Rotary Biological Contactors

CE - 370

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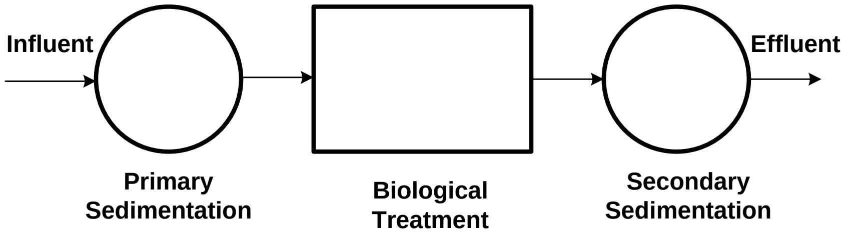
Biological Treatment



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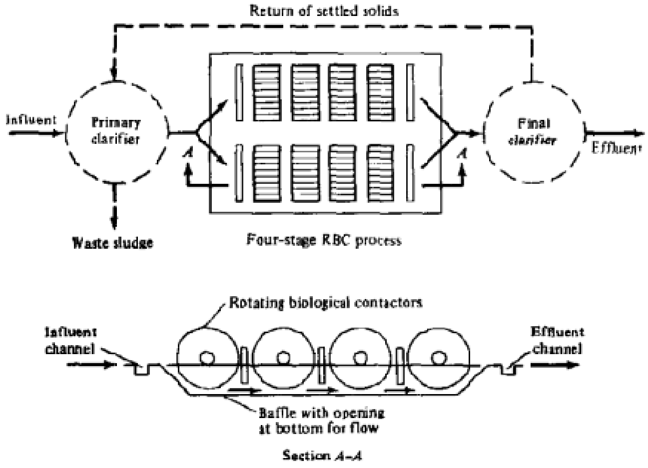
Rotating Biological Contactor (RBC)



Flow Diagram of an RBC

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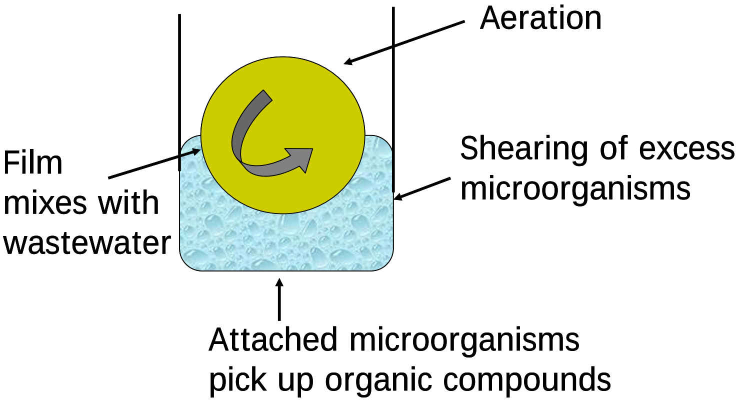
Rotating Biological Contactors



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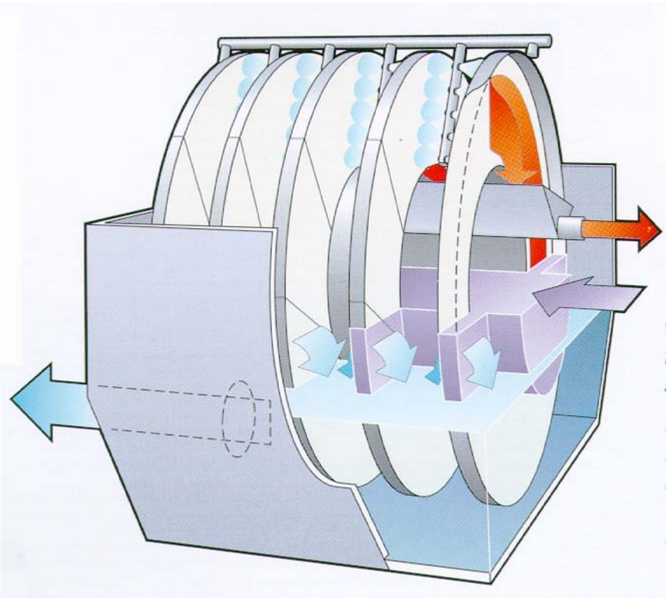
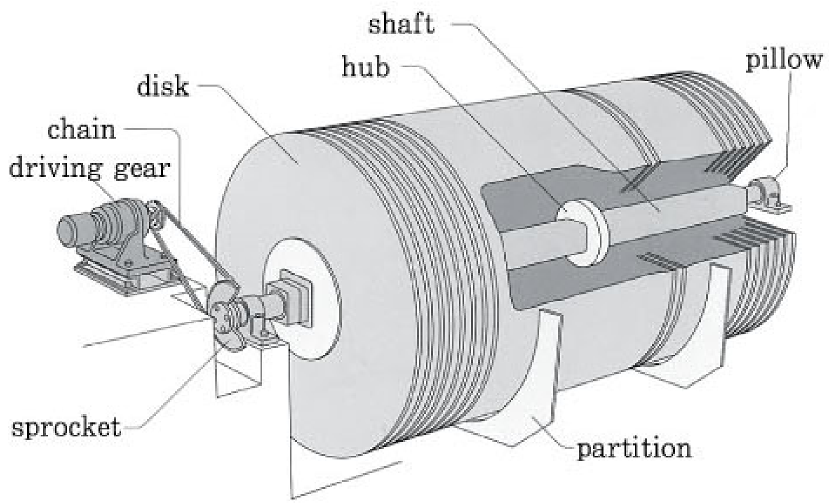
Main Characteristics

- Composed of multiple discs mounted on a horizontal shaft that passes through the center of the discs
- Wastewater flow is perpendicular to the shaft
- About 40% of the total disc area is submerged
- Biological film grows on the disc
- As the shaft rotates, the biological growth (film) sorbs organic matter from wastewater
- Oxygen is adsorbed from air to keep aerobic condition
- Multiple stages of RBC is used to achieve greater BOD5 removal
- Sloughed biological growths are removed in final clarifiers
- No recycle is employed
- Biological activities are reduced during cold weather
- In cold climates, RBCs are covered to avoid heat loss and protect against freezing




shaft
hub
pillow
disk
chain
driving gear
sprocket
partition

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Design

- The main design parameter is the wastewater flowrate per surface area of the discs
  - Is called the hydraulic loading (m^3/day-m^2)
  - Indirectly represents the F/M ratio
    - Wastewater flowrate is related to mass of substrate
    - Disc surface area is related to mass of microbes
- For municipal wastewater, four (4) stages are used, but if nitrification is required, five (5) stages are employed

Design

- Advantages
  - Low energy requirement compared to activated sludge
  - Can handle high loading rate
  - Ability to handle shock loadings
  - Ability of multistage to achieve high degree of nitrification
  - Minimal maintenance
  - Simple operation
  - Package configuration

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Kinetics

- Kinetic equation of RBC is based on substrate removal
  - (1/X)(dS/dt) = specific rate of substrate utilization
  - (dS/dt) = rate of substrate utilization
  - k = rate constant
  - S = substrate concentration
  - Q = flowrate
  - S_0 = influent substrate concentration
  - S_e = effluent substrate concentration
  - X = cell mass
  - A = disc area

$$-\frac{1}{X}\frac{dS}{dt} = kS$$

$$\frac{dS}{dt} = Q(S_0 - S_e)$$

$$-\frac{1}{X}Q(S_0 - S_e) = kS_e$$

$$X \propto A$$

$$\frac{Q}{A}(S_0 - S_e) = kS_e$$

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Kinetics

- The term $(Q/A)(S_o - S)$ is equal to the rate of reaction, r. Thus,

$$\frac{Q}{A}(S_0 - S) = r = kS \qquad \text{Equation 17.19}$$

This equation is in the form of (y = mx), so it can be graphically presented as shown in figure 17.10. Rearranging above equation:

$$\frac{Q}{A} = \frac{r_1}{S_o - S_1} = slope \qquad \text{Equation 17.20}$$

For a series of contactors (n contactors):

$$\frac{Q}{A} = \frac{r_n}{S_{n-1} - S_n} \qquad \text{Equation 17.21}$$

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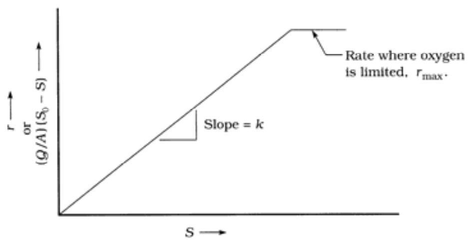

FIGURE 17.10
Plot of Equation (17.19)

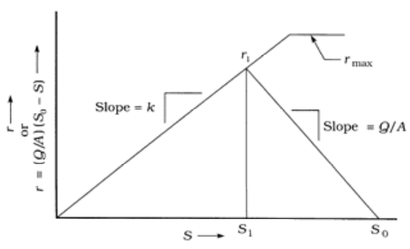

FIGURE 17.11
Plot of Equations (17.19) and (17.20)

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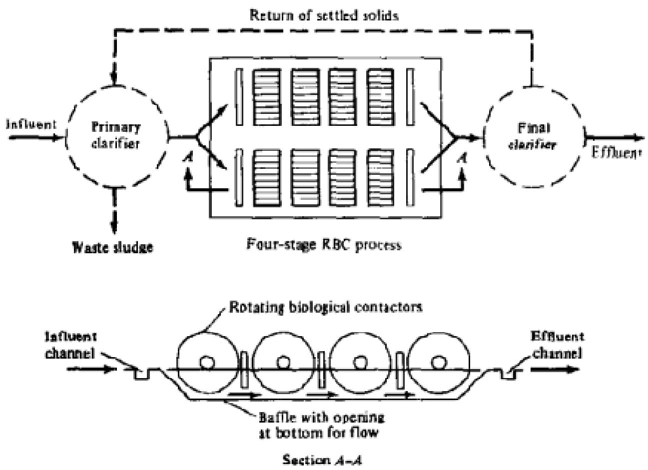

Flow Diagram of an RBC

Kinetics

- Graphical Solution to equation 17.21:
  - Hydraulic loading (Q/A) is determined by trail-and-error

$$\frac{Q}{A} = \frac{r_n}{S_{n-1} - S_n}$$

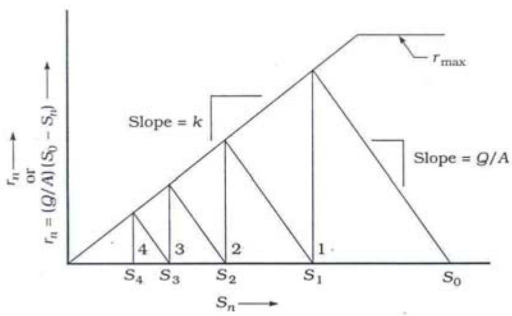

FIGURE 17.12 *Four-Stage Rotary Biological Contactor*

Kinetics

- Algebraic Solution to equation 17.21:

$$Divide \ \frac{Q}{A}(S_0 - S) = kS \ \ by \ (Q/A) \ and \ \ S$$

$$\frac{S_0 - S}{S} = \frac{k}{Q/A} \qquad rearrange \text{ , gives the following}$$

$$\frac{S}{S_0} = \frac{1}{1 + \frac{k}{Q/A}}$$

For the first stage,

$$S_1 = \left(\frac{1}{1 + \frac{k}{Q/A}} \right) S_o$$

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For the second stage,

$$S_2 = \left(\frac{1}{1 + \frac{k}{Q/A}} \right) S_1$$

or

$$S_2 = \left(\frac{1}{1 + \frac{k}{Q/A}} \right) \times \left(\frac{1}{1 + \frac{k}{Q/A}} \right) S_o$$

Therfore ,

$$\frac{S_2}{S_0} = \left(\frac{1}{1 + \frac{k}{Q/A}} \right)^2$$

or

$$\frac{S_n}{S_0} = \left(\frac{1}{1 + \frac{k}{Q/A}} \right)^n$$

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Example 17.5

EXAMPLE 17.5 AND 17.5 SI

Rotary Biological Contactors (RBC)

A municipality with a design population of 6900 persons is to have a rotary biological contactor plant designed. Pertinent data are average flow = 100 gal/cap-day (380 ℓ/cap-d), influent BOD_5 = 200 mg/ℓ, primary clarifier removes 33% BOD_5, total effluent BOD_5 = 20 mg/ℓ, and number of stages = 4. If a pilot-plant study gave a k value of 1.16 gal/day-ft^2 (47.3 ℓ/d-m^2) and the algebraic method is used, determine:

1. The design hydraulic loading.
2. The BOD_5 after each stage.
3. The disk area per stage.
4. The total disc area.
5. The number of shafts per stage and the total shafts for the plant if a shaft has 100,000 ft^2 (9289 m^2) of surface area.

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SOLUTION The performance of rotary biological contactors is given by

$$\frac{S_n}{S_0} = \left(\frac{1}{1 + \dfrac{k}{Q/A}}\right)^n$$

The influent BOD_5, $S_i = S_0 = 200(1 - 0.33) = 134$ mg/ℓ, the effluent BOD_5, $S_4 = 20$ mg/ℓ, and $k = 1.16$ gal/day-ft^2. Inserting these values into the performance equation gives

$$\frac{20}{134} = \left(\frac{1}{1 + \dfrac{1.16}{Q/A}}\right)^4$$

Solving this equation gives $\boxed{Q/A = 1.91 \text{ gal/day-ft}^2}$. The BOD_5 after each stage can now be determined by substituting $Q/A = 1.91$ gal/day-ft^2, $S_0 = 134$ mg/ℓ, and $k = 1.16$ gal/day-ft^2 into the performance equation to give

$$\frac{S_n}{134} = \left(\frac{1}{1 + 1.16/1.91}\right)^n = 0.6221^n$$

or

$$S_n = (134)(0.6221)^n$$

From this equation, $\boxed{S_1 = 83 \text{ mg/ℓ}, S_2 = 52 \text{ mg/ℓ}, S_3 = 32 \text{ mg/ℓ}, \text{ and } S_4 = 20 \text{ mg/ℓ}.}$ The influent flow = (6900 cap)(100 gal/cap-day) = 690,000 gal/day. The disc area per stage is

$$A = \left(\frac{690{,}000 \text{ gal}}{\text{day}}\right)\left(\frac{\text{day-ft}^2}{1.91 \text{ gal}}\right) = \boxed{362{,}000 \text{ ft}^2}$$

The total disc area is

$$A = \left(\frac{362{,}000 \text{ ft}^2}{\text{stage}}\right)\left(4 \text{ stages}\right) = \boxed{1{,}450{,}000 \text{ ft}^2}$$

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