Determination of BOD in Water Sample

DISSOLVED OXYGEN (DO):

- Amount of oxygen dissolved (and hence available to sustain marine life) in a body of water such as lake, river or stream .
- Dissolved oxygen is the indicator of water pollution.
- DO levels in natural and waste water depend on physical, chemical and biological activities in water body.
- Amounts of oxygen that can be dissolved in water by temperature.
- It is usually determined by Winkler's method known as iodometric method.

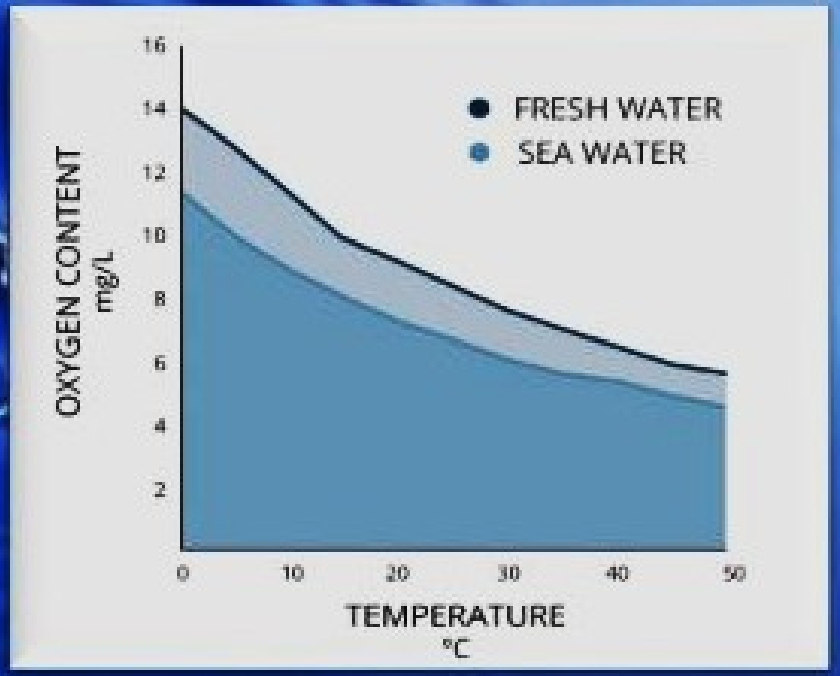


Dissolved Oxygen (DO) meter

DO LEVEL :

WATER QUALITY	DO LEVEL
Good quality(20° C sea level	8-9 ppm O_2
Moderate pollution	4-5 ppm O_2
Highly polluted	<4.5 ppm O_2

Dissolved Oxygen (mg/L) at Saturation in freshwater		
Temperature (C^0)	(F^0)	Dissolved Oxygen at saturation (mg/L)
0^0	32^0	14.6
5^0	41^0	12.8
10^0	50^0	11.3
15^0	59^0	10.1
20^0	68^0	9.1
25^0	77^0	8.3
30^0	86^0	7.6

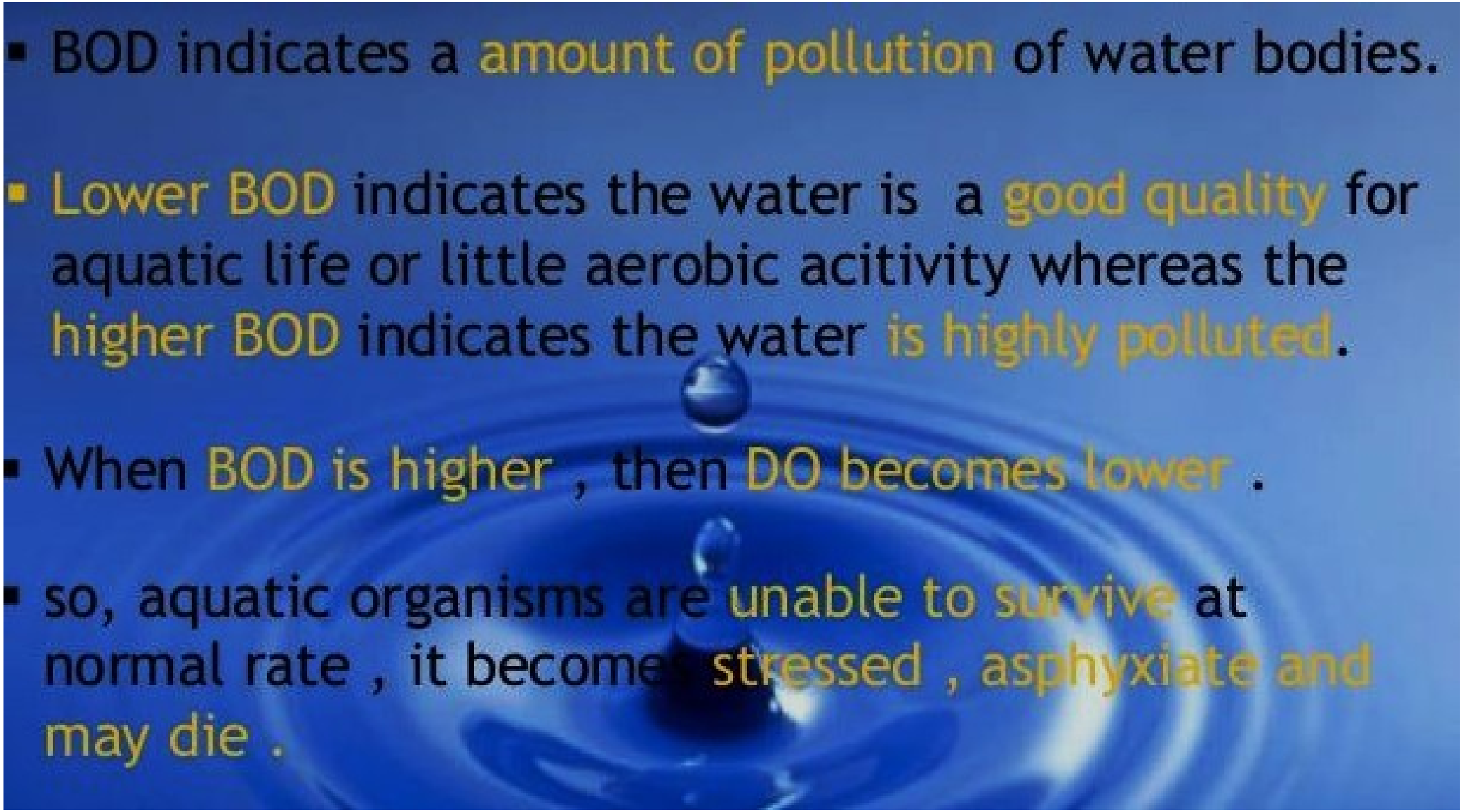


Biochemical Oxygen Demand

- BOD is the amount of dissolved oxygen required to breakdown the organic material of the sample by aerobic biological microorganisms at certain temperature over a specific period of time .
- This parameter is determined with the consumptio of oxygen by microorganisms during 5 days of incubation at 20° C .

$$\{CH_2O\} + O_2 \rightarrow CO_2 + H_2O$$

Biochemical Oxygen Demand



- BOD indicates a amount of pollution of water bodies.
- Lower BOD indicates the water is a good quality for aquatic life or little aerobic acitivity whereas the higher BOD indicates the water is highly polluted.
- When BOD is higher , then DO becomes lower .
- so, aquatic organisms are unable to survive at normal rate , it become stressed , asphyxiate and may die .

Biochemical Oxygen Demand

- Sewage contains Organic matter
  - Fats, Proteins and Carbohydrates

- Requires common basis for quantification

- The BOD test gives a measure of the **oxygen** utilized by **bacteria** during the oxidation of organic material contained in a wastewater sample.

Biochemical Oxygen Demand

- The test is based on the premise that all the biodegradable organic material contained in the wastewater sample will be oxidized to CO_2 and H_2O, using molecular oxygen as the electron acceptor.

- It is a direct measure of oxygen requirements and an indirect measure of biodegradable organic matter.

Biochemical Oxygen Demand

- To perform this test on industrial waste generally there is requirement to add microbial seed.

- This seed is added as sewage or the water from river or stream or soil sample where the industry discharges its waste





1.The sample is taken into a BOD bottle of volume 300mL. Say 10 mL



2. Diluted it with sufficient amount of dilution water if required. Say 290mL

3. Initial DO is to be calculated and final DO after 3days @27^{o}C or 5days @20^{o}C is measured

4. Difference between these reading multiplied by dilution factor gives BOD value.

$$BOD, mg/L = \frac{D_1 - D_2}{P}$$

When the dilution water is seeded

$$BODmg/L, = \frac{(D_1 - D_2) - (B_1 - B_2)f}{P}$$

Where:

D_1: Dissolved oxygen of diluted sample immediately after preparation, mg/L

D_2: Dissolved oxygen of diluted sample immediately after 5day incubation at 20°C, mg/L

B_1: Dissolved oxygen of seed control before incubation, mg/L

B_2: Dissolved oxygen of seed control after incubation, mg/

f : Fraction of seeded dilution water volume in sample to volume of seeded dilution water in seed control=1-P=290/300

P: Fraction of w/w sample to total combined volume i.e. 10/300

Biochemical Oxygen Demand

A BOD test was conducted at 20°C in which 15mL of waste sample was diluted with dilution water to 300mL.

Given:

Initial DO of diluted sample D_1 =8.8mg/L

Final DO after 5 days D_2=1.9mg/L

Initial DO of seeded dilution water B_1=9.1mg/L

Final DO of seeded dilution water B_2=7.9mg/L

Calculate

5-day BOD at 20°C

Biochemical Oxygen Demand

Ans:Forrmula, $BOD, mg/L = \frac{(D_1 - D_2) - (B_1 - B_2)f}{P}$

Where $f = \frac{300-15}{300} = 0.95$

$P = \frac{15}{300} = 0.05$

$BOD, mg/L = \frac{(8.8-1.9)-(9.1-7.9)0.95}{0.05} = 115.2\text{mg/L}$

BOD Calculation Example

A 15-ml water sample is diluted to 300 ml with nutrient solution and incubated in the dark for five days at 20° C. The initial dissolved oxygen concentration is 9.05 mg/l and the final concentration is 4.25 mg/l. The blank for the dilution water decreased in dissolved oxygen concentration from 9.05 mg/l to 8.80 mg/l. BOD_5 is estimated as:

Oxygen decrease in blank = (9.05 - 8.80) mg/l = 0.25 mg/l

Oxygen decrease in sample = (9.05 - 4.25) mg/l = 4.80 mg/l

$$\text{Dilution factor} = \frac{300 \text{ ml}}{15 \text{ ml}} = 20$$

$$BOD_5 = (4.80 \text{ mg/l} - 0.25 \text{ mg/l})\ 20 = 91 \text{ mg/l}$$

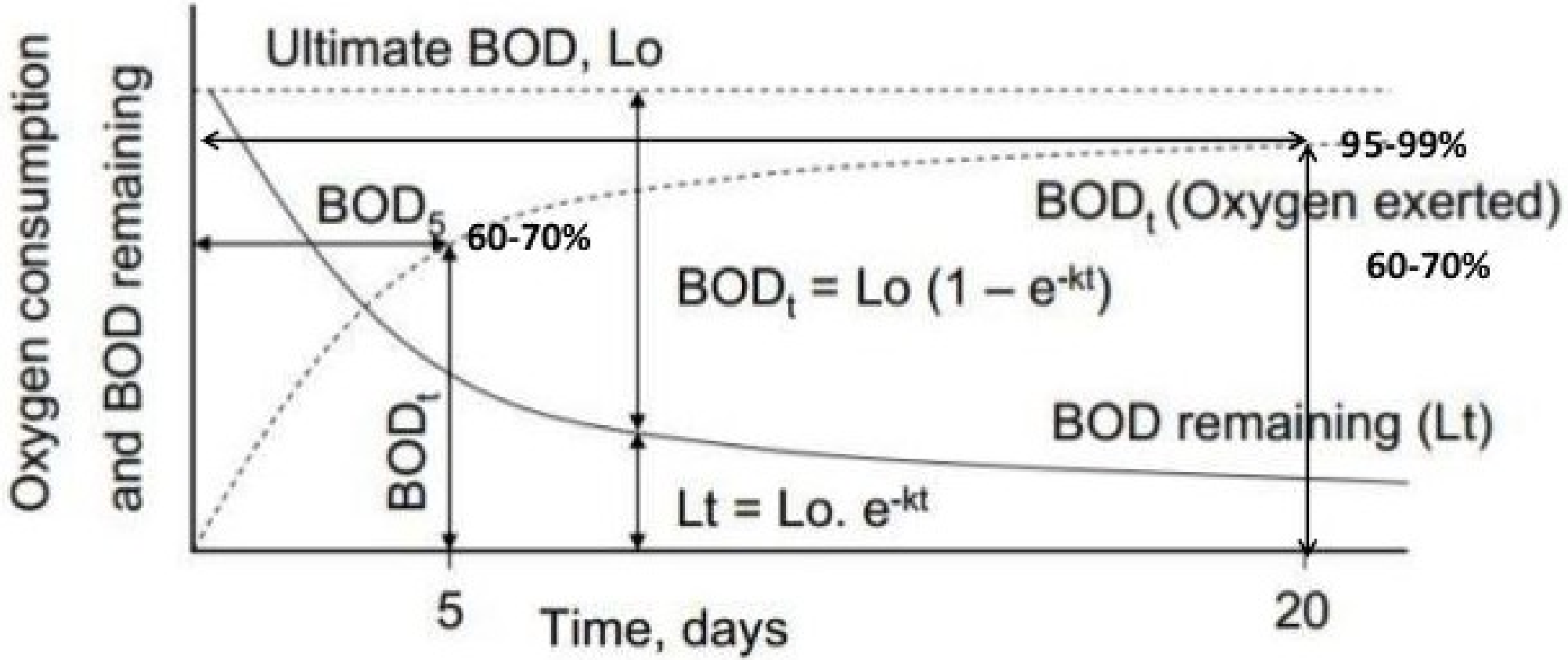
Biochemical Oxygen Demand

- As the microbial activity depends on temperature, BOD test is highly depends on temperature.

- Generally this temperature is chosen as $20^{o}C$ or $27^{o}C$.

Biochemical Oxygen Demand

$$\text{Organic matter} + O_2 \xrightarrow{\textit{Microorganisms}} CO_2 + H_2O + \text{New Cells} + \text{Stable Products}$$



Variation in DO profile during BOD test with duration of incubation at 20°C

The rate at which biodegradable organics are utilized by microorganisms is assumed to be a first order reaction; as such, the rate at which organic materials are utilized is proportional to the amount available (in wastewater).

$$\frac{dL_t}{dt} = -kL_t \quad (1)$$

where, L_t = oxygen equivalent of organics at time t, mg/L

k = reaction constant, d^{-1}

Equation (1) can be arranged as shown in Equation (2)

$$\frac{dL_t}{L_t} = -kdt \quad (2)$$

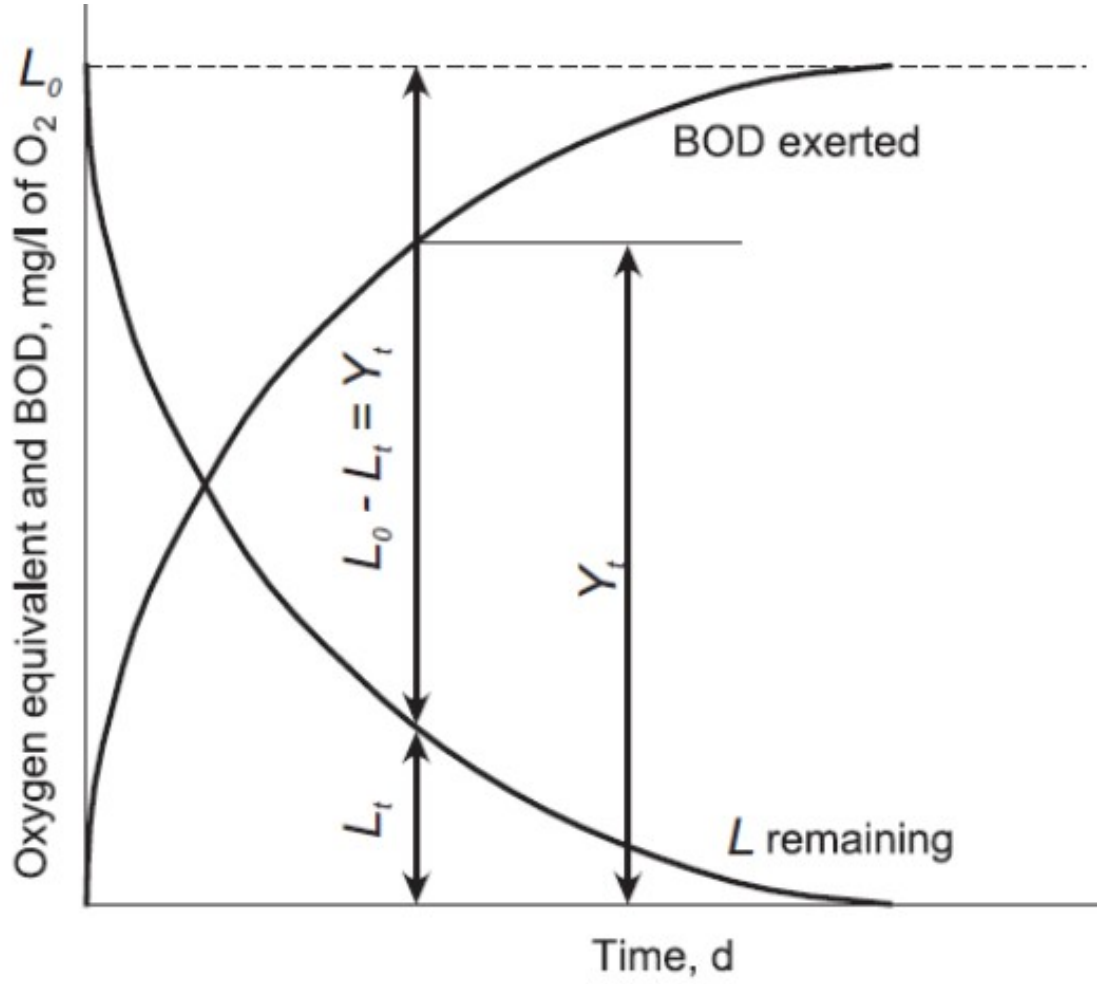
The integration of Equation (2) yields Equation (3)

$$\int_{L_0}^{L} \frac{dL_t}{L_t} = -k\int_{0}^{t} dt$$

$$L_t = L_0 e^{-kt} \quad (3)$$

where L_0 = total oxygen equivalent of the organics at time zero

L_t = oxygen amount remaining at time t



Biochemical Oxygen Demand

- $L_t = L_0 e^{-k_1 t}$

where, L_0: Ultimate BOD, mg/L

L_t : BOD remaining at any time, mg/L

k_1: 1^{st} order reaction rate constant, $1/d$

t : time, d

- But $L_0 = L + Y$
- $\therefore Y = L_0(1 - e^{-k_1 t})$
- where, Y: BOD Exerted at that time

Biochemical Oxygen Demand

- Rate constant k_1 is dependent on temperature, it can be calculated as,
- $k_{1t} = k_{1\,20^0}\Theta^{T-20}$

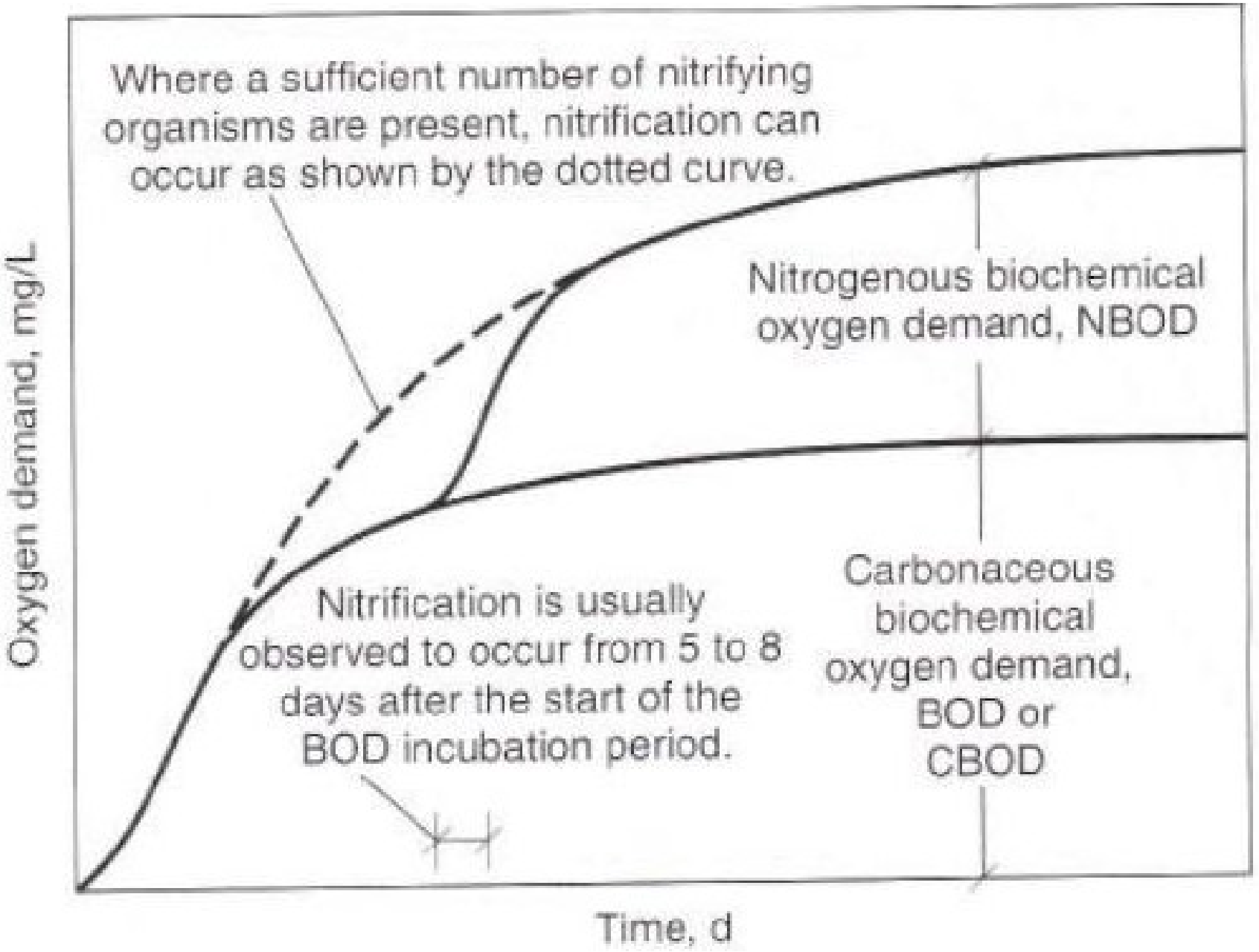
  where, $\Theta = 1.047$
- The value of Θ is temperature dependent

Why BOD test is conducted for 5^{th} day

- BOD theoretically takes infinite time to go to completion because the rate of oxidation is assumed to be proportional to the amount of organic matter remaining.
- Within 20day period the oxidation of carbonaceous matter is about 95-99% and in 5days it is 60-70%
- 20days is long time to wait for test
- After 8-10 days nitrifying bacteria start using oxygen to convert ammonia nitrogen to nitrite and then to nitrate.
- We are interested only in first stage BOD or carbonaceous BOD so we have chosen 5days for the test

Why BOD test is conducted for 5^{th} day

- Carbonaceous demand can be obtained by supressing nitrifying bacteria by adding growth inhibiters of nitrifying bacteria.
- Also this test is conducted on 5^{th} day so as to ensure less population of nitrifying bacteria.


Where a sufficient number of nitrifying organisms are present, nitrification can occur as shown by the dotted curve.
Nitrogenous biochemical oxygen demand, NBOD
Carbonaceous biochemical oxygen demand, BOD or CBOD
Nitrification is usually observed to occur from 5 to 8 days after the start of the BOD incubation period.
Oxygen demand, mg/L
Time, d

Biochemical Oxygen Demand

This test can be used to

1. Determine amount of oxygen required to stabilize organic matter biologically
2. Determine size of treatment facility
3. Measure the efficiency of treatment facilities
4. Determine compliance with wastewater discharge permits

BOD LEVEL :

BOD LEVEL (mg/l)	Remarks
1mg/l	very clean
2mg/l	clean
3mg/l	fairly
5mg/l	doubtful
10mg/l	contaminated

BOD of some collected samples from different sources:

- Normal water = 0-3
- River water = 5-20
- Sewerage water = 50-100
- Industrial water = 150-1000
- Land for irrigation = 100
- Marine coastal area = 100
- Inland surface water = 30
- Public sewers = 350