CE 213A
Introduction to Environmental Science

L13: Water Pollution
Indicators of Water Quality

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Schedule : LEC Mon Wed Fri 5:10 – 6 pm

Response of water bodies to chemical and biological pollution

WATER QUALITY INDICATORS

Indicators of water pollution

1. **Physicochemical**

   - DO, BOD, COD
     - Measurement methods
     - Limitations of BOD test
     - Need for measuring BOD, COD, TOC

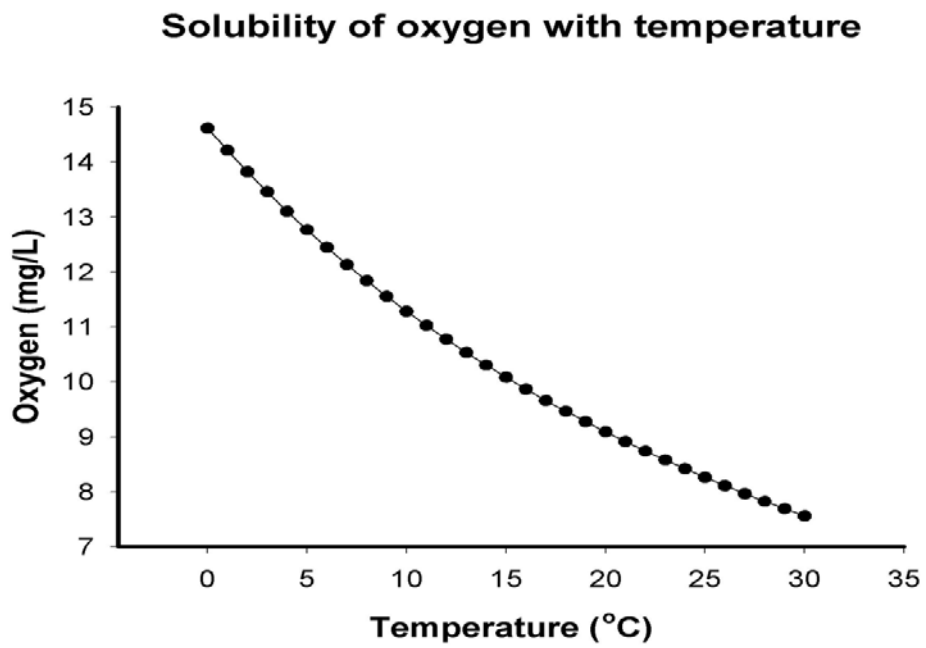
2. **Bacterial**
   - coliforms, fecal coliforms

Dissolved Oxygen

- Oxygen, although poorly soluble in water, is fundamental to aquatic life.
- Without free dissolved oxygen, streams and lakes become uninhabitable to aerobic organisms, including fish and most invertebrates.
- Dissolved oxygen is inversely proportional to temperature, and the maximum amount of oxygen that can be dissolved in water at 0°C is 14.6 mg/L.
- The amount of oxygen dissolved in water is usually measured with the ***Winkler*** test.

Temperature vs. DO content of water

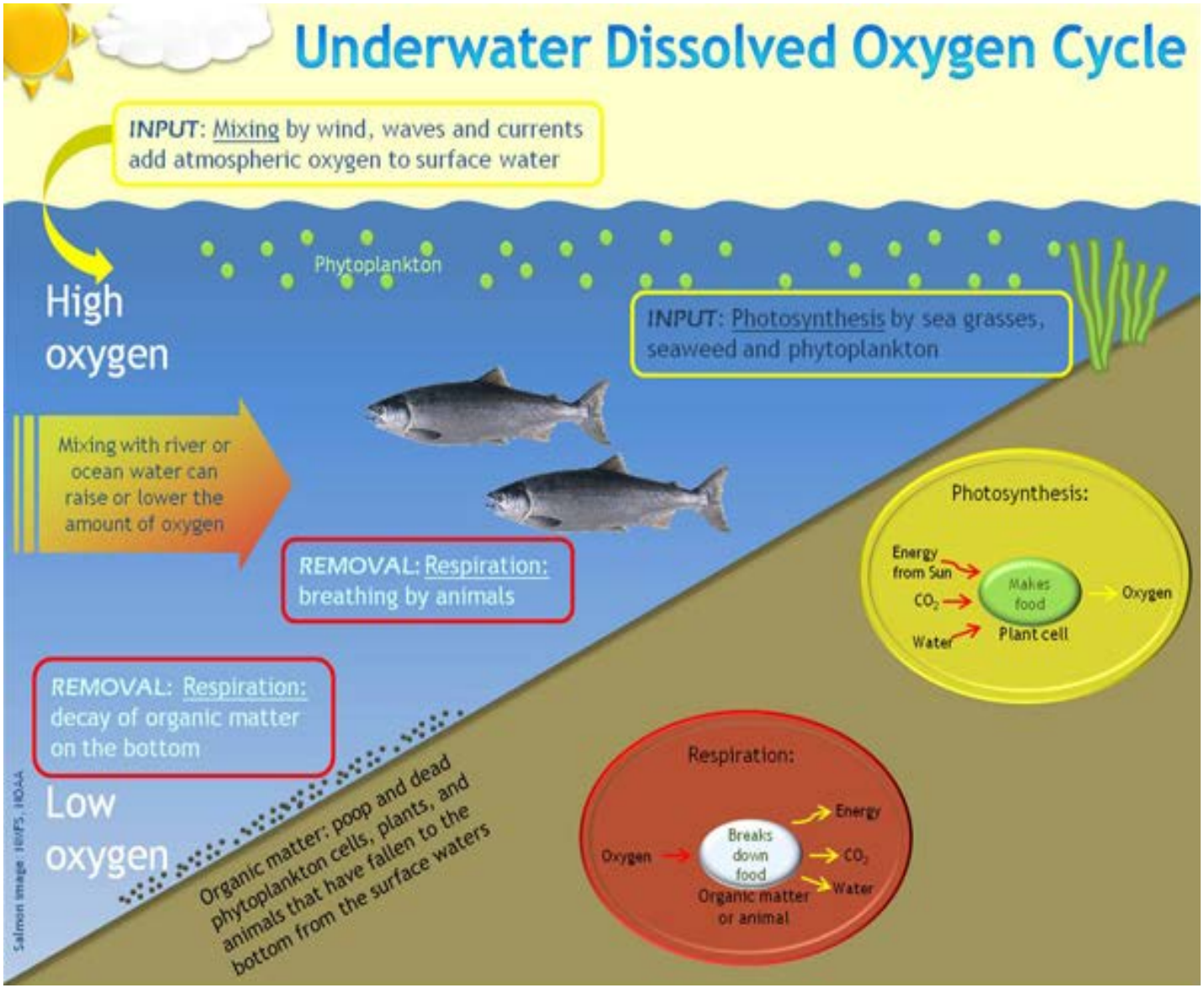
Temperature vs. Dissolved Oxygen



The saturation value decreases rapidly with increasing water temperature

Question
DO levels in a lake in
1. Africa vs. Scandinavia
2. Summer vs. winter

Underwater Dissolved Oxygen Cycle



Biochemical Oxygen Demand

- Amount of oxygen required by bacteria and other microorganisms in **stabilizing decomposable organic matter** .

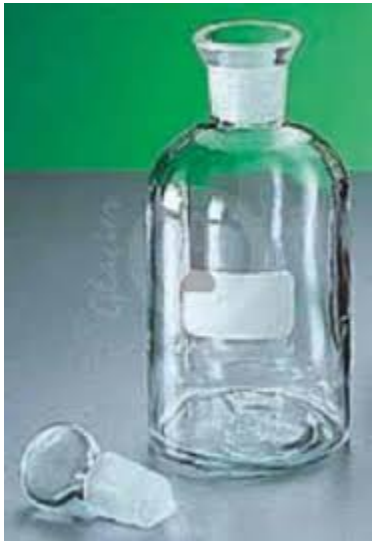
- A very low oxygen demand indicates either
  - clean water OR
  - the presence of a toxic or nondegradable pollutant.

The 5-day BOD test

The 5-day BOD test (BOD5) begins by placing water or effluent samples into **two standard** 60- or 300-mL BOD bottles.

One sample is analysed immediately to measure the initial **dissolved oxygen** concentration in the effluent, often using a Winkler titration.

The second BOD bottle is sealed and stored at 20°C in the dark.
(The samples are stored in the dark to avoid **photosynthetic oxygen generation**.)

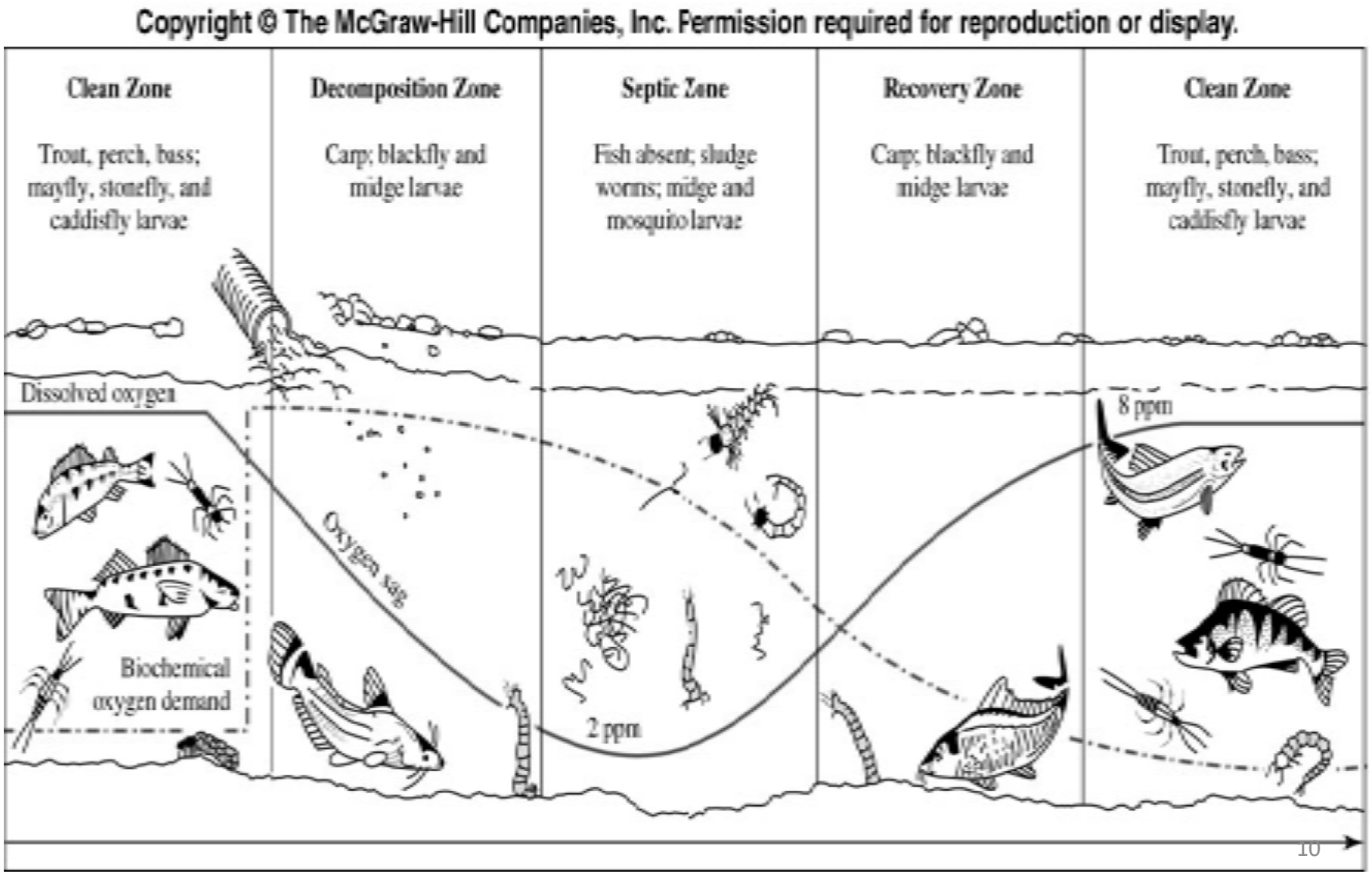


- After 5 days the amount of dissolved oxygen remaining in the sample is measured.
- The difference between the initial and ending oxygen concentrations is the BOD5.

$$[BOD\ ] = [DO]_{initial} - [DO]_{Final}$$

- **Test limitations** : One problem with the BOD test is that it takes ***5*** days to run.

Oxygen depletion in streams



BOD and Water Quality

BOD Level in mg/liter	Water Quality
1 - 2	**Very Good:** There will not be much organic matter present in the water supply.
3 - 5	**Fair:** Moderately Clean
6 - 9	**Poor:** Somewhat Polluted - Usually indicates that organic matter present and microorganisms are decomposing that waste.
100 or more	**Very Poor:** Very Polluted - Contains organic matter.

Ultimate BOD (UBOD)

- The ultimate biochemical oxygen demand ([UBOD]) is a parameter that quantifies the **oxygen required for the total biochemical degradation** of organic matter by aquatic microorganisms.

- APPLICATION: [UBOD] and the rate of oxygen consumption are frequently used in mathematical models to predict the impact of an effluent on receiving bodies such as lakes and rivers.

Sample Calculations for BOD

$$BOD_t = BOD_u (1 - e^{-K_T t})$$

Where, BOD_u is ultimate BOD

$$K_T = K_{20} (1.047^{T-20})$$

Question :
The BOD_5 of a waste water is determined to be 150mg/l at 20^0C. The K value is known to be 0.23 per day. What would be the BOD_8 be if the test were run at 15^0C ?

Limitations of BOD test

- Test period is too long - not good for process control
- Test is imprecise and unpredictable
- The test is simply not very easy
- Cannot evaluate accuracy

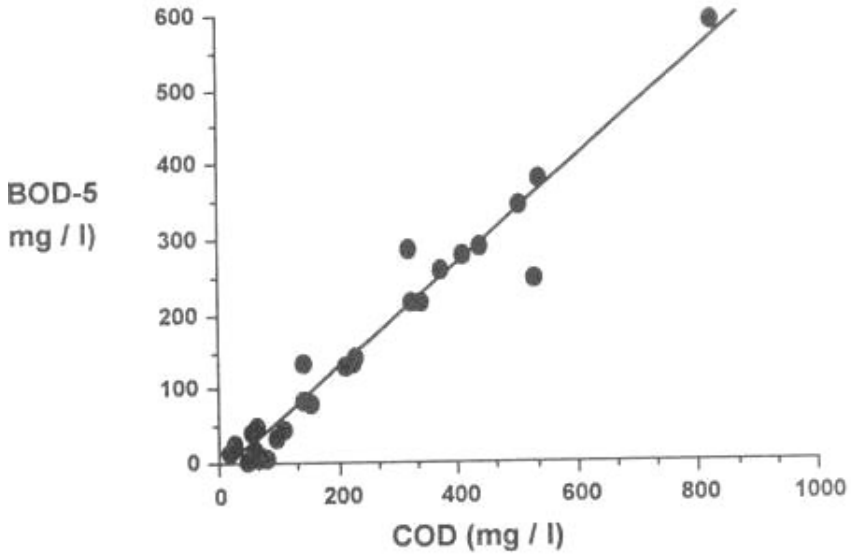
Chemical Oxygen Demand

It measures the amount of oxygen required to **chemically oxidize** organic compounds in water.

Why Measure COD?

- COD is used as a **general indicator of water quality** and is an integral part of all water quality management programs.

COD is often used to estimate BOD as a **strong correlation** exists between COD and BOD. However COD is a much faster, more accurate test.



What is the relationship between the COD and BOD values in Waste water?

- COD or Chemical Oxygen Demand is the total measurement of all chemicals (organics & in-organics) in the water / w.water;

- BOD is a measure of, the amount of oxygen required for the bacteria to degrade the organic components present in water / waste water.

- The ratio of BOD/COD :

  COD is higher than BOD; maximum of up to 4 times in medium scale industries; but it varies based on the industrial process and nature of the raw materials used;

What are the Current COD Methods Used?

- The most common COD method is the **wet chemistry** method.
- This involves a two hour digestion at high heat under **acidic conditions** in which **potassium dichromate acts as the oxidant** for any organic material present in a water sample. **Silver sulphate** is present as the **catalyst** and **mercuric sulphate** acts to complex out any interfering chloride.

What is the difference between BOD, COD or TOC? Why do I have to measure them?

- COD or Chemical Oxygen Demand is the total measurement of ***all chemicals in the water that can be oxidized***.
- TOC is the measurement of Total ***organic carbons.***
- BOD- Biochemical Oxygen Demand is supposed to measure the amount of food (or ***organic carbons***) ***that bacteria can oxidize.***
- Almost all wastewater treatment plants are required to measure one of these three items as a measure of the pollution value in the water.
- COD should always measure higher than TOC and then BOD.

http://www.environmentalleverage.com/BOD%20vs%20COD.htm

Pathogens

- From the public health standpoint, the bacteriological quality of water is as important as the chemical quality.

A large number of infectious diseases may be transmitted by water.

Microorganism	Effects on humans
Bacteria	
Campylobacter	Gastroenteritis
Clostridium botulinum	Gastroenteritis (botulism)
Clostridium perfringens	Gastroenteritus
E. coli O157:H7	Gastroenteritis
Legionella	Pneumonia-like pulmonary disease
Salmonella paratyphi	Paratyphoid
Salmonella typhi	Typhoid fever
Shigella (several species)	Shigellosis (dysentery)
Staphylococcus aureus	Gastroenteritis
Vibrio comma (*V. cholerae*)	Cholera
Yersinia enterocolitica	Gastroenteritis
Protozoans	
Cryptosporidium	Cryptosporidiasis
Entamoeba histolytica	Amoebic dysentery
Giardia lamblia	Giardiasis
Viruses	
Hepatitis A virus	Hepatitis
Poliovirus	Poliomyelitis

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L14: Water Pollution
Pollution in different water bodies and Effects

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Cause of concern

- Pollution of water bodies
- High consumption of water
- Health impacts

Pollution of Water Bodies

1. River
2. Lake
3. Groundwater
4. Ocean

Change in water quality as river flows downstream from point of origin over different land use type

- Pristine water at the point of origin in glaciers
- As River flows downstream, it flows over varying land use types, which influences water quality
- Anthropogenic sources of pollution also change water quality

Water Quality Indicators:
Case Study : River Ganga

Change in BOD in Ganga (UP)

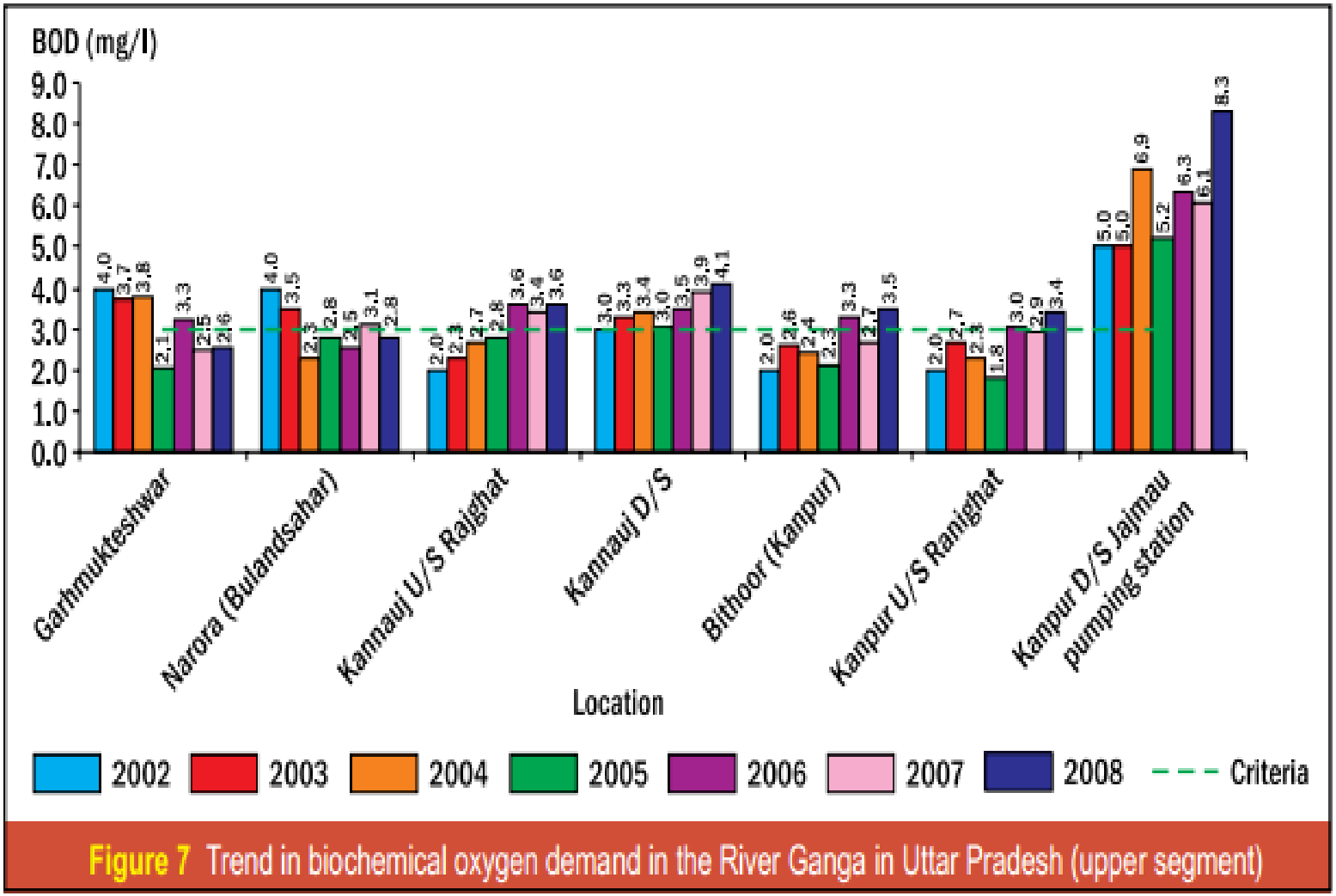


Figure 7 Trend in biochemical oxygen demand in the River Ganga in Uttar Pradesh (upper segment)

Source: UPPCB

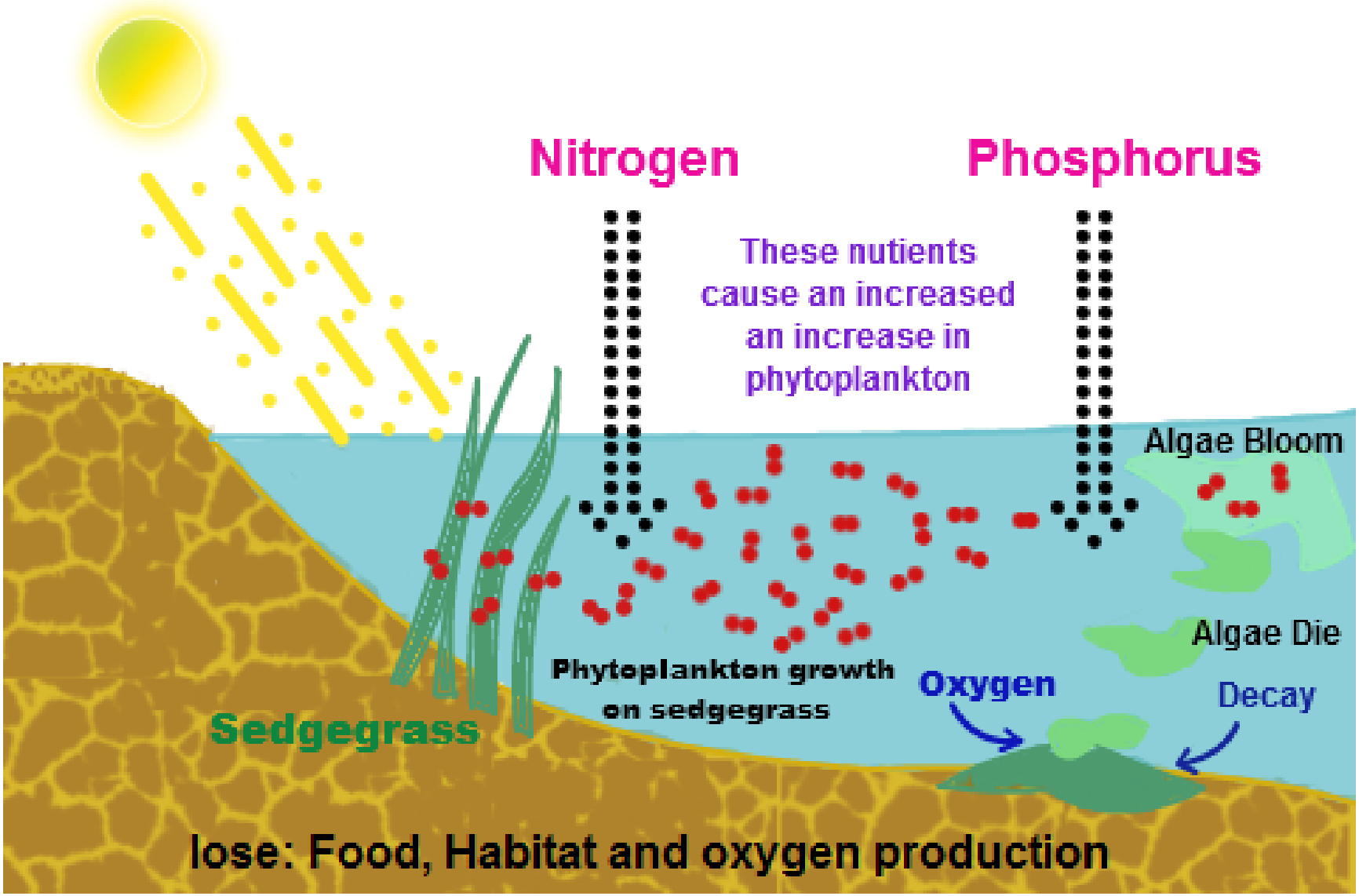
2. Lake Pollution

- Lakes more vulnerable to pollutants than streams
- Stratification in lakes and relatively little flow hinders rapid dilution of pollutants

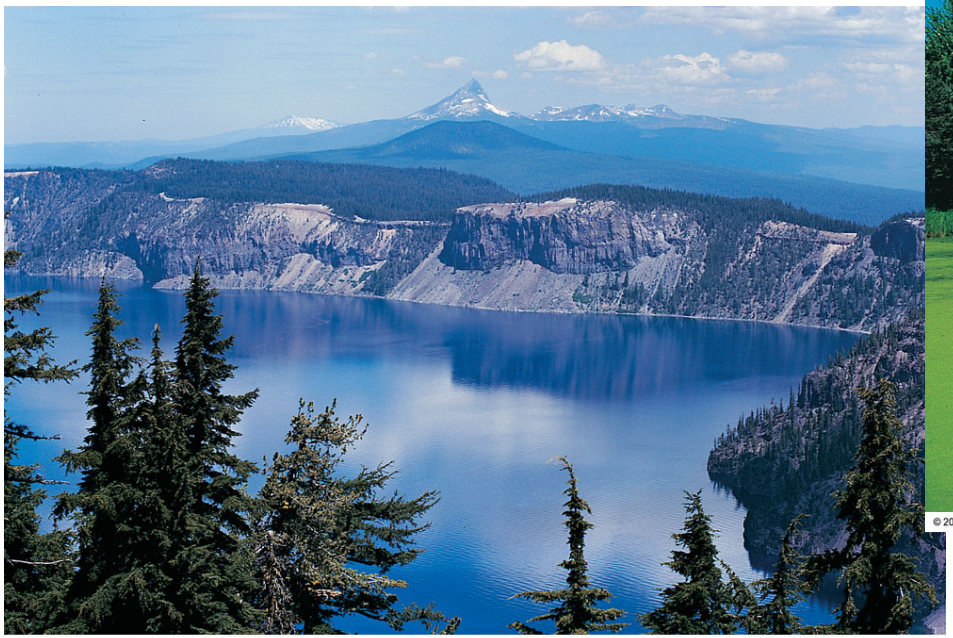
To examine:

- How pollutants enter lakes
- Eutrophication: causes and effects
- Oligotrophic and eutrophic lakes
- Cultural eutrophication
- Preventing or removing eutrophication

Eutrophication



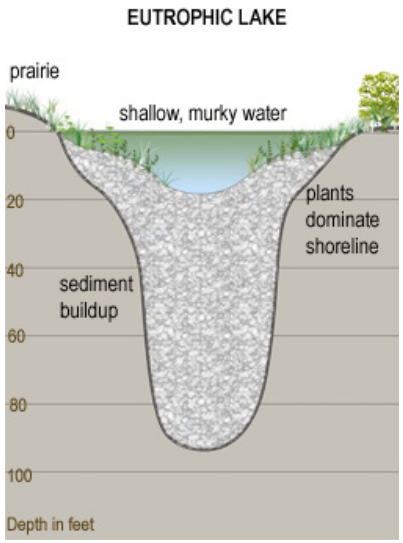
Oligotrophic and Eutrophic Lakes



Comparison

Oligotrophic Lake

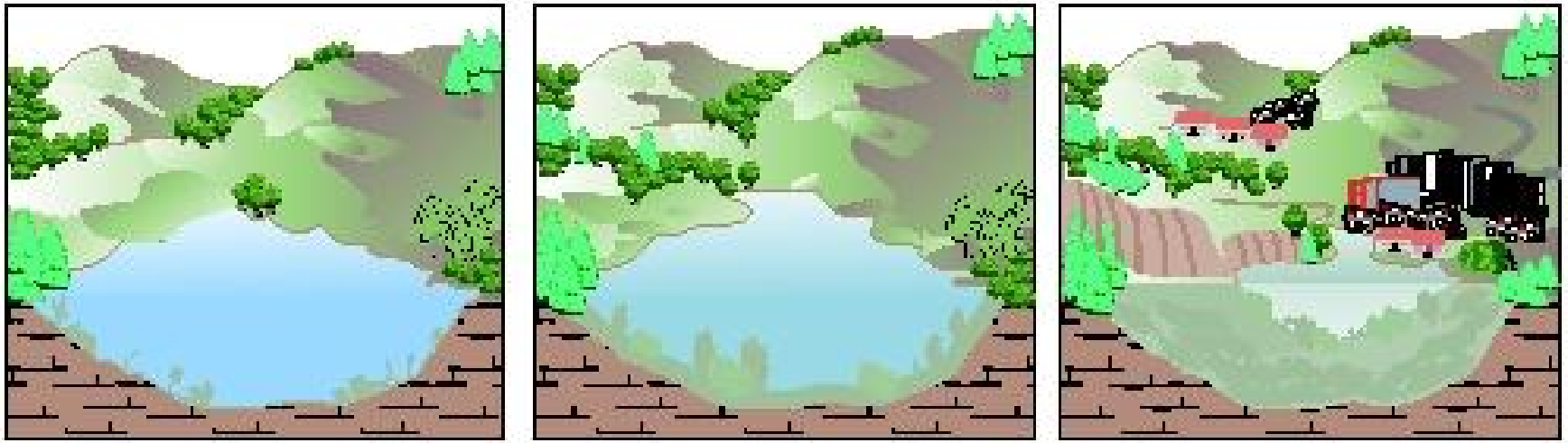
- characterized by a **low accumulation of dissolved nutrient salts**, supporting but a sparse growth of algae and other organisms, and having a high oxygen content owing to the low organic content.



Eutorphic Lake

- has high biological productivity. Due to **excessive nutrients**, especially nitrogen and phosphorus, these water bodies are able to support an abundance of aquatic plants.

  Usually, the water body will be dominated either by aquatic plants or algae.



NATURAL EUTROPHICATION AND LAKE AGING occurs over centuries, and results from natural sources of nutrients and sediments

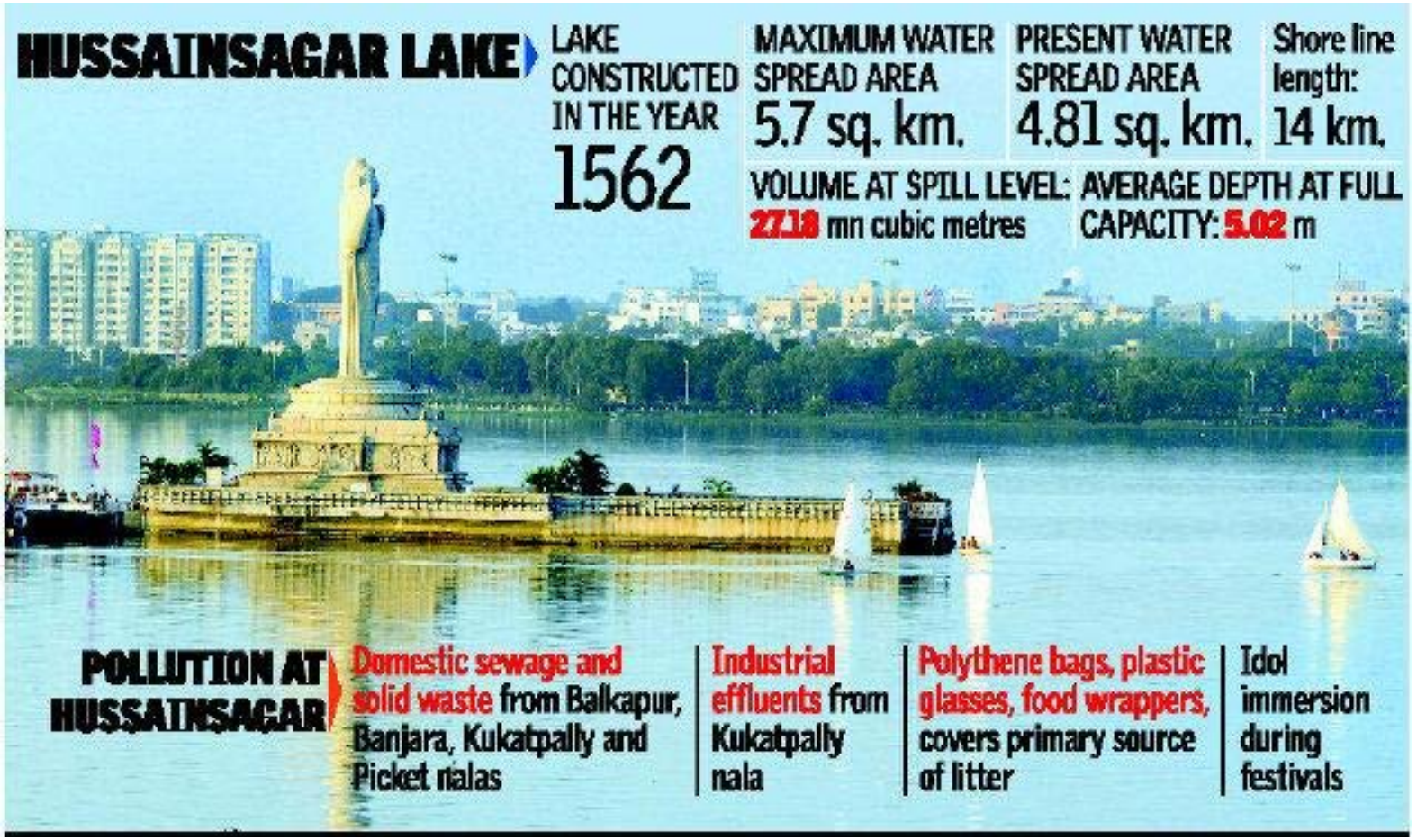
N A T U R A L : C E N T U R I E S

CULTURAL EUTROPHICATION AND LAKE AGING occurs over decades, and results from human-induced urban runoff, sewage effluent, industrial waste, fertilizers, pesticides, and excess sediments

C U L T U R A L : D E C A D E S

Case 1. Hussain Sagar Lake

Hussain Sagar is a heart shaped lake in **Hyderabad** built by Ibrahim Quli **Qutub** Shah in 1563, during the rule of Ibrahim Quli **Qutub** Shah. It is fed by **River Musi**.



Case 2. Lake pollution in Bangalore

Notable lakes in Bangalore are:

•Akshayanagara Kere - Situated in Akshayanagara near Hulimavu, Bannerghatta Road. ...

•Bellandur Lake - The largest lake in the city, situated to the southeast. ...

•Ulsoor lake - Situated in Halasuru near M G Road. ...

•Sankey tank - Renovated lately. ...

•Madiwala Lake

- One of the biggest lakes.

With most Bengaluru lakes polluted, birders head to the outskirts for better sighting

The Hindu, September 18, 2017
http://www.thehindu.com/news/cities/bangalore/with-most-bengaluru-lakes-polluted-birders-head-to-the-outskirts-for-better-sighting/article19705519.ece

Bengaluru: 356 flats near Bellandur Lake get STP ultimatum

Bangalore Mirror Bureau | Updated: Sep 27, 2017, 01.00 AM IST
http://bangaloremirror.indiatimes.com/bangalore/others/bengaluru-356-flats-near-bellandur-lake-get-stp-ultimatum/articleshow/60845722.cms

3. Groundwater Pollution: Causes and Persistence

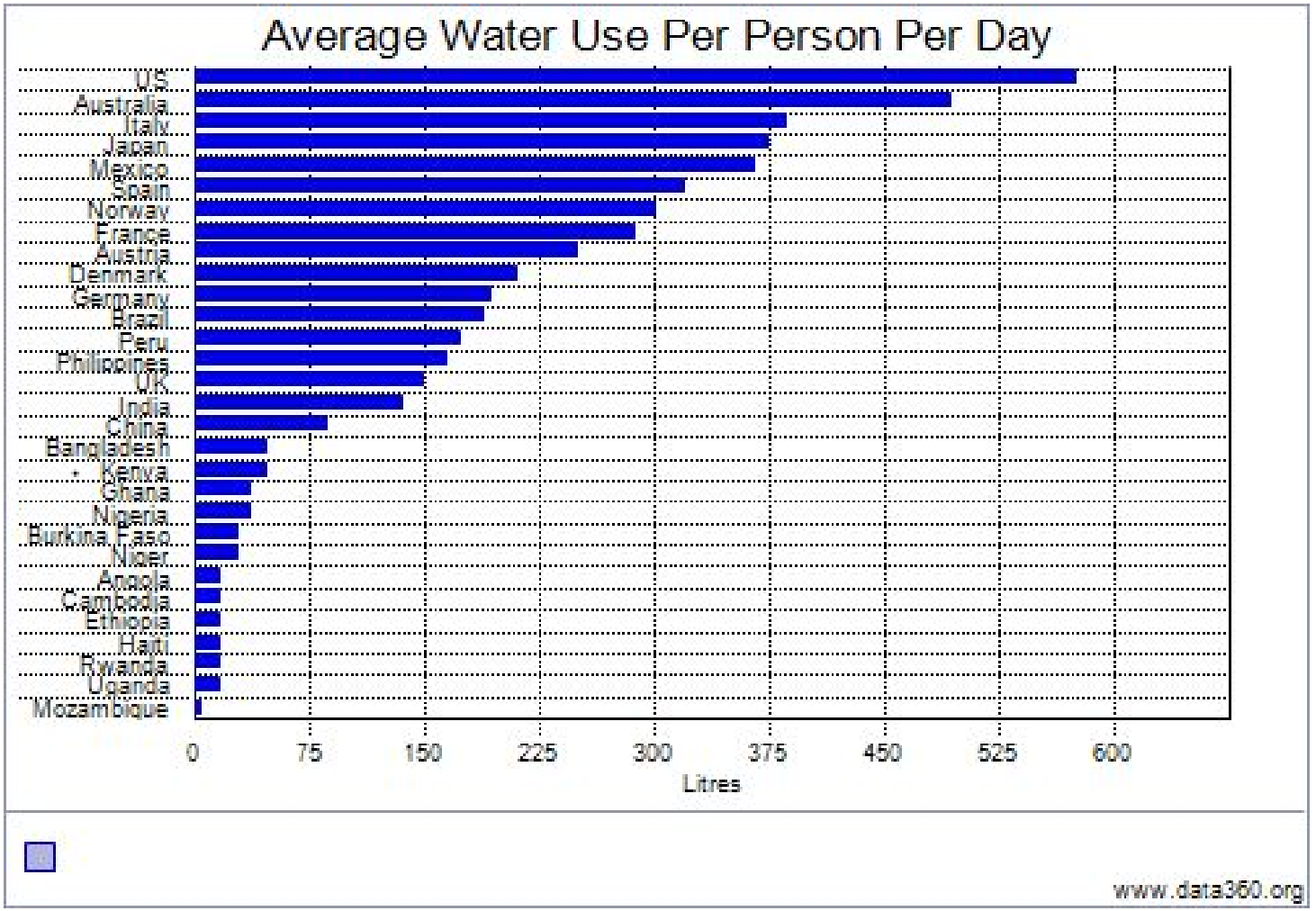
- Sources of groundwater pollution
- Slow flowing: slow dilution and dispersion
- Consequences of lower dissolved oxygen
- Fewer bacteria to decompose wastes
- *Cooler temperatures: slow down chemical reactions*
- *"Degradable" and nondegradable wastes in groundwater*

4. Ocean Pollution

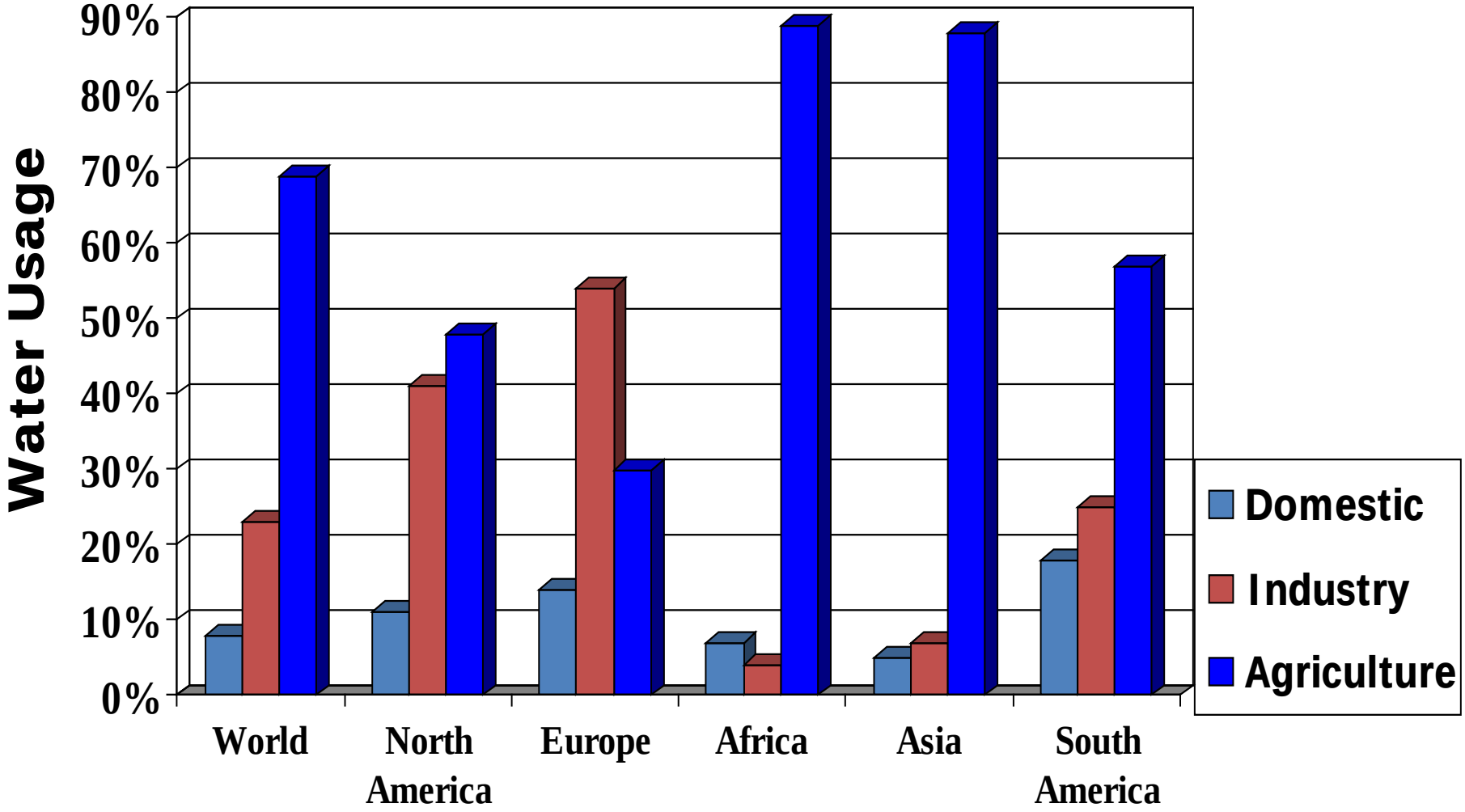
- How much pollution can oceans tolerate?
- Some pollutants degrade and dilute in oceans
- Ocean dumping controversies

WATER CONSUMPTION STATS

Per capita water consumption



Water usage


Water Usage
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
World
North America
Europe
Africa
Asia
South America
Domestic
Industry
Agriculture

Health impacts

Major Categories of Water Pollutants

- Infectious Agents
  - Bacteria, Viruses, Protozoa, Parasites
  - Source: Human and animal waste
- Oxygen-Demanding Waste
  - Organic debris & waste + aerobic bacteria
  - Source: Sewage, feedlots, paper-mills etc.
- 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

Major Categories of Water Pollutants

- 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

Effects of Water Pollution

- Polluted water will lead to……..
  - Soil contamination.
  - Air contamination.
  - Food chain contamination.
  - Aesthetic.

- Lack of clean water supply for
  - Domestic demand.
  - Industry use.
  - Agriculture use.

WATER POLLUTION

- Will also cause
  - Breeding of diseases vector.
  - Spreading of water borne diseases.
  - Food poisoning.
  - Skin problem.

Effects on Humans

- Diseases caused by:
  - Drinking contaminated water
  - Swimming in polluted water
  - Contact with chemically polluted water

Water Pollutants and Human health

- https://www.youtube.com/watch?v=OCBeyd6lEkI