Lecture 3

CE 433

Excerpts from Lecture notes of Professor M. Ashraf Ali, BUET.

Pollutant Discharge Limits

- If pollutant discharge continues unabated, rivers and lakes will lose their acceptability for their intended beneficial use
- Regulatory agencies' primary responsibility is to impose restrictions on the quality of domestic or industrial effluents on water bodies on the basis of certain guidelines or standards of a particular country
- In Bangladesh, DoE is the main regulatory agency which monitors effluent discharges by the industries and verify their compliance with the standards stated under the Environmental Conservation Rules 9ECR), 1997.

Surface Water Quality: Detection of Pollution

- Often pollution is first detected from visual observation. Visible signs of pollution include:
  - Floating debris
  - Occurrence of fish-kill
  - Bad taste and odor
  - Excessive growth of aquatic plants
  - Floating oil
  - Scum deposition

Principal Pollution Problems, affected uses and water quality variables

- Manifestation of problem
  - Fish kill, nuisance, odor, radical change in ecosystem
- Water use interference
  - Fishery, recreation, ecological health
- Water quality problem
  - Low dissolved oxygen
- Water quality variables
  - BOD, NH_3, TKN, Organic solids, phytoplankton, DO

Principal Pollution Problems, affected uses and water quality variables

- Manifestation of problem
  - Disease transmission, gastrointestinal disturbance, eye irritation
- Water use interference
  - Water supply, recreation
- Water quality problem
  - High bacterial levels
- Water quality variables
  - TC, FC, Fecal streptococci viruses

Principal Pollution Problems, affected uses and water quality variables

- Manifestation of problem
  - Taste and odor, excessive algae, unbalanced ecosystem
- Water use interference
  - Water supply, recreation, ecological health
- Water quality problem
  - Eutrophication
- Water quality variables
  - N, P, phytoplankton

Principal Pollution Problems, affected uses and water quality variables

- Manifestation of problem
  - Ecosystem upset – mortality, reproductive impairment (suspended carcinogen in water)
- Water use interference
  - Water supply, fishery, ecological health
- Water quality problem
  - High toxic chemical levels
- Water quality variables
  - Metals, pesticides, radioactive substances, other toxic chemicals

Water Quality Assessment Methods

- Chemical Assessment :
  - Well known and involve regular sampling of water in natural system, in the abstraction and treatment processes and of most effluents before being released
  - Assessment involves regular testing for the presence and concentration of the major chemical parameters (Tables 11.2 and 11.3)
  - Test protocols are according to Standard Methods

Bangladesh Standards

- Table 11.2: Bangladesh Standards for sewage discharge into surface and in land water bodies

Table 11.2 Bangladesh Standards for sewage discharge into surface and inland water bodies.

Parameters	Unit	Values
BOD	mg/l	40
Nitrate	mg/l	250
Phosphate	mg/l	35
Suspended Solids (SS)	mg/l	100
Temperature	°C	30
Coliforms	number/100ml	1000

Source: Schedule- 9, Rule-13, Environment Conservation Rules, 1997.

Bangladesh Standards

- Table 11.3: Bangladesh Standards for industrial effluent discharge

Parameters	Unit	Values
Ammonia-nitrogen (as elementary N)	mg/l	50
Ammonia (as free ammonia)	mg/l	5
Arsenic (as As)	mg/l	0.2
BOD_5 at 20°C	mg/l	50
Boron	mg/l	2
Cadmium (as Cd)	mg/l	0.05
Chloride	mg/l	600
Chromium (as total Cr)	mg/l	0.5
COD	mg/l	200
Chromium (as hexavalent Cr)	mg/l	0.1
Copper (as Cu)	mg/l	0.5
Dissolved oxygen (DO)	mg/l	4.5-8
Electro-conductivity (EC)	μSiemens/cm	1200
Total dissolved solids	mg/l	2100
Fluoride (as F)	mg/l	2
Sulfide (as S)	mg/l	1
Iron (as Fe)	mg/l	2
Total kjeldahl nitrogen (as N)	mg/l	100
Lead (as Pb)	mg/l	0.1
Manganese (as Mn)	mg/l	5
Mercury (as Hg)	mg/l	0.01

Parameters	Unit	Values
Nickel (as Ni)	mg/l	1.0
Nitrate (as elementary N)	mg/l	10.0
Oil and grease	mg/l	10
Phenolic compounds (as C_6H_5OH)	mg/l	1.0
Dissolved phosphorus (as P)	mg/l	8
pH		6-9
Selenium (as Se)	mg/l	0.05
Zinc (as Zn)	mg/l	5
Total dissolved solids	mg/l	2100
Temperature (thermal effluent)	°C (summer)	40
	°C (winter)	45
Suspended solids	mg/l	150
Cyanide	mg/l	0.1

Source: Schedule –10, Rule-13, Environment Conservation Rules, 1997

Water Quality Assessment Methods

- Biological Assessment
  - By measuring the extent of the ecological upset, the severity of the impact can be assessed
  - Severity or tolerance to pollution varies from species to species
  - Overall effects of altered physico-chemical environment can be monitored through changes in
    - Species composition
    - Dominant groups within species
    - Behavior
    - High mortality of sensitive life stages (e.g. eggs)
    - Physiology
    - Metabolism
    - Morphological deformities

Advantages and disadvantages of different water quality monitoring techniques

Realm	Performances of chemical monitoring	Performance of biological monitoring
Precision (i.e. pollutant concentration assessment)	Good	Poor
Discrimination (i.e. what kind of pollution)	Good	Poor
Reliability (how representative is a single or limited number of samples)	Poor	Good
Measure of ecological effects	No	Yes
Cost	Relatively high	Relatively low

Sayeed et al 2015

Oxygen Demanding Wastes

- Most common surface water pollutant
- Measured by
  - Biochemical Oxygen Demand (BOD)

  The amount of oxygen required by microorganisms to oxidize organic wastes aerobically is called “biochemical oxygen demand” (BOD). Usually expressed as mg/L

  - Chemical Oxygen Demand (COD)

  The amount of oxygen required for chemical oxidation of organic wastes is called “chemical oxygen demand” (COD). Usually expressed as mg/L

Aerobic vs Anaerobic decomposition

- Aerobic decomposition:

$$\text{Organic matter} + O_2 \xrightarrow{\text{bacteria}} CO_2 + H_2O + \text{New cells} + \text{stable product}$$

- Anaerobic decomposition:

$$\text{Organic matter} \xrightarrow{\text{bacteria}} CO_2 + CH_4 + \text{New cells} + \text{unstable products}$$

This produces highly objectionable end products e.g. H_2S, NH_3, CH_4 when emitted from water bodies.

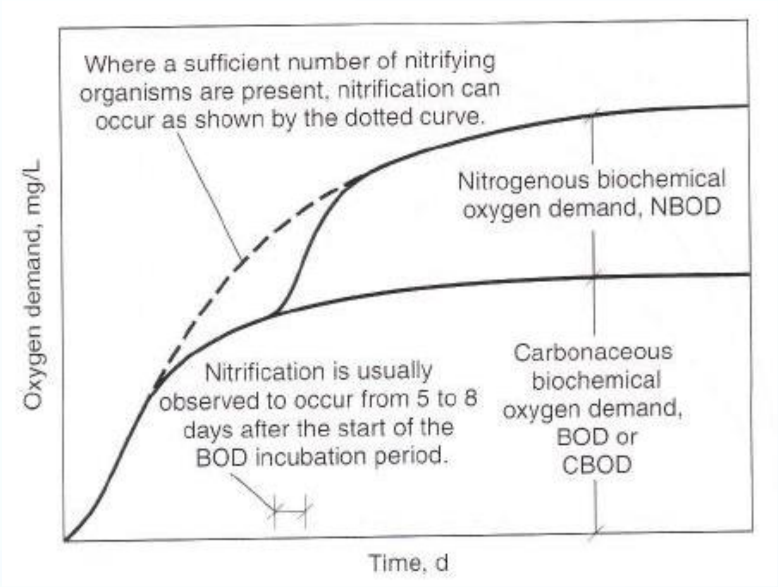
CH_4 is often called “swamp gas”

Categories of Biochemical Oxygen Demand

BOD

Carbonaceous BOD (CBOD)

Nitrogenous BOD (NBOD



- Carbonaceous organic material can be readily used by bacteria
- Decomposition of nitrogenous organic matter takes some time to start. There is a time lag in the growth of nitrifying bacteria necessary for oxidation of nitrogenous material

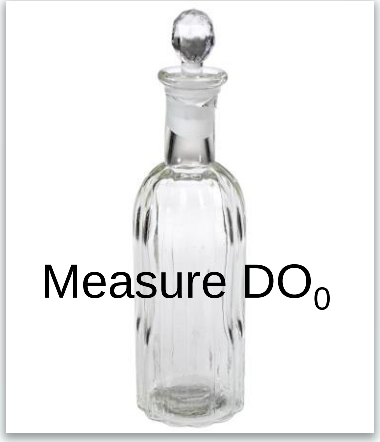
5 Day BOD Test

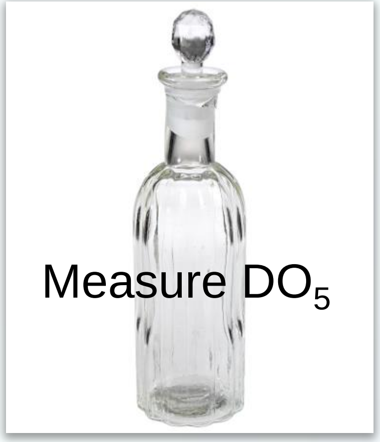
- Long time required for determining total O_2 required for decomposition of a particular waste sample (several weeks).
- It has become a standard practice to measure and report BOD over a period of 5-days (realizing that the ultimate demand is considerably higher).

Q. What kind of BOD would you expect to measure from 5-day BOD test? CBOD or NBOD?

5 Day BOD Test

- 300 mL BOD bottle used
- Stopper used to keep air from replenishing DO
- Light must be kept out of the bottle to keep algae from adding DO by photosynthesis
- Standard Temp is 20 degree C

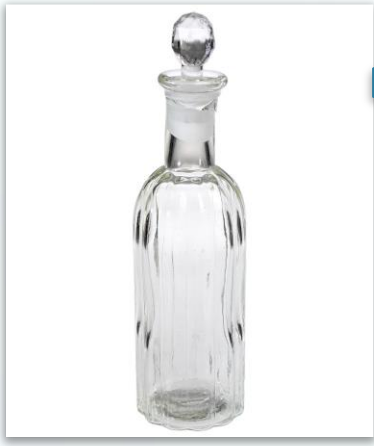




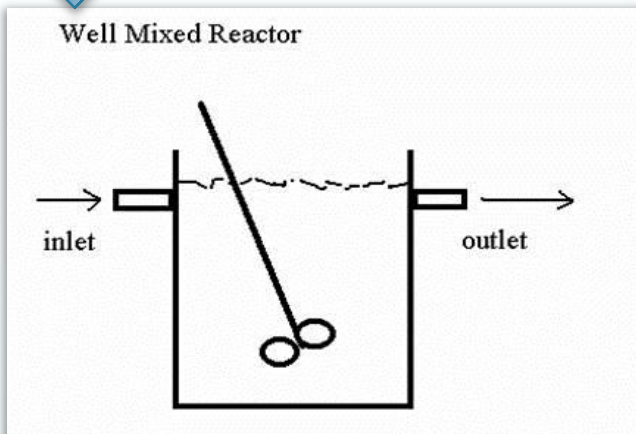
$$\mathbf{BOD_5 = (DO_0 - DO_5)\ mg/L}$$

- Oxygen demand of typical waste is often several hundred mg/L
- Saturated value of DO in water at 20^0C is only 9.1 mg/L
- Wastewater samples, therefore are diluted to keep final DO (after 5 days above zero.

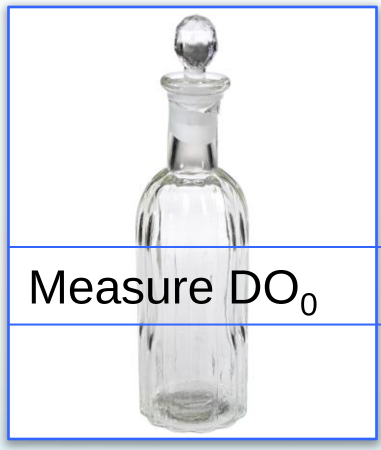
BOD Test – 1 (without dilution)



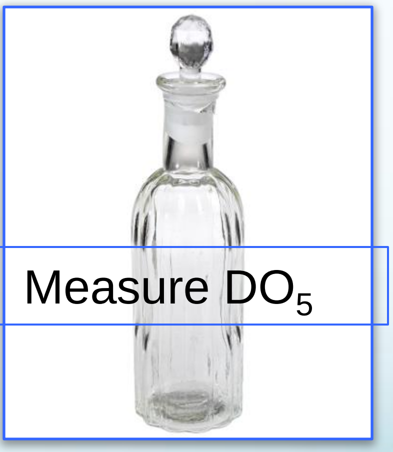
Sample



Aeration



Measure DO_0

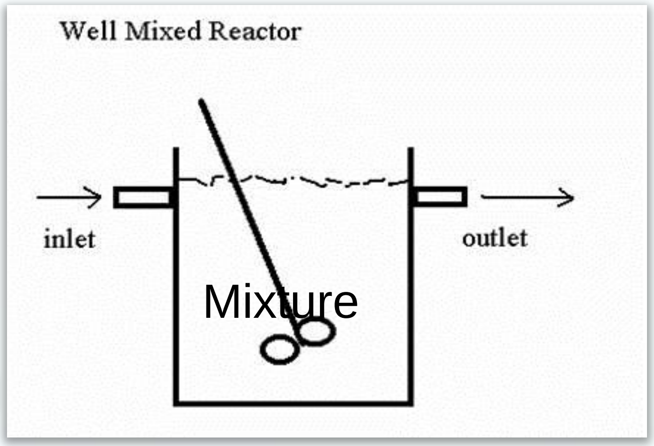


Measure DO_5

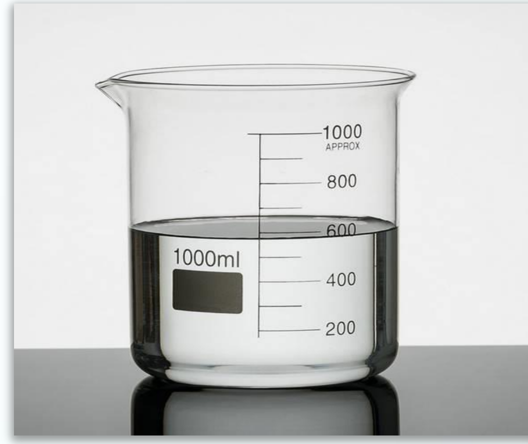
$$BOD_5 = (DO_0 – DO_5)\ \mathrm{mg/L}$$

BOD Test – 2 (with dilution)

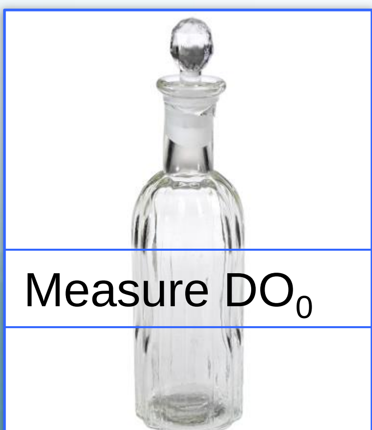
Sample



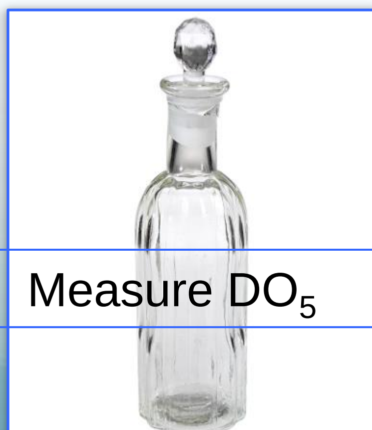
Aeration



Dilution water
(free from organic
matter



Measure DO_0



Measure DO_5

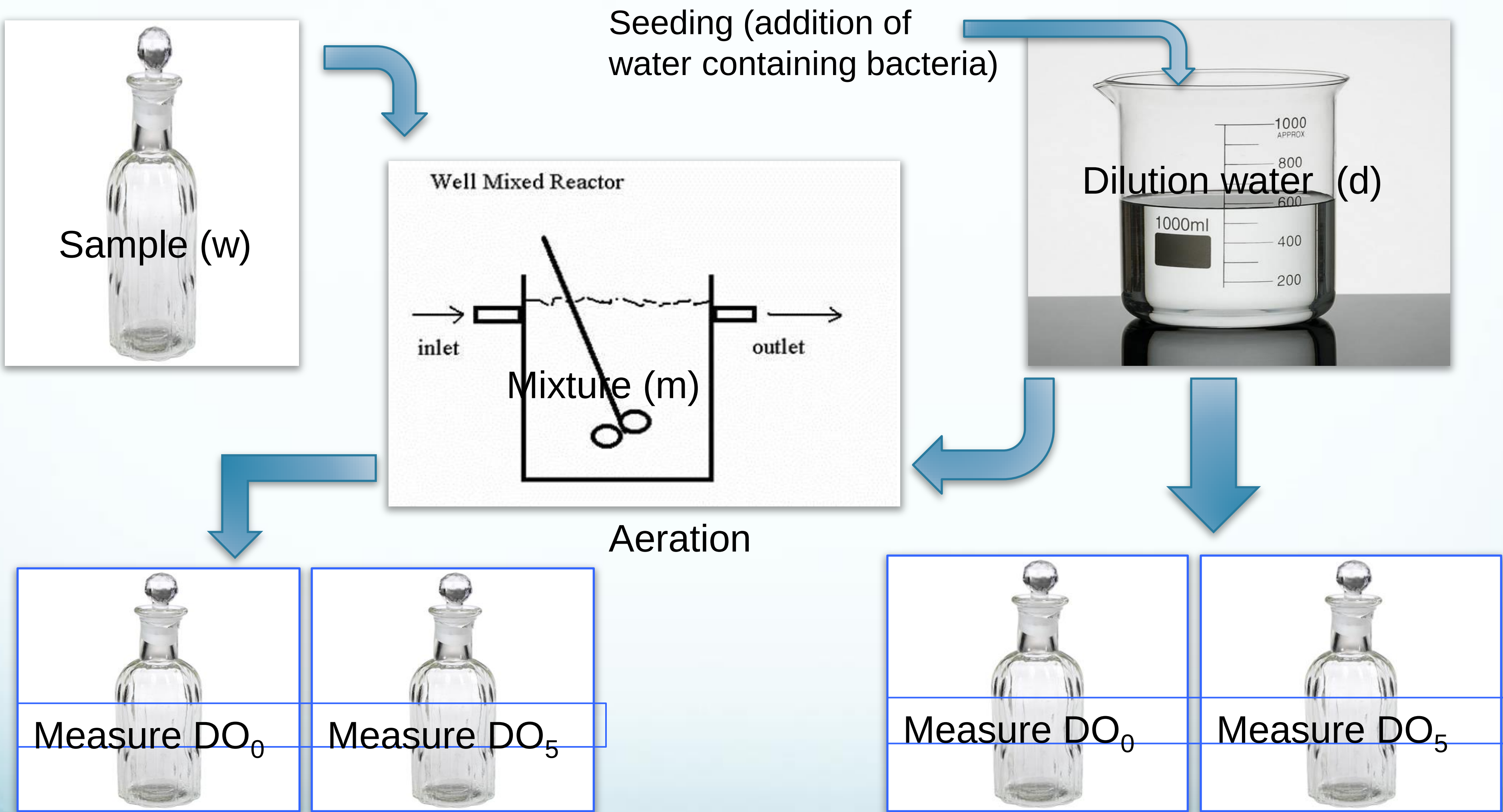
Dilution Factor =
Volume of mix/Volume of sample

$BOD_5 = (DO_0 – DO_5)$* Dilution Factor (mg/L)

BOD Test – 3 (Seeded BOD Test)

- In some cases, it becomes necessary to “seed” dilution water with microorganisms in order to ensure adequate bacterial population to carry out biodegradation.
- In such cases, it is necessary to subtract oxygen demand caused by the seed from the demand in the mixed sample of waste and dilution water, in order to determine BOD of waste.

BOD Test – 3 (Seeded BOD Test)



$BOD_m = (DO_0 – DO_5)$ mg/L

$BOD_d = (DO_0 – DO_5)$ mg/L

$$BOD_m . V_m = BOD_w . V_w + BOD_d . V_d \rightarrow \text{Find } BOD_w$$

Chemical Oxygen Demand

- Measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in an acid solution where

$$C_nH_aO_bN_c + dCr_2O_7^{-2} + (8d+c)H^+ \rightarrow nCO_2 + \frac{a+8d-3c}{2}H_2O + cNH_4^+ + 2dCr^{+3}$$

where $$d = \frac{2n}{3} + \frac{a}{6} - \frac{b}{3} - \frac{c}{2}$$

Why not cBOD is equal to COD ?

- 1.Many organic substances which are difficult to oxidize biologically (e.g lignin) can be oxidized chemically.
- 2.Inorganic substances that are oxidized by dichromate (e.g sulfide,sulfite, ferrous ion)
- 3. Certain organic substances may be toxic to microorganisms used in the BOD test.

BOD vs COD

Typical BOD/COD of untreated domestic wastewater:0.5-0.8

- **If BOD/COD ratio is 0.5:**

→Waste is considered to be easily treatable by biological means

- **If BOD/COD ratio is 0.3:**

→Organics in wastewater may be refractory

→Organics in wastewater are degradable. However, another substance in wastewater leads to inhibition of bacteria that uses organic matter

→Bacteria is not acclimated to wastewater

Problems

- A 15-mL sample of sewage is mixed with enough dilution water to fill a 300 mL BOD bottle. The bottle has an initial DO of 8.5 mg/L. At the end of 5 days, meausured DO is 2.8 mg/L. Calculate BOD_5 of the sewage.
- Consider the previous example. 15 mL sewage has been mixed with dilution water to fill 300 mL BOD bottle. Initial DO is 8.5 mg/L and DO after 5 days is 2.8 mg/L. For a BOD bottle filled with only dilution water, initial DO is 8.7 mg/L and after 5 days DO is 7.7 mg/L. Calculate BOD of sewage.