ENVIRONMENTAL ENGINEERING

Chapter 3 : Water Treatment (Part 2)

Physical, Chemical & Biological Processes

by
Siti Hajar Noor
Faculty of Chemical & Natural Resources Engineering
hajarnoor@ump.edu.my

Chapter Description

- Topic
  - Physical process
  - Chemical process
  - Biochemical process

- Topic Outcomes
  - State the principles and unit operation involves in physical, chemical and biochemical processes in the treatment.
  - Discuss the unit operation involves in the process

- References

  - Peavy, H.S., Rowe, D.R. and Tchobanoglous, G., Environmental Engineering, McGraw Hill, 1985.
  - Mackenze, I.D., Introduction to Environmental Engineering, 4th Edition, Davis A. Cornell, Mc Graw Hill, 2008.
  - Sawyer, C.N. Chemistry for Environmental Engineerin. 4th Edition, McGraw Hill, 1994.
  - Martin, T.A. and David, W.H. Fundamental of Environmental Engineering. 2003.
  - Environmental Quality Act 1974 (Subsidiary Legislation), International Law Book, Service June 2002.

Contents

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

1. Physical Processes

- Dilution
- Sedimentation & Resuspension
- Filtration
- Gas Transfer
- Heat Transfer

2. Chemical Processes

- Chemical Conversion

3. Biochemical Processes

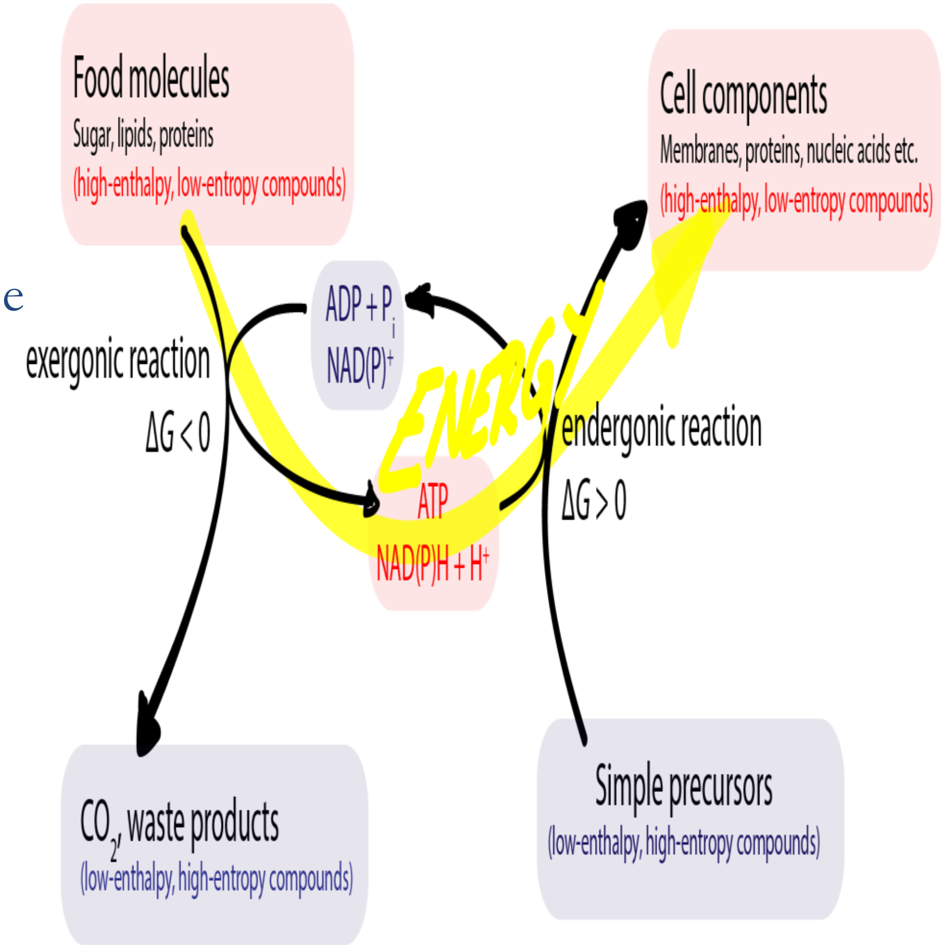
- Metabolic processes
- Microorganism in natural water system
- Dissolved oxygen balance
- Organic discharge & stream ecology

PART 2

BIOCHEMICAL PROCESSES

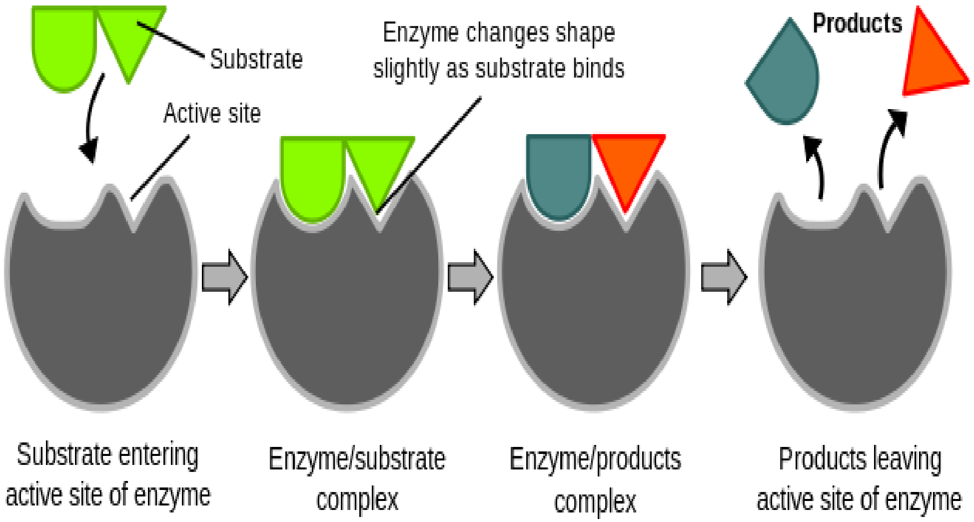
1-Metabolic Processes

- Metabolism- sum total of the processes by which living organism take and use food for subsistence, growth and reproduction.
- Two types of process (occur simultaneously):
  - **Catabolism** – breaks down molecules (*e.g.* glucose) into smaller units to release energy.
  - **Anabolism** –the process by which the body utilizes the energy released by catabolism to synthesize complex molecules (*e.g.* protein, nucleic acids, *etc.*).
- Endegenous catabolism – organisms used stored food for maintenance energy in a process.
- Each type of microorganism has different metabolic pathway; specific reactants and specific end products.

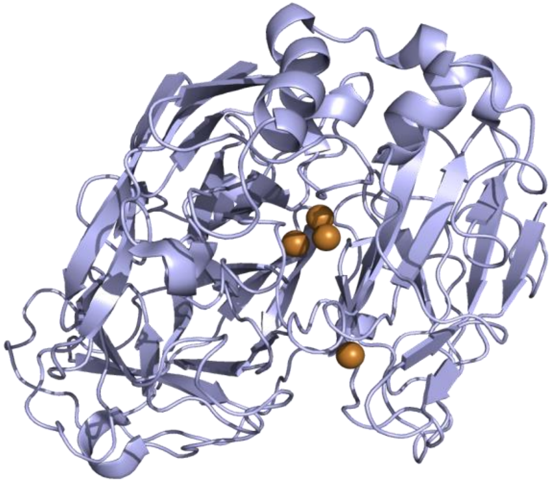


Source:https://upload.wikimedia.org/wikipedia/commons/thumb/8/80/Catabolism%2C_energy_carriers_and_anabolism.png/640px-Catabolism%2C_energy_carriers_and_anabolism.png

- **Enzyme:**
  - Organic catalyst that influence reaction without becoming reactant themselves.
  - Lower activation energy to initiate reactions.
  - Revert to its original form for reuse.
  - *Adaptive enzymes*: produced by cell when they are exposed to unusual, toxic substances
    - Microorganism capable of decomposing and utilizing the toxic compound (*e.g.*: phenol-splitting bacteria)



Source:https://upload.wikimedia.org/wikipedia/commons/thumb/2/24/Induced_fit_diagram.svg/1280px-Induced_fit_diagram.svg.png



Crystal structure of enzyme (laccase).

2-Microorganism in Natural Water System

Bacteria

- Primary decomposers of organic material.
- Classified according to energy and material sources they require.
  - ***Autotrophs* –** derive both energy & material from inorganic sources:
    - Oxidize nitrogen and sulfur to stable end products.
  - ***Heterotrophs* –** derive both energy & material from organic compound:
    - Most important in degradation of organic matters.
  - ***Phototrophs* –** utilize sunlight for an energy source, inorganic substance for material source.

Protozoa

- Ingest solid organic for foods.
- Consume organic materials & colloidal matters.

Algae

- Algal photosynthesis.
  - In presence of sunlight, algae metabolize inorganic compound with oxygen as waste.
  - Excessive nutrient & bright sunlight – algal produce too much O_2 thus the water become saturated.
  - In the absence of light, catabolism may deplete DO to the point where fish kills occur (heavy algal growth).

$$CO_2 + 2H_2O \xrightarrow{light} CH_2O + O_2 + H_2O$$

$$CH_2O + O_2 \longrightarrow CO_2 + H_2O$$

Source:https://encrypted-tbn0.gstatic.com/images?q=tbn:ANd9GcQYzo2Bq-2_bq68BCGdxaEyFdIpAvHp81m8oyudYK9VpZWyss-J

3-Dissolve Oxygen (DO) Balance

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

- At least 2 mg/L DO to maintain aquatics life.
- Two mechanism are known to contribute oxygen to surface water which are:
  a) **Reaeration** (dissolution of O_2 from atmosphere).

$$D = C_s - C$$

Where D is DO deficit; C_s is equilibrium concentration; C is oxygen concentration

Greater the D, greater the reaeration (DO decreased).

  b) **Algal photosynthesis** (produce O_2).

Rate of oxygen removal

- The rate at which dissolved O_2 disappears from the stream.

$$k_T = k_{20}\theta^{T-20^\circ}, \theta = 1.047$$

$$r_D = k_1 L_t$$

r_D: rate of O_2 deficit due to O_2 utilization .
k_1: reaction rate constant as described in chapter 2.
L_t: amount of O_2 remain at time t.

Rate of oxygen addition

- The rate of reaeration is a first order reaction with respect to magnitude of the O_2 deficit.

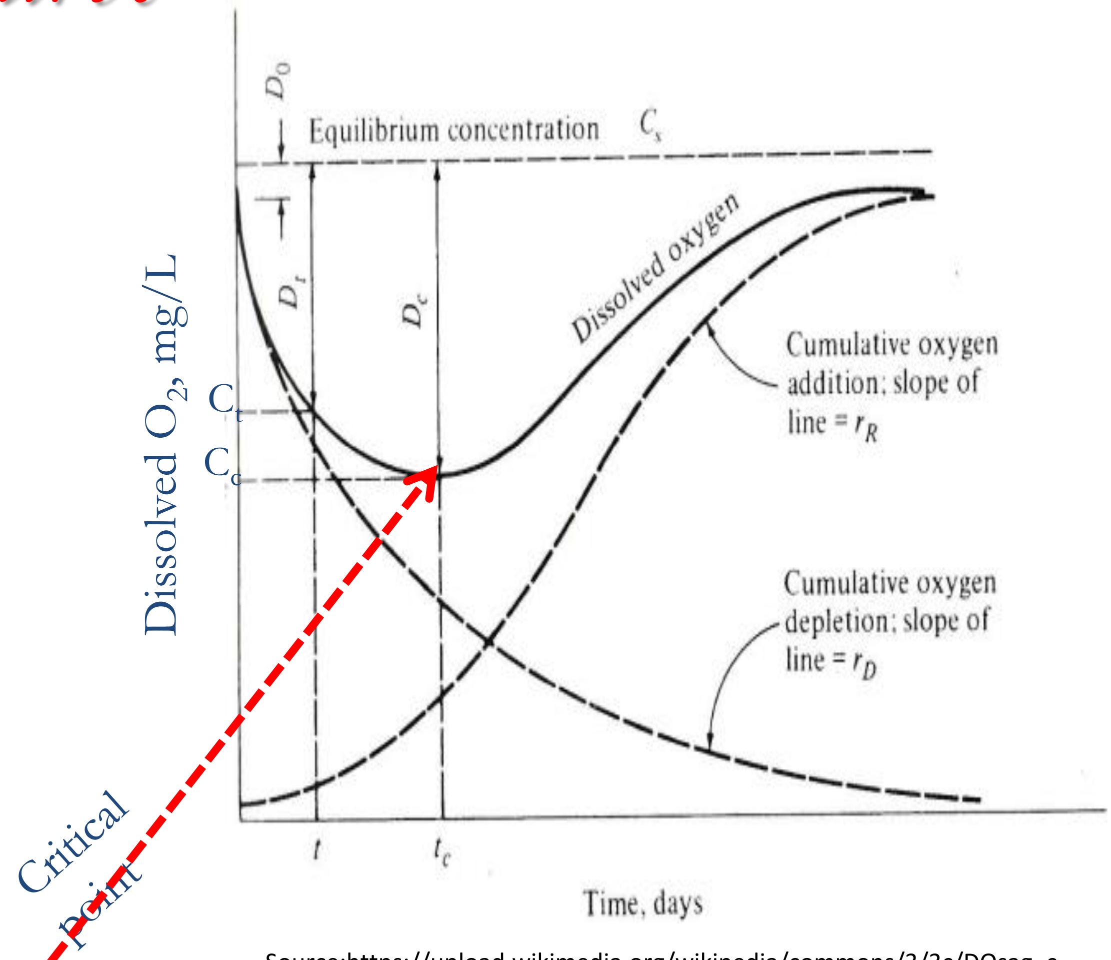
$$k_T = k_{20}\theta^{T-20^\circ}, \theta = 1.016$$

$$r_R = -k_2 D$$

r_R: rate at which O_2 dissolve from atmosphere.
k_2: reaeration rate constant. $D = C_s - C$
D: dissolve O_2 deficit defined by:

The oxygen sag curve

- Oxygen demand causes an oxygen deficit (oxygen shortage).
- The greater the oxygen deficit, the greater the rate of natural oxygen replenishment from the atmosphere into the stream.
- These two concurrent processes of oxygen consumption and oxygen replenishment produce an oxygen sag curve.



Source:https://upload.wikimedia.org/wikipedia/commons/3/3c/DOsag_curve.jpg

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

- Streeter-Phelps equation:

$$D_t = \frac{k_1 L_o}{k_2 - k_1}\left(e^{-k_1 t} - e^{-k_2 t}\right) + D_o e^{-k_2 t}$$

D_t : oxygen deficit at in river at time t.

D_o : initial oxygen deficit at in river at time 0.

L_o : initial ultimate BOD.

t : time of travel in the stream from the point of discharge (unit: day)

$$t = \frac{x}{u}$$

$\boldsymbol{x}$: *distance along the stream*
$\boldsymbol{u}$: *stream velocity*

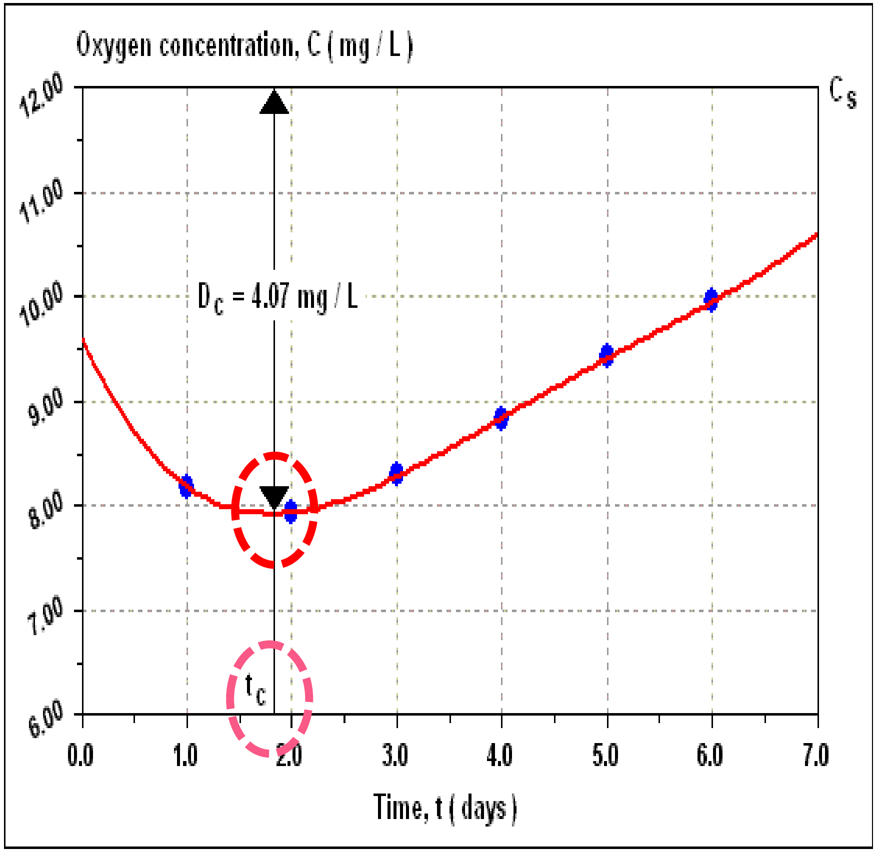
The critical deficit

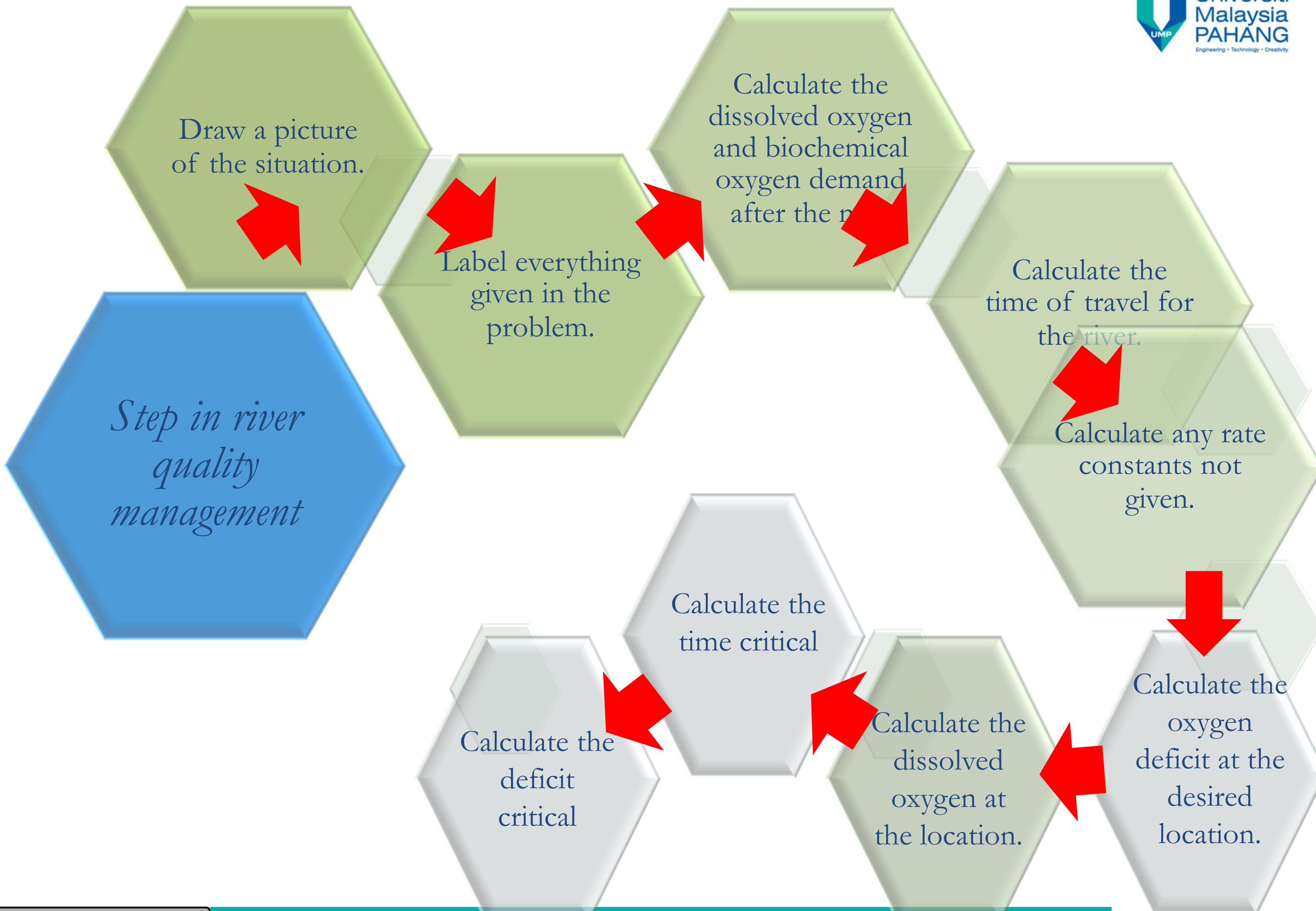
- The point of lowest concentration for represents the maximum impact on the dissolved oxygen due to wastewater discharge.
- Critical deficit, D_c

$$D_c = \frac{k_1}{k_2} L_o e^{-k_1 t_c}$$

- Critical time, t_c (time of travel to critical point):

$$t_c = \frac{1}{k_2 - k_1} \ln\left[\frac{k_2}{k_1}\left(1 - D_0 \frac{k_2 - k_1}{k_1 L_0}\right)\right]$$




Step in river quality management
Draw a picture of the situation.
Label everything given in the problem.
Calculate the dissolved oxygen and biochemical oxygen demand after the
Calculate the time of travel for the river.
Calculate any rate constants not given.
Calculate the oxygen deficit at the desired location.
Calculate the dissolved oxygen at the location.
Calculate the time critical
Calculate the deficit critical

End of Chapter 3

Communitising Technology

Author Information

Credit to the author: Dr Norhanimah Hamidi