Secondary Wastewater Treatment (Waste Stabilization Ponds)

Waste Stabilization Ponds(WSPs)

- Waste stabilization ponds (WSP) are shallow manmade basins into which wastewater flows and from which, after a retention time of several days a well treated effluent is discharged.
- Advantages of Waste stabilization ponds can be summarized as ***simplicity***, ***low-cost***, and ***high efficiency***.
- Because of these properties they are highly appropriate for use in developing countries like Pakistan.

Waste Stabilization Ponds(WSPs)

Types of WSPs:

WSP systems comprise a single series of following ponds:

- Anaerobic
- Facultative
- Maturation.

In essence, anaerobic and facultative ponds are designed for BOD removal and maturation ponds for pathogen removal.

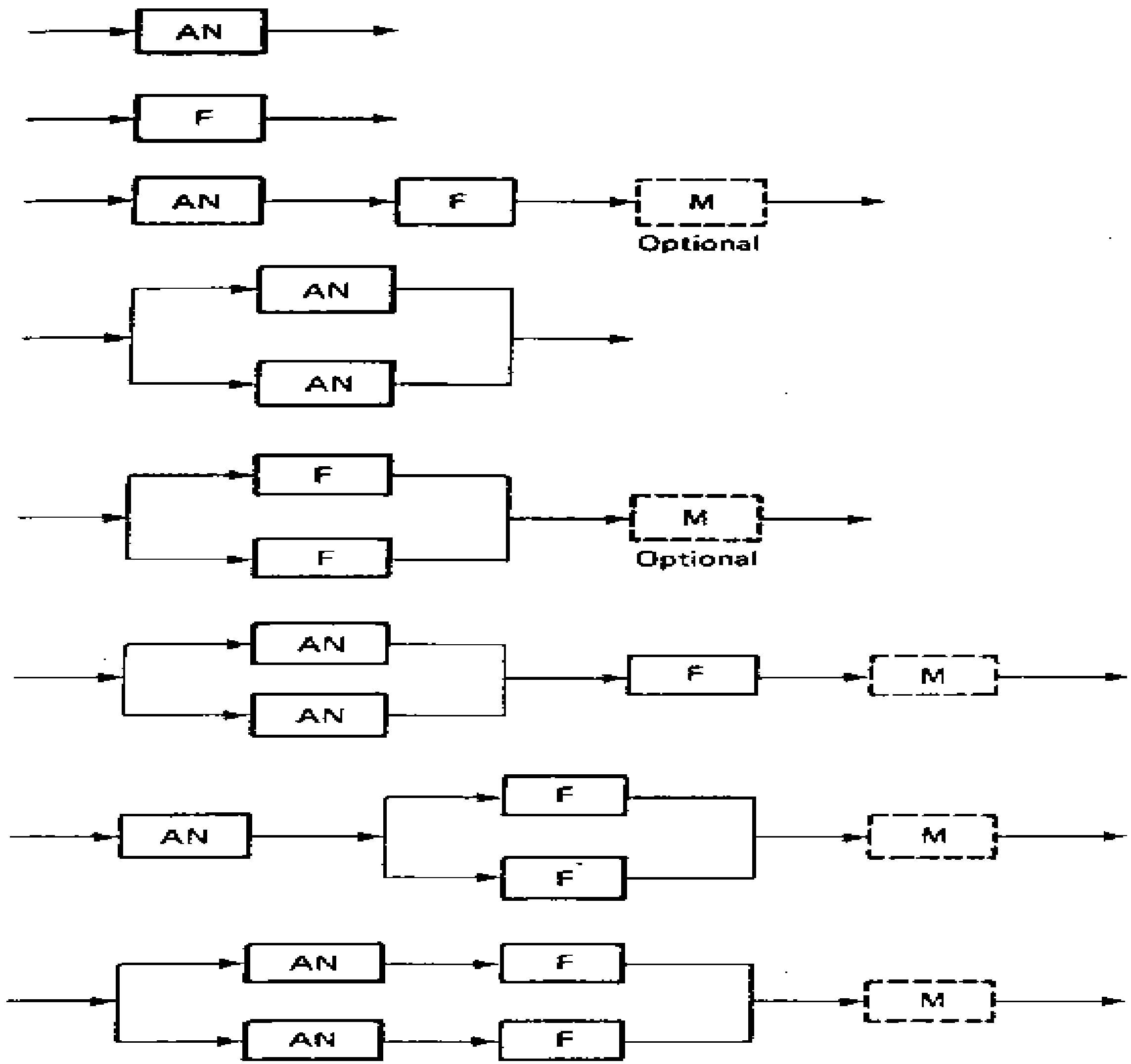


Fig: Different Configuration of WSPs

Waste Stabilization Ponds(WSPs)

- In many instances only anaerobic and facultative ponds will be required.
- In general maturation ponds will be required only when the treated wastewater is to be used for **unrestricted irrigation.**
- Restricted irrigation refers to the irrigation of industrial crops , such as cotton and sunflower, and food crop not for direct human consumption.
- Unrestricted irrigation covers vegetable crops, including raw vegetables.

Waste Stabilization Ponds(WSPs)

ADVANTAGES:

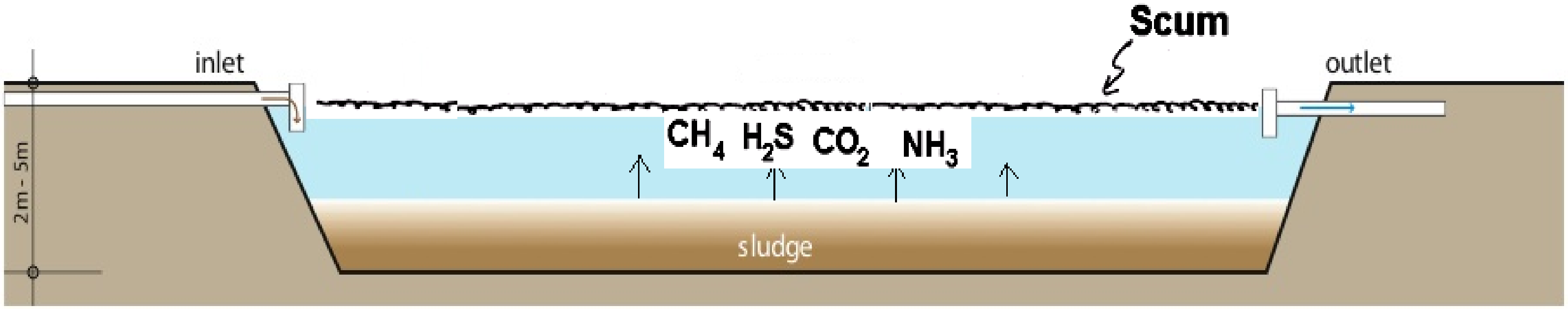
- High reduction in pathogens.
- Can be built and repaired with locally available materials.
- Low operating cost.
- No electrical energy required.
- No real problems with flies or odors if designed correctly.

DISADVANTAGES/LIMITATIONS:

- Requires large land area.
- Variable capital cost depending on the price of land.

1.Anaerobic Pond(AP)

- Anaerobic ponds are commonly **2-5 m deep** and receive such a high organic loading *(usually >100 g BOD/m^3.d,equivalent to 3000 kg/ha.d) that they contain no dissolved oxygen and no algae.*



Anaerobic Pond

- BOD and S.S. removal 40-70%
- Retention times are short (1 to 5 days)
- Odor problem
- Side Slopes 1V:3H
- L:W = 3:1 (max)
- Detention Time = 1-5 days

1.Anaerobic Pond(AP)

BOD Removal:

In anaerobic ponds BOD removal is achieved by;

- Sedimentation of settle able solids, and
- Subsequent anaerobic digestion in the resulting sludge layer
- De-sludging period 3-5 years
- Anaerobic ponds work extremely well in warm climates

1.Anaerobic Pond(AP)

Design

- They design on the basis of **volumetric BOD loading** (λ_v , g/m3-d),which is given by :

$$\lambda_v = L_i \times Q / V_a \ldots\ldots\ldots\ldots (1)$$

Where,
Li = influent BOD (mg/l)
Q =flow (m^3/d)
Va= anaerobic pond volume (m^3)

- **λ_v should lie between 100 and 400 g/m^3-d.**

1.Anaerobic Pond(AP)

Table: design values of permissible volumetric BOD loadings and % BOD removal in anaerobic ponds at various temperatures

Temperature	Volumetric loading rate	BOD removal
(°C)	(g/m3.d)	(%)
<10	100	40
10-20	20T-100	2T+20
20-25	10T+100	2T+20
>25	350	70

Source: Mara and Pearson (1986) Mara et al (1997)

θ_a

1.Anaerobic Pond(AP)

- The hydraulic retention time in the pond (θ_a) is determined from:

$$\theta_a = \frac{V_a}{Q}$$

Where,

θ_a=retention time

Q =flow (m^3/d)

Va= anaerobic pond volume (m^3)

- NOTE: Retention time in anaerobic ponds <1 day should not be used. Adopt 1 day at temperature > 20°C.

1.Anaerobic Pond(AP)

Pond Geometry and Dimensions:

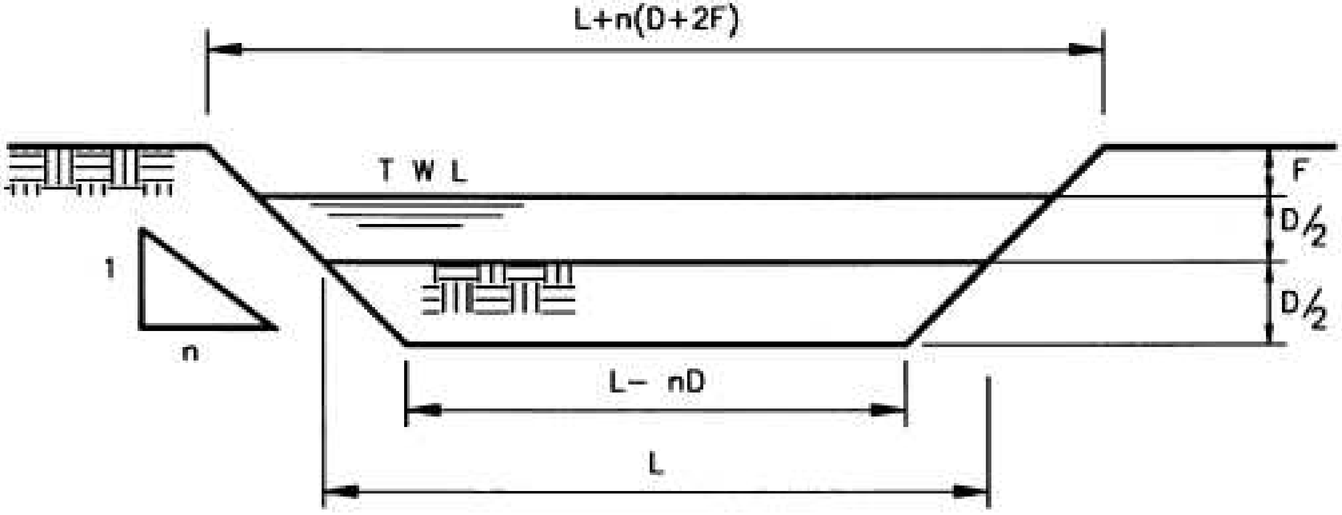
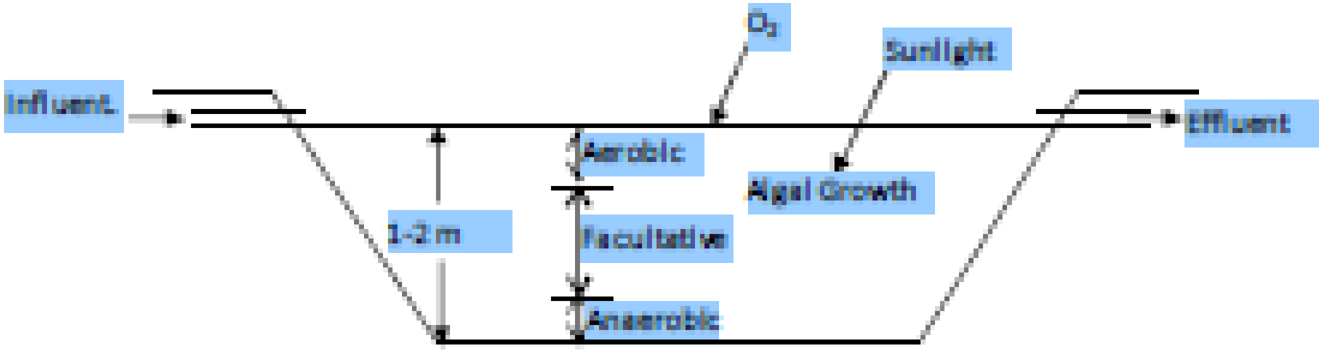


Fig: Calculation of top and bottom pond dimensions from those based on mid-depth

2. Facultative Pond(FP)

- FPs (**1-2m deep**)
- Side Slopes 1V:3H
- L:W = 3:1 (max)
- Retention Time = 7-20 days
- They are designed for BOD removal on the basis of a relatively low surface loading rate (100-400Kg BOD/ha-d) to permit the development of a healthy algal population.



- Oxygen for BOD removal by the pond bacteria is mostly generated by algal photosynthesis.

2. Facultative Pond(FP)

<u>Types:</u>

Facultative ponds are of two types:

- ***Primary facultative ponds*** which receive raw wastewater, and
- ***Secondary facultative ponds*** which receive settled wastewater (usually the effluent from anaerobic ponds).

2. Facultative Pond(FP)

BOD Removal in Secondary Facultative Ponds:

- The remaining non-settleable BOD (after anaerobic ponds) is oxidized by the bacteria.
- These bacteria obtain the oxygen they need from the photosynthetic activities of the micro-algae which grow naturally and abundantly in facultative ponds.
- The algae, in turn, depend largely on the bacteria for the carbon dioxide which they use in photosynthesis.
- So there exists a mutualistic relationship between the pond algae and the pond bacteria.

2. Facultative Pond(FP)

BOD Removal in Secondary Facultative Ponds:

This mutualistic relationship between the pond algae and the pond bacteria is also known as **“bacteria-algae symbiosis”.**

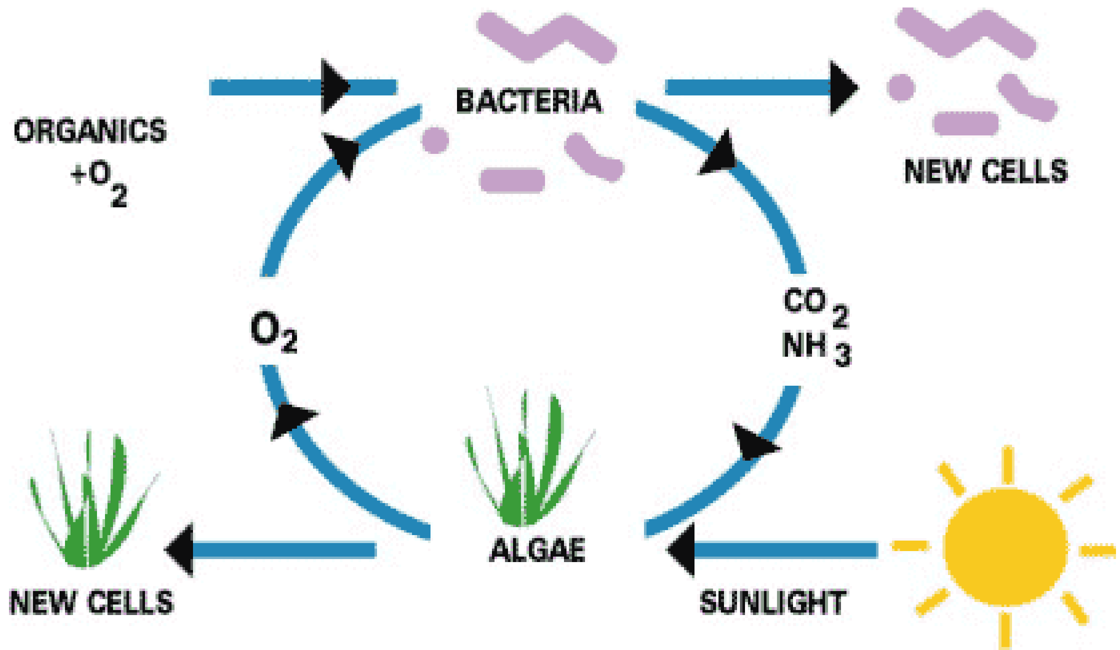


Fig: Bacteria-algae symbiosis in Facultative Ponds

2. Facultative Pond(FP)

BOD Removal in Secondary Facultative Ponds:

- As a result of the photosynthetic activities of the pond algae, there is a diurnal variation in the concentration of dissolved oxygen.
- The wind has an important effect on the behavior of facultative ponds, as it induces vertical mixing of the pond liquid.

2. Facultative Pond(FP)

BOD Removal in Primary Facultative Ponds:

In primary facultative ponds the functions of anaerobic and secondary facultative ponds are combined.

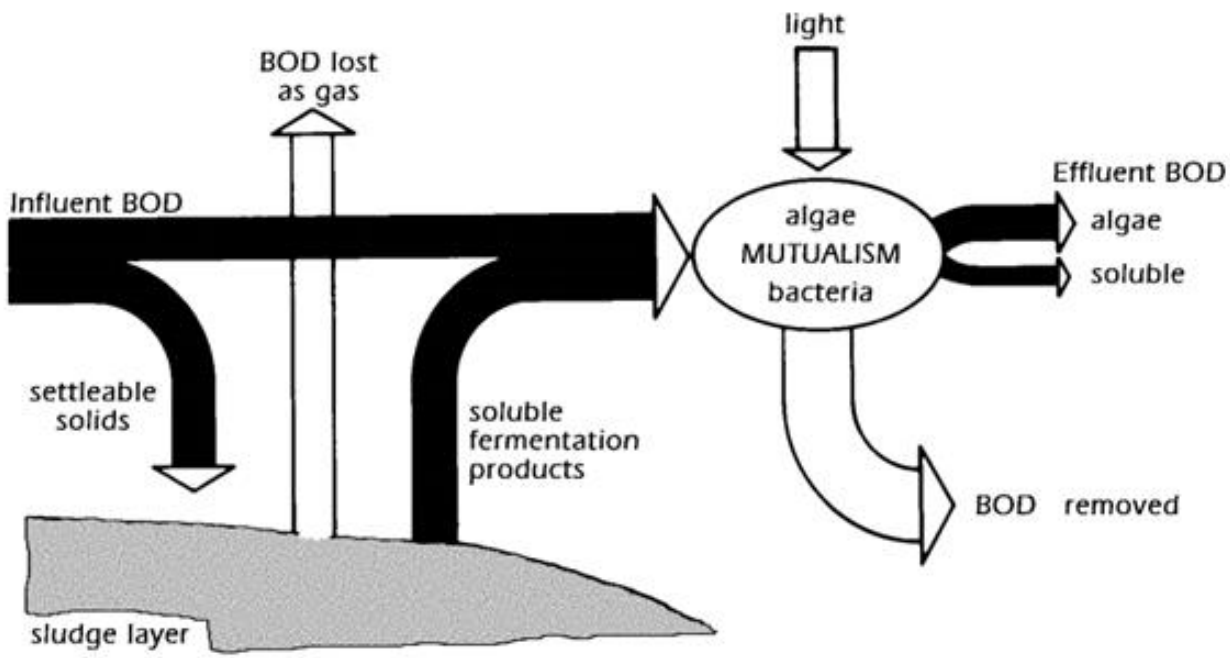


Figure Pathways of BOD removal in primary facultative ponds

2. Facultative Pond(FP)

DESIGN:

- Designed on the basis of surface BOD loading (λ_s,kg/ha d), which is given by:

$$\lambda_s = 10\ L_i\ X\ Q\ /\ A_f\ ....(2)$$

Where;

A_f= facultative pond area (m^2)

The permissible design value of λ_S is selected on the basis of temperature. An appropriate global design equation was given by Mara (1987):

$$\lambda_S = 350\ (1.107-0.002T)^{T-25}\ ....(3)$$

2. Facultative Pond(FP)

Table: Values of λs at various temperature

Temperature	Surface loading rate	Temperature	Surface loading rate
(°C)	(kg/ha.d)	(°C)	(kg/ha.d)
11	112	21	272
12	124	22	291
13	137	23	311
14	152	24	331
15	167	25	350
16	183	26	369
17	199	27	389
18	217	28	406
19	235	29	424
20	253	30	440

2. Facultative Pond(FP)

Retention time can be calculated as:

$$\theta_f = \frac{A_f D}{Q_m}$$

Where;

D=pond depth ,m

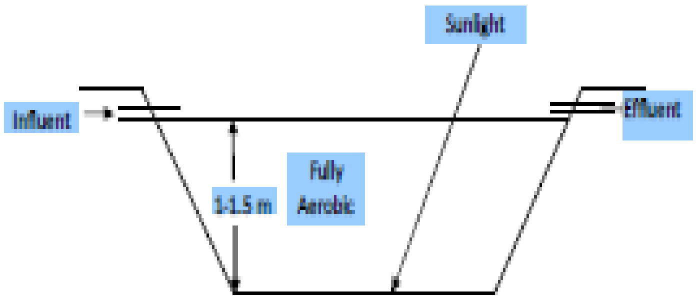
Q_m= mean flow,m3/d

- NOTE: A minimum value of retention time of 5 days should be adopted for temperature < 20°C,4 days for >20°C

3.Maturation Pond(MP)

The primary function of maturation ponds is the removal of excreted pathogens.

- A series of maturation ponds (1-1.5m deep) receives the effluent from a facultative pond.
- Side Slopes 1V:3H
- L:W = 3:1 (max)
- Retention Time = 4-14 days



- The size and number of maturation ponds is governed mainly by the required bacteriological quality of the final effluent.
- Maturation ponds are well oxygenated throughout the day.

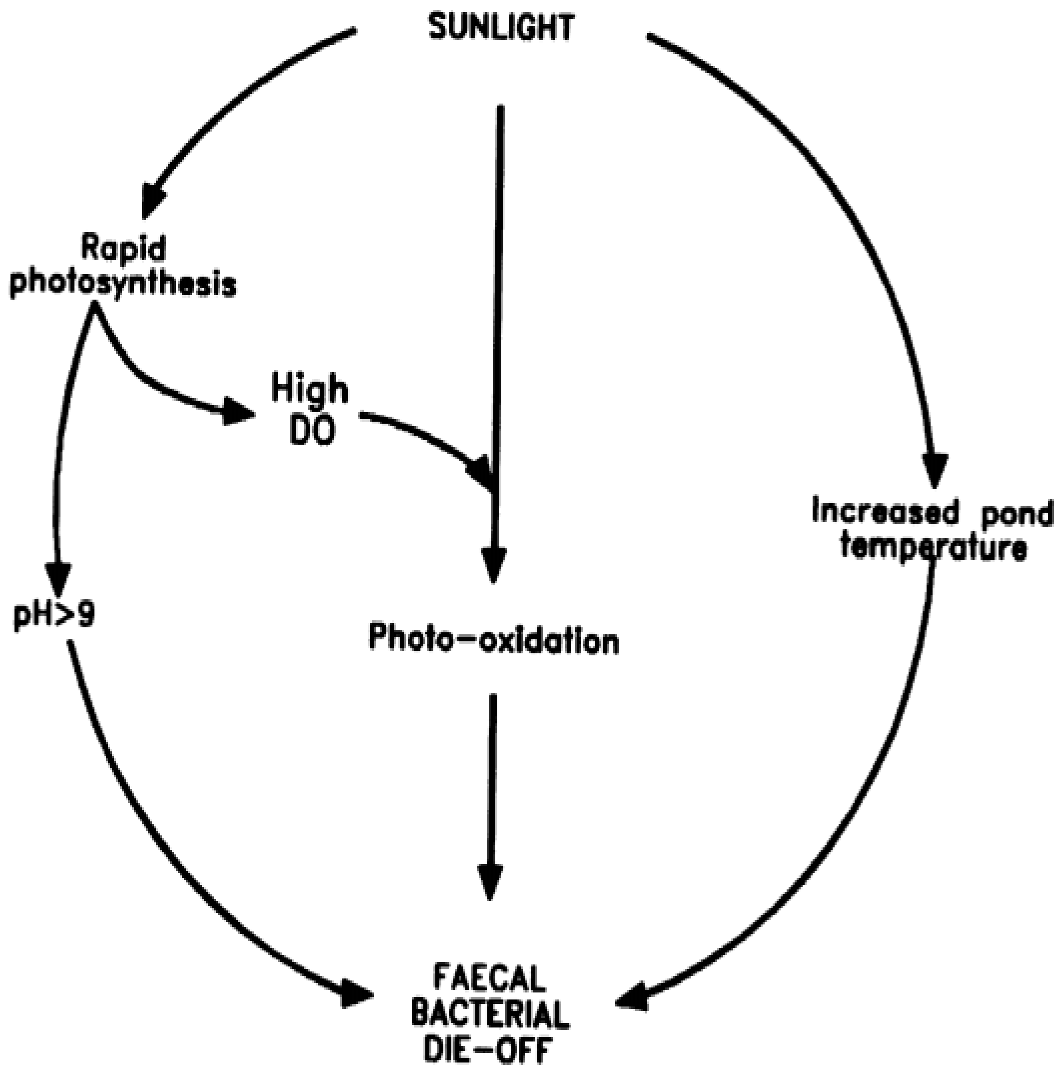
3.Maturation Pond(MP)

PATHOGEN REMOVAL:

Bacteria:

The principal mechanisms for fecal bacterial removal in facultative and maturation ponds are now known to be:

- Time and temperature,
- High pH (> 9), and
- High light intensity together with high dissolved oxygen concentration.



Conceptual mechanisms for faecal coliform die-off in ponds.

3.Maturation Pond(MP)

PATHOGEN REMOVAL

PATHOGEN REMOVAL:

Viruses:

- It occurs by adsorption on to settle able solids (including the pond algae) and consequent sedimentation.

Parasites:

- Protozoan cysts and helminthes eggs are removed by sedimentation, and consequently most removal takes place in the anaerobic and facultative ponds.

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3.Maturation Pond(MP)

- The method of Marais is generally used to design a pond series for fecal coliform removal.
- Fecal coliform removal is a first order kinetics

$$N_e = \frac{N_I}{(1 + K_T\theta)}$$

Where:

Ne= number of FC per 100 ml of effluent

Ni=number of FC per 100 ml of influent

K_T= first order rate constant for FC removal, per day

θ = retention time,day

3.Maturation Pond(MP)

For a series of MPs effluent concentration of pathogens can be calculated as

$$N_e = \left[\frac{N_I}{(1 + K_T\theta_a)\left(1 + K_T\theta_f\right)(1 + K_T\theta_m)^n}\right]$$

Removal efficiency of pathogens can be calculated as:

$$R = 100[1 - 0.41\exp\left(-0.491\theta + 0.0085\theta^2\right)]$$

Area of MP is calculated as:

$$A_m = \frac{\theta_m Q}{D}$$

3.Maturation Pond(MP)

Table: Values of K_T at various temperature for fecal coliform removal

Temperature	K_T	Temperature	K_T
(°C)	(per day)	(°C)	(per day)
11	0.54	21	3.09
12	0.65	22	3.68
13	0.77	23	4.38
14	0.92	24	5.21
15	0.09	25	6.20
16	1.30	26	7.38
17	1.54	27	8.77
18	1.84	28	10.40
19	2.18	29	12.44
20	2.60	30	14.8

Problem

- (A) Design a WSP system treat 10,000 m3/day of a wastewater which has a BOD of 200 mg/l. The design temperature is 25°C and the net evaporation rate is 5 mm/day.
- (B) Design a WSP system as in part (A) but for restricted irrigation. Assume that the wastewater contains 750 intestinal nematode eggs per litre and allowable intestinal nematode eggs are 1 per liter
- (C) Design a WSP system as in part (A) , but for unrestricted irrigation. Assume that the wastewater contains 5×10^7 fecal coliforms per 100 ml. Allowable concentration is 1000 per 100ml.