WATER POLLUTION

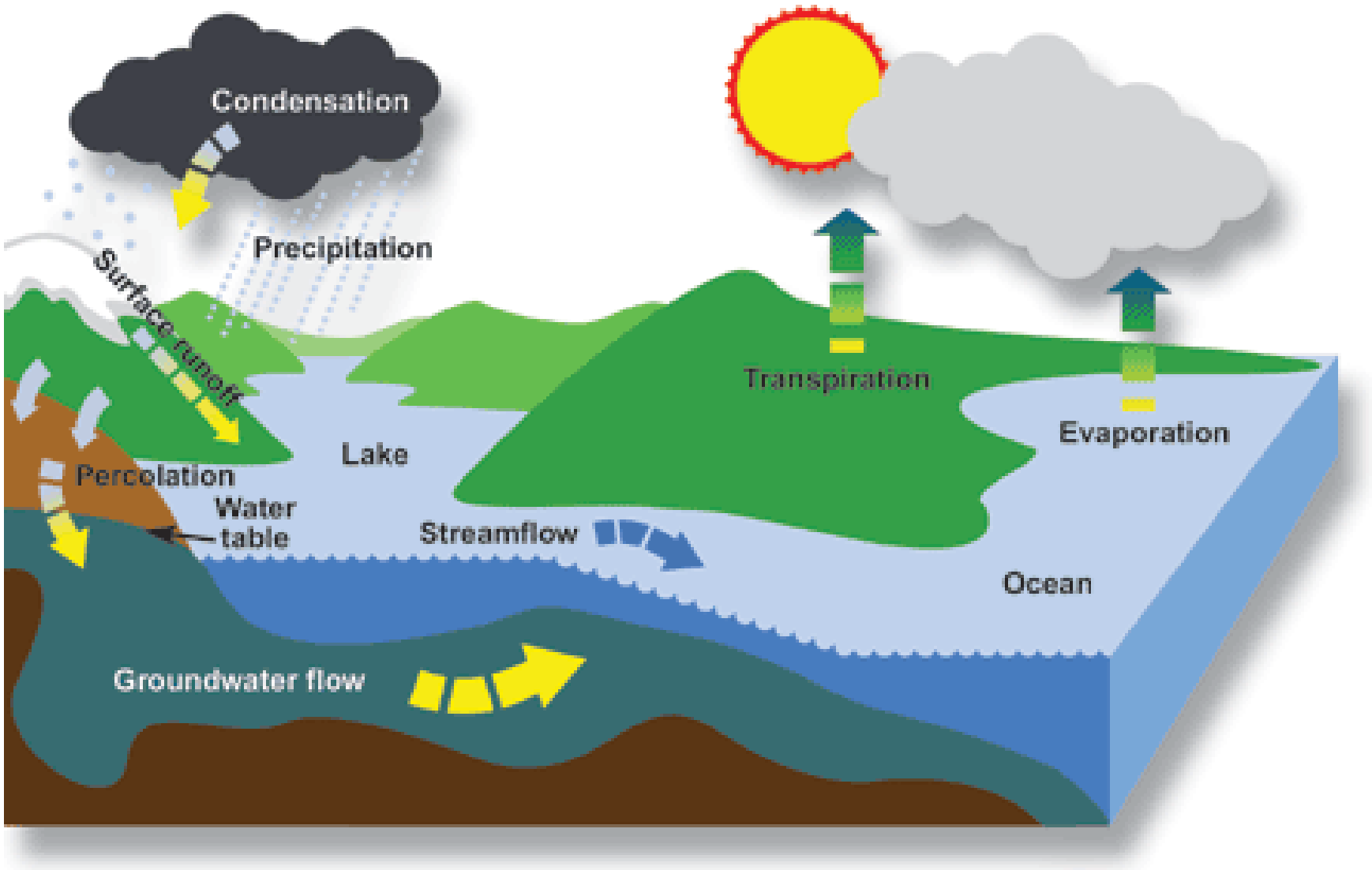
Dr. Rajesh Roshan Dash

Water

- Pure water is colourless, tasteless and odorless
- It is an excellent solvent that can dissolve most minerals that come in contact with it
- It comes to earth through precipitation/ rainfall through hydrologic cycle
- After rainfall some water passes over land and some percolates to subsurface

- 97.5% of the water on earth is salt water and the remaining 2.5% is freshwater.
- Gravity keeps moving water downhill
- Groundwater flows underground until it reaches a reservoir, river, or even the ocean.
- It flows through holes between rocks, dirt, and sand.
- Sometimes it seeps out of the ground and becomes surface water.
- Both surface and groundwater flow into bodies of water that add to our drinking water supply.
- How do we obtain fresh water resources then? Where does drinkable water come from?

HYDROLOGICAL CYCLE



Hydrologic Cycle Components

- Precipitation (vapor to liquid or solid)
- Evaporation and transpiration (liquid to vapor) and condensation (vapor to liquid)
- Surface runoff
- Infiltration, groundwater recharge, discharge and groundwater flow
- Snow accumulation, snowmelt, freeze and thaw (solid to liquid)

Of the total evapo-transpiration

– about 88% is from oceans & seas

– 12% is from land

Of the total rainfall,

– 77% is received by oceans & seas

– 23% is received by land.

Of the total rainfall on land

– 60% of this returns back to sky by evapo-transpiration

– 40% moves through run-off and infiltration.

Precipitation

- Types
  - Cyclonic
  - Convective
  - Orographic

Precipitation

Types

- Cyclonic

  Large whirling mass of air, at the centre of which the barometric pressure is low is known as a cyclone

- Convective

  Due to upward movement of air that is warmer than its surroundings

- Orographic

  Air masses strike natural barriers like mountains and rise up and condense

What are the sources of water?

- Surface sources
  - Ponds & Lakes
  - Streams & River
  - Storage Reservoirs
  - Ocean and Sea
- Subsurface/ Underground sources
  - Springs
  - Infiltration galleries
  - Infiltration wells
  - Wells and tubewells

SURFACE WATER

- Surface water is water in a river, lake, streams or fresh water wetland.
- Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, and sub-surface seepage.
- The total quantity of water at any given time dependent on factors include:
  - Storage capacity in lakes, wetlands and 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.

SUB-SURFACE WATER

- Sub-Surface water, or groundwater, is fresh water located in the pore space of soil and rocks.
- It is the water that is flowing within aquifers below the water table.
- Sometimes it is useful to make a distinction between sub-surface water that is closely associated with surface water and deep sub-surface water in an aquifer (sometimes called "fossil water").

- Possibility of occurrence of ground water depends upon
  - Porosity of soil

    Porosity = total volume of voids in soil aggregates/total volume of soil aggregates
  - Permeability of soil

    It is the ability of the porous medium to pass water through it

- Darcy's law for determining ground water velocity

  v = K.i

  K = Coefficient of permeability or hydraulic conductivity

  i = Hydraulic gradient

  As permeability depends on effect of porous medium and fluid particles properties

$$K = \frac{C.d^2.\gamma}{\mu} = \frac{C.d^2.\rho.g}{\mu} = \frac{C.d^2.g}{\nu}$$

  C = Shape factor, d = mean particle size of porous medium

  μ= dynamic viscosity of water, ν = kinematic viscosity of water

  γ = unit weight of water

Specific yield =

(Volume of water obtained by gravity drainage from saturated water bearing material/

total volume of material drained or dewatered)x100

Specific retention or field capacity =

(Volume of water held against gravity drainage/

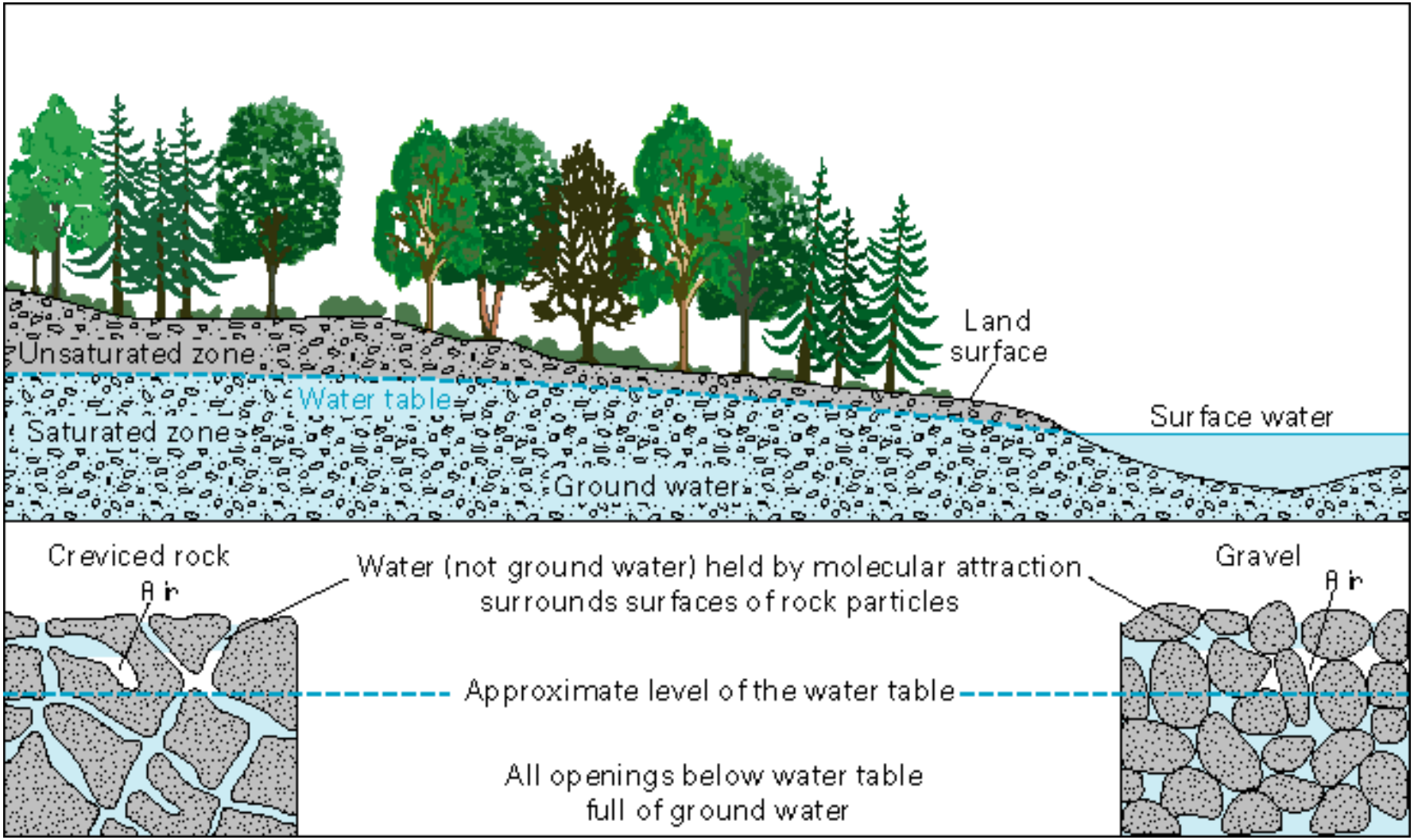
total volume of material drained or dewatered)x100

Specific yield+ Specific retention = porosity

AQUIFER

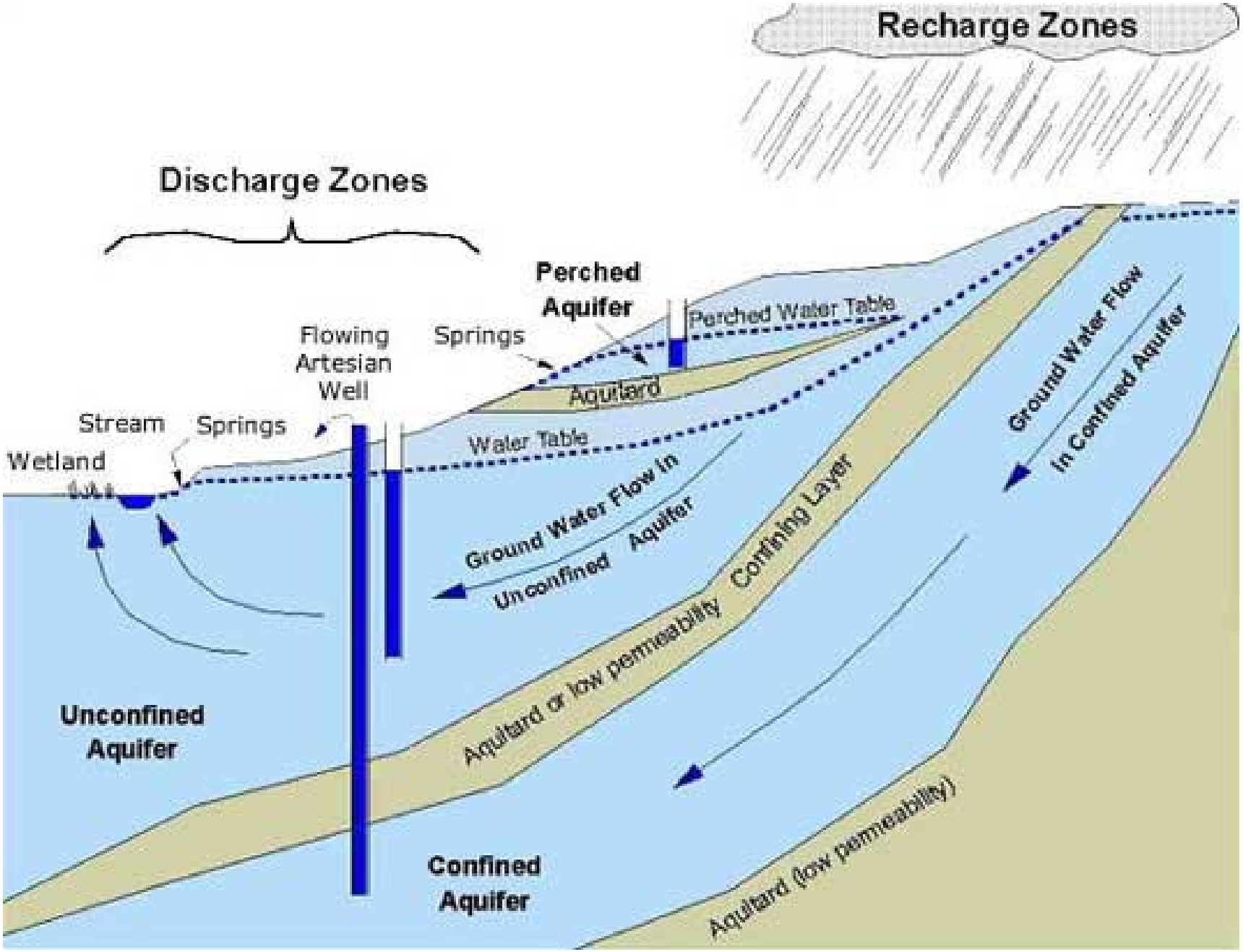
- An aquifer is a formation, group of formations, or part of a formation that contains sufficient saturated, permeable material to yield significant quantities of water to wells and springs
- The aquifer serves as the primary source of drinking water for most residents in planer areas, and also sustains more than one-fourth of the nation's agricultural production.
- Three main categories of aquifers:
  - unconfined,
  - confined and
  - perched.

  In reality, there can be a number of combinations and variations.

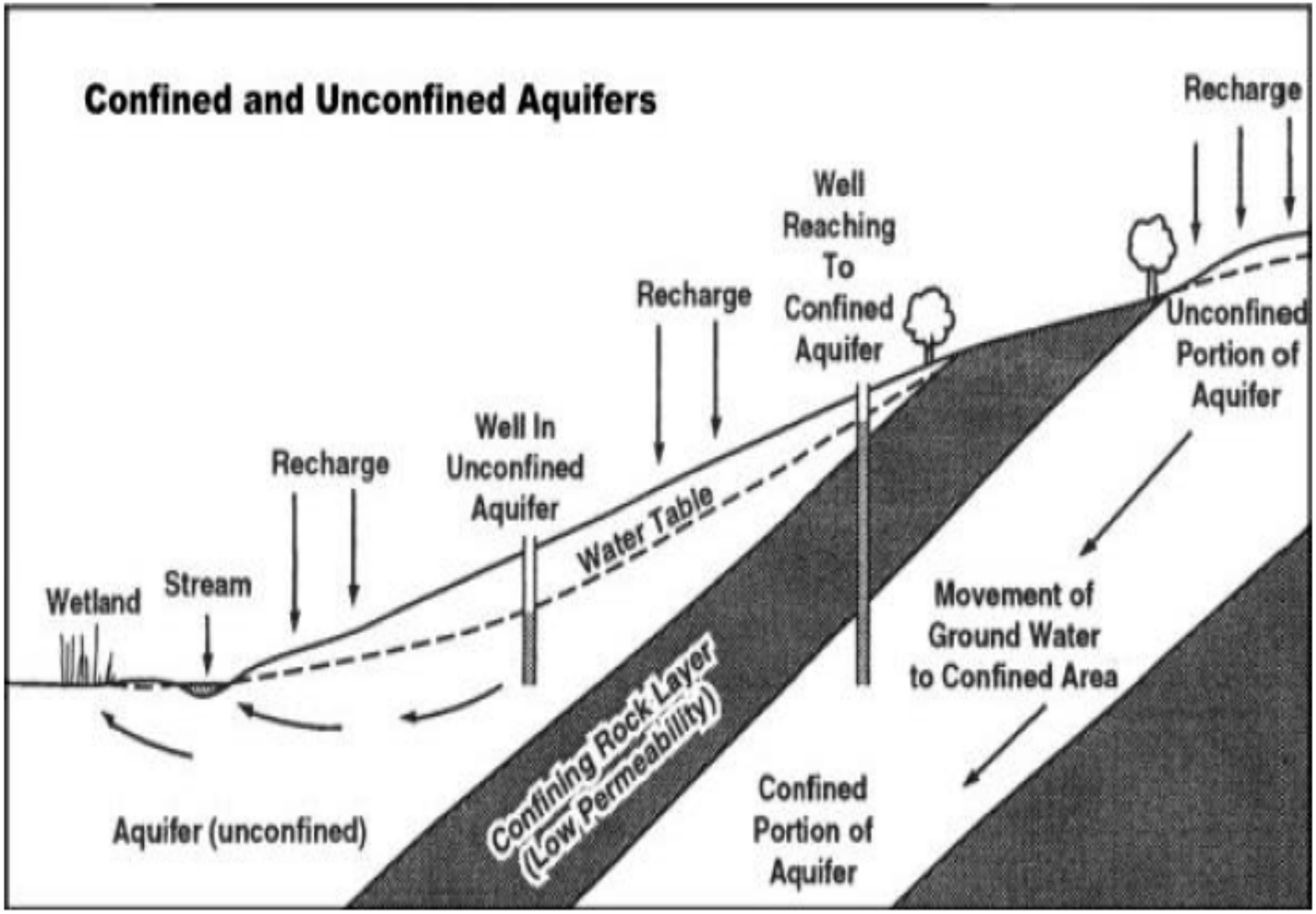

Land surface
Unsaturated zone
Water table
Saturated zone
Ground water
Surface water
Creviced rock
Air
Water (not ground water) held by molecular attraction surrounds surfaces of rock particles
Gravel
Air
Approximate level of the water table
All openings below water table full of ground water

AQUIFER

- Aquifuge: neither porous nor permeable, no water yield, ex: granite rock
- Aquitards: does not yield water freely, less permeability, ex: sandy clay
- Aquiclude: higly porous, containing large quantity of water, but impervious, no yield, ex: clay

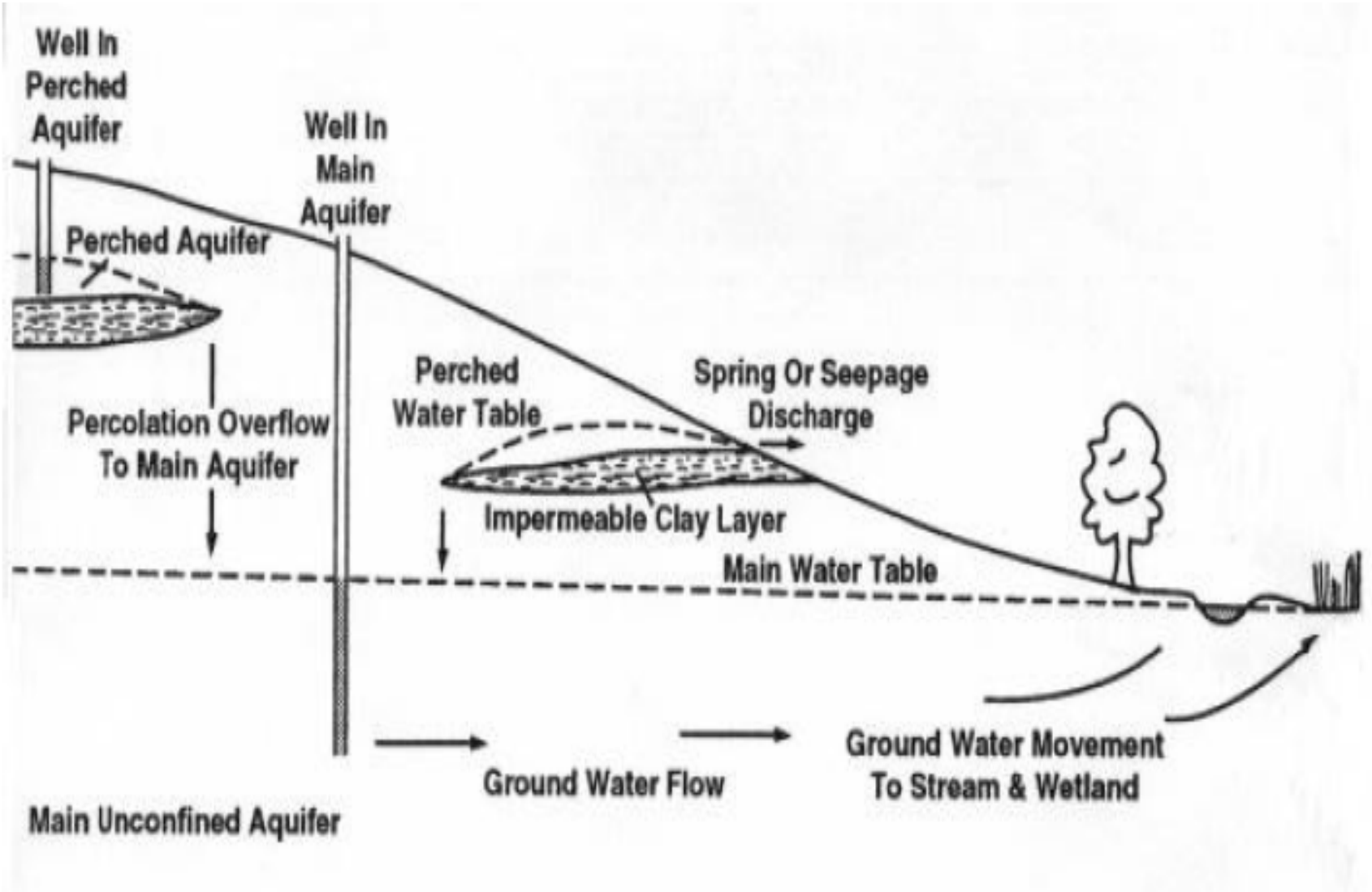

Recharge Zones
Discharge Zones
Perched Aquifer
Perched Water Table
Flowing Artesian Well
Springs
Aquitard
Stream
Springs
Wetland
Water Table
Ground Water Flow in Unconfined Aquifer
Ground Water Flow in Confined Aquifer
Aquitard or low permeability Confining Layer
Unconfined Aquifer
Confined Aquifer
Aquitard (low permeability)

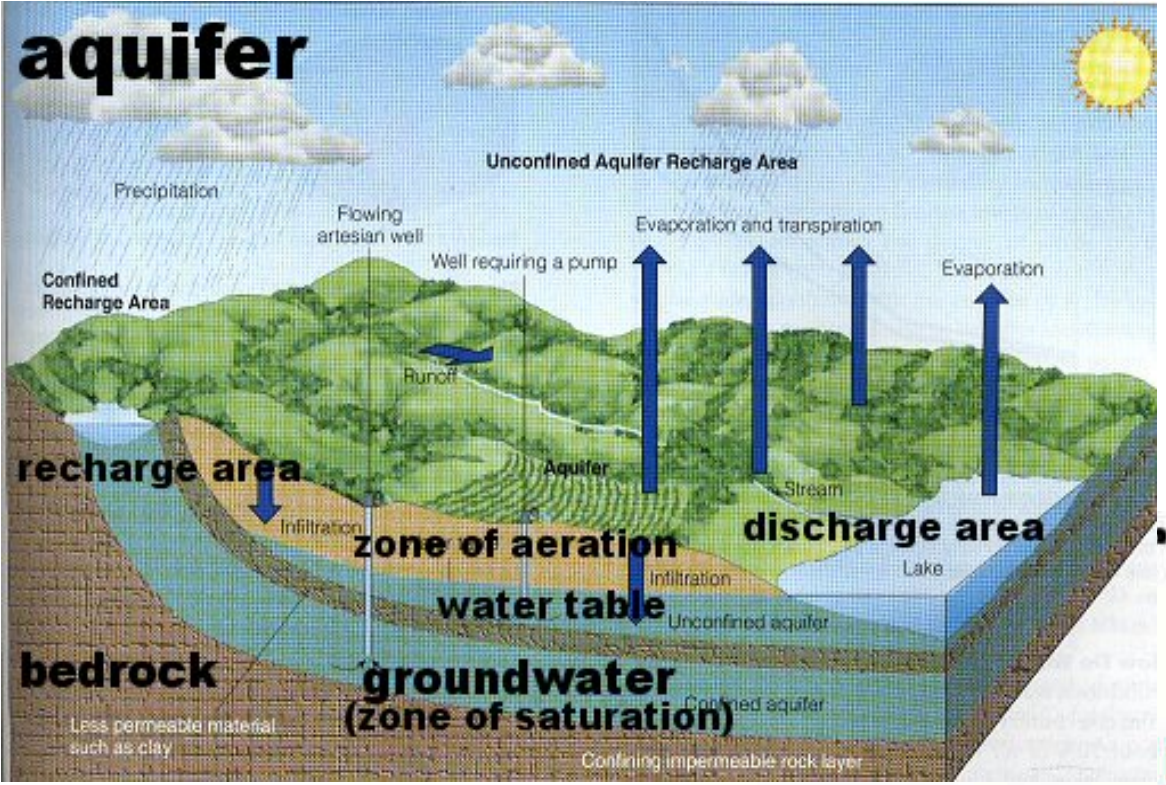
- **Unconfined aquifers** are covered by permeable geologic formations (either solid rock or unconsolidated sediments) and the upper surface/ formations are fully saturated.
- These aquifers are also known as water table aquifers.
- They receive recharge directly from the infiltration of rainfall and surface water.
- It's affected by atmospheric pressure and changing hydrologic conditions.
- Discharge and recharge rates depend on the hydrologic conditions above them.


Confined and Unconfined Aquifers
Recharge
Well Reaching To Confined Aquifer
Recharge
Unconfined Portion of Aquifer
Well In Unconfined Aquifer
Recharge
Water Table
Wetland
Stream
Movement of Ground Water to Confined Area
Confining Rock Layer (Low Permeability)
Aquifer (unconfined)
Confined Portion of Aquifer

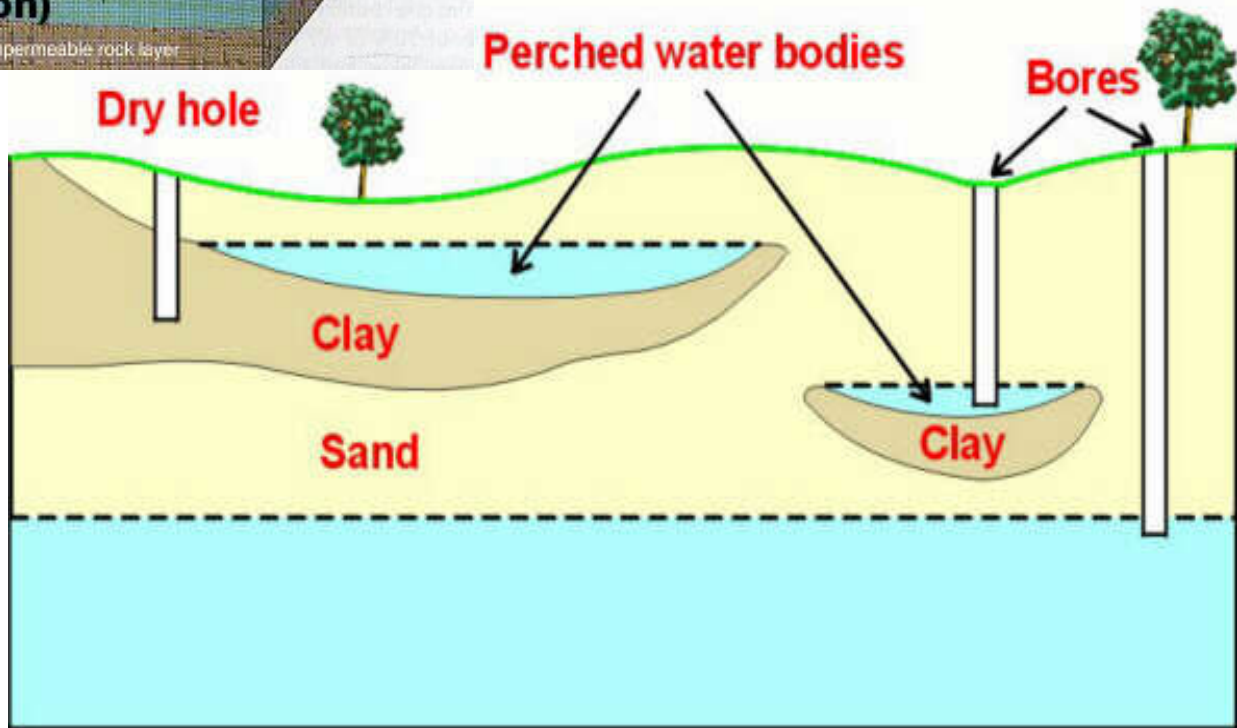
- **Confined aquifers** are those that are covered (confined) by an impermeable or semi-permeable layer of rock.
- Confined aquifers are not directly recharged by vertical infiltration.
- Confined aquifers are also known as artesian or pressure aquifers.
- They exist where the groundwater system is between layers of clay, dense rock or other materials with very low permeability.
- Water in confined aquifers may be very old, arriving millions of years ago.
- It's also under more pressure and when tapped by a well, water is forced up, sometimes above the soil surface.
- This is how a flowing artesian well is formed.

- **Perched aquifers** occur where ground water is perched above unsaturated rock formations as a result of a discontinuous impermeable layer.
- Perched aquifers are fairly common in glacial sediments.
- They also occur in other sedimentary formations where weathered layers, ancient soils or caliche (a calcareous layer common in semi-arid areas) have created impermeable zones.


Well In
Perched
Aquifer
Well In
Main
Aquifer
Perched Aquifer
Percolation Overflow
To Main Aquifer
Perched
Water Table
Spring Or Seepage
Discharge
Impermeable Clay Layer
Main Water Table
Ground Water Flow
Ground Water Movement
To Stream & Wetland
Main Unconfined Aquifer



anular Aquifer



What are the uses of water?

- Drinking
- Bathing
- Washing
- Irrigation
- Cooking
- Swimming, rafting
- Industrial usage etc.

- It forms body fluid of living beings
- It provide habitat and oxygen for aquatic life
- It acts as heat regulator or heat buffer
- It acts as coolant as well as medium of heat conductance
- It acts as excellent solvent for polar solute
- It acts as cleaning and diluting fluid
- Its flow along gravity is used in electricity generation
- It also acts as medium of smooth navigation

What is water quality

- Suitability of water to sustain various uses and processes

What is portable water?

- It should be free from disease producing microorganisms
- It should be colorless, odorless and clear
- It should be tasty, i.e. it should contain some useful salts
- It shouldn’t corrode pipe and other fittings
- It should be free from harmful salts and other objectionable matter
- It should be fresh

How does water get impurities?

- from natural sources
- from man made sources

Factors affecting water quality

- Natural
  - Geological
  - Topographical
  - Meteorological
  - Hydrological
  - Biological
- Manmade
  - Effect on hydrological changes
  - Building of dams
  - Discharge of polluted water

Natural sources of impurities

- Rain, snow falls through atmosphere dissolves:
  - Oxygen
  - Nitrogen
  - Carbon dioxide
  - Other gases
  - Dust
  - Dirt
  - Bacteria
  - Acid fumes

Natural sources of impurities

- Water runoff on surfaces, holds:
  - Silts and suspended material
  - Microorganisms
  - Organic and inorganic compounds
  - Vegetation cover
  - Sulphur, Phosphorus from soil

Natural sources of impurities

- Water percolates through ground holds:
  - Organic and inorganic compounds
  - Minerals like iron, manganese, arsenic, cadmium, lead, copper and zinc
  - Salts like fluoride, chloride, calcium, sodium
  - Other chemicals

Man made sources of impurities

- Contamination from domestic source
- Contamination from industrial source
- Contamination from agricultural source
  - **Point sources:** Sources whose location can be identified as single point. e.g., sewage and industrial effluent
  - **Non-point or diffused or area sources:** Sources that are scattered over a large area or that can not be identified as single point. e.g., run-off from agricultural land, forests, construction etc

Water pollutants: Types

- **Organic pollutants:** Majority of them are derivatives of living beings while some compounds are synthetic. They include
  - (a) Natural organic pollutants,
  - (b) Sewage and industrial effluents,
  - (c) Synthetic organic chemicals (SOCs),
  - (d) Microbiological pollutants, and
  - (e) Oils.
- **Inorganic pollutants:** These include variety of inorganic chemicals like mineral acids, bases, salts, metals, heavy metals etc. They come from natural sources (rocks) as well as man made sources (industries).

- **Radioactive pollutants:** These include different radioactive substances which are released into water from natural sources (rocks) as well as man made sources (nuclear waste, weapons etc.).
- **Suspended solids and sediments:** These include insoluble impurities like soil, sand and other solid particles which either remain as suspension in water or form sediments. Sources include soil erosion (by agriculture, mining, construction), sewage and other effluents.
- **Heat or thermal pollution:** Heated water from thermal power plants and industries is often discharged in water bodies. This increases temperature of water and decreases dissolved oxygen.

Broad classification of impurities/pollutants

- Suspended
- Dissolved
- Colloidal

Suspended impurities

- Impurities remain in suspension
- It include:
  - Silt, clay
  - Algae, fungi
  - Organic and inorganic matter
  - Minerals
- Neither settle down nor dissolve in water
- This makes water turbid
- The microbes present cause disease

Dissolved impurities

- Impurities dissolved in water
- It include salts of calcium, magnesium and sodium, gases etc
- Cause bad taste, odour, colour, hardness and alkalinity in water
- It causes acidity, strains on clothes, utensils and plumbing features, corrosion of metals

Colloidal impurities

- Particles neither suspended nor dissolved in water
- Colloidal particles are charged
- Silica glass, inorganic materials are colloidal in water
- Colloidal particles associated with disease producing bacteria

Effects of water pollution

- **Physical effects:** It includes increased temperature, depletion of dissolved oxygen (DO), increased turbidity, altered colour, oily surface etc. This results in reduced photosynthesis and loss of aquatic life.
- **Oxidation effects:** It includes biological and chemical oxidation. As a result of this different impurities get oxidized (e.g., sulphides into sulphate, ammonia into nitrite and nitrates) at the cost of dissolved oxygen.
- **Toxic chemical effects:** This includes poisonous effects of different compounds which results into fatal diseases or deaths of living beings. e.g., toxic metals like cadmium, mercury, chromium cause damage to liver, kidney and brain. Similarly pesticides, acids, dioxins cause damage.

- **Nutrient effects and Eutrophication:** Agricultural run-off brings lots of nutrients (nitrates and phosphates) to water bodies.

  This results into excessive growth of water weeds (chiefly algae) all over the surface and death of underlying organisms due to oxygen shortage.

  Finally the aquatic ecosystem collapse (destroyed). This is called Eutrophication.
- **Micro-organism effects:** Different micro-organisms (e.g., bacteria, virus) found in dirty water cause a number of water borne diseases e.g., cholera, typhoid, hepatitis, dysentery etc.

Water Quality Monitoring

Measurement onsite or in laboratory

- Collection & analysis of water samples
- Study & evaluation of analytical results
- Reports of the findings
- Information about
  - Location
  - Temperature
  - Time of collection of sample

What is monitored for water quality monitoring

- Water quality
- Composition & state of biological life present in water bodies
- Nature of particulates
- Physical description of water bodies (hydrology, dimensions, nature of lake bottom or river bed)

Potable water

'*Pristine*' quality water can never be available in nature. Even a man made drop of water, prepared in laboratory by lighting the hydrogen and oxygen gases in a test tube, may not be perfectly pure, because the water drop so formed will dissolve the glass of the test tube (although a very little bit).

A water that can be consumed in any desired amount without concern for adverse health effects is termed '***potable water***'. Potable does not necessarily mean that the water tastes good. This is in contrast to a *palatable water*, which is one that is pleasing to drink but not necessarily safe. We must provide a water that is both potable and palatable.

What are the characteristics of water examined?

- Physical
- Chemical
- Bacteriological

Physical Characteristics

- Turbidity
- Colour
- Taste, Odour/ smell
- Conductivity
- Temperature
- Particulate size
- Flow velocity
- Hydrological balance
- Dimensions of water bodies

Chemical Characteristics

- Solids
- Hardness
- Salts (Chlorides, fluorides)
- Metals (Iron, manganese, Arsenic, Chromium)
- pH value
- Nitrogen and its compound
- Dissolved gas
- Organic matter (BOD, COD)
- Plants, Algae, Organisms

Bacteriological Characteristics

- Occurrence, density, biomass of aquatic/parasitic organisms present:
  - Bacteria
  - Viruses
  - Protozoa
  - Worms
  - Algae
  - Fungi
- Toxicity
- Enzyme activity

Microbiological Examination

- Bacteria, Viruses
- Pathogens
- Aquatic plants
- Aquatic animals
- Aquatic molds
- Indicator Organisms
- Coliform Index
- Escherichea coli (E-Coli)
- Most Probable Number (MPN)
- Multiple Tube Fermentation Technique
- Membrane Filter Technique

***Water quality criterion*: That concentration of a water quality measure that will meet a specific water use.**

***Water quality standard*: The translation of a water quality criterion into a legally enforceable mass discharge or effluent limitation. Thus, the framework for assessing effluent limitations consists of two parts:**

- **A use for which the water body is to be protected or designated (e.g., recreation, agriculture)**
- **A numerical or qualitative pollutant concentration limit which will support that use**

Classification & Zoning of water bodies by CPCB, India

Designated-Best-Use	Class	Criteria
Drinking Water Source without conventional treatment but after disinfection	A	1 .Total Coliforms Organism MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/l or more 4. Biochemical Oxygen Demand 5 days 20^{o}C 2mg/l or less
Outdoor bathing (Organised)	B	1 .Total Coliforms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. Biochemical Oxygen Demand 5 days 20oC 3mg/l or less
Drinking water source after conventional treatment and disinfection	C	1 . Total Coliforms Organism MPN/100ml shall be 5000 or less 2. pH between 6 to 9 3. Dissolved Oxygen 4mg/l or more 4. Biochemical Oxygen Demand 5 days 20^{o}C 3mg/l or less
Propagation of Wild life and Fisheries	D	1 .pH between 6.5 to 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N) 4. Biochemical Oxygen Demand 5 days 20oC 2mg/l or less
Irrigation, Industrial Cooling, Controlled Waste disposal	E	1 .pH betwwn 6.0 to 8.5 2. Electrical Conductivity at 25oC micro mhos/cm Max. 2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/l
	Below-E	Not Meeting A, B, C, D & E Criteria

Tolerance Limits for Industrial Effluents [IS:2490(Part-I)]

Parameter (mg/L)	Inland Surface Water	Public Sewers	Land Irrigation	Ocean Discharge
pH	5.5-9.0	5.5-9.0	5.5-9.0	5.5-9.0
BOD_5	30	350	100	100
COD	250	-	-	250
SS	100	600	200	100
DS	2100	2100	2100	-
Temp (^oC)	40	45	-	45
Oil/Grease	10	20	10	20
Chloride	1000	1000	600	-
Sulphate	1000	1000	1000	-
NH_4-N	50	50	0	50
TKN	100	-	-	100

Tolerance Limits for Industrial Effluents [IS:2490(Part-I)]

Parameter (mg/L)	Inland Surface Water	Public Sewers	Land Irrigation	Ocean Discharge
Ammonia(Free)	5	-	-	5
Fluoride	2	15	-	15
Chromium(Hexa)	0.1	2	-	1
Chromium(Total)	2	2	-	2
Copper	3	3	-	3
Lead	0.1	1	-	1
Mercury	0.01	0.01	-	0.01
Cadmium	2	1	-	1

Odor & Color: Remove as far as practicable

COD: Relaxable for paper, dyestuff, pesticide, certain chemical/ petrochemical industries but must pass acute lethal toxicity test (IS:6587)

Drinking water Standards

Drinking water standards

Characteristics	World Health Organization (WHO)		Ministry of Works and Housing, (1975)	
	Highest desirable	Maximum permissible	Acceptable	Cause of rejection
Physico-chemical				
Turbidity (J.T.U.)	5.0	25.0	2.5	10.0
Colour (Pt-scale)	5.0	50.0	5.0	25.0
Taste and Odour	nothing	disagreeable	unobjectionable	unobjectionable
pH	7.0–8.5	6.5–9.2	7.0–8.5	6.5–9.2
Total solids	500	1500	500	1500
Total hardness	100	500	200	600
Chlorides	200	600	200	1000
Sulphates (as SO_4)	200	400	200	400
Fluorides (as F)	1.0	1.5	1.0	1.5
Nitrates (as NO_3)	45	45	45	45
Calcium (as Ca)	75	200	75	200
Magnesium	30	150	30	150
Iron (as Fe)	0.1	1.0	0.1	1.0
Manganese (as Mn)	0.05	0.5	0.05	0.5

Copper	0.05	1.0	0.05	1.5
Zinc	5.0	15.0	5.0	15.0
Phenolic compounds	0.001	0.002	0.001	0.002
Detergents, anionic	0.2	1.0	0.2	1.0
Mineral oil	0.01	0.30	0.01	0.30
Arsenic	0.05	0.05	0.05	0.05
Chromium (as Cr^{+6})	–	0.01	0.05	0.05
Cyanide	–	0.05	0.05	0.05
Lead	–	0.10	0.10	0.10
Selenium	–	0.01	0.01	0.01
Cadmium	–	0.01	0.01	0.01
Mercury	–	0.001	0.001	0.001
PCBs (µg/L)	–	0.2	0.2	0.2
Gross alfa-activity (PCi/L)	–	3.0	3.0	3.0
Gross beta-activity (PCi/L)	–	30.0	30.0	30.0

Bacteriological Standards

W.H.O.	*Ministry of Works and Housing*
(*a*) ***Water Entering*** *Distribution System:* If disinfected, coliform count in any sample of 100 mL should be zero.	(*a*) Coliform count in any sample of 100 mL should be zero.
(*b*) ***Water in the Distribution System:*** Ideally all samples taken from the distribution system including consumer's premises should be free from coliform organisms. Since in practice it is not always possible, following standards can be followed:	(*b*) Water in the distribution system shall satisfy all the three criteria indicated below:
(*i*) Throughout any year, 95% of the samples examined should not have any coliform organisms.	(*i*) *E. coli* count in 100 mL of any sample should be zero.
(*ii*) *E. coli* count in 100 mL of any samples should be zero.	(*ii*) Coliform organisms not more than 10 per 100 mL shall be present in any sample.
(*iii*) Coliform organisms not more than 10 per 100 mL shall be present in any sample.	(*iii*) Coliform organisms should not be detectable in 100 mL of any two consecutive samples of more than 50% of the samples collected for the year.
(iv) Coliform organisms should not be detectable in 100 mL of any two consecutive samples.	

Note: all the values are in mg/L except pH, otherwise stated.

Common Instrumental Methods of Analysis

Optical Methods of Analysis

- Absorption methods
- Ultraviolet Spectroscopy
- Infrared Spectroscopy
- Emission Methods
- Atomic Emission Spectroscopy
- Atomic Absorption Spectroscopy
- Inductively Coupled Plasma spectroscopy

Electrical Methods of Analysis

- Potentiometric Analysis
  - Gas Electrode
  - Metal electrode
  - Oxidation-Reduction Electrode
  - Electrode with Metal Contacting Slightly Soluble Salt
  - Membrane Electrode
  - Glass Electrode
  - Liuid Membrane Electrode
  - Gas-Permeable Membrane Probes
  - Crystalline Membrane Electrode
- Polarographic analysis
- Anodic Stripping Voltammetry

Chromatographic Methods of Analysis

- Gas Chromatography
- High-Performance Liquid Chromatography
- Ion Chromatography
- Capillary Electrophoresis

Other Instrumental Methods

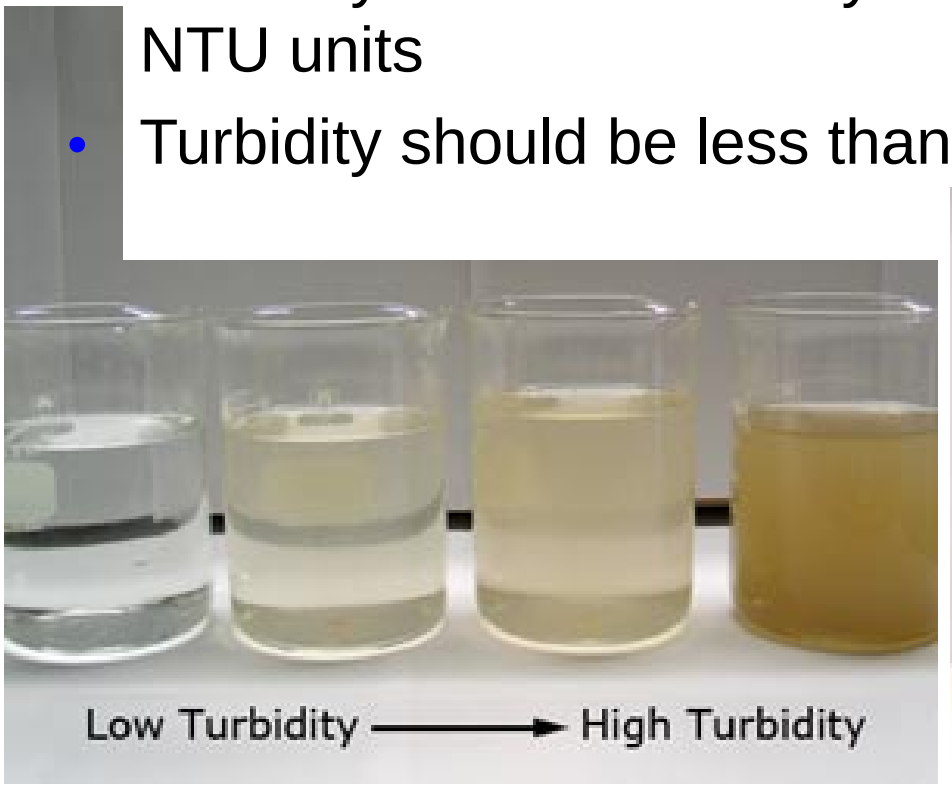
- Mass Spectrometry
- X-Ray Analysis
- Nuclear Magnetic Resonance Spectroscopy
- Radioactivity Measurements

Physical Characteristics

- Turbidity
- Colour
- Taste, Odour/ smell
- Conductivity
- Temperature
- Particulate size
- Flow velocity
- Hydrological balance
- Dimensions of water bodies

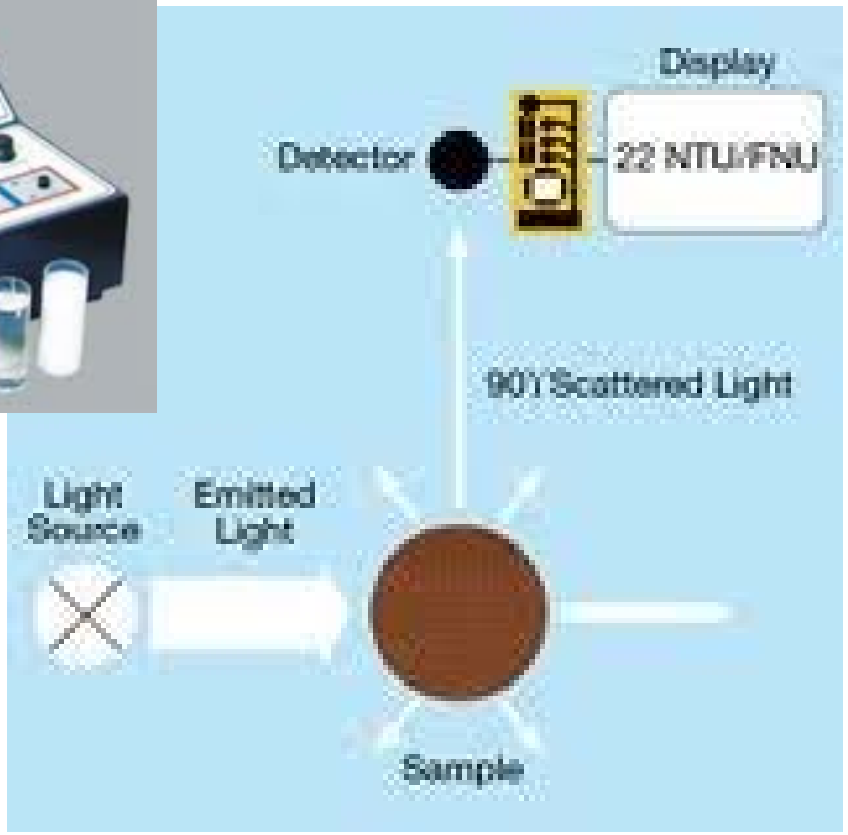
Turbidity

- Caused by the presence of clay, organic and inorganic material, microorganisms
- Turbidity represent the optical property and reduce the transmissibility of light
- Turbidity is measured by Silica unit: 1mg/L or JTU or NTU units
- Turbidity should be less than 5-10 NTU

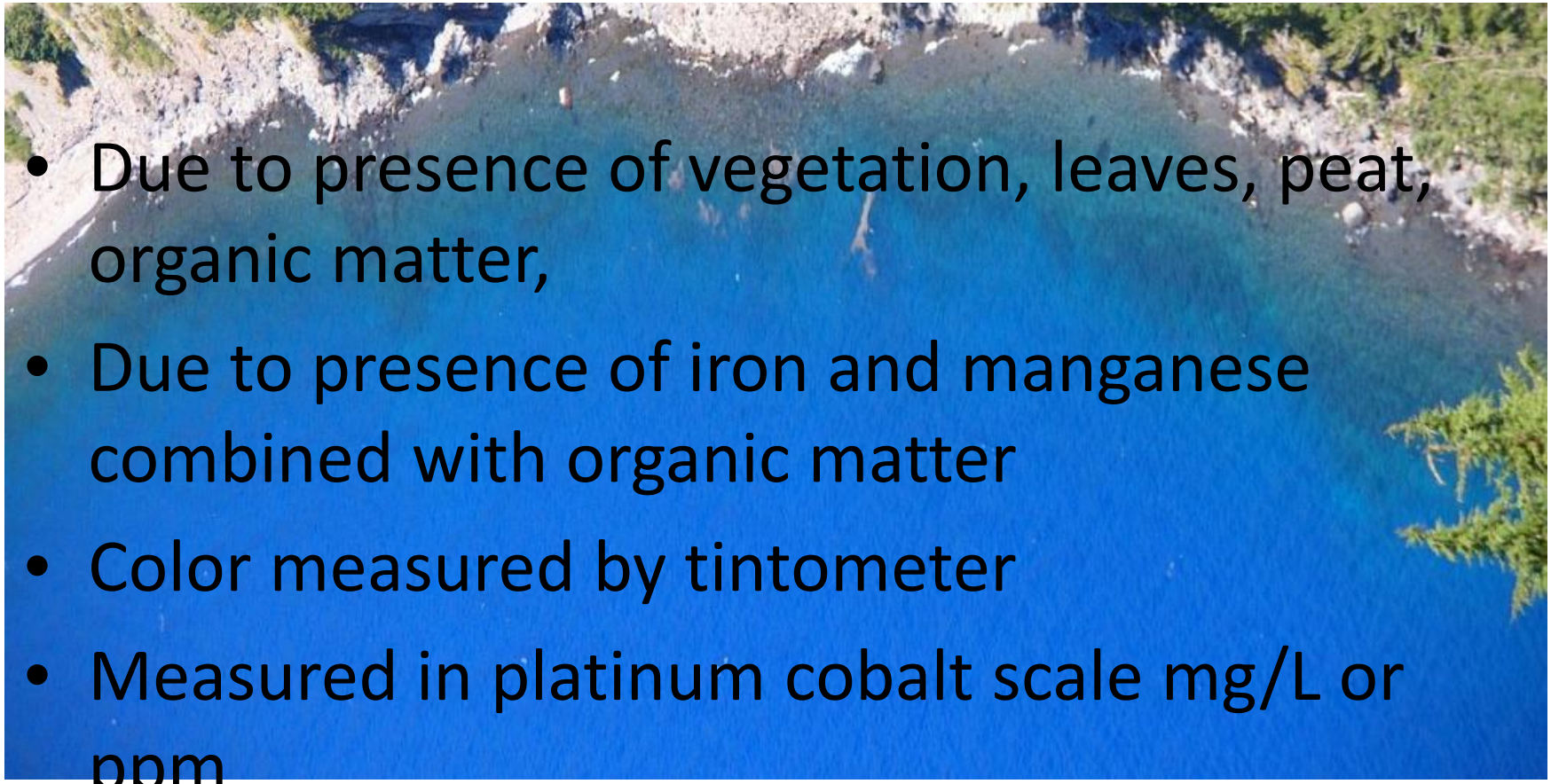


Turbidity

- Measured by: Turbidity rod or turbidimeter or Nephelometer



Colour



- Due to presence of vegetation, leaves, peat, organic matter,
- Due to presence of iron and manganese combined with organic matter
- Color measured by tintometer
- Measured in platinum cobalt scale mg/L or ppm
- Max permissible limit 20 ppm

Taste and Odour

- Due to presence of decomposed organic matters, microorganism and chemical substances
- Can't be measured accurately
- Only can be measured by diluting the water with distilled water
- Expressed as threshold odour number (dilution ratio)
- Threshold odour number = 1, never exceed 3

Conductivity

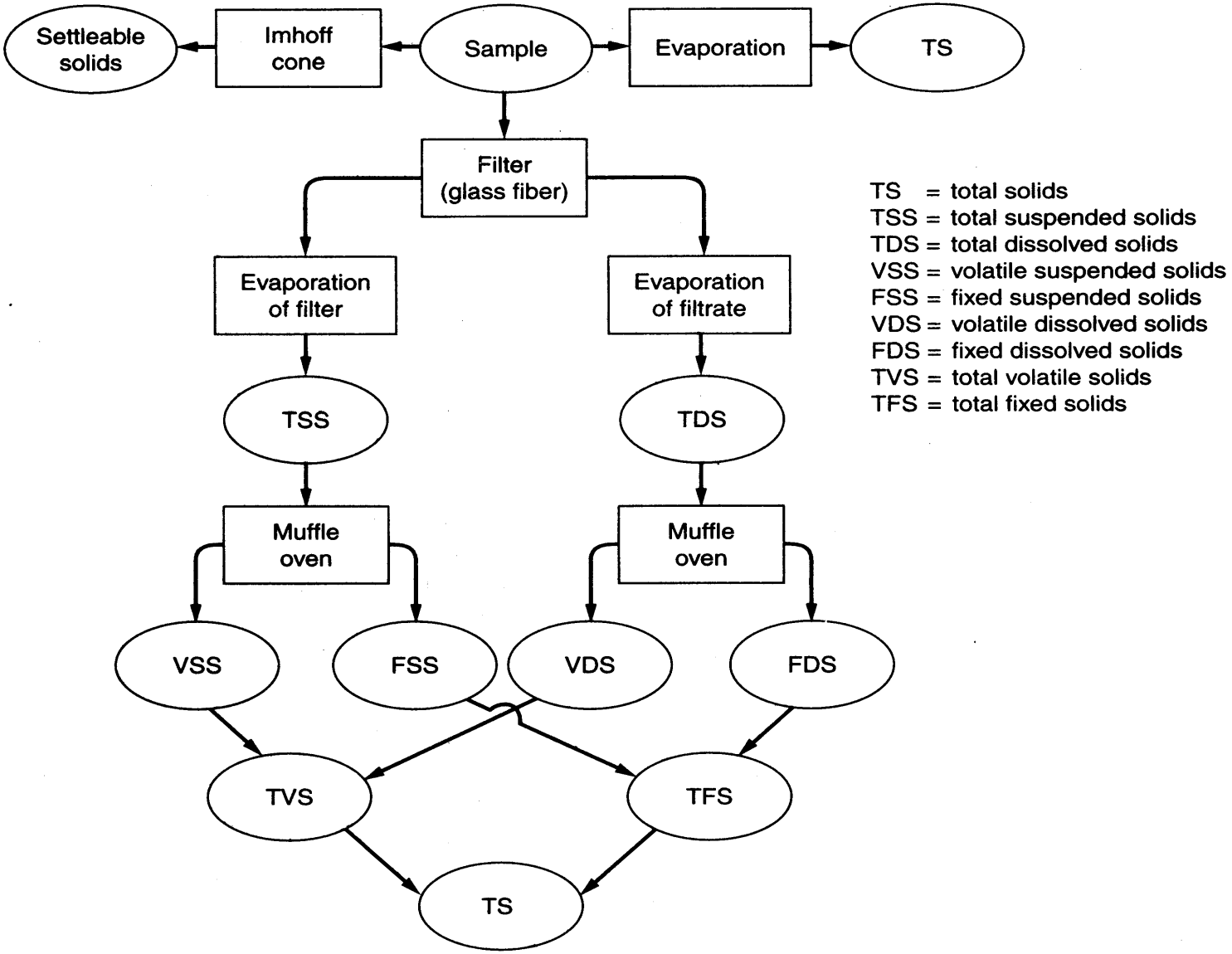
- The electrical conductivity of water is the traditional indicator for mineral deposits.
- Pure water is not a good conductor of electricity, dissolved ions increase conductivity
- Conductivity x coefficient (0.65) = dissolved salt content in mg/L

Chemical Characteristics

- Solids
- Hardness
- Salts (Chlorides, fluorides)
- Metals (Iron, manganese)
- pH value
- Nitrogen and its compound
- Dissolved gas
- Organic matter (BOD, COD)
- Plants, Algae, Organisms

Solids

- It can be dissolved/suspended and total
- It can be organic/inorganic
- Solids can be weighted after drying
- Total permissible amount of solid < 500 ppm, allowable upto 1000 ppm



Interrelationships of solids found in water and wastewater

pH

- The acidity or alkalinity of water expressed on a scale of 0 (acid) to 14 (alkali), pH 7 is considered neutral.
- In public water supplies pH should be 6.6-8.5

Hardness

- It is the property of water which prevents leathering of soap, scales in boiler, corrosion and incrustation of pipes
- It can be temporary/permanent
- Temporary hardness is caused due to presence of bicarbonates of calcium & magnesium
- Permanent hardness caused due to the presence of sulphur, chlorides and nitrates of calcium and magnesium
- Measurement of hardness done by titration (EDTA method)
- If hardness < 75 ppm : Soft water, > 200 ppm: Hard water

  75-200 ppm: Moderately hard water
- For public supples 75-115 ppm, as soft water is tasteless

Chlorides

- Chlorine in combination with other elements is chloride
- Chloride in water is due to contamination from wastewater
- It makes water saltish and dangerous
- > 250 mg/L makes water salty, hence it should be < 250 mg/L in public water supplies

Nitrogen and its compound

- Nitrogen compounds found in water as:
  - Free nitrogen/ Ammonia
  - Organic Nitrogen
  - Nitrite
  - Nitrate
- Nitrogen compounds found in water due to fixation of atmospheric nitrogen by certain microorganisms, plant debris, fertilizers

Free and Organic Nitrogen

- **Free ammonia** indicate recent pollution (1st stage of decomposition)/ presence of undecomposed organic matter
- Indicates direct inclusion of ammonia gas arising from urine of animal and human species
- It cause bad taste and odour of water and should be < 0.15 mg/L
- Ammonia gas measured by boiling in distillation process
- **Organic nitrogen** indicates the presence of fresh organic mater
- Indicate pollution in water and Should be < 0.3 mg/L
- Measured by adding strong alkaline solution of KMnO4 to already boiled water
- Sum of Free ammonia and Organic nitrogen is known as Kjedahl Nitrogen

Nitrite

- Presence of nitrites indicates partial decomposition of nitrogenous compound/ organic matter in water
- It causes various diseases
- It is objectionable in drinking water as it is found with various microorganisms
- It should be NIL in portable water

Nitrate

- Presence of nitrates indicates final stage of decomposition of nitrogenous compound/ organic matter in water
- It is loosely bound to soil and leached to ground water
- High level of nitrate found in ground water in india
- It causes Methaemoglobinemia or blue baby disease which characterized by blue colour skin
- It should be < 45 mg/L in portable water

Methemoglobinemia or blue baby disease

Fluorides

- Less than 0.8-1 ppm cause dental carries (tooth decay) due to formation of excessive cavities
- More than 1.5 ppm cause fluorosis (spotting and decolourisation of teeth)

Dental caries

- Less than 0.8-1 ppm cause dental carries

Dental fluorosis

- More than 1.5 ppm cause decolourization of teeth, dental/bone fluorosis, deformation of bone

Fluorosis

- More than 1.5 ppm cause decolourization of teeth, dental/bone fluorosis, deformation of bone

Iron and Manganese

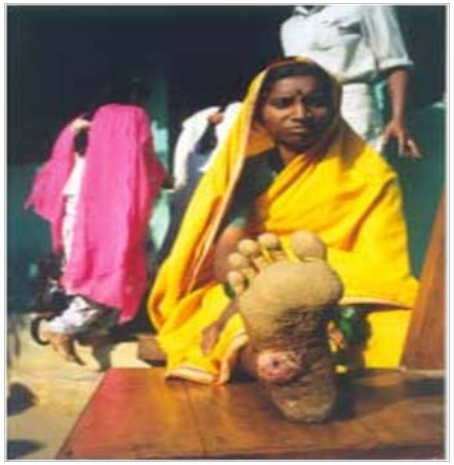
- Cause stains in plumbing fixtures and textiles, corrodes ferrous metals, incrustation in water mains due to deposition of ferric hydroxide
- Microorganism grow on iron makes the water bad taste and odour
- Water becomes reddish in presence of iron and iron bacteria, should be < 0.3 ppm
- Manganese causes brownish colour
- Manganese impart taste of coffee & tea, should be < 0.05 ppm

Other metals and compound

- Lead, Arsenic are poisonous, accumulate on body, cause skin disease and even death
- Barium and Boron have toxic effects on heart, blood vessels and nerves
- Chromium may cause cancer
- Cyanide is poisonous and cause respiration problem and even death

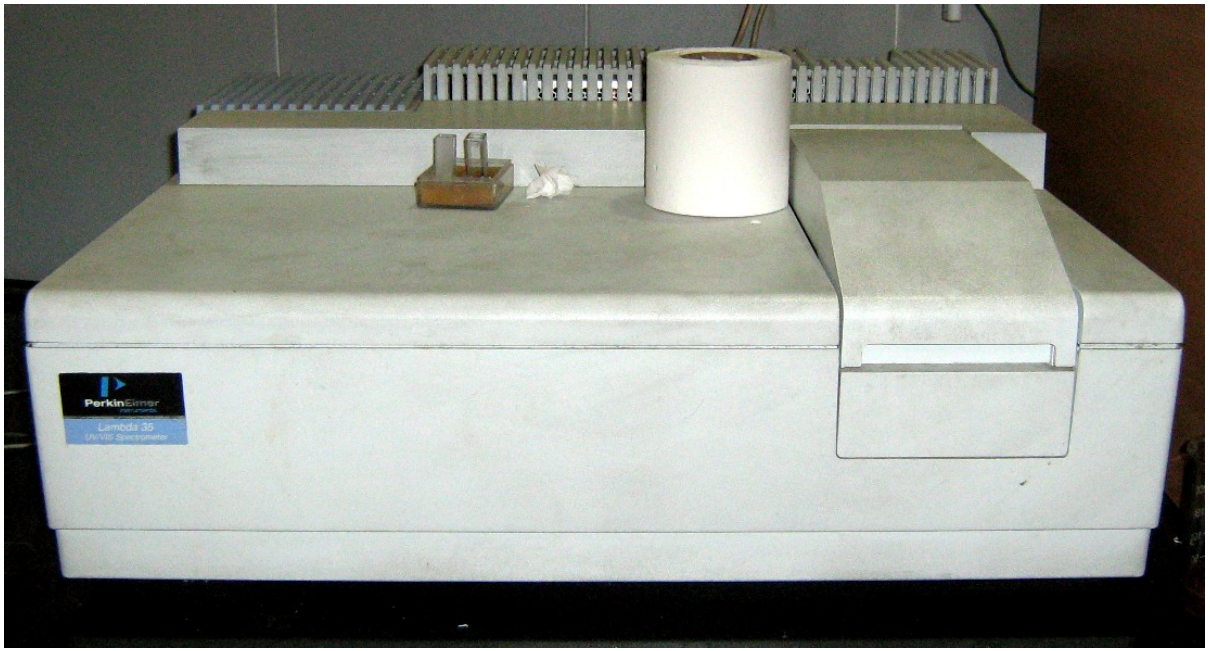
Arsenic Poisoning

A Patient from Hazipurbhita Jharkhand



A Patient from Chattisgarh

A Patient from Tiwaritola, Uttar Pradesh



Spectrophotometers

Dissolved Gases

- Hydrogen sulphide
- Methane
- Carbon dioxide
- Oxygen

Hydrogen sulphide & Methane

- It originates from anaerobic decomposition of organic matter
- It causes a rotten egg smell
- It promote growth of certain bacteria in distribution system, which clog pipes, screens and other structures
- It is corrosive to concrete and metal

Carbon dioxide

- It dissolves in water through atmosphere
- It makes the water corrosive

Dissolved Oxygen

- Surface water contain large amount of D.O. due to adsorption from atmosphere and produced from algae and fungi
- It is necessary for fish and aquatic organisms
- It helps to decompose organic mater under aerobic condition, which reduced smell in water and keep water fresh
- But in higher quantity it causes corrosion
- Saturation DO is 9.1 mg/L, for aquatic animals it should be > 4 mg/L, for human being > 7 mg/L

- Biochemical oxygen demand (BOD):

  It is a measure of the amount of oxygen required for the degradation of oxidisable/biodegradable organic materials

  BOD_5 = BOD of 5 days = Loss of oxygen in mg/L x Dilution ration

  BOD should be NIL in water

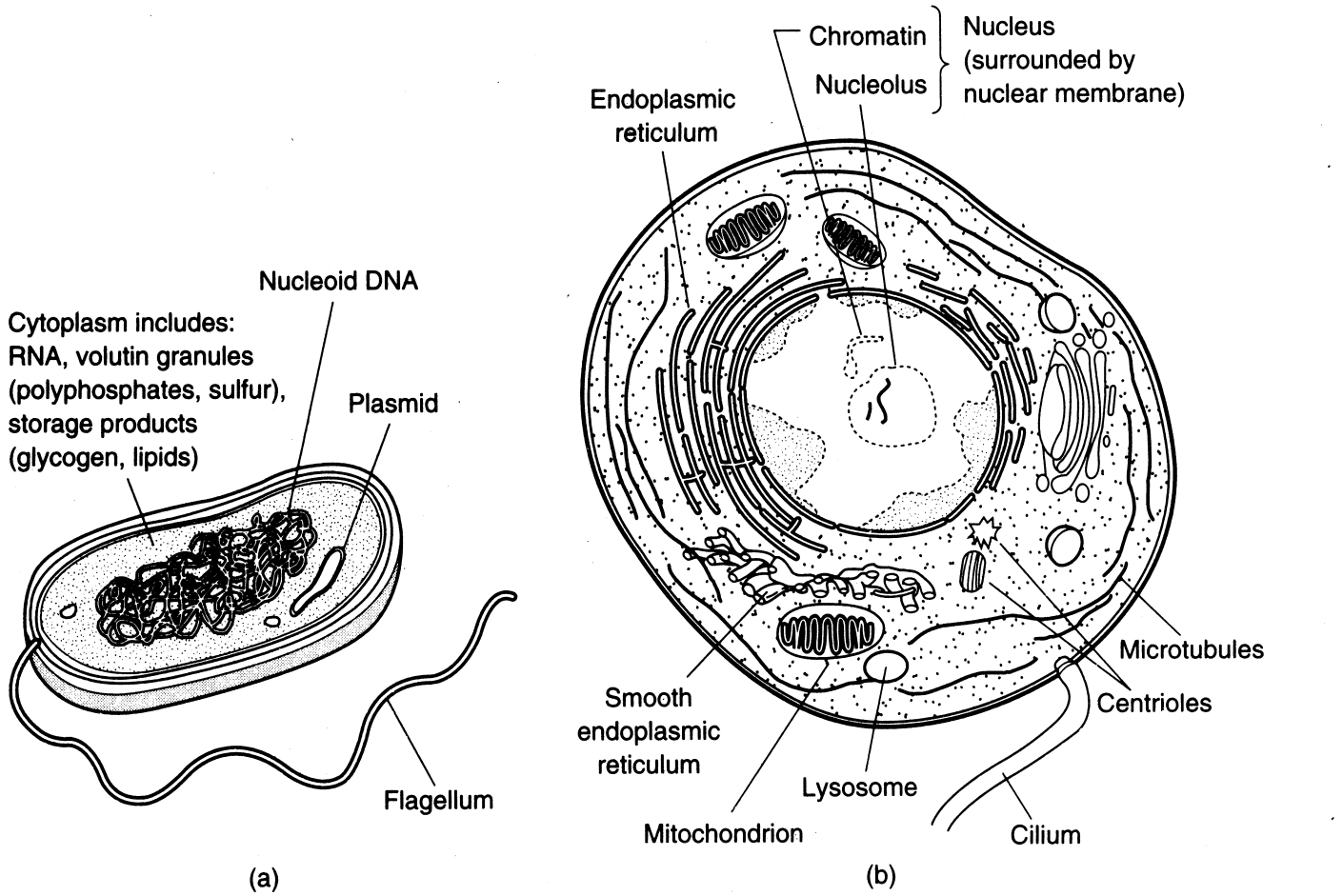
- Chemical oxygen demand (COD):

  It is a measure of total oxygen required for degrdation of organic materials

Bacteriological Characteristics

- Occurrence, density, biomass of aquatic organisms/parasitic organisms present:
  - Bacteria
  - Viruses
  - Protozoa
  - Worms
  - Algae
  - Fungi
- Toxicity
- Enzyme activity
- MPN

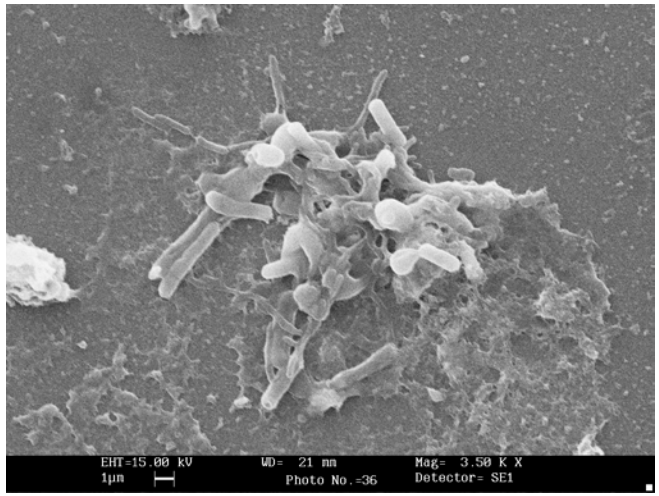
- Bacteria are minute single cell organisms possessing no defined nucleolus and no chlorophyll to help them in manufacturing their own food
- Microorganisms/Bacteria can be
  - Aerobic
  - Anaerobic
  - Facultative
- Harmless bacteria are known as non-pathogenic bacteria
- Harmful bacteria are known as pathogenic bacteria
- Bacterial count can be done to detect bacteria in water and wastewater

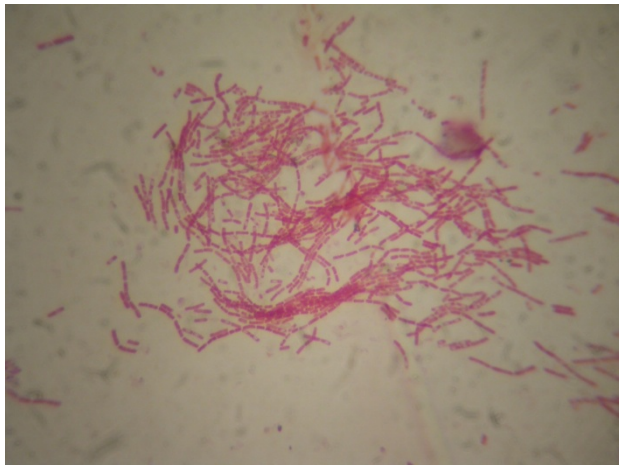


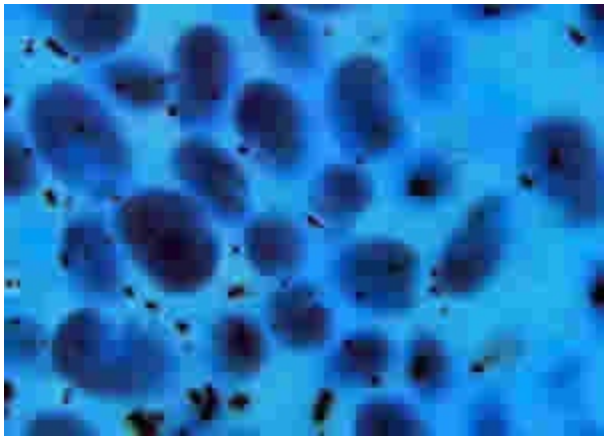
Typical structure of microorganism cells: (a) prokaryotic and (b) eukaryotic

Diseases caused by bacteria

- Typhoid fever
- Paratyphoid fever
- Dysentery
- Food poisoning
- Cholera
- Gastroenteritis







Viruses

- Viruses are group of infections or agents smaller than bacteria and difficult to study
- Diseases caused
  - Hepatitis Jaundice
  - Poliomyelitis

Protozoa

- Protozoa are single cell animals and are lowest and simplest form of life.
- They are bacteria eaters and destroy pathogens
- They form scum and unsightly deposits on porcelain utensils
- Diseases caused
  - Amoebic dysentery
  - Cryptsporidiosis/ Diarrhea

- Bacterial diseases:
- Cholera by *Vibrio cholerae*
- Typhoid fever by *Salmonella typhi*
- Viral diseases:
- Meningitis by *Coxsackie viruses*
- Hepatitis A by *Hepatitis A virus*
- Protozoal diseases:
- Amoebic dysentery by *Entamoeba histolytica*
- Dysentry by *Balantidium coli*

Worms

- Larvae of flies
- Diseases caused
  - Intestinal roundworm
  - Guniea worm
  - Itching, body pain

Algae, Plankton &Fungi

- Algae is a type of plant that grows in water and flourishes in the presence of sunlight.
- 7 types of algae exist depending on shape and colour having chlorophyll
- They may of 3 groups: Diatomacea, Chlorophylcea and Cyanophylcea
- Plankton are the microscopic plants and animal life that float in water and serve as food for small sea creatures and fishes
- Fungi are those plants those grow without sunlight and live on other plant and animals, dead or alive
- Cause turbidity in water
- Colour of water changes

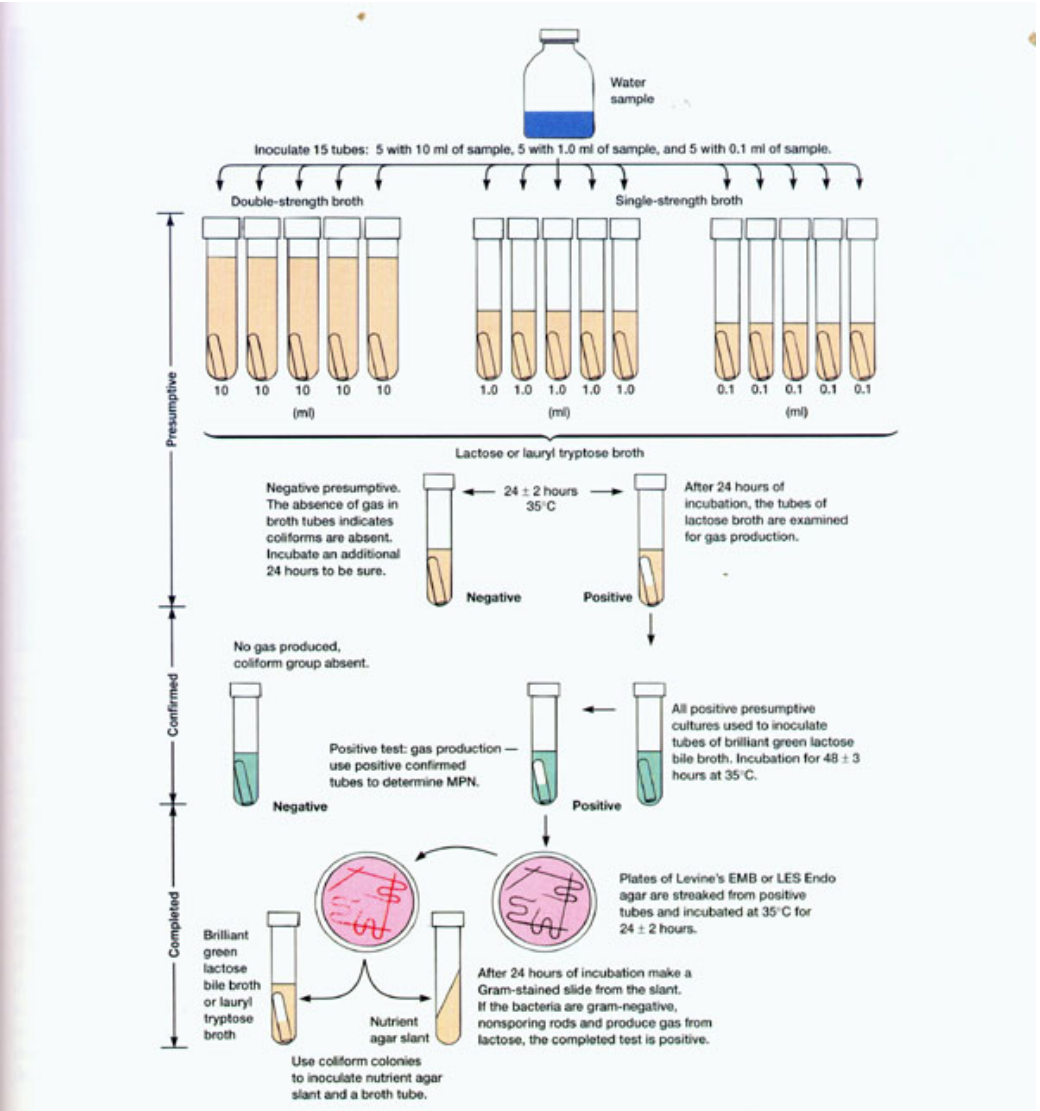
- Routine tests are conducted to detect and count presence of nonpathogenic indicator organisms, i.e. coliform group
  - Total coliform
  - Fecal coliform
- Coliforms are rod shaped nonpathogenic bacteria whose presence or absence indicates the presence and absence of pathogens
- Total coliform consists of members whose normal habitat is human bodies and cold blooded animal, soil vegetation and feces
- Fecal/ thermotolerant coliforms are 96% of total coliform and not found in soil and vegetation and exclusively found in feces

- Escherichia coli or E-Coli is member of fecal coliform
- Presence of E-coli indicates recent pollution with human and animal feces
- Other organisms present
  - Fecal streptococci
  - Lactobacilli
  - Clostridium perfingens
  - bacteroids

Tests

- Multiple tube fermentation technique
- Membrane filter technique

Multiple tube fermentation



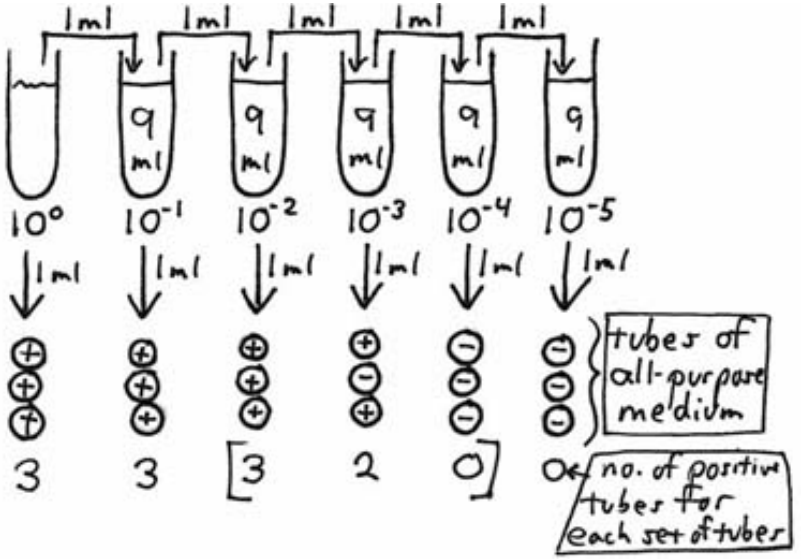


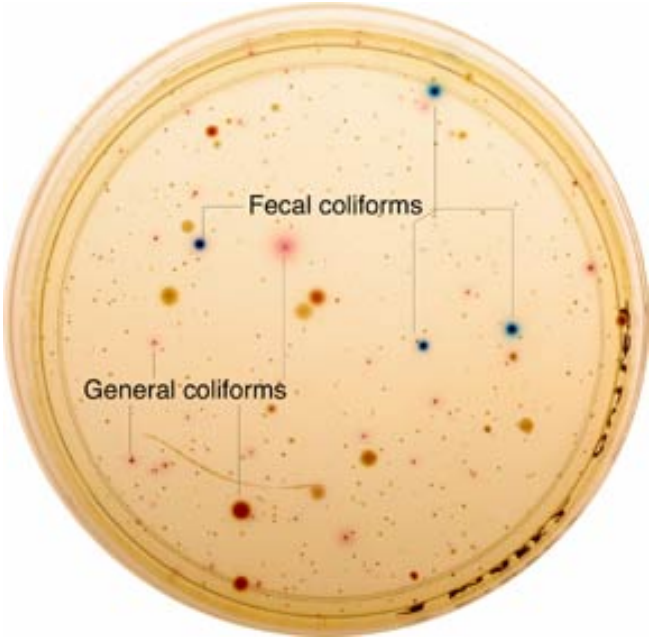
Figure 41.26 The Multiple-Tube Fermentation Test. The multiple-tube fermentation technique has been used for many years for the sanitary analysis of water. Lactose broth tubes are inoculated with different water volumes in the presumptive test. Tubes that are positive for gas production are inoculated into brilliant green lactose bile broth in the confirmed test, and positive tubes are used to calculate the most probable number (MPN) value. The completed test is used to establish that coliform bacteria are present.

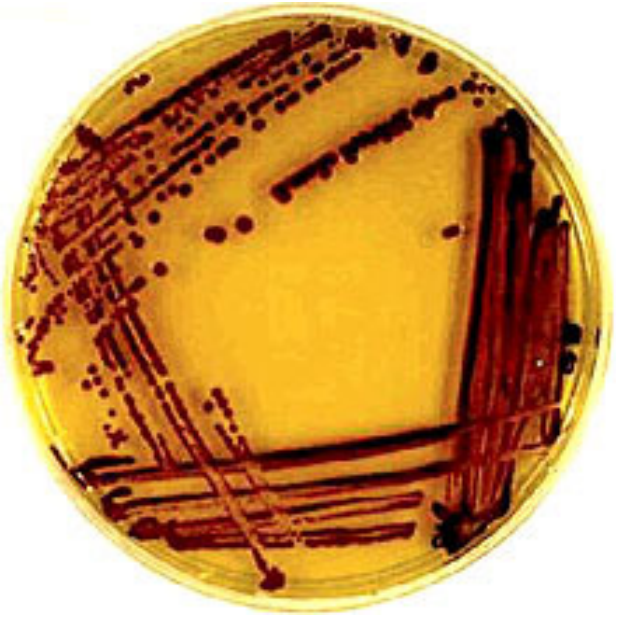
- Lactose broth, 35^{o}C, 24/48 h
- It is a presumptive test
- Result is presented as MPN (Most Probable Number)
- The growth in the test tubes are transferred to a test tube containing brilliant green bile lactose broth and incubated at 35^{o}C, 48 h for confirmatory coliform test
- For confirmatory fecal coliform test the growth is transferred to test tubes containg E.C. Medium broth and incubated at 44.5^{o}C, for 24 h

Membrane filter technique

- Water samples are filtered through a sterile membrane (porosity 80%, pore size 5-10 µm)
- Filter is rinsed with sterile buffer solution, placed upon a pad saturated with suitable nutrient medium, and incubated at required temperature
- Bacteria which are able to grow be counted and each colony represent one bacterium

- Colonies are counted after growing them on suitable nutrient medium
- Nutrient medium for
  - Total coliform count
    - M-Endo broth/ LES Endo Agar at 35^{o}C for 20-22h
    - Pink to darkred with golden metallic sheen with greenish tint colonies
  - Fecal coliform count
    - M-FC broth for 44.5^{o}C for 22 hr
    - Colonies are blue, other bacteria are grey
  - Fecal streptococci count
    - M-Enterococcus Agar or KF-streptococcus broth for 35^{o}C for 48 hr
    - Colonies are light pink to dark red


Fecal coliforms
General coliforms



Causes of disease

- Lack of sanitary waste disposal and of clean water for drinking, cooking, and washing is the cause of water borne diseases.
- Worldwide, an estimated 3 billion people lack sanitary toilet and over 2 billion people lack access to safe freshwater.
- These diseases often occur where public and private drinking water systems get their water from surface waters (rain, creeks, rivers, lakes etc.), which can be contaminated by infected animals or people.
- Runoff from landfills, septic fields, sewer pipes, residential or industrial developments can also contaminate surface water.
- Using contaminated sewage for fertilizer can result in epidemics of such diseases as cholera. In the early 1990s, for example, raw sewage water that was used to fertilize vegetable fields caused outbreaks of cholera in Chile and Peru.

Prevention

- Improving public sanitation and providing a clean water supply are the two steps needed to prevent most water-borne diseases and deaths.
- While the cost of building freshwater supply systems and sanitation facilities is high, the costs of *not* doing so is many times higher.
- In Karachi, Pakistan, for example, a study found that poor people living in areas without any sanitation or hygiene education spent six times more on medical care than people who lived in areas with access to sanitation and who had a basic knowledge of household hygiene.
- Disinfection is used to prevent the growth of pathogenic organisms in supply water. The two most common methods to kill microorganisms in the water supply are: oxidation with chemicals such as chlorine, chlorine dioxide or ozone, and irradiation with Ultra-Violet (UV) radiation.

Control measures and prevention of water pollution

- Two approaches are used: input control and output control. Input control means ‘reducing generation of pollutants’ while output control means ‘controlling pollutants after being produced’.
- Output control further involves two strategies: volume reduction and strength reduction. Volume reduction means reducing total volume of pollutant while strength reduction means reducing harmful effects of pollutants.
- Both, volume and strength of the polluted water can be reduced by different types of water treatment plants (WTP). This includes Sewage Treatment Plants (STP) and Effluent Treatment Plants (ETP).

- In these treatment plants, pollutants are removed through sequential steps that include: Primary treatment, Secondary treatment and Tertiary treatment.
  - In Primary treatment bigger impurities are removed using physical processes (sedimentation, filtering, decanting).
  - In Secondary treatment organic compound are oxidized by biological oxidation (in presence of bacteria).
  - In Tertiary treatment, the remaining impurities are oxidized by chemical oxidants and disinfection is done by UV-rays, ozone etc.
- Domestic and industrial waste waters should be discharged into rivers only after proper treatment through STPs and ETPs
- Solid wastes must not be mixed with liquid wastes and should not be thrown into to water bodies. They should be separately managed.

Self Purification of River Streams

- Sewage is created by residential, institutional, and commercial and industrial establishments and includes household waste liquid from toilets, baths, showers, kitchens, sinks and so forth that is disposed of via sewers.
- The separation and draining of household waste into grey water and blackwater is becoming more common in the developed world, with greywater being permitted to be used for watering plants or recycled for flushing toilets.
- Greywater is wastewater generated from domestic activities such as laundry, dishwashing, and bathing
- Blackwater used to describe wastewater containing fecal matter and urine. It is also known as brown water, foul water, or sewage
- Most sewage also includes some surface water from roofs or hard-standing areas and may include stormwater runoff.

- Sewerage systems capable of handling stormwater are known as combined systems or combined sewers. Such systems are usually avoided since they complicate and thereby reduce the efficiency of sewage treatment plants owing to their seasonality.
- The variability in flow also leads to often larger than necessary, and subsequently more expensive, treatment facilities. In addition, heavy storms that contribute more flows than the treatment plant can handle may overwhelm the sewage treatment system, causing a spill or overflow.
- Modern sewered developments tend to be provided with separate storm drain systems for rainwater.
- As rainfall travels over roofs and the ground, it may pick up various contaminants including soil particles and other sediment, heavy metals, organic compounds, animal waste, and oil and grease.

Natural Forces for Self-purification

- Physical
  - Dilution and Dispersion
  - Sedimentation
  - Sunlight
- Chemical/Biochemical
  - Oxidation
  - Reduction

Factors affecting Self-purification

- Temperature
- Turbulence
- Hydrography (velocity, surface expanses)
- Available D.O.
- Amount and type of organic matter
- Rate of reaeration

Zone of Pollution in river stream

- Zone of degradation
- Zone of active decomposition
- Zone of recovery
- Zone of Cleaner water

	← Zones of pollution →				
	Clear water	Zone of degrdation	Zone of active decomposition	Zone of recovery	Zone of clearer water
Dissolved oxygen sag curve	Saturation level 100% D.O. 40% Zero%	40%			
Physical Indices	Clear water, no bottom sludge, no colour	Floating solids ; bottom sludge present, colour getting turbid	Darker and greyish colour, evolution of gases like CH_4CO_2 H_2S etc. lot of sludge coming to the surface forming an ugly scum layer at top	Turbid with bottom sludge	Clear water with no bottom sludge

	← Zones of pollution →				
	Clear water	Zone of degrdation	Zone of active decomposition	Zone of recovery	Zone of clearer water
Dissolved oxygen sag curve	Saturation level 100% D.O. 40% Zero%	40%			
Fish presence	Ordinary fish like game, pan, food & forage etc. present	Tolerant fishes like carp, buffalo, gary, etc. present	No fish present	Tolerant fish like carp, buff alo, etc. are present	Ordinary fish like game, pan, food, and forage, etc. present
Bottom Animals					
Algae & Protozoa etc. called plankton					

- Oxygen Deficit = Saturation D.O. – Actual