ENVE 411

Water Engineering Design

DESIGN OF OZONE CONTACT CHAMBER

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Ozone in water treatment

- Ozone has been used extensively in Europe for disinfection and taste & odor control in water supplies
- Preozonation, intermediate ozonation, post-ozonation
- Post-ozonation➔ disinfection
- Intermediate ozonation ➔ before GAC

Ozone in water treatment

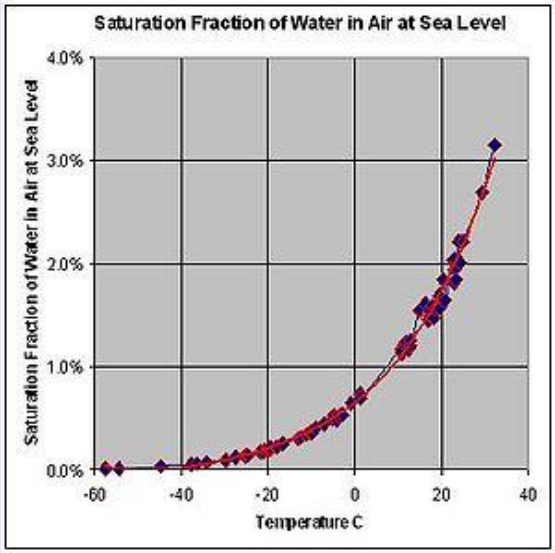
- Preozonation ;
  - removal of taste & odor
  - removal of color
  - removal of iron and manganese
  - enhanced removal of NOM
  - oxidation & volatilization of organics

Ozone Formation Reactions

Ozone is an unstable gas and must be produced on-site

Oxygen ⟷ Dried air

High-energy electrical field (corona) causes oxygen to dissociate.

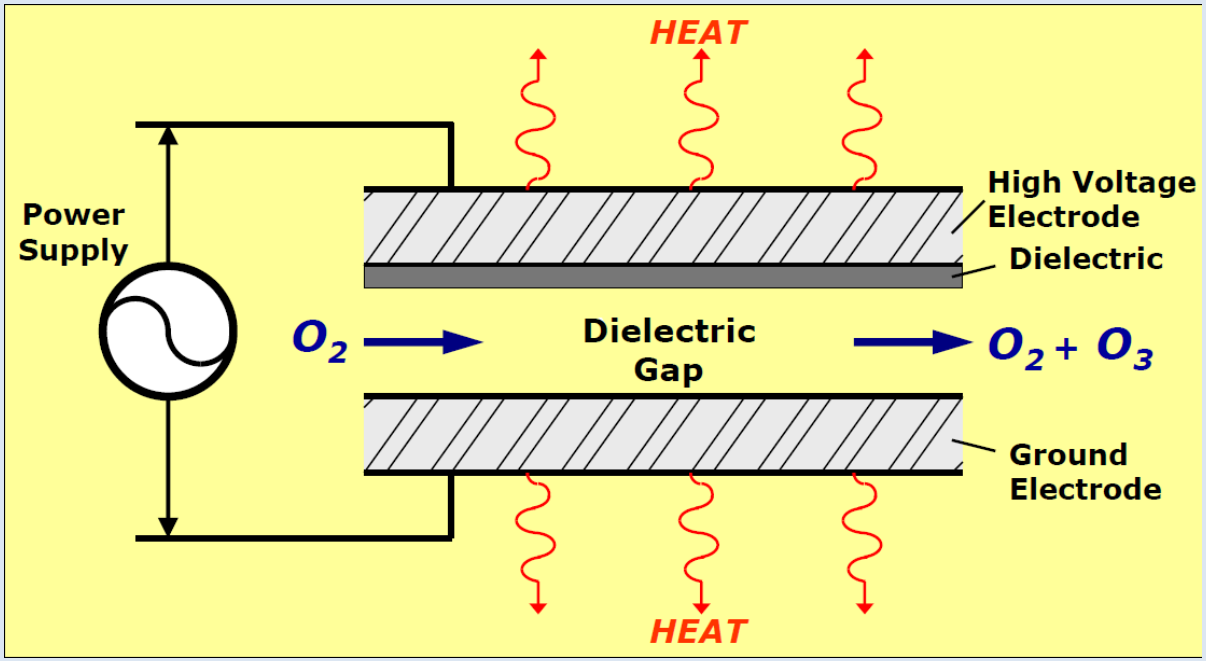


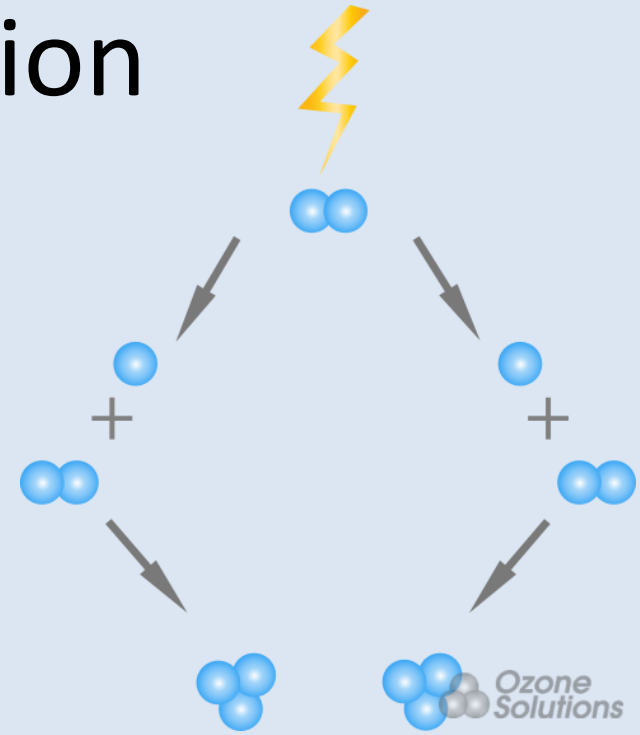
- Higher ozone production density
- High concentration of ozone in the product area
- Less energy requirement for creating corona

Air fed to the ozone generator must be dried to a maximum dew point of -65^{0}C

HNO3 production

Ozone generation





$$O_2 + 2e^- \rightarrow 2O^-$$

$$O^- + O_2 \rightarrow O_3$$

$$3O_2 + 2e^- \rightarrow 2O_3$$

Reaction is reversible and once ozone is formed it decomposes to oxygen at high temperatures (> 35°C)

Ozone generators use cooling systems to dissipate energy produced during generation

http://www.ozonesolutions.com/info/ozone-formation

Ozone reactions

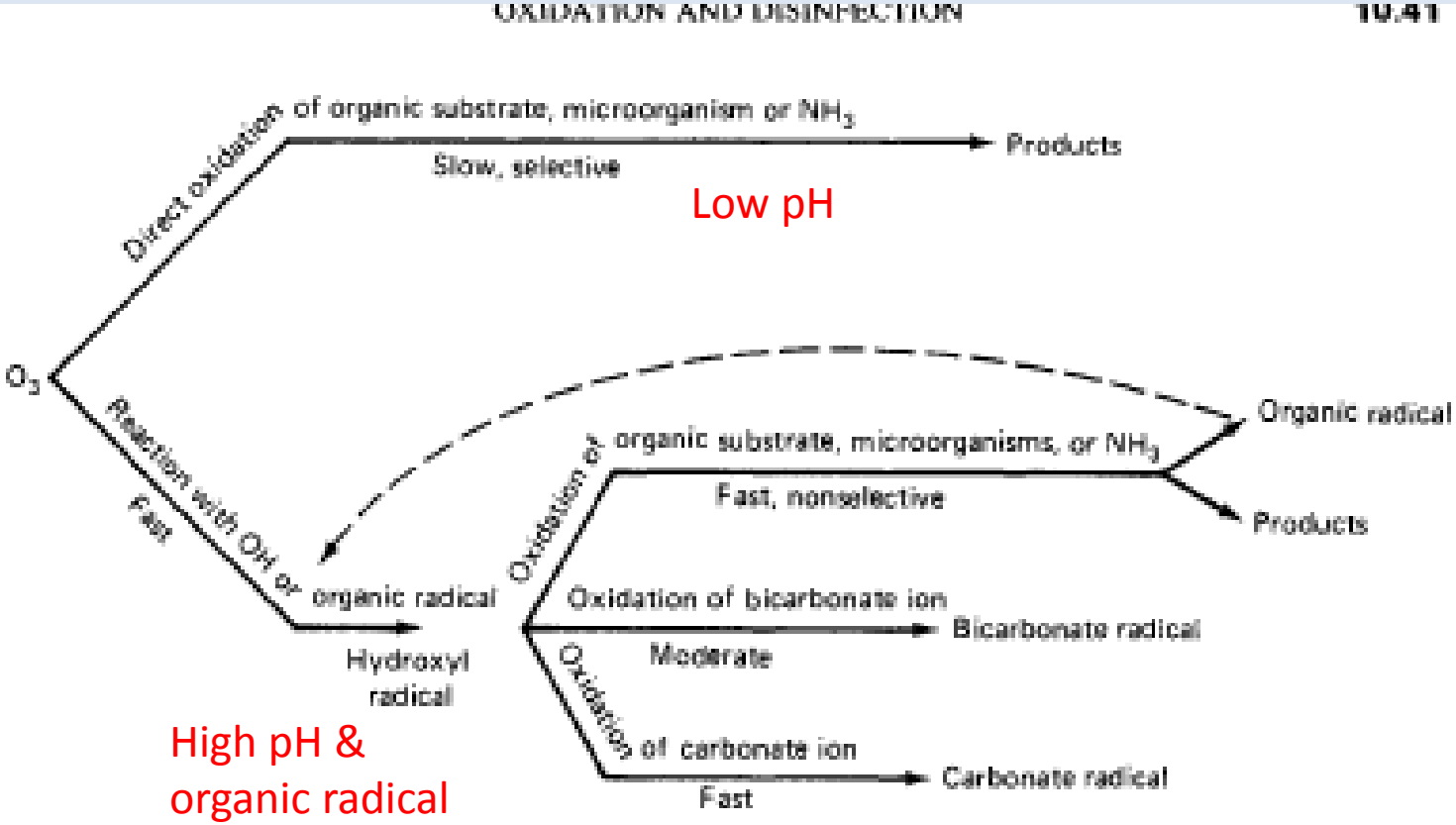


FIGURE 10.19 Reaction pathways of ozone in water. (*Source: J. Hoigne and H. Bader, "Role of Hydroxyl Radical Reactions in Ozonation Processes in Aqueous Solutions."* Water Resources Bulletin, *vol. 10, 1976, p. 377.*)

Why pre-ozonation used in Ömerli WTP

1. Fe & Mn removal
2. It is an algicide (a substance used for killing & preventing growth of algae, e.g. blue-green algae)
3. Prevention of formation of THM

THM formation: Organic compund + Cl_2 ⟶ THM

Trihalomethanes (THM)

THM: group name of organic compunds in which three of the four hydrogen atoms of methane (CH_4) are replaced with halogen atoms (e.g. Cl, Br)

Table of common trihalomethanes

Common trihalomethanes (ordered by molecular weight)

Molecular formula	IUPAC name	CAS registry number	Common name	Other names	Molecule
CHF_3	trifluoromethane	75-46-7	fluoroform	Freon 23, R-23, HFC-23	
$CHClF_2$	chlorodifluoromethane	75-45-6	chlorodifluoromethane	R-22, HCFC-22	
$CHCl_3$	trichloromethane	67-66-3	chloroform	methyl trichloride	
$CHBrCl_2$	bromodichloromethane	75-27-4	dichlorobromomethane	BDCM	
$CHBr_2Cl$	dibromochloromethane	124-48-1	chlorodibromomethane	CDBM	
$CHBr_3$	tribromomethane	75-25-2	bromoform	methyl tribromide	
CHI_3	triiodomethane	75-47-8	iodoform	methyl triiodide	

Most common one Trichloromethane (or chloroform)

MCLs in Water Supplies
EU standard <= 80 ppb
American std. <=100 ppb

THM conc. in Ömerli w/o preozonation = 300 ppb

THM in WTP

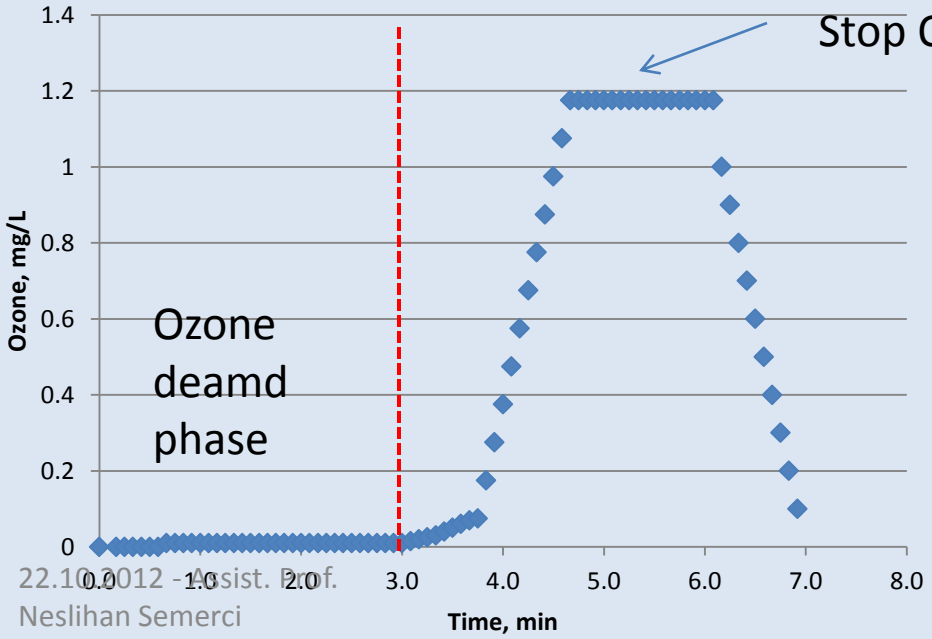
İSTANBUL SU KALİTESİ RAPORU EYLÜL (2012)

Parametre	TÜRK STANDARTLARI TS 266 2005	DÜNYA SAĞLIK TEŞKİLATI (WHO) 1993	ABD ÇEVRE KORUMA AJANSI (EPA) 2003	AVRUPA BİRLİĞİ (EC) 1998	TASFİYE TESİSİ ORTALAMA KALİTE DEĞERLERİ (GENEL CIKIŞ)						
					B.çekmece	İkitelli	Kağıthane	Ömerli (Emirli)	Ömerli(Mur.-Orhaniye)	Ömerli (Osmaniye)	Elmalı
Bulanıklık	1,0	5,0	1,0	1,0	0,2	0,2	0,1	0,2	0,2	0,2	0,3
BİRİNCİL STANDARTLAR (MİKROBİYOLOJİK), EMS/100 mL											
Koliform Bakteri	< 1	0	< 1	0	0	0	0	0	0	0	0
BİRİNCİL STANDARTLAR (Dezenfeksiyon Yan ürünleri), µg/L											
Toplam Trihalometanlar	100	460	80	100	58,6	28,0	20,0	28,8	26,0	22,8	45,1
Bromat	10	10	10	10	-	< 2	< 2	-	< 2	< 2	< 2
BİRİNCİL STANDARTLAR (İNORGANİK KİMYASALLAR), mg/L											
Alüminyum	0,20	0,20	0,20	0,20	< 0,05	< 0,05	0,05	< 0,05	< 0,05	< 0,05	< 0,05

In Büyükçekmece WTP, there was no pre-ozonation because the high bromide in the reservoir due to sea intrusion

What should be the O_3 concentration ?

- 1.0-5.0 mg/L for potable water treatment plants, depending on the purposes (disinfection, taste & odor control, color removal & control of THM)
- Residual ozone 0.3-0.9 mg/L
- Ozone conc. in Ömerli = 1.5 mg/L then increased to 2.1 mg/L



Contact time of 3 min is enough acc. to lab experiments

6 minutes were chosen (to be on the safe side)

Capacity of ozone generators

(1,000,000 m3/day x 1.5g/m3)/24 =62.5 kg O_3/hr

If you use dry air feed system ; 1 to 3.5 % by weight

If you use pure oxygen; 2 to 7% by weight

Capacity of compressor

62.5 kg O_3/hr x (100/2.5) = 2500 kg air /hr

Density of air at 20^0C = 1.204 kg/m^3

Volume of air = 2500 /1.204 = 2706 m^3/hr

# of diffusers: 2706 / 8 = 338 ~ 340 diffuser

OZONE CONTACT CHAMBER DESIGN

1. Select ozone contact time
   - pre ozonation : 3-5 min
   - post ozonation: 10 min

2. Determine the volume of the ozone contact chamber, V=tr.Q

3. Water depth should be 3-6 m.
   Use deeper tanks to increase ozone transfer efficiency (similar to aeration tanks in wastewater treatment, deep tanks, higher difuser eff.)

4. Determine the area of the tank; Area = V/depth
5. Select the number of tanks (minimum 2)
6. Determine the length and width of the tank

LAYOUT OF CONTACT CHAMBERS

Points to be considered ;

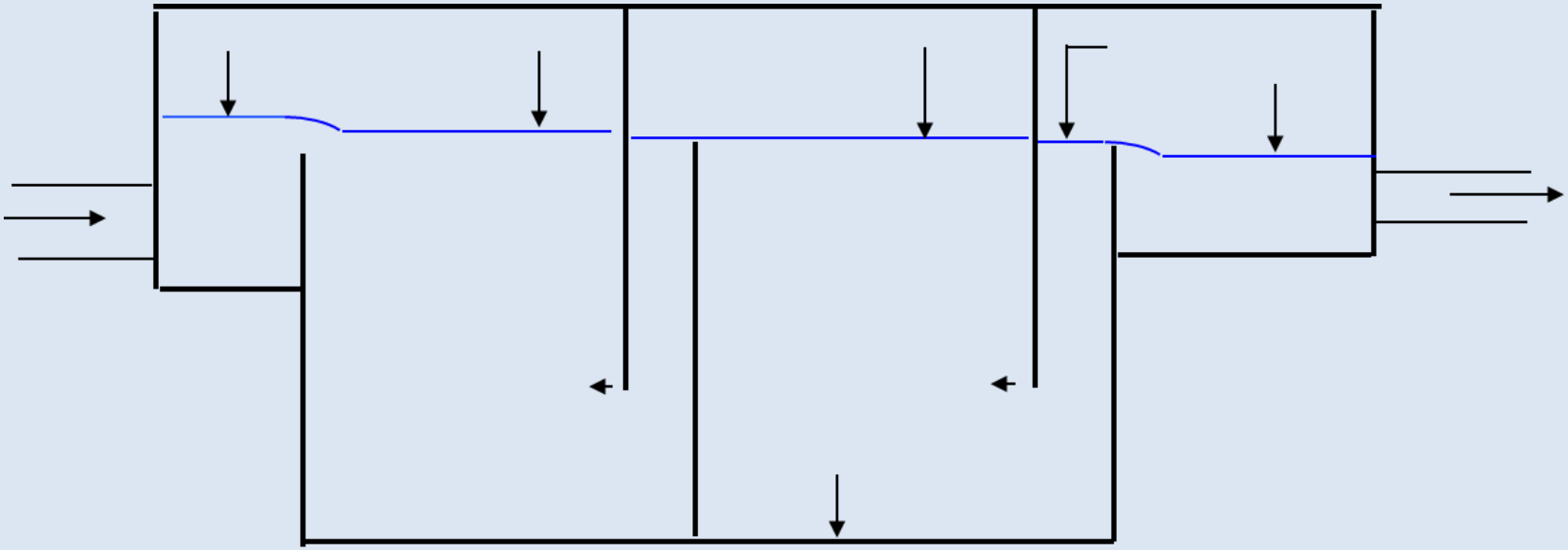
- Layout of the tanks should allow bypassing the all tanks
- Layout of the tanks should allow taking one tank out of the service during maintenance & cleaning periods
- Influent and effluent channels to the contact chambers should be designed adequately in order to have equal distribution
- Pass the water through the tanks with minimum possible head loss (velocities through the openings)
- Recheck the hydraulic of the system (water levels) when one tank out of service

# of compartments: 2

If the volumes of the compartments is equal;

2/3 of the ozone is given in the 1st compartment

1/3 of the ozone is given in the 2nd compartment



If the number of diffusers in each compartment is equal

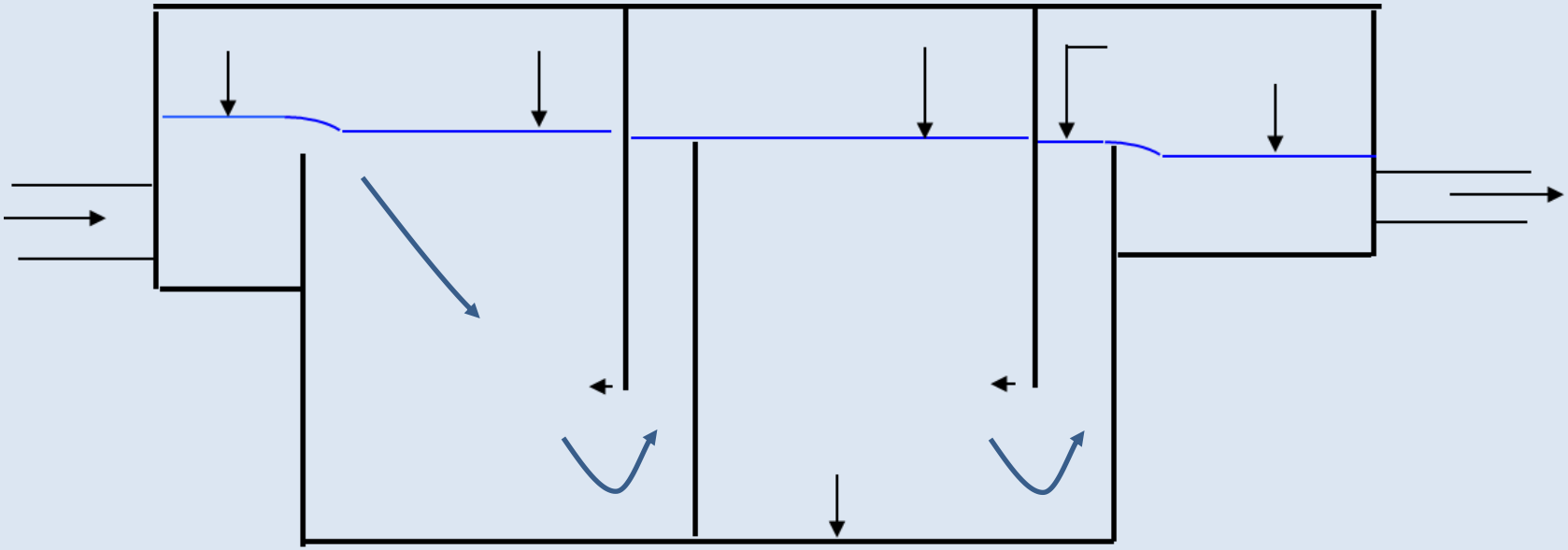
2/3 of the total volume ; 1st compartment

1/3 of the total volume ; 2nd compartment

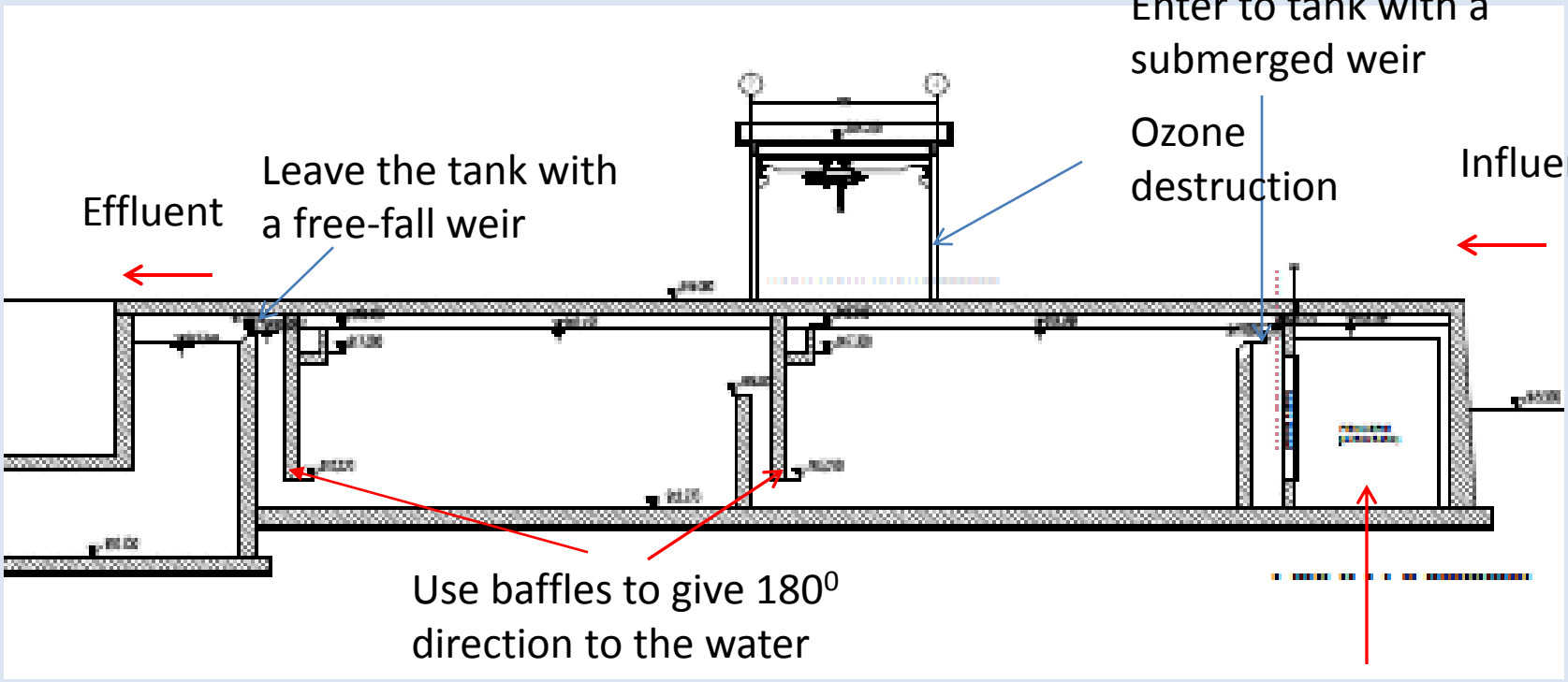
To obtain good contact between ozone and water ➔ Give the ozone from the bottom and water from the top of the tank

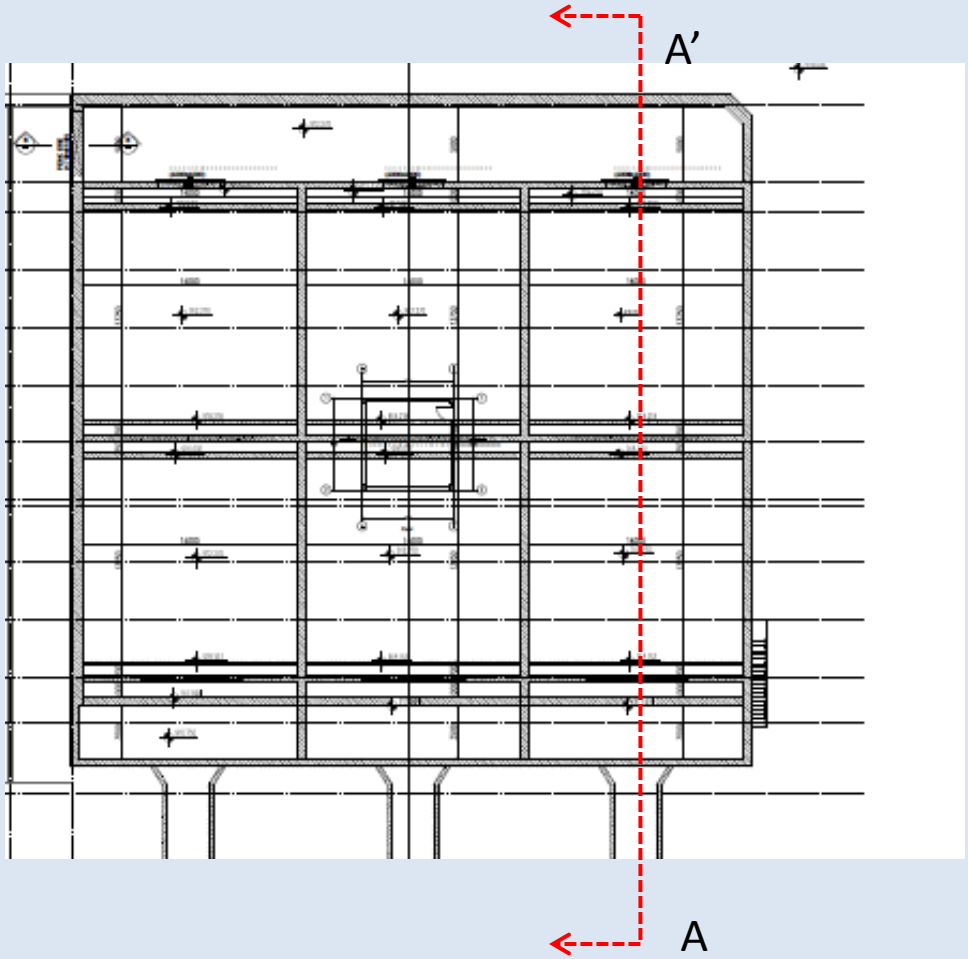
➔ Use baffles inside the tanks in order to increase the water path and prevent short circuiting

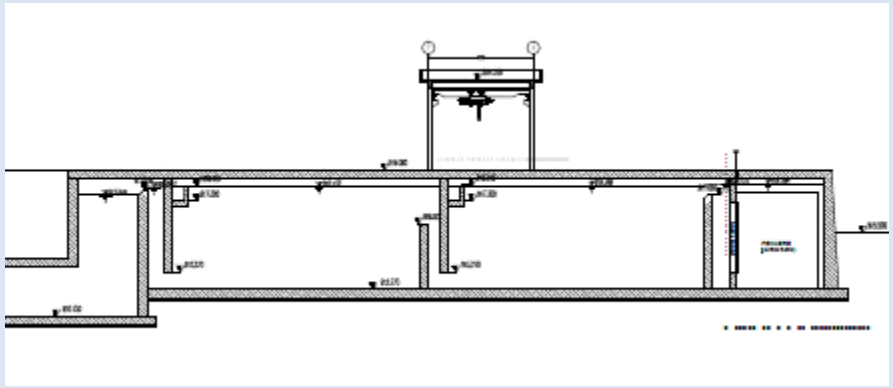
➔ Use weirs in the influent and effluent of the tank ➔ good contact and constant level of water in the tank



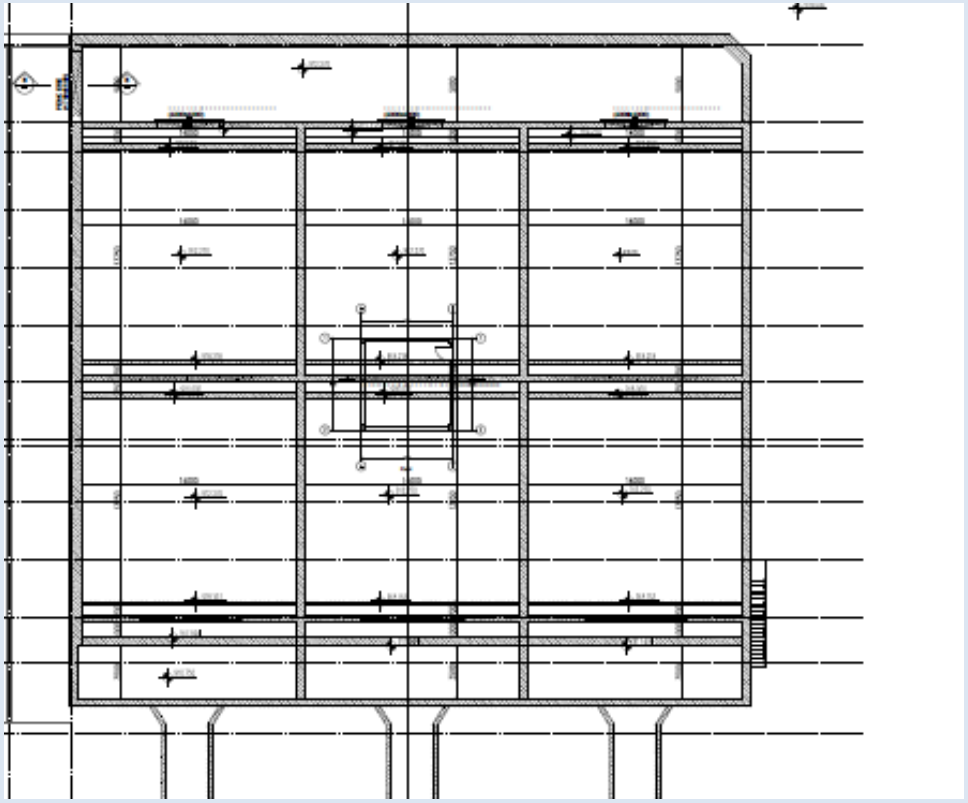
Control the velocities under and between baffles; do not increase the head loss

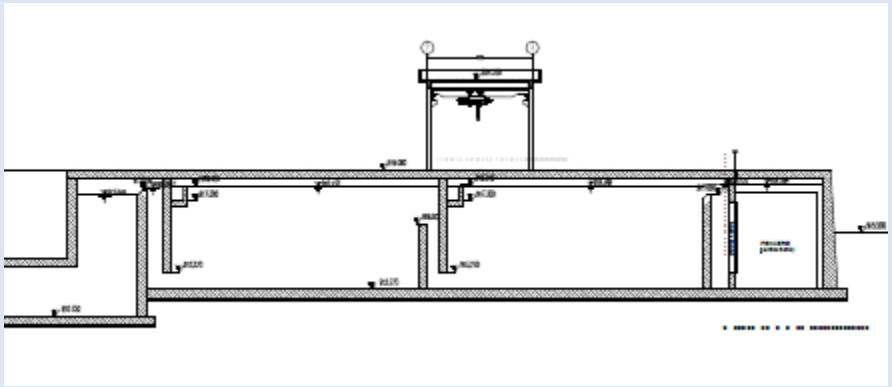

Enter to tank with a submerged weir
Ozone destruction
Influent
Effluent
Leave the tank with a free-fall weir
Use baffles to give 180^0 direction to the water
2nd compartment
1st compartment
Influent distribution channel





Section A-A’





A

Section A-A’

Velocity in the influent channel ;

Qeach= $\frac{1692000\ m^3/day}{86400}$ =19.58 m^3/s

c/ s area of the channel : 6 m x 5 m
=30 m^2

V = 19.58 / 30= 0.652m/s

Maximum velocity in the channel for equal distribution:

Vmax = $1.253\sqrt{DH}$

DH= Head loss through the inlet openings (orifices)

DH= 0.0228 m

Vmax =0.189 m/s

OZONE CONTACT CHAMBER HYDRAULIC CALCULATIONS