Waste Stabilization Ponds

Design Summaries

1. Anaerobic ponds
2. Facultative ponds
3. Maturation ponds

Design temperatures

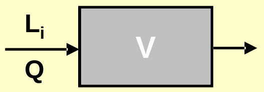
1. Anaerobic & facultative ponds:
   − mean air temperature of coldest month
2. Maturation ponds (to achieve required *E. coli* removal):
   − mean air temperature of coolest month in irrigation season

DESIGN OF ANAEROBIC PONDS

based on volumetric BOD loading, λ_v

$\lambda_V = L_i Q/V$ g/m³d

$= L_i/\theta_a$



L_i = influent BOD mg/l (= g/m³)

Q = flow, m³/d

V = volume, m³

V/Q = θ (retention time, days)

$\theta_a \nless 1$ d

DESIGN VALUES for λ_v & BOD removal

Design temp. (ºC)	BOD_5 loading (g/m³ day)	Percentage BOD removal
≤10	100	40
10–20	20T – 100*	2T + 20*
20–25	10T + 100*	2T + 20*
>25	350	70

* Linear interpolation (T = temperature, ºC)

Minimum retention time

- Calculate θ_a
- Min θ_a = 1 day
- If calculated value of θ_a is <1 day, then take θ_a = 1 day, and calculate the area from:

$$A_a = (Q \times 1)/D_a$$

- Take D_a = 3 m

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Now calculate L_e

FACULTATIVE PONDS

SURFACE BOD LOADING

λ_s – kg BOD/ha day

$$\lambda_s = 10 L_i Q/A$$

$L_i = L_{e(a)}$

L_i = influent BOD, mg/l *
Q = flow, m^3/day
A = pond area, m^2

NOTE UNITS! [*= g/m^3]

Design loading is a function of temperature:

GLOBAL DESIGN EQN FOR FACULTATIVE PONDS:

$$\lambda_s = 350(1.107 - 0.002T)^{T-25}$$

Note: 25°C

Facultative Pond Design PROCEDURE

1. Calculate area from BOD loading [= f(T)]
2. Choose depth (~1.5 m)
3. Calculate retention time, taking net evaporation into account – see →
4. Calculate unfiltered effluent BOD from first-order equation – see →
5. Calculate filtered effluent BOD (= 0.3 × unfiltered BOD)

EVAPORATION

e = net evaporation

= evaporation – rainfall, mm/day

[NB: Met. stations report mm/month]

Facultative ponds:

$\theta_f = A_f D/Q_m$ ← where Q_m = mean of inflow Q_i and outflow Q_e

$\therefore \theta_f = A_f D/[(Q_i + Q_e)/2]$

$Q_e = Q_i - 0.001eA_f$

$\therefore \theta_f = 2A_f D/(2Q_i - 0.001eA_f)$

Minimum retention time

- Min θ_f = 4 days
- If calculated value of θ_f is <4 days, then take θ_f = 4 days, and recalculate the area from:

  $$A_f = (Q \times 4)/D_f$$

- Take D_f = 1.5 m

BOD

$$L_e = \frac{L_i}{1 + k_1(V/Q)}$$

V/Q is the mean hydraulic time, days (symbol: θ)

$$L_e = \frac{L_i}{1 + k_1\theta}$$

L_e = unfiltered BOD
Filtered BOD = $0.3L_e$

For secondary facultative ponds k_1 for BOD removal varies with temperature as follows:

$$k_{1(T)} = 0.1(1.05)^{T-20}$$

NB: 20°C

Facultative ponds:

- So far we've calculated the area, chosen the depth, and calculated the retention time & effluent BOD
- Now check suitability of effluent for restricted irrigation:
  - $\leq 10^5$ *E. coli* per 100 ml, and
  - ≤ 1 egg per litre

1. E. coli removal

- General equation is:

  $N_e = N_i / [(1 + k_B\theta_{an})(1 + k_B\theta_{fac})(1 + k_B\theta_{mat})^n]$

- But as yet no maturation ponds, so:

  $N_{e(fac)} = N_i / [(1 + k_B\theta_{an})(1 + k_B\theta_{fac})]$

  where $k_B = 2.6(1.19)^{T-20}$

2. Egg removal

- Design equation is:

  $R\ (\%) = 100[1 - 0.41\exp(-0.41\theta + 0.0085\theta^2)]$,

  but use: $r = [1 - 0.41\exp(-0.41\theta + 0.0085\theta^2)]$

- Apply first to anaerobic pond (θ_a), then to facultative pond (θ_f); then:

- No. of eggs in fac. pond effluent = [(No. in raw wastewater) × $(1 - r_a)$ × $(1 - r_f)$]

MATURATION PONDS

- General equation is:

  $N_{fe} = N_i / [(1 + k_B\theta_{an})(1 + k_B\theta_{fac})(1 + k_B\theta_{mat})^n]$

- But $N_{e(fac)}$ already calculated, so use:

  $N_{fe} = N_{e(fac)} / (1 + k_B\theta_{mat})^n$

  N_{fe} = no. of *E. coli* per 100 ml of final effluent

MATURATION PONDS

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  $N_{fe} = N_i / [(1 + k_B\theta_{an})(1 + k_B\theta_{fac})(1 + k_B\theta_{mat})^n]$

- But $N_{e(fac)}$ already calculated, so use:

  $N_{fe} = N_{e(fac)} / (1 + k_B\theta_{mat})^n$

  N_{fe} = no. of *E. coli* per 100 ml of final effluent

- or (and this is better):

  $N_{fe} = N_{e(fac)} / [(1 + k_B\theta_{M1})(1 + k_B\theta_{mat})^n]$

Maturation Pond Design

Three-step procedure

- Step 1:

  Calculate: $\theta_{M1}^{min} = 10L_iD / 0.75\lambda_{s(fac)}$

  L_i → $= L_{e(fac)}$

  = Unfiltered BOD in fac. pond effluent

Maturation Pond Design

Three-step procedure

Step 1:

Calculate: $\theta_{M1}^{min} = 10L_iD/0.75\lambda_{s(fac)}$

$= L_{e(fac)}$

= Unfiltered BOD in fac. pond effluent

Step 1a: Determine no. of *E. coli* in M1 effluent

Step 2:

Calculate retention time in second & subsequent maturation ponds:

$\theta_m = \{[N_{e(fac)}/N_{fe}(1 + k_B\theta_{M1})]^{1/n} - 1\}/k_B$

now the retention time in M2, M3 etc.

Solve for n = 1, 2, 3 etc. and

STOP when $\theta_m < \theta_m^{min}$ (= 3 days) − assume this happens when n = ñ

Step 3:

Choose most appropriate combination* of θ_{mat} and n, including θ_{mat}^{min} and ñ

* ie, the one for which their product is a MINIMUM, as this gives the least land area requirement

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Now calculate the maturation pond areas taking evaporation into account ....

For facultative ponds we had:

- $\theta_f = A_fD/[(Q_i + Q_e)/2]$
- $Q_e = Q_i - 0.001eA_f$ ①

$\therefore \theta_f = 2A_fD/(2Q_i - 0.001eA_f)$ ②

For maturation ponds, rearrange ②:

$A_m = 2Q_i\theta_m/(2D_m + 0.001e\theta_m)$

❖ Q_i = effluent flow from preceding pond (use ① above)

❖ Take D_m = 1 m

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$\therefore \theta_f = 2A_fD/(2Q_i - 0.001eA_f)$ ②

Fac. ponds: A_f calc'd first, then θ_f − so θ_f corrected for evaporation.

For maturation ponds, rearrange ②:

$A_m = 2Q_i\theta_m/(2D_m + 0.001e\theta_m)$

❖ Q_i = effluent flow from preceding pond (use ① above)

❖ Take D_m = 1 m

Mat. ponds: θ_m calc'd first, then A_m − so A_m corrected for evaporation.