ENVE 301
Environmental Engineering Unit Operations

CHAPTER: 5

Aeration

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Aeration

Primary applications in water treatment

→**Removal of dissolved gases (degasification)**

- CO_2

High solubility of CO_2 reduces the pH of water which causes excessive consumption of lime or other neutralizing agents in coagulation and softening process. The corrosiveness of water is also higher at lower pH values.
Exposure of water droplets to air for 2sec will lower the CO_2 by 70-90%
CO_2 > 10mg/L → aeration is recommended
Otherwise lime addition should be used to neutralize the CO_2

- CH_4
- Volatile organics
- taste &odor causing volatile compounds

  not an efficient method for removing the taste & odor compounds produced by algae

  because the algal oils causing taste and odor not volatile to a significant extent.

- H_2S (highly soluble in water)

H_2S poisoning is one of the lauding causes of accidents in the field.

Hazardous levels

- 5ppm: Moderate odor.
- 10ppm: Eye irritation begins
- 30ppm: Strong , unpleasant odor of rotten egg
- 100ppm: Loss of smell
- >300ppm: Unconsciousness, death

Primary application of aeration in water treatment (continue) :

- oxygenation of water (gasification, absorption)
- Removal of iron (oxidation) (gasification, absorption)

Primary application of aeration in waste water treatment:

→ To supply oxygen to aeorobic biological treatment processes

→ Air stripping to remove toxic volatile organics

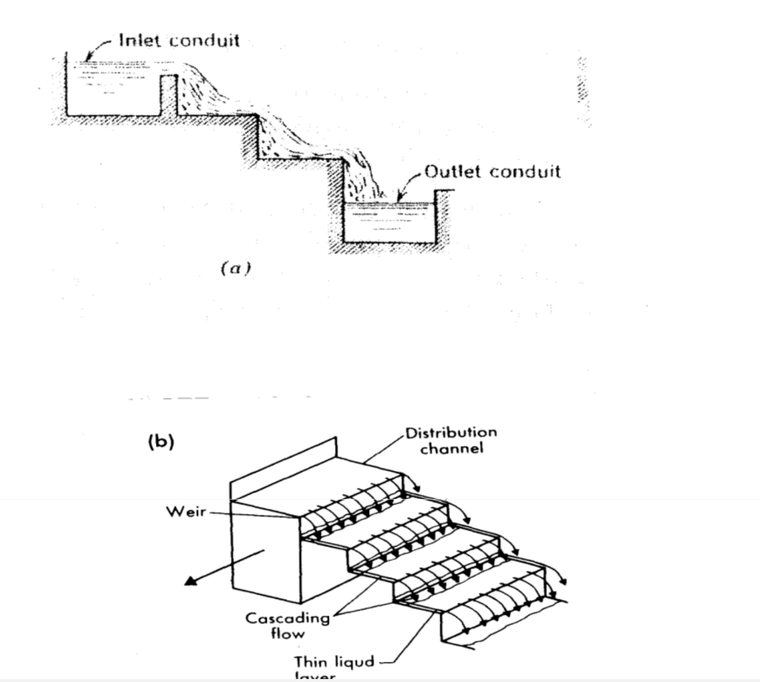
→ Air stripping to remove volatile compounds

Aerators

- **Gravity Aerators**

  e.g. Cascade aerators
- **Spray Aerators**
- **Diffused Air Aeration Systems**
- **Mechanical Aerators**

Cascade Aerator (Gravity Aerator)



Ref: Tchobanoglous and Scroeder, 1985, Addison-Wesley Publishing Company

→ Water falls down a series of steps

utilize the potential energy of water to create

interfaces for efficient gas transfer

→ the splashing of the water creates turbulence and water droplets

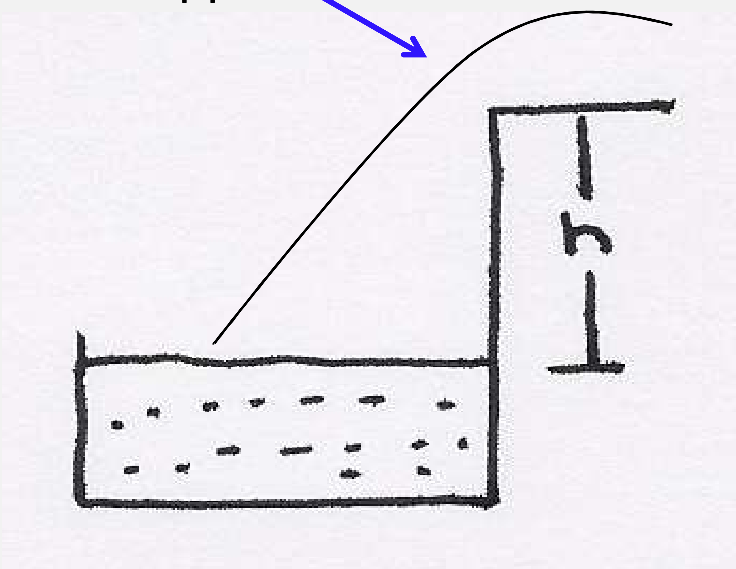
→Not efficient compared to other aeration methods

→Require little space [50 –200 m^2/ (m^3/sec)]

Cascade Aerator (Continue)

1st Mechanism (effective for degasification)

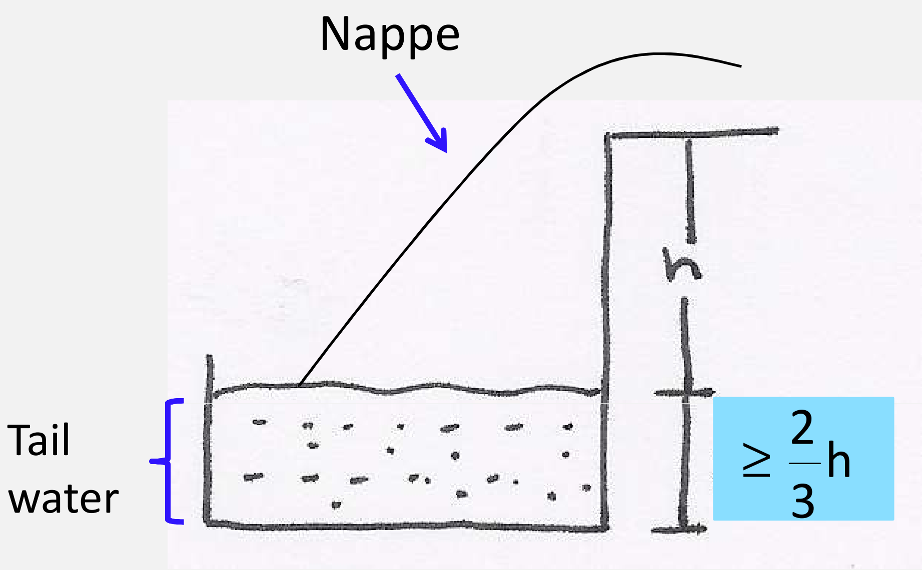
Nappe



$$h = \frac{1}{2} g t^2 \text{ (freefall)}$$

$t =$ average time of exposure of the surface A to air $= \sqrt{\dfrac{2h}{g}}$

2^{nd} Mechanism
(effective for gasification, e.g., oxygenation)



$$h = \frac{v^2}{2g}$$

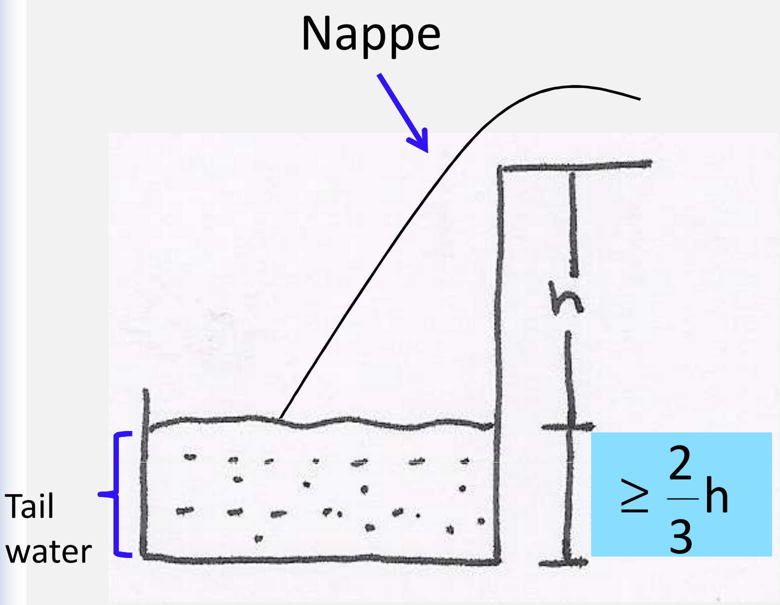
$$v = \sqrt{2gh}$$

When the nappe submerge into the receiving body of water

significant amounts of air is entrained.

The entrained air is then dispersed in the form of bubbles throughout the receiving body of water, which leads to an intense transfer of gases.

Cascade Aerator (continue)



$$h = \frac{v^2}{2g}$$

$$v = \sqrt{2gh}$$

The amount of air entrained depends on;

→ velocity of nappe when passing the surface of tail water

→ depth of tail water

Depth should be choosen such that ;

Final vel. of jets within the tail water before reaching the tank bottom = Rising vel. of bubbles produced

tail water depth ≥ (2/3) h

Subdivision into several steps & decreasing h → promotes DESORPTION OF GAS

each step leads to formation of new interfacial area

Decreasing the number of steps & increasing h → promotes SORRPTION OF GAS

→ *For gasification (sorption of gas)*

→ $$\frac{C_s - C}{C_s - C_o} = e^{-K_{La}t}$$

→ $$1 - \left(\frac{C_s - C}{C_s - C_o}\right) = 1 - e^{-K_{La}t}$$

→ $$\frac{C\text{-}C_0}{C_s - C_0} = 1 - e^{-K_{La}t} = K = efficiency \ \text{coeff.}$$

→ $$C - C_0 = K(C_s - C_0)$$

→ $$C - C_0 = KC_s - KC_0$$

→ $$C = C_0 - KCo + KC_s$$

→ $$C = C_0(1 - K) + KC_s$$

If the height of weir being divided in n equal steps each having an efficiency coeff.

$$C_1 = C_0(1-K_n) + K_n C_s$$

$$C_2 = C_1(1-K_n) + K_n C_s$$

$$C_3 = C_2(1-K_n) + K_n C_s$$

.

.

.

$$C_n = C_s - (C_s - C_0)\left(1-\frac{K}{n}\right)^n$$

$$K \longrightarrow \left.\begin{array}{l} \text{unpolluted water} = 0.45(1+0.046T)h \\ \\ \text{polluted water} = 0.36(1+0.046T)h \\ \\ \text{sewage} = 0.29(1+0.046T)h \end{array}\right\}$$

T=temperature, °C

h= m

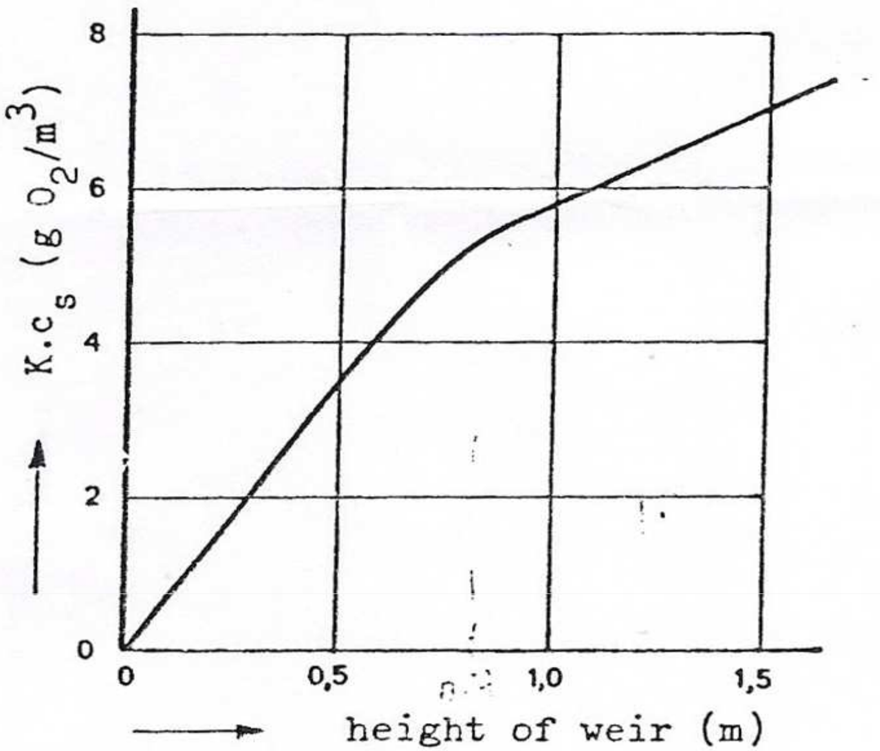


Fig. 3.1 EFFICIENCY COEFFICIENT IN DEPENDENCE OF THE HEIGHT OF FALL OVER WEIRS

Ref: Pöpel, 1979, Delft University

EXAMPLE 1: Raw water with 2g O_2/m^3 and a temperature of 10^0C is passed over a straight weir of a height of 0,65m. Estimate the downstream oxygen content.

For unpolluted water:

$$@10^0C \rightarrow C_s = 11.3g/m^3$$

K=0.45(1+0.046T)h

$$C = C_s - (C_s - C_0)\left(1 - \frac{K}{n}\right)^n$$

K=0.45(1+0.046.10)0.65

$$n = 1$$

K=0.427

$$C = 11.3 - (11.3 - 2)\left(1 - \frac{0.427}{1}\right)^1 = 5.97g/m^3$$

EXAMPLE 2: Determine the number of steps of a cascade to achieve maximum oxygenation , assuming an available head of 1.5m , an efficiency coefficient K depending on the weir height h as stated by Fig 3.1 given below

$$C_s = 10 g/m^3 \quad C_0 = 2 g/m^3$$

One step:

$$h = 1.5m \text{ from Fig.3.1} \rightarrow KC_s = 7 \rightarrow K = \frac{7}{10} = 0.7 = \frac{K}{n}$$

$$C_1 = C_s - (C_s - C_0)\left(1 - \frac{K}{n}\right)^n$$

$$C_1 = 10 - (10-2)(1-0.7)^1$$

$$C_1 = 7.6 g/m^3$$

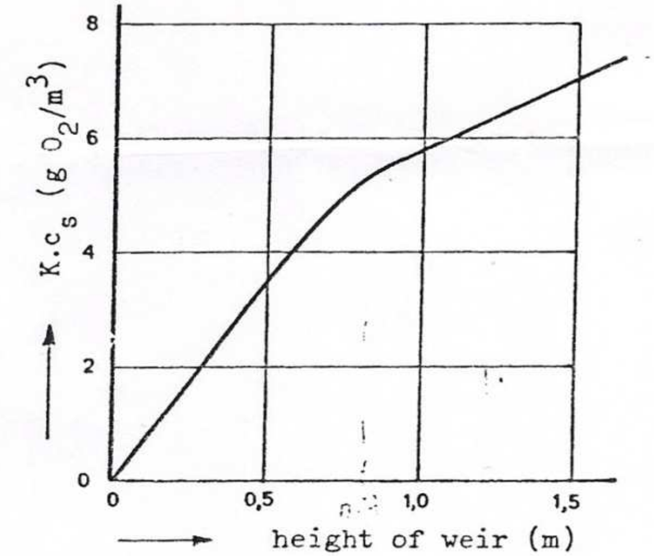


Fig. 3.1 EFFICIENCY COEFFICIENT IN DEPENDENCE OF THE HEIGHT OF FALL OVER WEIRS

Ref: Pöpel, 1979, Delft University

Two steps:

$$h=\frac{1.5}{2}=0.75\text{m from graph}\rightarrow KC_s=5\rightarrow K=\frac{5}{10}=0.5=\frac{K}{n}$$

$$C_2=C_s-(C_s-C_0)\left(1-\frac{K}{n}\right)^n$$

$$C_2=10-(10-2)(1-0.5)^2$$

$$C_2=8g/m^3$$

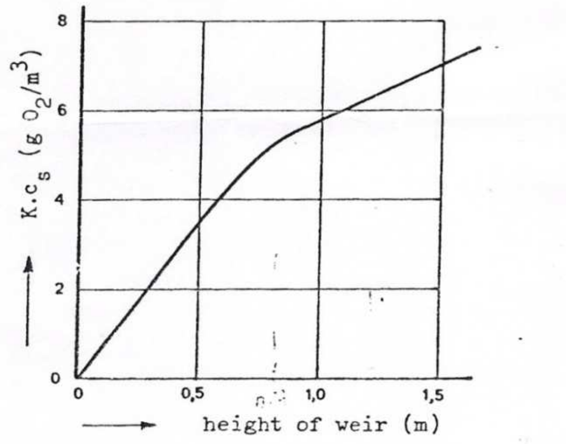


Fig. 3.1 EFFICIENCY COEFFICIENT IN DEPENDENCE OF THE HEIGHT OF FALL OVER WEIRS

Ref: Pöpel, 1979, Delft University

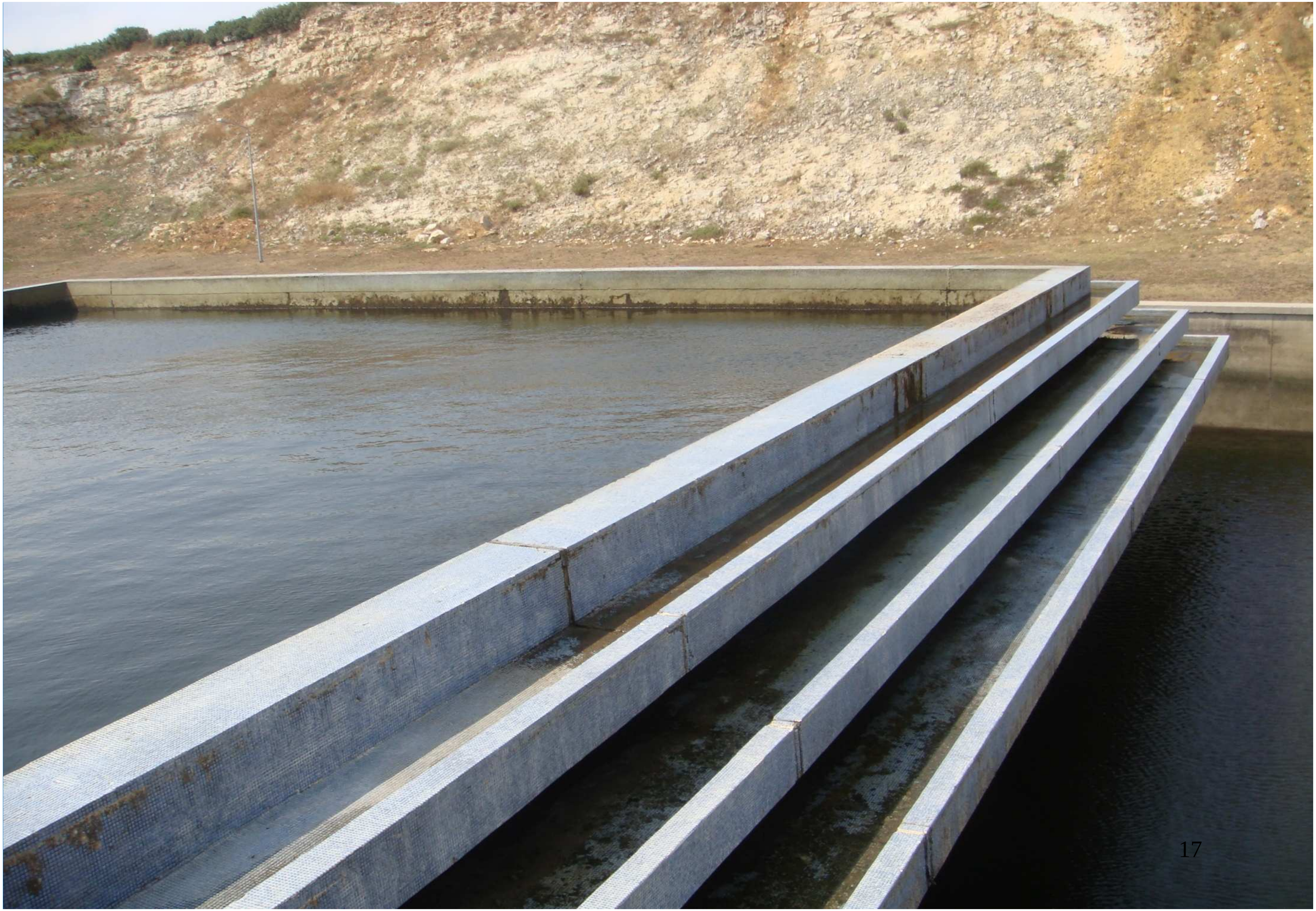
Three steps:

$$h=\frac{1.5}{3}=0.5\text{m from graph}\rightarrow KC_s=3.5\rightarrow K=\frac{K}{n}=\frac{3.5}{10}=0.35$$

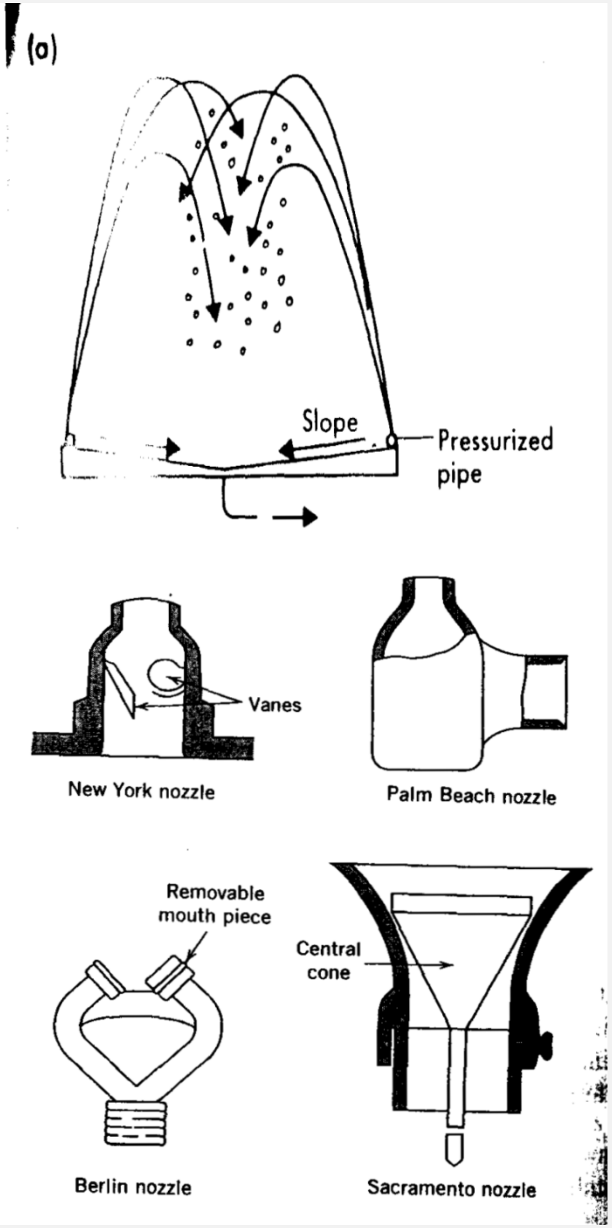
$$C_3=C_s-(C_s-C_0)\left(1-\frac{K}{n}\right)^n$$

$$C_3=10-(10-2)(1-0.35)^3$$

$$C_3=7.8g/m^3$$



Spray Aerator



Ref: Metcalf Eddy,1991 , McGraw Hill

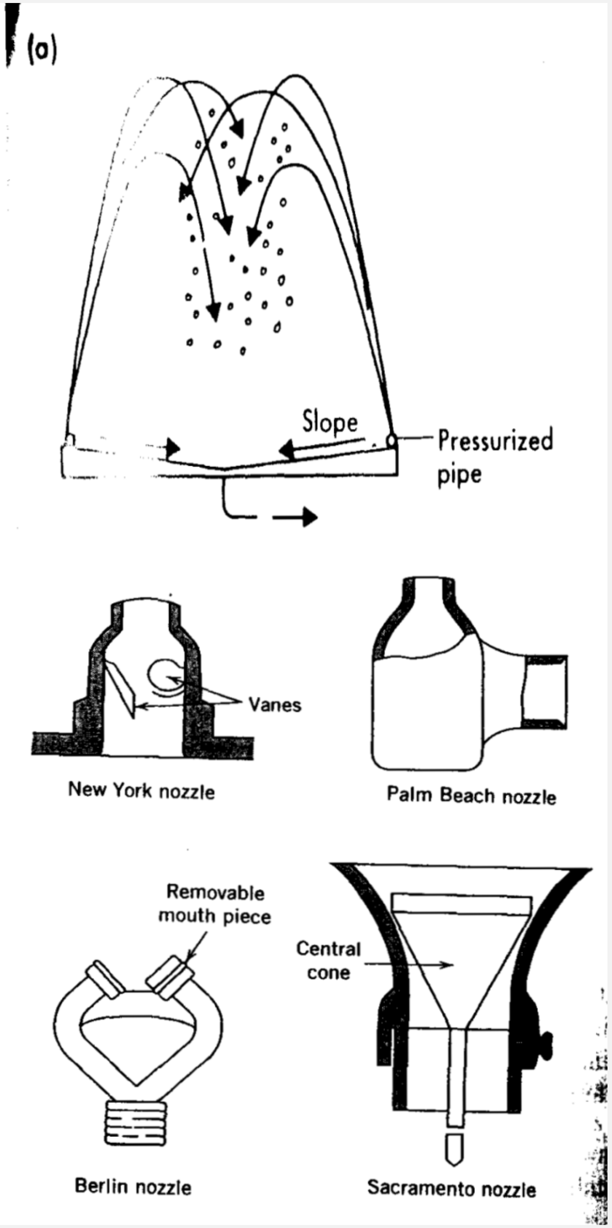
→applied in the course of water treatment for absorption of oxygen and/or desorption of gases

→water is distributed into air in the form of small droplets by means of

- orifices
- nozzles

mounted on a stationary pipe system

Spray Aerator (Continue)



Ref: Metcalf Eddy,1991 , McGraw Hill

→ orifices and nozzles may be costructed to discharge water

- vertically
- at an angle

in upward or downward direction

- Require relatively large area to collect the water

Diffused – Air Aeration Systems

→ air is introduced into liquid being aerated in the form of bubbles which typically rise through the liquid

→ common device for ;

transferring oxygen in aerobic biological treatment systems

air stripping of volatile organics

Ref: http://www.brightwaterfli.com/diffused_aeration_systems.htm

FINE BUBBLE

→ the size of bubbles varies from coarse to fine

- fine-bubble diffusers
- coarse bubble diffusers

Ref:http://www.hellotrade.com/diffused-gas-technologies-incorporated/ss-series-plenum-coarse-bubble-diffusers.html

COARSE BUBBLE

Diffused – Air Aeration Systems (continue)

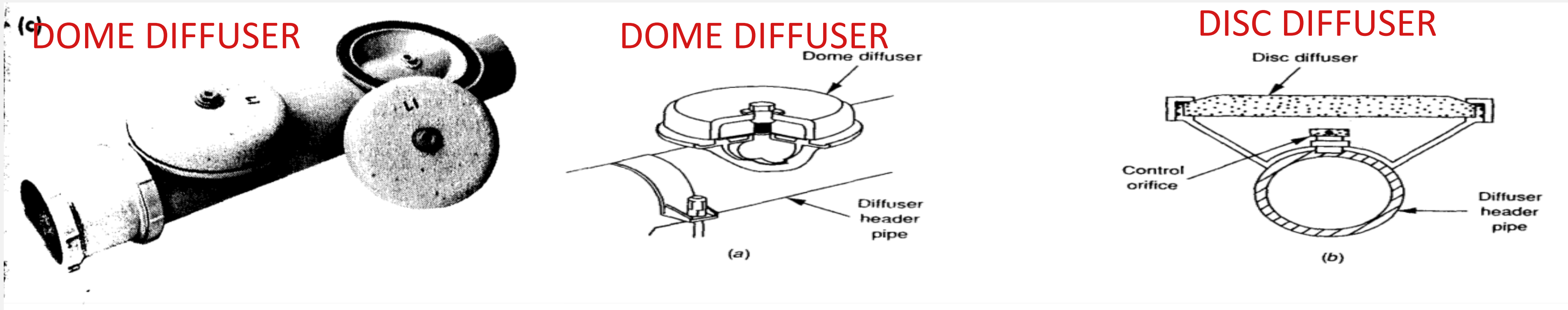
gas transfer rate $\propto$ size of bubbles

$\rightarrow$ smaller bubbles $\rightarrow$ greater A/∀ $\rightarrow$ more efficient than larger sized bubbles for mass transfer

- Porous diffusers (e.g., plate, dome, disc, tubular diffusers)
- Nonporous diffusers (e.g., fixed orifice, valved orifice)
- Other diffusers (e.g., jet aeration)

Diffused – Air Aeration Systems (continue)

Typical Porous Diffusers



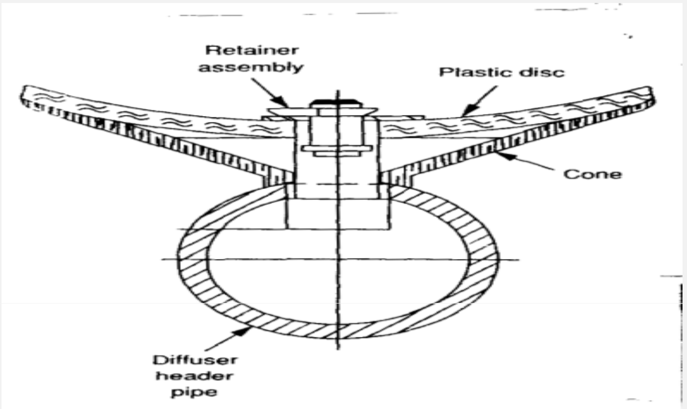
Ref: Metcalf & Eddy, 1991, McGraw Hill

Dome, disc diffusers→ are mounted on or screwed into air manifolds

Diffused – Air Aeration Systems (continue)

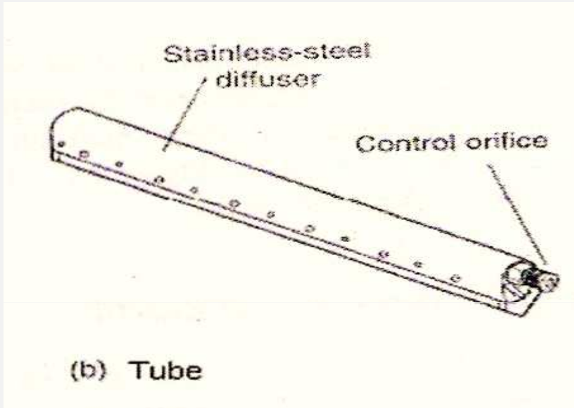
Typical Non Porous Diffusers

Valved orifice diffuser



Ref: Metcalf & Eddy, 1991, McGraw Hill

Perforated tube diffuser



Ref: Metcalf & Eddy, 1991, McGraw Hill

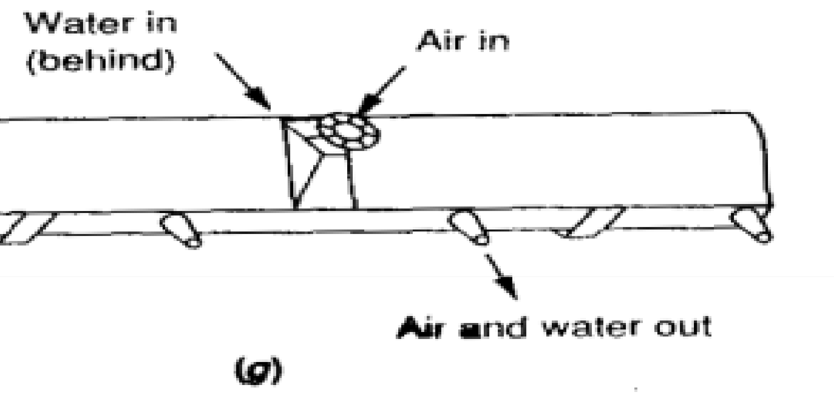
VALVED ORIFICE DIFFUSER
(non porpous diffuser)
Device that contains a check value to prevent backflow when air is shut off. Mounts on air distribution piping.

- Produce larger bubbles than porous diffusers
- Lower aeration efficiency
- Lower cost, less maintanance

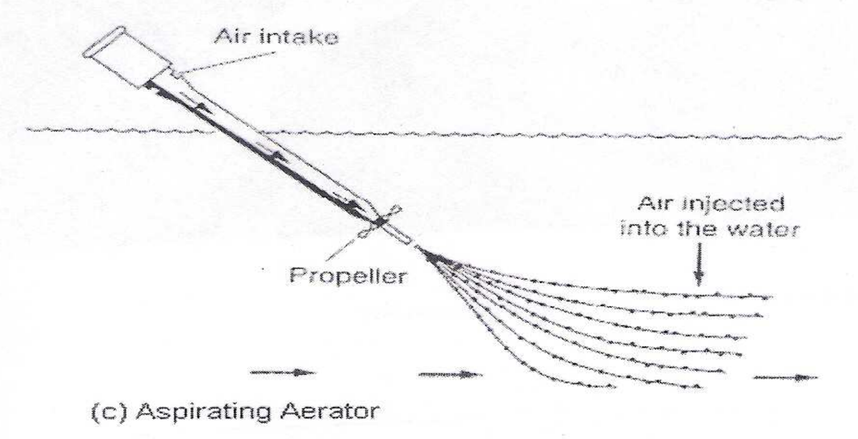
Diffused – Air Aeration Systems (continue)

Typical Other Diffusion Devices

Jet aerator



Aspirating aerators



Jet aerator

discharges a mixture of pumped liquid and compressed air through a nozzle.

TABLE 10-6
Description of air diffusion devices[a]

Type of diffuser or device	Transfer efficiency	Description	See Figure
Porous			
Plate	High	Square ceramic plates installed in fixed holders on tank floor.	
Dome	High	Dome-shaped ceramic diffusers mounted on air distribution pipes near tank floor.	10-10*a*
Disc	High	Rigid ceramic discs or flexible porous membrane mounted on air distribution pipes near tank floor.	10-10*b*
Tube	Moderate to high	Tubular-shaped diffuser that uses rigid ceramic media or flexible plastic or synthetic rubber sheath mounted on air distribution pipes.	10-10*c*
Nonporous			
Fixed orifice			
Perforated piping	Low	Air distribution piping with small holes drilled along the length.	
Spargers	Low	Devices usually constructed of molded plastic and mounted on air distribution pipes.	10-10*d*
Slotted tube	Low	Stainless steel tubing containing perforations and slots to provide a wide band of diffused air.	
Valved orifice	Low	Device that contains a check valve to prevent backflow when air is shut off. Mounts on air distribution piping.	10-10*e*
Static tubes	Low	Stationary vertical tube mounted on basin bottom that functions like an air lift pump.	10-10*f*
Perforated hose	Low	Perforated hose that runs lengthwise along basin and is anchored to the floor.	
Other devices			
Jet aeration	Moderate to high	Device that discharges a mixture of pumped liquid and compressed air through a nozzle assembly located near the tank bottom.	10-10*g*
Aspirating	Low	Inclined propeller pump assembly mounted at basin surface that draws in air and discharges air/water mixture below water surface.	10-10*h*
U-tube	High	Compressed air is discharged into the down leg of a deep vertical shaft.	10-10*i*

[a] Adapted from Ref. 63.

Ref: Metcalf Eddy,1991 , McGraw Hill

MECHANICAL AERATORS

- By producing a large air-water interface the transfer of oxygen from atmosphere is enhanced

- Can be VERTICAL SHAFT or HORIZONTAL SHAFT

Ref: http://en.wikipedia.org/wiki/File:Surface_Aerator.jpg

Ref: http://www.waterandwastewater.com/www_services/newsletter/april_18_2011.htm