

# Environmental Technology in Mining

## CHAPTER 3.1.1.2 WATER POLLUTION



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Y DEL MEDIOAMBIENTE

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# Water pollution



<https://www.iamrenew.com/environment/bangladeshs-polluted-waters-rivers-dying-due-to-dyeing/>

# Water pollution

- Impurities:

Substances in water other than H<sub>2</sub>O (usually refer to natural substances)

- Pollution:

Presence in water of foreign substances that **lower its quality** → constitute a health hazard or impair the **usefulness of water** (drinking, bathing, cultivating shellfish, ...)

- Categories of impurities/pollution:

- **Physical:** *turbidity, color, temperature, taste and odor*
- **Chemical:** *alkalinity, hardness, toxics and other compounds*
- **Microbiological:** *indicators of fecal contamination*
- **Radiological**

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- 1) Water pollution
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# Types of water pollution

- According to water receptor
  - Water pollution in rivers
  - Water pollution in lakes and reservoirs
  - Water pollution in estuaries
  - Groundwater pollution
  - Sea pollution

# Types of water pollution

- According to source:

- Domestic wastewater (DWW) or sewage

- Blackwater (water from toilets) + greywater

- Municipal or urban wastewater

- Domestic wastewater + industrial discharges + seepage water (+ urban runoff)

- Industrial wastewater (including mining)

- Livestock wastewater

- Agricultural wastewater



# Types of water pollution

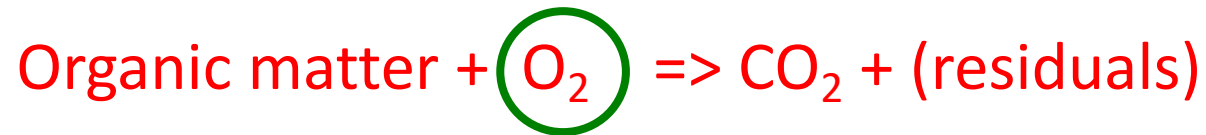
- According to pollutant
  - Oxygen-demanding material ( $\approx$  organic matter)
  - Nutrients
  - Solids
  - Toxics (metals, pesticides)
  - Emerging contaminants
  - Pathogenic Organisms
  - Heat

# Organic matter

- Chemical organic compounds:

contain C, O, H + N, P, S

may be oxidized:



# Organic matter

- Main effect on water:

## oxygen demand

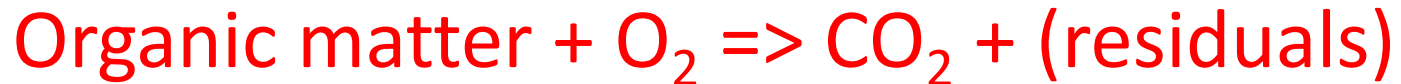
- Dissolved oxygen (DO) depletion in water poses a threat to fish and other aquatic life
- Critical DO varies among species (e.g. higher for salmon than for carp)

# Organic matter

- Measurement

- Indirect:

OM is oxidised and oxidant or subproducts are measured. Oxidation reaction:



- Thermal oxidation
    - Chemical oxidation
    - Biochemical oxidation

# Organic matter

- Thermal oxidation

- Based on the **combustion** of a sample at 950 °C



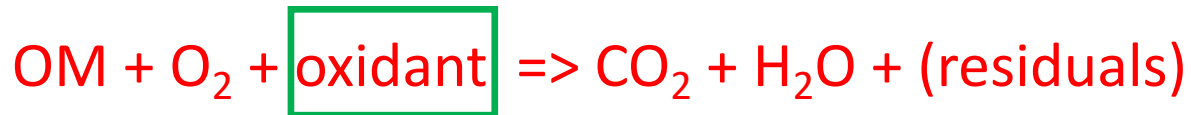
## Limitations:

- It also accounts for non oxidizable OM
  - Inorganic carbon must be removed previously
- 
- **Total Organic Carbon TOC (mg C/L)**  
Measures CO<sub>2</sub> released
  
  - **Total Oxygen Demand TOD (mg O<sub>2</sub>/L)**  
Measures O<sub>2</sub> consumed

# Organic matter

- Chemical oxidation

Measures the oxygen equivalent of the OM that can be oxidized by a strong **chemical oxidizing agent**



- **Chemical oxygen demand COD mg O<sub>2</sub>/L**

Oxidant: potassium dichromate  $\text{Cr}_2\text{O}_7\text{K}_2$

**Limitations:**

There may be differences between COD and TOD because:

- COD also accounts for inorganic matter (e.g.  $\text{Fe}^{++}$ )
- COD cannot account for non chemically oxidizable OM (e.g. benzene)

For DWW COD = 250-1000 mg/L

# Organic matter

- Chemical oxidation
  - **Permanganate oxidability** mg O<sub>2</sub>/L
    - Oxidant: potassium permanganate MnO<sub>4</sub>K
    - For low contaminated natural waters

# Organic matter

- Biochemical oxidation

The oxidation of the OM is carried out by **microorganisms** that use OM as food source



Measures biodegradable OM

- **Biochemical oxygen demand** **BOD** mg O<sub>2</sub>/L

It usually refers to oxygen consumed after 5 days (BOD<sub>5</sub>) (because complete oxidation may take a long time)

For DWW: BOD<sub>5</sub> = 100-300 mg/L



# Organic matter: BOD

- BOD test

A water sample with enough oxygen is placed in a closed container (and inoculated with bacteria if needed). Oxygen consumption after a certain time is measured



Mameaw.piti, CC BY-SA 4.0 <<https://creativecommons.org/licenses/by-sa/4.0/>>, via Wikimedia Commons

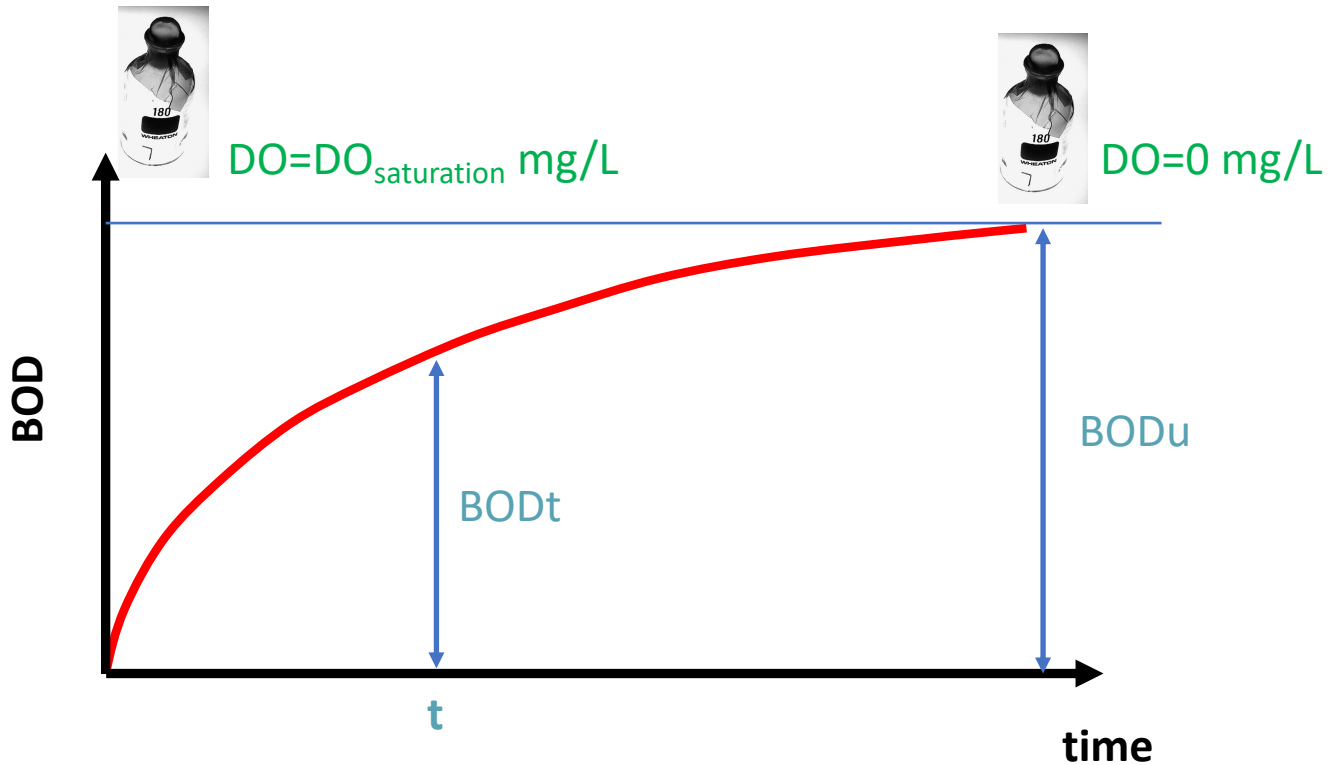


<https://www.flickr.com/photos/23116228@N07/3231600029>

BOD bottles

# Organic matter: BOD

- BOD test



$BOD_t$  : BOD at time  $t$  (mg/L)  
 $BOD_u$  : ultimate BOD (mg/L)  
 $k_1$ : reaction rate constant ( $d^{-1}$ )

$$BOD_t = BOD_u (1 - e^{-k_1 \cdot t})$$

# Organic matter: BOD

- BOD test

## Typical values for the BOD rate constant

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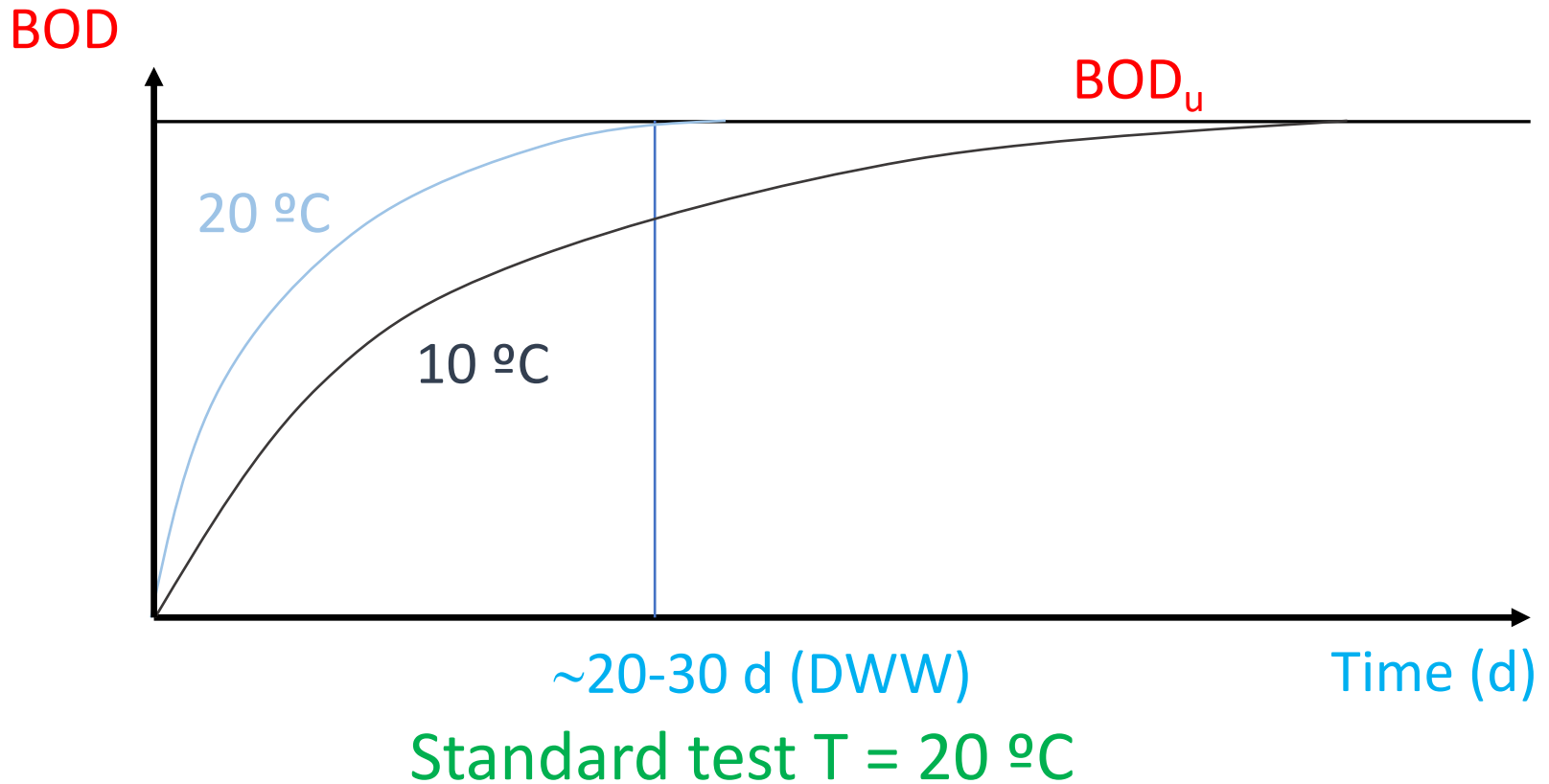
Sample	$k$ (20°C) (day <sup>-1</sup> )
Raw sewage	0.35–0.70
Well-treated sewage	0.12–0.23
Polluted river water	0.12–0.23

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# Organic matter: BOD

- Factors affecting BOD test
  - Temperature

↓ T => ↓ biological activity



# Organic matter: BOD

- Factors affecting BOD test

- Light

If  $\exists$  light  $\Rightarrow \exists$  algae  $\Rightarrow$  O<sub>2</sub> production

Standard test = darkness

- Microorganisms

- If no  $\exists$  microorganisms  $\Rightarrow$  inoculation is needed
    - BOD essay should be performed with acclimated organisms
    - For DWW  $\Rightarrow$  usually  $\exists$  acclimated microorganisms

Standard test = inoculum of microorganisms

# Organic matter: BOD

- Factors affecting BOD test

- **Dilution:** If  $BOD > DO_{\text{saturation}}$  ( $\sim 9 \text{ mg/L}$ ) dilution is needed to have enough DO during the whole experiment

Ej:

to measure 90 mg/L, sample must be diluted at least 10 times

to measure 900 mg/L, sample must be diluted at least 100 times

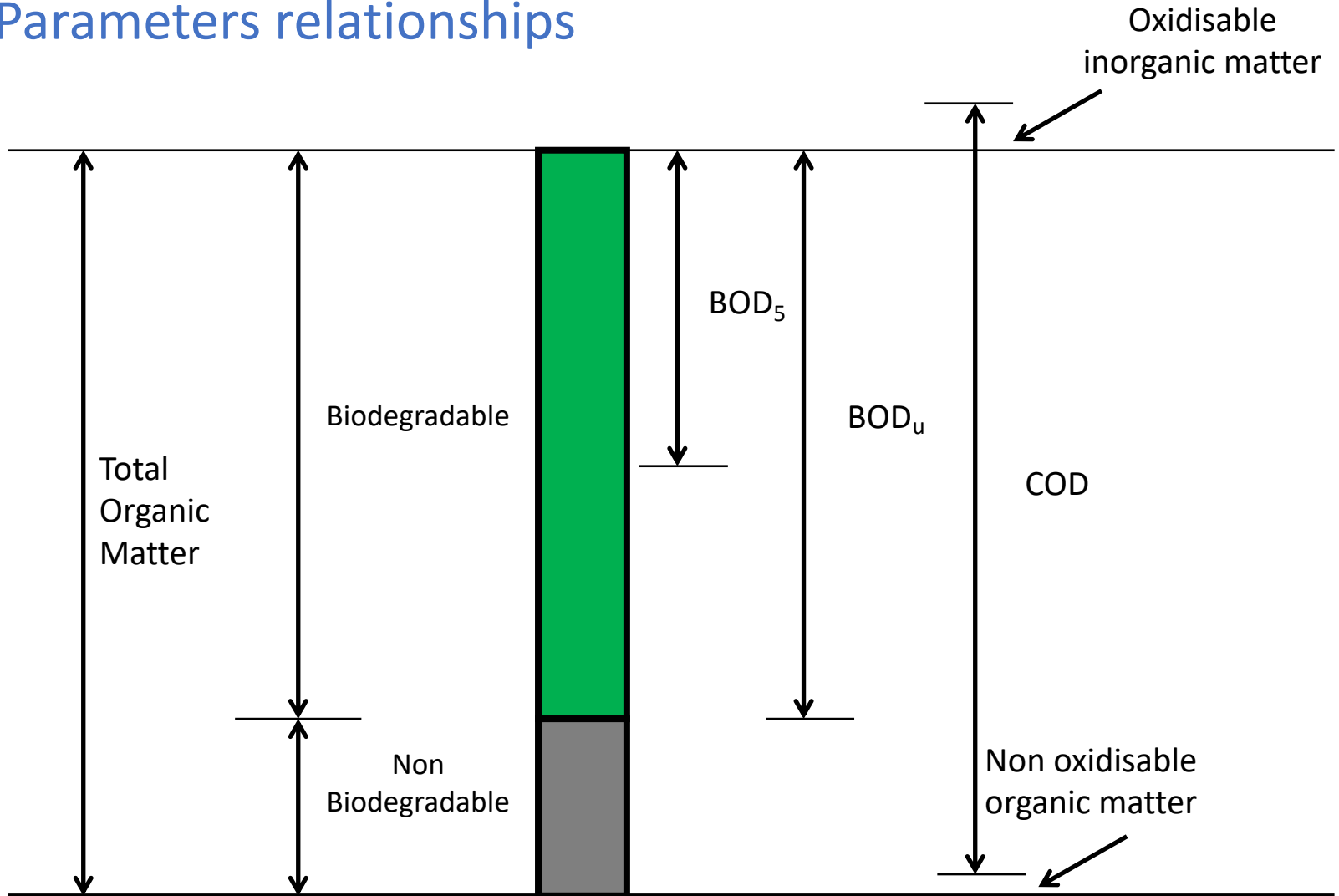
Standard test:

- Preaeration of water

- Sample dilution so that  $DO_{\text{final}} > 0 \text{ mg/L}$

# Organic matter

- Parameters relationships



# Organic matter

- Population equivalent (p.e.)

1 p.e. means the organic biodegradable load having a BOD<sub>5</sub> of **60 g of oxygen per day** (EU Directive urban waste water treatment)

Takes into account non domestic pollution sources. For instance:

1 cow = 10 p.e.

1 pig = 3 p.e.

The size of agglomerations is expressed in p.e.

Ej. The Waste Water Treatment Plant of Vuelta Ostrera is designed to treat 310,000 p.e.



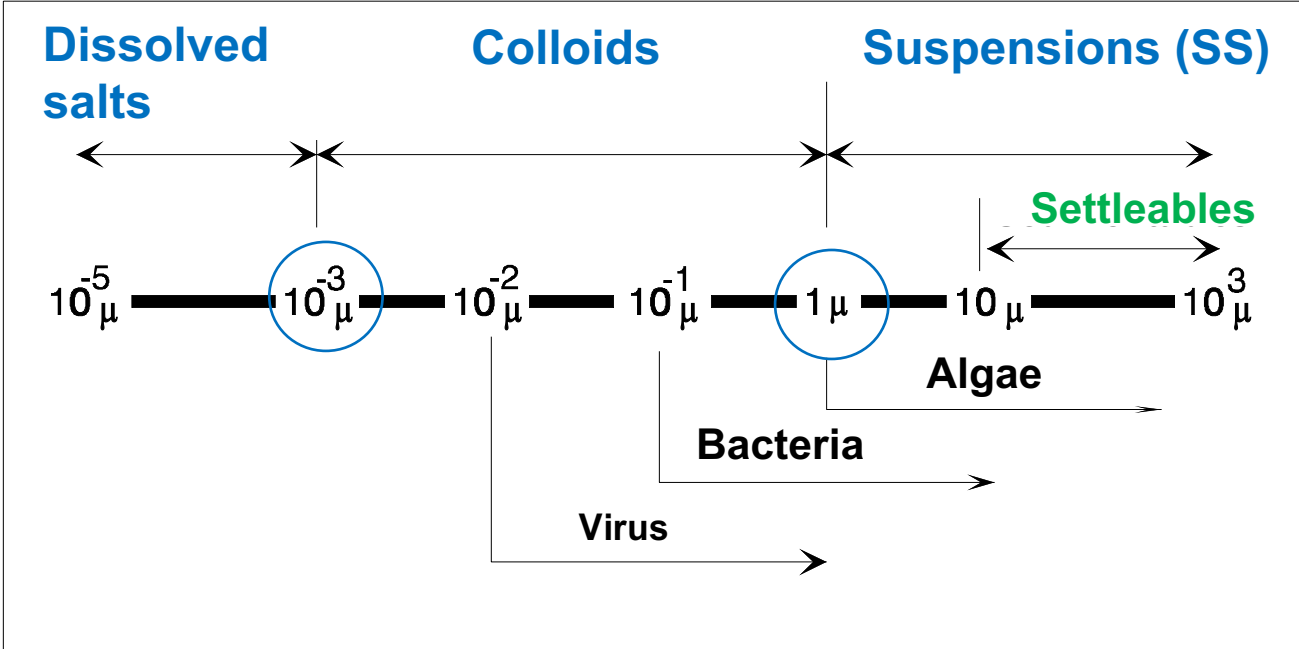
# Nutrients

- Only pollutants when they are in excess (N, P)
- Impacts:
  - The food chain is disturbed (some organisms proliferate at the expense of others)
  - Example: excessive growth of algae in water bodies (**eutrophication**)
- Sources:
  - Phosphorus-based **detergents**
  - **Fertilizers**
  - **Food** processing wastes

# Solids

Remainder!

## Types of solids in water



# Solids

- One of the most important physical parameters to characterize water pollution
- The **residue left after evaporation** (coarse and floating matter are removed before analysis): everything that isn't a gas or doesn't evaporate.
- Includes salts, silt and clay, plankton, algae, fine organic debris and other organic and inorganic matter.

# Solids

- Can be organic or inorganic;  
suspended or dissolved;  
settleable, colloidal and matter in solution.
- Expressed in mg/L  
(Exception: Settleable solids in mL/L)
- **Turbidity** is an indirect way of measuring the suspended solids (nephelometer, NTU nephelometric turbidity units)

# Solids

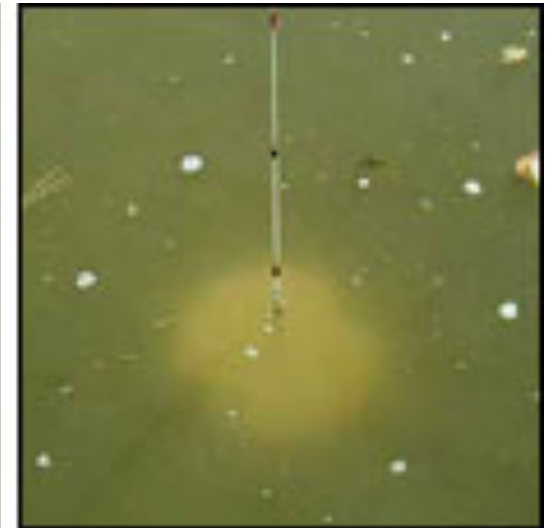
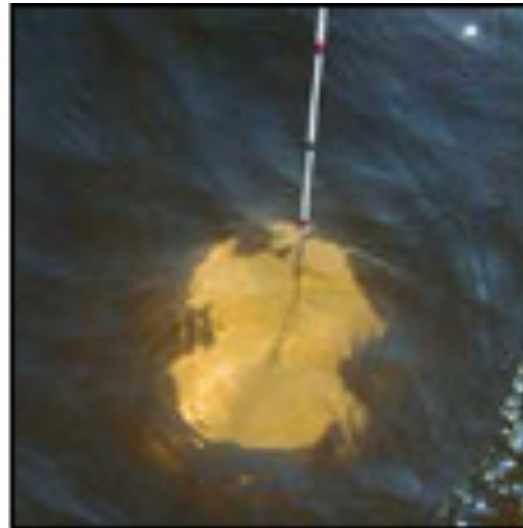
- Measurement of turbidity

- Nephelometer [NTU]



- Secchi disc depth (clarity in big water bodies)[m]

Depth that a black and white Secchi disc can be lowered into a body of water until visibility is lost.



# Solids

- Classified by:

- Evaporation (105 °C)

- Total Solids **TS**

- Filtration ( $\approx 1\mu\text{m}$  pore size)

- Total Suspended Solids **TSS**

- Total Dissolved Solids **TDS**

- Settling (Imhoff cone)

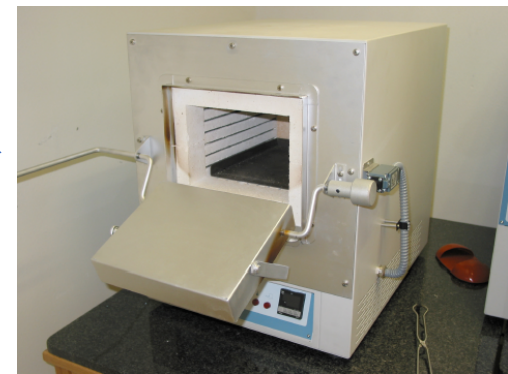
- Settleable Solids

- Non settleable solids

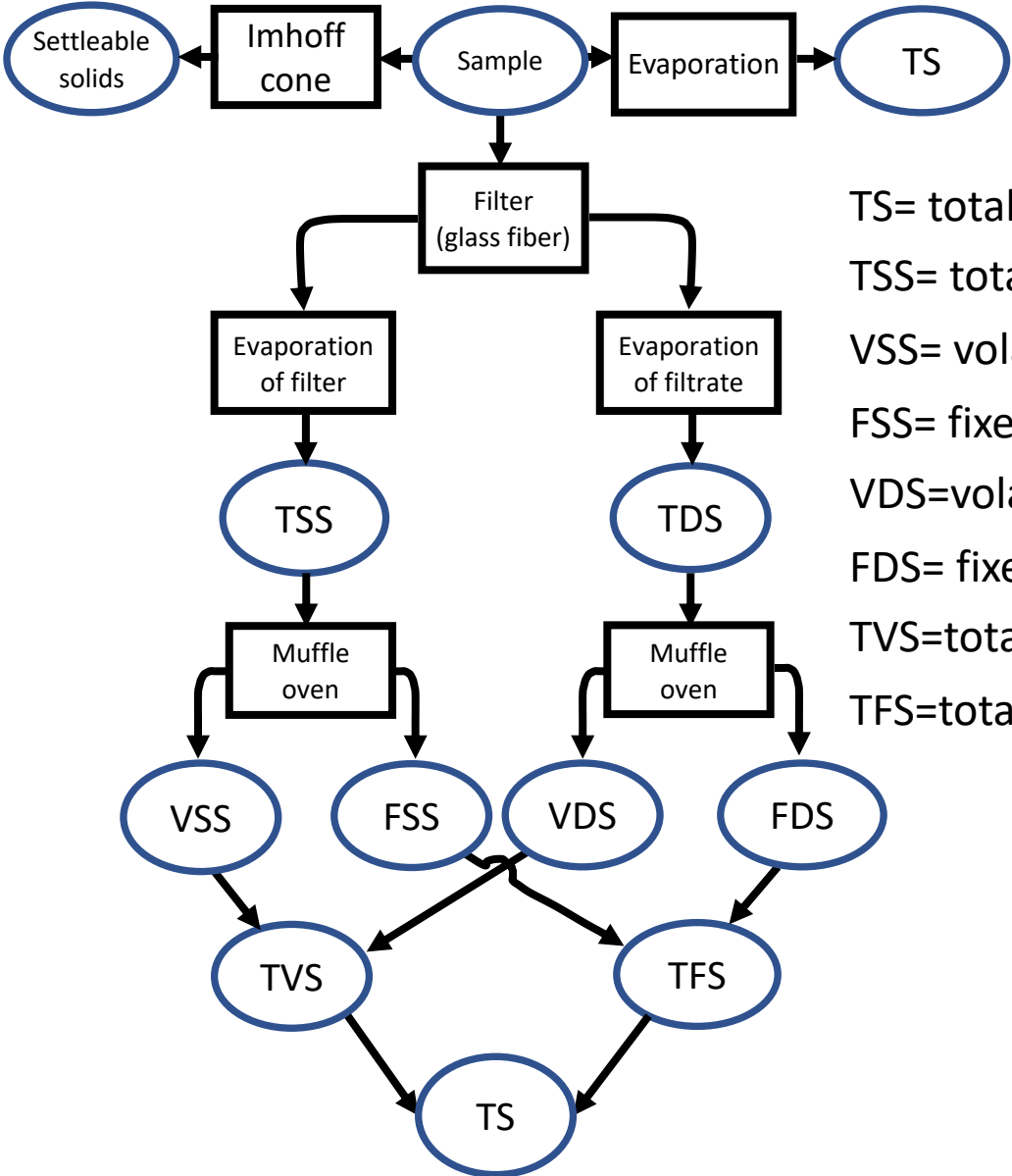
- Ignition ( $500\pm 5$  °C) (Muffle oven)

- Volatile Solids **VS**

- Fixed Solids **FS**



# Solids



- TS= total solids
- TSS= total suspended solids
- VSS= volatile suspended solids
- FSS= fixed suspended solids
- VDS=volatile dissolved solids
- FDS= fixed dissolved solids
- TVS=total volatile solids
- TFS=total fixed solids

# Solids

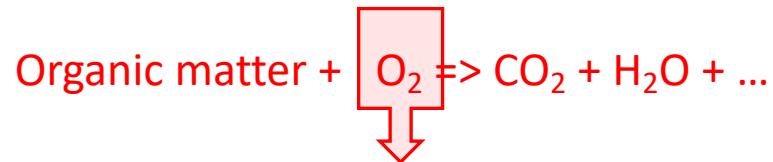
- Importance and meaning

- **Settleable** solids:

- Form sediments that can destroy ecological habitats (e.g. beds for salmon eggs)
    - Contribute to the blocking of pipes

- $\uparrow$  **TDS** (mainly salts): water not useful for water supply or irrigation (crop and soil damage)

- In general, **VS** are presumed to be organic matter, which can exert an oxygen demand



The concentration of  $\text{O}_2$  in water is reduced!



# Solids

- Importance and meaning

- **Suspended solids** must be removed from drinking water, because:
  - **Viruses** and **bacteria** are solids themselves
  - Pathogens can be carried on the surface of particles (SS are a **shelter** for microorganisms)
  - Turbidity reduces the **aesthetic** acceptability of drinking water

# Solids

- Importance and meaning

- Colloidal particles cause turbidity

- Turbidity can block sunlight from reaching submerged plants and algae

- Less photosynthesis => dissolved oxygen decreases

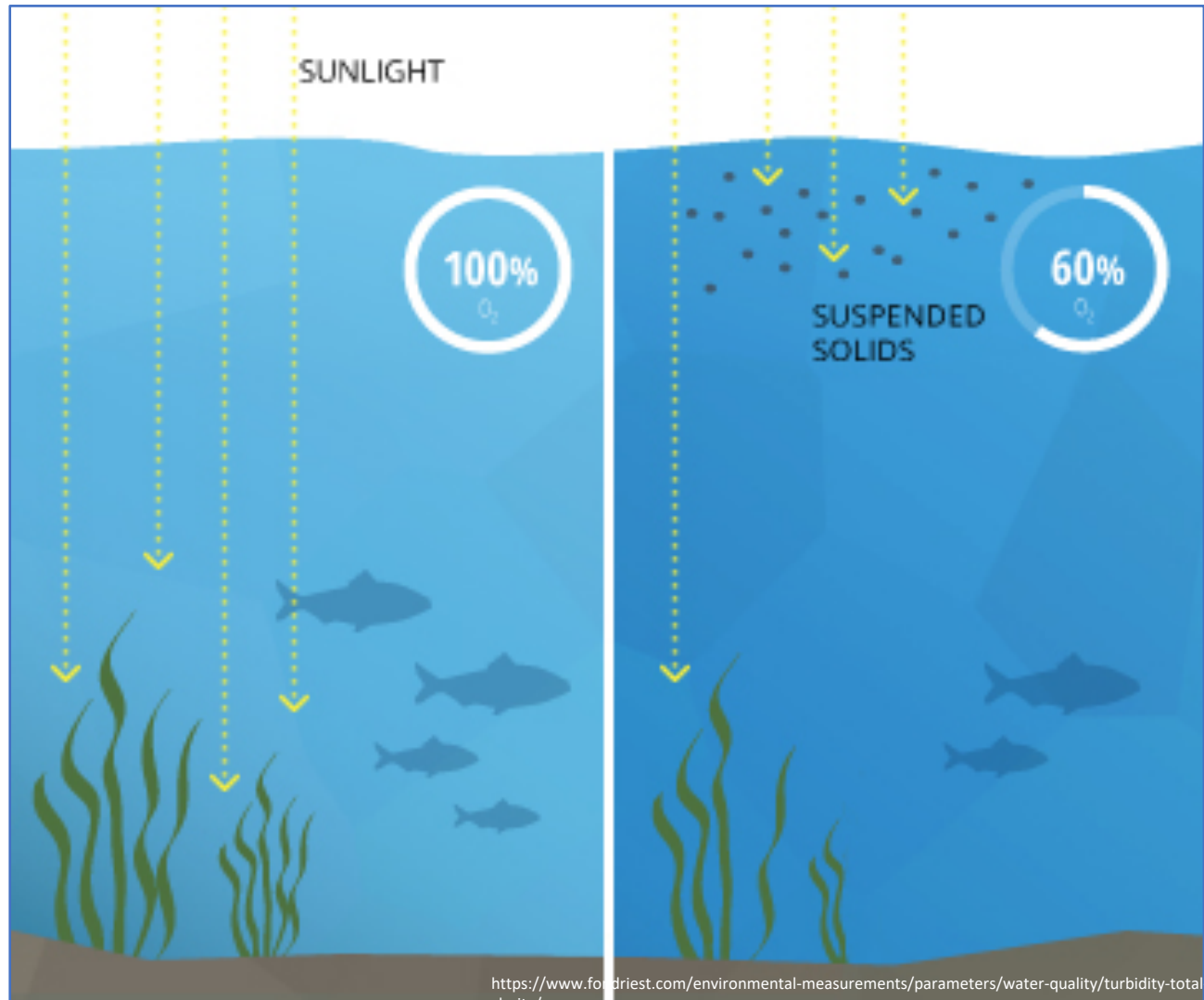
- Vegetation die-off

- => organic matter decomposition = dissolved oxygen decreases

- => seaweed and underwater plants are food sources for aquatic organisms, and their population decreases

# Solids

- Importance and meaning



# Toxics

- Toxic inorganic substances:
  - Nitrates ( $\text{NO}_3^-$ ) → methemoglobinemia
  - Cyanides (CN) → cyanosis
  - Heavy metals: As, Ba, Cd, Cr, Pb, Hg, Se, Ag → toxicity, cancer, anaemia, ...
- Toxic organic substances:
  - Pesticides, insecticides, solvents ...
  - Over 120 compounds

# Microbiological Characteristics

Pathogen: organism that causes disease:

- viruses, bacteria, protozoa, helminths,
- from fecal discharges of infected individuals or animals

**Are difficult to indentify!!**



Indicators of fecal contamination → properties:

- Inhabitants of the intestinal tract
- Excreted in large quantities
- Survive in water for long periods of time
- Relatively easy to culture in the lab

E.g. Total Coliform test (colonies/100 mL)



# Emerging contaminants

- Any synthetic or naturally occurring chemical or microorganisms that is **not commonly monitored** in the environment and cause known or suspected adverse ecological and (or) human health effects.
- Types:
  - **Pharmaceuticals and Personal Care Products (PPCPs)**
    - E.g. Analgesics, antibiotics, hygiene products...
  - **Endocrine-disrupting chemicals**
    - E.g. estrogens, androgens, some pesticides.



## Chapter review (1/2)

- There are many types of water pollution, according to receptor, source and pollutant
- Organic matter:
  - The main effect on water is oxygen demand
  - Measured by oxidation: thermal (TOC, TOD), chemical (COD, permanganate oxidability), biochemical (BOD)
  - BOD test is affected by several factors (temperature, light, microorganisms, dilution)
  - Population equivalent (60 g of oxygen per day)



## Chapter review (2/2)

- Nutrients (N, P), eutrophication
- Solids
  - Turbidity; TS, TSS, TDS, VS, FS, settleable
  - There are many types of water pollution, according to receptor, source and pollutant
- Toxics, organic and inorganic
- Microbiological (Total Coliform test)
- Emerging contaminants