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LECTURE

MODELLING THE MARINE ENVIRONMENT

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Lecture 7

PROCESS OF SUBSTANCE TRANSMISSION

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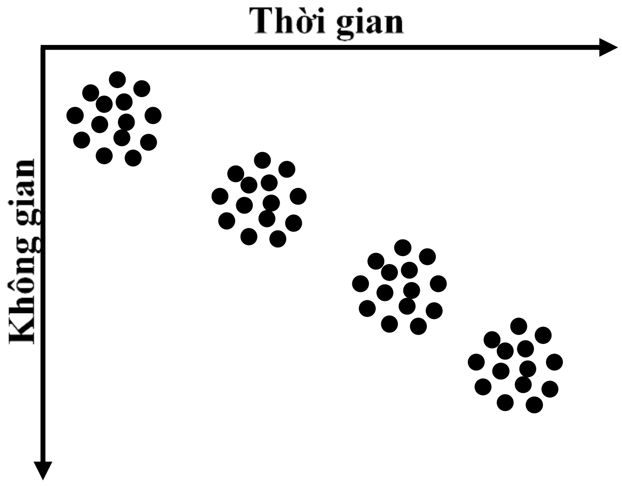
Lecture 7D

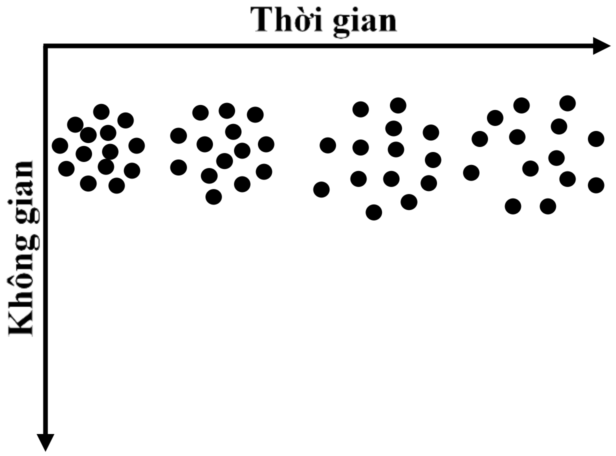
ADVECTION AND DISUSION

ADVECTION AND DISUSION

- ❖ Advection: Advection results from flow that is unidirectional and does not change the identity of the substance being transported. As in Figure advection moves matter from one position in space to another
- ❖ Diffusion: Refer to the moment of the mass due to random water motion or mixing
  - **Molecular diffusion**
  - **Turbulent diffusion**



(a) Advection



(b) Diffustion

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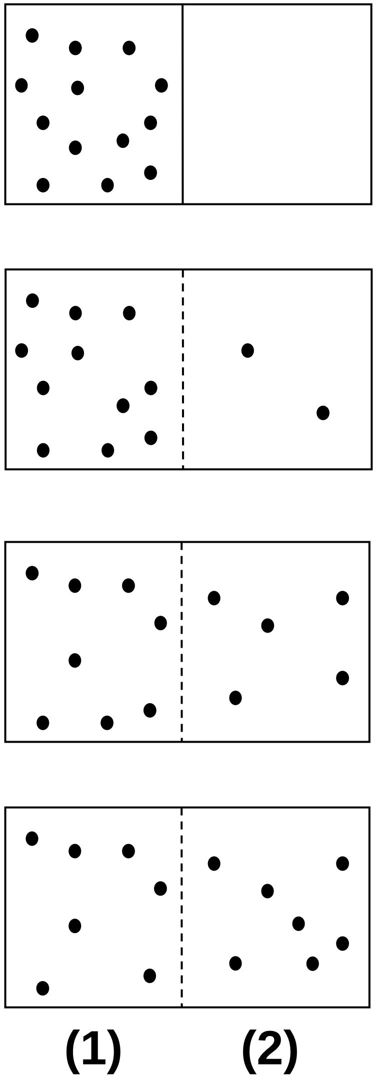
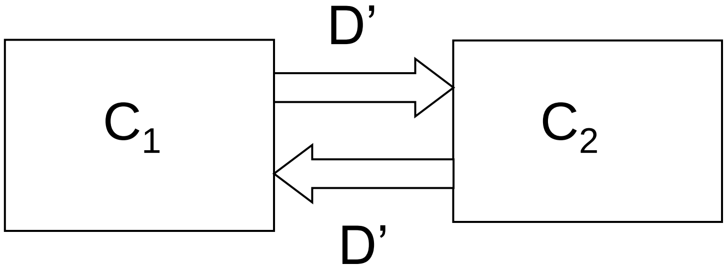
DIFFUSION

- **Experiment**
-





Mass equation balance for lake1:

$$V_1 \frac{dC_1}{dt} = D'(C_2 - C_1)$$

Where:

V_1 : Lake volume 1;
C_1, C_2 : concentration of 1 and 2;
D’ : Diffusion $[m^3/\text{năm}]$

DIFFUSION

❖ **Three factors affect diffusion:**

- The mixing flow D’ reflects the intensity of the mixing. Thus, if the tanks was subjects to only weak mixing such as due to Brownian motion, D’ would be small. If it were subjected to vigorous phýical mixing, D’ would be large
- Mass transport is directly proportional to the interface area
- Mass transport is proportional to the difference in concentration between the two lakes (gradient concentration)
- Diffuse to the right if $C_1 > C_2$
  + Diffuse to the left if C1 < C2
  + Do not diffuse if C1 = C

Example 1. Simulation of the time required for the experiment described on Figure 2 to be completed 95%.

Lời giải:

Mass balance equation

$$\frac{V}{2}\frac{dC_1}{dt} = D'\left(C_2 - C_1\right)$$

$V_1 = V_{2,}$: $C_{10} = C_1 + C_2$

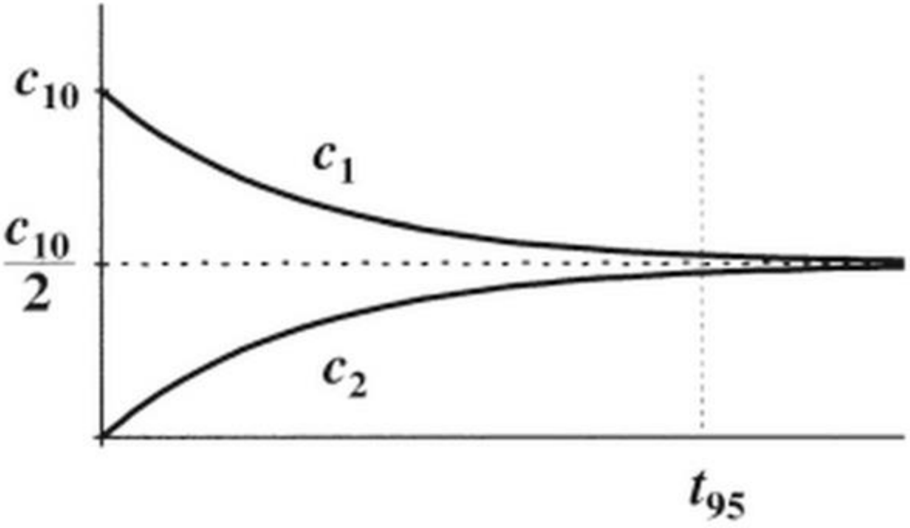
Mass balancing equations at the moment:

$$\frac{dC_1}{dt} + \frac{4D'}{V}C_1 = \frac{2D'}{V}C_{10}$$

Which can be solved

$$C_1 = C_{10}e^{-\frac{4D'}{V}t} + \frac{C_{10}}{2}\left(1 - e^{-\frac{4D'}{V}t}\right)$$

$$C_2 = \frac{C_{10}}{2}\left(1 - e^{-\frac{4D'}{V}t}\right)$$



$$t_{95} = \frac{3}{\lambda} = \frac{3V}{4D'}$$

FICK’S FIRST LAW

In 1855, physicist Adolf Fick introduced the diffusion model:

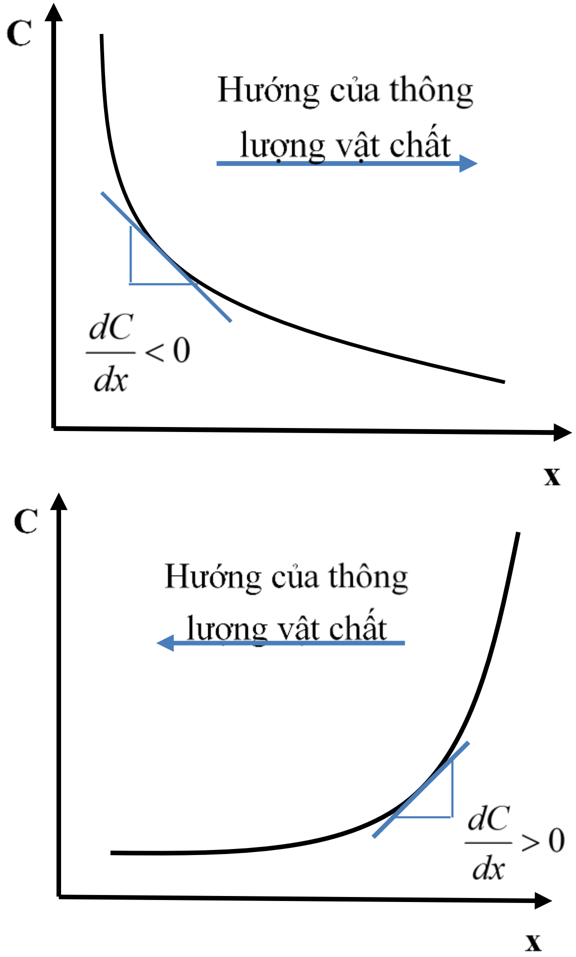
$$J_x = -D\frac{dC}{dx}$$

Where:

J_x : mass flux in the x ditection[$ML^{-2}T^{-1}$]

D: diffusion coefficient [L^2T^{-1}]

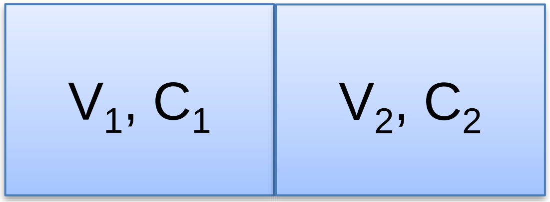
Fick's Law: Mass flux is proportional to the gradient (that is, the derivative or rsate of change)



Graphical depictions the effect of concentration gradients on the mass flux.

FICK'S FIRST LAW

- **Determination of diffusion coefficient**



$$V_1\frac{dc_1}{dt} = -JA_c$$

l: mixing length [L]

$$J_x = -D\frac{dc}{dx}$$

$$\frac{dc}{dx} \cong \frac{c_2 - c_1}{l}$$

Combining these equations

$$V_1\frac{dc_1}{dt} = \underbrace{\boxed{\frac{DA_c}{l}}}_{D'}(c_2 - c_1)$$

In diffusion, two important quantities are d diffusion coefficient and blend length l. For the molecular, the parameter is defined [LT^{-1}]:

$v_d = \frac{D}{l}$ where v_d is called a diffusion mass − transfer coefficient

For, **Turbulent diffusion** : $E' = \frac{EA_c}{l}$

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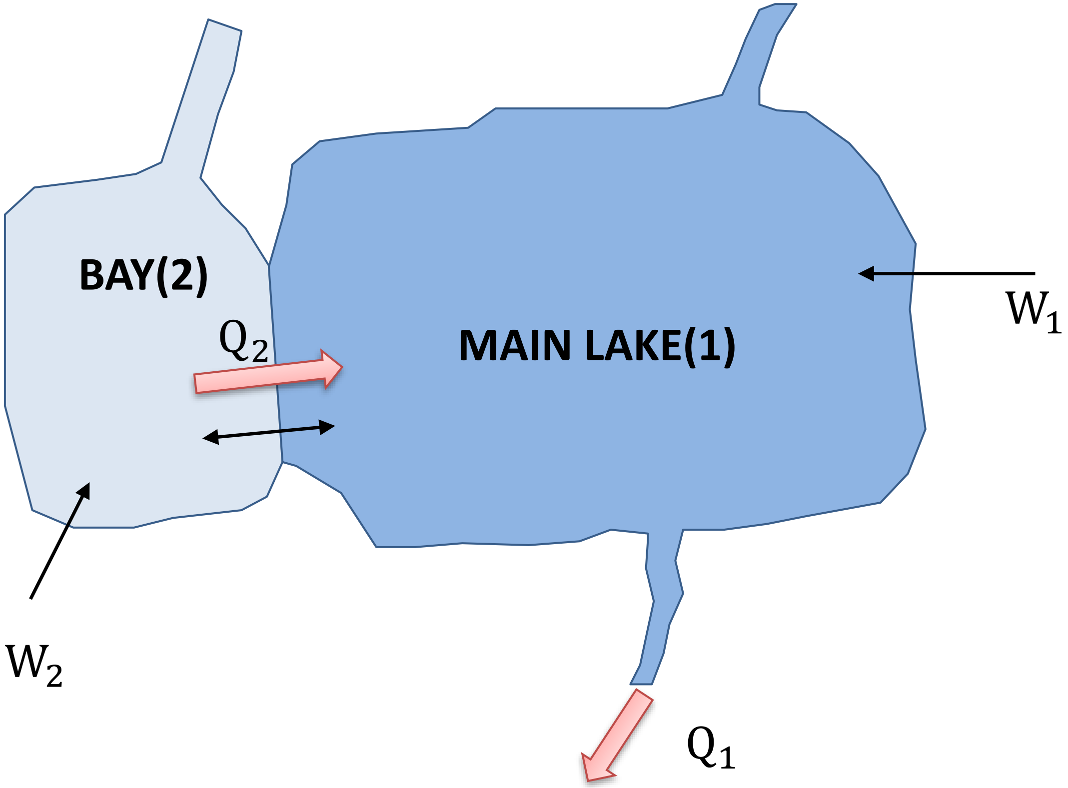
EMBAYMENT MODEL



Mass balancing equation:

Main lake

$$V_1 \frac{dC_1}{dt} = W_1 - Q_1C_1 - k_1V_1C_1 + Q_2C_2 + E'\left(C_2 - C_1\right)$$

Bay

$$V_2 \frac{dC_2}{dt} = W_2 - Q_2C_2 - k_2V_2C_2 + E'\left(C_1 - C_2\right)$$

EMBAYMENT MODEL (Cont)

❖ Estimation of Diffusion

Conservatve are substances that do not have a decomposition process. (k=0)

Mass balance for the bay(2):

$$V_2 \frac{dC_2}{dt} = W_2 - Q_2C_2 + E'(C_1 - C_2)$$

Steady – state slotions

$$E' = \frac{W_2 - Q_2C_2}{C_2 - C_1}$$

Example 2: For a lake and bay, parameters presented in the table

	BAY		LAKE		
Volume	V_2	8	V_1	3507	10^9 m^3
Depth	H_2	5.81	H_1	60.3	m
Surface area	A_2	1,376	A_1	58,194	10^6 m^2
Outflow	Q_2	7	Q_1	161	10^9 $m^3 yr^{-1}$
Chloride concentration	C_2	15.2	C_1	5.4	g m^{-3}
Chloride loading	W_2	0.353	W_1	0	10^{12} g yr^{-1}
Phosphours loading	W_{p2}	1.42	W_{p1}	4.05	10^{12} mg yr^{-1}

Note that the mass diffusion coefficient is determined based on the concentration gradient of Chlo (preservative). Determine the diffusion coefficient and mass-transfer coefficient for the process.

Solutions:

$$E' = \frac{0.353 \times 10^{12} - [7 \times 10^9 \times 15.2]}{15.2 - 5.4} = 25.2 \times 10^9 \quad m^3/năm$$

Mass- transfer coefficient:

$$v_d = \frac{E'}{A_c} = \frac{25.2 \times 10^9}{0.17 \times 10^6} = 1.48 \times 10^5 \; m/năm$$

Diffusion coefficient

$$E = v_d l = 1.48 \times 10^5 \times 10 \times 10^3 = 1.48 \times 10^9 \; m^2/năm$$

Example 3: For a lake and bay, parameters presented in the table

	BAY		LAKE		
Volume	V_2	8	V_1	3507	10^9 m^3
Depth	H_2	5.81	H_1	60.3	m
Surface area	A_2	1,376	A_1	58,194	10^6 m^2
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Phosphours loading	W_{p2}	1.42	W_{p1}	4.05	10^{12} mg yr^{-1}

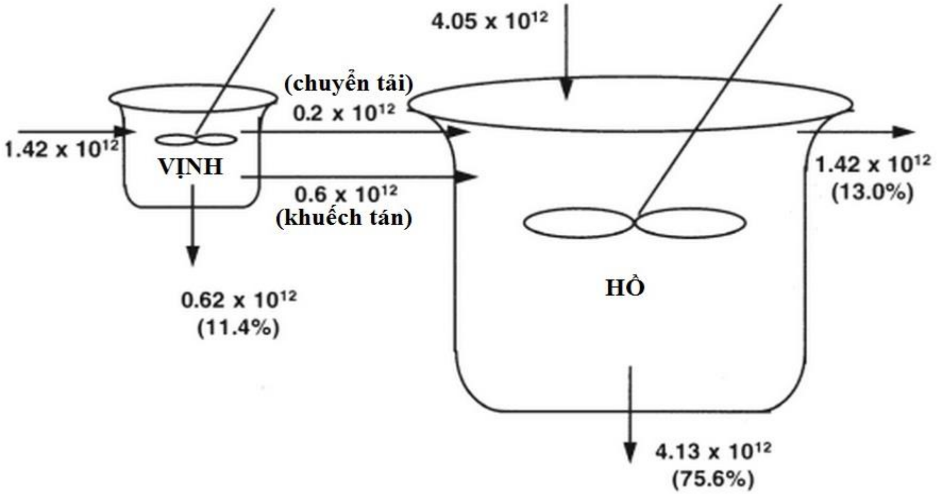
For the deposition rate of phosphorus is v = 16 m/yr. Determine (a) the concentration of inflows, (b) the concentration in the stable state of the lake and bay.

Solution

(a) Inflow flow

$$Q_{1,in} = Q_1 - Q_2 = 161\times10^9 - 7\times10^9 = 154\times10^9\, m^3 yr^{-1}$$

Inflow concentration



$$C_{1,in} = \frac{4.05\times10^{12}}{154\times10^9} = 26.3\mu g L^{-1}$$

$$C_{2,in} = \frac{1.42\times10^{12}}{7\times10^9} = 202.9\mu g L^{-1}$$

(b) Steady – state solution

$$C_1 = \frac{1}{1.102\times10^{12}} W_{p1} + \frac{1}{1.857\times10^{12}} W_{p2} = 3.671 + 0.768 = 4.44\mu g L^{-1}$$

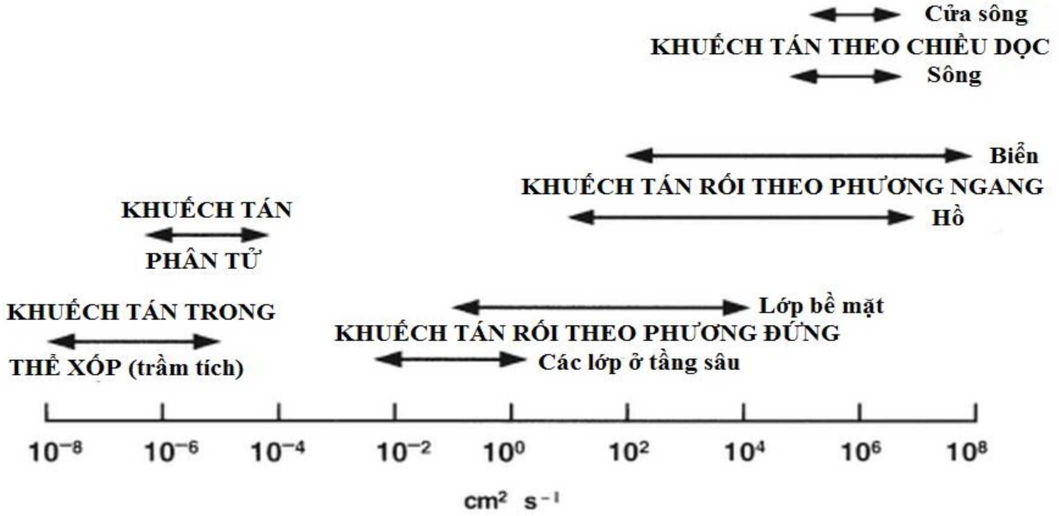
$$C_2 = \frac{1}{2.373\times10^{12}} W_{p1} + \frac{1}{5.345\times10^{12}} W_{p2} = 1.705 + 26.658 = 28.36\mu g L^{-1}$$

ADDITIONAL TRANSPORT MECHANISMS

❖ Diffusion

Mass is spreads via random molecular motion or due to large-scale agitation in the water environment.

- There are two important differences.:
  - + Turbulent motion is greater than the random molecular motion, therefore mixing caused by tangle diffusion is greater than molecular diffusion.
  - + Molecular diffusion takes place uniformly at scale, while Turbulent diffusion takes place in wider-sized ranges. Therefore, diffusion depends on space.



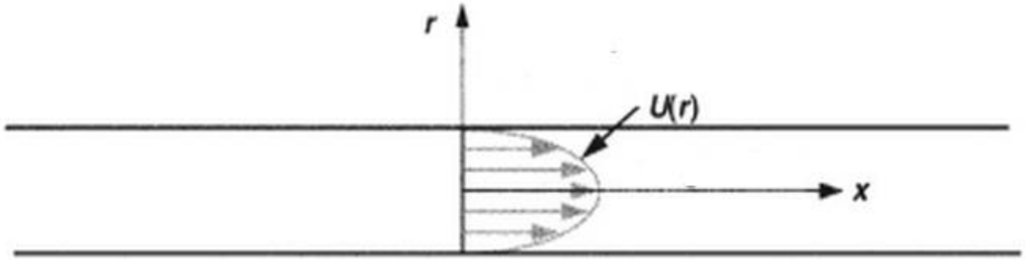
The value range of diffusion coefficients in water and sediment environments

ADDITIONAL TRANSPORT MECHANISMS (cont)

- **Dispersion**

Dispersion involves the process of causing pollutants to spread out. This process is the result of a change in the flow velocity through space.

(a) khuếch tán



(b) phân tán

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ADDITIONAL TRANSPORT MECHANISMS (cont)

CONDUCTION AND CONVECTION

Conduction and convection are two pro- cesses that originate from heat transfer and aerodynamics that are roughly analogous to diffusion and advection

- Conduction refers to the transfer of heat by molecular activity from one sub- stance to another or through a substance
- **Convection** which generally refers to the motions in a fluid that result in the transport and mixing of the fluid's properties, takes two forms.
  - Free convection refers to vertical atmospheric motions due to the buoyancy of heated or cooled fluid, For example in meteorology, the rising of heated surface air and sinking of cooler air aloft is called "free convection
  - Forced convection is due to external forces. An example is the lateral movement of heat or mass due to the wind. Thus forced convection is akin to advection