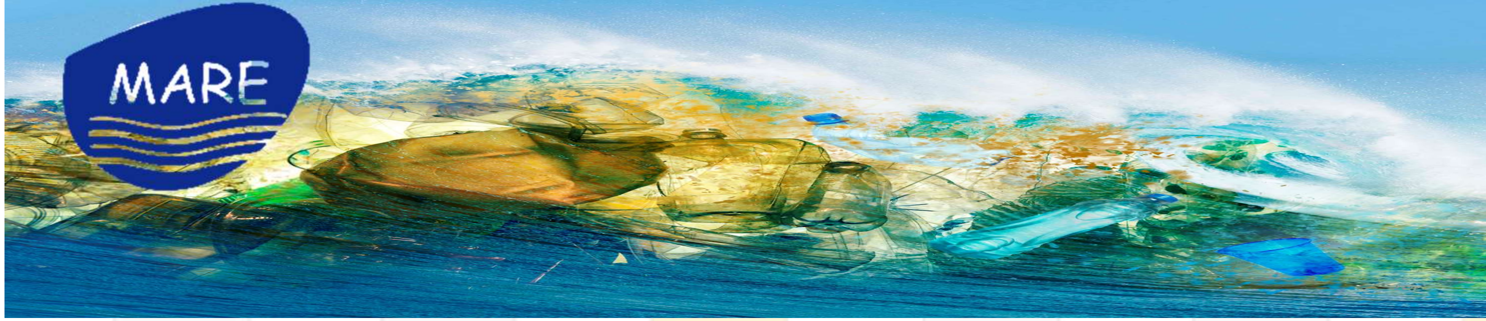

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LECTURE 2:

INTRODUCTION TO MARINE ENVIRONMENT MODELING

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CONTENTS

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- ❖ **Purpose of modelling the marine environmental**
- ❖ **Fundamental quantities**
  - Mass and Concentration
  - Rates
- ❖ **Mathematical models**
  - Model Implementations
  - Conservations of Mass and the Mass Balance

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PURPOSES OF MODELLING THE MARINE ENVIRONMENTAL

❖ Distribution Load Discharge

- Control the marine environment to achieve a specified environmental quality
- Fishery management and offshores works

❖ Determining Total Maximum Daily Load (TMDL)

- TMDL – Total Maximum Daily Load: the calculation of the maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant. A TMDL determines a pollutant reduction target and allocates load reductions necessary to the source(s) of the pollutant.

PURPOSES OF MODELLING THE MARINE ENVIRONMENTAL

❖ **Modelling**

- Understanding the processes of the transmission of substances to the marine and ocean environment

❖ **Understanding of ecosystem**

Understanding of natural system and their reactions to changing conditions.

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FUNDAMENTAL QUANTITIES

❖ Mass and concentration

- **Mass(m):** The amount of pollutant in a system
- **Concentration(C): conventinally express in metric units.**

$$C = \frac{m}{V}$$

C: Concentration [ML^{-3}]

m: mass [M]

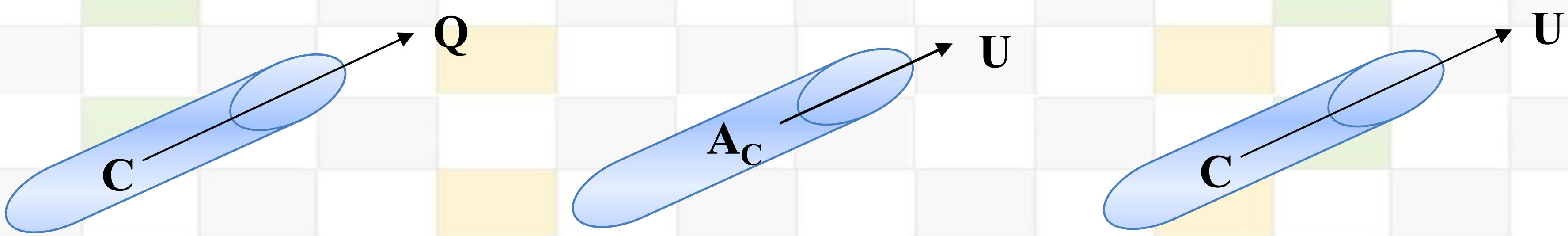
V: Volume [L^3]

Some water – quality variables along with typical units

Varibales	Units
Total Disolved solids, salinity	$gL^{-1} \Leftrightarrow kg\ m^{-3} \Leftrightarrow ppt$
DO, BOD, NO_2	$mgL^{-1} \Leftrightarrow g\ m^{-3} \Leftrightarrow ppm$
PO^4, Chlorophyll a, Toxics	$\mu gL^{-1} \Leftrightarrow mg\ m^{-3} \Leftrightarrow ppb$
Toxics	$ngL^{-1} \Leftrightarrow \mu g\ m^{-3} \Leftrightarrow pptr$

FUNDAMENTAL QUANTITIES (cont.)

❖Rates



Loading: W = Q.C

Flow: Q = U.A_c

Flux: J = U.C

Flux is used to designate the rate of movement of an extensive quantity like mas or heat through a conduit.

$$J = \frac{m}{tA_c} = \frac{W}{A_c}$$

W: Loading [M/T].

C: Concentration[M/L^3].

Q: Flow [L^3/T].

U: Velocity [L/T].

t: time [T].

A_C: Cross-section area[L^2].

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FUNDAMENTAL QUANTITIES (cont.)

Example 1:

A pond having constant volume and no outlet has a surface area A , of 104 m^2 and a mean depth H of 2 m . It initially has a concentration of 0.8 ppm . Two days later a measurement indicates that the concentration has risen to 1.5 ppm

(a) What was the mass loading rate during this time ?

(b) If you hypothesize that the only possible source of this pollutant was from the atmosphere , estimate the flux that occurred .

FUNDAMENTAL QUANTITIES (cont.)

Example 1

Solution:

(a) The volume of the system can be calculated as:

$$V = A_s\, H = 10^4\ m^2\ (2m\ ) = 2 \times 10^4\ m^3$$

The mass of pollutant at the initial time (t= 0) can be computed as:

$$m = Vc = 2 \times 10^4\ m^3\ (\ 0.8\ g\ m^{-3}\ ) = 1.6 \times 10^4\ g$$

and at t = 2d is 3.0 x 10^4 g . Therefore the increase in mass is 1.4 x 10^4 g and the mass loading rate is:

$$W = \frac{1.4\ x\ 10^4 \mathrm{g}}{2\mathrm{d}} = 0.7 \times 10^4\ g\ /d^{-1}$$

(b) The flux of pollutant can be computed as

$$J = \frac{0.7\ x\ 10^4 \mathrm{g/d}^{-1}}{1\ x\ 10^4\ \mathrm{m}^2} = 0.7\ g\ (m^2\ d)^{-1}$$

MATHEMATICAL MODELS

Mathematical modes can be represented generally:

C = f (W, physics, chemistry, biology)

→ The cause – effect relationship between loading and concentration depends on the physicals, chemical and biological characteristics of the receiving water.

$$C = \frac{1}{a} W$$

where a = an assimilation factor ($L^3 T^{-1}$) that represents the physics , chemistry , and biology of the receiving water . This Equation is called " linear " because c and W are directly proportional to each other . Consequently if W is doubled , c is doubled . Similarly if W is halved , c is halve

MATHEMATICAL MODELS

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❖ Model Implementation

(a) Simulation mode: the model is used to simulate system response (concentration) as a function of a stimulus (loading) and system characteristics (the assimilation factor)

$$C = \frac{1}{a}W$$

(b) Design mode I (Assimilative capacity)

The model can be rearranged to yield : **W = ac**

This implementation is referred to as a " design " mode because it provides information that can be directly used for engineering design of the system. It is formally referred to as an " assimilative capacity " computation because it provides an estimate of the loading required to meet a desirable concentration level or standard . Thus it forms the basis for wastewater treatment plant design . It should also clarify why a is called an " assimilation factor

(c) Design Mode II (environmental modification)

A second design implementation is **a = W/C**. In this case the environment itself becomes the focus of the remedial effort . This equation is formulated to determine how , for a given loading rate , the environment might be modified to achieve the prescribed standard . This type of application is needed when affordable treatment (that is , reduction in W) is not adequate to meet water - quality standards .

MATHEMATICAL MODELS

Example 2: (ASSIMILATION FACTOR)

Lake Ontario in the early 1970s had a total phosphorus loading of approximately 10,500 mta (metric tonnes per annum , where a metric tonne equals 1000 kg) and an in - lake concentration of 21 μg/L. In 1973 the state of New York and the province of Ontario ordered a reduction of detergent phosphate content . This action reduced loadings to 8000 mta .

(a) Compute the assimilation factor for Lake Ontario?

(b) What in - lake concentration would result from the detergent phosphate reduction action ?

(c) If the water - quality objective is to bring in - lake levels down to 10 μg L^{-1}, how much additional load reduction is needed ?

MATHEMATICAL MODELS

Example 2: (ASSIMILATION FACTOR)

Solution:

(a) The assimilation factor can be calculated as

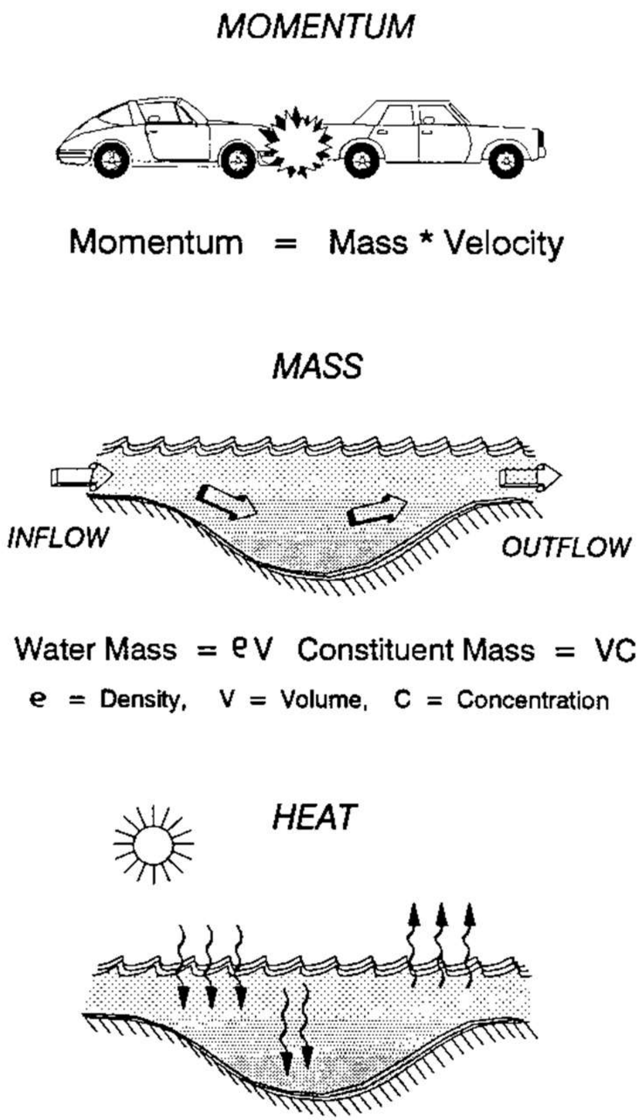
$$a = \frac{W}{c} = \frac{10{,}500\ \text{mta}}{21\mu g/L} = 500\,\frac{\text{mta}}{\mu g\ L^{-1}}$$

(b) In - lake levels from the phosphorus reduction can be calculated as:

$$c = \frac{W}{a} = \frac{8000\ \text{mta}}{500\frac{\text{mta}}{\mu g\ L^{-1}}} = 16\ \mu g\ L^{-1}$$

(c) $W = ac = 500\,\frac{\text{mta}}{\mu g\ L^{-1}} \times 10\ \mu g\ L^{-1} = 5000$ mta

CONSERVATIONS OF MASS AND THE MASS BALANCE



❖ **Law of Conservation of Mass**

The mass in an isolated system can neither be created nor be destroyed but can be transformed from one form to another **(**Antoine Lavoisier's 1789)

- Some of Law of Conservation:
  - Mass
  - Momentum
  - Heat

In quantitative terms the principle is expressed as a mass - balance equation that accounts for all transfers of matter across the system's boundaries and all transformations occurring within the system

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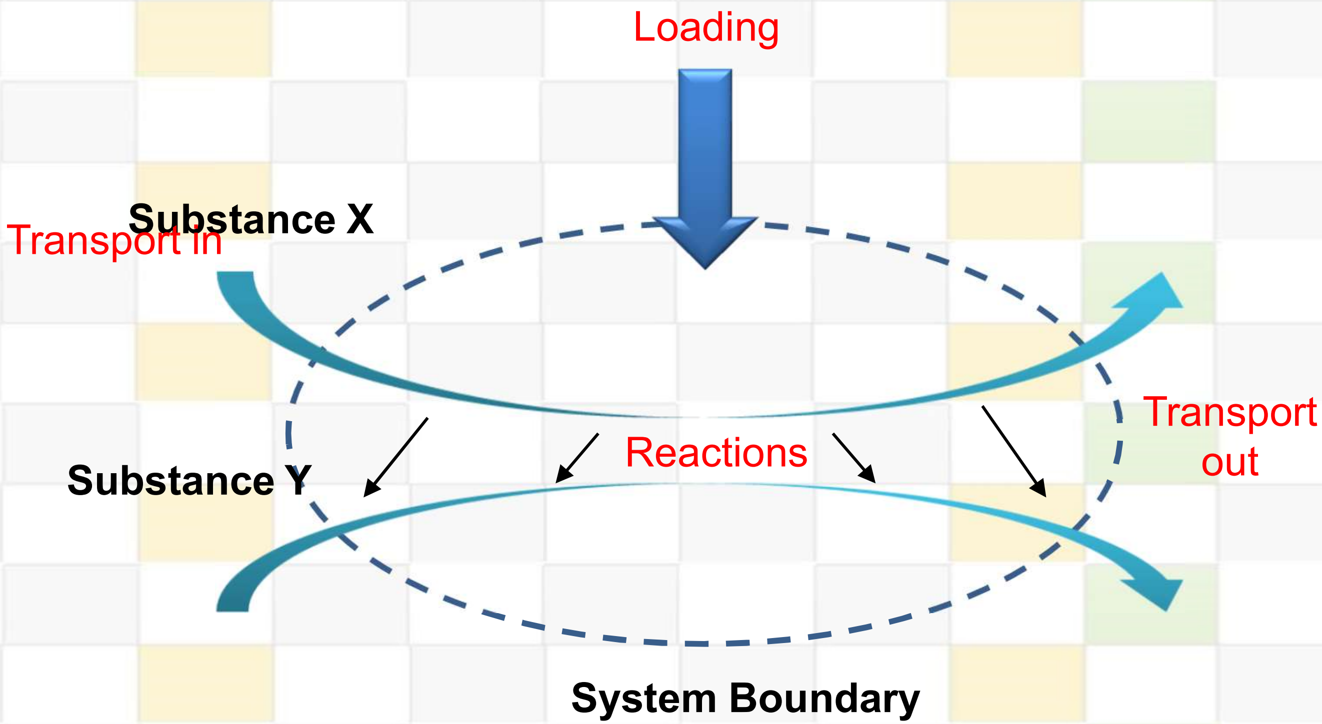
CONSERVATIONS OF MASS AND THE MASS BALANCE



For a finite period of time this can be expressed as:

Accumulation = loadings transport ± reactions

CONSERVATIONS OF MASS AND THE MASS BALANCE

SYNTHESIS REACTIONS	DECOMPOSITION REACTIONS	NON - REACTIVE SUBSTANCES
• Product of chemical reaction • The growth of algae in the water • Gas absorption • Chemical desorption	• Reactants • BOD • Radioactive decay • Sedimentation • Decomposition of organic matter • Chemical adsorption • Degasification	• Chloride Cl^-, Bromide Br^- • Non-biodegradable organic matter • Metals • Stable isotopes

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HISTORICAL DEVELOPMENT OF WATER – QUANLITY MODELS

- 1925-1960: Streeter-Phelps
- 1960-1970: Computerization
- 1970-1977: Biology
- 1977 – present: Toxics

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- **1925-1960 (streeter-Phelps)**

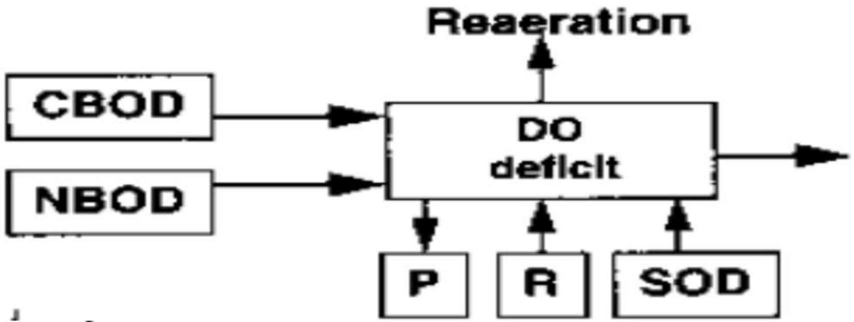
Problems: untreated and primary effluent

Pollutants: BOD/DO

Systems: streams/estuaries (1D)

Kinetics: linear, feed-forward

Solutions: analytical



- **1960-1970** (computerization)

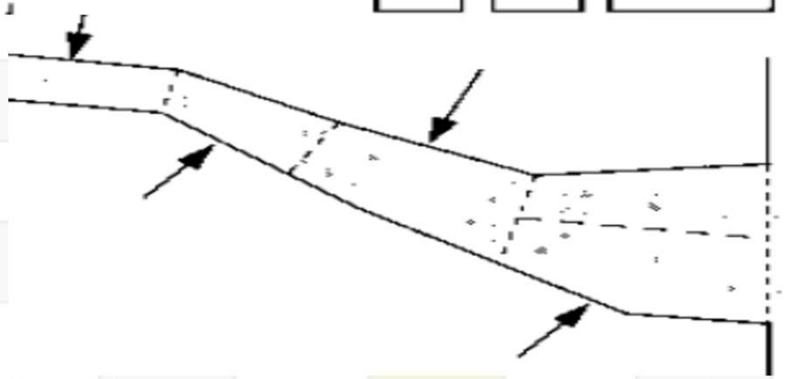
Problems: primary and secondary effluent

Pollutants: BOD/DO

Systems: estuaries/streams(1D/2D)

Kinetics: linear, feed-forward

Solutions: analytical and numerical



- **1970-1977 (biology)**

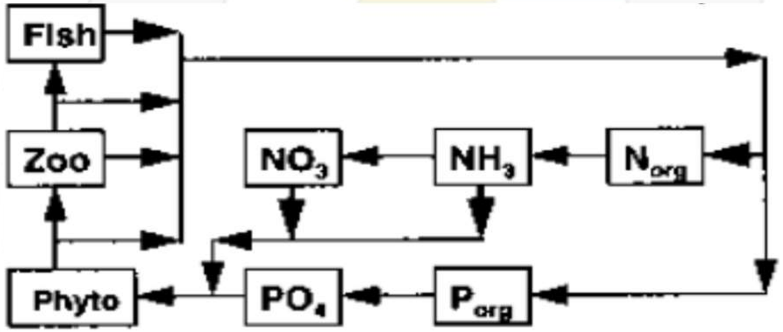
Problems: eutrophication

Pollutants: nutrients

Systems: lakes/estuaries/streams (1D/2D/3D)

Kinetics: nonlinear, feedback

Solutions: numerical



- **1977 - nay (toxics)**

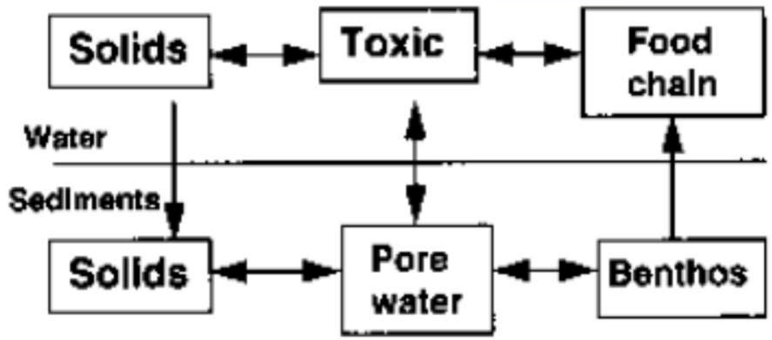
Problems: Toxics

Pollutants: organic,m metals

Systems: Sediment-water interactions/food chain ineteraction (lakes/estuaries/stream)

Kinetics: linear, equilibrum

Solutions: numerical and analytical



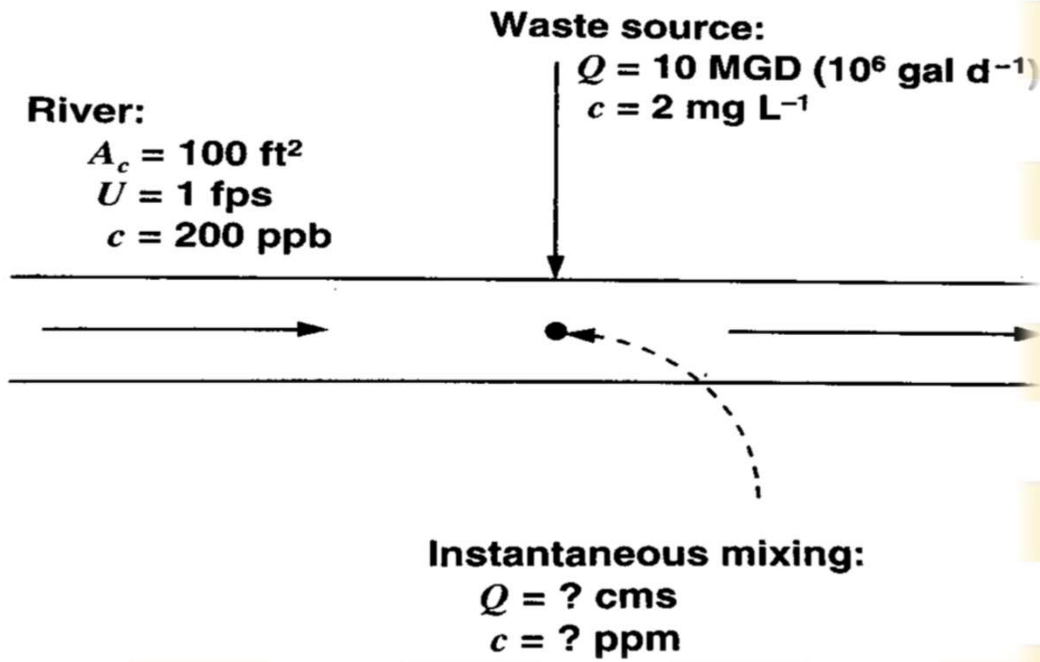
EXERCISES

Ex.2.1: A waste source enters a river as depicted in figure below.

(a) What is the resulting flow rate in m^3s^{-1} (cms)?

(b) If instantaneous mixing occurs, what is the resulting concentration in ppm?

where: 1 gallon=3.785 l, 1ft=0.3048 m, 1ft/s=0.3048 m/s.

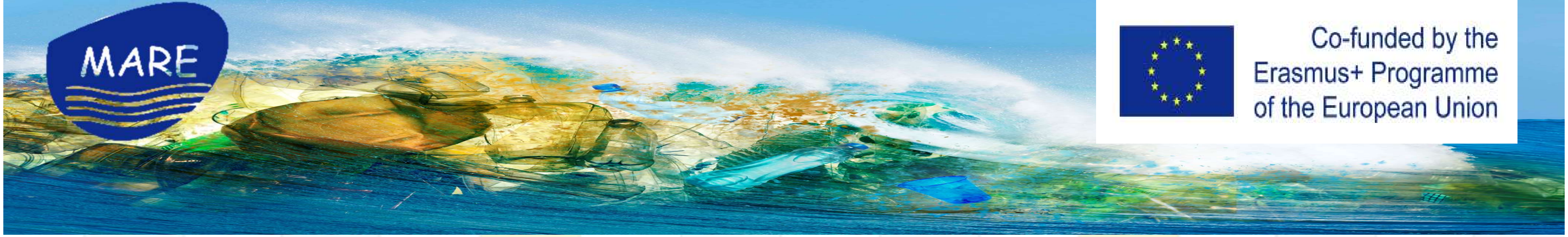


EXERCISES

Ex. 2.2: I the early 1970s Lake Michigan had a total phosphourus loading 6950 mta (mta: metric tones per annum. Metric tone=1000kg;T.e mta=10^3 kg/year) and an in-lake concentration of 8 μg/L

a) Determine the lake's assimilation factor (km^3/year)

b) What loading rate would be required to bring in-lake levels down to approximately 5 μg/L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