WASTEWATER – TYPES, CHARACTERISTICS & REGULATION

Definition of wastewater

Water that has been used, Can be polluted…etc

Types of wastewater

Domestic: wastewater by residential, shop houses, offices, schools etc. and normally generated from toilets, sinks and bathrooms.

Industrial: wastewater generated by industries. Quantity and quality depends on the type of industry

Storm water: rainwater, may contain pollutants

Why treat wastewater?

- Untreated wastewater harmful to health
- Breeding sites for insects, pests and micro organisms
- Can cause environmental pollution and affect ecosystem

Wastewater Characteristics

- ✓ Physical
- ✓ Chemical
- ✓ Biological

Physical Characteristics

1. Colour:

Depends mainly on the wastewater constituent

2. Odour:

Not significant if aerobic. Anaerobic wastewater release hydrogen sulphide (smells like rotten egg)

3. Temperature:

higher than water temperature due to the microbiological activities

4. Turbidity:

caused by the presence of solids mainly suspendedsolids (SS) from clay, sand, human waste and plant fibres

Chemical Characteristics

Organic compounds:

Definition

All organic compounds contain carbon in combination with one or more elements.

Properties of organic compounds

- **Usually combustible**
- **Have lower melting and boiling points**
- **Less soluble in water**
- **Have very high molecular weight**
- **Most organic compounds can serve as a source of food for micro-organisms**

Source(s):

Nature: fibres, vegetable oils, animal oils and fats, cellulose, starch, sugar.

Synthesis: a wide variety of compounds and materials prepared by manufacturing processes. E.g. DDT, polyvinyl chloride.

Fermentation: Alcohols, acetone, glycerol, antibiotics, acids.

Classification of organic matter (difference in degradability)

Biodegradable organics

Non-biodegradable organics

Biodegradable organics

Food for micro-organisms

Fast and easily oxidized by micro-organisms

e.g. starch, fat protein, alcohol, human and animal waste.

Non-biodegradable organics

Difficult and much more longer to biodegrade

Or toxic to micro-organisms

e.g. PVC, pesticide, industrial waste, cellulose, phenol, lignic acid.

Effect(s)

- Affects the dissolved oxygen content in the water
- Destroying aquatic life
- Damaging the ecosystem
- Some organics can cause cancer

Trihalomethane (THM-carcinogenic compound) are produced in water and wastewater treatment plants when natural organic compounds combine with chlorine added for disinfection purposes.

Normally, wastewater has high organic content. The organic content are measured by Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) and the value is about 100 to 400 mg/L.

What is Biochemical Oxygen Demand (BOD)?

Definition

- ✓ The quantity of oxygen utilised by a mixed population of micro-organisms to biologically degrade the organic matter in the wastewater.

BOD is the most important parameter in water pollution control

- ✓ It is used as a measure of organic pollution as a basis for estimating the oxygen needed for biological processes, and as an indicator of process performance.

$$\text{Organic matter} + O_2 \xrightarrow{\text{microorganism}} CO_2 + H_2O + \text{new cells}$$

BOD test
5-day at 20°C & 3-day at 30°C
Test method (BOD_5 @ 20°C)

- ✓ A water sample containing degradable organic matter is placed in a BOD bottle.
- ✓ If needed, add dilution water (known quantity). Dilution water is prepared by adding phosphate buffer (pH 7.2), magnesium sulphate, calcium chloride and ferric chloride into distilled water. Aerate the dilution water to saturate it with oxygen before use.
- ✓ Measure DO in the bottle after 15 minutes (DOi)
- ✓ Closed the bottle and placed it in incubator for 5 days, at temperature 20°C
- ✓ After 5 days, measure DO in the bottle (DOt).

BOD bottle

Calculation of BOD,

$$BOD_t = \frac{DO_i - DO_t}{P}$$

Where

BOD_t = biochemical oxygen demand, mg/L

DO_i = initial DO of the diluted wastewater sample about 15 min. after preparation, mg/L

DO_t = final DO of the diluted wastewater sample after incubation for five days, mg/L

P = dilution factor

<u>Why dilution is needed?</u>

For a valid BOD test, the final DO should not be less than 1 mg/L. BOD test is invalid if DO_t value near zero.

Dilution can decrease organic strength of the sample. By using dilution factor, the actual value can be obtained.

<u>Dilution of wastes:</u>

- **By direct pipetting into 300 mL BOD bottle**
- **The overall biological conversion proceeds sequentially, with oxidation of carbonaceous material as the first step (known as carbonaceous oxygen demand):**

BOD Analysis

In aerobic processes (O_2 is present), heterotrophic bacteria oxidise about 1/3 of the colloidal and dissolved organic matter to stable end products (CO_2 + H_2O) and convert the remaining 2/3 into new microbial cells that can be removed from the wastewater by settling.

$$\text{Organic matter} + O_2 \longrightarrow CO_2 + H_2O + \text{new cells}$$

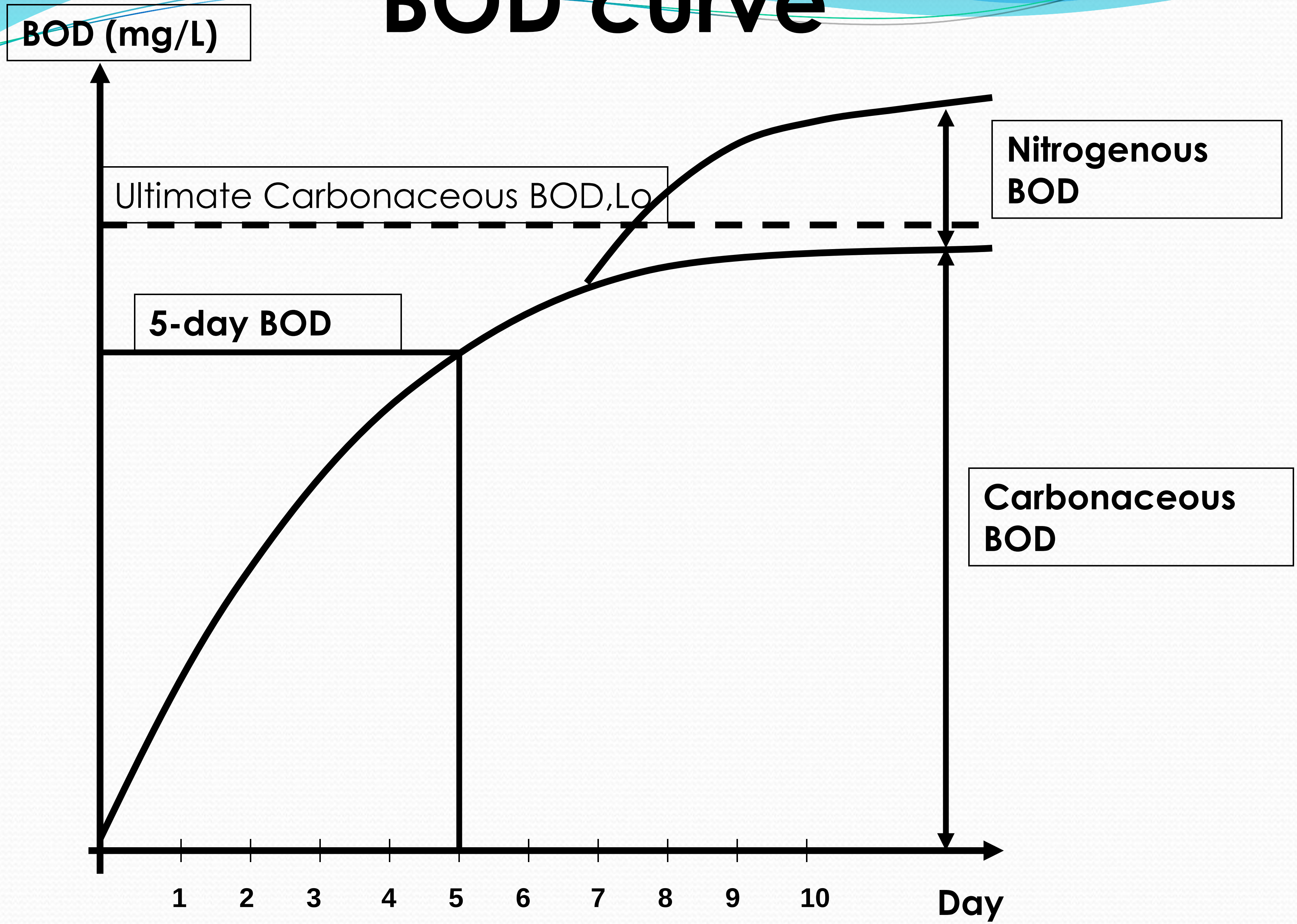
Under continuing aerobic conditions, autotrophic bacteria then convert the nitrogen in organic compounds to nitrates (known as nitrification oxygen demand)

$$\text{Organic-Nitrogen} \longrightarrow \text{Ammonia-Nitrogen (decomposition)}$$

and

$$NH_3 - N + O_2 \longrightarrow \text{Nitrate-Nitrogen (nitrification)}$$

BOD curve


BOD (mg/L)
Ultimate Carbonaceous BOD,Lo
Nitrogenous BOD
5-day BOD
Carbonaceous BOD
1
2
3
4
5
6
7
8
9
10
Day

The ultimate BOD (Lo) is defined as the maximum BOD exerted by the waste.

The carbonaceous oxygen demand curve can be expressed mathematically as

$$BOD_t = Lo\,(1-10^{-Kt})$$

Where

BOD_t = biochemical oxygen demand at time t, mg/L

Lo = ultimate BOD, mg/L

t = time, days

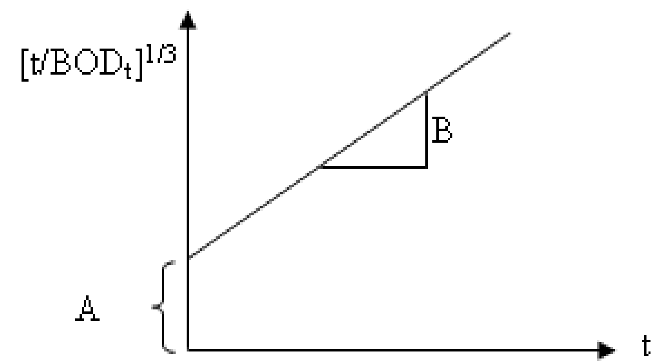
K = reaction rate constant, day^{-1}

Determination of BOD K-Rate

Time (day)	BOD_t (mg/L)	$[time/BOD_t]^{1/3}$
1	X	$[1/X]^{1/3}$
2	Y	$[2/Y]^{1/3}$
3	Z	$[3/Z]^{1/3}$

From the experiment results of BOD for various values of t, calculate $[time/BOD_t]^{1/3}$ for each day.

- ✓ Plot $[t/ BOD_t]^{1/3}$ versus t
- ✓ Determine the intercept (A) and slope (B) from the plot.
- ✓ Calculate K = 2.61 (B/A)



BOD rate constant, per day

- **K (base 10)**

$$L_o = \frac{BOD_t}{1-10^{-Kt}}$$

- **k (base e)**

$$L_o = \frac{BOD_t}{1-e^{-kt}}$$

- K = k/2.3

Effects of Temperature on Reaction Rates and Ultimate BOD

<u>Reaction Rate Constant, K</u>

- most biological processes speed up as the temperature increases and slow down as the temperature drops. The rate of utilization is affected by temperature

The relationship for the change in the reaction rate constant (K) with temperature is expressed as

$$K_T = K_{20} \times \Theta^{(T-20)}$$

Where

K_T = reaction rate constant at temperature T, per day

K_{20} = reaction rate constant at 20°C, per day

Θ = temperature coefficient = 1.047

T = temperature of biological reaction, °C

Ultimate BOD (Lo)

$$ {}_{T}L_o = {}_{20}L_o[1 + 0.02(T - 20)] $$

where

$_{T}Lo$ = ultimate BOD at temperature T, mg/L

$_{20}Lo$ = ultimate BOD at 20°C, mg/L

Example:

A BOD test was conducted on a domestic wastewater at 30°C. The wastewater portion added to a BOD bottle was 20 mL and the dissolved oxygen values listed below were measured.

Time(days)	DO (mg/L)
0	7.4
1	5.5
2	4.5
3	3.7
4	2.5
5	2.1

- Calculate values of BOD_3
- Determine the BOD rate constant, K_{30}
- Calculate values of BOD_5 at 20°C

What is Chemical Oxygen Demand (COD)?

Definition

- The quantity of oxygen needed to chemically oxidize the organic compound in sample, converted to carbon dioxide and water.
- Commonly used to define the strength of industrial wastewaters

Test Procedure

- Add measured quantities of potassium dichromate, sulphuric acid reagent containing silver sulphate, and a measured volume of sample into a flask.
- The mixture is refluxed (vaporized and condensed) for two hours. The oxidation of organic matter converts.

$$\text{Organic matter} + Cr_2O_7^{2-} + H^+ \longrightarrow CO_2 + H_2O + 2Cr_3+$$

The mixture is titrated with ferrous ammonium sulphate (FAS) to measure the excess dichromate remaining in sample.

A blank sample of distilled water is carried through the same COD testing procedure as the wastewater sample.

COD is calculated from the following equation:

$$COD = \frac{8000(a-b)}{\forall} \times$$ **Normality of $Fe(NH_4)_2(SO_4)_2$**

Where:

COD = chemical oxygen demand, mg/L

a = amount of ferrous ammonium sulphate titrant added to blank, mL

b = amount of titrant added to sample, mL

$\forall$ = volume of sample, mL

8000 = multiplier to express COD in mg/L of oxygen

Example:

The results of a COD test for raw wastewater (50 mL used) are given. Volumes of FAS used for blank and the sample are 24.53 mL and 12.88 mL, respectively. The normality of FAS is 0.242. Calculate the COD concentration for the sample.

B. Inorganic compounds:

Definition

When placed in water, inorganic compounds dissociate into electrically charged atoms referred to as ions.

All atoms linked in ionic bond.

Source(s):

- May cover heavy metals, nutrients (nitrogen and phosphorus), alkalinity, chlorides, sulphur, and other inorganic pollutants.

Effect(s):

i. Diseases

- NO_2^- → "blue baby syndrome"

ii. Aesthetic

- Si^{+4} → turbidity

iii. Disturb human activity such as the formation of scale in boiler system and excessive usage of soap

- Ca^{+2}, Mg^{+2} → hardness

3. Biological Characteristics

The principal groups of microorganisms found in wastewater are bacteria, fungi, protozoa, microscopic plants and animals, and viruses. Most microorganisms (bacteria, protozoa) are responsible and are beneficial for biological treatment processes of wastewater.

- Pathogenic organisms are usually excreted by humans from the gastrointestinal tract and discharge to wastewater. Water-borne disease include cholera, typhoid, paratyphoid fever, and diarrhea. The number of pathogenic organisms in wasteaters is generally low in density and they are difficult to isolate and identify.

- Therefore, indicator bacteria such as total coliform (TC) and fecal coliform (FC) are used as indicator organisms.

6.6 Wastewater Quality Standards

- **Regulations in Environmental Quality (Wastewater and Industrial Effluent), 1978:**
- **Sets standards for wastewater discharged from wastewater treatment plant and industrial effluent**
- **Standard A and Standard B**

THIRD SCHEDULE

ENVIRONMENTAL QUALITY ACT 1974

ENVIRONMENTAL QUALITY (SEWAGE AND INDUSTRIAL EFFLUENTS) REGULATIONS 1978

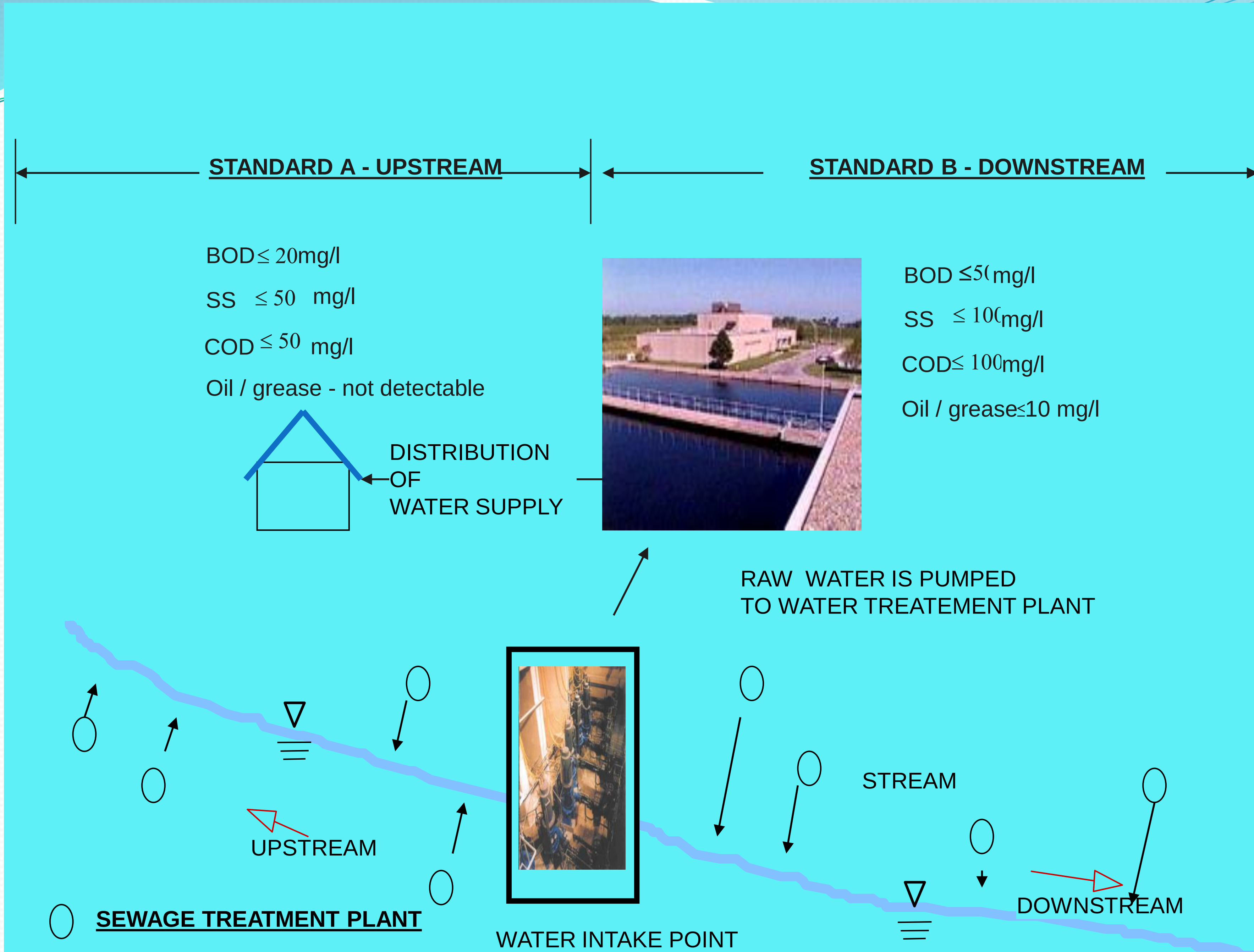
[Regulation 8 (1), 8 (2), 8 (3)]

PARAMETER LIMITS OF EFFLUENT OF STANDARDS A AND B

Parameter		*Unit*	*Standard*	
			A	*B*
(1)		*(2)*	*(3)*	*(4)*
(i)	Temperature	C	40	40
(ii)	pH Value	—	6.0-9.0	5.5-9.0
(iii)	BOD_5 at 20°C	mg/l	20	50
(iv)	COD	mg/l	50	100
(v)	Suspended Solids	mg/l	50	100
(vi)	Mercury	mg/l	0.005	0.05
(vii)	Cadmium	mg/l	0.01	0.02
(viii)	Chromium, Hexavalent	mg/l	0.05	0.05
(ix)	Arsenic	mg/l	0.05	0.10
(x)	Cyanide	mg/l	0.05	0.10
(xi)	Lead	mg/l	0.10	0.5
(xii)	Chromium, Trivalent	mg/l	0.20	1.0
(xiii)	Copper	mg/l	0.20	1.0

STANDARD-A APPLIES

The catchment areas referred to in this regulation shall be the areas upstream of surface or above sub-surface water supply intakes, for the purpose of Human Consumption Including drinking.



STANDARD A - UPSTREAM
STANDARD B - DOWNSTREAM
BOD≤ 20mg/l
SS ≤ 50 mg/l
COD ≤ 50 mg/l
Oil / grease - not detectable
BOD ≤5(mg/l
SS ≤ 10(mg/l
COD≤ 100mg/l
Oil / grease≤10 mg/l
DISTRIBUTION
OF
WATER SUPPLY
RAW WATER IS PUMPED
TO WATER TREATEMENT PLANT
STREAM
UPSTREAM
DOWNSTREAM
SEWAGE TREATMENT PLANT
WATER INTAKE POINT