ENVE 302
Environmental Engineering Unit Processes

CHAPTER: 11
PONDS & LAGOONS

Assist. Prof. Bilge Alpaslan Kocamemi
Marmara University
Department of Environmental Engineering
Istanbul, Turkey

PONDS & LAGOONS

→ suspended-culture biological systems

→ large, shallow earthen basins (usually lined)

→ wastewater is retained long enough for natural purification process to provide the necessary degree of treatment

→ climate play an important role in the operation because they are often installed and operated locations with widely varying climatic conditions

→ the effect of temperature change must be considered in the design

Ponds: some oxygen is supplied by diffusion from the air
bulk of the oxygen is provided by photosynthesis

Lagoons: oxygen is provided by artificial aeration (mechanical aerators)

PONDS

Aerobic Ponds

most frequently used as additional treatment process

are often referred to as polishing or tertiary ponds

Anaeorobic ponds

can be used for partial treatment of a strong organic wastewater

must be followed by some form of aerobic treatment

Facultative Ponds

in which both aerobic and anaeorobic zones exist

most commonly used one for municipal wastewater treatment

LAGOONS

AEROBIC LAGOON

Flow through partially mixed lagoon

the energy input is sufficient to meet the oxygen requirements but insufficient to maintain all of the solids in suspension

HRT=SRT

The solids in the effluent are removed prior to discharge in an external sedimentation facility

Lagoon with solids recycle

sufficient energy is supplied both to meet the oxygen requirement and to keep the entire tank content mixed and aerated

essentially same as the extended aeration activated sludge process with the exception that an earthen basin (typically lined) is used in place of a reinforced concrete

FACULTATIVE PARTIALLY MIXED LAGOON

the energy input is only sufficient to transfer the amount of oxygen required for biological treatment but is not sufficient to maintain the solids in suspension

a portion of incoming solids will settle along with a portion of biological solids produced from the conversion of the soluble organic substrate

In time, settled solids will undergo anaeorobic decomposition

the effect of algae is negligible

eventually facultative lagoons must be dewatered and the accumulated solids are removed

Table 8-29
Typical characteristics of different types of aerated suspended growth lagoons

	Unit	Type of aerated lagoon: Facultative	Aerobic flow-through	Aerobic with solids recycling
TSS	mg/L	50-200	100-400	1500-3000
VSS / TSS	unitless	50-80	70-80	50-80
SRT	d		3-6 typically 5	Warm: 10-20 Moderate: 20-30 Cold: over 30
HRT	d	4-10	3-6 typically 5	0.25-2.0
overall BOD removal rate, k	d^{-1}	0.5-0.8	0.5-1.5	
Temp. coefficient	unitless	1.04	1.04	1.04
depth	m	2-5	2-5	2-5
mixing regime		partially mixed	partially mixed	Nominal complete-mix
minimum power	$kW/10^3 m^3$	1-1.25	5.0-8.0	16-20
sludge		Sludge accumulates internally in the lagoon	Sludge accumulates in external sedimentation facility	Sludge recycled to process from sedimentation tank. Waste sludge is discharged to sludge drying beds
nitrification		No	Not typically	Likely, especially in warm climates

Table 8-29
Typical characteristics of different types of aerated suspended growth lagoons

	Unit	Type of aerated lagoon		
		Facultative	Aerobic flow-through	Aerobic with solids recycling
TSS	mg/L	50-200	100-400	1500-3000
VSS / TSS	unitless	50-80	70-80	50-80
SRT	d		3-6 typically 5	Warm: 10-20 Moderate: 20-30 Cold: over 30
HRT	d	4-10	3-6 typically 5	0.25-2.0
overall BOD removal rate, k	d^{-1}	0.5-0.8	0.5-1.5	
Temp. coefficient	unitless	1.04	1.04	1.04
depth	m	2-5	2-5	2-5
mixing regime		partially mixed	partially mixed	Nominal complete-mix
minimum power	$kW/10^3 m^3$	1-1.25	5.0-8.0	16-20
sludge		Sludge accumulates internally in the lagoon	Sludge accumulates in external sedimentation facility	Sludge recycled to process from sedimentation tank. Waste sludge is discharged to sludge drying beds
nitrification		No	Not typically	Likely, especially in warm climates

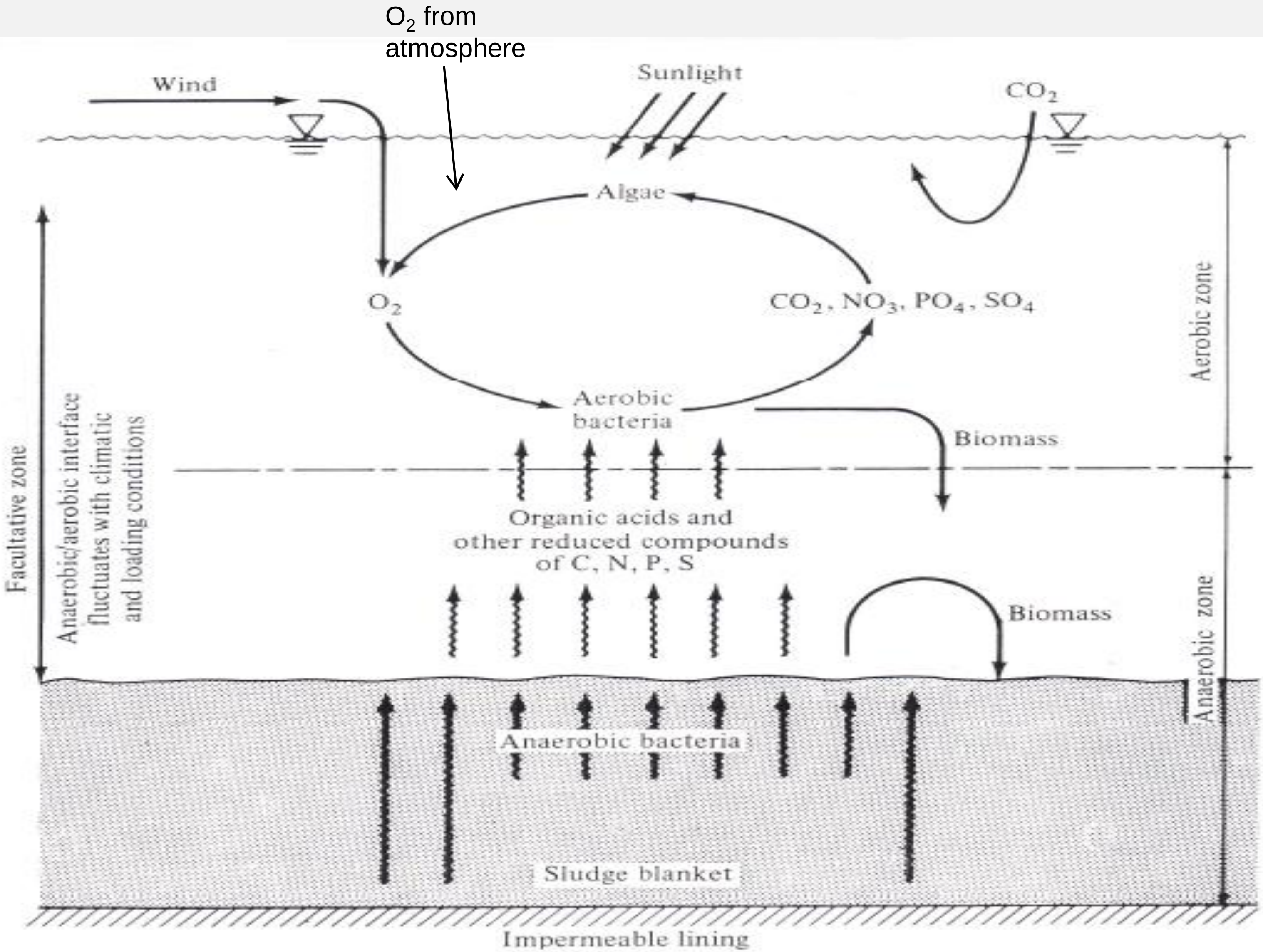

Figure 5-21 Generalized diagram of facultative pond reaction.

In the upper portion;

Aerobic conditions are maintained

- by oxygen generated by algae
- by penetration of atmospheric oxygen (to a lesser extent)

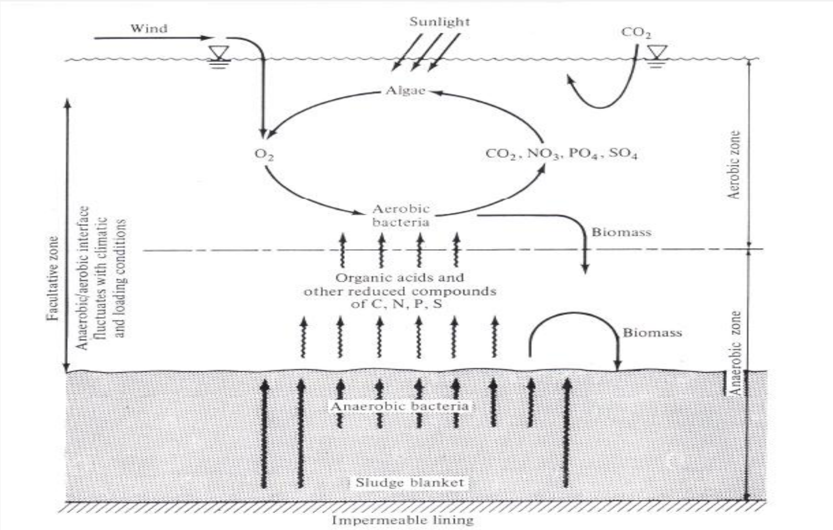

Figure 5-21 Generalized diagram of facultative pond reaction.

Symbiotic relationship (mutually beneficial) between algae and bacteria

- Bacteria use O_2 as e^- acceptor
- Oxidize ww organics to end products, CO_2, NO_3^-, PO_4^{3-}
- Algae use these compounds with sunlight as energy source and produce oxygen as an end product. Produced O_2 is used by bacteria

Boundary between aerobic and anaerobic zone

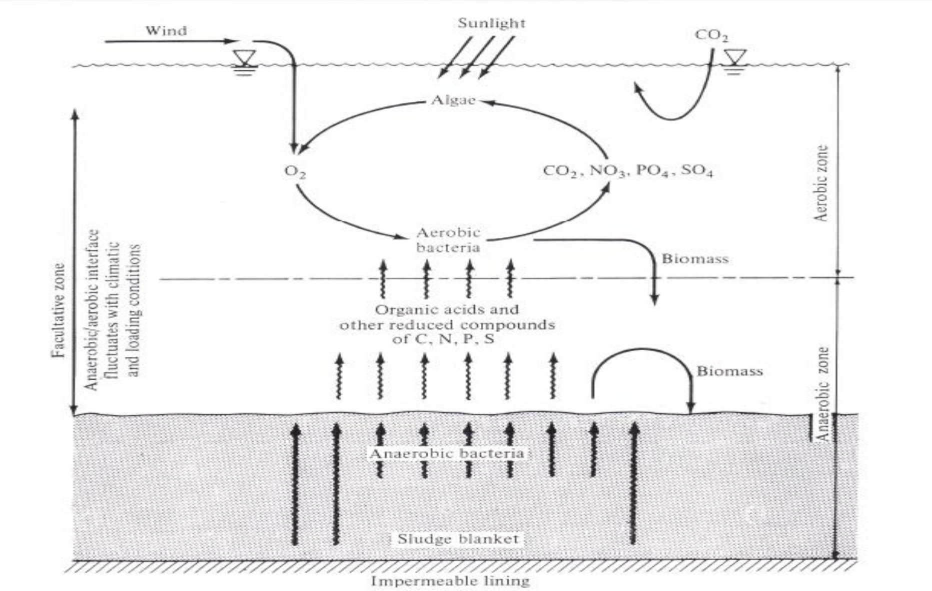

Figure 5-21 Generalized diagram of facultative pond reaction.

Not stationary

Mixing by wind action and penetration by sunlight may extend the aerobic area downward.

Conversely, calm water and weak lighting result in the anaerobic layer rising toward surface.

(diurnal fluctuations in aerobic-anaerobic interface)

In the lower portion;

Sludge along the bottom prevent oxygen transfer to that region and anaerobic conditions prevail

In anaerobic zone

- Organic acids
- Gases
- Products of decomposition

are foods for organisms in the aerobic zone

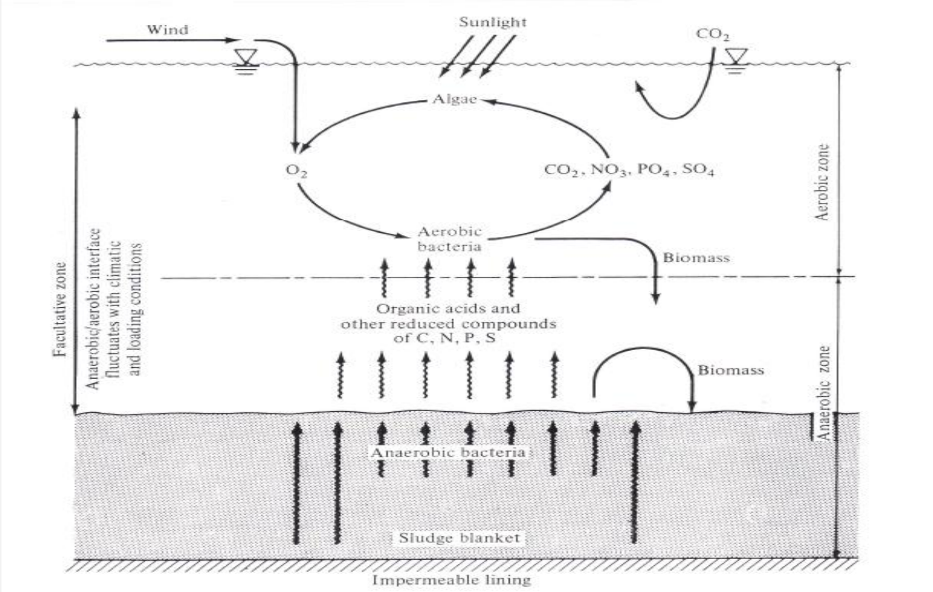

Figure 5-21 Generalized diagram of facultative pond reaction.

Biological solids produced in the aerobic zone

- Settle to bottom where they die
- Providing food for the anaerobic organisims

Process Design Considerations For Flow Through Lagoons

Aerated flow through lagoon can be considered to be a complete mix reactor without recycle

SRT = HRT

1 st Approach : Equations derived from the mass balance for activated sludge systems (see Chapter 4 slides)

$$S = \text{effluent subst conc} = \frac{K_s(1 + k_d\theta_c)}{\theta_c(Yk - k_d) - 1}$$

$$X = \frac{\theta_c}{\theta}\left[\frac{Y(S_o - S)}{1 + k_d\theta_c}\right]$$

2nd Approach : CFSTR, 1 st order kinetics (BOD removal) , steady-state conditions (see Enve 301 slides)

$$C = \frac{C_0}{1 + k\frac{V}{Q}} = \frac{C_0}{1 + k\theta}$$

C_0= influent BOD conc, g/m3

C= effluent BOD conc., g/m3

k= overall first order BOD removal rate constant, day^{-1}

k= 0.5-1.5 day^{-1}

Ambient Temperature correction

$$T_w = \frac{A f T_a + Q T_i}{A f + Q}$$

T_i= influent ww temp, ^0C

T_w= lagoon water temperature , ^0C

T_a= ambient air temperature , ^0C

F= proportionality factor

İncorparates the appropriate heat-transfer coeff

and includes the effect of surface area increase

due to aeration, wind, humidity (0.5)

A= surface area of lagoon, m2

Q= flowrate, m3/d

Oxygen Requirement

$$Oxygen\ required = Q(S_0 - S) - 1.42 P_{X,bio}$$

Biomass as VSS daily includes;

→ active biomass

→cell debris

$$P_{X,bio} = \frac{QY(S_0 - S)}{1 + k_d \theta_c} + \frac{f_d . k_d . Q . Y(S_0 - S)\theta c}{1 + k_d \theta_c}$$

Mixing Requirement

The following relationship has been found for low-speed mechanical aerators:

$$P = 0.004X + 5 \qquad \text{for } X < 2000 \text{ mg/L}$$

P= power required for maintaining the solids in suspension , $kW/10^3 m^3$

X= total suspended solids, mg/l

Other relationships:

The threshold energy input = 1.5 -1.75 $kw/10^3$ m3

Energy required to maintain all solids in suspension is considerably greater

Example: Design a flow-through aerated lagoon to treat wastewater flow of 3800 m3/d

Influent TSS= 200 g/m3

Influent sBOD = 200 g/m3

Effluent sBOD = 30 g/m3

<u>Kinetic coefficients for Temperature 20-25^{0}C:</u>

Y= 0.65 g/g, Ks= 100 g/m3, k= 6 g/g.d, kd= 0.07 g/g.d

VSS/TSS = 0.85

1st order observed soluble BOD removal rate constant (k_{20} = 2.5 d^{-1})

Summer air temperature = 30^{0}C

Winter air temperature during coldest month= 6^{0}C

Wastewater temperature during winter = 16 ^{0}C

Wastewater temperature during summer= 22 ^{0}C

Temp. Coeff = ϴ =1.06

Aeration constants, α = 0.85 β= 1

Aerator oxygen transfer rate = 1.8 kg O2/kw.h

Elev= 500 m

Do in ww= 1.5 mg/L

Lagoon depth = 3.3 m

Design sludge age = 5 days, power required for mixing = 8 kW/10^3 m3

Figure 5-68

Oxygen Solubility correction factor versus elevation