ENVE 301
Environmental Engineering Unit Operations

Lecture 6
Cascade Aeration Cont'd

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Cascade Aeration

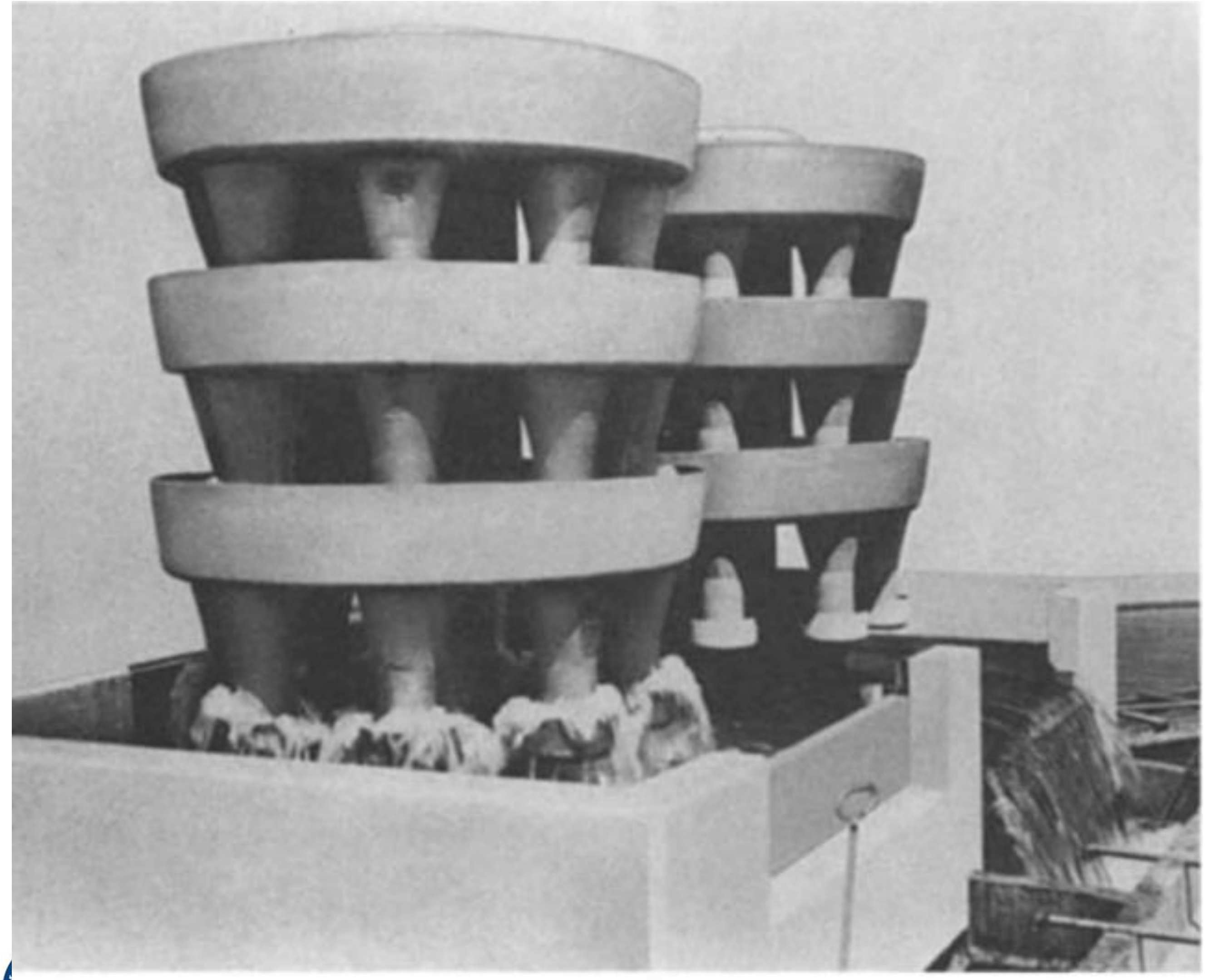

FIGURE 5.1 View of a typical cone aerator. (*Courtesy of Ondeo Degremont.*)

Ref: AWWA ASCE Water Treatment Plant Desing, 4t Edition, Baruth EE (Ed.) McGrawHill

Cascade Aeration

Ref: http://www.pub.gov.sg/products/usedwater/Pages/IndustrialWaterProductionProcess.aspx?Print2=yes

Cascade Aeration – as a final stage of ww treatment

Ref:
http://yorkcity.org/final-effluent-aeration

Cascade Aeration

Ref:

http://www.holar.is/~aquafarmer/node66.html

Cascade Aeration – Ömerli WTP

Picture: Courtesy of Prof. Dr. A.M. Saatcı

Cascade Aeration

Picture: Courtesy of Assist. Prof. B. Alpaslan-Kocamemi

Design Considerations for Cascade Aeration

Surface Loading: 50-100 m^3/m^2.sec (Literature)

Surface Loading: 50-200 m^2/m^3.sec (Prof. Dr. A.M. Saatcı notes)

Total Height: 2-7 m (0.3-0.6 m per step)

If step height <0.6 m → less oxygen transfer
desorption will prevail

For optimum desorption; step height 0.2-0.4 m

- Conversion of **1 mg/L Fe^{2+}** requires **0.14 mg/L O_2**

$$4Fe^{2+} + O_2 + 10H_2O \rightarrow 4Fe(OH)_3 + 8H^+$$

Fe molecular weight: 55.8 g/mol

- Conversion of **1 mg/L Mn^{2+}** requires **0.29 mg/L O_2**

$$2Mn^{2+} + O_2 + 2H_2O \rightarrow 2MnO_2 + 4H^+$$

Mn molecular weight: 54.9 g/mol

Cascade Aeration – Absorption

- If the steps of the cascade aerator is equal K_n=K/n;

$$C_n = C_s - (C_s - C_o)\left(1 - \frac{K}{n}\right)^n$$

- In completely mixed system cascade aeration;

$$K = \frac{1}{1 + \frac{1}{k_L a t}}$$

- In aeration (spray etc.)

$$\frac{C_t - C_o}{C_s - C_o} = 1 - e^{-K_L a t} = K(efficiency\ coef.)$$

$$C_t = C_o(1 - K) + K C_s$$

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Power/Energy Dissipation

Power dissipation should be < 30 watt.s/m^3

$$P = \rho g Q \Delta h$$

$$\Delta h = \frac{V^2}{2g}$$

Δh: Velocity Head, m
Q: Flow Rate, m^3/s
g: gravitational acceleration, 9.81 m/s^2
ρ: density of water, 1000 kg/m^3
V: Velocity of water, m/s
P: Power watt.s (kgm^2/s^2)

Efficiency of Oxygen Transfer in Cascades

$$Efficiency\ of\ O_2 transfer = \frac{mg\ O_2\ trasferred/time}{power\ exerted\ by\ flow}$$

$$Efficiency\ of\ O_2 transfer = \frac{mg\ O_2\ trasferred/time}{\rho \cdot g \cdot Q \cdot \Delta h}$$

- Efficiency of O_2 transfer should be 1.5 – 2.5 kg O_2/kW-h

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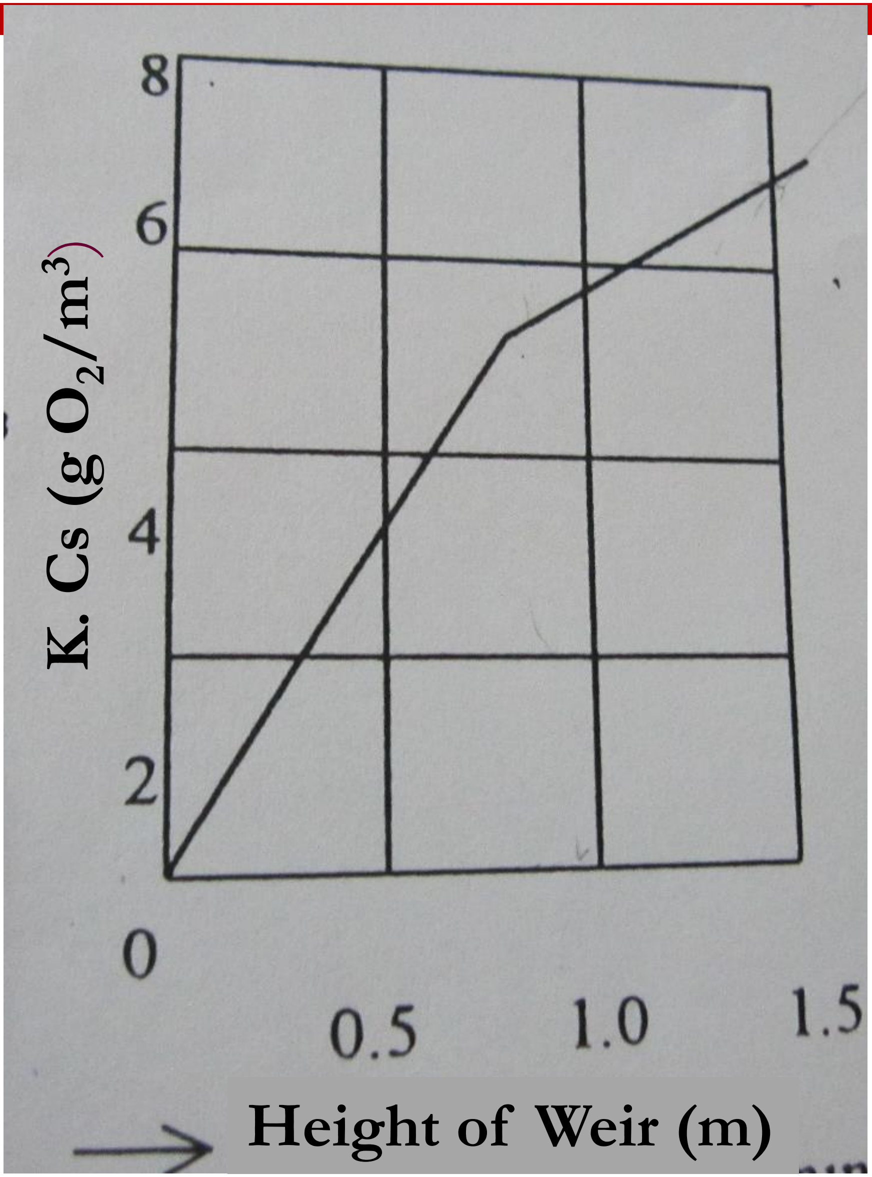
Efficiency Coefficient vs height of fall over weirs



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Example-1

- What would be the contact time in cascade aeration (completely mixed) if a gas transfer efficiency of 92% is required? Assume $k_La=0.02$ s^{-1}.

K=0.92

$$K = \frac{1}{1 + \frac{1}{k_L a t}}$$

$$t = \frac{K}{(1 - K) k_L a}$$

$$t = \frac{0.92}{(1 - 0.92)0.02}$$

$$t = 575 \text{ sec} = 9.6 \text{ min}$$

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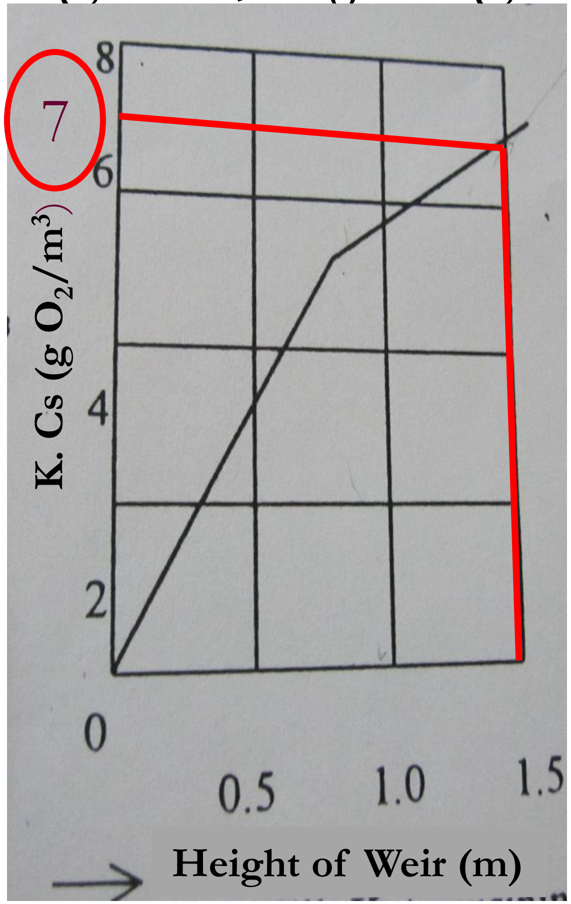
Example-2

- Calculate the number of steps for maximum oxygenation; h=1.5 m, C_s=10 g/m^3, C_o=2 g/m^3

$$C_n = C_s - (C_s - C_o)\left(1 - \frac{K}{n}\right)^n$$



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Example-3

Calculate the amount of oxygenation for a three-step cascade aeration system located at 610 m (0.93 atm) above the sea level. Assume a DO saturation value of 9.17 mg/L (20^{o}C, 1 atm), assume that the temperature at 610 m will be the same. Calculate the K value for unpolluted water. C_o=2mg/L. Total h=2m.

$$C_n = C_s - (C_s - C_o)\left(1 - \frac{K}{n}\right)^n$$

K=0.45(1+0.046T)h