CHAPTER 9

WASTE STABILIZATION POND

WASTE STABILIZATION PONDS

- Waste stabilization ponds are shallow man-made basins. It can be round, square or rectangular.
- Stabilization ponds have been employed for treatment of wastewater for over 300 years.

ADVANTAGES

Simplicity

- simple to construct
- simple to operate and maintain
- only unskilled labour is needed

Low Cost

- cheaper than other wastewater treatment processes
- no need for expensive equipment

High Efficiency

- BOD removals > 90%
- Total nitrogen removals is 70-90%
- Total phosphorus removal is 30-45%
- Efficient in removing pathogens

THE PRINCIPAL REQUIREMENTS FOR WSP

- Sufficient land is available
- The soil should preferably have a coefficient of permeability less than 10^{-7} m/s (to avoid the need for pond lining)

TYPES OF WSP

1. Facultative pond
2. Maturation pond

FACULTATIVE POND

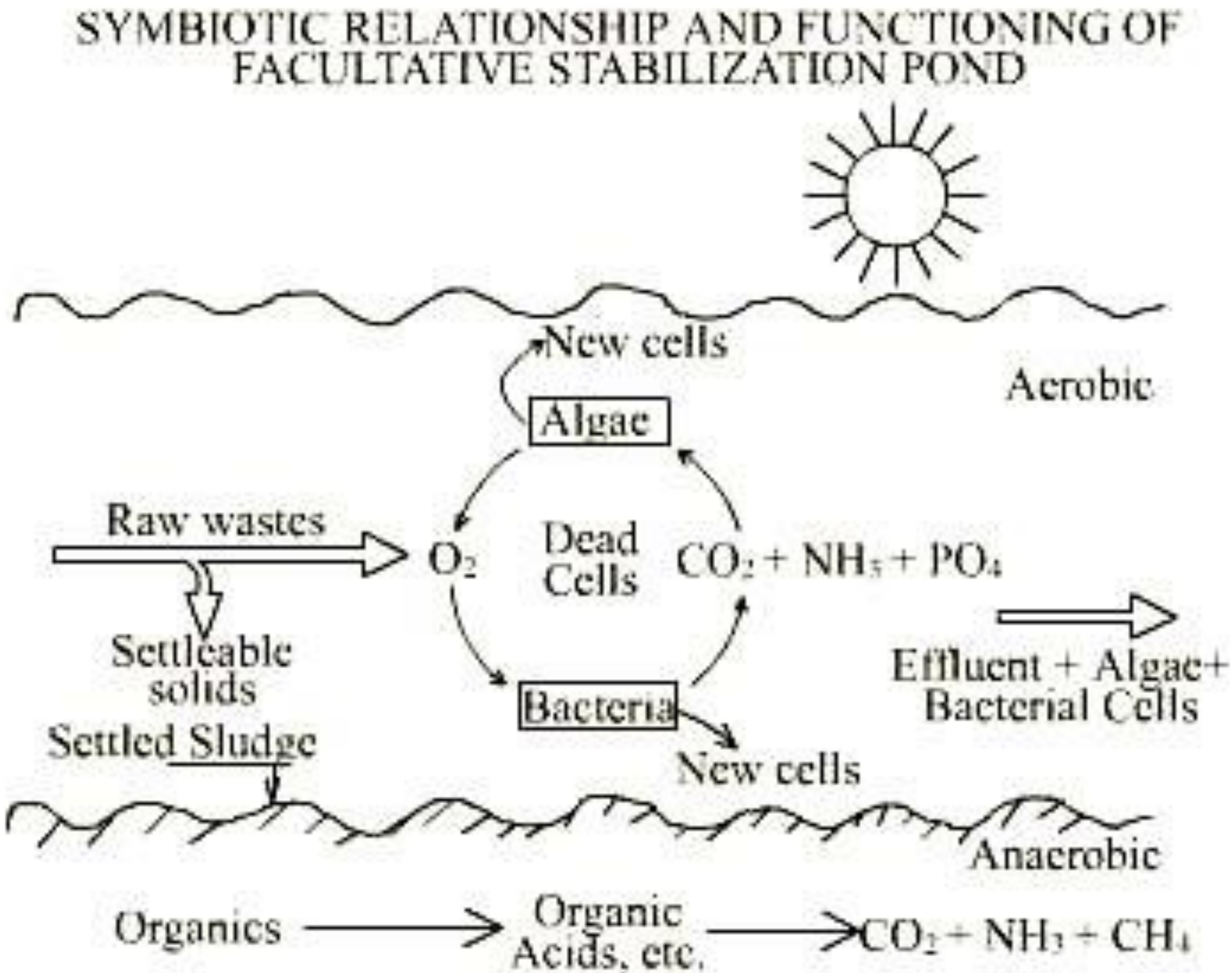
- 1-2 m deep
- The primary function is the removal of BOD

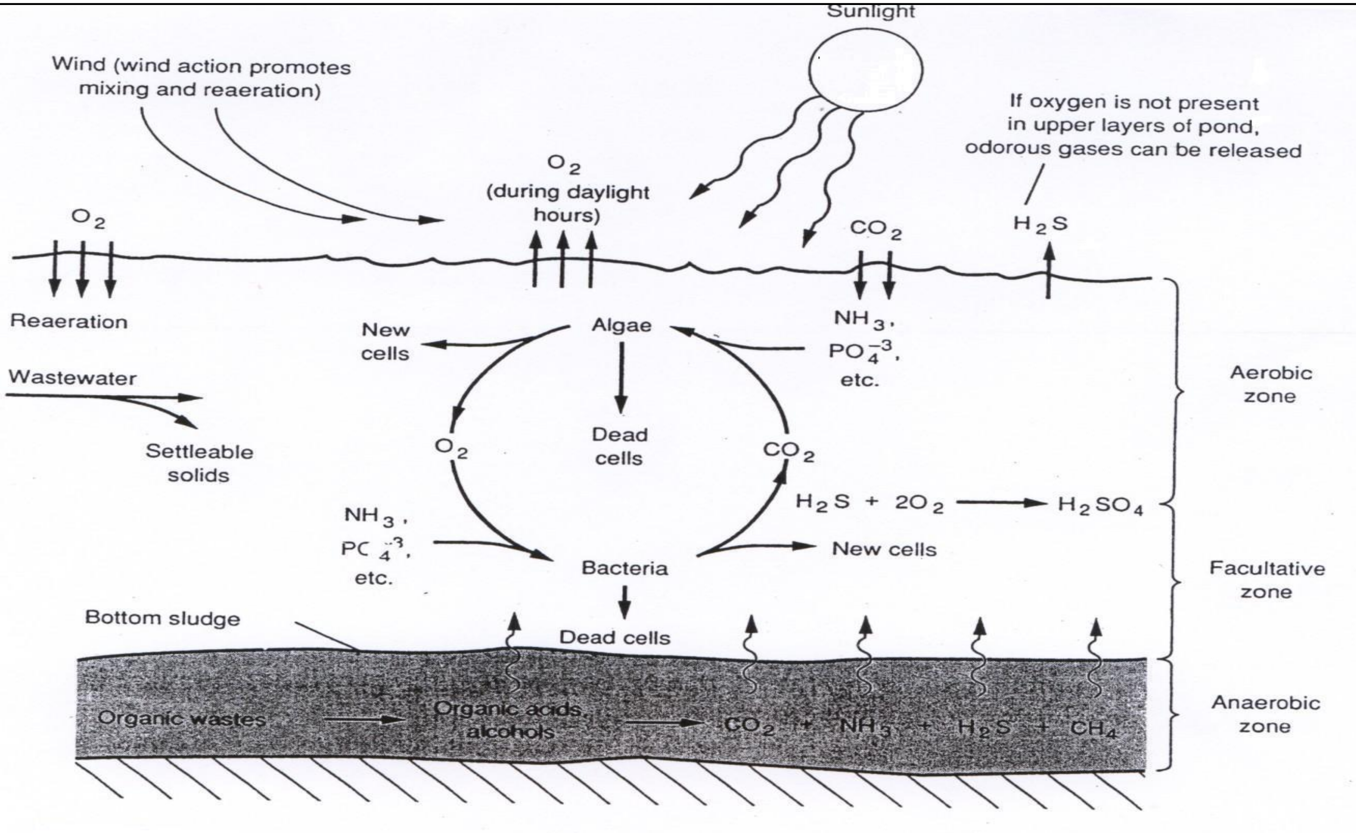
3 ZONE EXIST:

a) A surface zone where aerobic bacteria and algae exist in a symbiotic relationship. The algae provide the bacteria with oxygen and the bacteria provide the algae with carbon dioxide.

b) An anaerobic bottom zone in which accumulated solids are decomposed by anaerobic bacteria.

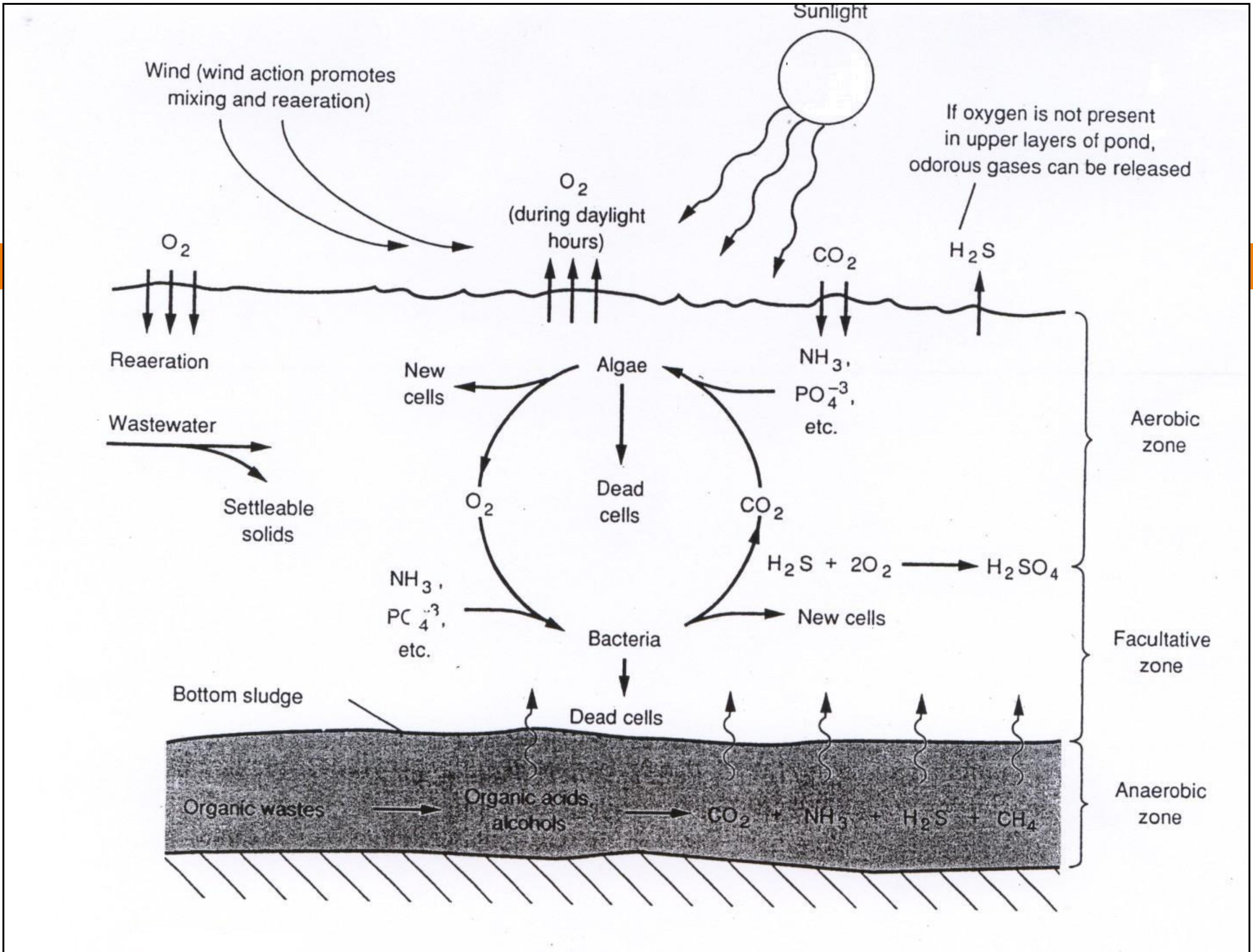
c) An intermediate zone that is partly aerobic and partly anaerobic in which the decomposition of organic wastes is carried out by facultative bacteria.


SYMBIOTIC RELATIONSHIP AND FUNCTIONING OF FACULTATIVE STABILIZATION POND
New cells
Aerobic
Algae
Raw wastes
O2
Dead Cells
CO2 + NH3 + PO4
Settleable solids
Effluent + Algae+ Bacterial Cells
Bacteria
Settled Sludge
New cells
Anaerobic
Organics
Organic Acids, etc.
CO2 + NH3 + CH4



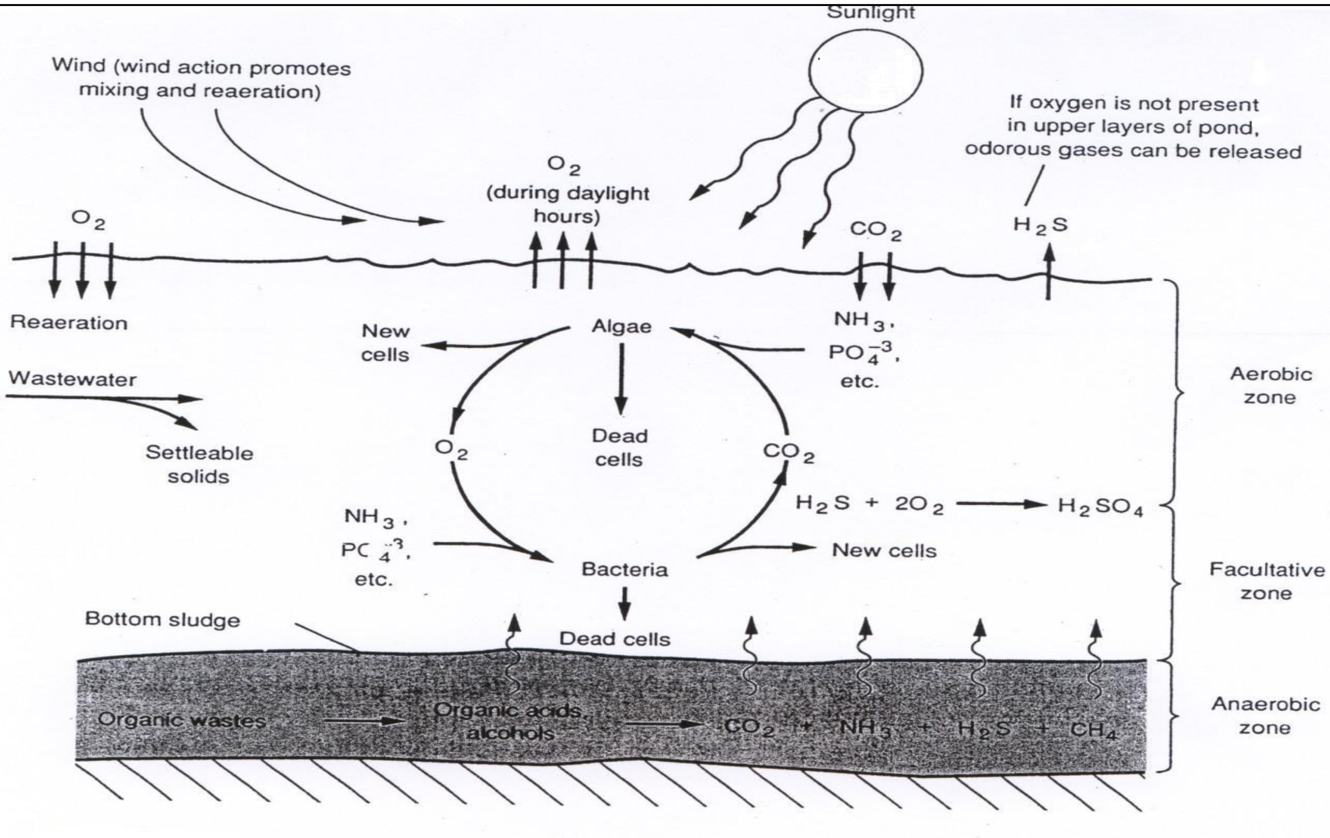
Schematic representation of a waste-stabilization pond

A surface zone where aerobic bacteria and algae exist in a symbiotic relationship. The algae provide the bacteria with oxygen and the bacteria provide the algae with carbon dioxide.



Schematic representation of a waste-stabilization pond

An anaerobic bottom zone in which accumulated solids are decomposed by anaerobic bacteria.



Schematic representation of a waste-stabilization pond

An intermediate zone that is partly aerobic and partly anaerobic in which the decomposition of organic wastes is carried out by facultative bacteria.

MATURATION POND

- 1-1.5 m deep
- Receive the effluent from a facultative pond
- Primary function is the removal of pathogens

BOD REMOVAL

- In facultative ponds, BOD removal is achieved by sedimentation of settleable solids and the remaining non-settleable BOD is oxidized by heterotrophic bacteria

- In maturation ponds only a small amount of BOD removal occurs

PATHOGEN REMOVAL

Bacteria

- Faecal bacteria are mainly removed in facultative and especially maturation ponds

PATHOGEN REMOVAL (CONT.)

- The principal mechanism for faecal bacteria removal are:
  - Time and temperature

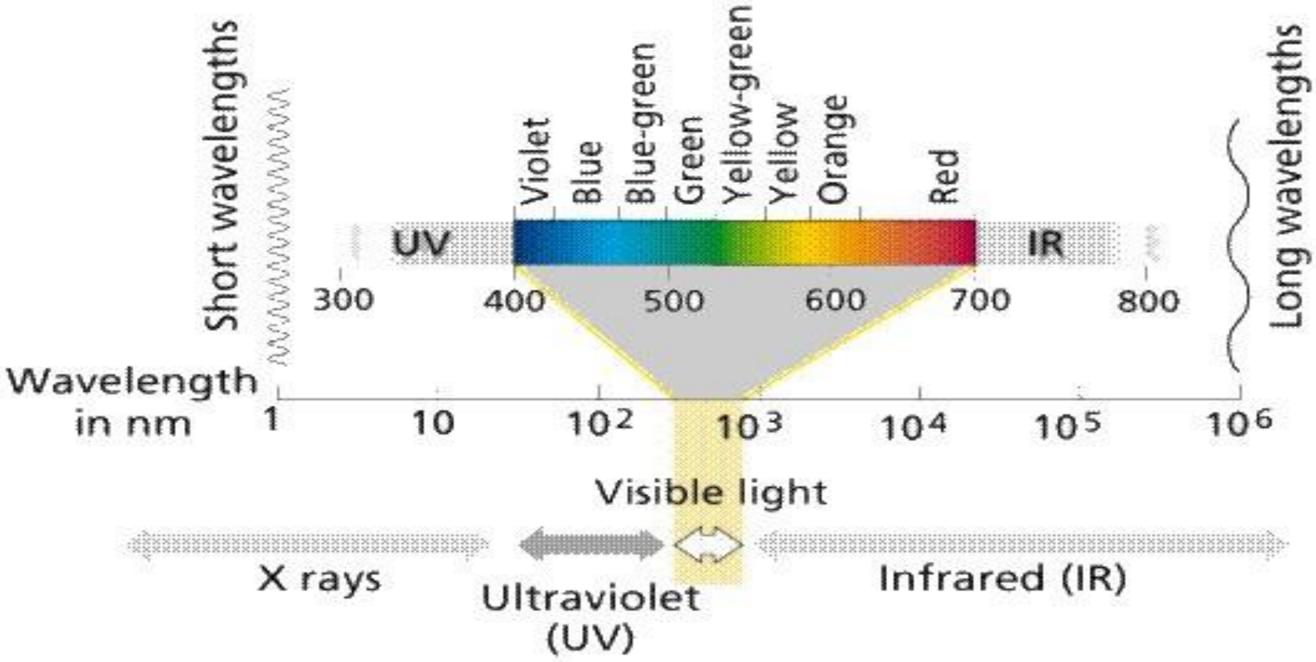
    - Faecal bacteria die-off in ponds increase with both time and temperature
  - High pH:

    - Faecal bacteria (except Vibrio Cholerae) die very quickly (within minutes) at pH>9

PATHOGEN REMOVAL (CONT.)

- High light intensity

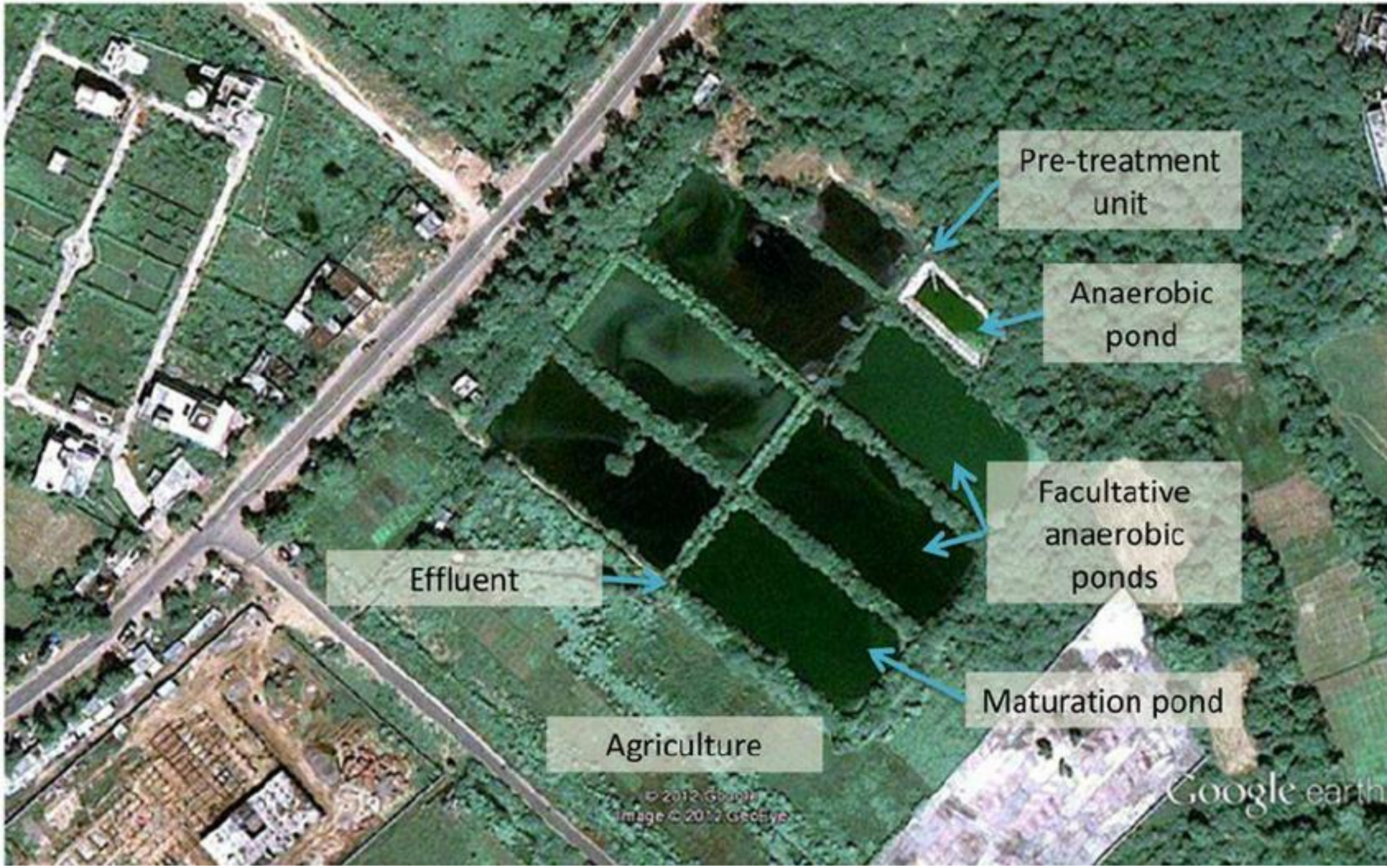
  - Light of wavelength 425 – 700 nm can damage faecal bacteria



PATHOGEN REMOVAL (CONT.)

Parasites

- protozoan cyst and helminth eggs are removed by sedimentation


Pre-treatment unit
Anaerobic pond
Facultative anaerobic ponds
Effluent
Maturation pond
Agriculture
Google earth

DESIGN OF WSP

FACULTATIVE PONDS

Surface BOD loading (λ_s, kg/ha d)

$$\lambda_s = 10 L_i Q / A_f \qquad (9.1)$$

where A_f = facultative pond area, m^2

The permissible BOD loading, $\lambda_{s,max}$

$$\lambda_{s,max} = 350\,(1.107 - 0.002T)^{T-25} \quad (9.2)$$

Once a suitable value of λ_s has been selected, the pond area is calculated from equation (9.2) and its retention time (t_f, d) from:

$$t_f = A_f D/Q \qquad (9.3)$$

Where

D = pond depth, m

Q = wastewater flow, m^3/day

MATURATION PONDS

a) **Faecal Coliform Removal**

Faecal coliform removal can be modeled by first order kinetics in a completely mixed reactor.

The resulting equation for a single pond is:

$$N_e = N_i/(1 + k_T t) \qquad (9.4)$$

Where N_e = number of FC per 100 mL of effluent

N_i = number of FC per 100 mL of influent

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

t = retention time, day

For a series of facultative and maturation ponds, equation (8.4) becomes:

$$N_e = \frac{N_i}{\left(1 + K_T t_f\right)\left(1 + K_T t_m\right)^n} \qquad (9.5)$$

Where N_e and N_i now refer to the numbers of FC per 100 mL of the final effluent and raw wastewater respectively, and n is the number of maturation ponds.

The value of k_T is highly temperature dependent.

$$k_T = 2.6\ (1.19)^{T-20} \qquad (9.6)$$

Check the BOD effluent concentration, l_e

$$l_e = \frac{l_i}{K_1 t + 1} \qquad (9.7)$$

Where l_e = BOD effluent concentration, mg/L

l_i = BOD influent concentration, mg/L

K_1 = first order rate constant for BOD removal, per day

t = retention time, day

The value of K_1 is highly temperature dependent

$$K_{1(T)} = K_{1(20)} 1.05^{T-20} \qquad (9.8)$$

where K_1 @ 20°C = 0.3 per day

For n ponds in series, BOD effluent can be calculated as follows

$$l_e = \frac{l_i}{(1 + K_1 t_f)(1 + K_1 t_m)^n} \qquad (9.9)$$

Example

Constant Population

Design a waste stabilization pond to treat 10,000 m^3/day of a wastewater which has a BOD of 150 mg/L and 1 x 10^8 FC per 100 mL. The effluent should contain no more than 5000 FC per 100 mL and 20 mg/L BOD . The design temperature is 28°C.

Solution

(a) Facultative Ponds

Design loading

$$= 350\ (1.107 - 0.002T)^{T-25} \quad \text{(Eq. 9.2)}$$

$$\lambda_s = 350[1.107 - (0.002 \times 28)]^{28-25}$$

$$= 406\ \text{kg/ha.day}$$

$$A_f = 10\ L_iQ/\ \lambda_s \qquad \text{(Eq. 9.1)}$$

$$= 10 \times 150 \times 10{,}000/406$$

$$= 36{,}946\ m^2$$

$t_f = A_f D/Q$ (Eq.9.3)

Taking a depth of 1.5 m, this becomes:

$t_f = 36,946 \times 1.5/10,000$

$= 5.5$ d

(b) Maturation Ponds

Faecal Coliform Removal

$k_T = 2.6\ (1.19)^{T-20}$ (Eq. 9.6)

$k_{28} = 2.6(1.19)^{8} = 10.46\ d^{-1}$

$$N_e = \frac{N_i}{(1+K_T t_f)(1+K_T t_m)^n}$$

(Eq. 9.5)

Taking t_m = 3 days, this becomes:

$$N_e = \frac{10^8}{(1+10.46\times 5.5)(1+10.46\times 3)^n}$$

For n = 1, N_e = 52,765 > 5000 FC/100 mL

For n = 2, N_e = 1,630 < 5000 FC/100 mL → OK

For a depth of 1.5 m, the area of the maturation pond is

$$A_m = Q\, t_m / D$$

$$= 10{,}000 \times 3/1.5$$

$$= 20{,}000\ m^2$$

For one maturation pond, Area = 20,000/2 = 10,000 m^2

BOD Removal

Facultative and Maturation Pond:

$$K_{1(28)} = 0.3x1.05^{28-20} = 0.44/day$$

$$l_e = \frac{l_i}{(1 + K_1 t_f)(1 + K_1 t_m)^n}$$

$$l_e = \frac{150}{(1 + 0.44 \times 5.5)(1 + 0.44 \times 3)^2}$$ **= 8.15 mg/L**