ENVE 100

INTRODUCTION TO ENVIRONMENTAL ENGINEERING

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Chapter 1

Water Pollution

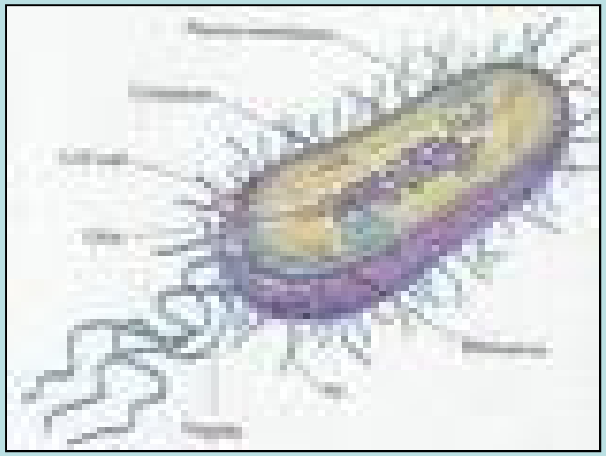
WATER

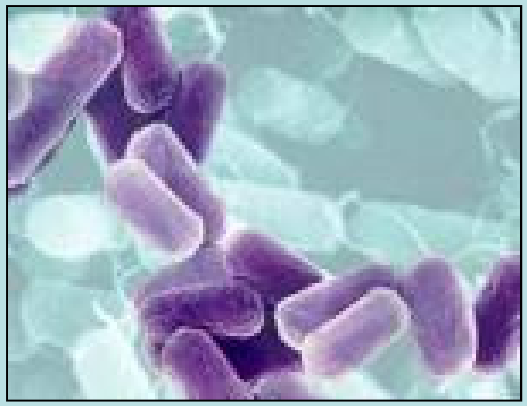
- one of the most abundant compounds found in nature
- covering approximately three-fourths (3/4) of the surface of the earth
- several factors serve to limit the amount of water available for human use.

IMPORTANCE OF WATER

- Life on planet Earth would be impossible without water.

- All life forms, from simple bacteria to complex multicellular plants and animals, contain water.



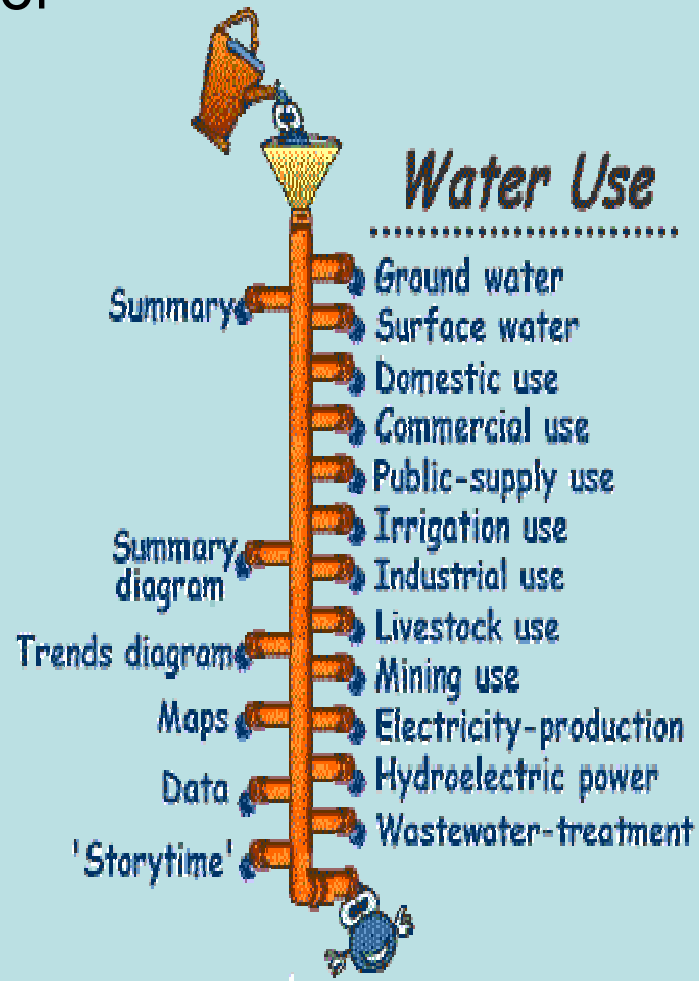


IMPORTANCE OF WATER

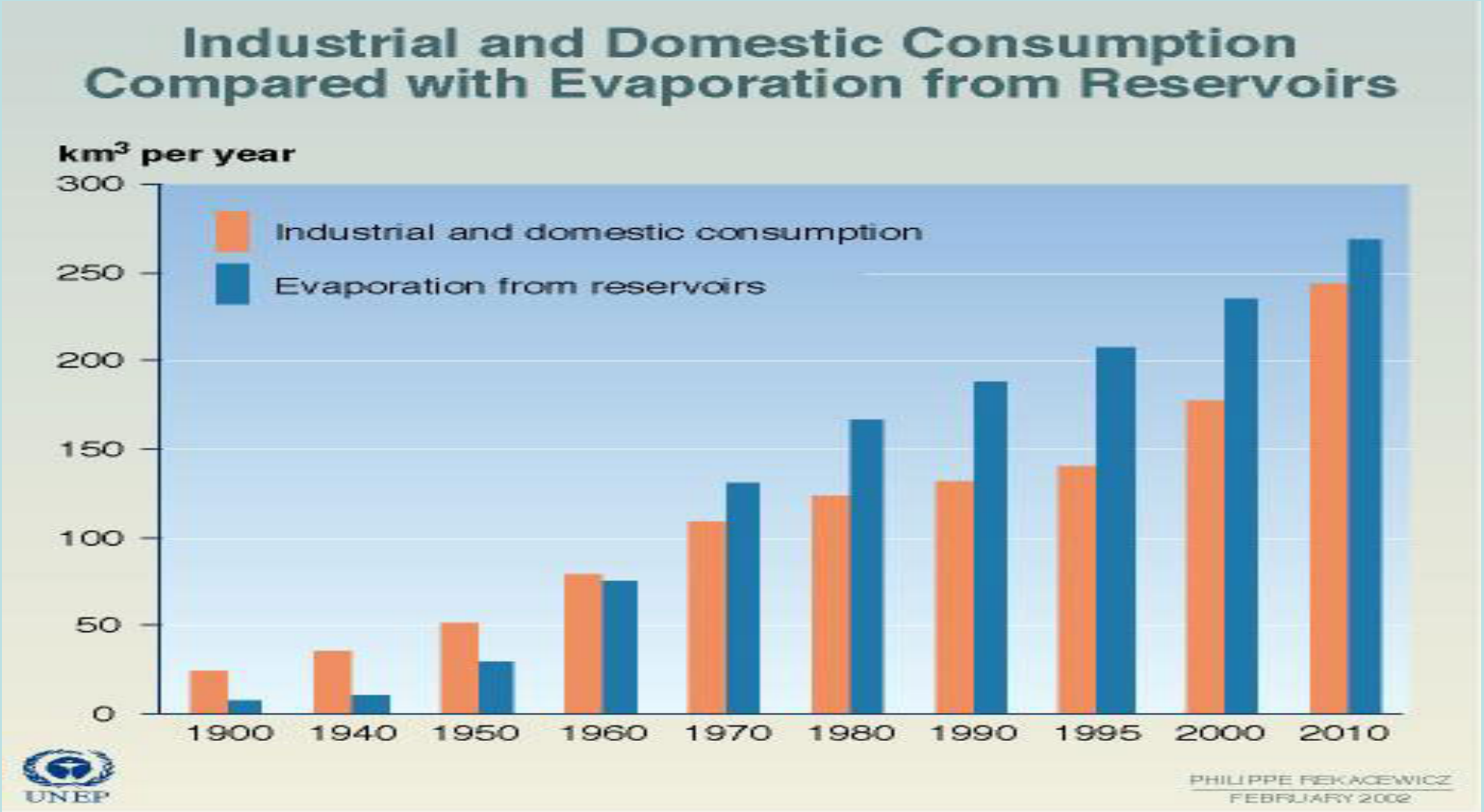
- Humans are composed of approximately 70 % water (by weight), and we depend on water for our survival as well as for our convenience:
- drink it
- cook with it
- wash with it

Domestic use

- travel on it and
- use enormous amount of it for agriculture, manufacturing, mining, energy production and waste disposal.



IMPORTANCE OF WATER



Source: Igor A. Shiklomanov, State Hydrological Institute (SHI, St. Petersburg) and United Nations Educational,Scientific and Cultural Organisation (UNESCO, Paris), 1999.

Worldwide we are using increasingly more water, in part because our population is increasing and in part because, on the average, each person using more water.

PROPERTIES OF WATER

Physical properties:

- **Most common liquid on the planet**
- **Only common inorganic liquid**
- **Exists in all 3 physical states (solid, liquid, gas)**
- **excellent solvent for ionic and polar compounds**
- **very high dielectric constant**
- **highest surface tension of any liquid except mercury (at STP)**

Thermal properties:

Specific Heat = 1 cal / gm
Latent heat of fusion = 80 cal / gm
Latent heat of vaporization = 540 cal / gm (at 100o C)
Expands upon freezing by about 11%

PROPERTIES OF WATER

- “universal solvent” : many materials do dissolve in water.
- never completely pure : because it contains dissolved gases from the atmosphere and dissolved mineral salts from the Earth.
- obeys the general physical rule: that heat expands and cold contracts.

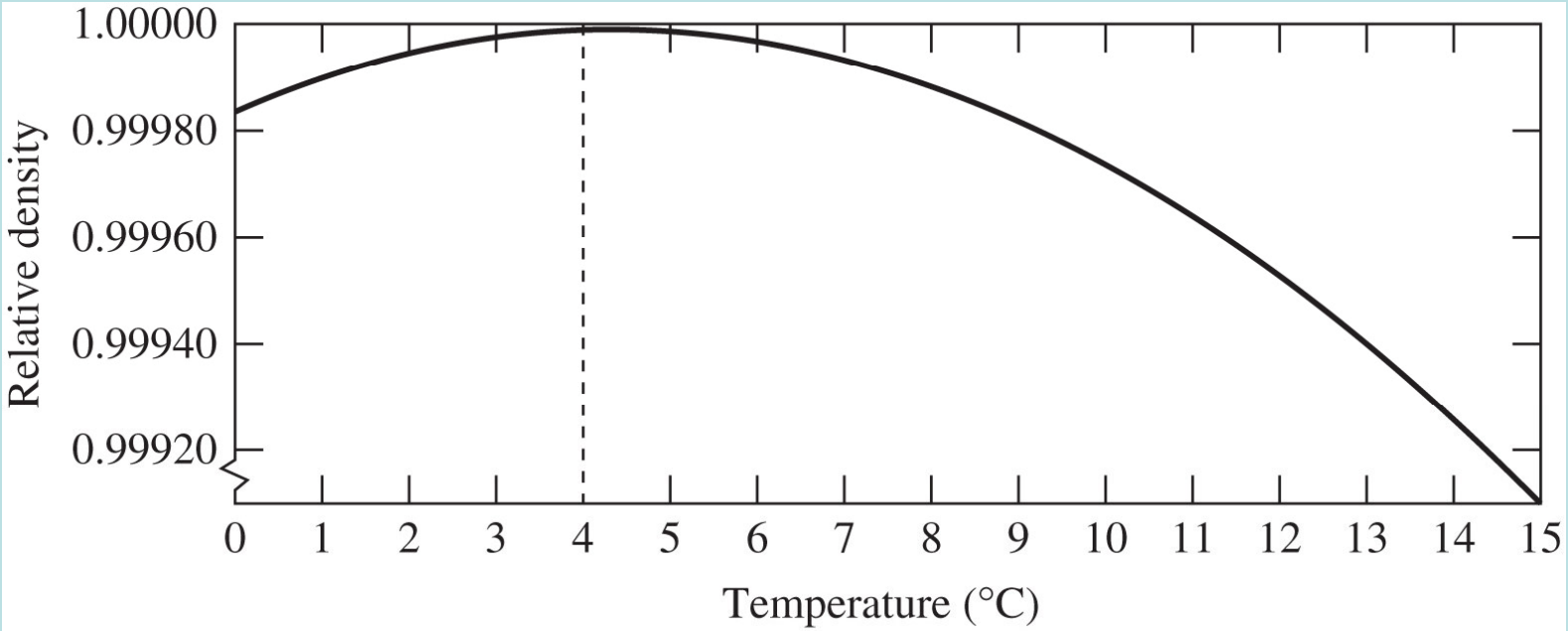


Figure: 05-20

World Water Distribution

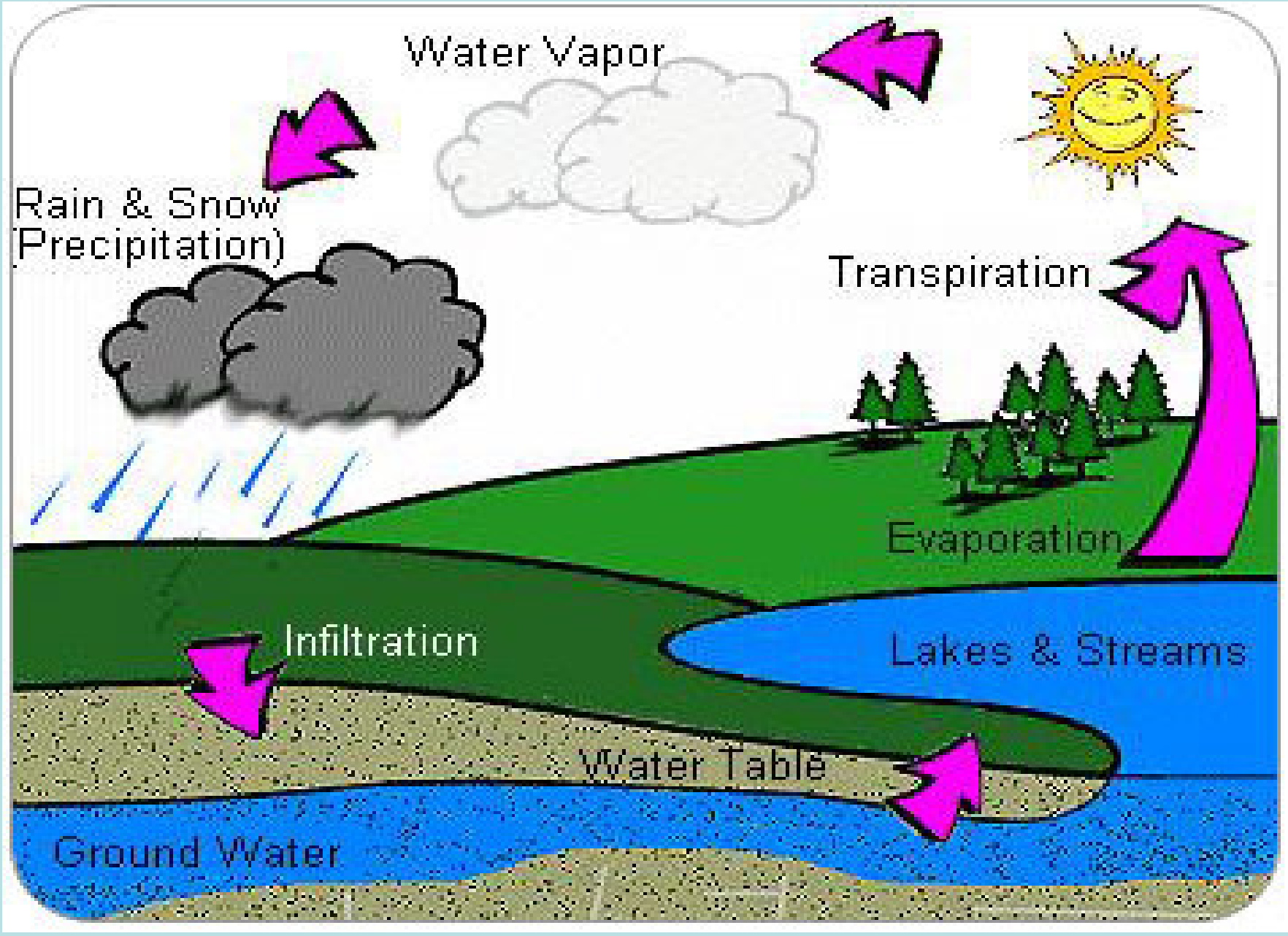
Location	% of total
Land Areas	
• Freshwater Lakes	0.009
• Saline Lakes and inland seas	0.008
• Rivers	0.0001
• Soil Moisture	0.005
• Groundwater	0.61
• Ice caps and glaciers	2.14
Atmosphere (water vapor)	0.001
Oceans	97.3
	100

Where is the water?

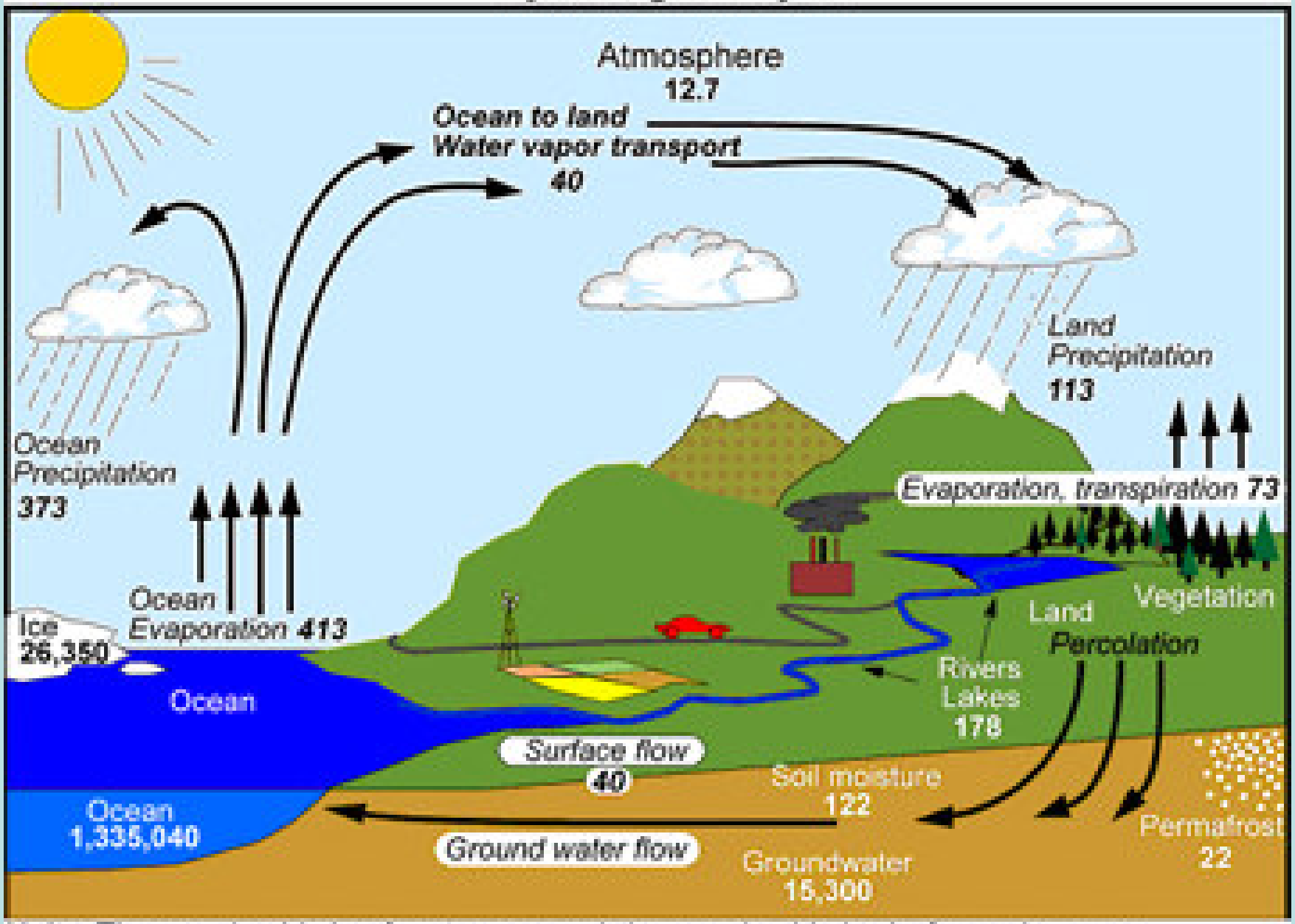
- Oceans 97.5% (1.35 billion km3)
- Ice 1.8%
- Groundwater 0.63%
- Lakes and Rivers 0.02%
- Atmosphere 0.001%

- Total Freshwater Only 2.5%
  - 74 % ice
  - 25% groundwater
  - 1% lakes and rivers

HYDROLOGICAL CYCLE



Hydrological Cycle



Units: Thousand cubic km for storage, and *thousand cubic km/yr* for exchanges

DISTRIBUTION OF WATER

Over 97% oceans and other saline bodies;

- ➔ **is not readily used for most purposes**
- ➔ **high concentration of salts**
- ➔ **land plants are poisoned by too much salt**
- ➔ **used for thermal cooling of power plants**
- ➔ **sink for much of our pollution**

- **Saline water** ⟶ **Fresh water**
  Desalination technique

- **a little over 2%**

➔**is tied up in ice caps and glaciers and along with atmospheric and soil moisture**

➔**is inaccessible**

➔**difficult or expensive to bring it to where we live.**

DISTRIBUTION OF WATER

remaining 0.62 % ➔ in fresh water lakes, rivers and ground water

➔used for general livelihood and support of technical and agricultural activities of human

SURFACE WATER

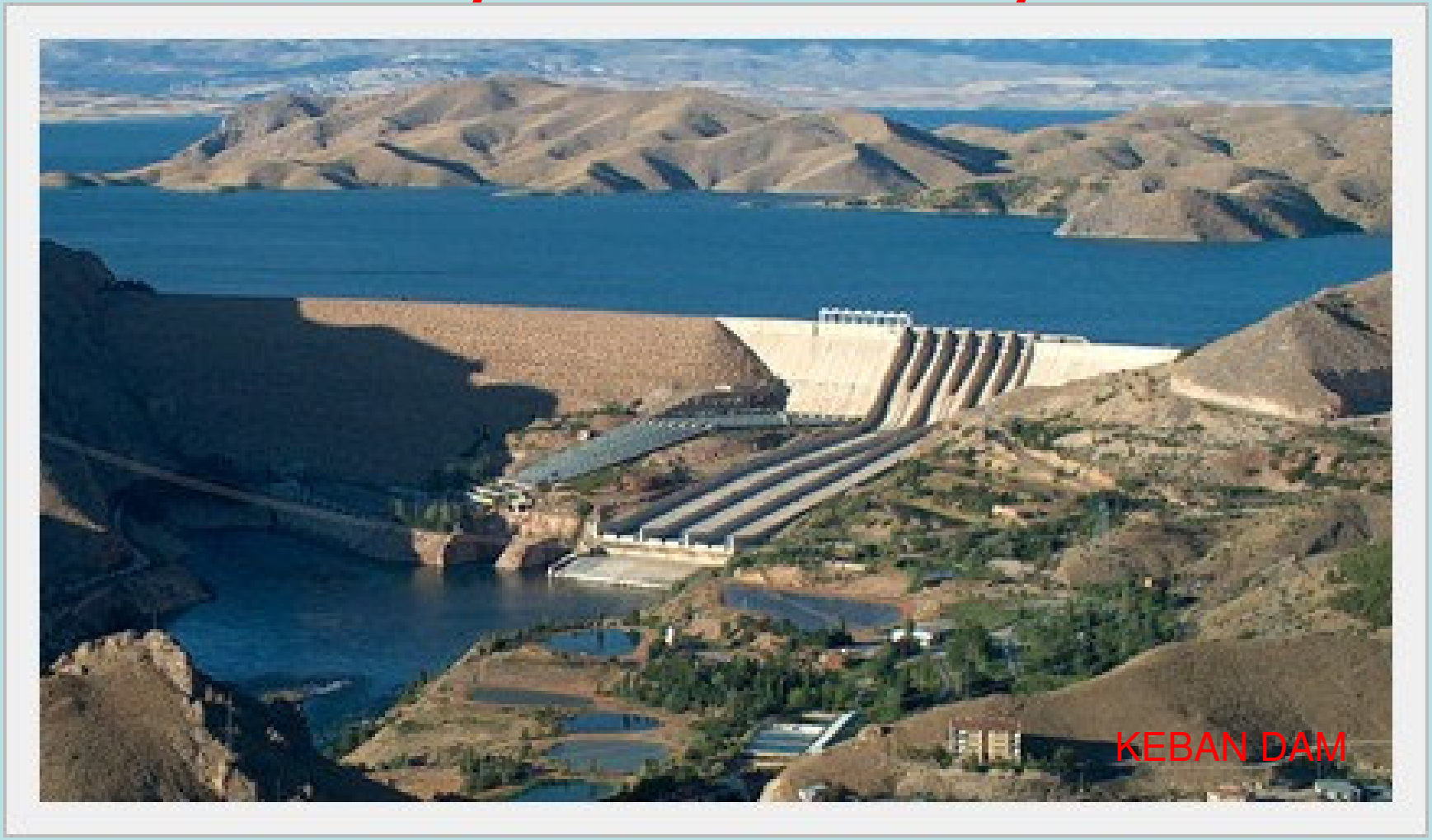
- **Surface water : streams, rivers and lakes.**
- **It is fed by springs and snowmelt,**
- **runs off from concrete and other impermeable surfaces typical of urban environments.**
- **polluted water in storm drains usually ends up directly in the nearest river.**

Surface Water for Irrigation

- Imperial Valley, CA

The largest use of surface water is for irrigation purposes

Surface Water for Hydroelectricity

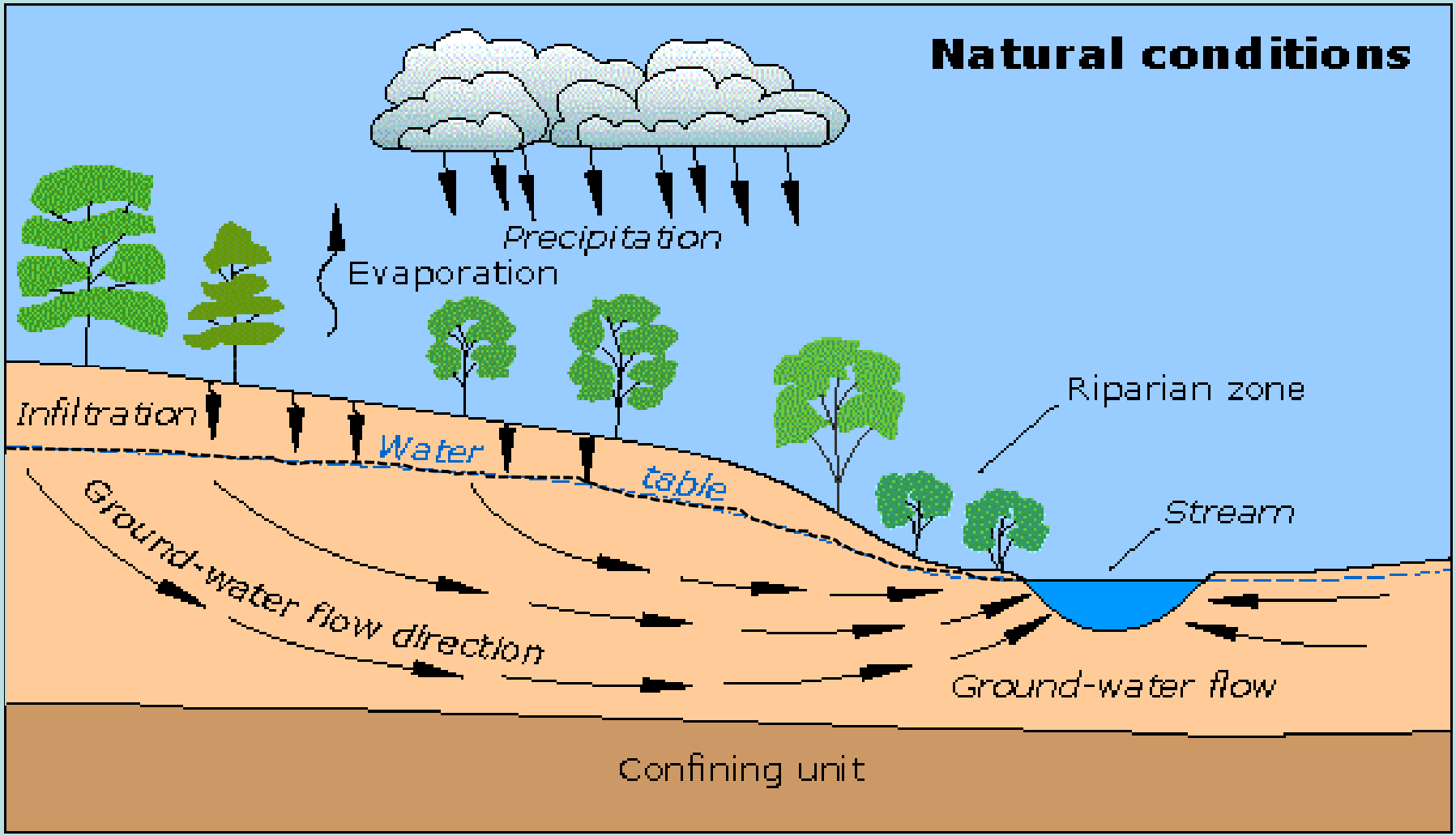


Source: http://imageshack.us/photo/my-images/201/keban.jpg/sr=1

Surface Water for Cooling

- Three Mile Island, PA

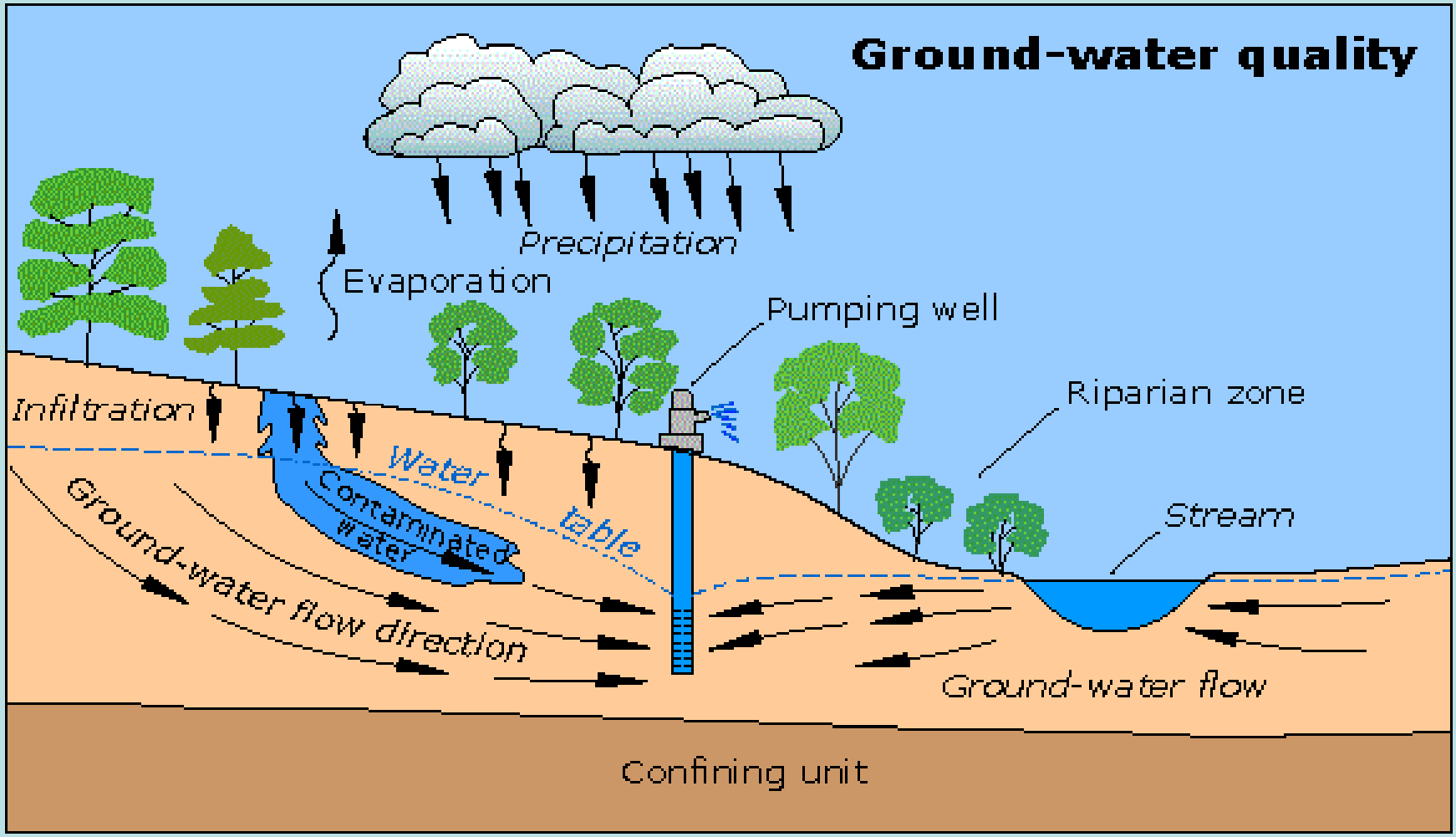
GROUND WATER



GROUND WATER

- **Ground water that has infiltrated through the soil tends to be free of organic pollutants.**
- **wells are the source of most drinking water,**
- **but the major use of groundwater is irrigation for agriculture.**
- **Chlorinated hydrocarbons such as DDT that have been used in pesticides tend to break down less readily, and are spreading though out the environment.**

POLLUTED GROUND WATER



Water Use:

- Agriculture - 65%
- Industry - 20%
- Public Water Supply - 7%

- the water quality requirements are usually (not always) highest for public water supplies.
- Some industries have higher WQ requirements

Public water supplies should be free of:

- visible suspended matter
- excessive color, taste, or odor
- objectionable levels of salts
- aggressive (toward pipes and other materials) constituents
- pathogenic organisms or bacteria indicating fecal contamination

Water Supply: uses and sources

- **I. Uses.**
- **domestic (potable) water** - water supplied by a public water supply and used for drinking, cooking, cleaning, lawn and garden watering, etc.
- **industrial water :**
- ***process water*** - water used in a manufacturing process, or actually incorporated in the final product (eg. brewing and beverage industry)
- ***boiler feed water*** - water that will be boiled to steam. Mineral content of the water is a concern here because of the problem of "scale" formation in boilers.
- ***cooling water*** - water used for cooling in industrial processes
- **bathing** (swimming pools and spas), **washing and cleaning** operations,**irrigation, stock watering, recreation** (swimming, boating, fishing),**ecosystem support** (including fish and wildlife), **electric power generation,fire fighting,navigation**

WATER USE & WATER QUALITY

- Domestic water supplies are subject to the highest quality standards, but some industrial uses may require water quality exceeding that of drinking water.
- Drinking water , industrial process water, and boiler feed water generally require at least some treatment to achieve the desired quality.
- Water used in swimming pools is usually drawn from a municipal water supply, although sometimes wells or even surface waters may be used as a source.
- Swimming pool and spa water must be filtered and disinfected (either with ozone or halogens) to maintain suitable chemical and microbiological quality.
- Water used for cleaning is likewise usually drawn from a municipal water source, although groundwater or surface water may be used if it is free of corrosive chemicals and sediment.
- Cooling water is often treated chemically (usually with chlorine) to reduce fouling of pumps and pipes by bacteria and algae.

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WATER USE & WATER QUALITY

- Water used for irrigation and stock watering may be of lower quality and is generally not treated, but rather is simply withdrawn from the source and used directly.
  - Such waters must still be ***free of toxic substances*** and be of reasonable microbiological quality.
- Water suitable for stock watering and irrigation is generally suitable for use by wildlife as well. Fish and other aquatic life generally require a higher quality of water than is needed for any of the above uses. ***Inert solids, oxygen, and thermal standards*** are all higher for the maintenance of healthy and diverse aquatic ecosystems.
- Water based recreational activities such as ***swimming*** and ***water skiing*** which involve actual contact between people and water, require water of suitable microbiological quality. The safety of such waters is usually determined by ***coliform counts***.

WATER USE & WATER QUALITY

- Water for fighting fires, while usually withdrawn from municipal water systems, does not require high quality water, and in rural areas may be withdrawn from ponds and streams.

WATER POLLUTION

- Pollution can be defined as: "***to make foul*** or ***unclean***; ***dirty***."
- 1) ***Water Pollution*** may be defined as the presence in water of ***impurities*** in such quantity and of such nature as to impair the use of water for ***a stated purpose***.
  2) Water is considered to be polluted when it contains ***chemical and/or biological substances*** in quantities that affect its beneficial use.
  3) Water pollution occurs when a body of water is adversely affected due to the addition of large amounts of materials to the water. When it is unfit for its ***intended use***, water is considered polluted.
- 4***)*** Any ***contamination*** of water that lessens its value to humans and nature

- **Thus the notation of water pollution is relative and depends on the profile of desired usage.**

SOURCES OF WATER POLLUTION

- ***Point source:***
  - Harmful substances are emitted directly into a body of water.
  - comes from well defined source
  - include sewage-treatment plants, industrial plants, and animal feedlots
  - reduced by pollution control devices
  - treat it so is less harmful
  - concentrate it so can be disposed of appropriately
- ***Non-point Source*** :
  - Delivers pollutants indirectly through environmental changes.
  - comes from dispersed area
  - Unlike pollution from industrial and sewage treatment plants, comes from many diffuse sources.
  - NPS pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and even our underground sources of drinking water.

SOURCES OF WATER POLLUTION

- agriculture is the leading contributor to water quality impairments
- The most common NPS pollutants are sediment and nutrients. These wash into water bodies from agricultural land, small and medium-sized animal feeding operations, construction sites, and other areas of disturbance.
- Other common NPS pollutants include pesticides, pathogens (bacteria and viruses), salts, oil, grease, toxic chemicals, and heavy metals.
- Almost all money spent on point sources. The technology exists for point sources of pollution to be monitored and regulated.
- Nonpoint sources are much more difficult to control. Pollution arising from nonpoint sources accounts for a majority of the contaminants in streams and lakes

Surface water

- it is water found in a river, lake or other surface impoundments.
- not very high in mineral content
- is exposed to many different contaminants, such as animal wastes, pesticides, insecticides, industrial wastes, algae and many other organic materials.
- possibly contains Giardia or Coliform Bacteria from the feces of wild animals, and should be boiled or disinfected by some means prior to drinking.

Ground Water

- is that which is trapped beneath the ground.
- Because of the many sources of recharge, ground water may contain any or all of the contaminants found in surface water as well as the dissolved minerals it picks up during it's long stay underground.
- Waters that contains dissolved minerals, such as calcium and magnesium above certain levels are considered "**hard water**".
- Because water is considered a "solvent", ie, over time it can break down the ionic bonds that hold most substances together, it tends to dissolve and 'gather up' small amounts of whatever it comes in contact with. For instance, in areas of the world where rock such as

  limestone, gypsum, fluorspar**,** magnetite, pyrite and magnesite are common, well water is usually very high in calcium content, and therefore considered "hard".

WATER POLLUTANTS

1. Pathogens
2. Oxygen-Demanding waste
3. Nutrients
4. Salts
5. Thermal Pollution
6. Heavy Metals
7. Pesticides
8. Volatile Organic Compounds

PATHOGENS

- pathogens are disease causing agents that grow and multiply within the host.
- the resulting growth of M.O. in a host is called an infection.
- examples to pathogens: Bacteria, Viruses, Protozoa, Helminths.
- are present in human and animal waste, in byproducts of fruit and vegetable processing and in slaughterhouses' refuse.
- remain viable in raw wastewater

PATHOGENS

- The intestinal discharges of an infected individual, a carrier, may contain billions of these pathogens.
- If they are allowed to enter the water supply, they can cause epidemics of immense proportions.
- This is particularly important because pathogens are present in wastes of infected individuals in enormous amounts.
- One person suffering from cholera excretes 10^{13} bacteria each day, a dose that could theoretically infect up to 10 million people.

PATHOGENS

- Because it is not possible to test water for all potential pathogens, a common practice is to check for ***indicator organisms***, which are present in large numbers of feces.
- Most water tests are based on a count of the numbers of ***Escherichia coli (E. Coli)***, a type of bacteria present in the intestines of mammals.
- Presence of ***E. Coli*** in natural waters points to the presence of feces and so indicates the possibility that ***pathogenic bacteria*** are also present.
- If the number of E. coli in natural waters exceeds ***10,000 in one liter***, the water is designated unsuitable for swimming and water sports.
- Although the ability of pathogens to survive in water varies widely, they do their best at low temperatures, low salinity, low light intensity and high turbidity.

OXYGEN DEMANDING WASTES

- Dissolved oxygen (DO) is one of the most important measures of the quality of a water source.
- For a healthy fish population minimum recommended DO concentration is 5 mg/L.
- Oxygen demanding wastes are substances that oxidize in the receiving body of water
- **Oxygen Demand:** Sewage and other organic materials are decomposed into carbon dioxide and water by the action of microorganisms. This degradation process known as, cell respiration, requires the presence of oxygen.

OXYGEN DEMANDING WASTES

$$Organic\ material\ + O_2\ + nutrients \xrightarrow{M.O} CO_2 + H_2O + new\ cells + nutrients + energy$$

- **Oxygen demanding material:** Anything that can be oxidized in the receiving water with the consumption of dissolved molecular oxygen
-
- Usually biodegradable organic matter but also includes certain inorganic compounds (e.g. Fe, Mn)

$$4Fe^{+2} + O_2 + 10H_2O \rightarrow 4Fe(OH)_3 + 8H^+$$

$$2Mn^{+2} + O_2 + 2H_2O \rightarrow 2MnO_2 + 4H^+$$

OXYGEN DEMANDING WASTES

- As bacteria decompose these wastes, they utilize oxygen dissolved in water, which reduces the remaining amount of DO.
- The consumption of DO posses a threat to higher forms of aquatic life
- As DO $\downarrow$ undesirable odors, taste and colors reduces the acceptabiltity of that water as a domestic supply and reduce its attractiveness for recreational uses.
- Oxygen demanding materials in domestic sewage come primarily from human waste and food residue.

Measurement of Oxygen Demanding Waste

- To predict the extent of oxygen depletion, it is necessary to know how much waste is being discharged and how much oxygen is required to degrade the waste

- Oxygen demanding waste are commonly measured by determining the amount of oxygen consumed during degradation in a manner approximating degradation in natural water
- **BIOCHEMICAL OXYGEN DEMAND (BOD):** The amount of oxygen required by microorganisms to degrade the waste biologically

- **CHEMICAL OXYGEN DEMAND (COD):**The amount of oxygen needed to oxidize the wastes chemically

Organics

Biodegradable

organics that can be utilized for food for naturally occuring microrganisms (M.O.) within a reasonable length of time

Non biodegradable (refractory)

- Organic materials resistant to biological degredation
- Cellulose, phenols ➔ constituents of woody plants
- Usually mesaured by the chemical oxygen demand (COD)

COD = biodegradable + nonbiodegradable
BOD = biodegradable

COD> BOD

NUTRIENTS

- Nutrients are chemicals that are essential to the growth of living things
- Nutrients: Nitrogen, phosphorus, carbon, sulfur, calcium, potassium, manganese etc.
- Can be considered as pollutants when their concentrations are sufficient to allow excessive growth of aquatic plants, particularly algae
- Nutrient enrichment can lead to blooms of algae, which eventually die and decompose
-

NUTRIENTS

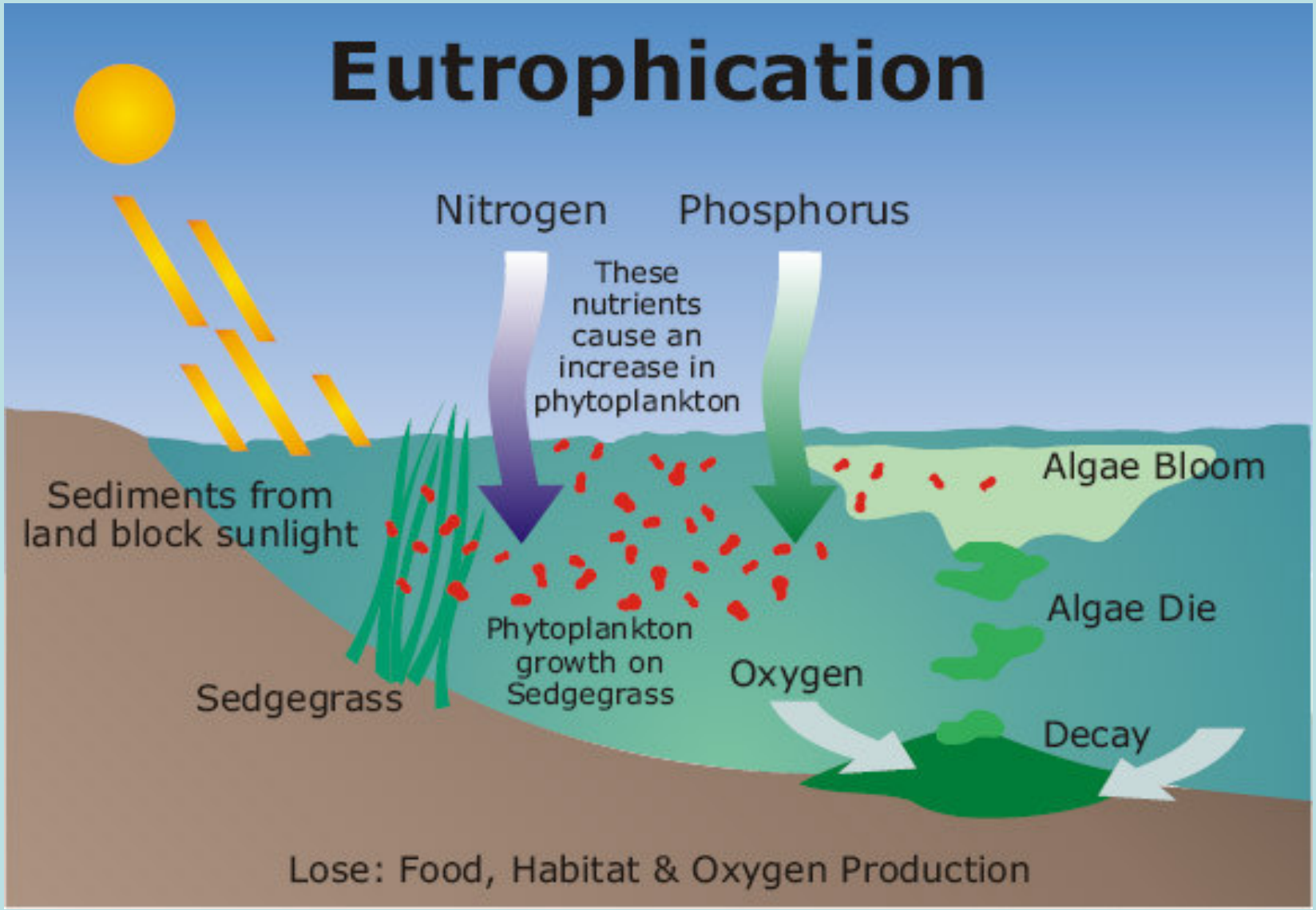
- Decomposition removes oxygen from the water, potentially leading to levels of DO that are insufficient to sustain normal life forms
- Algae and decaying organic matter add color, turbidity, odors and objectionable tastes to water
- Most important nutrients: carbon (C), nitrogen (N), phosphorus (P)
- **Limiting nutrient** : Least avaliable relative to the plant's need
- Phosphorus in fresh water
- Nitrogen in sea water
- NO_3^- (nitrate) ➔ blue baby syndrome

EUTROPHICATION

- Natural eutrophication is the process by which lakes gradually age and become more productive. It normally takes thousands of years to progress.
- However, humans, through their various cultural activities, have greatly accelerated this process in thousands of lakes around the globe.
- Cultural or anthropogenic "**eutrophication**" is water pollution caused by excessive plant nutrients.
- Humans add excessive amounts of plant nutrients (primarily phosphorus, nitrogen, and carbon) to streams and lakes in various ways.

EUTROPHICATION

- **Sources:** Runoff from agricultural fields, field lots, urban lawns, and golf courses is one source of these nutrients.
- Untreated, or partially-treated, domestic sewage is another major source. Sewage was a particular source of phosphorus to lakes when detergents contained large amounts of phosphates.
- The excessive growth, or "blooms", of algae promoted by these phosphates changed water quality.
- These algal blooms led to oxygen depletion and resultant fish kills.
- Many native fish species disappeared, to be replaced by species more resistant to the new conditions.
- They cause problems including enrichment, bad odors and a high biological oxygen demand.


Eutrophication
Nitrogen
Phosphorus
These nutrients cause an increase in phytoplankton
Sediments from land block sunlight
Algae Bloom
Algae Die
Phytoplankton growth on Sedgegrass
Oxygen
Sedgegrass
Decay
Lose: Food, Habitat & Oxygen Production

THERMAL POLLUTION

- A number of industries including steam generated electric power plants use water to remove excess heat from their operations.
- A rise in temperature of a body of water has a number of chemical, physical and biological effects.
- The effect of heat is complex and influences many aspects of a natural aquatic system.
- Heated waters are discharged from cooling systems of power plants and industry, often extremely high flow rates.

THERMAL POLLUTION

- Since solubility of oxygen in water is an inverse function of temperature, warmer waters have less dissolved oxygen.

- Heat also accelerates metabolism and bacteria decomposition, which depletes dissolved oxygen further.

- A temperature difference as small as 5-7^{0}C between the heated discharge and the receiving water body may be detrimental to many life forms.

ORGANIC COMPOUNDS

- Most of the organic compounds (carbon-containing) found in water are synthetic chemicals that are created for human activities:
    - Pesticides
    - Solvents
    - Industrial chemicals
    - Plastics
- are toxic to fish and other aquatic organisms.
- Many of them are not biodegradable and bioaccumulate in aquatic organisms.

SALTS

- Water naturally accumulates a variety of dissolved solids, or salts as it passes through soils and rocks on its way to the sea.
  - cations: sodium, calcium, magnesium and potassium
  - anions : chloride, sulfate and biocarbonate

- ***"total dissolved solids"*** measure of salinity
- Fresh water < 1500 mg/L TDS
- Brackish water up to 5000 mg/L TDS
- Saline water > 5000 mg/L TDS
- Sea water ~30,000-34,000 mg/L TDS

SALTS

- The concentration of dissolved solids is an important indicator of the usefulness of water for various applications.
- Drinking water ➔ max. TDS = 500 mg/L
- Irrigation water ➔ 1500 mg/L can be tolerated by most crops
- Water with 2100 mg/L of TDS is not suitable for irrigation.