Wastewater Characteristics

Types of Wastewater

Domestic

Industrial

Domestic

Residential, shop houses, offices, schools etc.

Toilets, sinks and bathrooms

Industrial

Manufacturing processes

Domestic Wastewater

Characteristics

Physical

Chemical

Biological

Physical Characteristics

Colour

Depends mainly on the wastewater constituent

Odour

Not significant if aerobic

Anaerobic releases hydrogen sulphide (rotten egg)

Temperature

High due to the microbial activities

Solids

Suspended Solids (SS) + Dissolved Solids (DS) = Total Solids (TS)

Solids

Suspended Solids (SS) + Dissolved Solids (DS) = Total Solids (TS)

Clay, sand, human waste, plant fibres

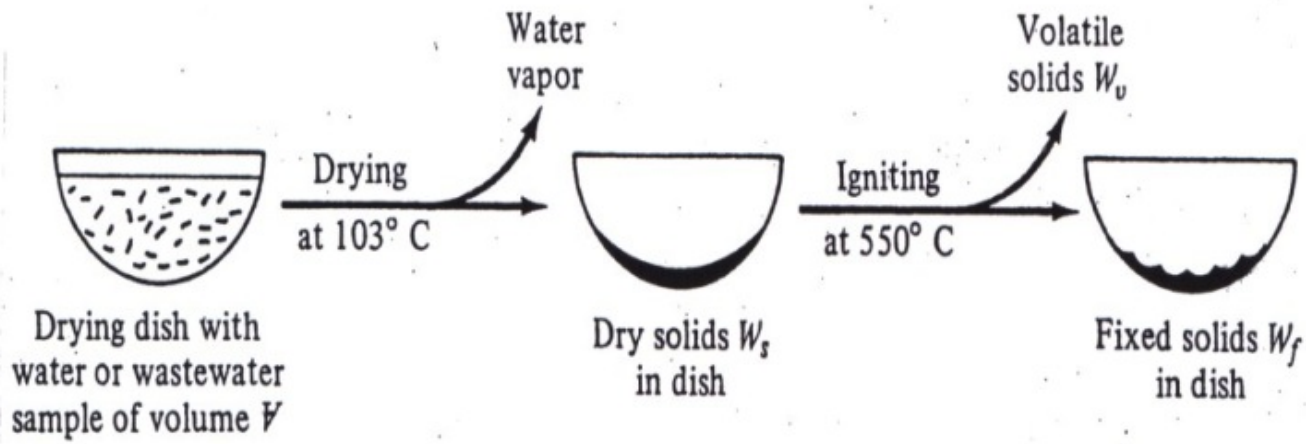
Measurement of Total Solids

Dish

Oven

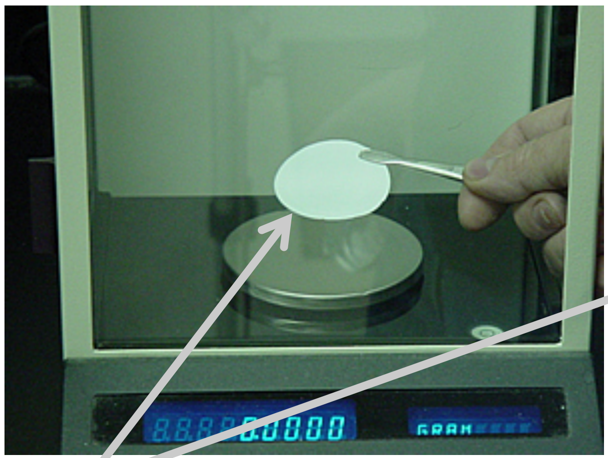
Balance

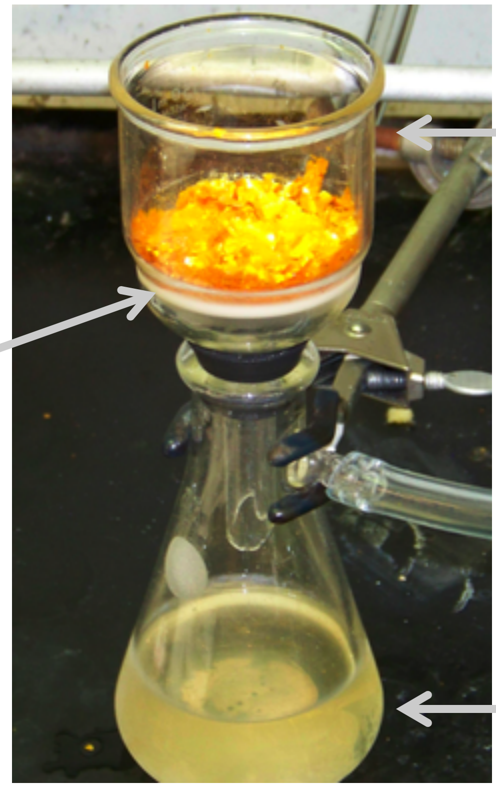
Measurement of Total Solids



$$\text{Total solids} = \frac{W_s}{V} \qquad \text{Total volatile solids} = \frac{W_s - W_f}{V} = \frac{W_v}{V}$$

Measurement of Suspended Solids

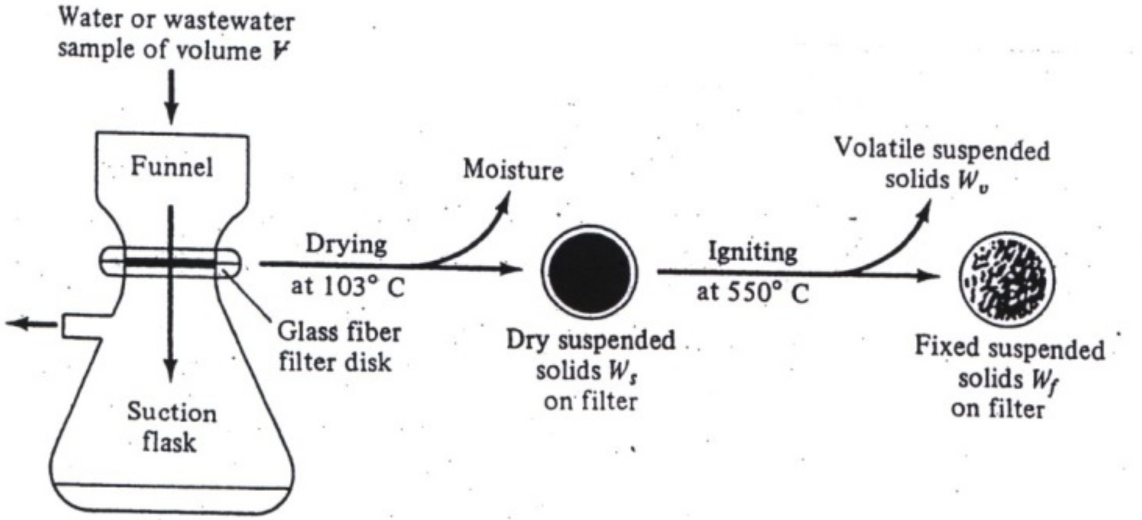




Funnel

Flask

Filter paper

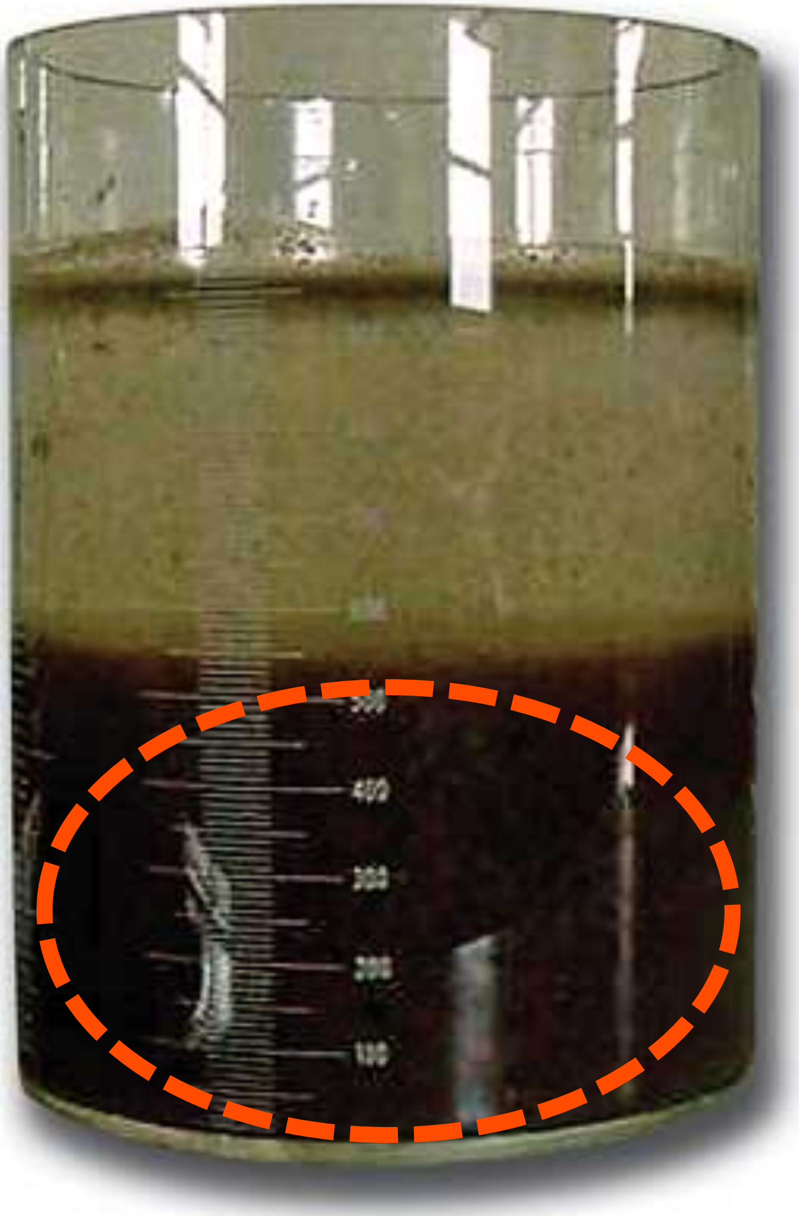


$$\text{Suspended solids} = \frac{W_s}{\forall} \qquad \text{Volatile suspended solids} = \frac{W_s - W_f}{\forall} = \frac{W_v}{\forall}$$

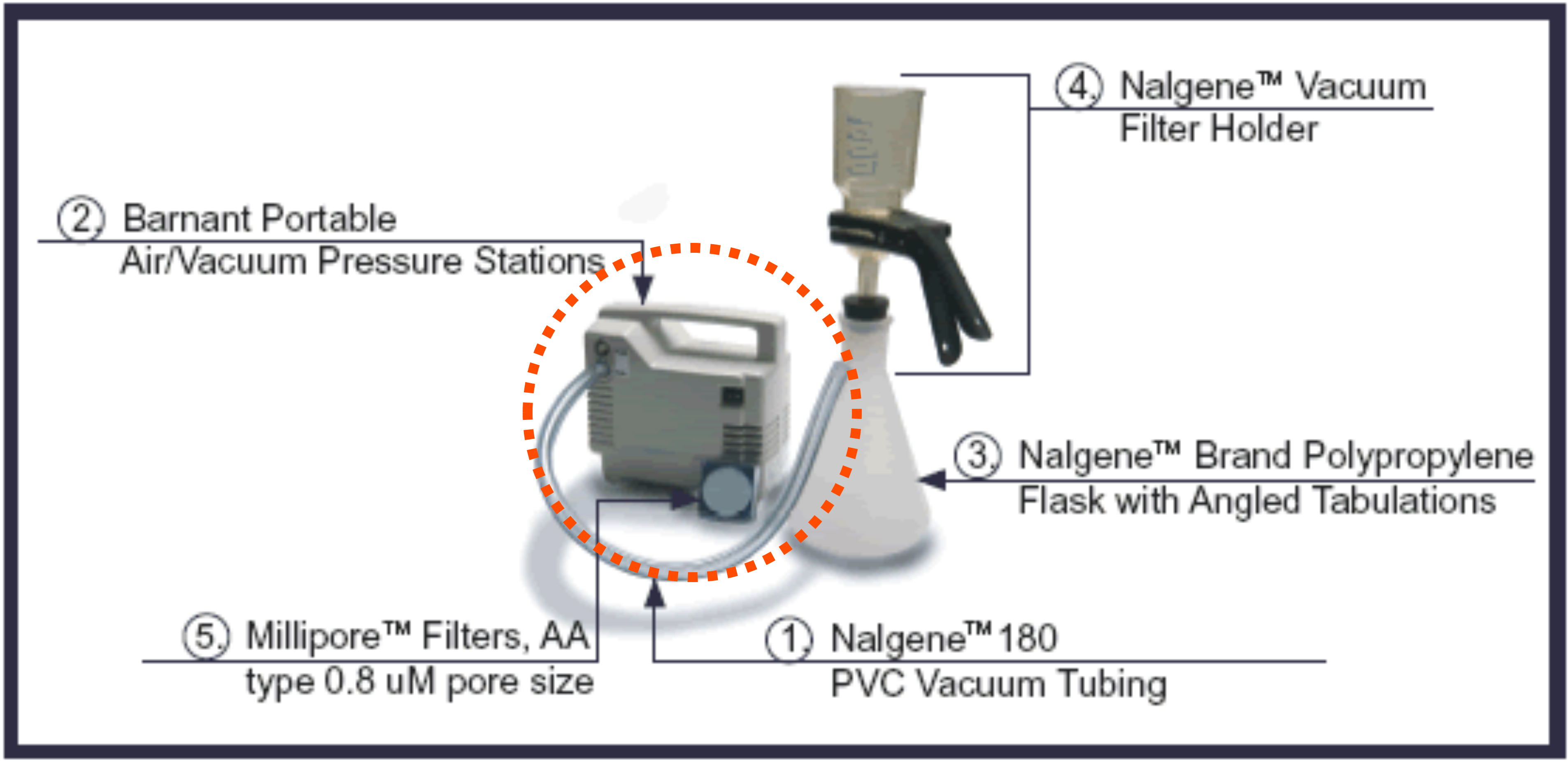
Total Solids (TS) =
Total Dissolved Solids (TDS) +
Total Suspended Solids (TSS)

Total Solids (TS) =
Total Fixed Solids (TFS) +
Total Volatile Solids (TVS)

Total Suspended Solids (TSS) = Fixed Suspended Solids (FSS) + Volatile Suspended Solids (VSS)



- Highly concentrated!



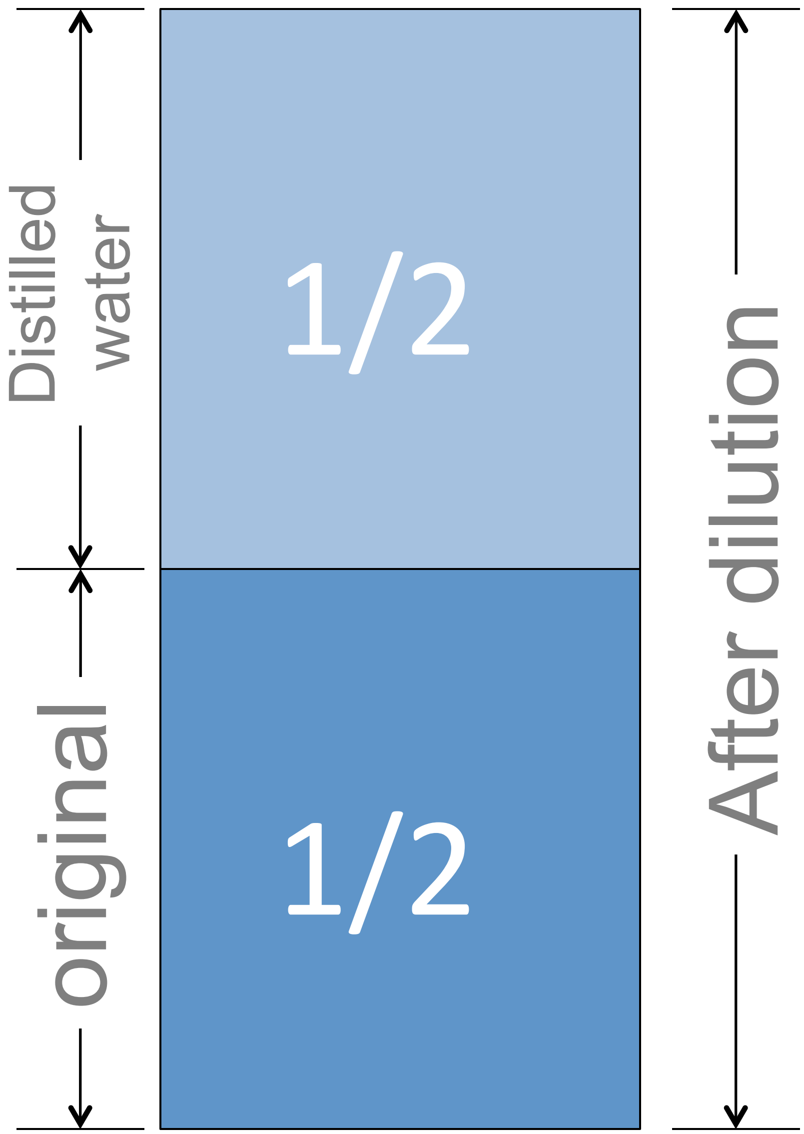
(4) Nalgene™ Vacuum Filter Holder
(2) Barnant Portable Air/Vacuum Pressure Stations
(3) Nalgene™ Brand Polypropylene Flask with Angled Tabulations
(5) Millipore™ Filters, AA type 0.8 uM pore size
(1) Nalgene™ 180 PVC Vacuum Tubing

Dilution

Sample concentration too high

Above measuring limit of equipment

Use distilled water as dilution solution

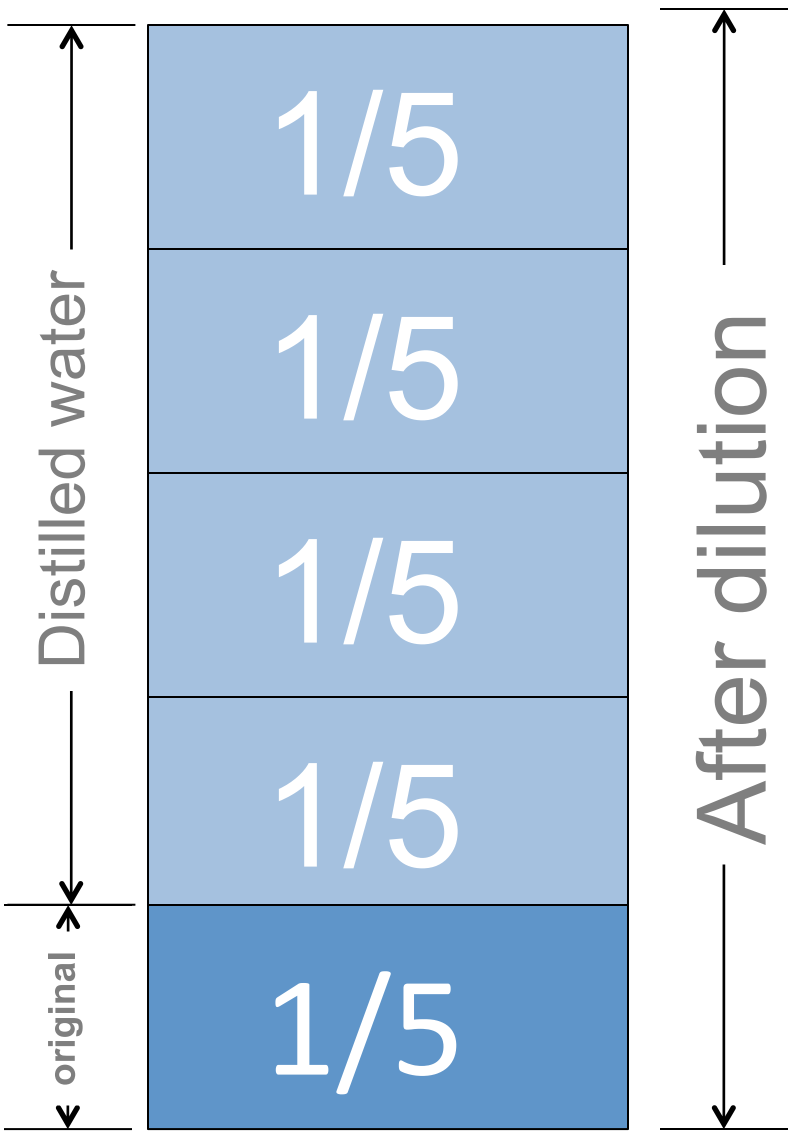


Dilution factor (DF)

½ = 0.5

or

50%



Dilution factor (DF)

1/5 = 0.2

or

20%

$$\mathrm{DF} = \frac{\textit{actual}\ \text{vol. sample}}{\textit{actual}\ \text{vol. sample} + \text{vol. dilution water}}$$

$$\textbf{Actual conc.} = \frac{\textbf{measured concentration}}{\textbf{dilution factor}}$$

Based on dissolved oxygen requirements, which type give more energy to the bacteria and which type give the least?

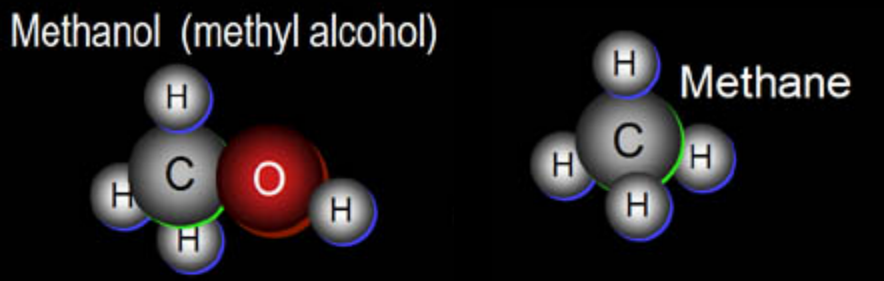
Based on energy and carbon source requirements, how to you categorize algae?

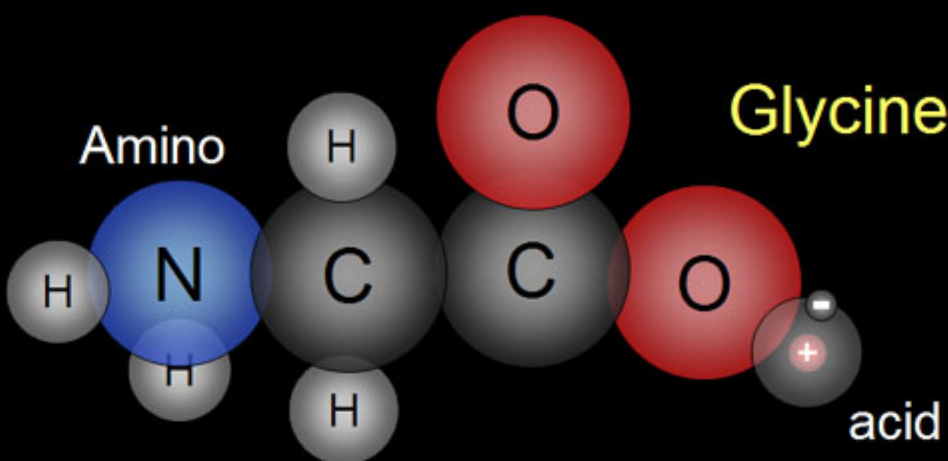
Chemical Characteristics

Organic compounds

Inorganic compounds

Organic Compounds





Contain carbon (C) in combination with one or more elements

Properties

Usually combustible

Have lower melting and boiling points

Less soluble in water

High molecular weight

Most serve as source of food for microorganisms

Sources

Natural

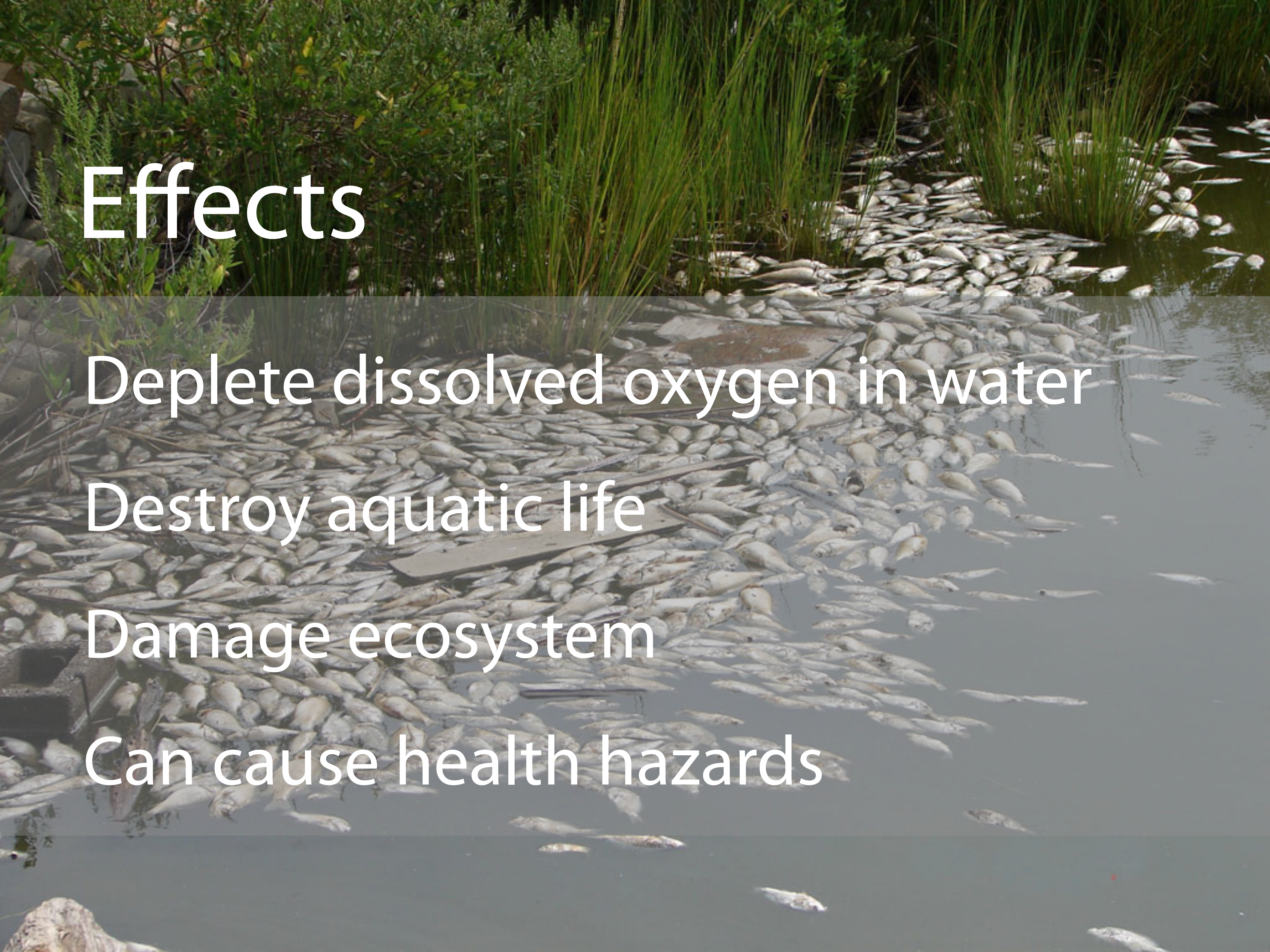
Synthetic

Natural


Sugar
Starch
Cellulose
Glycogen
Mazola
Sweet-Unsalted Premium
Mazola
Rich in CORN OIL
Margarine
100% PURE
Mazola
CORN OIL
32 FL.OZ. (1 QT) .946 L
Mazola
Margarine

Synthetic


PRO Star
SYNTHETIC BLEND
4 STROKE
OUTBOARD OIL
25w40
DANGER:
1 U.S. Gallon/3.79 Liters


Effects
Deplete dissolved oxygen in water
Destroy aquatic life
Damage ecosystem
Can cause health hazards

Classification

① Biodegradable organics

② Non-biodegradable organics

Biodegradable

Easily degraded by micro-organisms

Food for micro-organisms

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

Non-biodegradable

Difficult to biodegrade

Longer time to biodegrade

Toxic to micro-organisms

e.g. plastic, PVC, pesticide, cellulose, some industrial wastewater

Measurements of Organics

Biological oxygen demand (BOD)

Biochemical oxygen demand (BOD)

Chemical oxygen demand (COD)

Domestic wastewater

BOD: 100 to 400 mg/L

COD ≅ 2 to 3 of BOD value

Biochemical Oxygen Demand (BOD)

Definition

Quantity of oxygen utilised by micro-organisms to biologically degrade the organic matter in the water under aerobic condition

$$Organics \xrightarrow[]{O_2 \downarrow \text{ microorganisms}} CO_2 + H_2O + \text{new cells}$$

Important parameters in water pollution control

Estimate oxygen needed for biological processes

Main Apparatus

DO meter

BOD bottle (300 mL)

Procedures – BOD_5 at 20°C

1. Place water sample in BOD bottle
2. 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.

3. Measure DO in the bottle after 15 minutes (DO_i)
4. Close the bottle and place in incubator for 5 days, at 20°C
5. After 5 days, measure DO in the bottle (DO_t)

Calculation

$$BOD_t = (DO_i - DO_t) / DF$$

BOD_t	=	Biochemical Oxygen Demand, mg/L
DO_i	=	initial DO of the sample about 15 min. after preparation, mg/L
DO_t	=	final DO of the sample after incubation for t days, mg/L
DF	=	dilution factor
	=	sample volume / (sample volume + volume of dilution water)

Why Dilution in BOD Test

BOD test is invalid if DO_t value near zero

Final DO $\geq$ 1 mg/L

BOD Dilution Factor

Volume of sample (mL)	Range of BOD value (mg/L)	Volume of sample (mL)	Range of BOD value (mg/L)
0.02	30,000-105,000	5.00	120-420
0.05	12,000-42,000	10.00	60-210
0.10	6,000-21,000	20.00	30-105
0.20	3,000-10,500	50.00	12-42
0.50	1,200-4,200	100.00	6-21
1.00	600-2,100	300.00	0-7
2.00	300-1,050		

What happen in BOD bottle?

BOD Bottle = Biological Reactor

Biological Process

1/3

organic matter

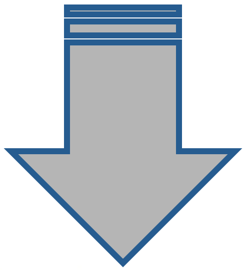
↓

$CO_2 + H_2O$

Biological Process

2/3

organic matter



new cells

O_2

↓

microorganisms

Organic matter → $CO_2 + H_2O +$ new cells

Heterotrophic bacteria

"Carbonaceous Oxygen Demand"

O_2

↓

microorganisms

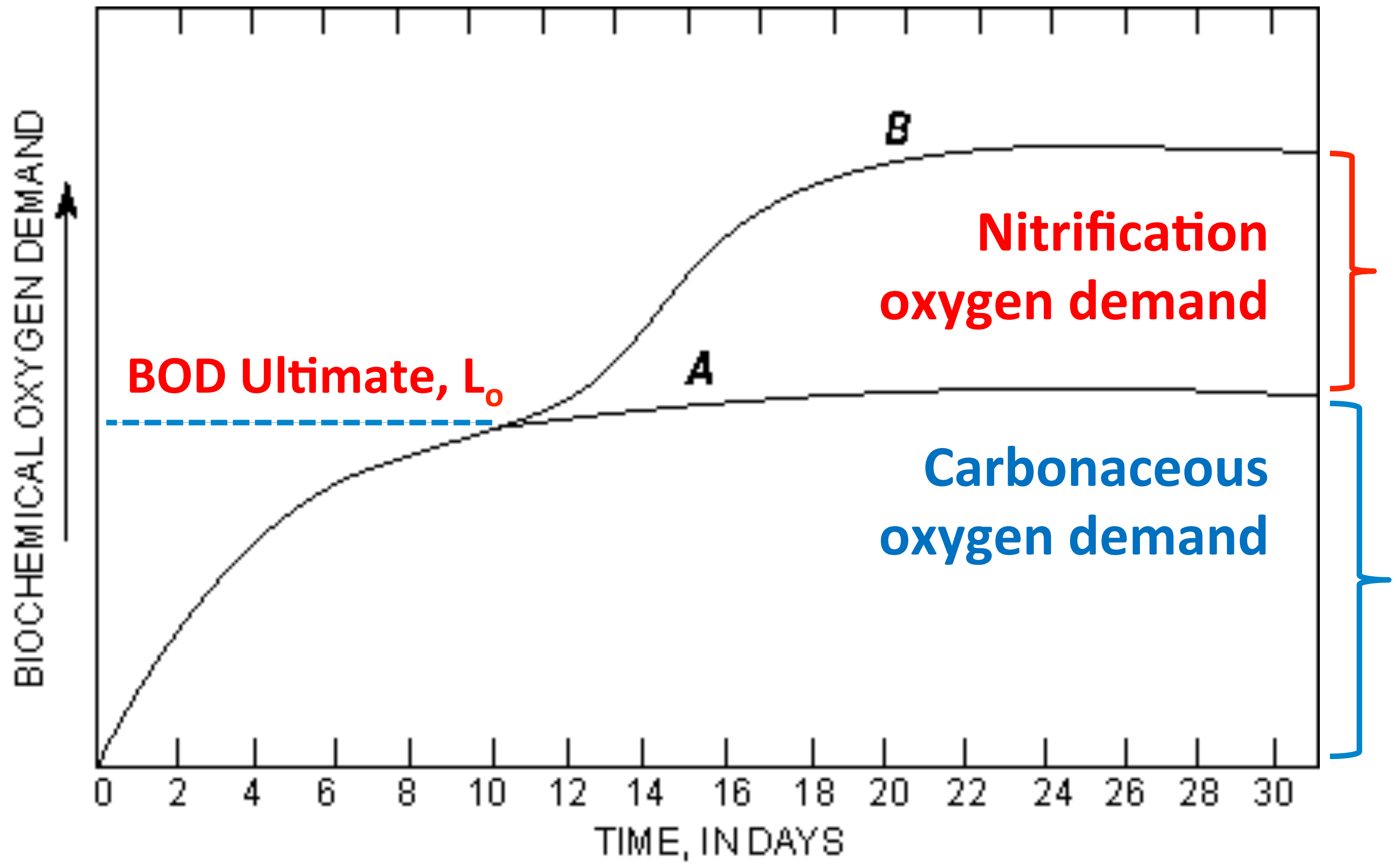
$NH_3 - N \rightarrow$ Nitrate-N

(nitrification)

Autotrophic bacteria

"Nitrification Oxygen Demand"

BOD Curve


BIOCHEMICAL OXYGEN DEMAND
B
A
Nitrification
oxygen demand
BOD Ultimate, L_o
Carbonaceous
oxygen demand
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
TIME, IN DAYS

The ultimate BOD (L_o):

Maximum BOD exerted by the waste

The carbonaceous oxygen demand curve can be expressed mathematically as

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

$$BOD_t = L_o\,(1 - e^{-kt})$$

where

BOD_t	=	BOD at time t, mg/L
L_o	=	ultimate BOD, mg/L
t	=	time, days
K, k	=	reaction rate constant, day^{-1}

BOD Reaction Rate Constant, K

Speed of the reaction

Biodegradability of the compound

Simple compounds (eg. sugars and starches) easily degraded by microorganisms

- High K value

More complex (eg. phenols and cellulose) difficult to degrade

- Low K values

Water Type, K per day (base 10)

Tap water, 0.04

Surface water, 0.04 – 0.1

Raw sewage, 0.15 – 0.30

Well-treated sewage, 0.05 – 0.10

Determination of BOD Rate Constant, K

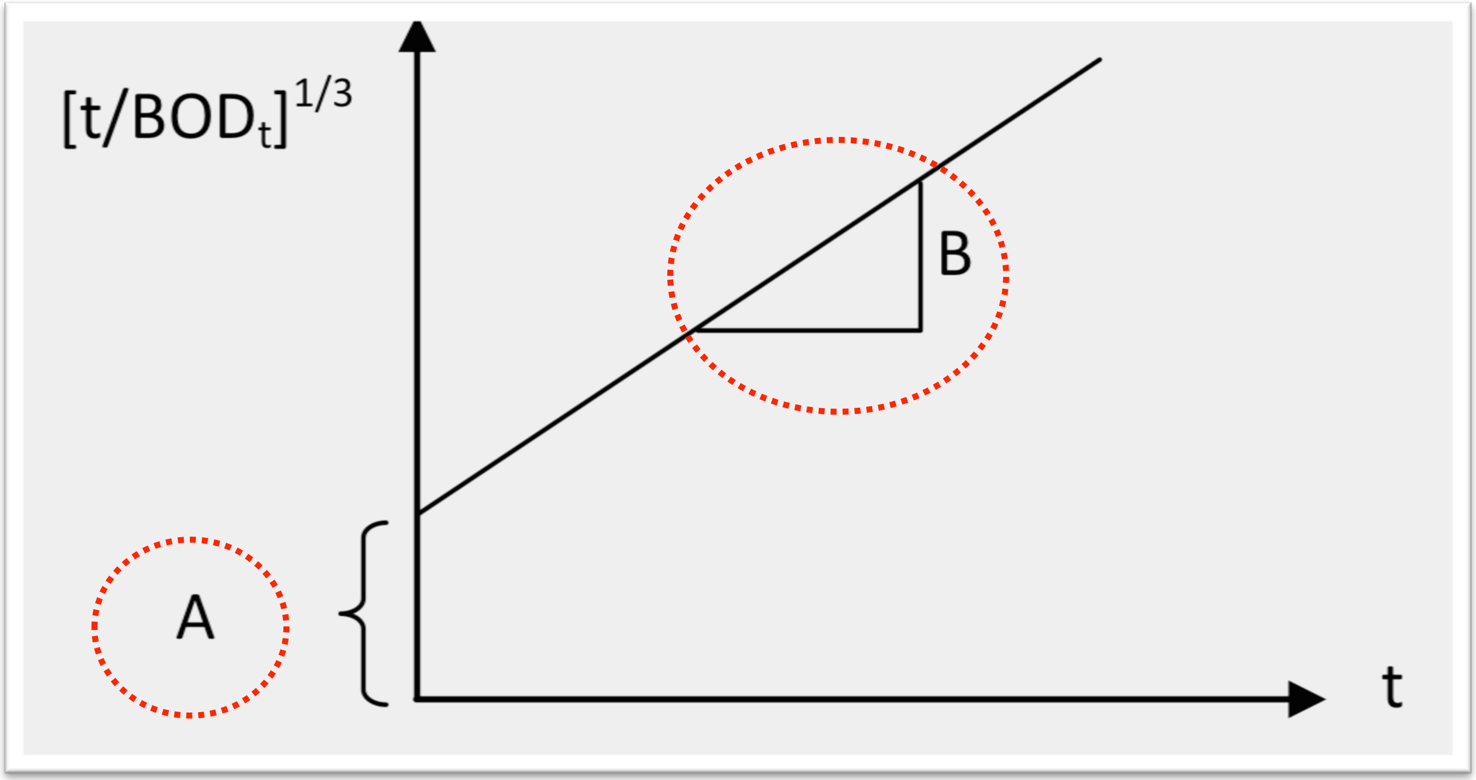
1. Conduct a series of BOD test

t (day)	BOD_t (mg/L)
1	W
2	X
3	Y
4	Z

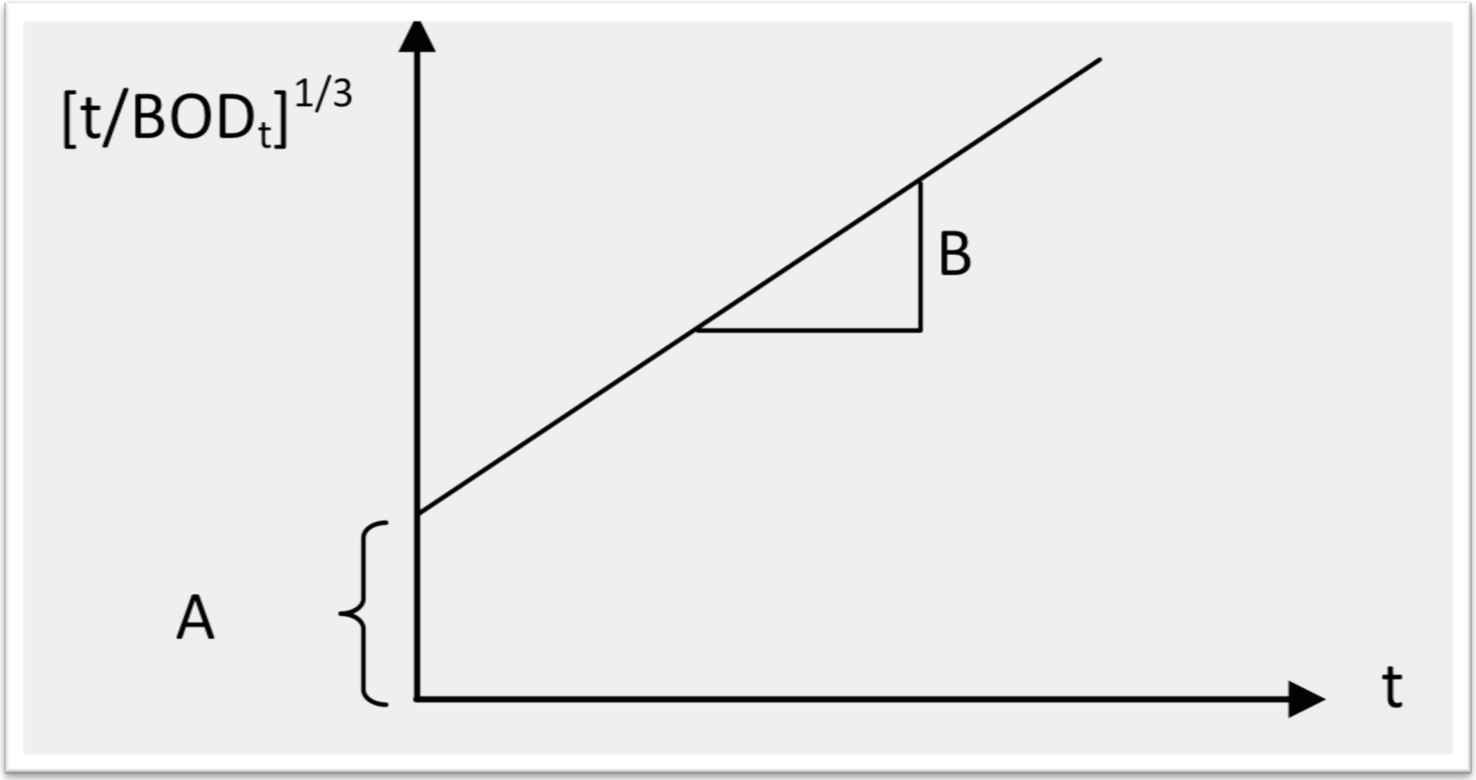
2. From the experiment results of BOD for various values of t, calculate $[time/BOD_t]^{1/3}$ for each day

t (day)	BOD_t (mg/L)	$[time/BOD_t]^{1/3}$
1	W	$[1/W]^{1/3}$
2	X	$[2/X]^{1/3}$
3	Y	$[3/Y]^{1/3}$
4	Z	$[4/Z]^{1/3}$

3. Plot $[t/ BOD_t]^{1/3}$ versus t



4. Determine the intercept (A) and slope (B) from the plot.



$$K = 2.61\ (B/A)$$

K (base 10)

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

k (base e)

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

$K = k/2.3$

Effect of Temperature (T)

Increases as the T increases

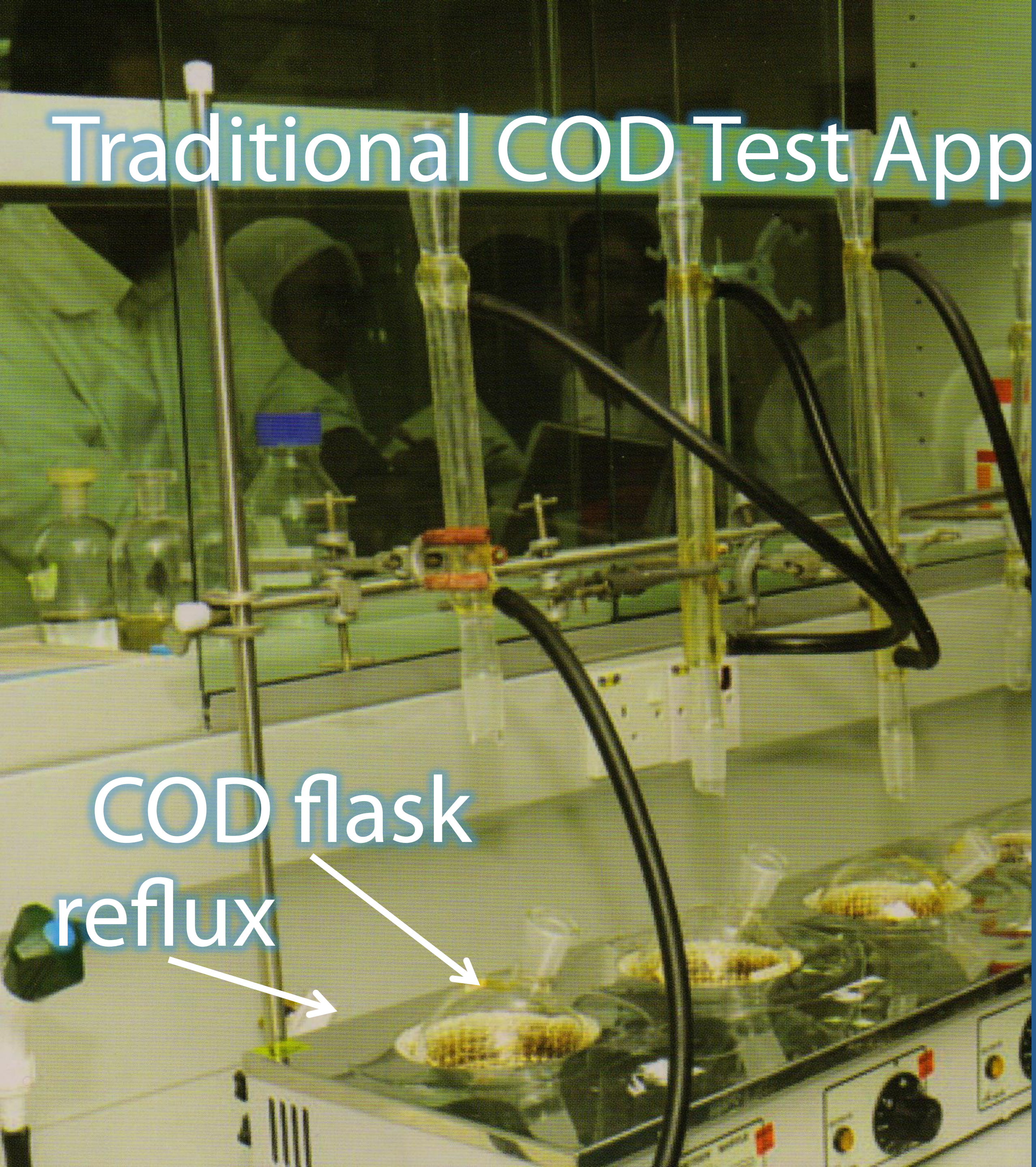
$$K_T = K_{20} \times 1.047^{(T-20)}$$

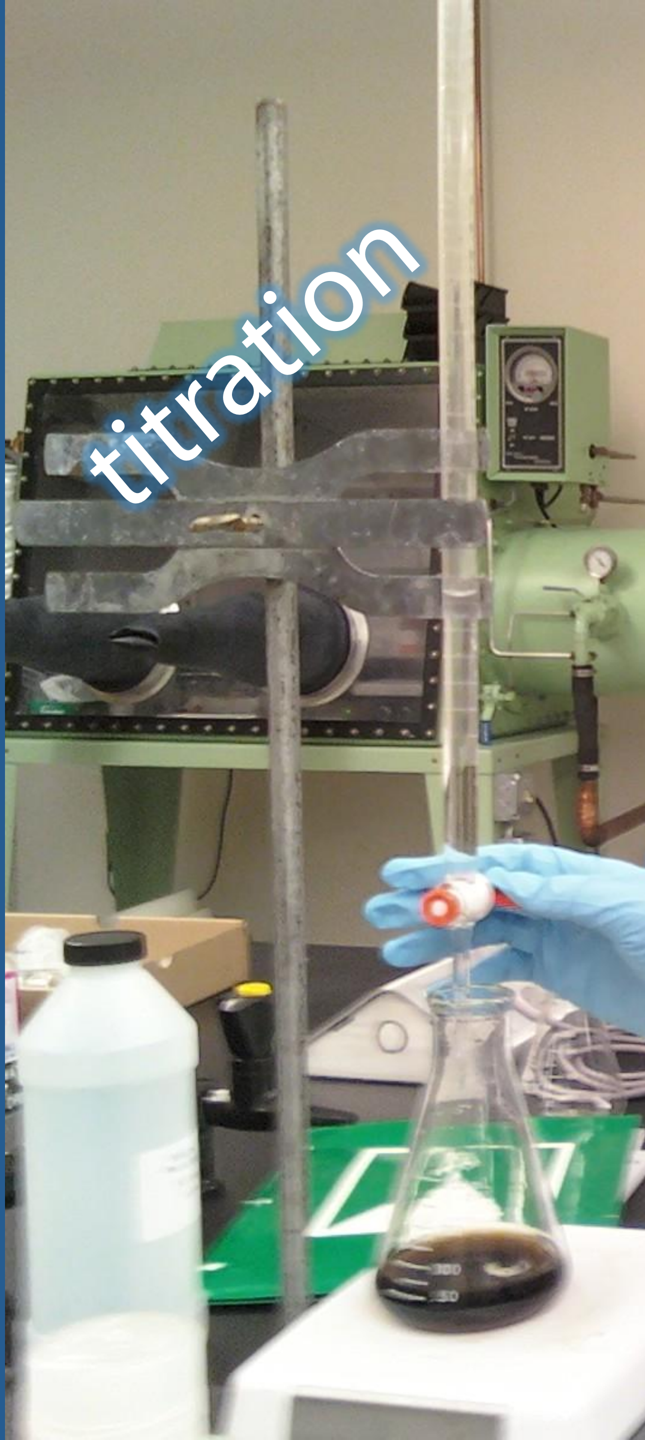
Chemical Oxygen Demand (COD)

The quantity of equivalent oxygen needed to chemically oxidize the organic compound in sample, converted to carbon dioxide and water

BOD: The quantity of oxygen utilised by a mixed population of micro-organisms to biologically degrade the organic matter in the wastewater under aerobic condition

- COD: The quantity of equivalent oxygen needed to chemically oxidize the organic compound in sample, converted to carbon dioxide and water


Traditional COD Test App
COD flask
reflux


titration

Test Procedures

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

$$\text{Organic matter} + Cr_2O_7^{2-} + H^+ \rightarrow CO_2 + H_2O + 2Cr^{3+}$$

3. The mixture is titrated with ferrous ammonium sulphate (FAS) to measure the excess dichromate remaining in sample.
4. A blank sample of distilled water is carried through the same COD testing procedure as the wastewater sample.

COD calculation

$$COD = \frac{8000(a-b)}{V} \times \text{Normality of FAS}$$

where:

COD = chemical oxygen demand, mg/L

a = amount of FAS added to blank, mL

b = amount of FAS added to sample, mL

V = volume of sample, mL

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

HACH Apparatus

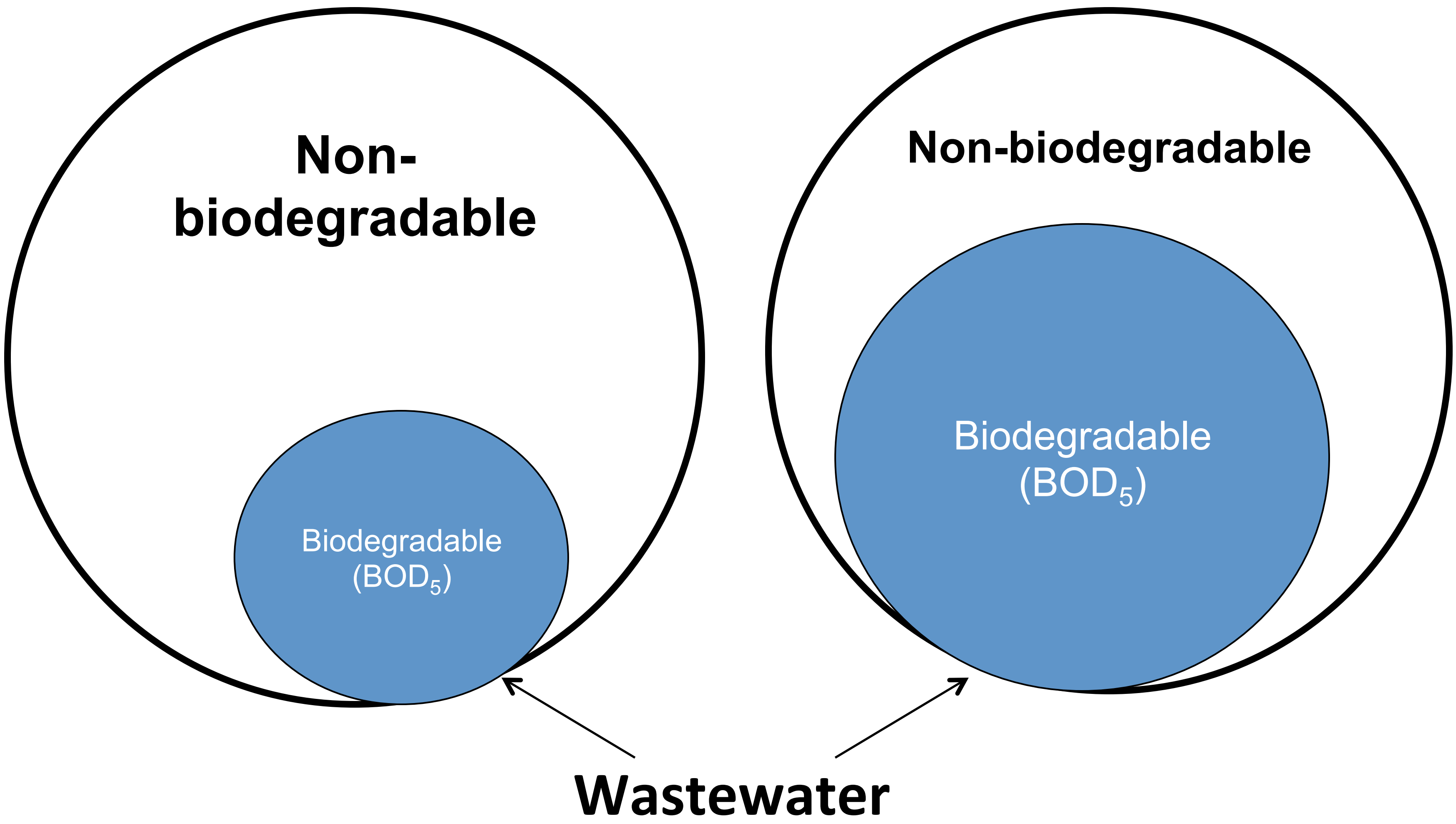
Solution of sample + dichromate

HACH Reflux

HACH Spectrophotometer

BOD: The quantity of oxygen utilised by a mixed population of micro-organisms to biologically degrade the organic matter in the wastewater under aerobic condition

COD: The quantity of equivalent oxygen needed to chemically oxidize the organic compound in sample, converted to carbon dioxide and water

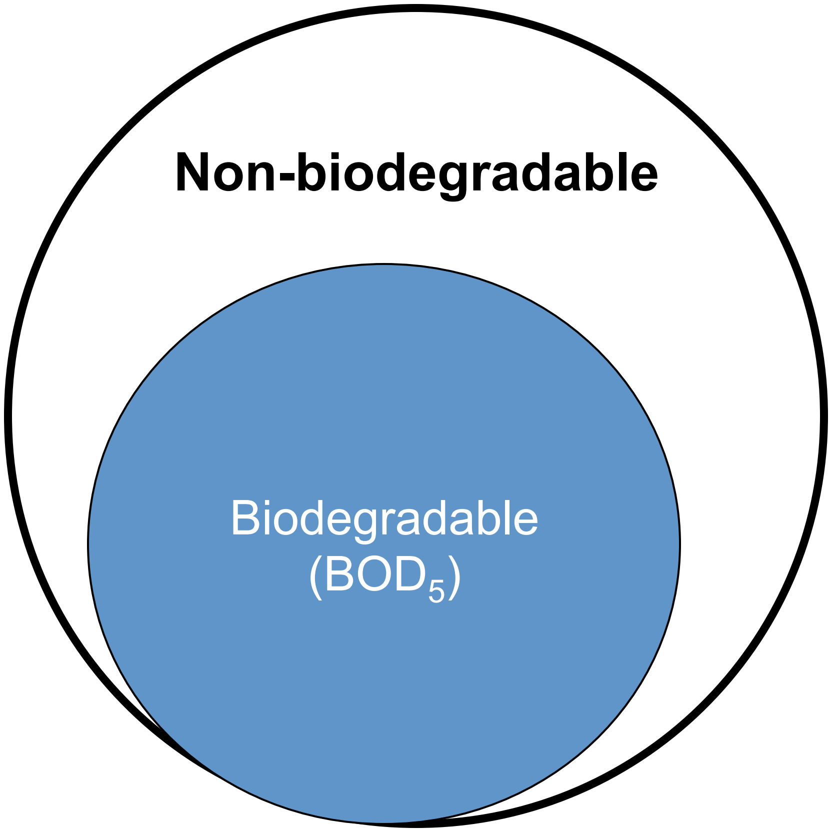

Non-biodegradable
Biodegradable (BOD5)
Non-biodegradable
Biodegradable (BOD5)
Wastewater

BOD:

Biodegradable

COD:

Biodegradable +
Non-biodegradable



Relation between COD and BOD

COD > BOD

$COD/BOD_5 \approx 2$ to 3,
biodegradable organic

$COD >> BOD_5$,
non-biodegradable organic

Inorganic Compounds

Dissociate in water into electrically charged atoms (ions)

$$NaCl \rightarrow Na^{+} + Cl^{-}$$

$$NH_3 + H_2O \rightarrow NH_4^{+} + HO^{-}$$

Sources

N and P – domestic & industrial w/ water

Alkalinity (HCO_3^-) - natural

Chlorides (Cl^-) - natural

Sulphur (S) – natural

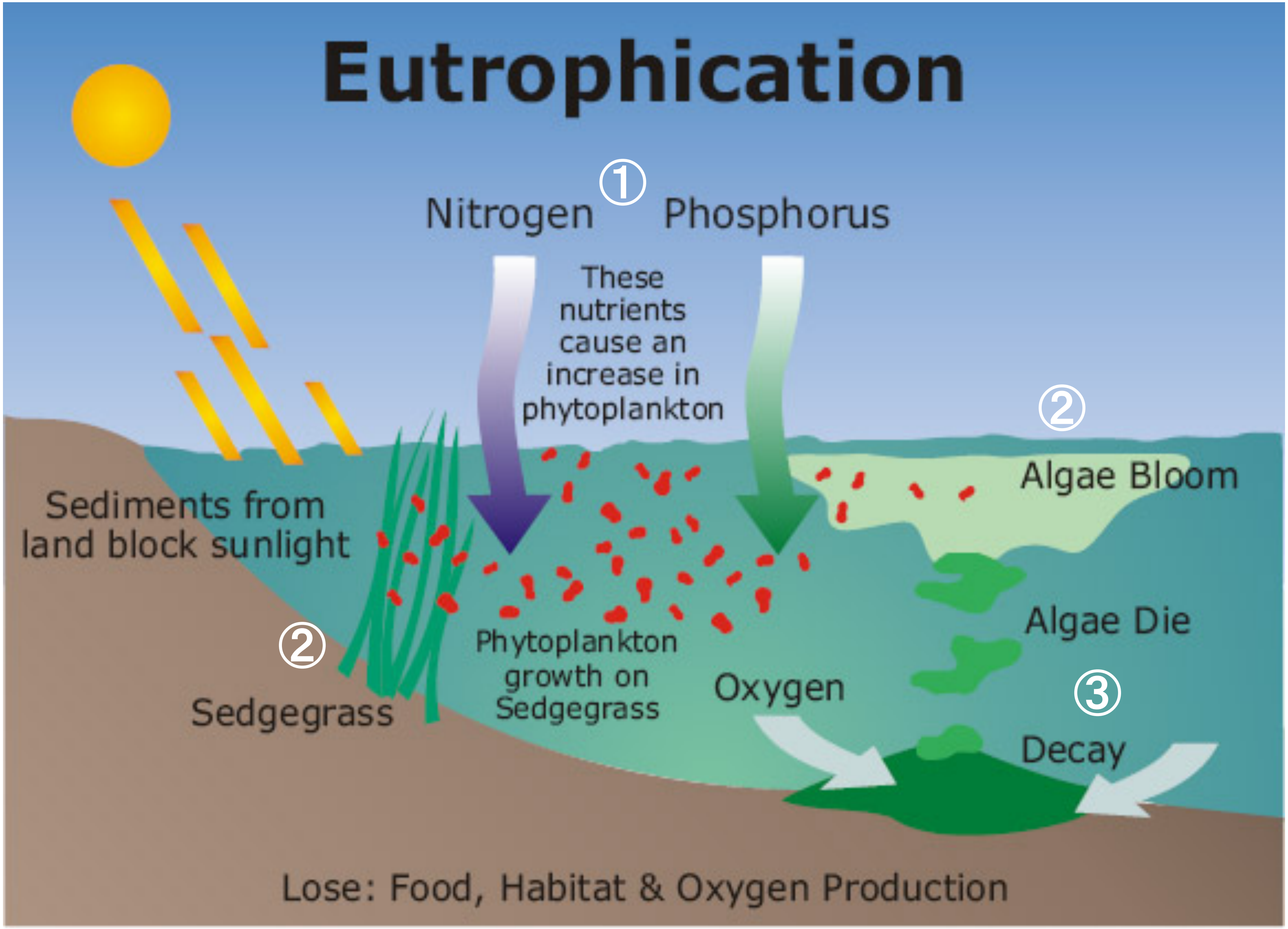
Metals (eg. Fe^{2+}, Cu^{2+}, Pb^{2+}) – industrial w/water

Effect of nutrients (N & P)

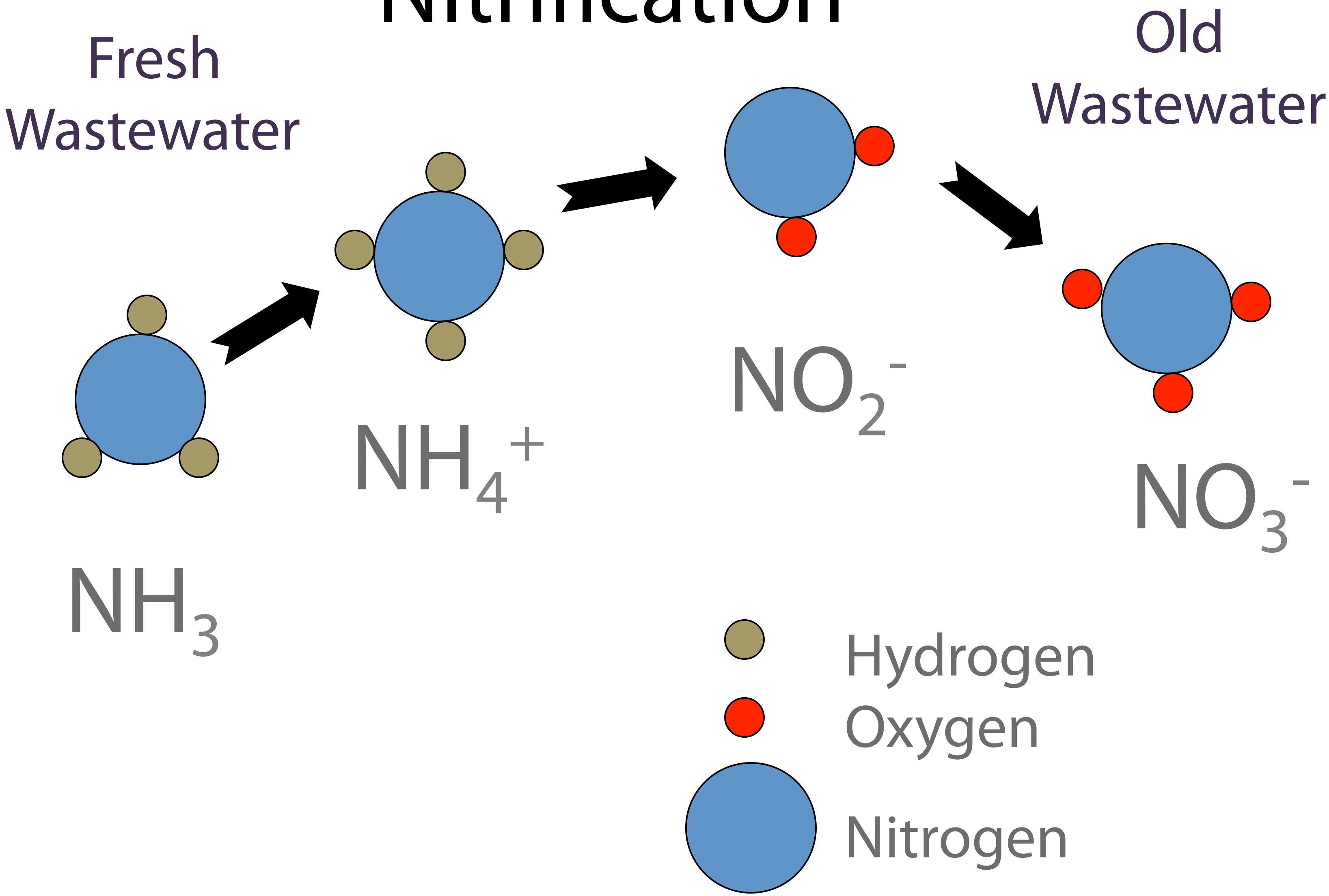
Eutrophication

Excessive algae breeding due to high N and P


Eutrophication
environmentalgeography.wordpress.com


Eutrophication
①
Nitrogen
Phosphorus
These nutrients cause an increase in phytoplankton
②
Algae Bloom
Sediments from land block sunlight
Algae Die
②
Phytoplankton growth on Sedgegrass
Oxygen
③
Sedgegrass
Decay
Lose: Food, Habitat & Oxygen Production

Nitrification



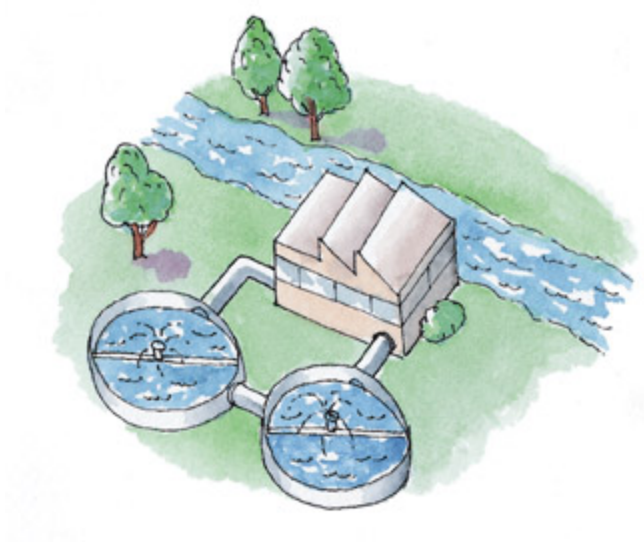
Wastewater Quality Standards

Environmental Quality Act, 1974

Regulations in Environmental Quality (Sewage), 2009

Standards for sewage treatment plant effluent

Standard A and Standard B




Intake Point
UTM's STP
STD. B
SAJ
N
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2010 MapIt
Image © 2011 DigitalGlobe
©2007 Google
Pointer 1°33'09.29" N 103°39'17.21" E elev 44 ft Streaming |||||||||| 100%
Eye alt 7247 ft

STD. A
STD. A
STD. A
SAJ
STD. B
N
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2010 MapIt
Image © 2011 DigitalGlobe
©2007 Google
Pointer 1°33'38.35" N 103°39'26.03" E elev 104 ft Streaming |||||||||| 100%
Eye alt 16593 ft

Std. A – Upstream of IP
Std. B – Downstream of IP

(i) **Sistem pengolahan kumbahan baru**

Parameter	Unit	Standad A	Standad B
(1)	(2)	(3)	(4)
(a) Suhu	°C	40	40
(b) Nilai pH	–	6.0-9.0	5.5-9.0
(c) BOD_5 pada 20°C	mg/L	20	50
(d) COD	mg/L	120	200
(e) Pepejal Terampai	mg/L	50	100
(f) Minyak dan Gris	mg/L	5.0	10.0
(g) Nitrogen Ammonia (badan air yang terkepung)	mg/L	5.0	5.0
(h) Nitrogen Ammonia (sungai)	mg/L	10.0	20.0
(i) Nitrogen Nitrat (sungai)	mg/L	20.0	50.0
(j) Nitrogen Nitrat (badan air yang terkepung)	mg/L	10.0	10.0
(k) Fosforus (badan air yang terkepung)	mg/L	5.0	10.0

(iii) **Sistem pengolahan kumbahan yang ada (diluluskan selepas Januari 1999)**

Semua sistem pengolahan kumbahan yang telah diluluskan selepas *Guidelines for Developers: Sewerage Treatment Vol. IV, 2nd edition* dan dikuatkuasakan oleh Jabatan Perkhidmatan Pembetungan, Kementerian Perumahan dan Kerajaan Tempatan, bermula Januari 1999 sehingga tarikh permulaan kuat kuasa Peraturan-Peraturan ini.

	Parameter	Unit	Standard A	Standard B
(a)	BOD_5 pada 20°C	mg/L	20	50
(b)	COD	mg/L	120	200
(c)	Pepejal Terampai	mg/L	50	100
(d)	Minyak dan Gris	mg/L	20	20
(e)	Nitrogen Ammonia	mg/L	50	50

Nota: Standard A terpakai kepada pembuangan ke dalam mana-mana perairan pedalaman dalam kawasan tadahan yang disenaraikan dalam Jadual Ketiga, manakala Standard B terpakai kepada mana-mana perairan pedalaman yang lain atau perairan Malaysia.

(ii) **Sistem pengolahan kumbahan sedia ada (diluluskan sebelum Januari 1999)**

Kategori ini merujuk kepada semua sistem pengolahan kumbahan yang telah diluluskan sebelum *Guidelines for Developers: Sewerage Treatment Vol. IV, 2nd edition* dan dikuatkuasakan oleh Jabatan Perkhidmatan Pembetungan, Kementerian Perumahan dan Kerajaan Tempatan, bermula Januari 1999. Di bawah ialah syarat-syarat yang boleh diterima bagi pembuangan kumbahan mengikut jenis sistem pengolahan kumbahan:

			Jenis sistem pengolahan kumbahan									
			Tangki Septik Komunal		Tangki Imhoff		Lagun Pengudaraan		Kolam Oksidasi		Sistem Mekanikal	
	Parameter (1)	Unit (2)	A (3)	B (4)	A (5)	B (6)	A (7)	B (8)	A (9)	B (10)	A (11)	B (12)
(a)	BOD_5 pada 20°C	mg/L	200	200	175	175	100	100	120	120	60	60
(b)	COD	mg/L	–	–	–	–	300	300	360	360	180	240
(c)	Pepejal Terampai	mg/L	180	180	150	150	120	120	150	150	100	120
(d)	Minyak dan Gris	mg/L	–	–	–	–	–	–	–	–	20	20
(e)	Nitrogen Ammonia	mg/L	–	–	100	100	80	80	70	70	60	60