ENVIRONMENTAL ENGINEERING

CHAPTER 2 : WATER & WASTEWASTER QUALITY MANAGEMENT (Part 2)

Physical, Chemical & Biological parameters

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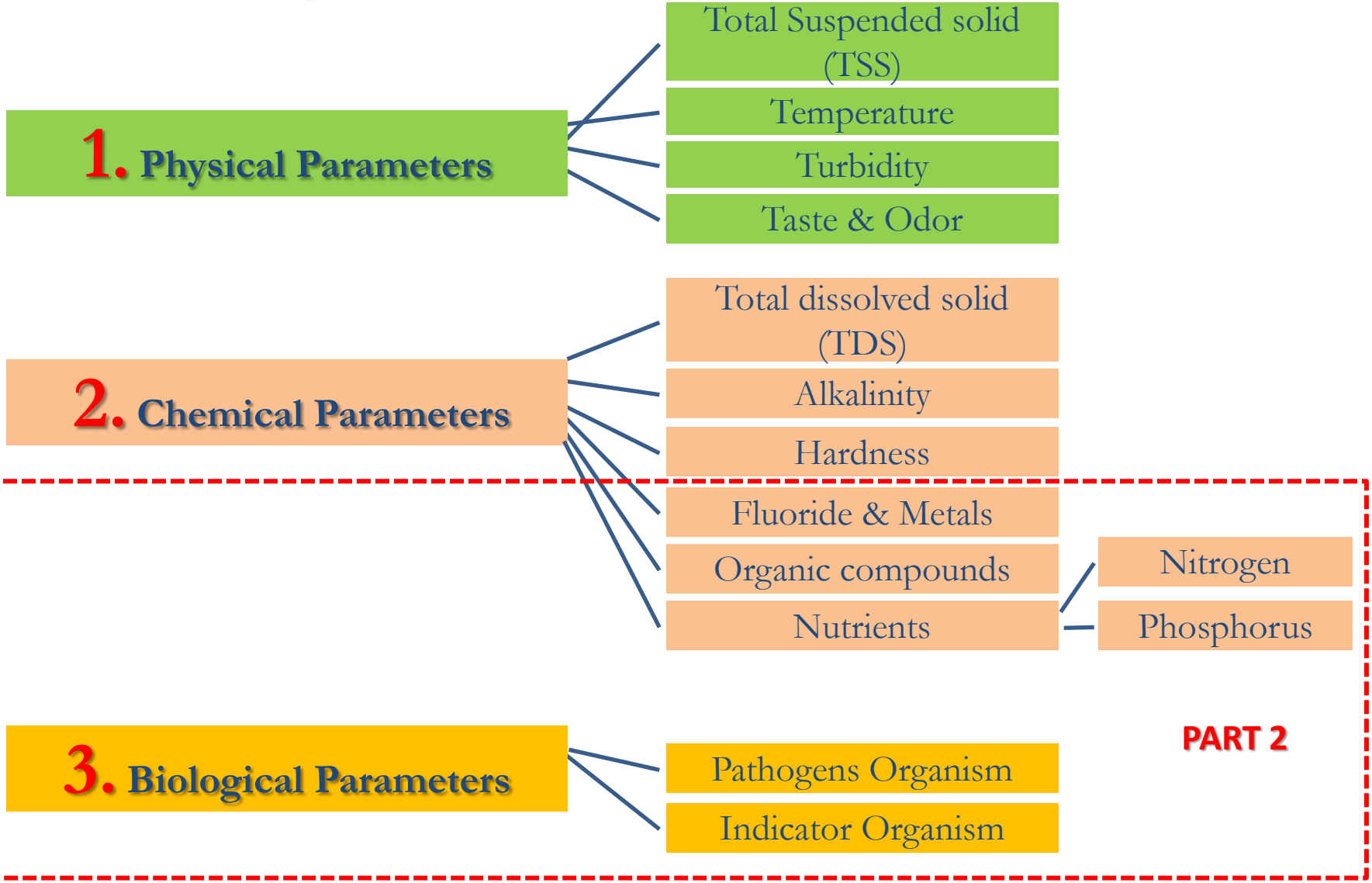
Chapter Description

- Topic
  - Wastewater Characteristics
  - Effluent Standard
- Expected Outcomes
  - Explanation of the physical, chemical and biochemical wastewater quality parameters such as suspended solids, turbidity, alkalinity, hardness, BOD, microorganisms and nutrient
  - Discuss the principles and unit operation involves in the wastewater treatment method
  - State the Environmental Protection Agency regulation practices in Malaysia
- References

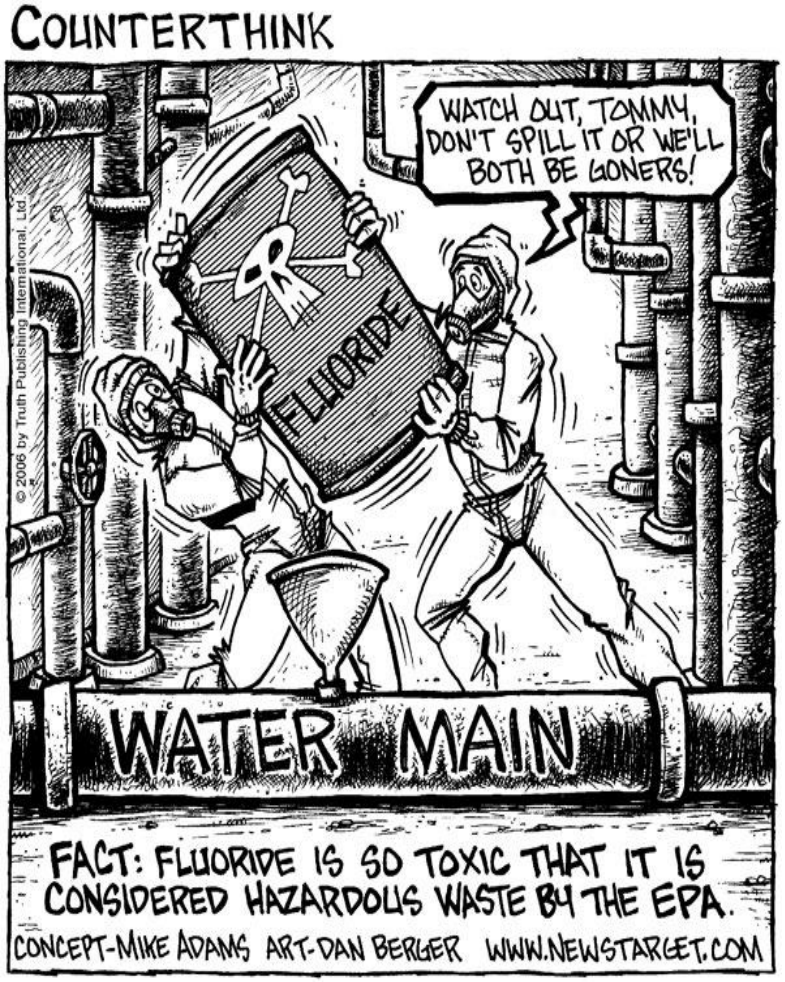
  - Peavy, H.S., Rowe, D.R. and Tchobanoglous, G., Environmental Engineering, McGraw Hill, 1985.
  - Mackenze, I.D., Introduction to Environmental Engineering, 4th Edition, Davis A. Cornell, Mc Graw Hill, 2008.
  - Sawyer, C.N. Chemistry for Environmental Engineerin. 4th Edition, McGraw Hill, 1994.
  - Martin, T.A. and David, W.H. Fundamental of Environmental Engineering. 2003.
  - Environmental Quality Act 1974 (Subsidiary Legislation), International Law Book, Service June 2002.

Water Quality Parameters



4. Fluoride & Metals

- ***Fluoride***
  - In groundwater (few regions)
  - Toxic to human and animal in large quantity.
  - Concentration of approximately 1.0 mg/L in drinking water help to prevent dental cavities in children.
  - Excessive dosage of fluoride can also result in bone fluorosis and other skeletal abnormalities.



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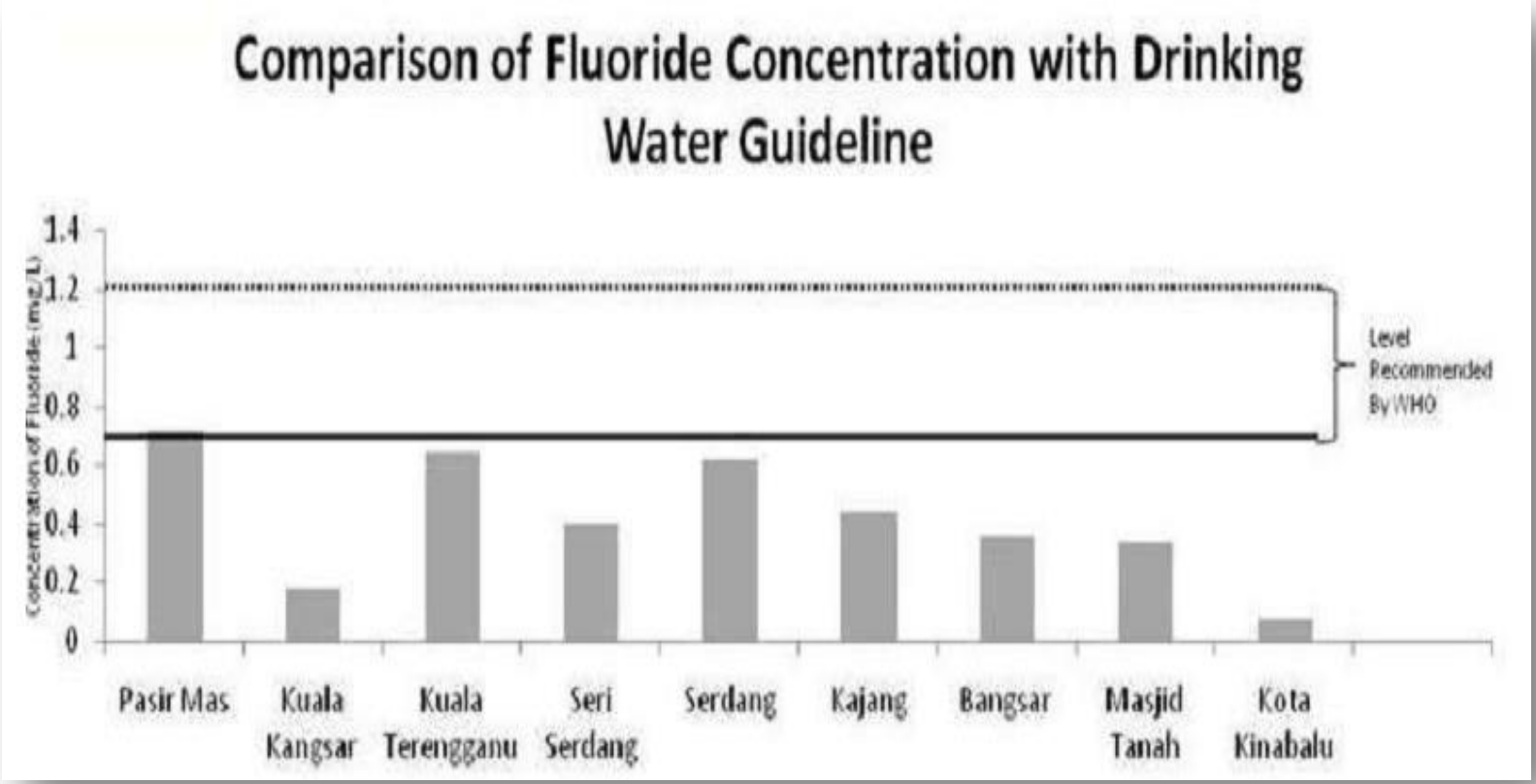


Shaharuddin *et al.* (2009) Fluoride Concentration in Malaysian Drinking Water, *American-Eurasian J. Agric. & Environ. Sci.*, 6 (4): 417-420.

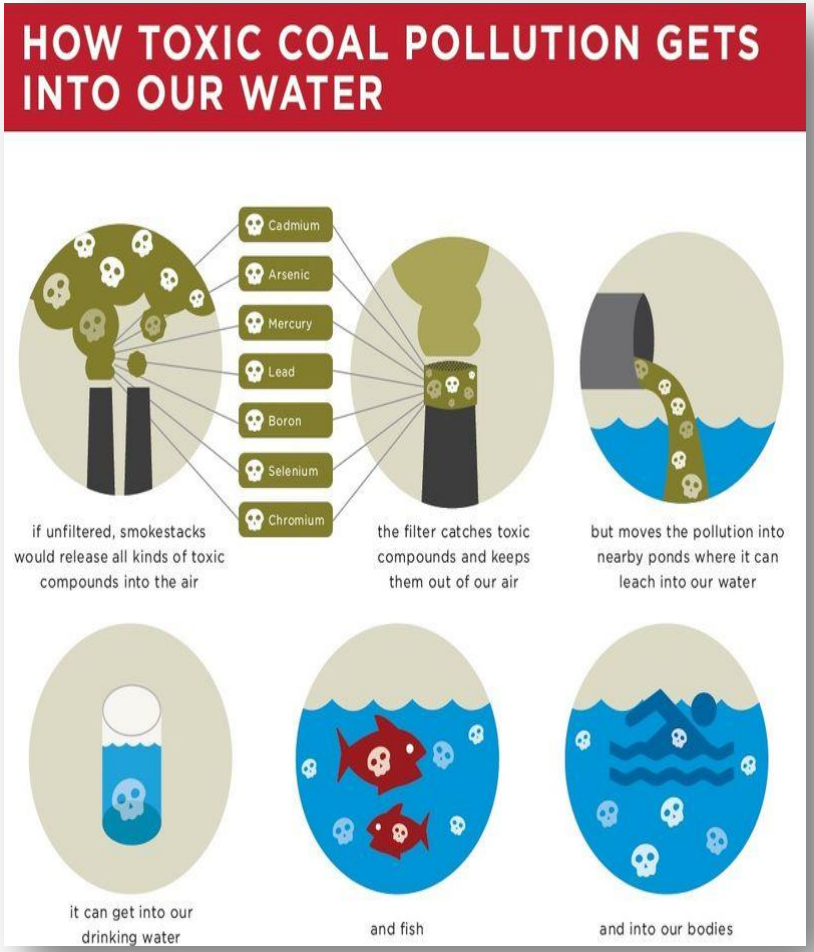
Metals

Nontoxic metals

- sodium, aluminum, manganese, iron
- Sodium: excessive concentration may cause bitter taste and hazard to cardiac and kidney patients
- Small quantities of iron and manganese may cause color problems

Toxic metals

- Arsenic, mercury, silver, barium, lead
- Harmful to humans and animals



5. Organics Compounds

Biodegradable organics

- Consists of organics that can be utilized for food by naturally occurring microorganisms within a reasonable length of time.
- Dissolved form: consists of starches, fats, proteins, alcohol *etc.*
- May cause color, taste, odor problems- main problem is action of microorganisms.
- Microbial utilization – can be oxidation/reduction.
- Aerobic (oxygen present) environment, the end products are stable and acceptable.
- Anaerobic (oxygen absent) environment, unstable product. When oxygen present, anaerobe products will be oxidized to aerobe end products.

Biochemical Oxygen Demand (BOD)

- The amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions.

- Measured by determining the oxygen consumed from a sample placed in an air-tight container and kept in a controlled environment for preselected period of time.

- In a standard test : 300mL BOD bottle, incubated at 20^{O}C for 5 days, light is excluded to prevent algal growth that may produce oxygen.

- Dissolved oxygen (DO) = oxygen solubility in water, depends on temperature, TDS and atmospheric pressure

Decomposable:
organic matter that can serve as food for bacteria, and energy is derived from its oxidation

BOD of diluted sample is calculated by:

DO_I: *Initial dissolved oxygen*

DO_F: *Final dissolved oxygen*

$$BOD\,(mg/L) = \frac{\mathrm{DO_I}\,(mg/L) - DO_F\,(mg/L)}{P}, P = \frac{sample\,used, mL}{size\,of\,bottle, mL}$$

P: *Decimal fraction of the sample.*

- BOD_5 represent oxygen consumed in 5 days.
- To calculate BOD for any period:

$$\frac{dL_t}{dt} = -kL_t$$

$\boldsymbol{k}$: *reaction constant*, d^{-1}

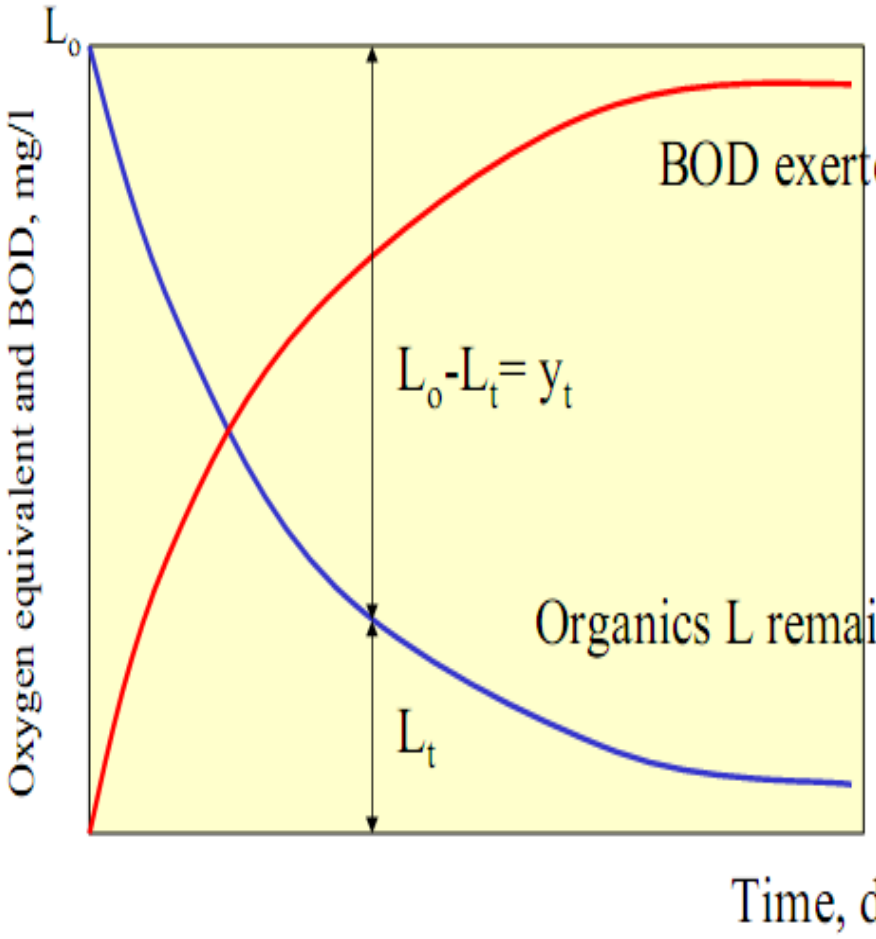
$\boldsymbol{L_t}$: *oxygen equivalent of the organics at time t*, mg/L

- dL_t/dt = the rate at which organic polluting matter is destroyed.

$$L_t = L_o e^{-kt}$$

$\boldsymbol{L_o}$: *total oxygen equivalent of the organics at time* 0, mg/L

BOD and oxygen equivalent relationship:



Organics L remaining $\frac{dL_t}{dt} = -kL_t$

$$y_t = L_o - L_t$$

$$y_t = L_o(1 - e^{-kt})$$

y_t represents the BOD_t of water

- Value y_t approaches L_o, indicating that the total/ultimate BOD (y_u)
- y_u = initial oxygen equivalent of the water L_o

$$y_u = \frac{y_t}{(1 - e^{-kt})}$$

- Value of k for any given organic compound is temperature-dependent.
- k value increase with increasing temperature (because microbe more active at higher temperature).
- Typical values of k are shown in Table 2.6 or can be determine using *van't Hoff-Arrhenius* model:

$$k_T = k_{20}\theta^{T-20^\circ}, \theta = 1.047$$

Example 4

Example 2-9: BOD conversions The BOD_5 of a wastewater is determined to be 150 mg/L at 20°C. The k value is known to be 0.23 per day. What would the BOD_8 be if the test were run at 15°C?

Solution:

1. Determine the ultimate BOD (y_u)

$$y_u = \frac{y_5}{1 - e^{-kt}}$$

$$= \frac{150}{1 - e^{-0.23 \times 5}}$$

$$= 220 mg/L$$

2. Correct the k value for 15°C.

$$k_T = k_{20}\theta^{T-20}$$
$$= 0.23\left(1.047^{-5}\right)$$
$$= 0.18$$

3. Calculate y_8

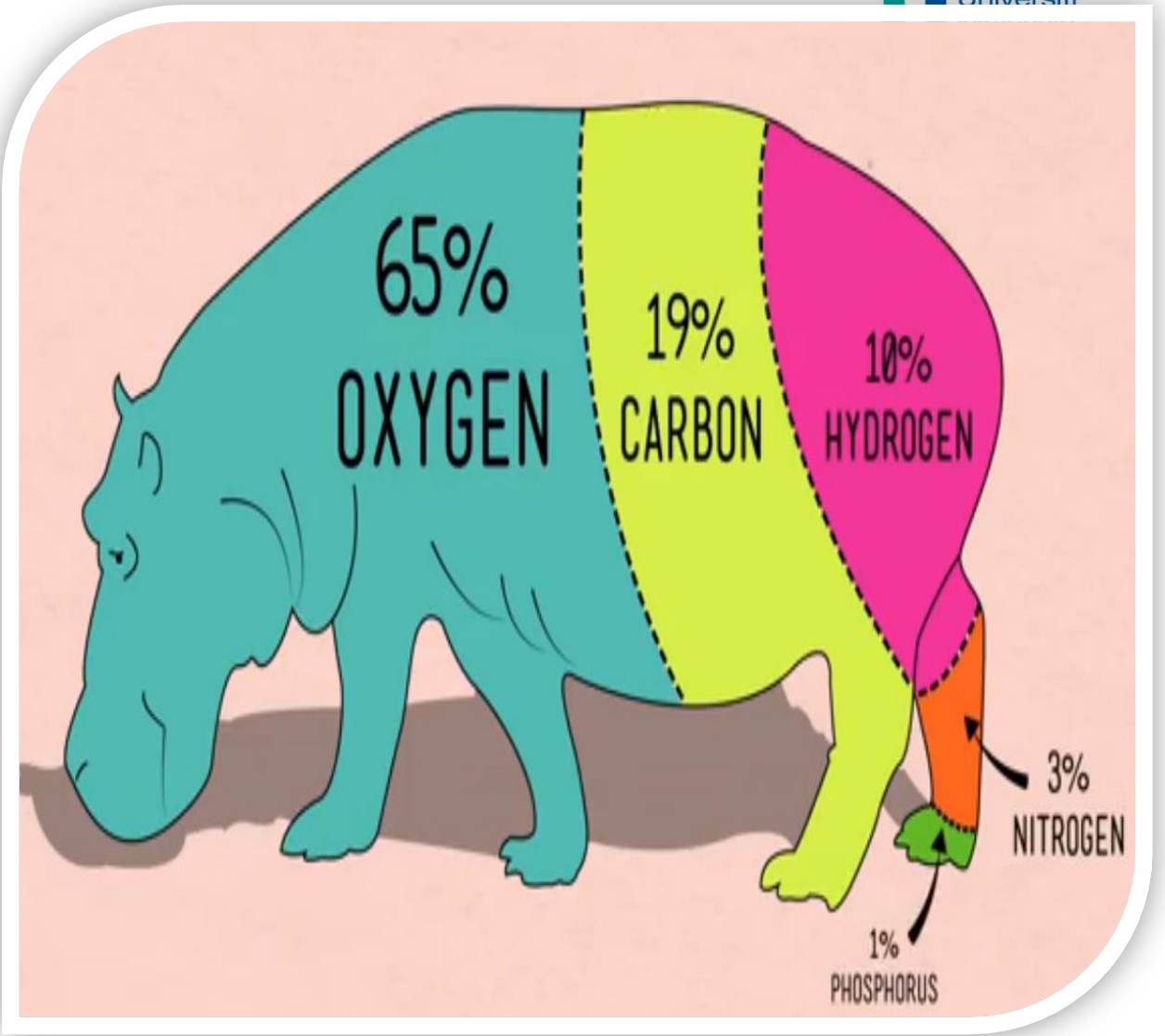
$$y_t = y_u\left(1-e^{-kt}\right)$$
$$y_8 = 220(1-e^{-0.18\times 8})$$
$$= 168 mg/L$$

Nonbiodegradable organics

- Resistant to biological degradation.
- Tannic & lignic acid, cellulose, phenols – biodegrade so slowly.
- Molecules with strong bond (polysaccharides) and ringed structure (benzene) are nonbiodegradable.
- Some organics are not biodegrade because they are toxic to organism (*e.g.*: pesticides; hydrocarbon compound combined with chlorine)
- Measurement : Chemical oxygen demand (COD) test or Total organic carbon (TOC)
- COD: higher than BOD (more compound can be oxidized chemically)

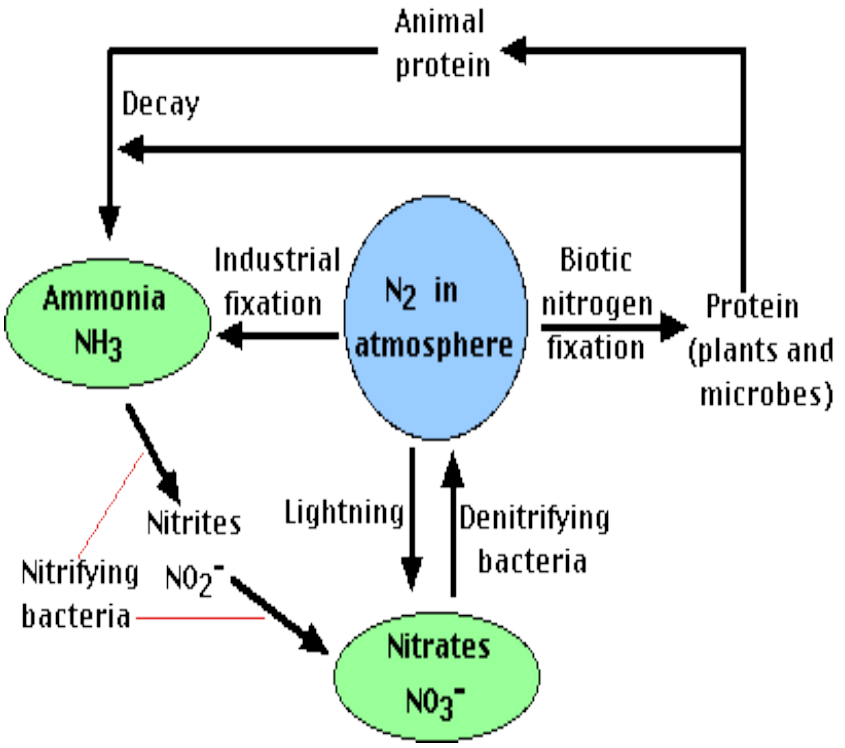
6. Nutrients

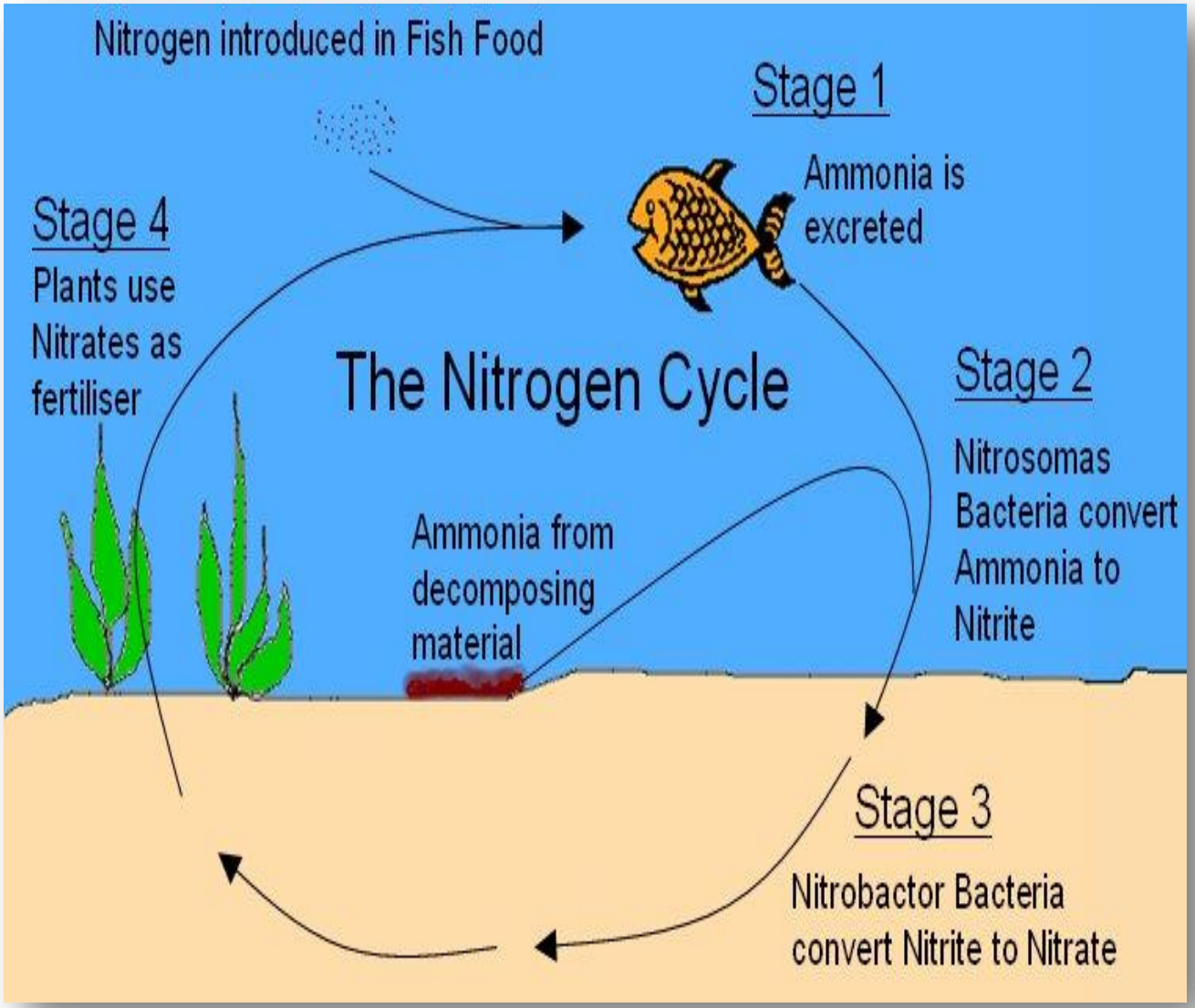
- Elements essential to the growth and reproduction of organisms.
- Limiting factor nutrient: nitrogen and phosphorus.



Nitrogen

- Constituents of proteins, chlorophyll and biological compound.
- Upon death of plants or animals, complex organic matter is broken down to simple forms by bacterial decomposition (*e.g.*:proteinous matter).
- Proteins converted to amino acid and finally reduced to ammonia (NH_3).
- If oxygen present, NH_3 oxidized to nitrite (NO_2^-) and then to nitrate (NO_3^-).





Phosphorus

- Appears as phosphate (PO_4^{3-}) in aquatic environments. Also as orthophosphate, condensed phosphates or organic phosphates
- Main sources : domestic sewage, animal feedlots, surface runoff from agricultural areas
- Not toxic, do not have direct health effect to organism- indirect threat to water quality
- Phosphate and nitrogen is the limiting nutrient
- N:P ratio in surface water is set at 10:1. Therefore, if N:P in the water <10, the limiting nutrient is N.
- If N:P ratio >10, then P is the limiting nutrient

BIOLOGICAL PARAMETERS

Biological Parameters

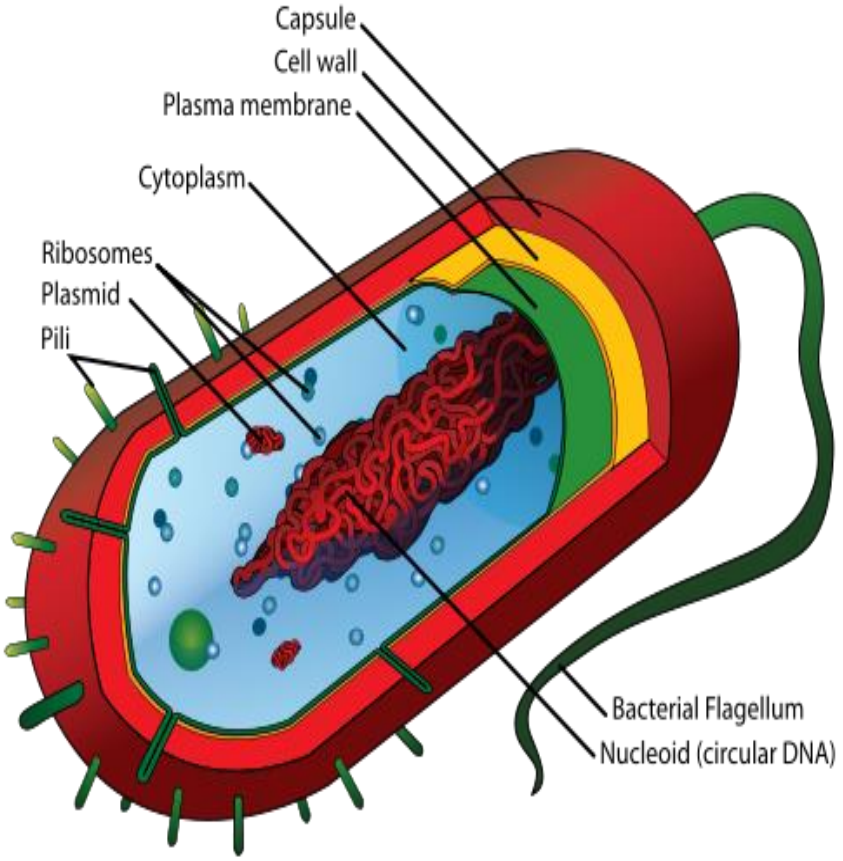
- Biological species – their present or absence may indicate in general terms the characteristics of a given water body.

Pathogens

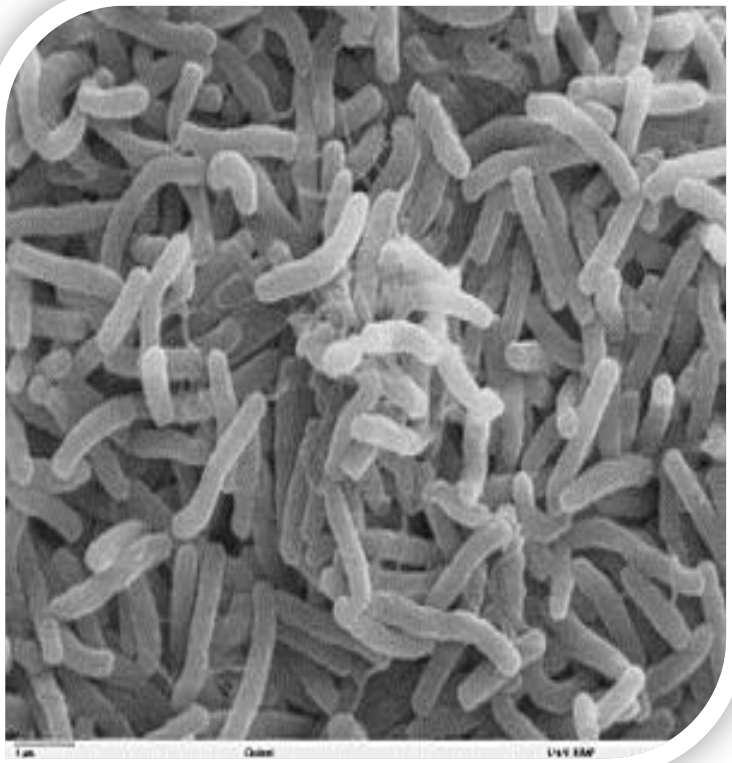
- capable of infecting, transmitting diseases to humans.

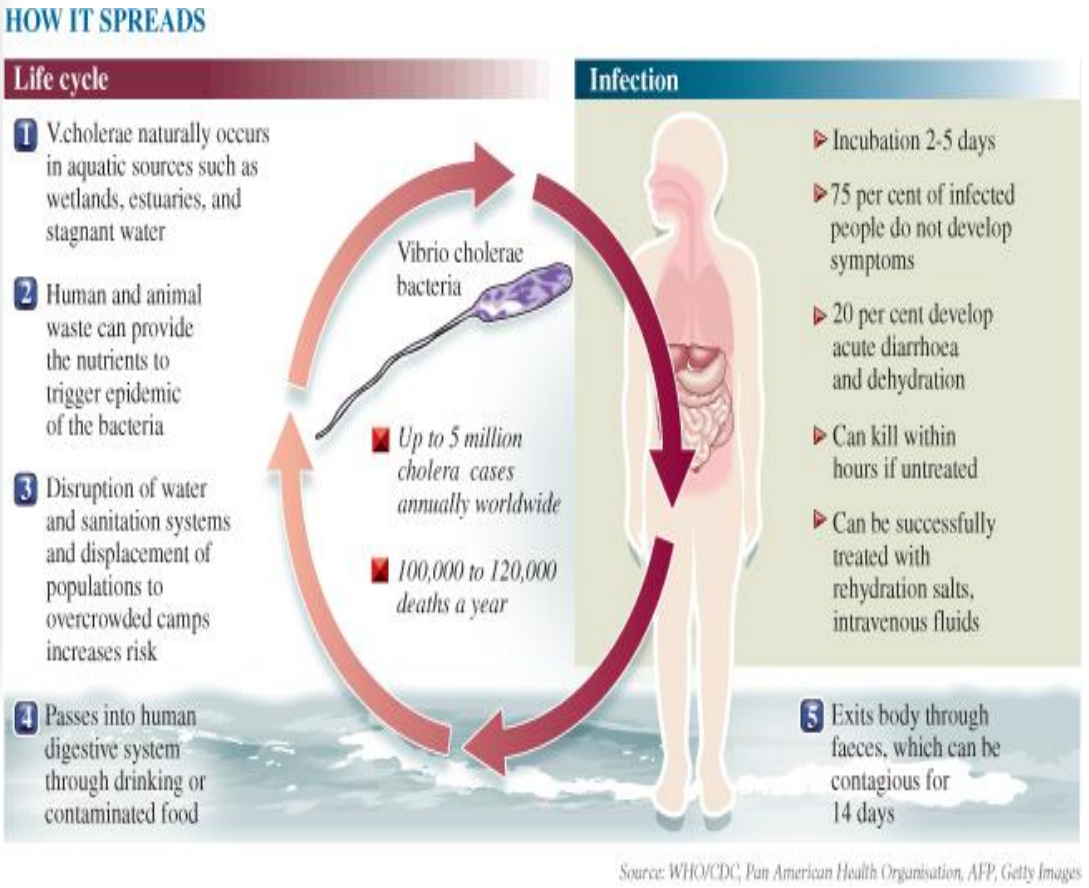
Bacteria – single cell microbe

- Organism that derive both energy and material from inorganic source – autotrophs.
- Bacteria that obtain both energy and material from organic compound – heterotrophs.
- Aerobic heterotrophs require oxygen and anaerobic heterotrophs utilize organics in the absence of oxygen.
- Utilize sunlight for an energy source and inorganic substance for a material source.



Vibrio Cholerae

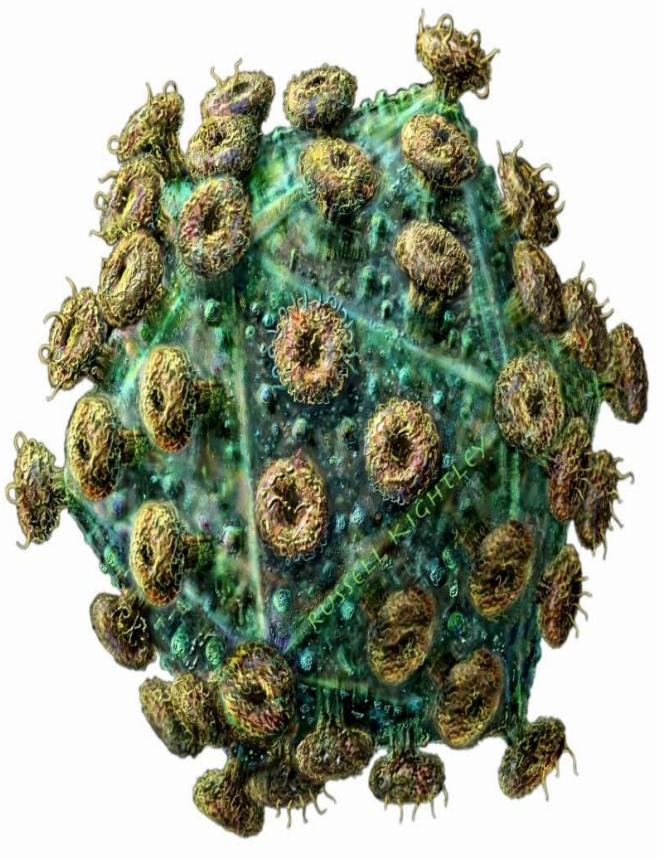


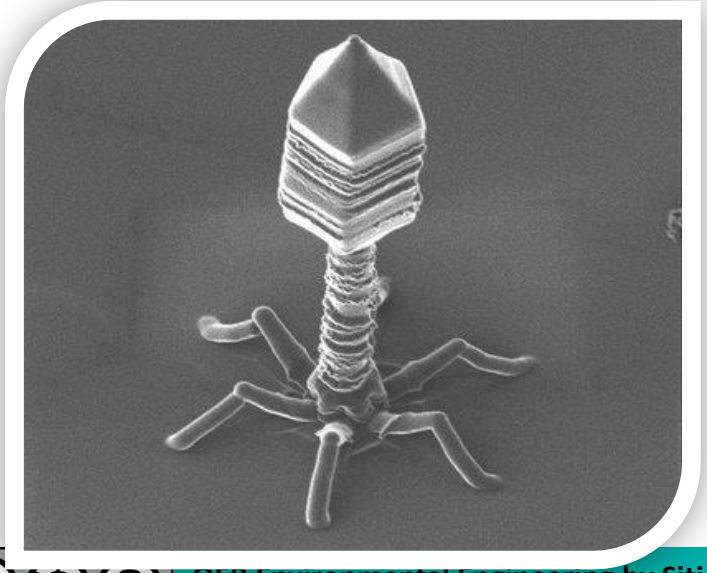


- Transmission occurs primarily by drinking water or eating food that has been contaminated.
- The severity of the diarrhea and vomiting can lead to rapid dehydration, and death in some cases.

Viruses

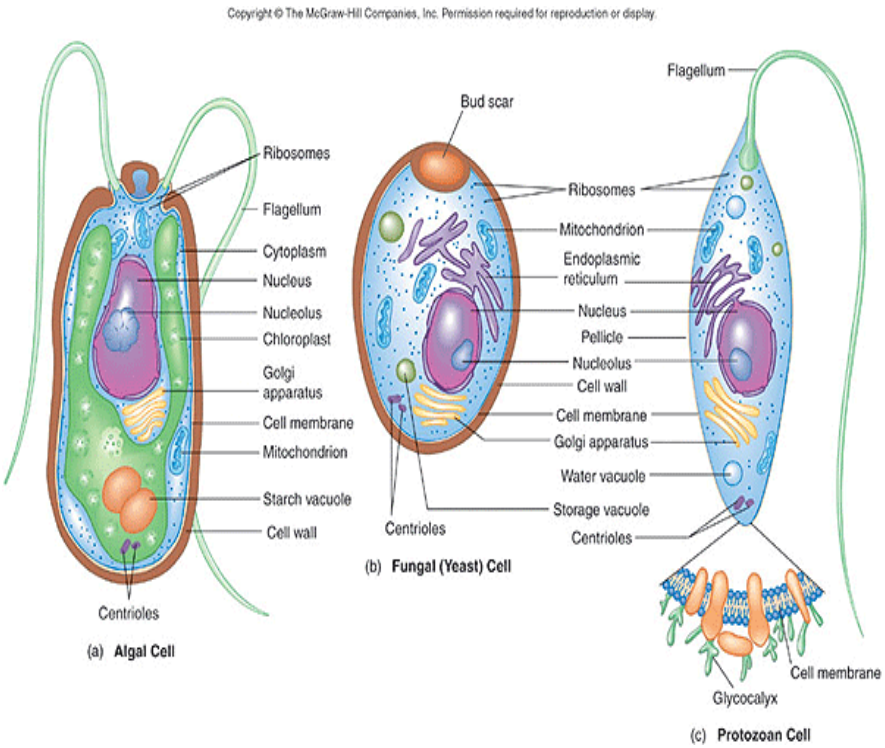
- the smallest biological structures
- Parasites - requires host to live
- Cause diseases – polio, hepatitis





Helminths

- also known as parasitic worms.
- Contamination may result from human, animals, and aquatic species.



Protozoa

- lowest form of animal life, unicellular organisms
- Highly adaptable in natural waters

Pathogen indicators

- Pathogen organisms
  - Live and breed in host and disseminated through feces
  - Small in quantity
  - Their presence is hard to detect

- Indicators organisms – their presence shows that pollution has occurred and suggests the TYPE and Level of pollution

- **Ideal indicator:**

i. Be applicable to all types of water

ii. Always be present when pathogen are present

iii. Always be absent when pathogen are absent

iv. Lend itself to routine quantitative testing procedures without interference from confusion of results

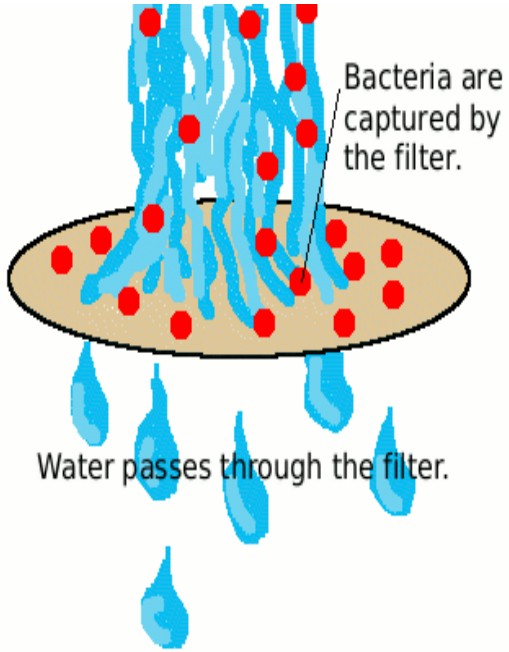
v. Safety for lab personnel

- Typical indicators used are **coliform groups.**
- Coliforms groups : Fecal coliforms (*E. Coli* – indicator for fecal pollution, easy to grow).
- Determination experimental methods : Membrane Filtration Method and Most Probable Number (MPN).

Parameter measure : Total Coliform (TC)

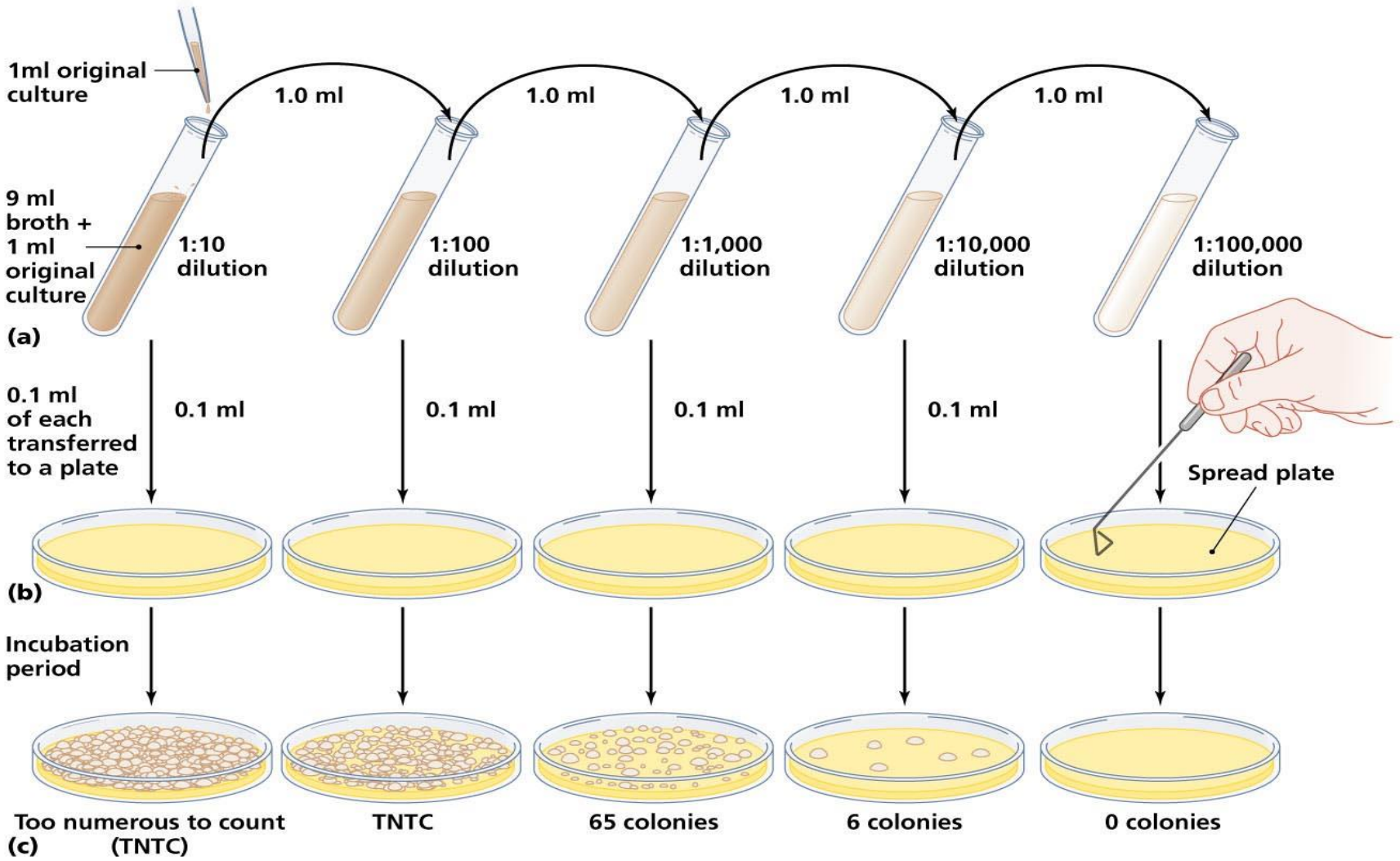
1. Using membrane filter technique (pore do not exceed 0.45µm)

- To determine the number of coliform organisms that are present in water.
- Advantage : faster than MPN procedure and gives a direct count of the number.
- Can be determine by passing a known volume of water sample through a membrane filter that has a very small pore size. The bacteria are retained on the filter then contacted with an agar that contains nutrients necessary for the growth of the bacteria. After incubation, the coliform colonies can be counted and the concentration in the original water sample determined.



2. Multiple-tube fermentation test

- Use lactose and other substances broth.
- 3 set of 5 test tubes, consider positive with air bubble.
- Incubate 24 ± 2 hours, 35 ± 0.5°C
- The dilution of the water sample is in sequence. 10 mL, 1 mL and 0.1 mL to use Most Probable number (MPN) index.



- Example of a result

10ml	+	+	+	+	–	4
1ml	+	+	–	–	+	3
0.1 ml	–	–	–	–	–	0

- If the dilution for the above results is 10mL, 1mL and 0.1mL, Index MPN gives the results as 27 MPN/100mL
- If the dilution is at 1mL, 0.1mL and 0.01mL, the result should be 270MPN/100mL
- Thomas formula is used if the number combination is not in the MPN index

$$\frac{MPN}{100mL} = \frac{no\ of\ positive\ tubes \times 100}{\sqrt{(total\ sample\ in\ mL\ in\ negative\ tubes) \times (total\ sample\ in\ mL\ for\ all\ tubes)}}$$

End of Chapter 2

Author Information

Credit to the author: Dr Norhanimah Hamidi