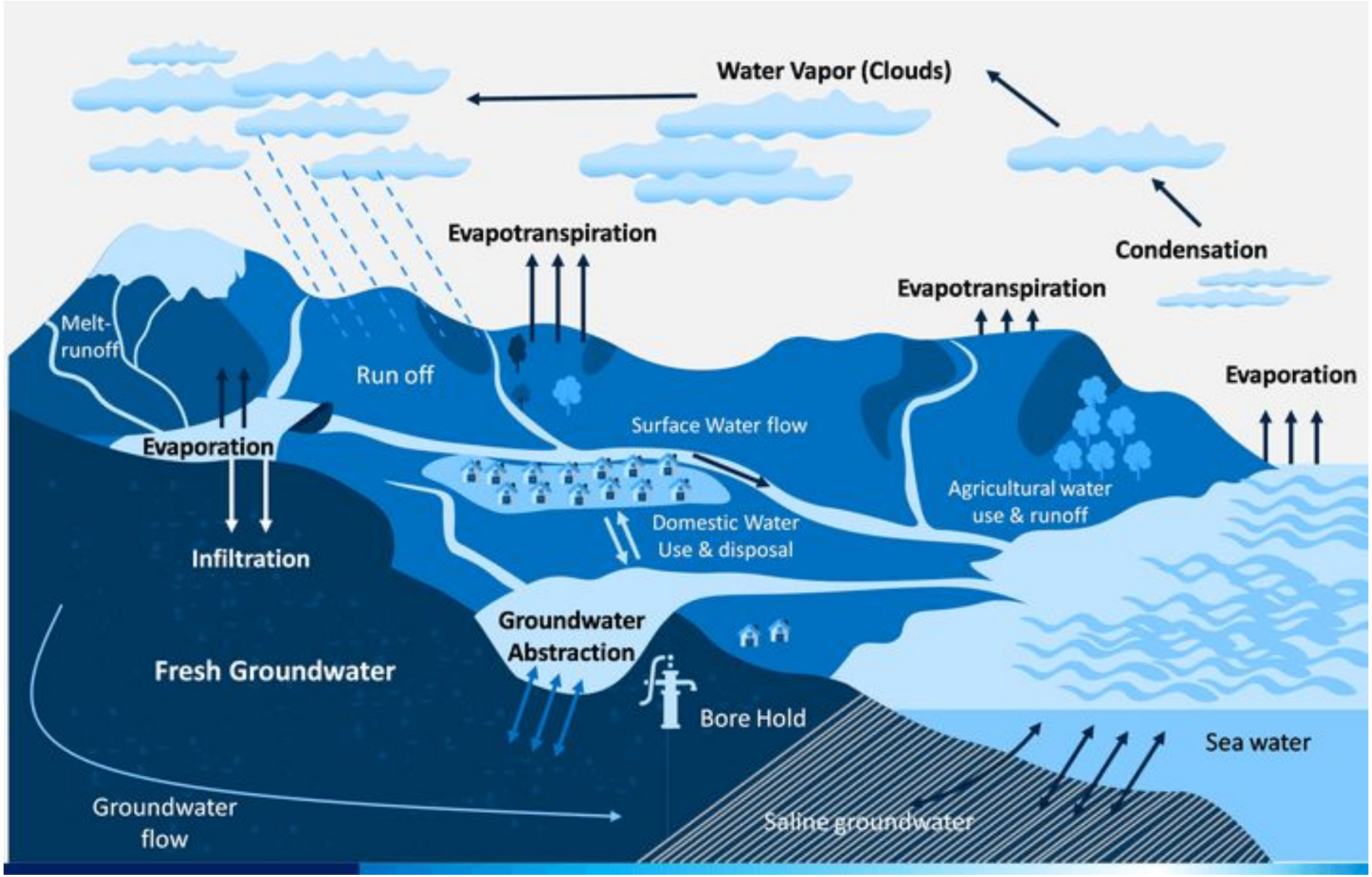
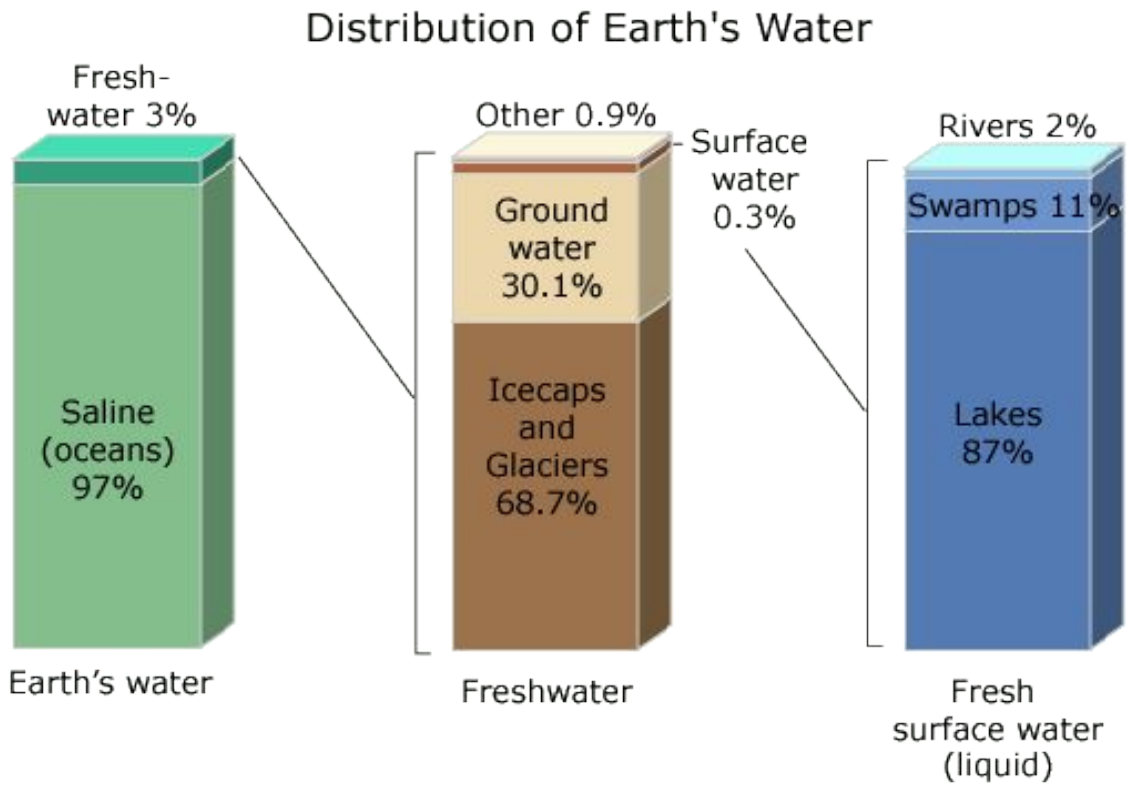
Water Pollution

The Hydrologic Cycle



Water Source



- The left-side bar shows that about 97% of all water is in the oceans.
- The middle bar shows the distribution of the remaining 3% of all Earth's water that is freshwater.
- The majority, about 69%, is locked up in glaciers and icecaps and remaining 30% freshwater, almost all of it is groundwater.
- Of all the freshwater on Earth, only about 0.3% is contained in rivers and lakes as surface water.

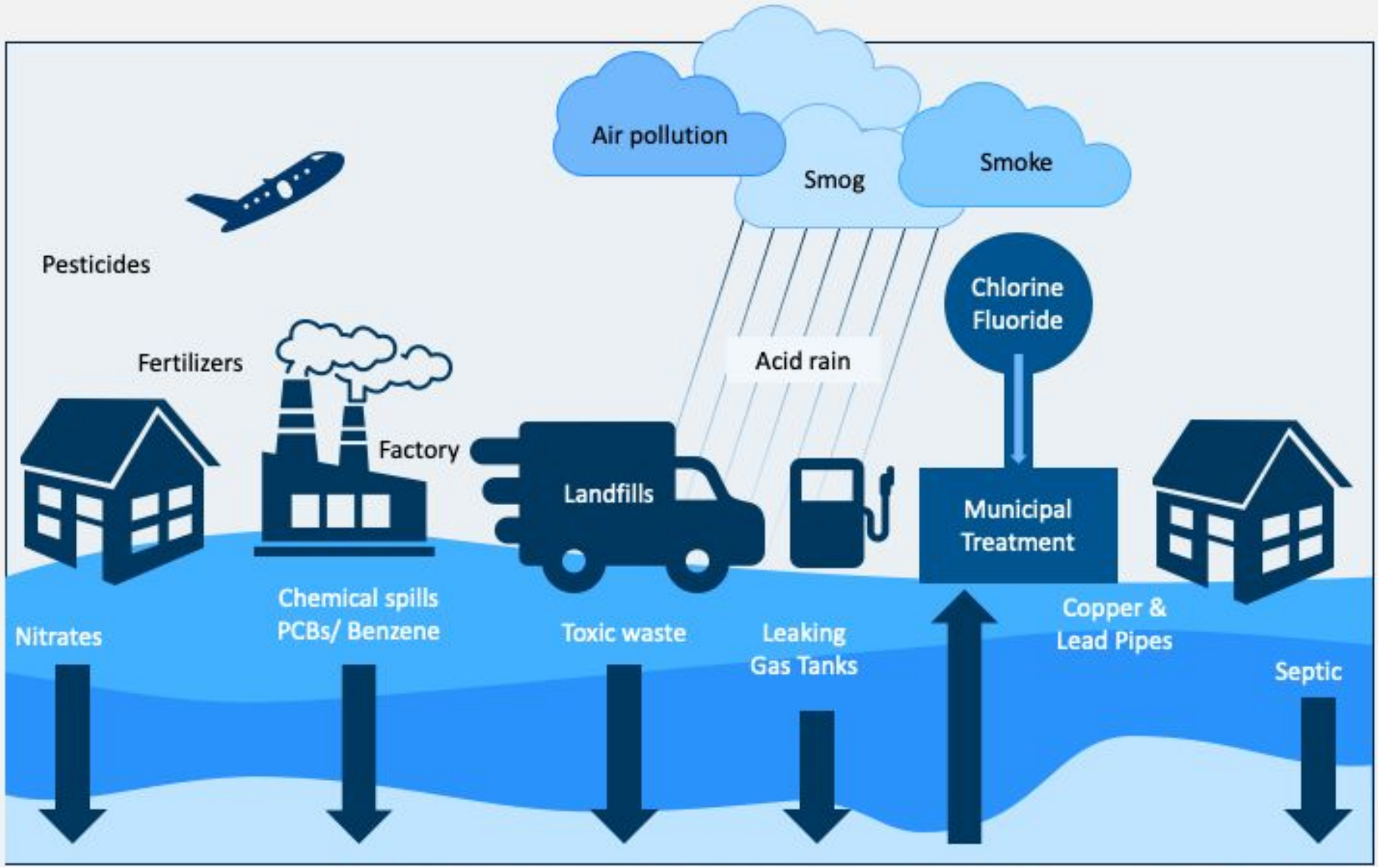
What is water pollution?

Any chemical, biological, or physical change in water quality that has a harmful effect on living organisms or makes water unsuitable for desired usage.



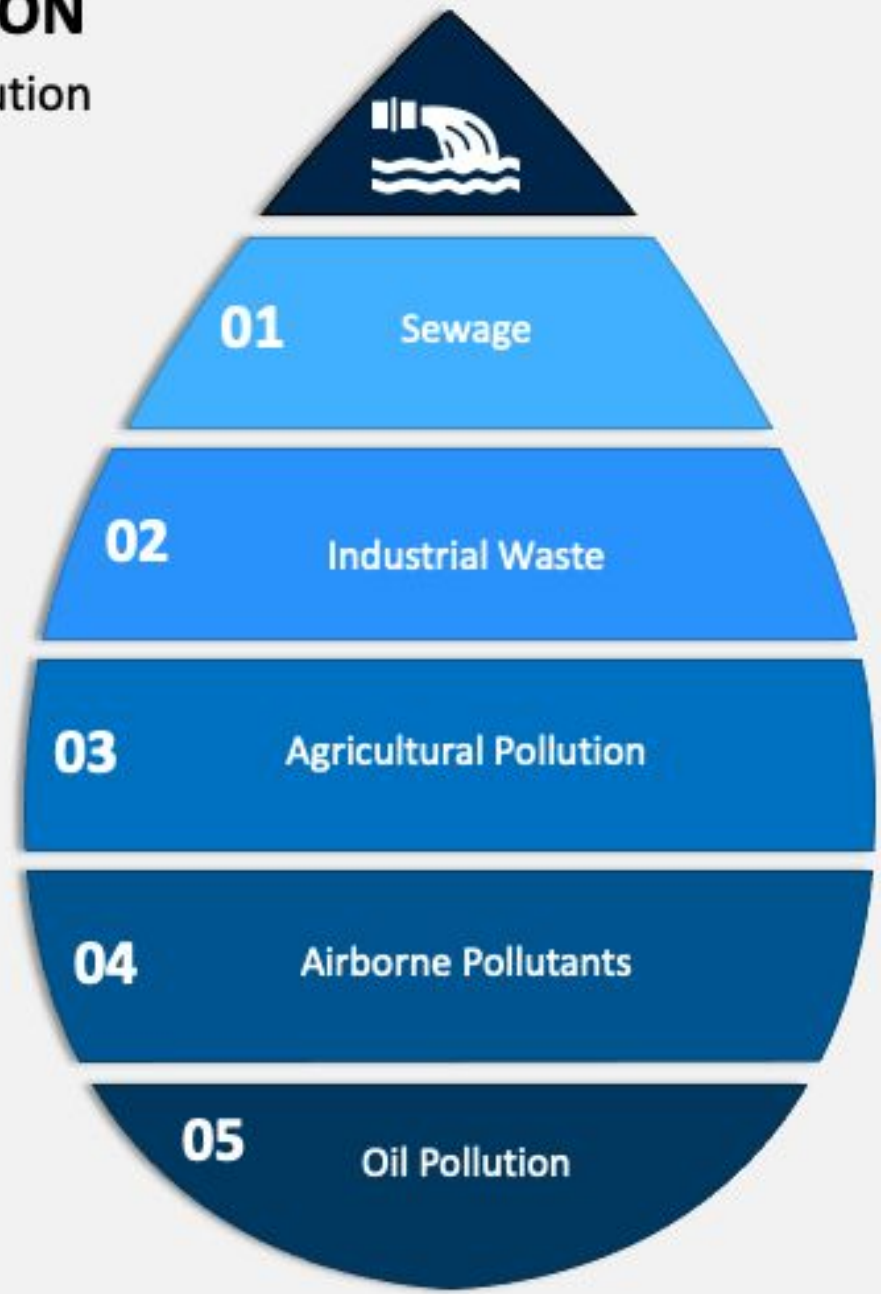
WATER POLLUTION

Potential Sources of Water Contamination



WATER POLLUTION

Causes of Water Pollution



Water Pollution

- Surface Water Pollution
- Ground Water Pollution

Types/Categories of Pollutants

Nature of Origin

- Point Sources: Have well defined point of discharge

Types: i) Municipal point sources

ii) Industrial discharges

- Non-point Sources: Origin of discharge is diffuse; not possible to relate discharge to a well defined location.

Types: i) Agriculture ii) Silviculture iii) Atmosphere iv) urban and suburban runoff v) groundwater vi) drainage from abandoned mines and construction activities, leaching from land disposal and solid waste.

Types/Categories of Pollutants

Group of Substances

- Oxygen demanding wastes
- Nutrients
- Pathogens
- Suspended solids
- Salts
- Toxic metals
- Toxic organic compounds
- Heat
- Radioactive substances

Major Pollutant Categories and Principal sources of Pollutants

Pollutant Category	Point Sources		Non-Point Sources	
	Domestic Sewage	Industrial Waste	Agricultural runoff	Urban run off
Oxygen-demanding waste	X	X	X	X
Nutrients	X	X	X	X
Pathogens	X	X	X	X
Suspended solids/sediments	X	X	X	X
Salts		X	X	X
Toxic metals		X		X
Toxic organic chemicals		X	X	
Heat		X		

Pathogens

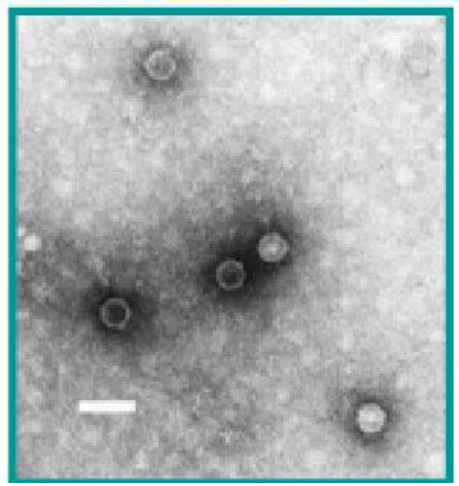
Disease-causing organisms that grow and multiply within the host

- Source: Human and animal excreta
- Pathogens associated with water include:
  - Bacteria: responsible for cholera, bacillary dysentery, typhoid and paratyphoid fever
  - Virus: responsible for hepatitis, poliomylitis, respiratory and eye infections
  - Protozoa: responsible for amoebic dysentery, giardiasis
  - Helminths (parasitic worms): Hookworm, ascariasis

Pathogenic Microorganisms in Water

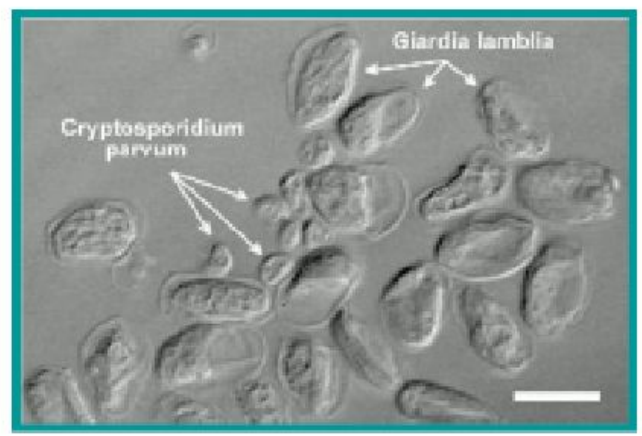
Bacteria



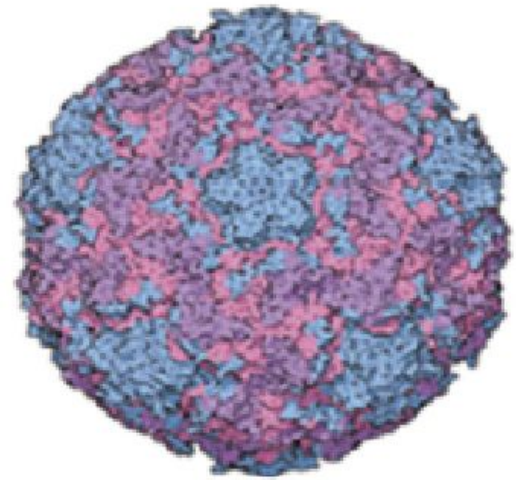


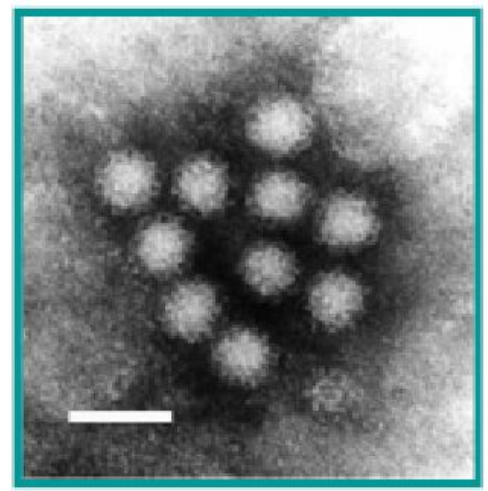
Parasites





Viruses





Pathogens

Classification of infections diseases associated with water:

- Waterborne disease: Oral ingestion of pathogens in water contaminated by urine or feces
- Water-washed disease: Disease spread enhanced by scarcity of water making cleanliness difficult
- Water-based disease: water provides the habitat for intermediate host organisms, transmission to humans through water contact
- Water-related disease: Insect vectors (e.g., mosquitoes) rely on water to habitat, but human water contact not needed

Pathogen Indicators: - Total Coliform

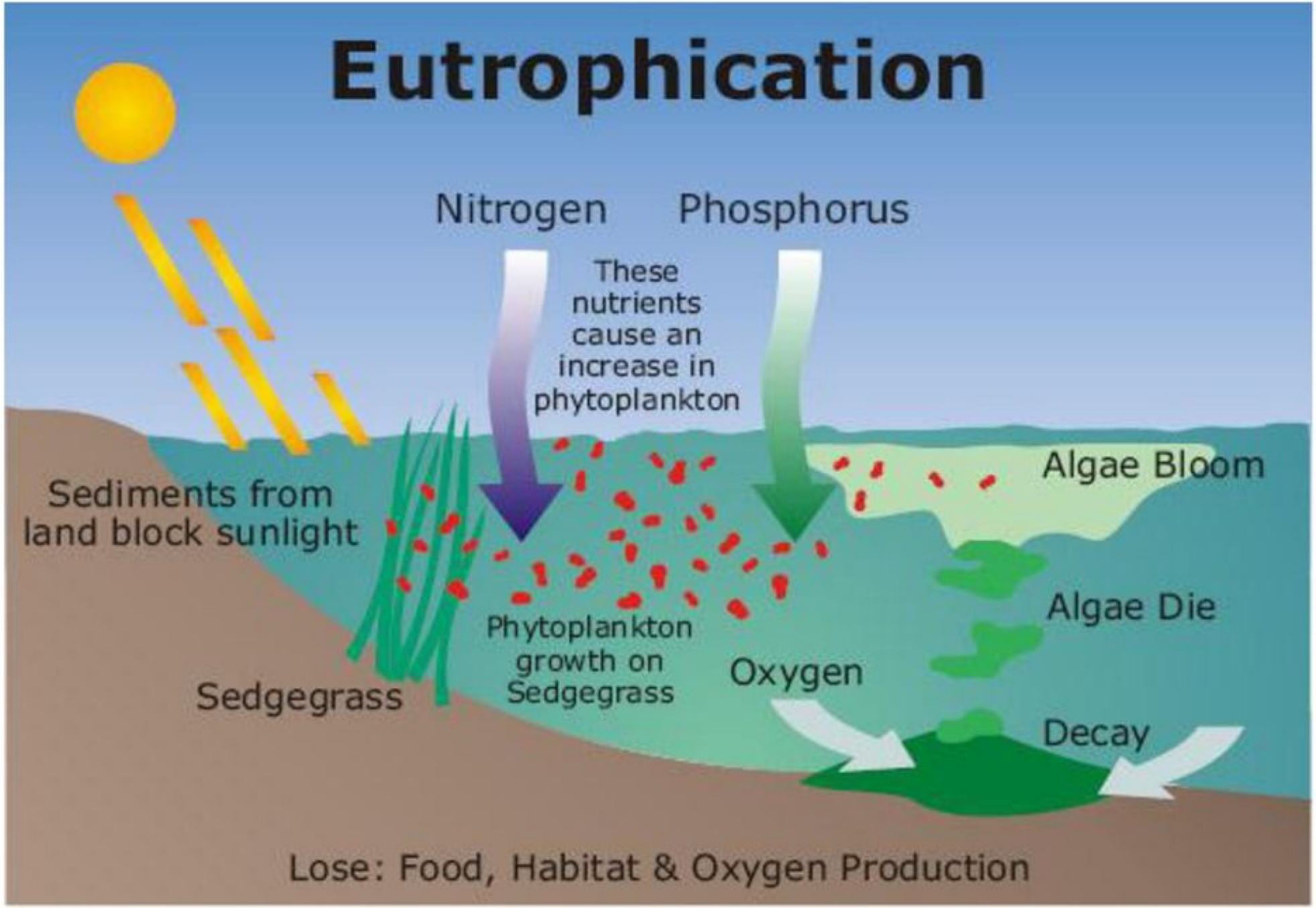
- Faecal Coliform
- Thermotolerant coliform
- E coli

Nutrients

- Chemicals that are essential for the growth of living things (N, P, C, S, Fe, Mn, B, Ca, etc.)
- Nutrients are pollutants when their concentrations are sufficient to allow excessive growth of aquatic plants, particularly algae.
- The process of nutrient enrichment, leading to excessive growth of algae, is called eutrophication (algal bloom). This phenomenon is particularly important for lakes

Nutrients: Problems

- Algae eventually die and their decomposition removes DO from water
- Algae and decaying organic matter add color, turbidity, odor and objectionable taste to water, making it less attractive as a source for domestic water supply, recreational and other uses.
- Notice the greenish (sometimes reddish) color of pond, lake, river water, especially during dry season


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

Harmful Algal Blooms (HABs)

Microcystis sp. bloom





HAB



Anabaenopsis sp. bloom



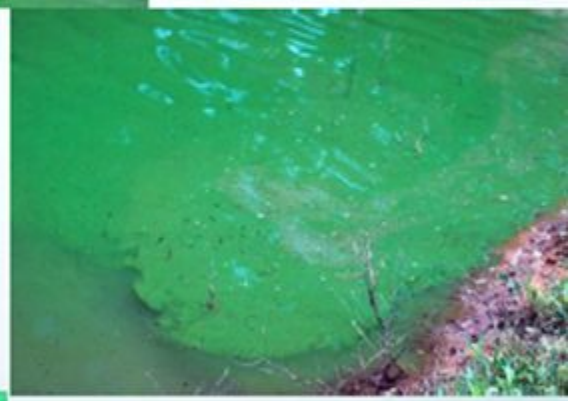
mixture of cyanobacteria

Nutrients: Sources

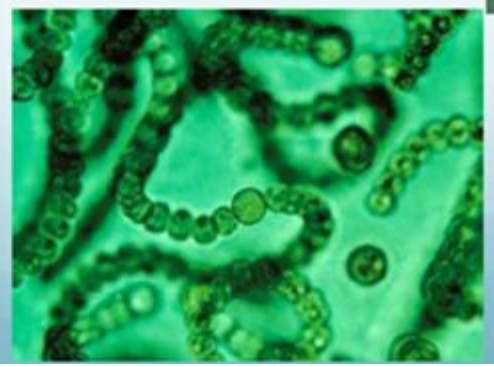
- Major sources of nitrogen and phosphorus include municipal wastewater discharges, runoff from animal feedlots, chemical fertilizers and phosphorus based detergents



- In addition, there are also natural sources that may add nitrogen to the water bodies. Certain bacteria and blue-green algae can directly obtain nitrogen from the atmosphere. These life forms are abundant in lakes and have high biological productivity.



- Certain form of acid rain can also contribute nitrogen to the lakes.



Salts

- Water naturally accumulates a variety of dissolved solids and salts as it passes through soils and rocks.
- Certain industrial discharges also contain significant dissolved salts (eg. Tannery effluent)

Typical cations: Na^{+}, Ca^{2+}, Mg^{2+}, K^{+}

Typical anions: Cl^{-}, SO_4^{2-}, HCO_3^{-}

Effects: Taste, odor

Salts

Commonly used measures of salinity:

- TDS (Total Dissolved Solids)
- Cl^- (Chloride)
- Electrical Conductivity (EC)

- Freshwater: TDS <1500 mg/L
- Seawater: TDS ~ 30,000 – 34,000 mg/L
- Drinking water standard (Bangladesh): 1000 mg/L
- Agriculture: TDS upto 1500 mg/L can be tolerated by most crops. Concentrations above 2100 mg/L generally unsuitable for irrigation

Suspended solids

- Organic or inorganic particles that are carried by the wastewater into receiving waters are termed suspended solids
- Many of these particles settle to the bottom of as sediment
- Colloidal particles that do not settle readily are the cause of turbidity found in many surface waters
- Organic suspended solids may exert an oxygen demand
- Inorganic suspended solids are discharged by some industries, result mostly from soil erosion

Suspended solids

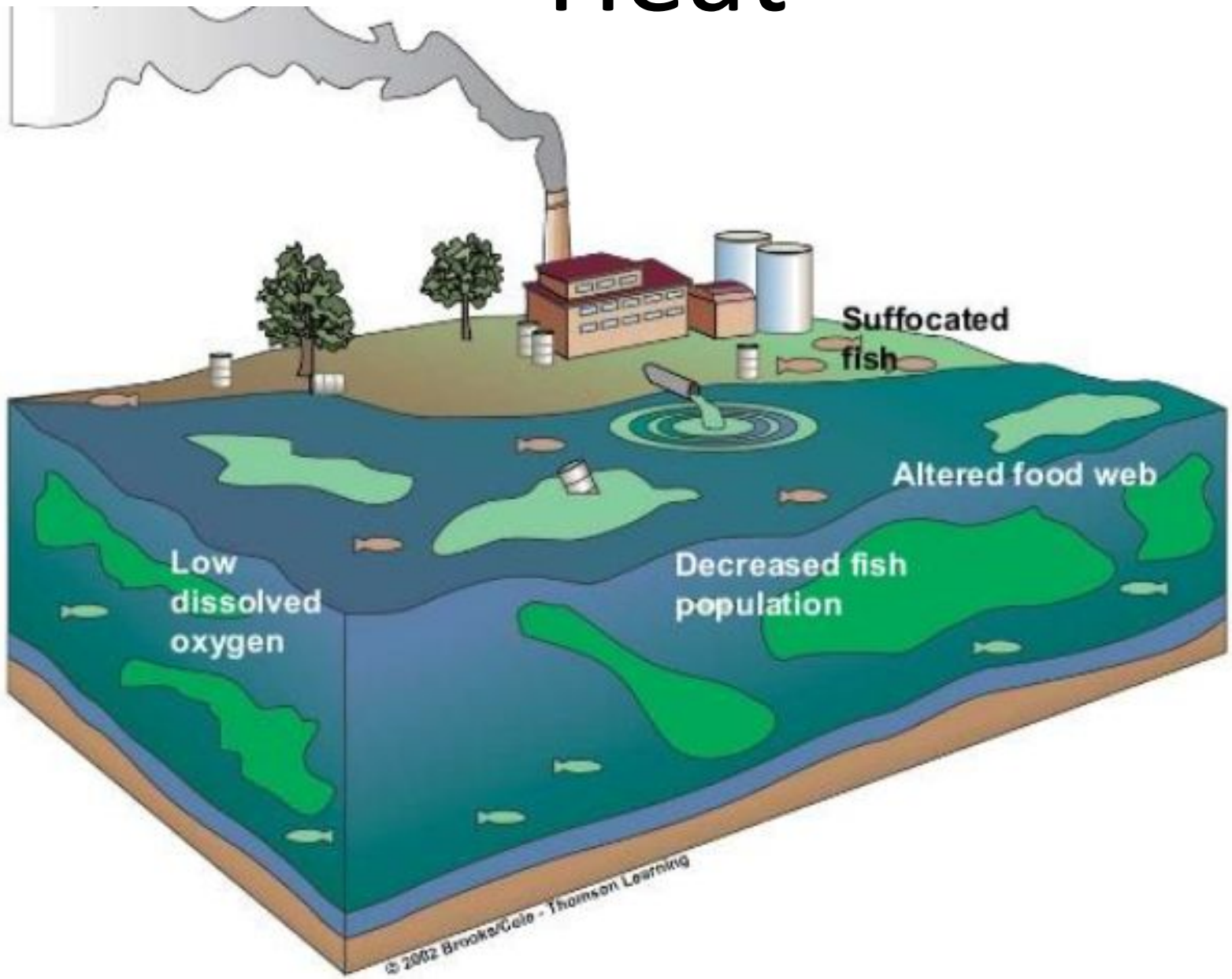
Problems:

- An excessive sediment loads deposited into lakes and reservoirs reduce their usefulness
- In rapidly flowing streams, sediments can disrupt ecological habitats of many aquatic species
- For domestic water supply, excessive suspended solids necessitate water treatment at an increases cost

Heat

- Impact of Climate change
- Primarily from industrial cooling water that is discharged into river (typically from power plants)
- Adverse impacts:
  - Sudden change in temperature can make it difficult for local ecology to ever acclimate
  - Adverse impact on dissolved oxygen

Heat


Suffocated fish
Altered food web
Low dissolved oxygen
Decreased fish population
© 2002 Brooks/Cole - Thomson Learning

Oxygen Demanding Wastes

- Major Sources:

Biodegradable organic substances contained in

i) Municipal wastewater (mainly human waste and food residue)

ii) Industrial wastewater (e.g. from tannery, textile, paper & pulp and food processing industries)

- Minor Sources:

Crop residue, decaying plants and leaves, animal droppings, oxidation at certain inorganic compounds

Oxygen Demanding Wastes

Substances that oxidize in the receiving body of water with the consumption of dissolved oxygen

$$\text{Organic matter} + O_2 \xrightarrow{\text{bacteria}} CO_2 + H_2O + \text{New cells} + \text{stable product}$$

Oxygen Demanding Wastes

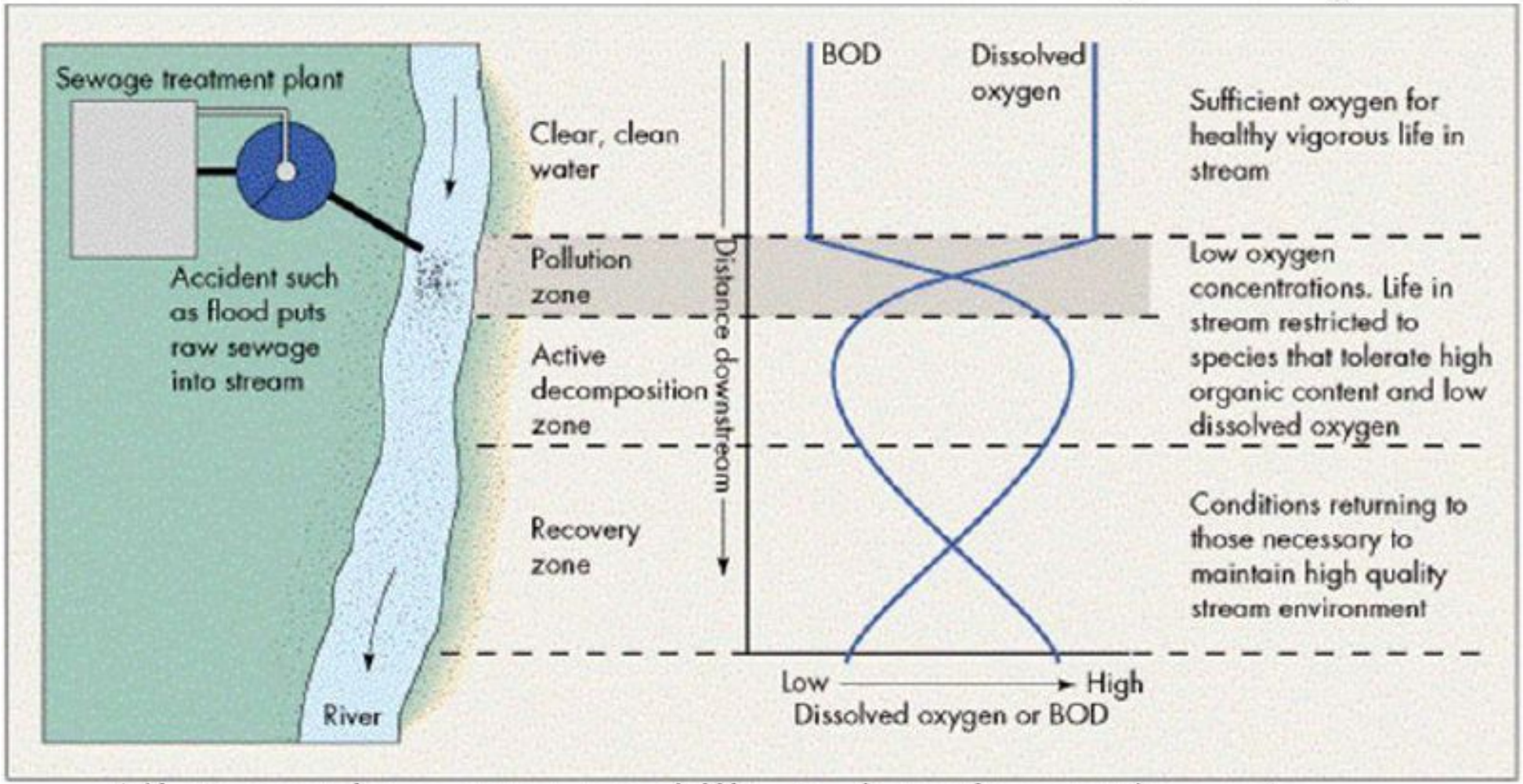
- Most common surface water pollutant
- Measured by
  - Biochemical Oxygen Demand (BOD)

The amount of oxygen required by microorganisms to oxidize organic wastes aerobically is called “biochemical oxygen demand” (BOD). Usually expressed as mg/L

  - Chemical Oxygen Demand (COD)

The amount of oxygen required for chemical oxidation of organic wastes is called “chemical oxygen demand” (COD). Usually expressed as mg/L

BOD Effects on Water Quality



All streams have some capability to degrade organic waste. Problems occur when stream is overloaded with biochemical oxygen-demanding waste.

Oxygen Demanding Waste

Effects:

- Causes depletion of dissolved oxygen (DO) in water
- Saturation value of DO in water: 8-15 mg/L (depending on temperature and salinity. Minimum DO required for healthy fish population: 4-8 mg/L; 3 mg/L for certain species
- If DO drops below the level necessary to sustain normal life. Then the aquatic system is classified as “polluted”
- Oxygen demanding wastes also cause color, taste and odor problem

Heavy Metals

- Usually it simply denotes metals that are toxic. Toxic metals include: Al, As, Be, Bi, Cd. Cn, Co, Mn, Hg, Pb, Se etc.

- Adverse Impacts:
  - Nervous system and kidney damage – creation of mutation and induction of tumor
  - Source: Industrial discharges, natural (eg. As in groundwater of Bangladesh)
  - Often referred to as “Persistent” (inorganic) pollutant (ie, remain in the environment for long without degradation)
  - Heavy metals of concern in Bangladesh groundwater:

    - As and Mn

Pesticides

Chemicals that kill undesirable organisms:

- Categories:
  - Insecticides – most widely used
  - Herbicides – destroy plants, weeds, etc.
  - Rodenticides – kill rats, mice, etc.
  - Fungicides – kill fungi or their spores

- The main groups of synthetic organic insecticides include:
  - Organochlorine (chlorinated hydrocarbons)
  - Organophosphates
  - Carbamates

Volatile Organic Compounds (VOC)

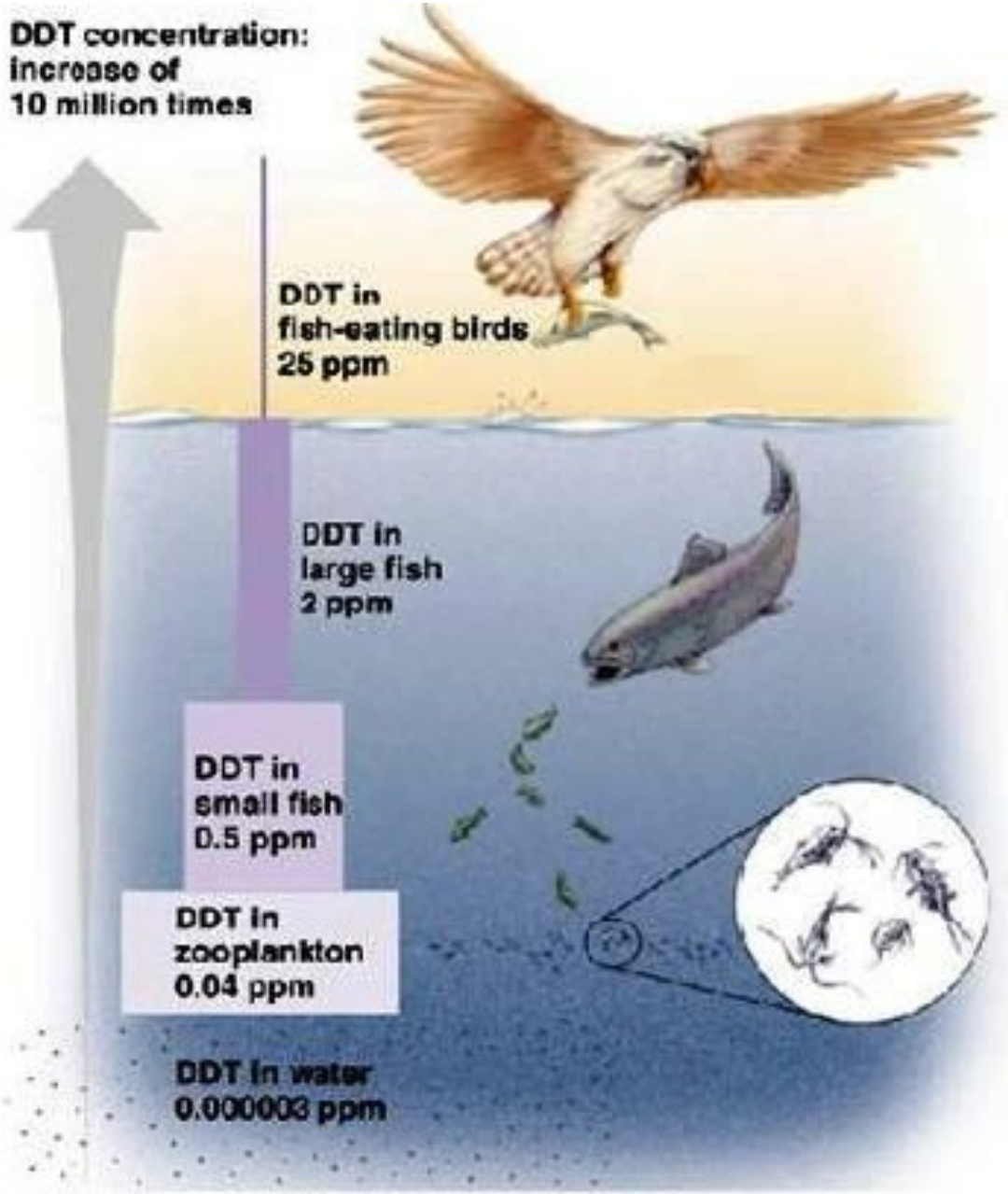
- Often used as solvents in industrial processes
- Most commonly found contaminant in groundwater
- "Persistent Organic Compound" (POC)
  - 5 VOCs are specially toxic and persistent and their presence in drinking water is a cause of special concern. These are:
    - Vinyl Chloride: human carcinogen
    - Tetrachloroethylene: suspected carcinogen
    - Trichloroehtylene: suspected carcinogen
    - 1,2 – Dichloroethane: causes injury to central nervous system, liver and kidneys
    - Carbon Tetrachloride: Very toxic if ingested. A few mL can cause death

Persistent Organic Pollutants (POPs)

Organic substances that:

- possess toxic characteristics;
- are persistent;
- Bioaccumulate;
- are prone to long-range trans-boundary atmospheric transport and deposition;
- are likely to cause significant adverse human health or environmental effects near to and distant from their sources

Biological magnification of DDT in a food chain



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Adverse Effects on Human Health and Ecosystems

- **Direct** ← Effects on HUMANS
  - Infections,
  - Toxicity,
  - Carcinogenesis
  - Other disease acute or chronic
- **Indirect** ← Effects on ECOSYSTEMS
  - Eutrophication,
  - Oxygen depletion - Hypoxia,
  - Harmful algal bloom formation,
  - Aquatic toxicity,
  - Accumulation in fish and sediments,
  - Bioaccumulation,
  - Endocrine disruption,
  - Antibiotic resistance development

Impacts on Human Health

- Microbial contamination in water bodies causes diseases like cholera, dysentery, diarrhea, polio, typhoid, hepatitis, etc.
- Heavy metals in drinking water can affect vital organs such as the kidney, liver, and nervous system.
- Nitrates in drinking water cause blue baby syndrome in infants. It is a disease in which the blood cannot properly carry oxygen and the infant die. (decreased oxygen-carrying capacity of hemoglobin in babies leading to death)

Impacts on Aquatic Life

- Higher levels of nitrogen and phosphorus in agricultural run-off cause excessive growth of algae (Eutrophication). This process may result in oxygen depletion of the water body.
- The algae and other organisms eventually die off and bacteria may consume all the oxygen from the water during the decomposition of algae. This causes the death of fish in such water bodies due to low oxygen levels.



Impacts on Soil

- Untreated wastewater can adversely affect the soil system.
- Water pollution can contaminate the soil with heavy metals and other pollutants.
- Heavy metals affect the microbial activity in the soil.
- Heavy metals affect the crop plants growing in the contaminated soil.





Effects on Ecosystems
(and indirect effects on human health)

Eutrophication: An Enrichment Problem



Figure 22-2a Environment, 5/e

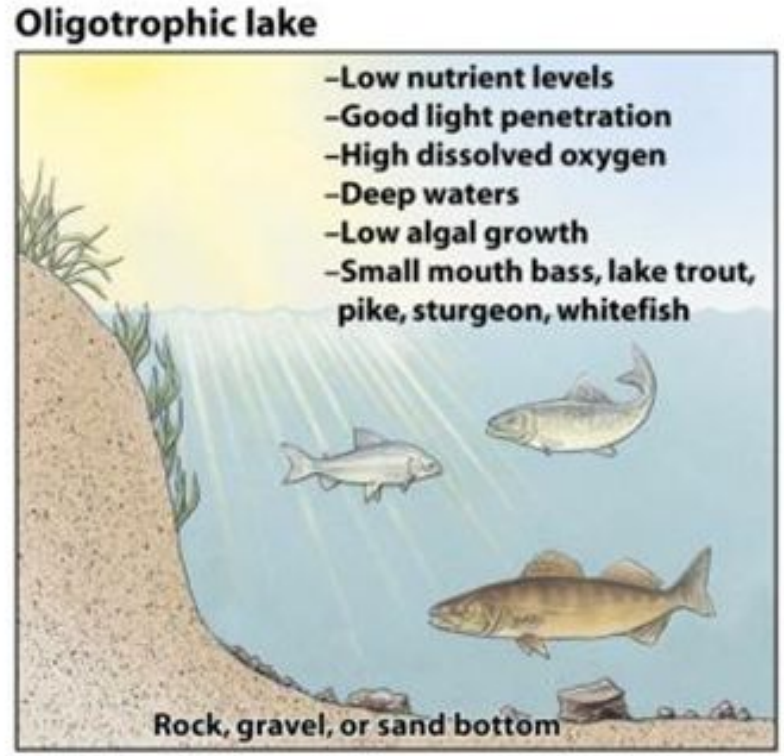


Figure 22-2c Environment, 5/e
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Oligotrophic lake

Eutrophication: An Enrichment Problem



Figure 22-2b Environment, 5/e

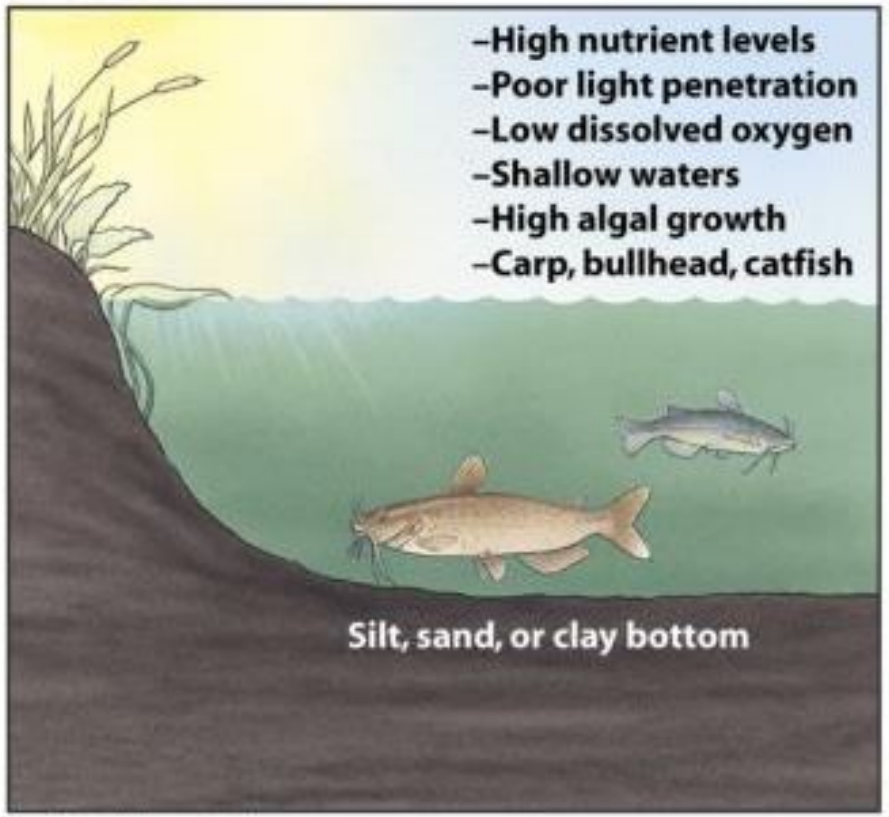


Figure 22-2d Environment, 5/e
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Eutrophic lake

Pollutant Discharge Limits

- If pollutant discharge continues unabated, rivers and lakes will lose their acceptability for their intended beneficial use
- Regulatory agencies' primary responsibility is to impose restrictions on the quality of domestic or industrial effluents on water bodies on the basis of certain guidelines or standards of a particular country
- In Bangladesh, DoE is the main regulatory agency which monitors effluent discharges by the industries and verify their compliance with the standards stated under the Environmental Conservation Rules ECR), 1997.

Bangladesh Standards

Table Bangladesh Standards for sewage discharge into surface and inland water bodies.

Parameters	Unit	Values
BOD	mg/l	40
Nitrate	mg/l	250
Phosphate	mg/l	35
Suspended Solids (SS)	mg/l	100
Temperature	°C	30
Coliforms	number/100ml	1000

Source: Schedule- 9, Rule-13, Environment Conservation Rules, 1997.

Bangladesh Standards

Table : Bangladesh Standards for industrial effluent discharge

Parameters	Unit	Values
Ammonia-nitrogen (as elementary N)	mg/l	50
Ammonia (as free ammonia)	mg/l	5
Arsenic (as As)	mg/l	0.2
BOD_5 at 20°C	mg/l	50
Boron	mg/l	2
Cadmium (as Cd)	mg/l	0.05
Chloride	mg/l	600
Chromium (as total Cr)	mg/l	0.5
COD	mg/l	200
Chromium (as hexavalent Cr)	mg/l	0.1
Copper (as Cu)	mg/l	0.5
Dissolved oxygen (DO)	mg/l	4.5-8
Electro-conductivity (EC)	µSiemens/cm	1200
Total dissolved solids	mg/l	2100
Fluoride (as F)	mg/l	2
Sulfide (as S)	mg/l	1
Iron (as Fe)	mg/l	2
Total kjeldahl nitrogen (as N)	mg/l	100
Lead (as Pb)	mg/l	0.1
Manganese (as Mn)	mg/l	5
Mercury (as Hg)	mg/l	0.01
Nickel (as Ni)	mg/l	1.0
Nitrate (as elementary N)	mg/l	10.0
Oil and grease	mg/l	10
Phenolic compounds (as C_6H_5OH)	mg/l	1.0
Dissolved phosphorus (as P)	mg/l	8
pH		6-9
Selenium (as Se)	mg/l	0.05
Zinc (as Zn)	mg/l	5
Total dissolved solids	mg/l	2100
Temperature (thermal effluent)	°C (summer) °C (winter)	40 45
Suspended solids	mg/l	150
Cyanide	mg/l	0.1

Source: Schedule –10, Rule-13, Environment Conservation Rules, 1997