LECTURE

MODELLING THE MARINE ENVIRONMENT

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Lecture 8

BOD AND OXYGEN SATURATION

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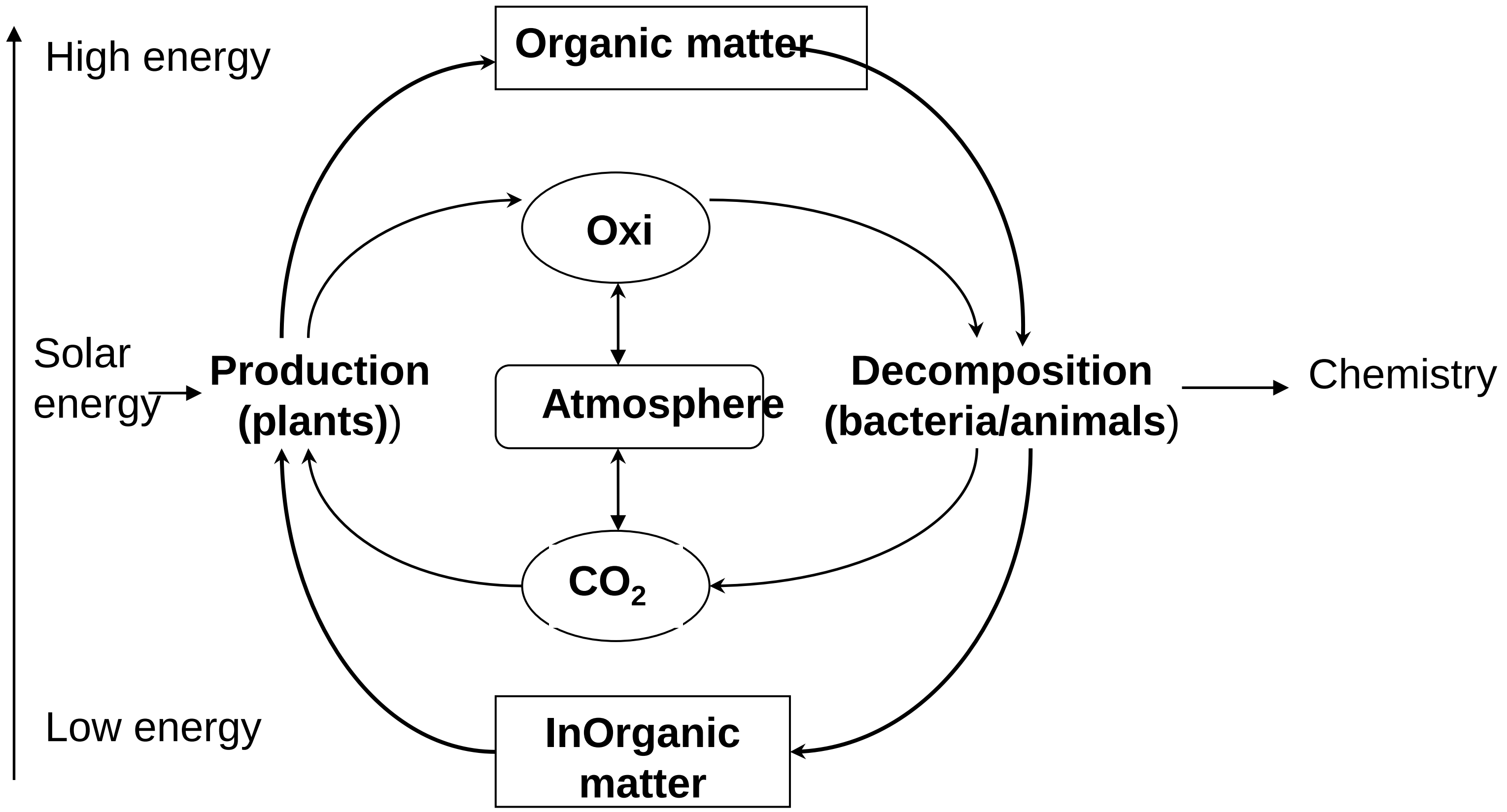
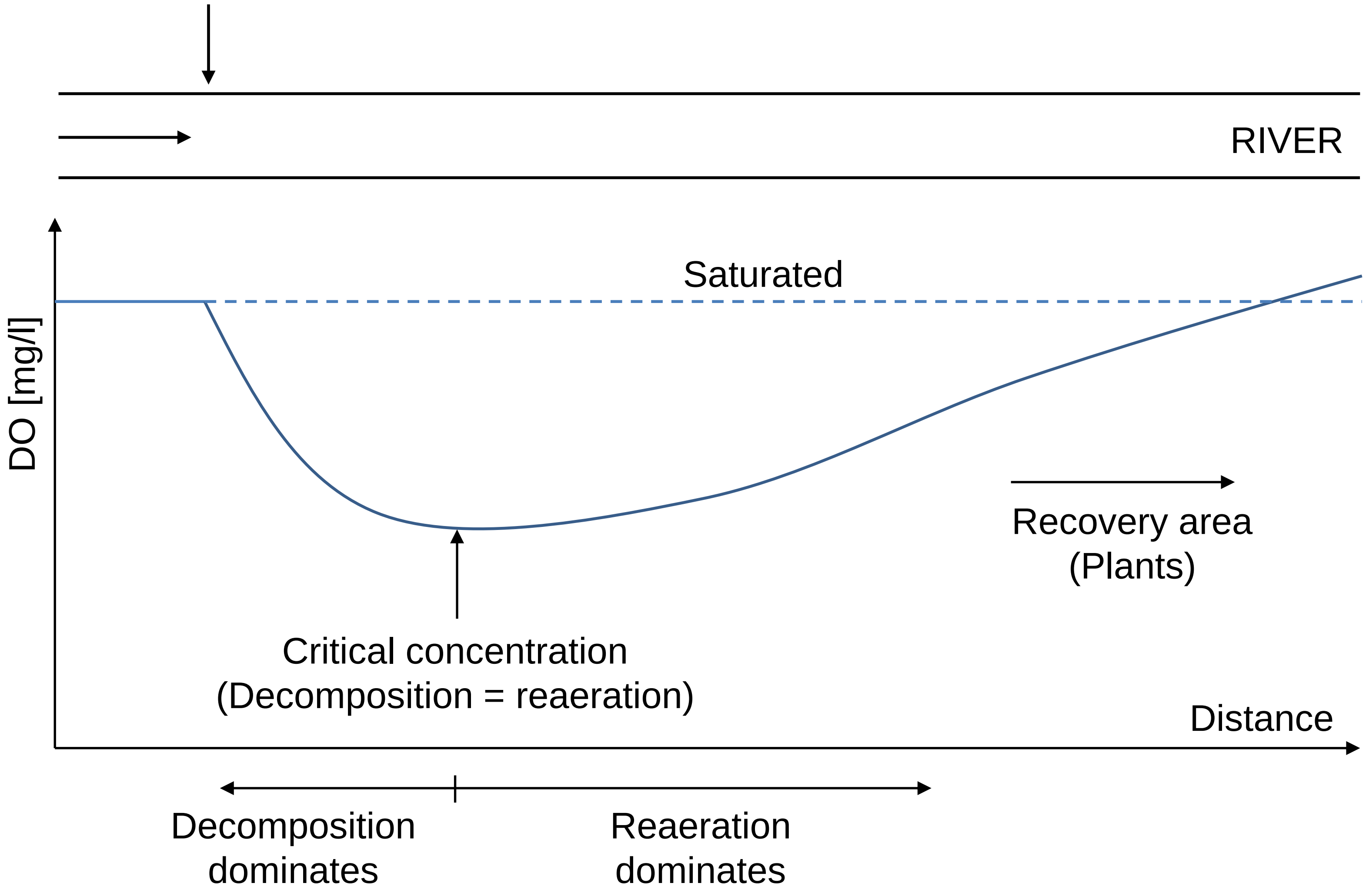
ORGANIC MATTER DECOMPOSITION AND PRODUCTION CYCLE



The cycle above can be described by chemical equations:

$$6CO_2 + 6H_2O \underset{\text{respiration}}{\overset{\text{photosynthesis}}{\rightleftharpoons}} C_6H_{12}O_6 + 6O_2$$

SATURATED DISSOLVED OXYGEN



EXPERIMENT

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The organic matter decomposition cycle is described by the following chemical equation:

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{Respiratory}} 6CO_2 + 6H_2O$$

Mass balancing equation:

Glucose: $$V\frac{dg}{dt} = -k_1 Vg$$

Oxy: $$V\frac{do}{dt} = -r_{og}k_1 Vg$$

k_1: rate of decomposition [1/day]

r_{og}: the stoichiometric of oxygen consumed to glucose decomposition (mg O/mg-glucose)

At t = 0: g = g_0 và o = o_0

$$g = g_0 e^{-k_1 t}$$

$$o = o_0 - r_{og}g_0\left(1 - e^{-k_1 t}\right)$$

EXPERIMENT (TT)

<u>Example 1:</u> Put 2mg of glucose in a 250ml bottle, then add a small amount of bacteria. Fill the bottle with water and close the lid. The initial oxygen level was $10mgL^{-1}$. If glucose breaks down at a rate of 0.1/day, determine the concentration of oxygen as a function over time in this experiment.

EXPERIMENT (cont)

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Solution:

Initial concentration of glucose

$$g_0 = \frac{2\ \text{mg}}{250\ \text{mL}}\left(\frac{1000\ \text{mL}}{\text{L}}\right) = 8\text{mg/L}$$

stoichiometry:

$$r_{og} = \frac{6(32)}{6 \times 12 + 1 \times 12 + 6 \times 16} = 1.0667\ \text{mgO/mg glucose}$$

Glucose levels break down and oxygen depletion over time:

$$g = 8e^{-0.1t}$$

$$o = 10 - 8.5333(1 - e^{-0.1t})$$

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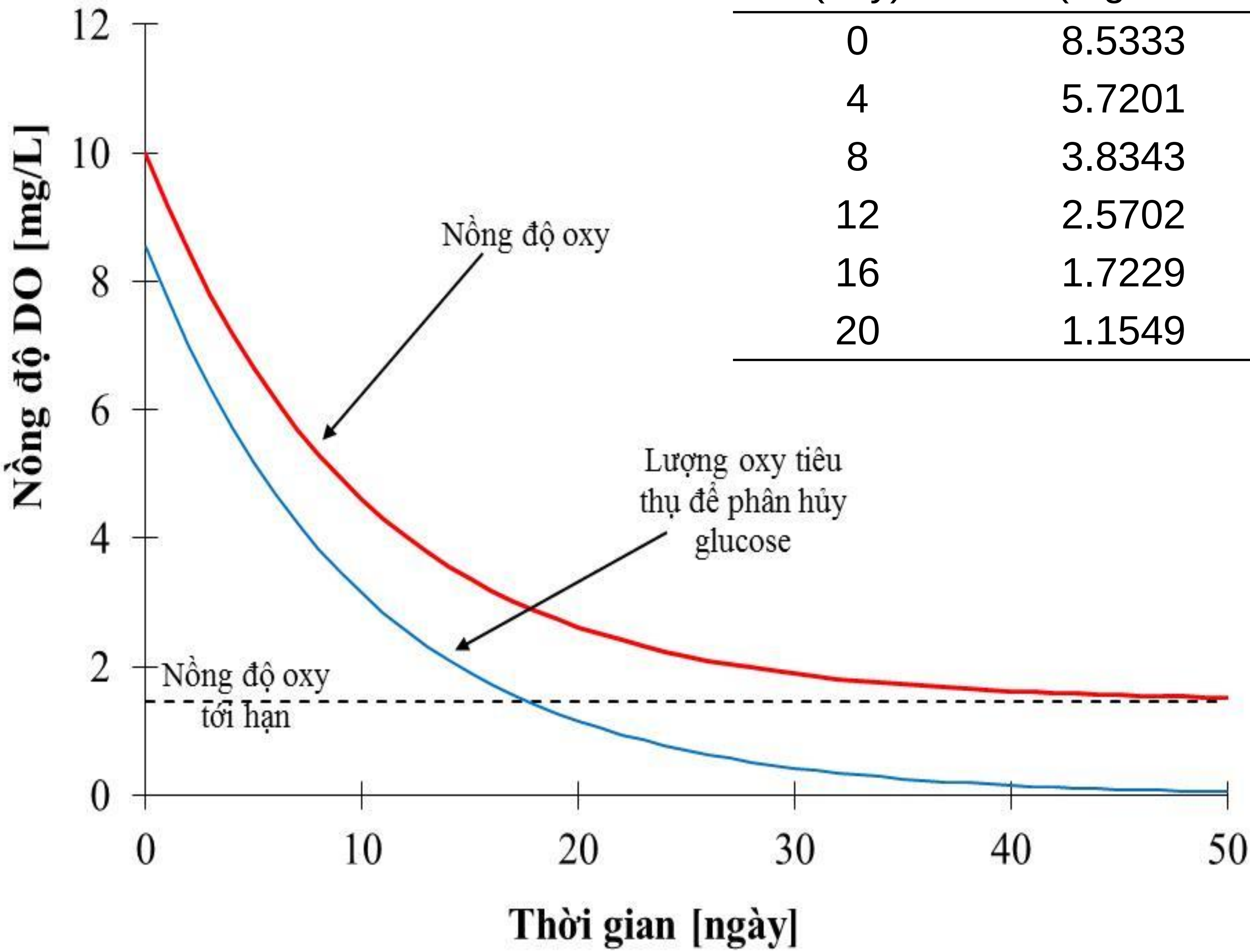
Time (day)	Glucose (mgO/L	Oxy (mgO/L)
0	8.5333	10.000
4	5.7201	7.187
8	3.8343	5.301
12	2.5702	4.037
16	1.7229	3.190
20	1.1549	2.622



BIOCHEMICAL OXYGEN DEMAND (BOD)

- **Biochemical oxygen demand (BOD)** is the amount of oxygen needed for microorganisms to oxidize organic matter over a certain period of time.
- Mass balancing equation for oxidizing organic matter in the bottle:
- $V\frac{dL}{dt} = -k_1 VL$

L: the amount of oxidized organic matter left in the bottle: [mgO L^{-1}]

At t = 0: L = L_0 Experiment with the equation now.

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

Amount of oxygen consumed during decomposition:

$$y = L_0 - L \rightarrow y = L_0\left(1 - e^{-k_1 t}\right)$$

Where y is BOD (mgO L^{-1}); L_0 is the initial concentration of oxidized organic matter (expressed in units of oxygen) or ultimate BOD

BIOCHEMICAL OXYGEN DEMAND (BOD)

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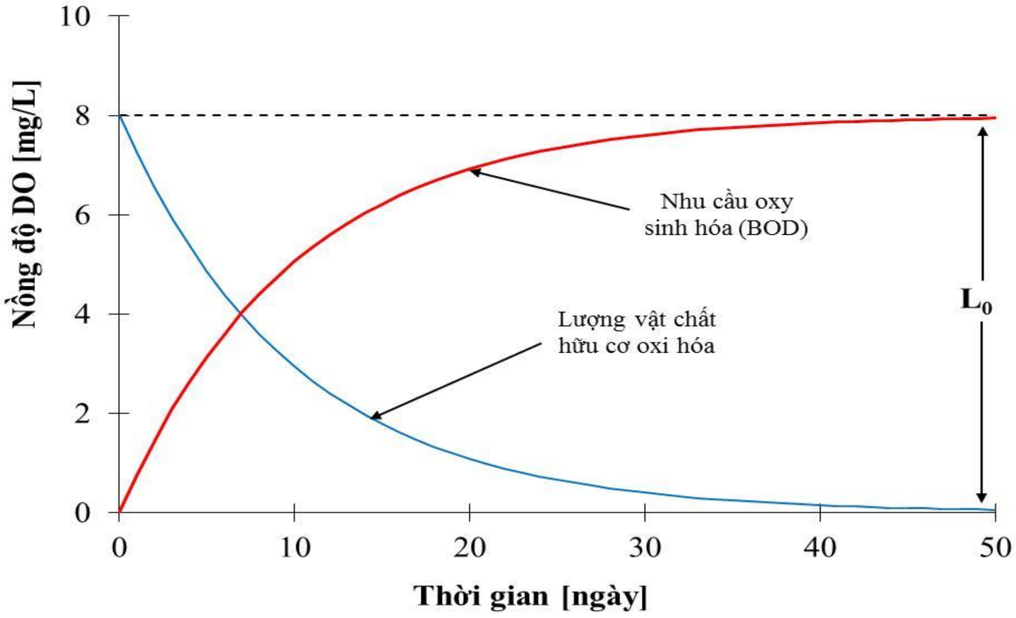
Mass balance equation for oxygen:

$$V\frac{do}{dt} = -k_1 V L_0 e^{-k_1 t}$$

At t = 0: o = o_0 , the solution of the equation

$$o = o_0 - L_0\left(1 - e^{-k_1 t}\right)$$



The L0 value is the initial concentration of dissolved organic matter or final BOD

BOD FOR A STREAM

Mass balance equation for a Stream

$$\frac{dL}{dt} = -U\frac{dL}{dx} - k_r L$$

k_r = total removal rate (d^{-1}) includes the process of decomposition and sttling,

$$k_r = k_d + k_s$$

In a steady - state

$$0 = -U\frac{dL}{dx} - k_r L$$

Let's say at the point of discharge, the mixing process is complete.

$$L_0 = \frac{Q_w L_w + Q_r L_r}{Q_w + Q_r}$$

Tại t = 0: L = L_0 the solution as below

$$L = L_0 e^{-\frac{k_r}{U}x}$$

BOD FOR A STREAM

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Exercises

A discharge stream (flow 2 cms, BOD is 10 mg/l) from an active sludge treatment plant poured into a river (flow 5 cms and BOD is 0 mg/l). Characteristics of the river: $k_{r,}$ 20 = 0.2 days-1, cross-section area is 25 m^2, and T = 28°C, θ =1,047 for BOD decomposition.

a. Determination of BOD levels at the mixing point

b. How far is the distance from the discharge point so that the BOD concentration reaches 5% of the original BOD valu?

DO SATURATION

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❖ **The effect of temperature.** (APHA 1992)

$$\ln o_{sf} = -139.34411 + \frac{1.575701.10^{5}}{T_a} - \frac{6.642308.10^{7}}{T_a^{2}} + \frac{1.243800.10^{10}}{T_a^{3}} - \frac{8.621949.10^{11}}{T_a^{4}}$$

o_{sf} Is the concentration of do saturation at the pressure 1 atm (mg L^{-1}) and T_a is absolute temperature. (K), T_a = T + 273.15

❖ **Effects of salinity** (APHA 1992)

$$\ln o_{ss} = \ln o_{sf} - S\left(1.7674.10^{-2} - \frac{1.0754.10^{1}}{T_a} + \frac{2.1407.10^{3}}{T_a^{2}}\right)$$

o_{ss} is the concentration of do saturation in seawater at pressure 1 atm (mgL^{-1}), S is salinity (gL^{-1} or ppt).

S=1.80655 x Chlor

Chlor is a concentration of chloride (ppt). The higher the salinity, the lower the amount of oxygen in the water.

MARE

DO SATURATION (cont)

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❖ Effects of pressure (APHA 1992)

$$o_{sp} = o_{si}\,p\left[\frac{\left(1 - \frac{p_{wv-}}{p}\right)(1-\theta p)}{(1-p_{wv})(1-\theta)}\right]$$

p = atmospheric pressure (atm);

o_{sp} = saturated oxygen concentration at pressure p (mg L^{-1});

o_{s1} = saturation concentration of dissolved oxygen at pressure 1 atm (mgL^{-1});

p_{wv} = partial pressure part of steam (atm)

$$\ln p_{wv} = 11.8571 - \frac{3840.70}{T_a} - \frac{216.961}{T_a^2}$$

$$\theta = 0.000975 - 1.426.10^{-5}T + 6.436.10^{-8}T^2$$

Zison el at (1978) advanced approximation formula based on altitude

$$o_{sp} = o_{s1}\left[1 - 0.1148 * elev(km)\right]$$

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DO SATURATION (cont)

Exercises

DO, temperature, and salinity are measured at an estuaries as follows:

Distance from the sea	30	20	10
Temperature, °C	25	22	18
Salinity, ppt	5	10	20
DO	5	6.5	7.5

Calculate the percentage of saturated oxygen at the above 3 locations