporation occurs when the physical state of water is changed from a liquid state to a gaseous state. A considerable amount of heat, is exchanged during the change of state.
- The change from solid to liquid is called or melting.- To melt 1 gram of ice requires 80 calories. (A calorie is defined as the amount of energy needed to raise one gram of water by 1°C.)
- The change from liquid to ice is called solidification. This process will release 80 calories per gram.
- The change from liquid to vapor is called evaporation. This process requires 600 calories.

- Typically, solar radiation and other factors such as air temperature, wind, and atmospheric pressure affect the amount of natural evaporation that takes place in any geographic area.
- Evaporation can occur on raindrops, and on free water surfaces such as seas and lakes. It can even occur from water settled on vegetation, soil, rocks and snow.
- There is also evaporation caused by human activities. Evaporated moisture is lifted into the atmosphere from the ocean, land surfaces, and water bodies as water vapor. Some vapor always exists in the atmosphere.

CONDENSATION

- Condensation is the process by which water vapor changes it's physical state from a vapor, most commonly, to a liquid. Water vapor condenses onto small airborne particles to form dew, fog, or clouds.
- The most active particles that form clouds are sea salts, atmospheric ions caused by lightning and combustion products containing sulfurous and nitrous acids.
- Condensation is brought about by cooling of the air or by increasing the amount of vapor in the air to its saturation point. When water vapor condenses back into a liquid state, the same large amount of heat (600 calories of energy per gram) that was needed to make it a vapor is released to the environment.

PRECIPITATION

- Precipitation is the process that occurs when all forms of water particles fall from the atmosphere and reach the ground. There are two sub-processes that cause clouds to release precipitation, the coalescence process and the ice-crystal process.

There are two processes in which meteorologists and scientists say precipitation forms:

1) Collision and Coalescence Process
2) Ice-Crystal Process

- **Rain**: Water vapor condenses into liquid water droplets forming clouds. These *droplets coalesce* (join together) and become heavy enough to be pulled down by gravity as precipitation and do not evaporate before they hit the ground as a raindrop.

  H_2O_V ---------------------> liquid water ------------------> rain
  (Clouds)

  * **Snow**: Water vapor condenses into liquid water droplets forming clouds. But also within the clouds **water vapor changes to *ice crystals by deposition***. These ice crystals coalesce (join together) and become heavy enough to be pulled down by gravity as precipitation and do not melt before they hit the ground as a snowflake.

  H_2O_V ---------------------> ice crystals ----------------------------> snow
  (Clouds)

- Cloud droplet average size is about 20 microns in diameter & fall very slowly, about 1000 m/48 hrs. Thus they usually evaporate.

- Collision and coalescence involve interaction of liquid water droplets with other liquid water droplets - it is most important in clouds with temperatures above freezing - hence the name "warm rain process" . The maximum size a raindrop will achieve is about 5 mm. If it gets bigger, then it gets pulled apart by friction and drag forces as it falls. It occurs in tropical climates.
- **Fall or Terminal Velocities of Cloud droplets and Raindrops:**

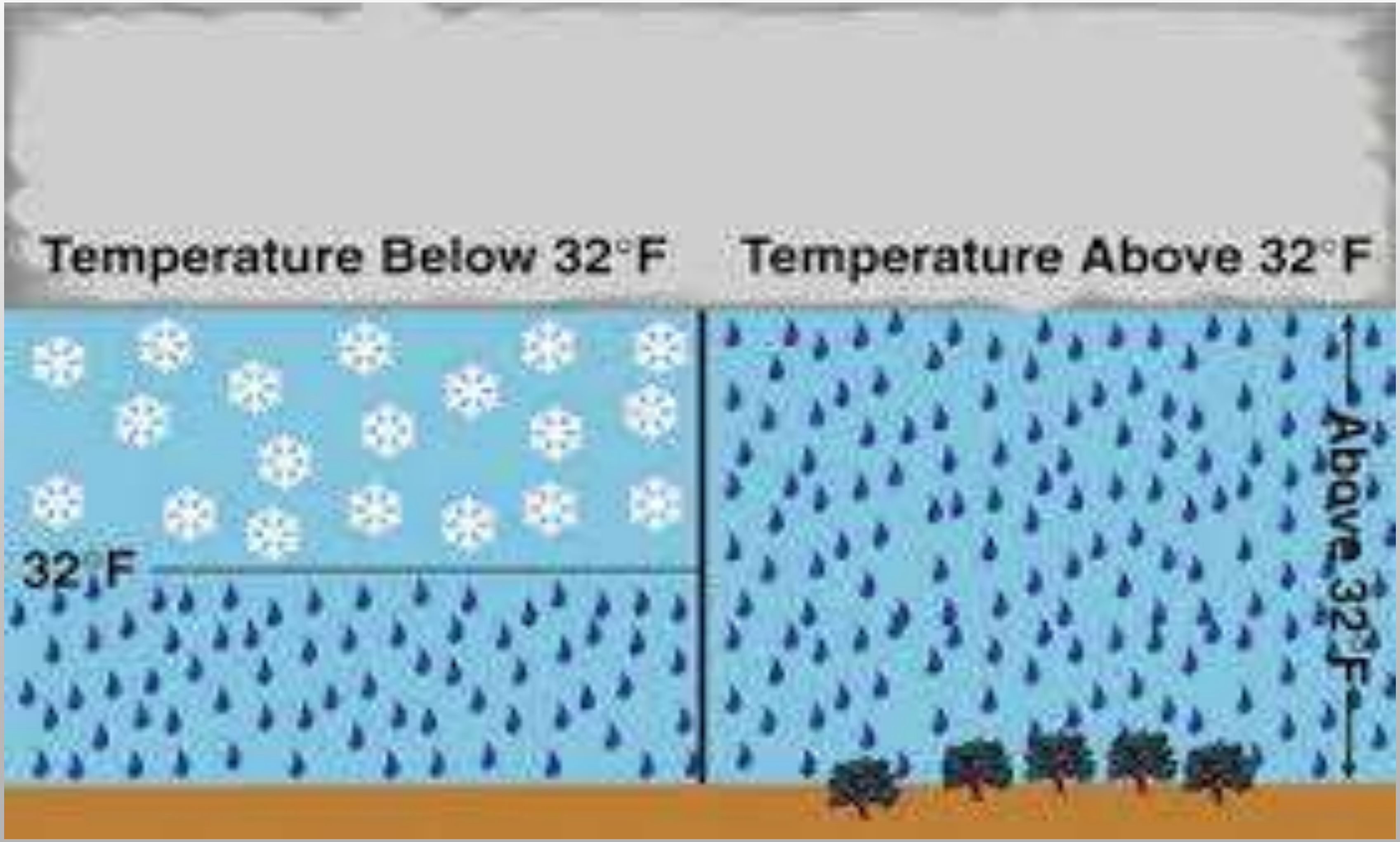
Type	**Diameter (mm)**	**Velocity (kph)/(mph)**
Typical cloud droplet	0.02	.04 / .03
Drizzle	0.5	7 / 4
Raindrop	2 - 5	23 - 33 / 14 - 20

- So, in this process, the **water vapor gets converted to raindrop**.

(gas) (liquid)

- The **Bergeron process** is most important in clouds with temperatures below freezing. It involves interactions between ice particles, supercooled water, and water vapor - hence the name "three-phase process").
- Need freezing nuclei to initiate change of water vapor to solid (ice) and thus need Tºs below -10ºC, where both liquid drops & ice crystals can exist.
- The basic process is water vapor changing to ice crystals by deposition, and these ice crystals joining with other ice crystals to make snow crystals & then snowflakes.
- If they melt while falling, then they become a raindrop.
- So, **in this process, water vapor gets converted to ice crystal to raindrop**.
  (gas) (solid) (liquid)

Comparison of **collision** and **coalescence**, and **Bergeron** process



INTERCEPTION

- Interception is the process of interrupting the movement of water in the chain of transportation events leading to streams. When rain first begins, the water striking leaves and other organic materials spreads over the surfaces in a thin layer or it collects at points or edges.
- When the maximum surface storage capability on the surface of the material is exceeded, the material stores additional water in growing drops along its edges. Eventually the weight of the drops exceed the surface tension and water falls to the ground.
- Wind and the impact of rain drops can also release the water from the organic material. The water layer on organic surfaces and the drops of water along the edges are also freely exposed to evaporation.
- Additionally, interception of water on the ground surface during freezing and sub-freezing conditions can be substantial. The interception of falling snow and ice on vegetation also occurs.

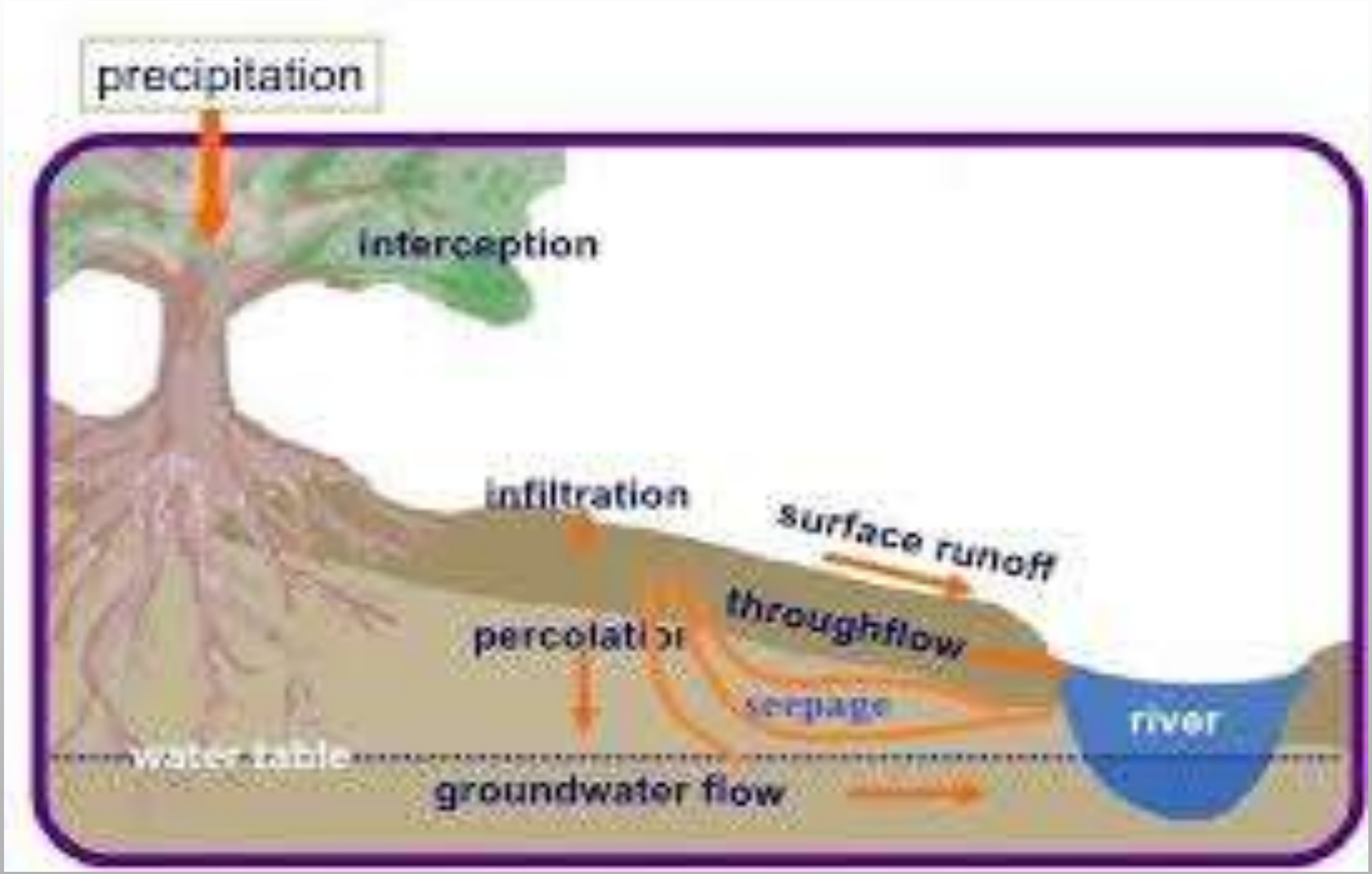
Interception

INFILTRATION

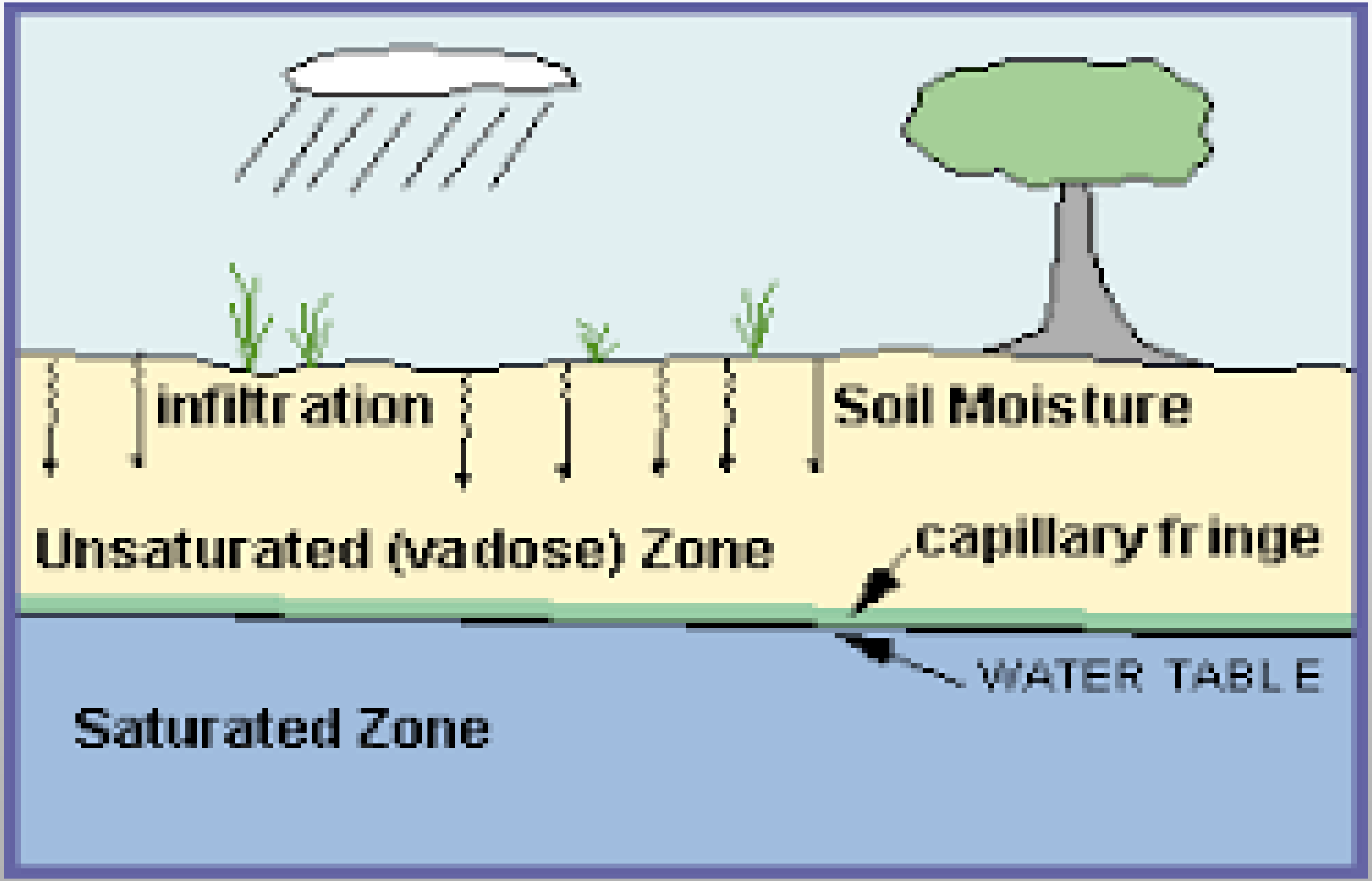
- Infiltration is the physical process involving movement of water through the boundary area where the atmosphere interfaces with the soil. The surface phenomenon is governed by soil surface conditions.
- Water transfer is related to the porosity of the soil and the permeability of the soil profile. Typically, the infiltration rate depends on the puddling of the water at the soil surface by the impact of raindrops, the texture and structure of the soil, the initial soil moisture content, the decreasing water concentration as the water moves deeper into the soil filling of the pores in the soil matrices, changes in the soil composition, and to the swelling of the wetted soils that in turn close cracks in the soil.
- Water that is infiltrated and stored in the soil can also become the water that later is evapo transpired or becomes subsurface runoff.

PERCOLATION

- Percolation is the movement of water though the soil, and it's layers, by gravity and capillary forces. The prime moving force of groundwater is gravity. Water that is in the zone of aeration where air exists is called vadose water. Water that is in the zone of saturation is called groundwater.
- For all practical purposes, all groundwater originates as surface water. Once underground, the water is moved by gravity. The boundary that separates the vadose and the saturation zones is called the water table.
- Usually the direction of water movement is changed from downward and a horizontal component to the movement is added that is based on the geologic boundary conditions.
- Geologic formations in the earth's crust serve as natural subterranean reservoirs for storing water. Others can also serve as conduits for the movement of water.
- Essentially, all groundwater is in motion. Some of it, however, moves extremely slowly. A geologic formation which transmits water from one location to another in sufficient quantity for economic development is called an aquifer. The movement of water is possible because of the voids or pores in the geologic formations. Some formations conduct water back to the ground surface. A spring is a place where the water table reaches the ground surface.


precipitation
interception
infiltration
surface runoff
throughflow
percolation
seepage
river
water table
groundwater flow

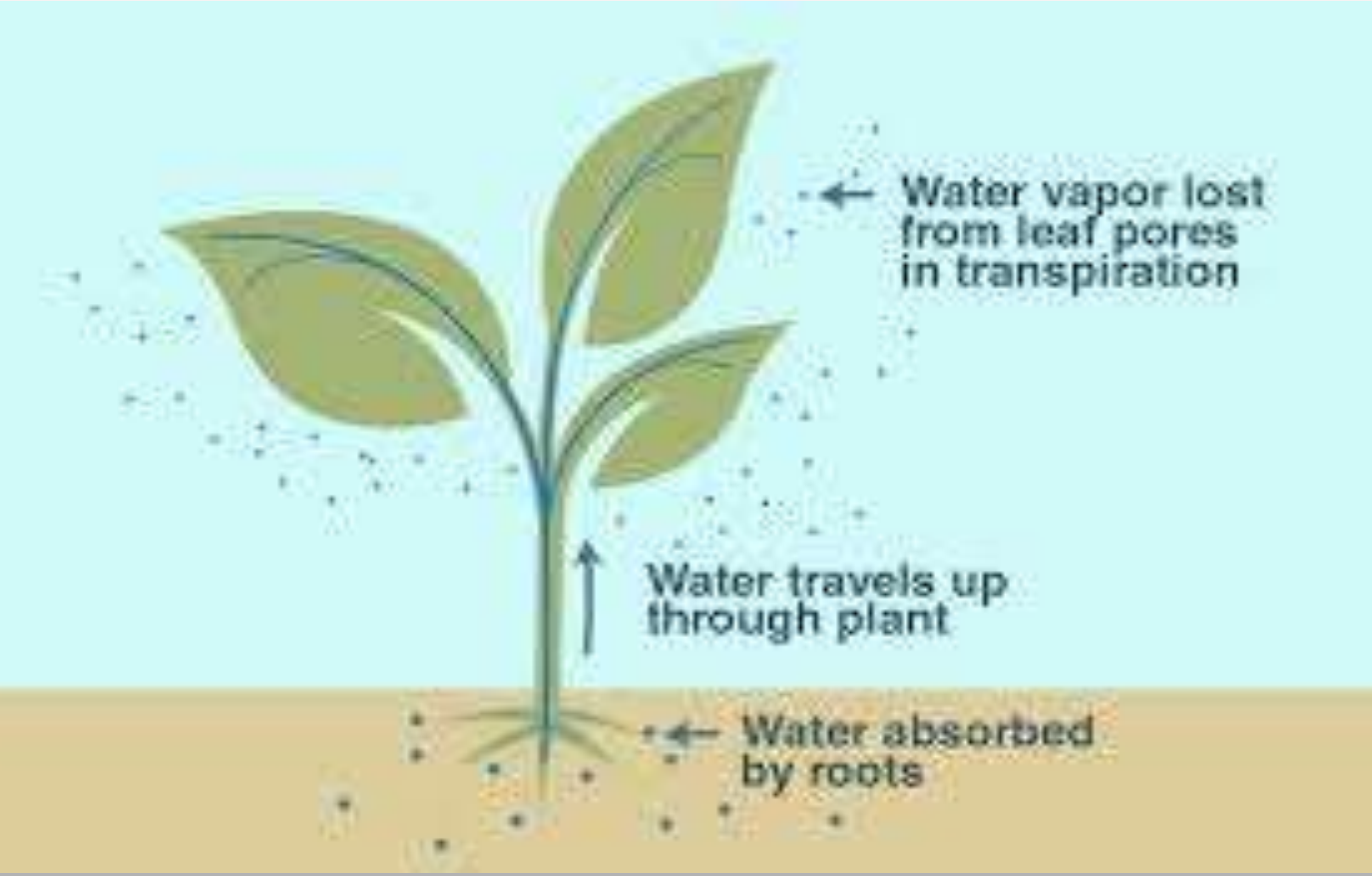
Groundwater



TRANSPIRATION

- Transpiration is the biological process that occurs mostly in the day. Water inside of plants is transferred from the plant to the atmosphere as water vapor through numerous individual leave openings.
- Leaves undergoing rapid transpiration can be significantly cooler than the surrounding air. Transpiration is greatly affected by the species of plants that are in the soil and it is strongly affected by the amount of light to which the plants are exposed.
- Water can be transpired freely by plants until a water deficit develops in the plant and it water-releasing cells (stomata) begin to close. Transpiration then continues at a must slower rate.

Transpiration



RUNOFF

- Runoff is flow from a drainage basin or watershed that appears in surface streams. It generally consists of the flow that is unaffected by artificial diversions, storages or other works that society might have on or in a stream channel.
- The flow is made up partly of precipitation that falls directly on the stream , surface runoff that flows over the land surface and through channels, subsurface runoff that infiltrates the surface soils and moves laterally towards the stream, and groundwater runoff from deep percolation through the soil horizons.
- When each of the component flows enter the stream, they form the total runoff. The total runoff in the stream channels is called streamflow and it is generally regarded as direct runoff or base flow.

WATER STORAGE

- There are three basic locations of water storage that occur in the planetary water cycle. Water is stored in the atmosphere; water is stored on the surface of the earth, and water stored in the ground. Water stored in the atmosphere can be moved relatively quickly from one part of the planet to another part of the planet.
- The type of storage that occurs on the land surface and under the ground largely depend on the geologic features related to the types of soil and the types of rocks present at the storage locations. Storage occurs as surface storage in oceans, lakes, reservoirs, and glaciers; underground storage occurs in the soil, in aquifers, and in the crevices of rock formations.
- On average, water the atmosphere is renewed every 16 days. Soil moisture is replaced about every year. Globally, waters in wetlands are replaced about every 5 years while the residence time of lake water is about 17 years. In areas of low development by society, groundwater renewal can exceed 1,400 years.
- The uneven distribution and movement of water over time, and the spatial distribution of water in both geographic and geologic areas, can cause extreme phenomena such as floods and droughts to occur.

- ESTIMATED GLOBAL WATER CYCLE
- TYPE OF LOCATION VOLUME PERCENT OF TOTAL
- WATER millions of millions of VOLUME
- cu. miles cu kilometer
- SALT WATER 97.00
- oceans 314.2 1308.0 (96.4%)
- saline bodies 2.1 8.7 (0.6%)
- FRESH WATER 2.90
- ice & snow 6.9 28.7 (2.1%)
- lakes 0.5 2.1 (0.15%)
- rivers 0.01 0.04 (0.003%)

  accessible
- groundwater 1.0 4.2 (0.31%)

- ATMOSPHERIC 0.10

- sea
- evaporation 0.1 0.42 (0.03%)

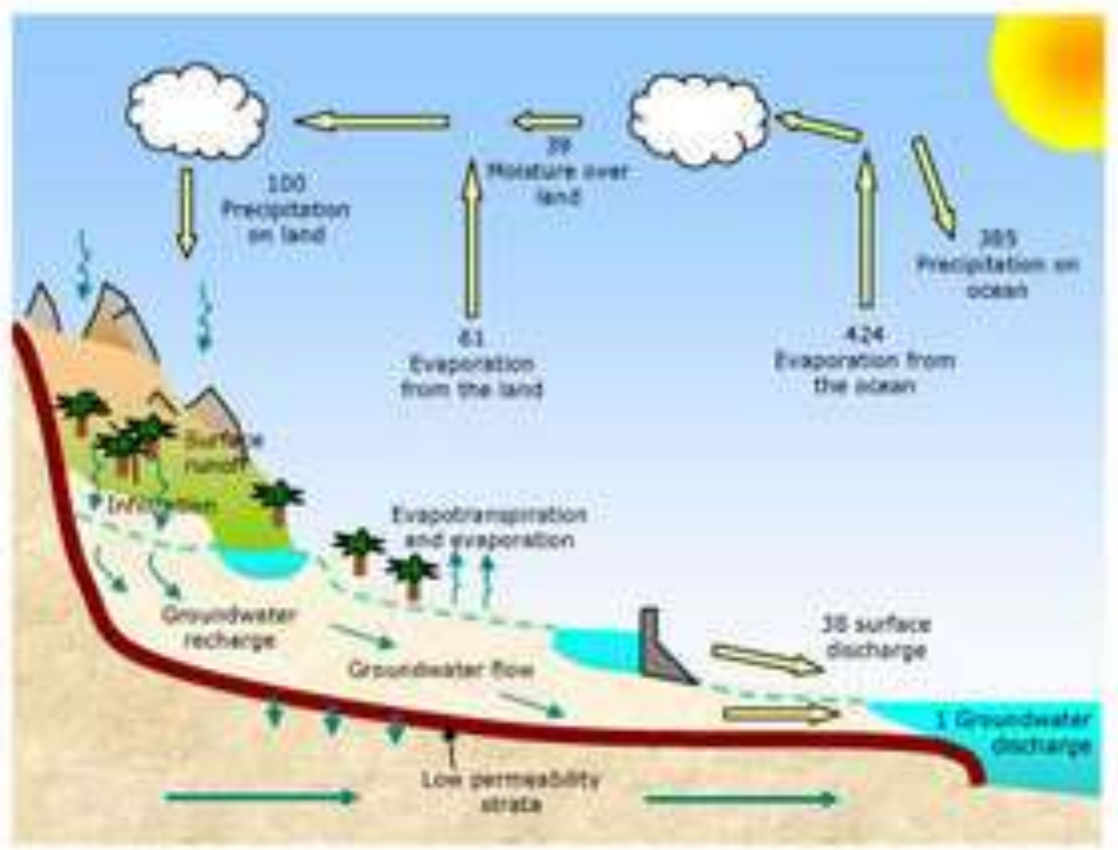
- land
- evaporation 0.05 0.21 (0.015%)

- precipitation
- over sea 0.09 0.37 (0.03%)

- precipitation
- over land 0.03 0.12 (0.01%)

- water vapor 0.005 0.02 (0.002%)
- ROUNDED TOTAL 326.00 1357.00 100.0

Figure illustrates yearly flow volumes in thousands of cubic kilometers.

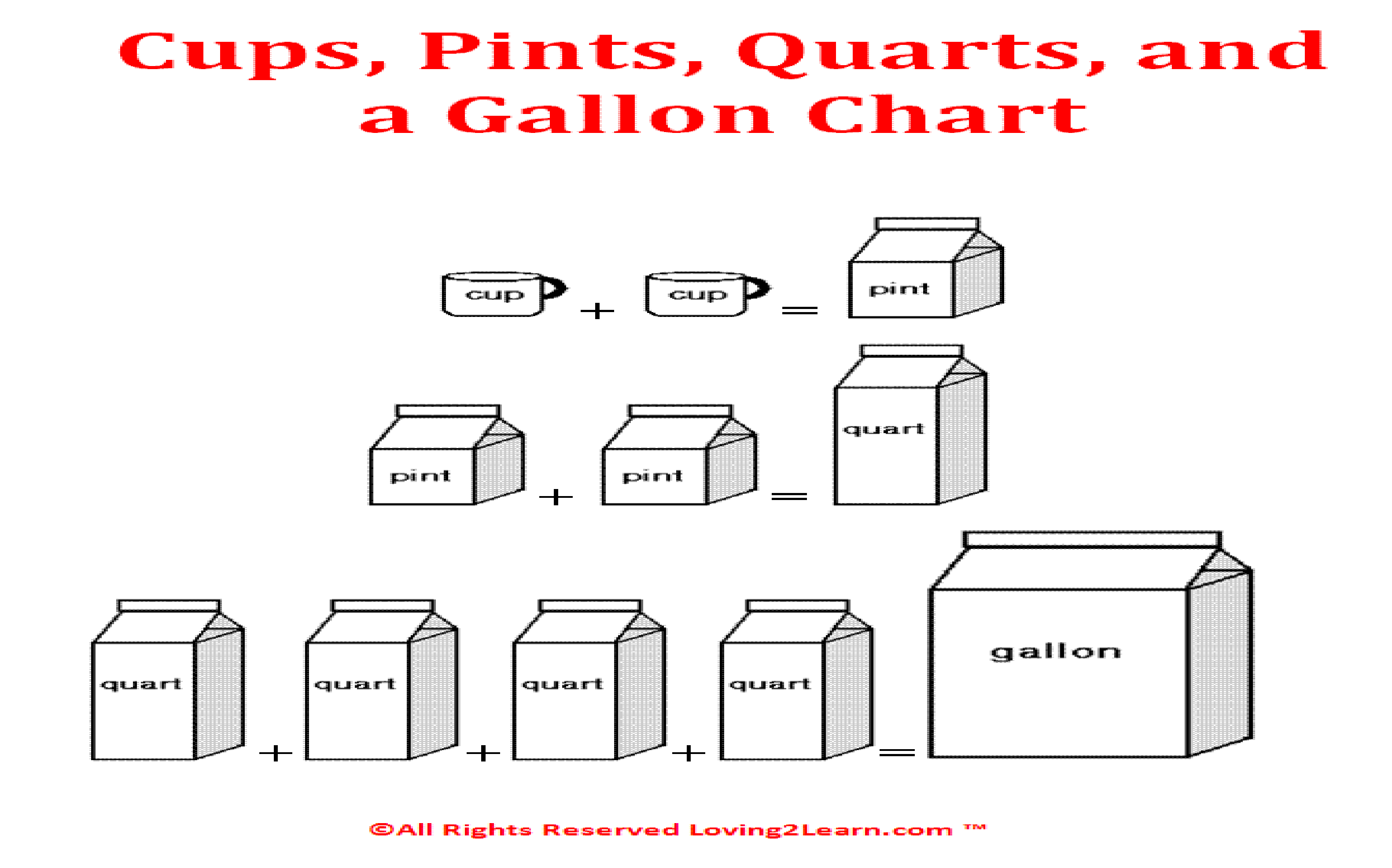


- *If a fifty-five gallon drum of water represented the total supply of water on the planet then:*

  a) the oceans would be represented by 53 gallons, 1 quart, 1 pint and 12 ounces;
  b) the icecaps and glaciers would represent 1 gallon, and 12 ounces;
  c) the atmosphere would contribute 1 pint and 4.5 ounces;
  d) groundwater would add up to 1 quart, and 11.4 ounces;
  e) freshwater lakes would represent one half ounce;
  f) inland seas and saline lakes would add up to over one third of an ounce;
  g) soil moisture and vadose water would total to about one fourth of an ounce;
  h) the rivers of the world would only add up to one-hundredth of an ounce (less than one one-millionth of the water on the planet).

Ref:https://www.nwrfc.noaa.gov/info/water_cycle/hydrology.cgi
https://water.usgs.gov/edu/watercyclesummary.html
hopkins.uga.edu/dir/GEOG1111/Lectures1111/LECT12Precip.htm

Conversion table



Thank you

Structure, polarity and properties of water

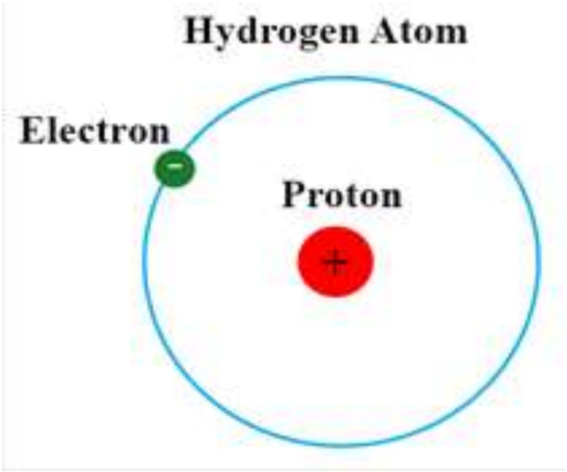
Dr.M.Vasanthy

Professor

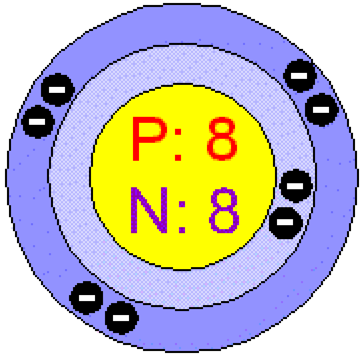
Structure of water

- Water has a simple molecular structure. There are 4 pairs of electrons surrounding the oxygen atom, two pairs involved in covalent bonds with hydrogen, and two unshared pairs on the opposite side of the oxygen atom.
- Oxygen is an "electronegative" or electron "loving" atom compared with hydrogen.
- A water molecule consists of two hydrogen atoms and one oxygen atom. The three atoms make an angle; the H-O-H angle is approximately 104.5 degrees.

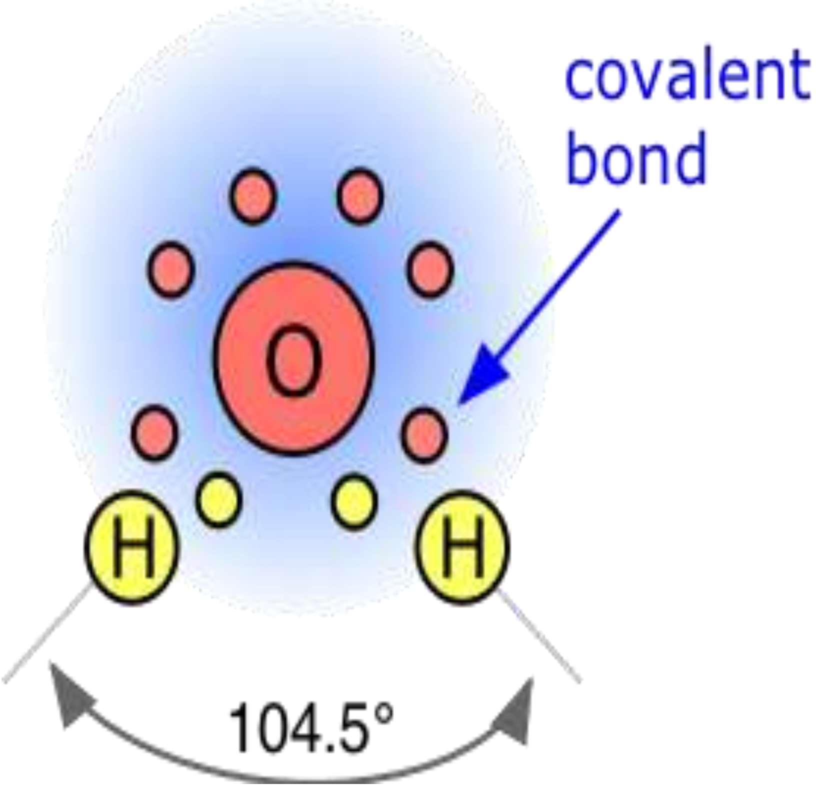
Hydrogen – atomic number-01 – 1 proton -1 electron



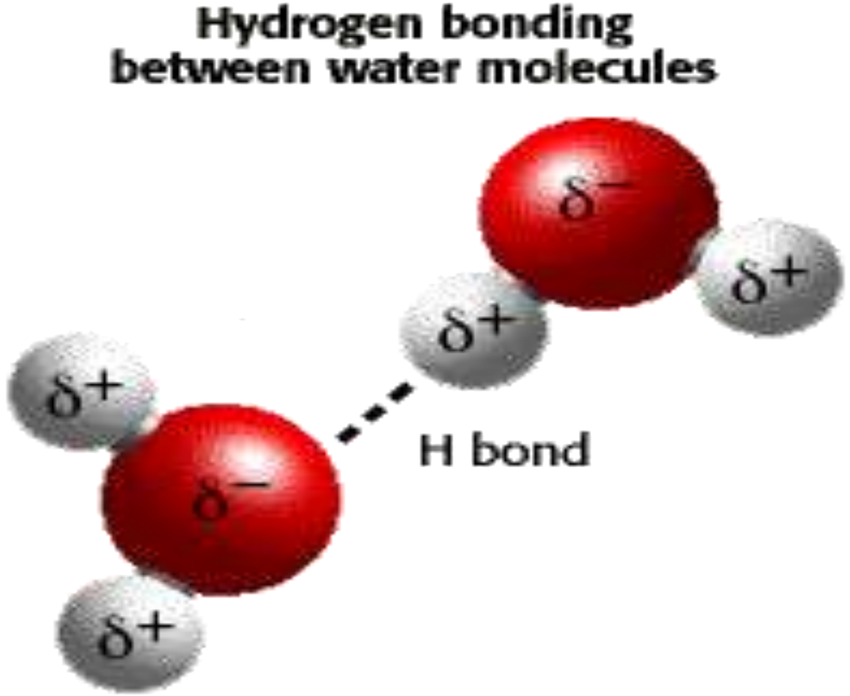
Oxygen – atomic number-08 – 8 proton 8 electron – 8 neutron



Structure of water molecule



Polarity of water molecule



Properties-The polarity of water

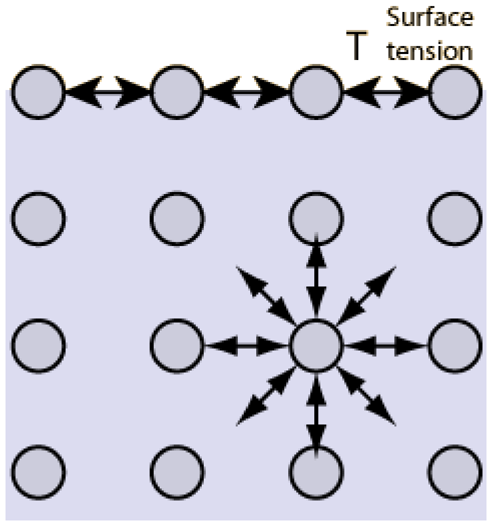
- Water is a "polar" molecule, meaning that there is an uneven distribution of electron density.
- Water has a partial negative charge (Delta-) near the oxygen atom due the unshared pairs of electrons, and partial positive charges (Delta+) near the hydrogen atoms.
- An electrostatic attraction between the partial positive charge near the hydrogen atoms and the partial negative charge near the oxygen results in the formation of a hydrogen bond.
- The ability of ions and other molecules to dissolve in water is due to polarity. Water acts as a polar solvent because it can be attracted to either the positive or negative electrical charge on a solute. The slight negative charge near the oxygen atom attracts nearby hydrogen atoms from water or positive-charged regions of other molecules. The slightly positive hydrogen side of each water molecule attracts other oxygen atoms and negatively-charged regions of other molecules.

Properties of water

- Water is termed as the "universal solvent" because water can dissolve more substances than any other liquid. Some substances, like common table salt (sodium chloride-NaCl), dissolve in water very easily. When placed in water, sodium chloride molecules fall apart. The positively charged sodium ion (Na^+) binds to oxygen, while the negatively charged chloride ion (Cl^-) attaches to hydrogen. This makes a very stable "salty" water molecule. This property of water allows for the transport of nutrients vital to life in animals and plants. A drop of rainwater falling through the air dissolves atmospheric gases.
- Surface Tension :Water molecules at the surface (next to air) hold closely together, forming an invisible film. The cohesive forces between liquid molecules are responsible for the phenomenon known as surface tension. Water's surface tension can hold weight that would normally sink. Some aquatic insects such as the water strider or pond skater rely on surface tension to walk on water. Next to mercury, water has the highest surface tension of all commonly occurring liquids. Surface tension is typically measured in dynes/cm. Water at 20°C has a surface tension of 72.8 dynes/cm compared to 22.3 for ethyl alcohol and 465 for mercury.

Cohesion and surface tension

- The cohesive forces between molecules down into a liquid are shared with all neighbouring atoms. Those on the surface have no neighbouring atoms above, and exhibit stronger attractive forces upon their nearest neighbours on the surface. This enhancement of the intermolecular attractive forces at the surface is called surface tension. https://www.khanacademy.org/science/biology/water-acids-and-bases/cohesion-and-adhesion/v/surface-tension



Water exhibits cohesion and adhesion properties

- Molecules in liquid state experience strong intermolecular attractive forces. When those forces are between like molecules, they are referred to as cohesive forces. For example, the molecules of a water droplet are held together by cohesive forces, and the especially strong cohesive forces at the surface constitute surface tension.
- When the attractive forces are between unlike molecules, they are said to be adhesive forces. The adhesive forces between water molecules and the walls of a glass tube are stronger than the cohesive forces lead to an upward turning meniscus at the walls of the vessel and contribute to capillary action.

- A water drop is composed of water molecules that like to stick together-an example of the property of cohesion. In the picture of pine needles, the water droplets are stuck to the end of the pine needles-an example of the property of adhesion.

- **Water meniscus is concave, mercury meniscus is convex**
- A meniscus can go up or down. It all depends on if the molecules of the liquid are more attracted to the outside material or to themselves. A concave meniscus, which is what you normally will see, occurs when the molecules of the liquid are attracted to those of the container.

Examples for surface tension

- **Walking on water:** Small insects such as the water strider can walk on water because their weight is not enough to penetrate the surface.
- **Floating a needle :** If carefully placed on the surface, a small needle can be made to float on the surface of water even though it is several times as dense as water. If the surface is agitated to break up the surface tension, then needle will quickly sink.

Thermal Properties

- water has a high **specific heat capacity**, which is defined as the amount of heat needed to raise the temperature of one gram of a substance by one degree Celsius. The amount of heat needed to raise the temperature of 1 g water by 1 °C is the **calorie**. Precisely, water has to absorb **4.184** Joules of heat for the temperature of one gram of water to increase 1 degree celsius (°C).
- Because of its high heat capacity, water can minimize changes in temperature.
- For instance, the specific heat capacity of water is about five times greater than that of sand. The land cools faster than the sea once the sun goes down, and the slow-cooling water can release heat to nearby land during the night.

- Heat of Vaporization—Water has a high heat of vaporization. Just as it takes a lot of heat to increase the temperature of liquid water, it also takes an unusual amount of heat to vaporize a given amount of water, because hydrogen bonds must be broken in order for the molecules to get converted as gas. That is, water has a high **heat of vaporization**, the amount of energy needed to change one gram of a liquid substance to a gas at constant temperature. The **heat of vaporization of water** is about 2,260 kJ/kg, which is equal to 40.8 kJ/mol.
- Boiling and Freezing—Pure water at sea level boils at 100°C (212°F) and freezes at 0°C(32° F), but extra energy is needed to push water molecules into the air. This is called latent heat—the heat required to change water from one phase to another. At higher elevations (lower atmospheric pressure) water's boiling temperature decreases.
- Energy is lost when water freezes. A great deal of heat is released into the environment when liquid water changes to ice.

Water density

- The density of water is the weight of the water per its unit volume, which depends on the temperature of the water. The value is 1 gram per milliliter or 1 gram per cubic centimeter.

References

- http://mvhs.shodor.org/riverweb/jigsaw/PoW.pdf
- echo2.epfl.ch/VICAIRE/mod_2/chapt_2/main.htm
- http://hyperphysics.phy-astr.gsu.edu/hbase/surten.html

Sources of water and water pollution

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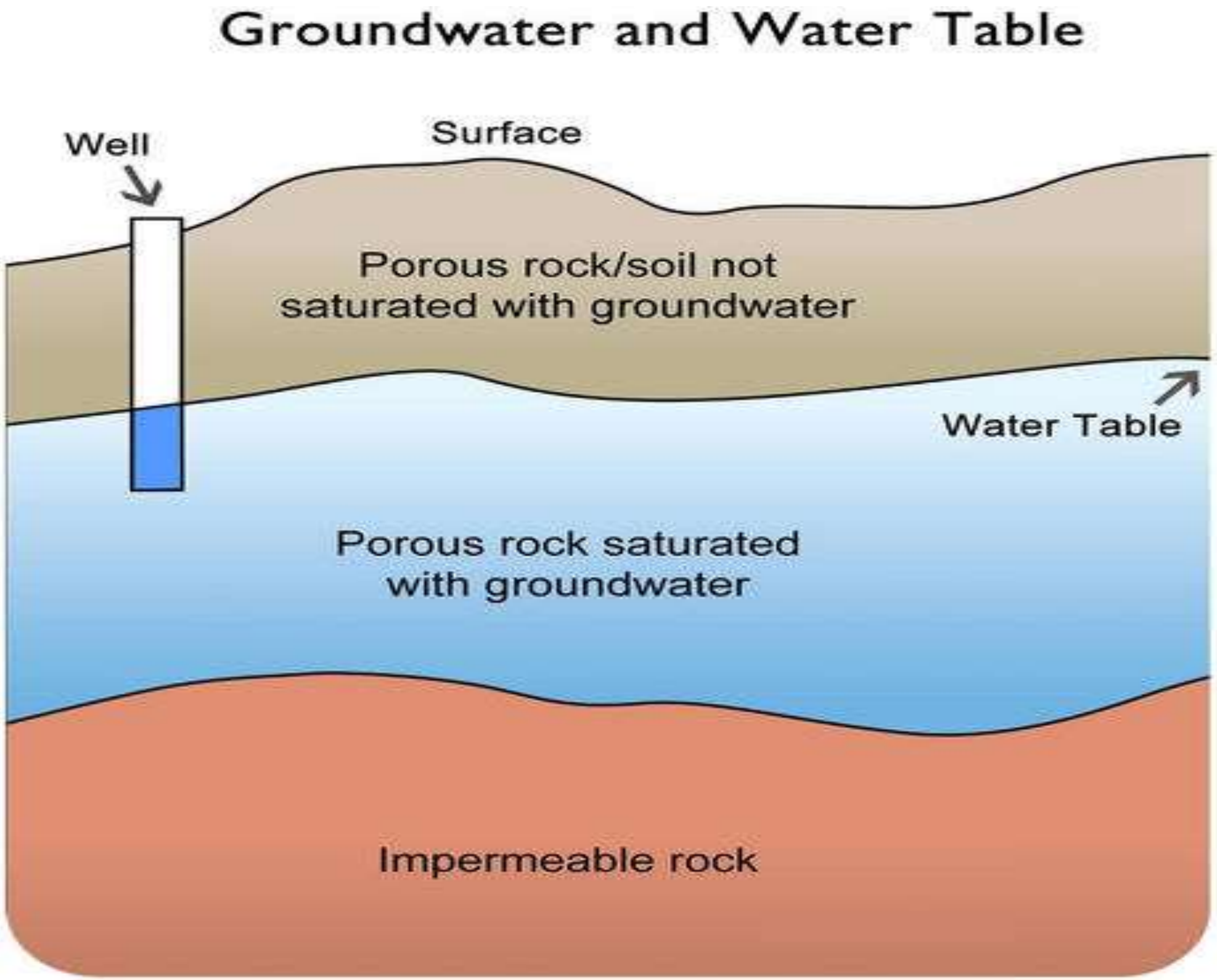
Ground water

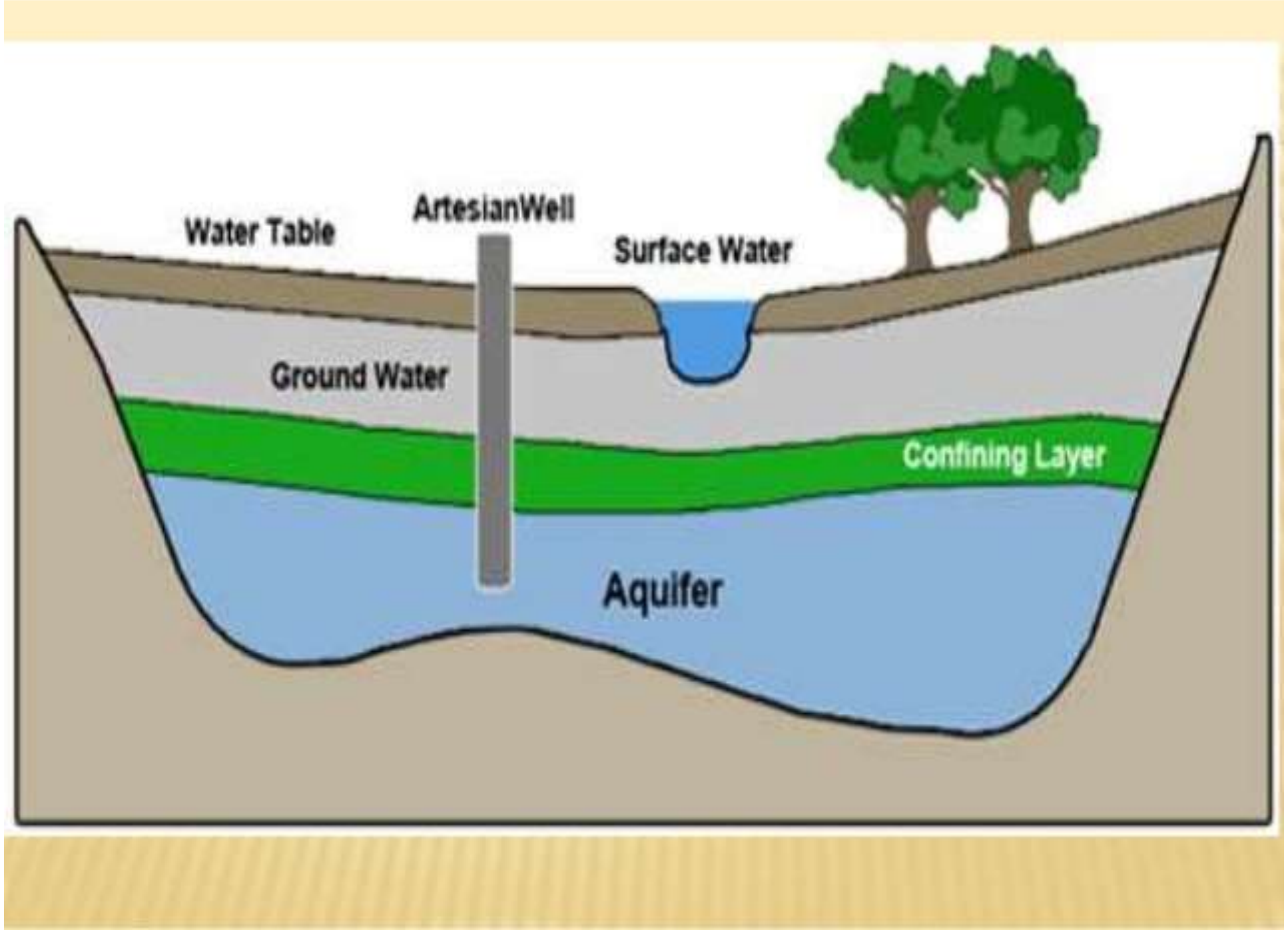
- In fact, ground water is simply the subsurface water that fully saturates pores or cracks in soils and rocks. Ground water is replenished by precipitation and, depending on the local climate and geology, is unevenly distributed in both quantity and quality.
- When rain falls or snow melts, some of the water evaporates, some is transpired by plants, some flows overland and collects in streams, and some infiltrates into the pores or cracks of the soil and rocks.
- The first water that enters the soil replaces water that has been evaporated or used by plants during a preceding dry period. Between the land surface and the aquifer water is a zone that hydrologists call the unsaturated zone.
- In this unsaturated zone, there usually is at least a little water, mostly in smaller openings of the soil and rock; the larger openings usually contain air instead of water. After a significant rain, the zone may be almost saturated; after a long dry spell, it may be almost dry. Some water is held in the unsaturated zone by molecular attraction, and it will not flow toward or enter a well.

- After the water requirements for plant and soil are satisfied, any excess water will infiltrate to the water table--the top of the zone below which the openings in rocks are saturated
- Below the water table, all the openings in the rocks are full of water that moves through the aquifer to streams, springs, or wells from which water is being withdrawn.
- Natural refilling of aquifers at depth is a slow process because ground water moves slowly through the unsaturated zone and the aquifer. The rate of recharge is also an important consideration.

Saturated , unsaturated zones and water table



Aquifer



Water Table
ArtesianWell
Surface Water
Ground Water
Confining Layer
Aquifer

- A well, in simple concept, may be regarded as nothing more than an extra large pore in the rock.
- A well dug or drilled into saturated rocks will fill with water approximately to the level of the water table.
- If water is pumped from a well, gravity will force water to move from the saturated rocks into the well to replace the pumped water.
- This leads to the question: Will water be forced in fast enough under a pumping stress to assure a continuing water supply?
- Some rock, such as clay or solid granite, may have only a few hairline cracks through which water can move. Obviously, such rocks transmit only small quantities of water and are poor aquifers.
- By comparison, rocks such as fractured sandstones and cavernous limestone have large connected openings that permit water to move more freely; such rocks transmit larger quantities of water and are good aquifers. The amounts of water that an aquifer will yield to a well may range from a few hundred gallons a day to as much as several million gallons a day.

- An aquifer may be only a few or tens of feet thick to hundreds of feet thick. It may lie a few feet below the land surface to thousands of feet below. It may underlie thousands of square miles to just a few acres.
- The quantity of water a given type of rock will hold depends on the rock's porosity--a measure of pore space between the grains of the rock or of cracks in the rock that can fill with water.
- For example, if the grains of a sand or gravel aquifer are all about the same size, or "well sorted," the water-filled spaces between the grains account for a large proportion of the volume of the aquifer.
- If the grains, however, are poorly sorted, the spaces between larger grains may be filled with smaller grains instead of water. Sand and gravel aquifers having well-sorted grains, therefore, hold and transmit larger quantities of water than such aquifers with poorly sorted grains.

- After entering an aquifer, water moves slowly toward lower lying places and eventually is discharged from the aquifer from springs, seeps into streams, or is intercepted by wells. Ground water in aquifers between layers of poorly permeable rock, such as clay or shale, may be confined under pressure.
- If such a confined aquifer is tapped by a well, water will rise above the top of the aquifer and may even flow from the well onto the land surface. Water confined in this way is said to be under artesian pressure, and the aquifer is called an artesian aquifer.
- The word artesian comes from the town of Artois in France, the old Roman city of Artesium, where the best known flowing artesian wells were drilled in the Middle Ages.
- Deep wells drilled into rock to intersect the water table and reaching far below it are often called artesian wells. The word artesian, properly used, refers to situations where the water is confined under pressure below layers of relatively impermeable rock.

- A spring is the result of an aquifer being filled to the point that the water overflows onto the land surface. There are different kinds of springs and they may be classified according to the geologic formation from which they obtain their water, such as limestone springs or lava-rock springs; or according to the amount of water they discharge-large or small; or according to the temperature of the water-hot, warm, or cold; or by the forces causing the spring-gravity or artesian flow.
- Thermal springs are ordinary springs except that the water is warm and, in some places, hot. Many thermal springs occur in regions of recent volcanic activity and are fed by water heated by contact with hot rocks far below the surface.
- Such are the thermal springs called geysers in Yellowstone National Park.
- Water that does not have time to cool before it emerges forms a thermal spring. The famous Warm Springs of Georgia and Hot Springs of Arkansas are of this type.

Yellowstone National Park

Surface water

- Sources of surface water can include any above-ground collection of water such as **rivers, lakes, ponds and oceans**. Some sources of surface water are also fed by **underground aquifers**.
- Although the only natural input to any surface water system is **precipitation** within its water shed, the total quantity of water in that system at any given time is also dependent on many other factors.
- These factors include storage capacity in lakes, wetlands and artificial reservoirs, **the permeability of the soil beneath these storage bodies**, the **runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates.**
- All of these factors also affect the proportion of water loss.
- Human activities can have a large and sometimes devastating impact on these factors. Humans often increase storage capacity by constructing reservoirs and decrease it by draining wetlands.

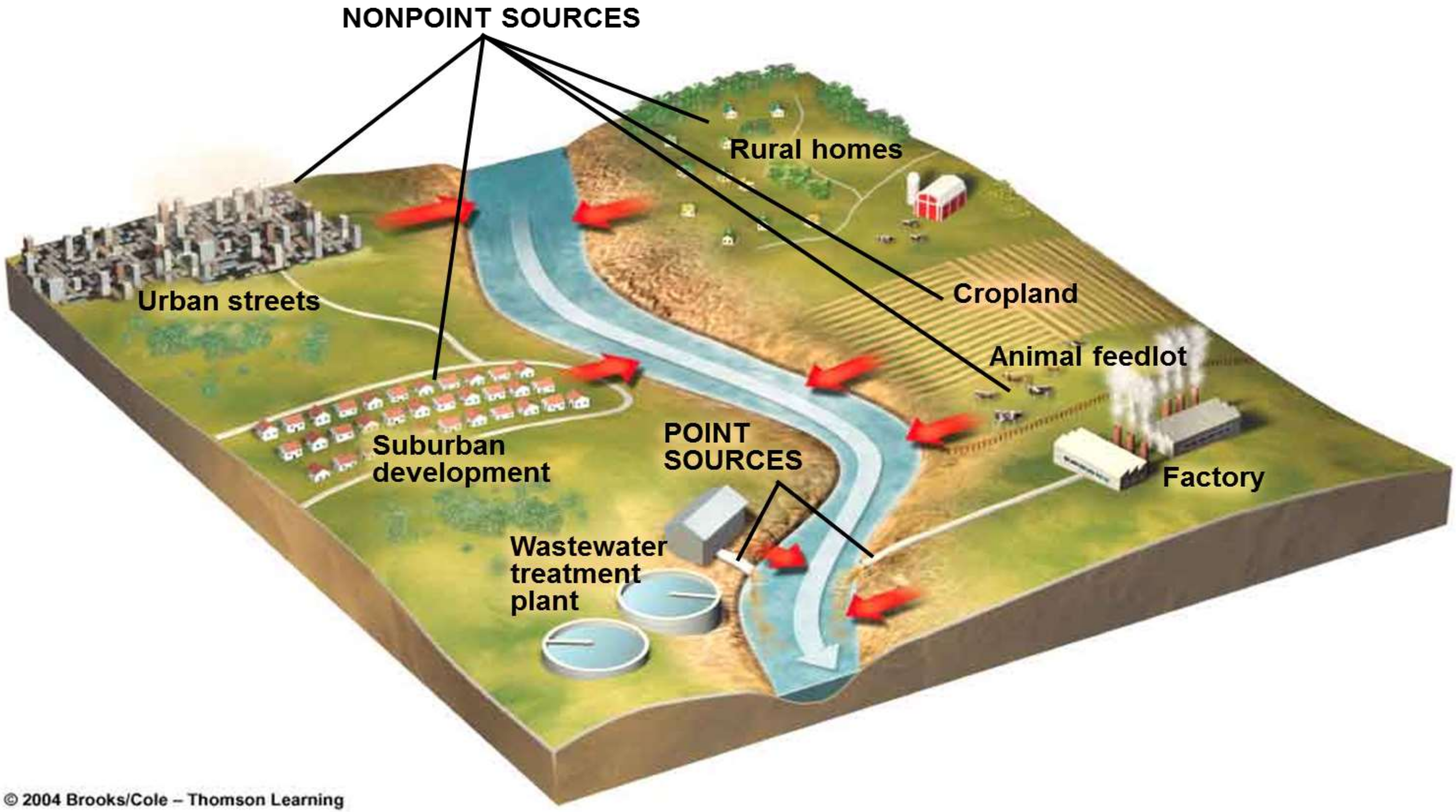
- Of the **3 percent of earth's water considered freshwater,** 70 percent of that small amount is currently locked in glaciers and ice caps.
- In theory, frozen glacial and ice cap water could be melted and used, but the amount of energy needed to melt and transport vast quantities of ice make it economically impractical.
- Glaciers and ice caps also play vitally important roles in the regulation of earth's climates and global temperatures, making their preservation very important.
- Although ocean water makes up nearly 97 percent of all water on earth, it is not a viable source of potable water unless salt and other impurities are removed.
- Desalination, the process by which salt is removed from water, is a rapidly growing practice. While salt and other microscopic particles can be removed from water in a variety of ways, the most promising method is through reverse osmosis.
- This process forces saltwater through filters with microscopic pores that remove salt and other microbes. Reverse osmosis requires large amounts of energy, making it a very expensive process.

Water Pollution

- Water pollution is any chemical, physical or biological change in the quality of water that has a harmful effect on any living thing that drinks or uses or lives (in) it. When humans drink polluted water it often has serious effects on their health. Water pollution can also make water unsuitable for the desired use.
- Water pollution is usually caused by human activities. Different human activities result in pollution of water. There are two sorts of sources, point and nonpoint sources.

Point and Non point sources of Pollution

- Pollutants enter the water environment from two main types of sources.
- **Point sources**
- A point source is a single, identifiable source of pollution, such as a pipe or a drain. Industrial wastes are commonly discharged to rivers and the sea in this way.
- **Nonpoint sources**
- Non-point sources of pollution are often termed ‘diffuse’ pollution and refer to those inputs and impacts which occur over a wide area and are not easily attributed to a single source. They are often associated with particular land uses, as opposed to individual point source discharges.
- Urban land use : In our urban areas rainfall run-off as stormwater is one of the major nonpoint sources of pollution impacting the water quality of our waterways and bays. Stormwater from street surfaces is often contaminated with car oil, dust and the faeces of animals and soil and sediment run-off from construction sites, and in industrial areas often contains more toxicants and chemicals.


NONPOINT SOURCES
Rural homes
Urban streets
Cropland
Animal feedlot
Suburban development
POINT SOURCES
Factory
Wastewater treatment plant

- In some outer-urban and urban fringe areas, a reticulated sewerage system is not available so sewage is discharged to onsite wastewater systems and septic tanks. Seepage and surface run-off of septic tank effluents may also be forms of non-point source pollution of streams in these areas.
- Agricultural land use
- In farming areas non-point sources of pollution include pesticides, fertilisers, animal manure and soil washed into streams in rainfall run-off.
- Forestry land use
- Forestry operations may contribute to non-point source pollution of streams by increasing soil erosion and sediment run-off.
- Non-point source pollution is often more difficult to control than point source pollution. In urban areas the provision of reticulated sewerage systems and adequate street cleaning are important measures, while in farming and forestry areas, soil conservation practices and the controlled application of pesticides and fertilisers are necessary if pollution of waterways is to be avoided.

Major Categories of Water Pollutants

- Infectious Agents
  - Bacteria, Viruses, Protozoa, Parasitic Worms
  - Source: Human and animal waste
- Oxygen-Demanding Waste
  - Organic debris & waste + aerobic bacteria
  - Source: Sewage, feedlots, paper-mills, food processing
- Inorganic Chemicals
  - Acids, Metals, Salts
  - Sources: Surface runoff, Industrial effluent, household cleansers
- Radioactive Materials
  - Iodine, radon, uranium, cesium, thorium
  - Source: Coal & Nuclear Power plants, mining, weapons production, natural
- Plant Nutrients
  - Nitrates, Phosphates,
  - Source: Sewage, manure, agricultural and landscaping runoff
- Organic Chemicals
  - Oil, Gasoline, Plastics, Pesticides, Solvents, detergents
  - Sources: Industrial effluent, Household cleansers, runoff from farms and yards
- Eroded Sediment
  - Soil, Silt
- Heat/Thermal Pollution
  - Source: Power plants, Industrial

Oxygen sag curve

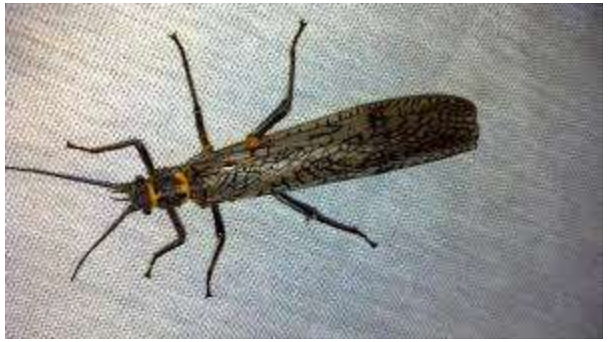
- The disposal of oxygen demanding waste into the aquatic ecosystem result in a reduction in the dissolved oxygen at the point of disposal of the waste due to the load of organic matter.
- Along with the reduction of the DO , the biological oxygen demand of the water system increases resulting in the increase in population of trash fishes namely carp, gar and leeches in the decomposition zone.
- Following which in the Septic zone, further reduction happens in the DO level, resulting in further increase of BOD resulting in the absence of fishes, presence of fungi, sludge worms and anaerobic bacteria.
- But in due course, due to the mixing action of the air, growth of algae on the surface of the water system the recovery zone comes into existence with the organisms seen in the decomposition zone.
- Finally the Clean zone as it was earlier appears with the clear water organisms such as trout, bass, mayfly, perch, stonefly etc.,
- The trend of reduction of DO accompanied by an increase in BOD and the reverse phenomenon is referred to as Oxygen sag curve.

- Carp

Gar

Mayfly

stonefly

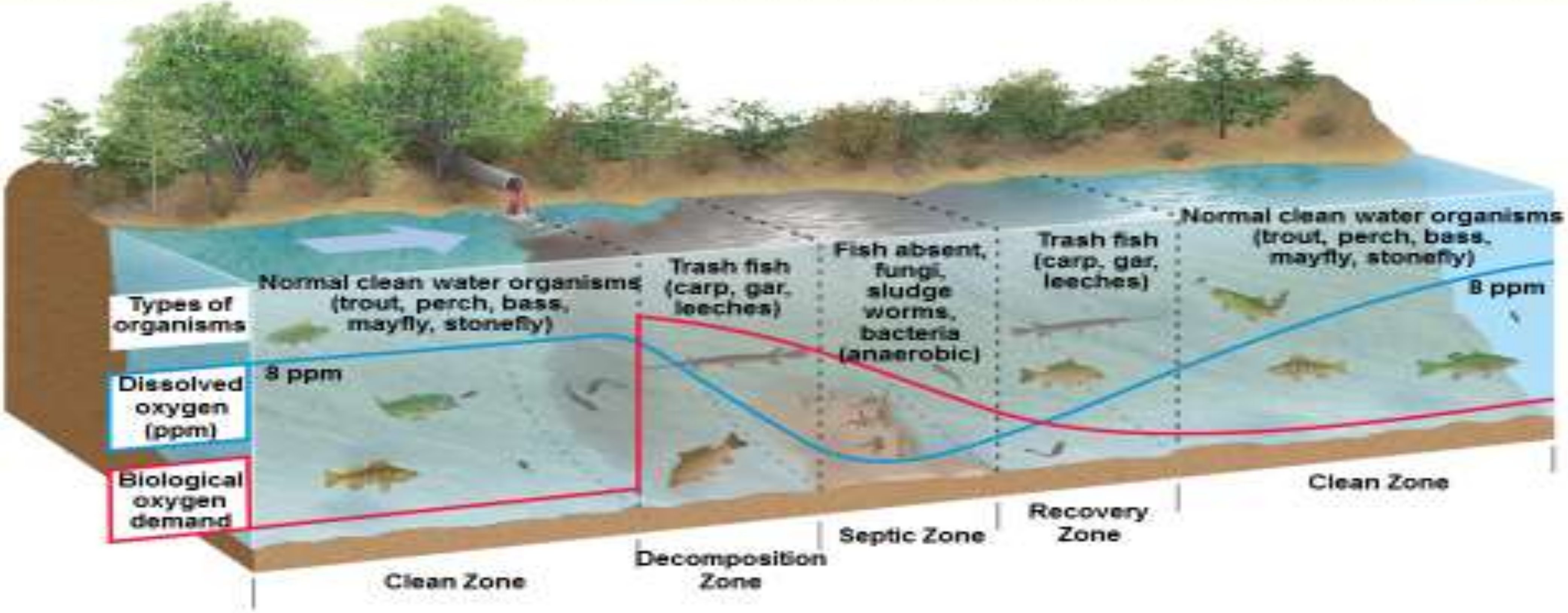


- Trout

Perch

Leech

Pollution in Streams

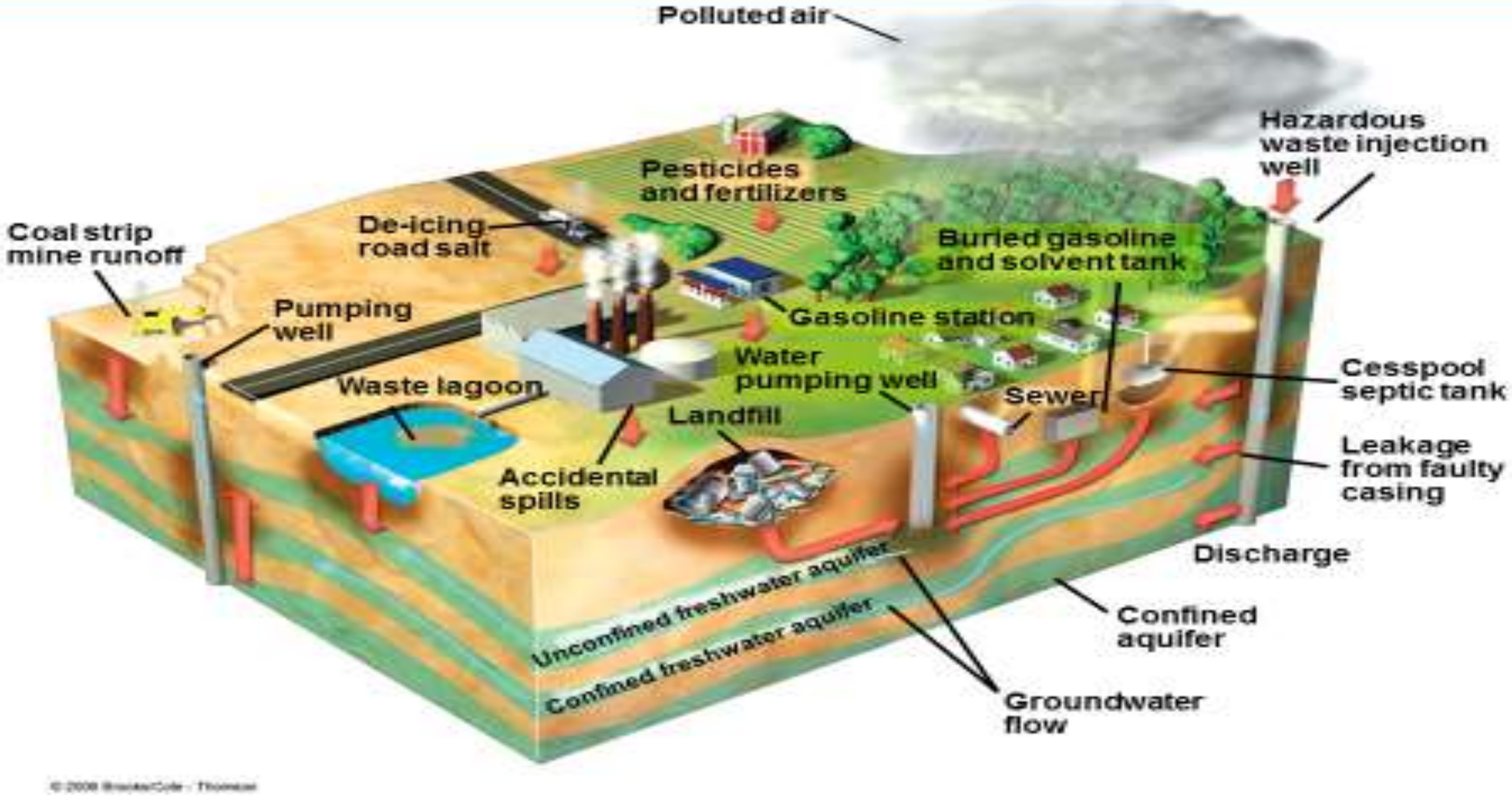


Lake Pollution

- Dilution less effective than with streams
- Stratification in lakes and relatively little flow hinder rapid dilution of pollutants
- Lakes more vulnerable to pollutants than streams
- How pollutants enter lakes
- Eutrophication: causes and effects
- Oligotrophic and eutrophic lakes
- Cultural eutrophication
- Preventing or removing eutrophication

Oligotrophic and Eutrophic Lakes

Groundwater Pollution



- Water pollution is mainly caused by
- Natural process: Decomposition of wastes which occurs in the main water resources.
- Anthropogenic processes: The activities include industrial, agricultural, urban, domestic, radioactive etc.,
- The Common water pollutants include the Domestic sewage, Synthetic detergents, Industrial effluents, Heavy metals, Agricultural wastes, Temperature, Microorganisms, Radioactivity, Planktonic blooms, nutrients,Silt and oil etc.,

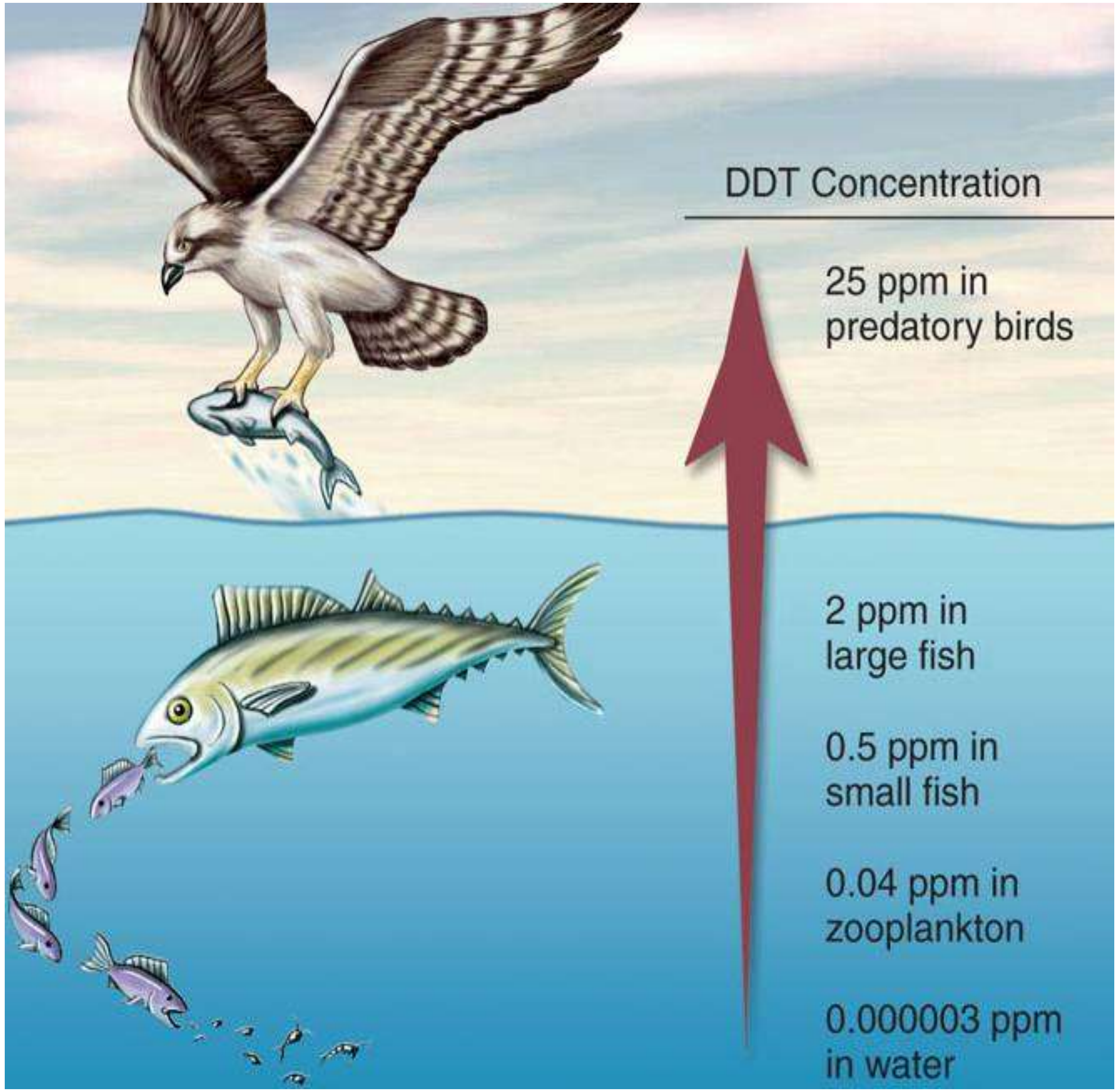
- **Sources of Water Pollution**
- **Domestic sewage:** Domestic sewage consists of human faeces, urine and the dirty used-up water from the houses. It contains a large number of pathogenic bacteria and virus which cause major water borne diseases.
- **Industrial effluent**: The trade wastes and effluents of industries play a significant role in pollution of water. The industries such as paper and pulp, distillery, fertilizer, electroplating, tanning, oil, etc., pollute the water sources / contribute to water pollution by the discharge of effluents.
- **Agricultural wastes:** Plant nutrients, pesticides, insecticides, herbicides, fertilizers, farm wastes, manure, slurry and soil erosion results in pollution of the water sources.
- **Planktonic blooms:** Domestic sewage and fertilizers add larger quantities of nutrients such as nitrates and phosphates to the fresh water ecosystem. The rich supply of these nutrients make blue green algae, green algae and other phytoplankton to grow abundantly which is termed as eutrophication.

- **Heavy Metals:** Toxic metals are added to the aquatic system from industrial processes, domestic sewage discharge, street dust, land run off and fossil fuel burning.
- **Temperature**: Higher temperature in water is contributed by the waste water / effluent discharged directly from atomic, nuclear and thermal power plants. In such effluents heat happens to be the pollutant.
- **Radioactivity:** Radioactive pollutants enter into water streams from various sources such as nuclear power plants, nuclear reactors, nuclear test, nuclear installations, etc., The extremely toxic radioactive elements such as Pu, Np, Cs, Ru, U etc., were found to pollute water.
- **Silt:** Siltation is the most widespread and damaging pollutant especially in hill streams which occurs due to heavy runoff.
- **Oil:** Oil is a major source of pollution in ocean. The major sources of oil pollution in sea water are cargo tanker washings at sea, import oil losses, bilge pumping at sea and maritime accidents.
- **Synthetic Detergent:** The term detergent, means cleansing agent which is derived from surfactant (10-30%) builder (15%) and others.

Effects of Water Pollution

Pollution	Effects
Sewage and Domestic waste	Water borne diseases like cholera (*Vibrio cholerae*), typhoid (*Salmonella typhi*), dysentery, Amoebiasis (*Entamoeba histolytica*), various other health problems, depletion of dissolved oxygen, objectionable odour.
Industrial effluents	It causes deleterious effects on living things and may bring death or sub lethal pathology of kidneys, liver, lungs, brain and reproductive system.
Agricultural waste	Excessive fertilizer leads to accumulation of nitrates in children called methemoglobinaemia, Richness of nutrients results in eutrophication.

Eutrophication	During eutrophication, algal bloom release toxic chemicals in to the aquatic system. Algal bloom leads to oxygen depletion and an increase in CO_2 level. Thus, aquatic organisms begin to die which may result in succession.
Bioaccumulation (or)Biological magnification	Aquatic plants and animals can accumulate certain pesticides in their body tissues in greater concentration than in water. This phenomenon is commonly referred to as biological magnification or biological amplification, eg., DDT. It is more threatening as its concentration continuously increases in successive trophic levels in a food chain which results in many health hazards DDT absorbed by fish eating birds 25 ppm ↑ DDT in large fish 2 ppm ↑ DDT in small fish 0.5 ppm ↑ DDT in Zooplankton 0.003 ppm ↑ DDT in water 0.000003 ppm


DDT Concentration
25 ppm in predatory birds
2 ppm in large fish
0.5 ppm in small fish
0.04 ppm in zooplankton
0.000003 ppm in water

Heavy Metals	Pathological effects on Man
Lead (Pb)	Anaemia, vomiting, damage of liver, brain and kidney
Arsenic(As)	Mental disturbance, lung cancer, ulcer, kidney damage
Mercury (Hg)	Abdominal pain, headache, diarrhoea, chest pain,Minamata disease
Cadmium (Cd)	Growth retardation, diarrhoea, bone deformation, kidney damage, anemia, injury to liver, Itai-Itai or Ouch-Ouch disease
Barium (Ba)	Excessive salivation, diarrhoea, paralysis
Chromium (Cr)	Gastro intestinal ulceration, diseases of central nervous system, cancer, nephritis
Zinc (Zn)	Vomiting, renal damage
Copper (Cu)	Hypertension, uremia, coma

Temperature	Reduction of dissolved oxygen, increase in Biological oxygen demand, early hatching of fish eggs and fish mortality, migration of aquatic biota
Radioactivity	Serious skin cancer, carcinoma, melanoma, breast cancer, leukemia, DNA damage and cataract.
Siltation	Reduced visibility, Reduction in direct light penetration, Decrease in photosynthetic rate, Chances of anaerobic digestion in the benthos zone.
Oil	Reduction of dissolved oxygen in the water, reduction in the -light-penetration, direct oil coating makes the fishes unable to respire and clog their gill slits
Synthetic Detergent	Although detergents are not highly toxic to fishes they do cause damage to gills and remove the protective mucus from skin and the intestine.

- https://pubs.usgs.gov/gip/gw/quality.html
- Read more: https://www.lenntech.com/water-pollution-faq.htm#ixzz56sD4DdZk