19.3.3 Factors Affecting Pond Ecosystem

The principal members of abiotic component of ponds ecosystem are oxygen, carbon dioxide, water light and nutrients; while the biotic components are algae, bacteria, protozoa, and variety of other organisms. Various factors affect the pond design, such as (Arceivala and Asolekar, 2007):

- Wastewater characteristics and fluctuation,
- Environmental factors, solar radiation, sky clearance, temperature, and their variation,
- Algal growth pattern and their diurnal and seasonal variation,
- Bacterial growth pattern and decay rates,
- Hydraulic transport pattern,
- Evaporation and seepage,
- Solids settlement, liquefaction, gasification, upward diffusion, sludge accumulation,
- Gas transfer at interface.

19.3.4 Design Guidelines for Oxidation Pond

1. *Depth of Pond:* It should be within 1 m to 1.5 m. The ponds are designed with such a shallow depth to provide proper penetration of light, thus allowing growth of aquatic plants and production oxygen. When these ponds are used for sewage treatment the primary objective is organic removal a depth of 1 m to 1.2 m is used. Shallow ponds experience higher temperature variation than deeper ponds. So, an optimum pond depth is necessary.
2. *Surface area of Pond:* Sufficient surface area must be provided so that oxygen yields from the pond is greater than the ultimate BOD load applied. NEERI gives photosynthetic oxygen yield for different latitude in India:

Latitude (^{0}N)	Yield of photosynthetic O_2 (kg/ha.day)
16	275
20	250
24	225
28	200

Individual pond area should not be greater than 0.5 ha. If any system requires more area then it is desirable to have more than one pond. 25 % more area is provided than that calculated to account for embankments.

3. *Substrate removal rate:* Substrate removal rate K_p varies from 0.13 to 0.20 per day at 25 ^{0}C and 0.10 to 0.15 at 20 ^{0}C. For other temperature it can be calculated as:

   $Kp (T^oC) = Kp (20^oC)(1.035)^{(T-20)}$ (56)

   The size of the pond will be half when plug flow pattern is maintained rather than completely mixed conditions. This can be achieved by providing ponds in series.

4. *Detention time (T):* It should be adequate enough for the bacteria to stabilize the applied BOD load to a desirable degree.

5. *Sulphide production:* Sulphide production in oxidation ponds can be calculated from the following empirical relationship (Arceivala and Asolekar, 2007):

   S^{2-} (mg/l) = $(0.0001058 * BOD_5 – 0.001655 * T + 0.0553) * SO_4^{2-}$

   Where, BOD_5 is in kg/ha.days,

   T = detention time in days,

   SO_4^{2-} in mg/l.

   Sulphide ion concentration should not be greater than 4 mg/L. At concentrations higher than this algal growth is inhibited.

6. *Coliform removal:* To use the pond effluent for irrigation coliform concentration should be less than 1000/100 ml.

   Coliform removal follows the first order rate equation (Arceivala and Asolekar, 2007):

   $dN/dt = K_b.N$, (57)

   where, N = Number of organisms at any given time, t

   K_b = Death rate, per unit time (1 to 1.2 per day at 20^{0}C)

7. *Sludge accumulation:* In ponds sludge accumulation occurs at the rate 0.05 to 0.08 m^3/capita/year. Sludge accumulation causes decrease in efficiency of the ponds, so they require cleaning every 7 to 10 year.

8. *Pretreatment:* Medium screens and grit removal devices should be provided before the ponds.

9. Inlet pipe with the bell mouth at its end discharging near the centre of the pond is provided.

10. The overflow arrangement is box structure with multiple valve draw-off lines to permit operation with seasonal variations in depth.

11. If the soil is pervious it should be sealed to prohibit seepage.

Example: 5

Design an Oxidation Pond with efficiency 85 % for a wastewater stream of 2 MLD with a BOD of 200 mg/L and the effluent coming out of the pond should have a BOD less than 30 mg/L. Temperature of the influent wastewater is 30^0C and the oxidation pond is located at a place having latitude 22^0N.

Solution

- Assuming that 65 % of the effluent solids are biodegradable,
- Biodegradable effluent solids = 0.65*30 = 19.5 mg/l.
- At 22^0N, considering oxygen production by photosynthesis = 235 kg/hectare.day,
- And K_p = 0.23/day.
- The oxidation pond is designed for plug flow conditions.
- For plug flow conditions, dispersion number, D/UL = 0.2
- $K_p t$ (for efficiency = 85%, D/UL = 0.2) = 2.5 (Arceivala and Asolekar, 2007)
- Therefore, detention time, t = $K_p t/K_p$ = 2.5/0.23 = 10.87 days.
- Now, wastewater flow = 2 MLD = 2000 m^3/day
- Therefore, pond volume = detention time * flow = 2000 * 10.87 = 21739.14 m^3
- Maximum BOD load that can be applied on the pond = 235/0.85 = 276.47 kg/day
- Influent ultimate BOD = 1.4 * 200* 2 = 560 kg/ha.day
- Therefore, minimum pond area required = 560/276.47 = 2.02 ha
- Gross land area required = 1.25 * 2.02 = 2.53 ha
- Minimum pond depth = (Pond Volume)/(Pond depth) = (21739.14/2.02)*10000 = 1.07 m
- Provide length = 225 m, breadth = 115 m, free board = 1m,
- Therefore depth of the pond = 2.07 m

- To maintain plug flow conditions the pond is divided into 3 cells along length with each cell length = 75 m.

19.3.5 Design of Facultative Stabilization Pond

In design the oxygen resources of the pond are equated to the applied organic loading. The principal source of oxygen is photosynthesis and that is dependent on solar energy. The solar energy again is related to geographical meteorological and astronomical phenomenon, and varies principally with time in year and the altitude of the place. The yield of photosynthetic oxygen for different latitude is given earlier. Yield of photosynthetic oxygen may be calculated directly if the amount of solar energy in $Cal/m^2.day$ and the efficiency of conversion of light energy to fix energy in the form of algal cells are known.

In design of facultative ponds part of the organic matter is considered to undergo anaerobic decomposition and the photosynthetic oxygen yield is equated to the remaining organic matter to support aerobic oxidation. The organic loading in kg of BOD per hectare per day applied on pond can be estimated using (Rao and Dutta, 2007):

$$Lo = 10(d/t)\,BODu \qquad (58)$$

Where. Lo = Organic loading in kg/hect.day

d = depth of pond in m

t = detention time in days

BODu = ultimate soluble BOD, mg/L

(Loading = ((BOD*Q)/A), now A=V/d, therefore loading = BOD*Q/(V/d), hence loading = BOD.d/t)

The organic loading may be modified for **elevations** above mean sea level by dividing by factor (1 + 0.003 EL). Where EL is elevation of pond site above MSL in hundred meters. For every 10% decrease in the sky clearance factor below 75%, the pond area may be increased by 3%.

Example: 6

Design facultative stabilization pond to treat a domestic sewage of 2 MLD, located at a place where the latitude is 20 ^{o}N and 500 m above mean sea level. The five day 20 ^{o}C BOD of the sewage is 200 mg/L. Suitable other data may be assumed for Indian conditions.

Solution

$BOD_5 = BODu(1 – e^{-k.t})$

Therfore, $BODu = BOD_5 / (1 – e^{-k.t})$

Assuming k = 0.23 per day

Ultimate BOD = $200 / (1 – e^{-5 \text{ x } 0.23}) = 293$ mg/L

At 20 ^{o}N, the yield of photosynthetic oxygen = 250 kg/hect.day.

Since the place is 500 m above MSL, the oxygen yield = 250/(1 + 0.03x5) = 246.3 kg/hect.d

Now organic loading can be calculated as

Lo = 10 (d/t) BODu = 10 (d/t) x 293

Assuming 50% of this load is non settleable, and it undergoes aerobic decomposition in the top layer.

The oxygen requirement = 10 (d/t) x 293 x 0.5

Equating this to photosynthetic oxygen yield of 246.3 kg/hect.day and solving

d/t = 0.168

Provide d = 1.5 m, hence t = 1.5/0.171 = 8.922 days

Now, Volume = flow x detention time = depth x surface area

Therefore, Area required = $2 \text{ x } 10^3 \text{ x } 8.922/1.5 = 11.90 \text{ x } 10^3 \text{ m}^2$

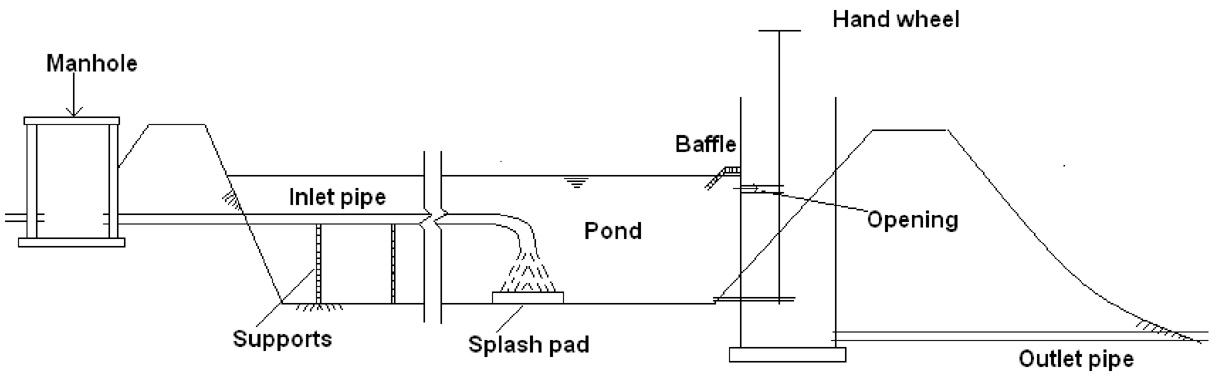

Figure 19.16 Schematic of facultative waste stabilization pond