Islamic University of Gaza -Environmental Engineering Department

Water Treatment

EENV 4331

Lecture 2: Aeration

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2.1 Purpose of Aeration in water Treatment

Aeration is used for many purposes in water Treatment , the main uses are:

1. **Increase the dissolved oxygen concentration in water.**
2. **Decrease CO_2 concentration thereby reduce its corrosiveness.**
3. **Reduce taste and odor caused by dissolved gases such as Hydrogen sulphide (H_2S) and methane (CH_4) that are removed during aeration.**
4. **Oxidize iron and manganese from their soluble to insoluble states and cause them to precipitate so that they maybe removed by sedimentation and filtration processes.**
5. **Remove certain volatile organic compounds.**

2.2 Types of aerators used in water Treatment

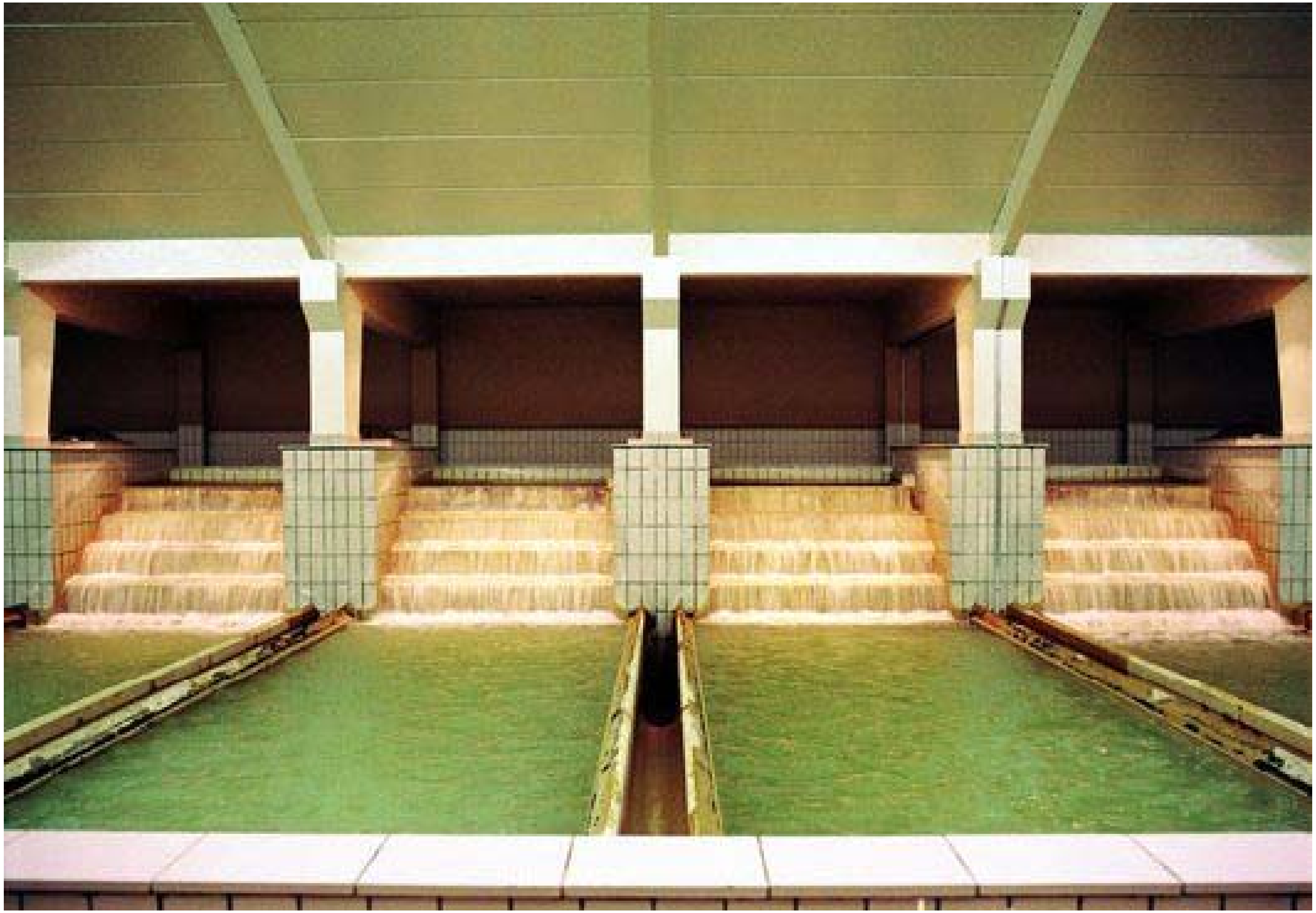
The most common aerators used in water treatment are :

1. **Gravity Aerators:** In gravity aerators, water is allowed to fall by gravity such that a large area of water is exposed to atmosphere, sometimes aided by turbulence. Cascade aerators and Multi-tray aerators are two examples of this type.

2. **Fountain Aerators :** These are also known as spray aerators with special nozzles to produce a fine spray.

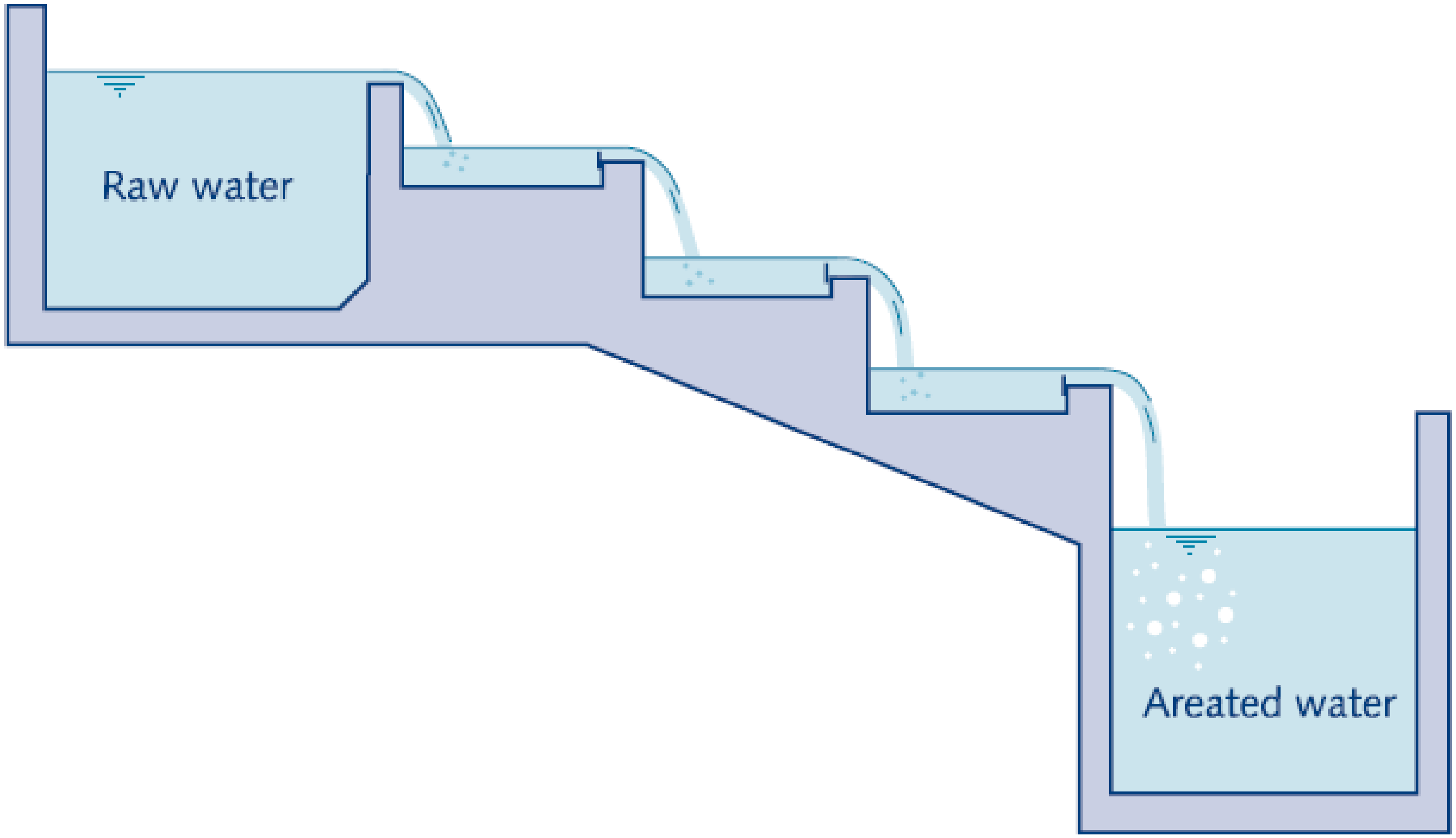
3. **Injection or Diffused Aerators :** It consists of a tank with perforated pipes, tubes or diffuser plates, fixed at the bottom to release fine air bubbles from compressor unit.

4. **Mechanical Aerators :** Mixing paddles as in flocculation are used. Paddles may be either submerged or at the surface.



Cascade Aerator

Cascade Aerator



Cascade Aerator

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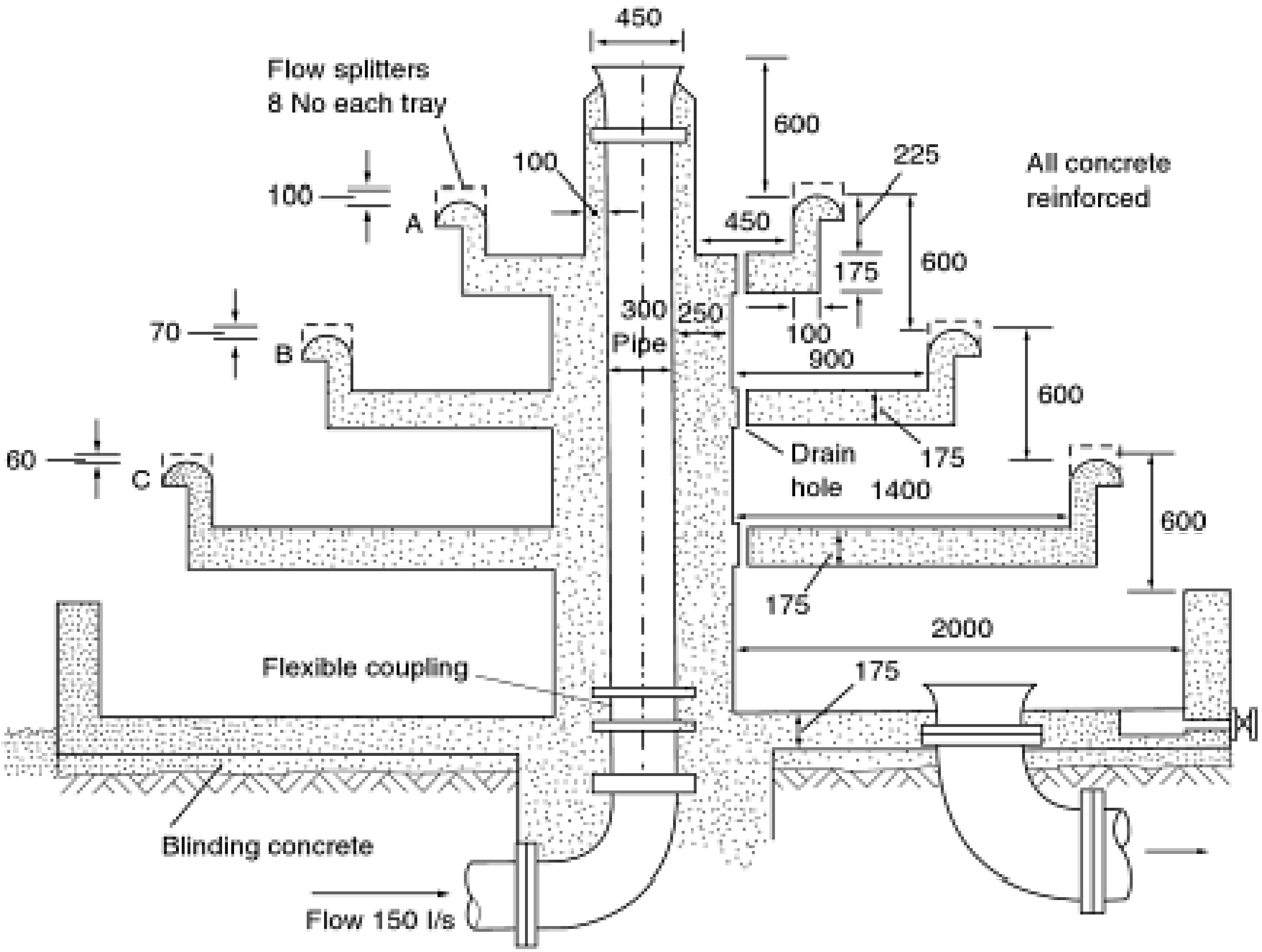
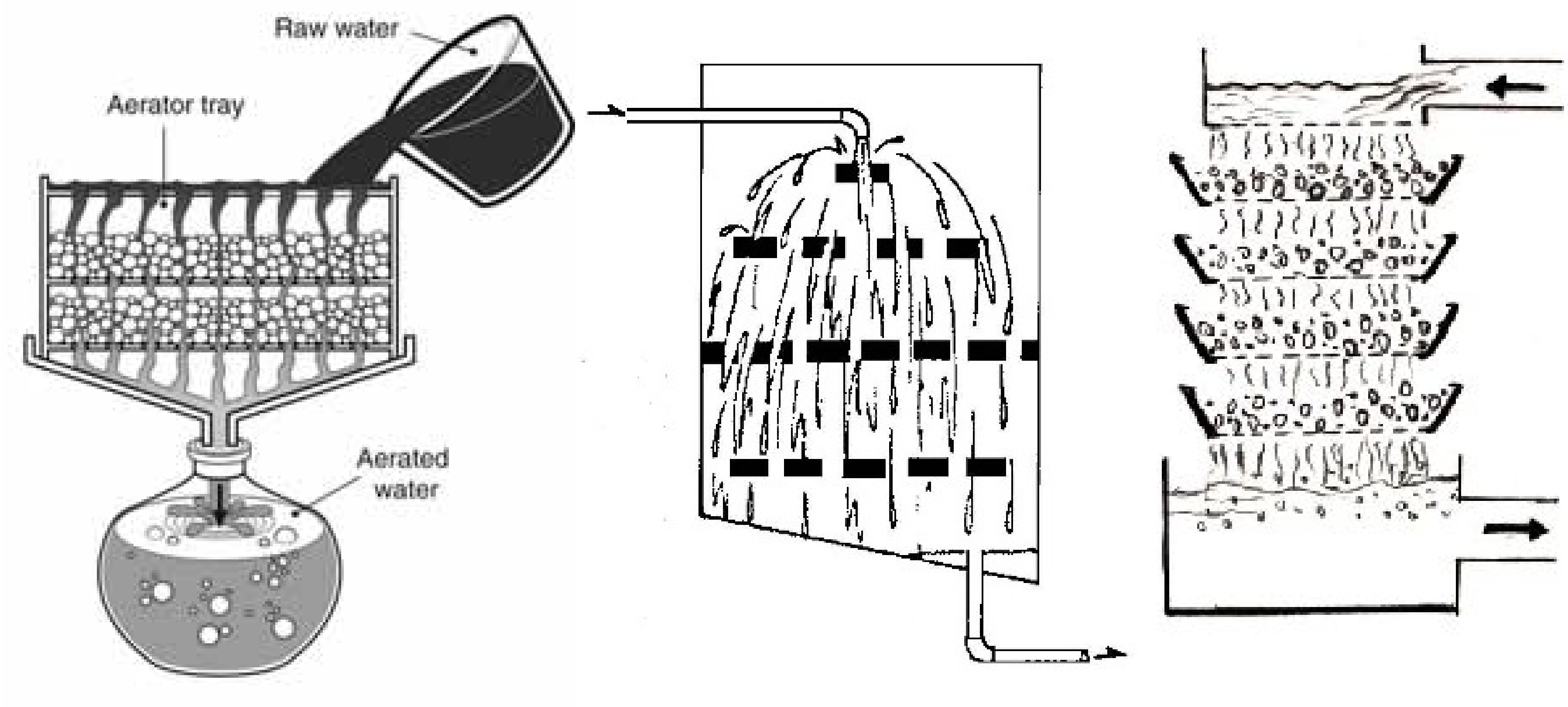
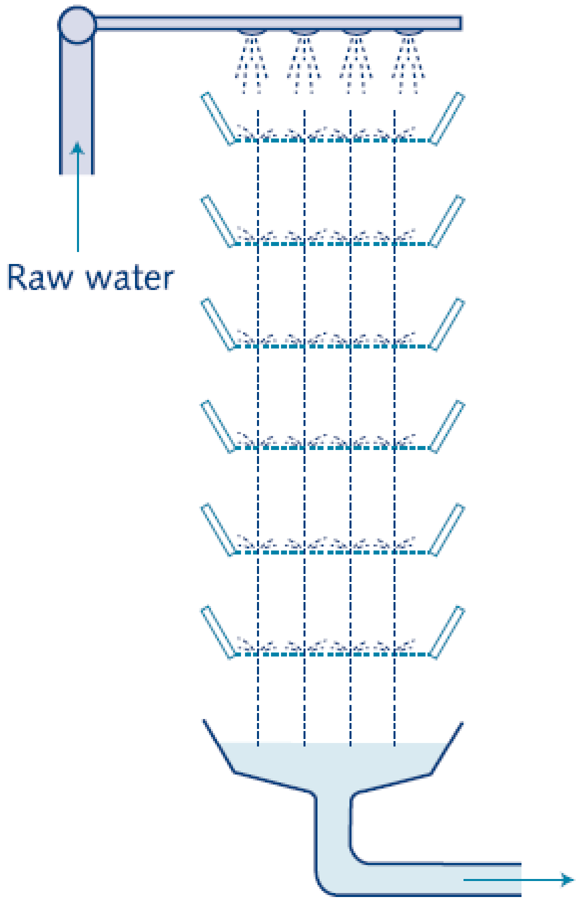
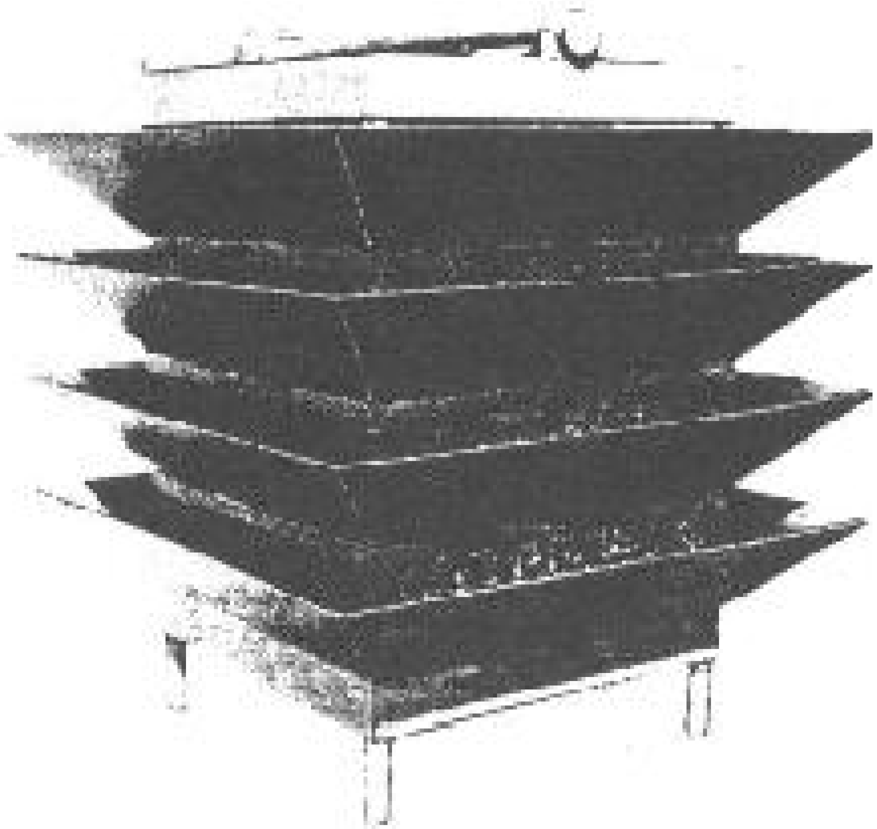


Cascade Aerator



Multi Tray Aerators





Multi Tray Aerators

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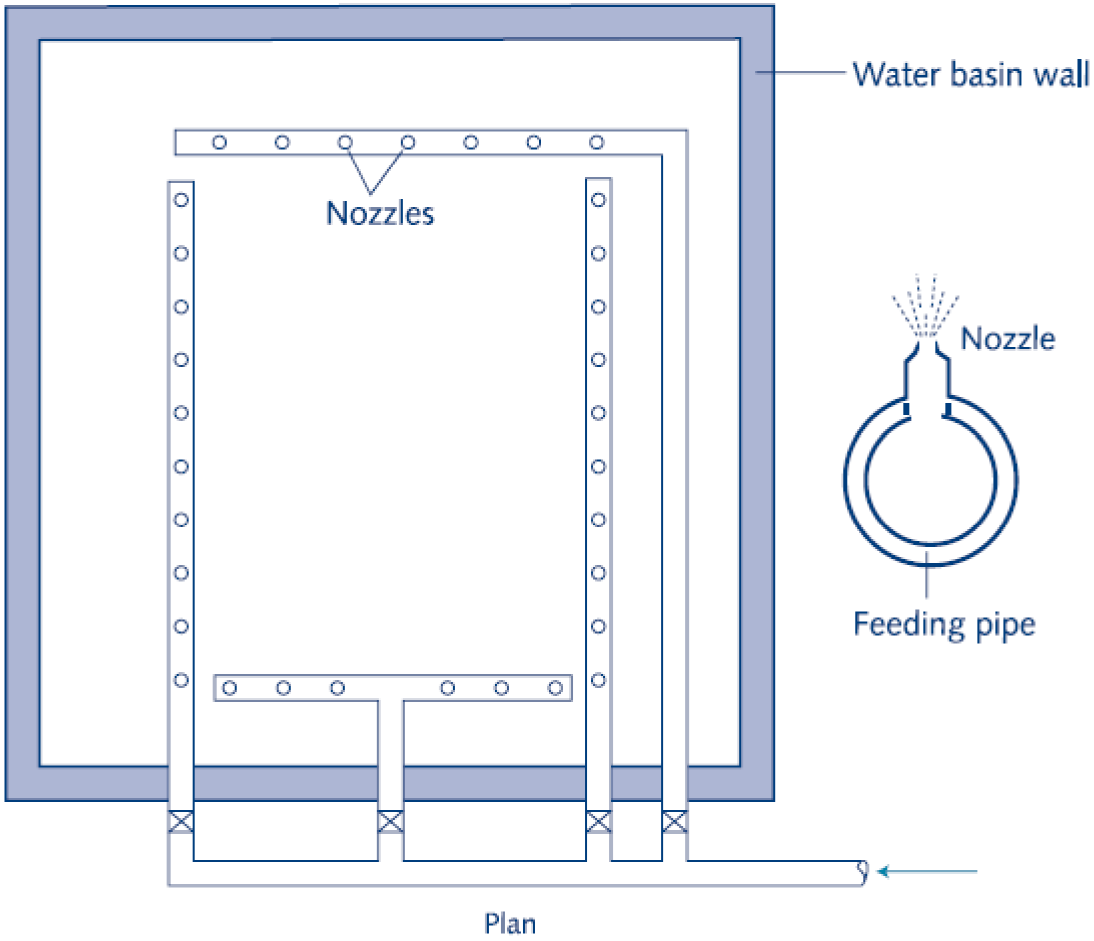

Spray Aerators: Nozzles

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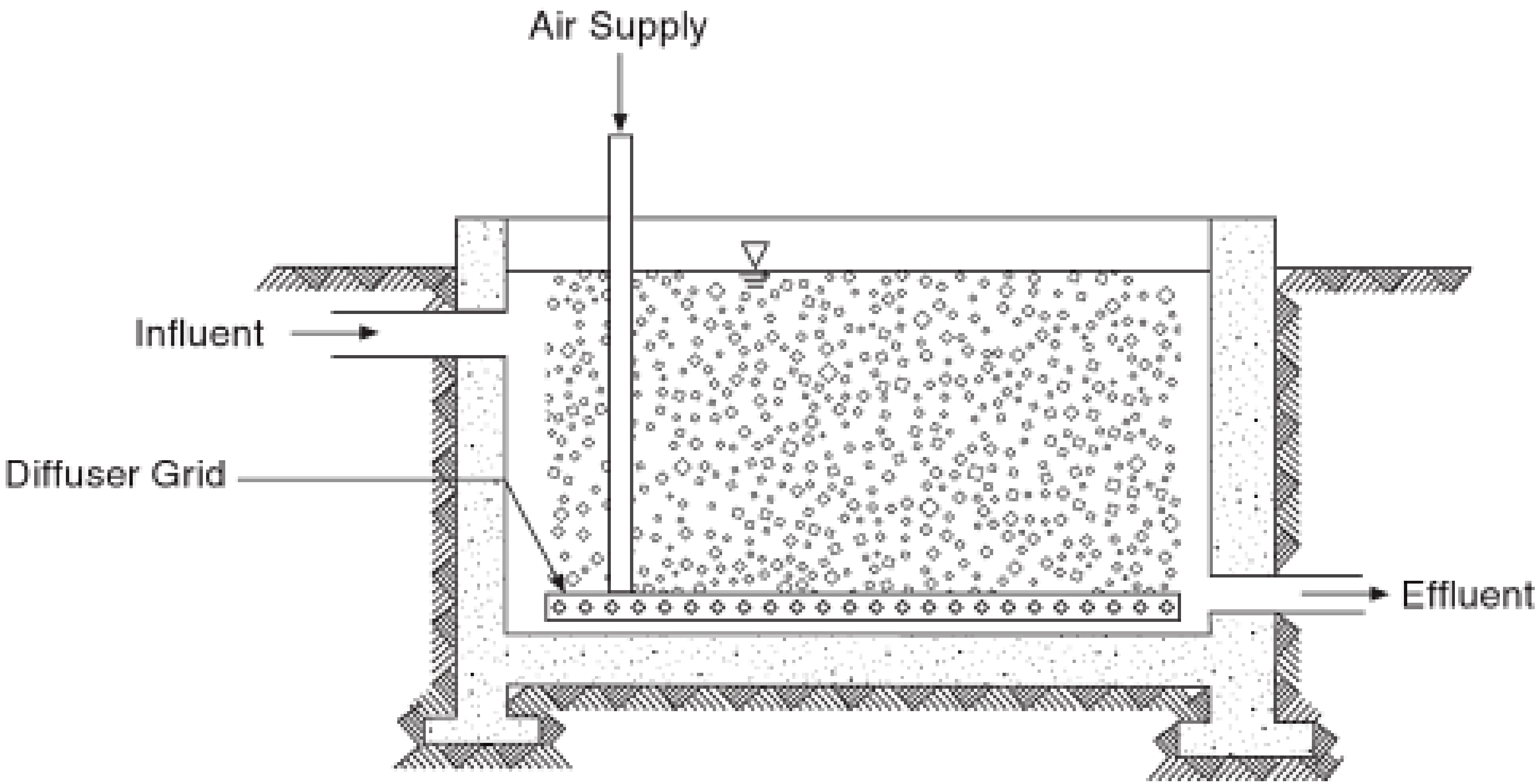
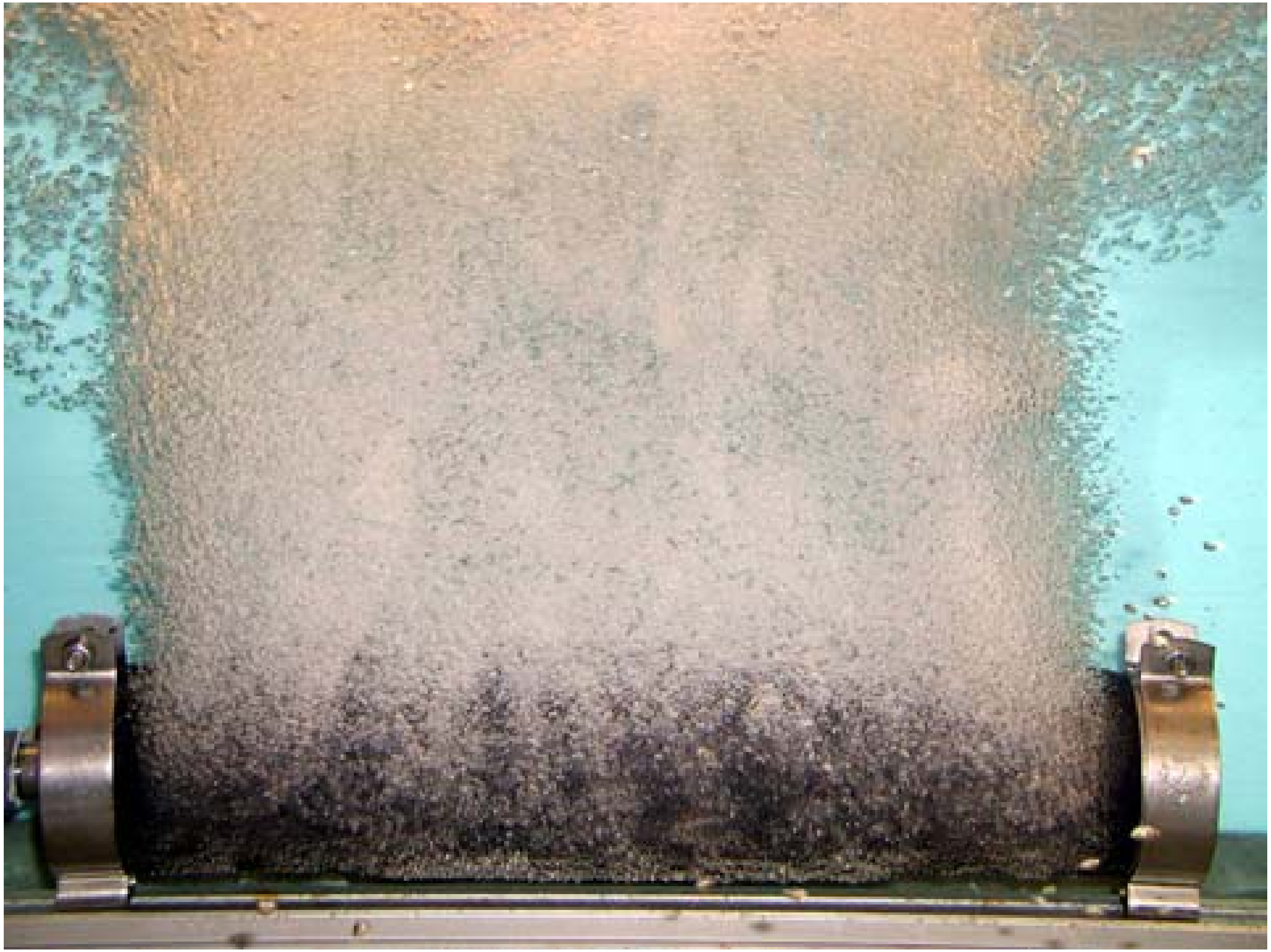


Diffused Air System



Diffused Air System

Mechanical Aerators

Cascade Aerator

$$K = \frac{c_{w,e} - c_{w,o}}{c_s - c_{w,o}} = 1 - (1-k)^n$$

K = total efficiency
k = efficiency per step, k = f (h, kind of gas)
n = number of steps

h (m)	0.2	0.4	0.6	0.8	1.0	1.2
k_{O2} (%)	14	25	36	46	51	55
k_{CO2} (%)	14	14	15	15	15	15
k_{CH4} (%)	14	27	37	48	56	62

$C_{w,e}$ = gas concentration in the effluent water, mg/L
$C_{w,0}$ = gas concentration in the influent water, mg/L
C_s = gas saturation concentration in water at specific temperature , mg/L
h = height of one step, m

Cascade Aerator

Henry's law

$$c_s = k_D \cdot c_a$$

c_s = saturation concentration of the gas in water [g/m3]

c_a = concentration of gas in air [g/m3]

k_D= distribution coefficient [-]

k_D	MW	0°C	10°C	20°C
nitrogen (N_2)	28	0.023	0.019	0.016
oxygen (O_2)	32	0.049	0.039	0.033
methane (CH_4)	16	0.055	0.043	0.034
carbon dioxide (CO_2)	44	1.710	1.230	0.942
hydrogen sulfide (H_2S)	34	4.690	3.650	2.870
tetra (C_2Cl_4)	167	-	3.20	1.21
tri (C_2HCl_3)	131.5	-	3.90	2.43
chloroform ($CHCl_3$)	119.5	-	9.0	7.87
ammonia	17	-	0.94	0.76

Cascade Aerator

$$C_a = \frac{(MW)_{gas} * C_g}{V_{air} * 10^3}$$

C_a = gas concentration in air, mg/L
$(MW)_{gas}$ = molecular weight of gas, gram
C_g = gas concentration in air, ppm
V_{air} = volume of 1 mole of air at a given pressure and temperature, L

$$V_{air} = \frac{nRT}{P}$$

n = number of air moles, (in this case n =1)
R = universal gas constant, 0.08285 (atm.L)/(mole.K)
T = temperature in degrees Kelven.
P = air pressure , atm

Typical values of Cg :

CH_4 = 1.5-2.00 ppp
H_2S = 20-30 ppm
CO_2 = 350-450 ppm

Cascade Aerator

Example:

Calculate the saturation concentration of H_2S in water at air temperature of 20 ^{0}C and a pressure of 1 atm if its concentration in air is 30 ppm.

Solution:

$(MW)_{gas}$ = 2+32.1 = 34.1 g

$$V_{air} = \frac{1*0.08285*(20+273.15)}{1} = 24.29\ L$$

$$C_a = \frac{34.1*30}{24.29*10^3} = 0.042 mg / L$$

From the Table , k_D for H_2S at 20 ^oC = 2.87

$C_s = K_D * C_a$ = 2.87 * 0.042 = 0.1205 mg/L

You can calculate C_S for CO_2, O_2, CH_4 in the same procedure of this example.

Cascade Aerator

Example:

Cascade is to be used to remove methane from ground water. The cascade has 5 steps each 0.40 m. The initial concentration of methane in the ground water is 0.80 mg/L and its saturation concentration (C_S) in water under atmospheric pressure is is close to 0 mg/L.

-What is the efficiency of methane removal after the 5 steps?

-What is the effluent methane concentration?

Solution:

From the table in a previous slide: k_{CH4} = 27 %

$K = 1- (1-k)^n = 1- (1- 0.27)^5 = 0.793$

$$K = \frac{C_{w,e} - C_{w,0}}{C_s - C_{w,0}}, \quad 0.793 = \frac{C_{w,e} - 0.80}{0.0 - 0.80}$$

$C_{w,e} = (C_{CH4})_{effluent}$ = 0.166 mg CH_4/L.

Cascade Aerator

Example:

What is the length of the Cascade aerator in the previous example if its capacity is 35 m^3/h per 1 m length of the step. The total water flow to be treated is 625 m^3/h. What is the total surface area of the cascade if the width to height ratio of the steps is 1:1?

Solution:

- $L_{cascade}$ = 625/35 = 17.86 m
- $A_{cascade}$ = (number of steps -1)*step width*$L_{cascade}$
  = (5-1)*0.40*17.86 = 28.58 m^2

Multiple tray aerator

- This is an economical solution that occupies little space.
- It consists of three to eight trays with perforated bottoms. The holes are 5 to 13 mm in diameter and spaced at 75 mm center to center.
- The trays are placed one on top of another with a 30-50cm space between them.
- The water is evenly distributed in the first tray through porous pipes, or by stopping the gush with a bar (as shown in the figure), so that the water trickles into the tray at a rate of 40-200 L/min per square meter of the tray's surface.
- Small droplets are then sprayed into the next tray.
- To obtain a finer spray, the aerator trays can be filled with thick gravel approximately 10cm deep (50-150 mm) in diameter.

Multiple tray aerator

The removal of carbon dioxide by multiple tray aerators is represented by the following equation (AWWA,1990):

$$\frac{C}{C_0} = e^{-kn}$$

C = effluent concentration, mg/l
C_0 = influent concentration, mg/l
k = removal rate constant, from 0.28 to 0.37 for CO_2.
n = number of trays

Multiple tray aerator

Example:

A ground water containing 8 mg/L of CO_2 is to be degasified using multiple tray aerator with three steps. The groundwater flow rate is 990 L/min. The k value is 0.33 and the hydraulic loading rate of the trays is 400 L/(min.m^2)

1. What is the CO_2 concentration in the treated effluent?
2. What is the size of the trays if the length to width ratio is 2:1?

Solution:

1. **$C = C_0 * e^{-kn} = C_0 * e^{-0.33X3} = 8*0.3716 = 2.98$ mg CO_2/L**
2. **Area of each tray = (990 L/min)/[(400L/(min.m^2)] = 2.47 m^2**

Dimensions of the tray : L = 2 W

$$L * W = 2.47 \text{ m}^2$$

$$2W*W = 2.47 \text{ m}^2$$

$$W = 1.57 \text{ m}$$

$$L = 3.14 \text{ m}$$

Removal of Iron and Manganese from water by Aeration:

- Iron and manganese in excess of 0.30 mg/L and 0.05 mg/L , respectively ,should be removed according to secondary standards of EPA. They cause staining of laundry and plumbing fixtures, produce unacceptable taste and color.

- Aeration provides the dissolved oxygen needed to convert the iron and manganese from their ferrous and manganous forms to their insoluble oxidized ferric and manganic forms. The produced precipitates of ferric hydroxide and manganic oxide are then removed by sedimentation followed by rapid sand filtration.

- It takes 0.14 mg/L of O_2 to oxidize 1 mg/L of iron; and 0.29 mg/L of O_2 to oxidize 1 mg/L of manganese.

Oxidation reaction of iron is:

$$4\,Fe(HCO_3)_2 + 2H_2O + O_2 > 4\,Fe(OH)_3 \downarrow + 8CO_2$$

Oxidation reaction of iron is:

$$2MnSO_4 + 2H_2O + O_2 > 2MnO_2 \downarrow + 2H_2SO_4$$

$$2Mn(HCO_3)_2 + O_2 > 2MnO_2 \downarrow + 2H_2O + 4CO_2$$