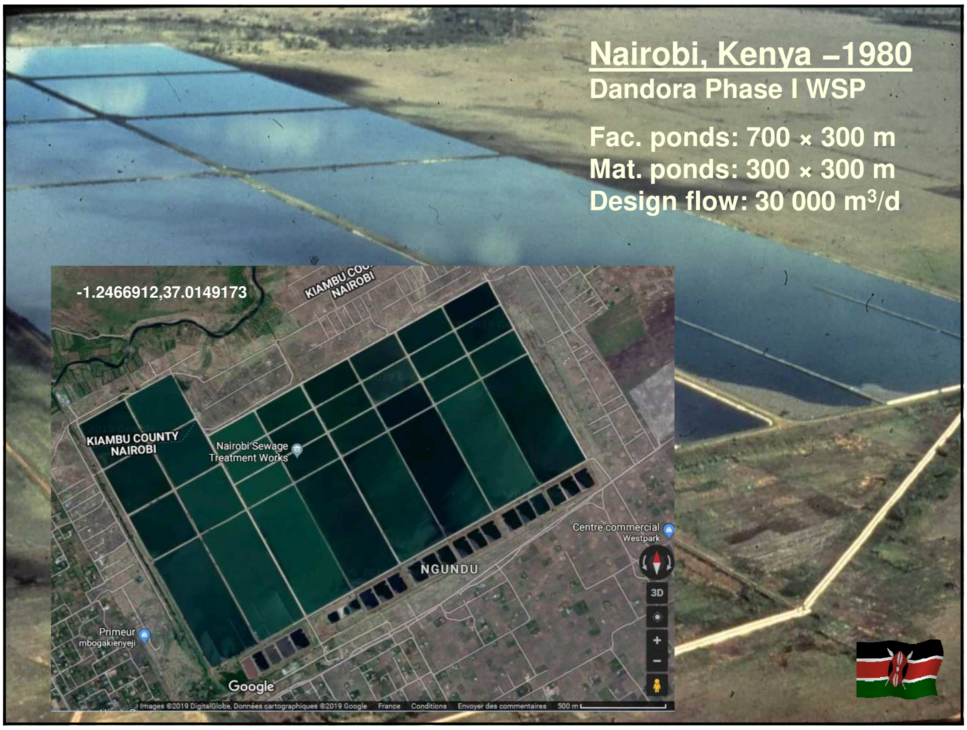
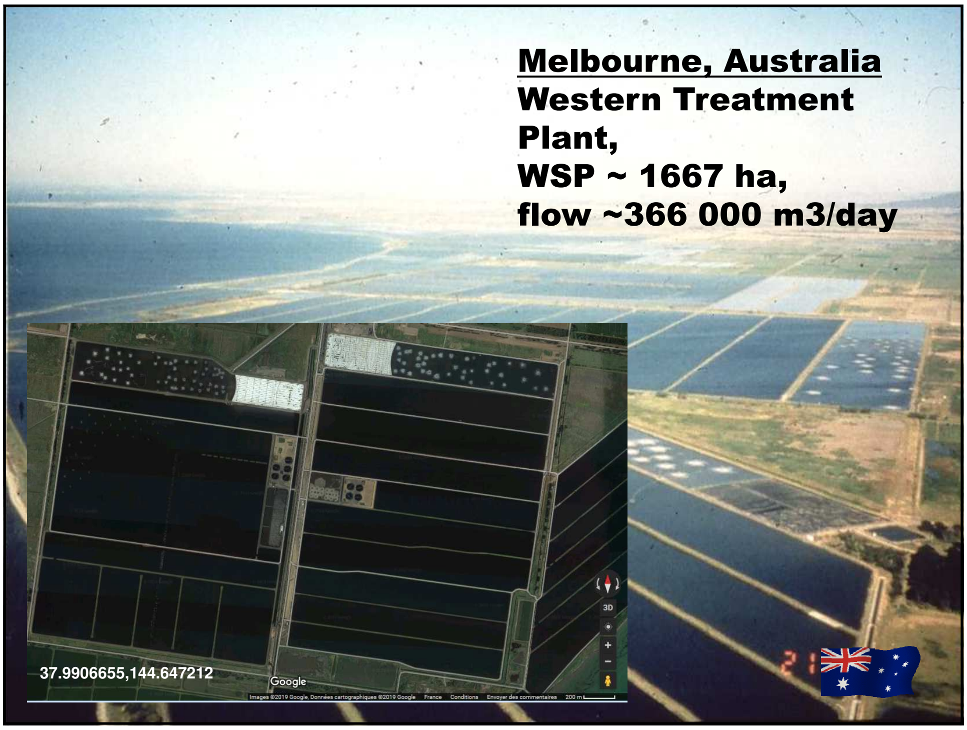
Natural Wastewater Treatment

INTRODUCTION TO WASTE STABILIZATION PONDS

Martin SEIDL v2022

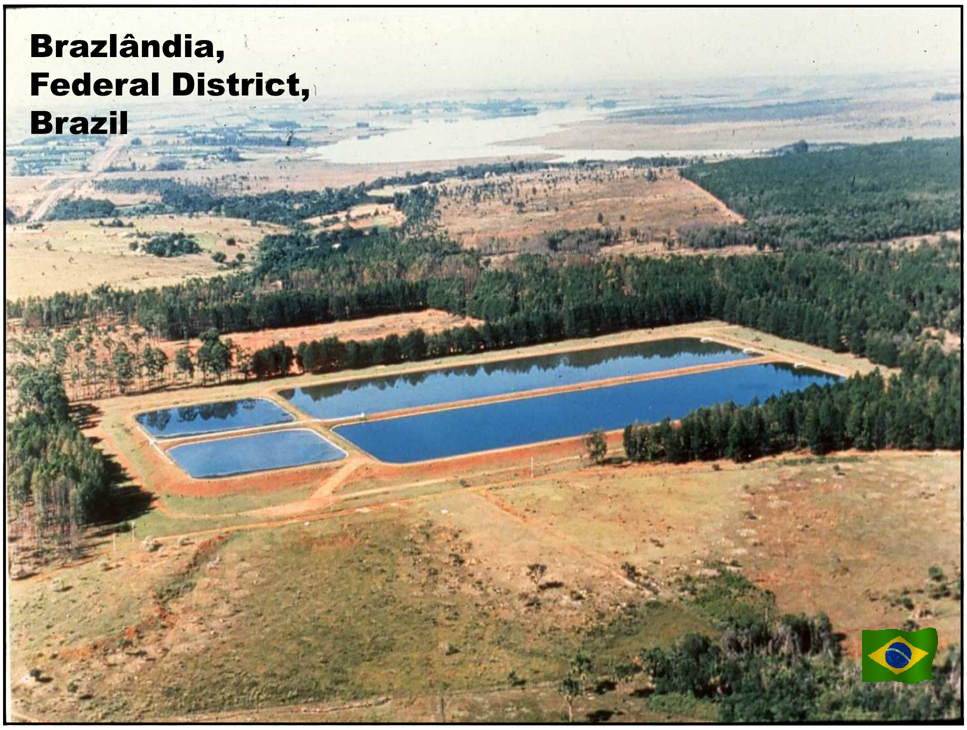
after Duncan MARA School of Civil Engineering




Melbourne, Australia
Western Treatment Plant,
WSP ~ 1667 ha,
flow ~366 000 m3/day
37.9906655,144.647212
Google


Mèze,
Montpellier,
France
43.4211067,3.5861687
Google
Ardam
Entech Ingenieurs Conseil


Ginebra Colombia
UASB post treatment


Brazlândia,
Federal District,
Brazil

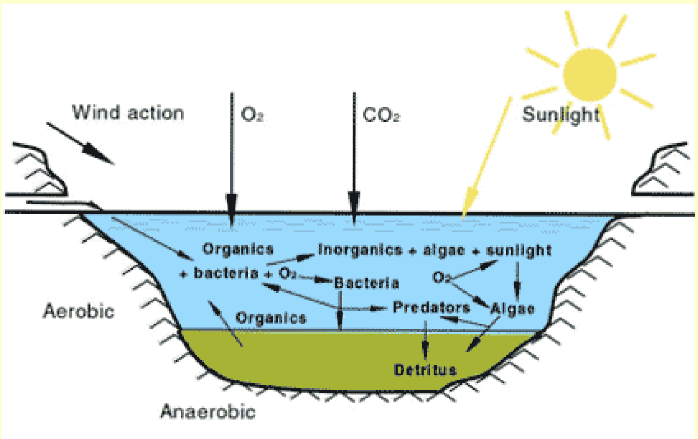
- **Wastewater Lagoon Mixing Case Study**

https://youtu.be/vazxt0pSNGU

off line

PRINCIPLES

The Cycle



Algal–bacterial mutualism

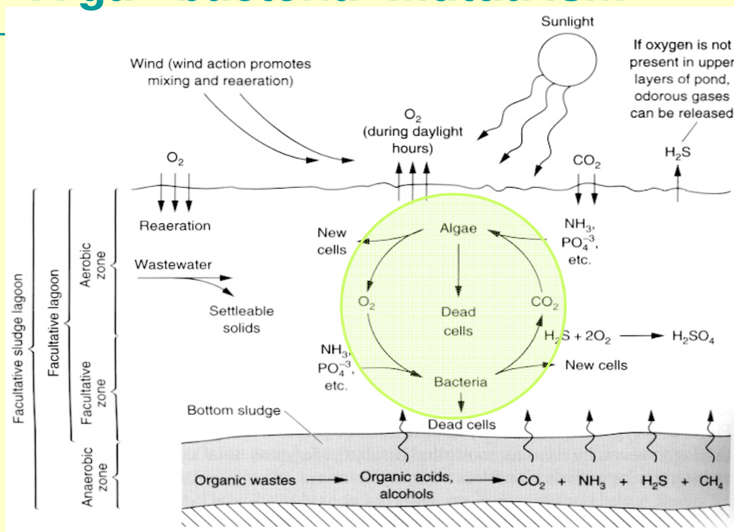


FIGURE 8-2
Definition sketch for the interactions occurring in a facultative lagoon (from Tchobanoglous and Schroeder, 1985).

Photosynthesis

- Algae use light energy to 'fix' carbon dioxide, and oxygen is produced from water as a by-product:

$$106CO_2 + 236H_2O + 16NH_4 + HPO_4 \xrightarrow{\text{LIGHT}} C_{106}H_{181}O_{45}N_{16}P + 118O_2 + 171H_2O + 14H^+$$

ALGAE

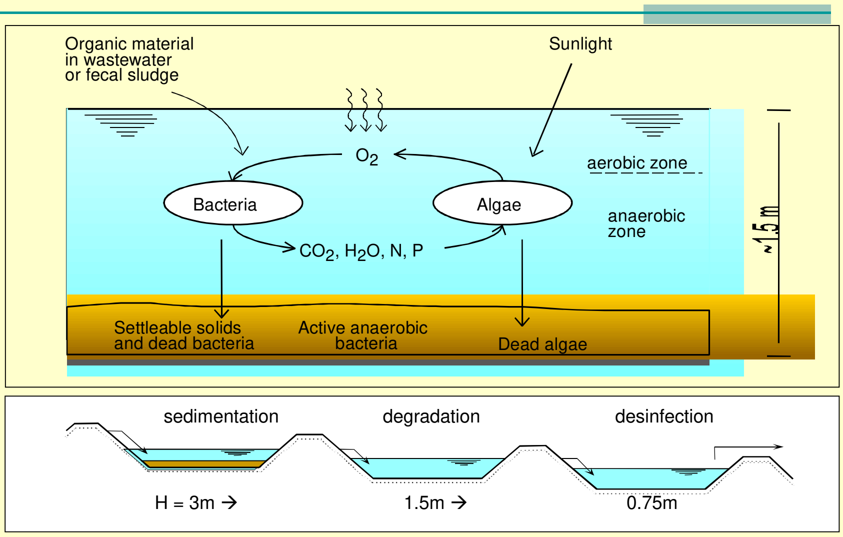
1 g algae produces ~1.5 g O_2 which ≈ 1.5 g BOD_u ≈ 1 g BOD_5

Advantages of WSP

- Simple & reliable
- Low cost
- Good pathogen removal
- Sustainable

PROCESS OPTIMIZATION

Spatial process separation



Types of WSP

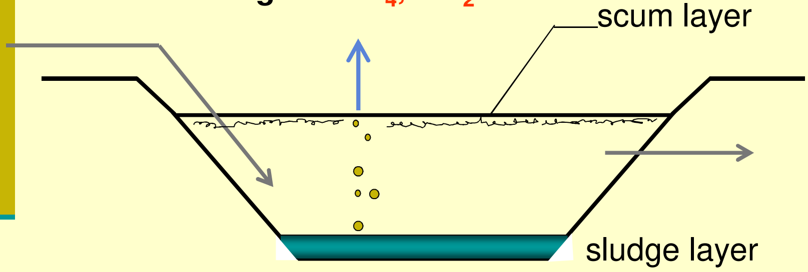
- Shallow, generally rectangular lakes, usually arranged in a series of:

1. **Anaerobic** (bacteria),
   BOD removal,
2. **Facultative** (Algae)**,**
   BOD removal
3. **Maturation ponds** (Algae)
   pathogen removal

1) Anaerobic ponds

About 30% of influent BOD leaves as biogas

'**Biogas**': CH_4, CO_2



- same groups of anaerobic bacteria involved as in septic tanks and anaerobic digesters → require same environmental conditions (eg, pH >6.5)

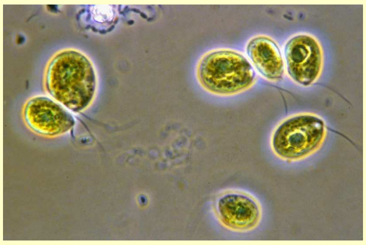
functions

- **high organic (BOD) loading** →
  devoid of dissolved oxygen
- **no algae** →
  surface area not important
- sedimentation
- >200 g DBO5/m3/d (Von Sperling 2015)
- depth range 1–5 m;
  depends on ground conditions
  – usually 2–4 m

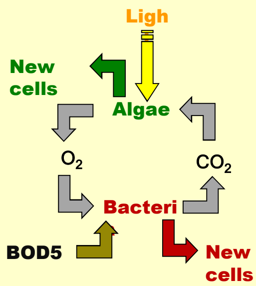
Operation

- sedimentation of settleable solids and
- intense anaerobic digestion (>15°C) with copious 'biogas' (CH4 & CO2) production
- high BOD & SS removal
- functions much like an open septic tank

ALGAE: occasional surface film of sulphide-tolerant *Chlamydomonas*

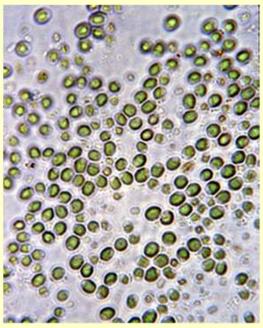


2) Facultative ponds



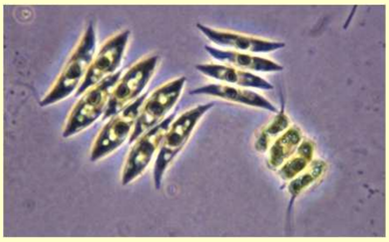
- algal-bacterial mutualism: algae produce O_2, used by heterotrophic bacteria which produce CO_2 which is used by the algae.
- Common facultative pond algae: *Chlorella, Euglena, Scenedesmus……*
- can receive raw wastewater: "primary fac. ponds"; or settled wastewater : "secondary fac. ponds"

Chlorella spp.



Chlorella spp.

Euglena spp.



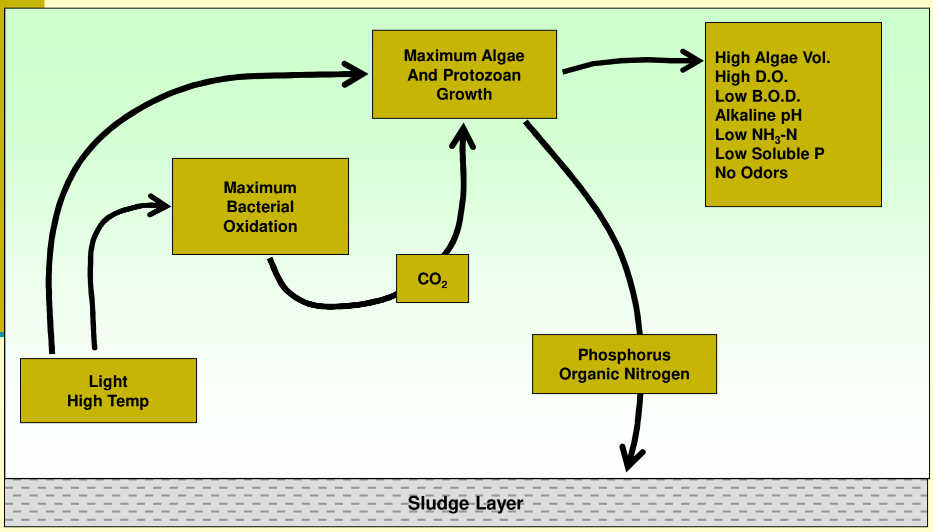
Scenedesmus quadricauda

operation

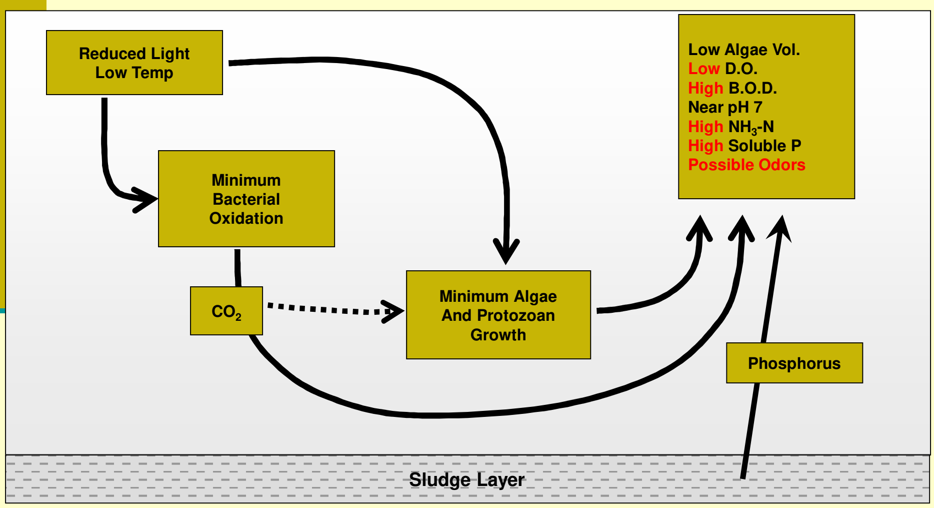
- ❑ profuse presence of various species of mainly motile microalgae – around 500–2000 μg/l of chlorophyll a. So facultative ponds are (or should be) dark green.
- ❑ thin sludge layer in facultative ponds that receive raw wastewater (intense anaerobic digestion & CH_4 production).
- ❑ effluent BOD mainly due to algae (70– 90%). This “algal” BOD is very different from “wastewater” BOD.
- Load > 200 kg BOD/d/ha

Seasonal variations

Summer To Fall



Winter To Early Spring



DESIGN

Basic

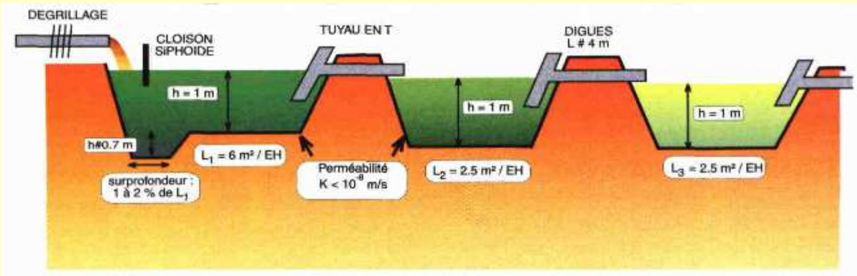
- Preliminary treatment (screening, grit removal), followed by:
- One or more WSP series, each comprising:
  - an anaerobic pond,
  - a facultative pond, and depending on required effluent quality
  - one or more maturation ponds
- RETENTION TIME in pond series: depends on climate (temperature), but in general ~5–50 days (in conventional WWTW ≤1 day)

Dimensionnement simplifié

(SATESE – CEMAGREF 1997)

- Ville 10 000 EH
- Etude agence : 11 m²/ EH
- **anaérobie : 1 2m / 6 m²**
- **maturation : 1m / 2,5 m²**
- **Finition : 1m / 2,5 m²**
- T séjour ?

- 1er bassin dimensionné à 6 m2 / EH, éventuellement doté d'une sur-profondeur en entrée pour circonscrire le cône de sédimentation des éléments les plus grossiers charriés par le réseau.
- 2 autres bassins successifs, chacun dimensionné sur la base de 2.5 m2/EH



1. Anaerobic ponds

(Varon & Maara 2004)

- The volumetric BOD loading (λv, g/m3 d) is given by:
- λv = *L*i**Q*/*V*a
- where *L*i is the BOD5 of the raw wastewater (mg/l = g/m3), *Q* is the wastewater flow (m3/d) and *V*a is the anaerobic pond volume (m3).
- The permissible range of λv is 100 g/m3 d at temperatures ≤10°C, increasing linearly to 300 g/m3 d at 20°C, and then more slowly to 350 g/m3 d at 25°C and above.
- The design temperature is the mean temperature of the coldest month. Once the temperature is known, the value of λv is determined and the value of *V*a calculated.
- The anaerobic pond area is then determined by dividing *V*a by the pond depth (e.g., 3 m).
- BOD5 removal is 40% at temperatures ≤10°C, increasing linearly to 70% at 25°C and above.

2. Facultative ponds

(Varon & Maara 2004)

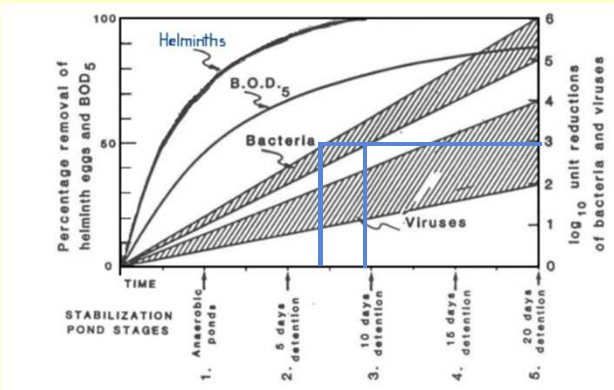
- The surface BOD5 loading (λs, kg/ha d) is given by:
- $\lambda s = 10*Li*Q / Af$
- where Li is the BOD of the anaerobic pond effluent (mg/l) and Af is the facultative pond area (m^2).

- The value of λs depends on the design temperature (T, °C), as follows:
- $\lambda s = 350\ (1.107 - 0.002*T)T^{-25}$
- The value of λs is determined for the design temperature and the value of Af calculated.

2. Maturation ponds

(Varon & Maara 2004)

- These are designed for *E. coli* and helminth egg removal as shown in Section 1.5 on the
- reuse of WSPs effluents in agriculture and/or aquaculture



Retention times

(Varon & Maara 2004)

- The mean hydraulic retention time (θ, days) in an individual WSP is given by:
- $\theta = V/Q$ (or AD/Q)
- where V is the pond volume (m3), Q the wastewater flow through the pond (m3/d), A is the pond area (m2) and D is the pond working liquid depth (m).
- **The minimum design retention time is one day in anaerobic ponds, four days in facultative ponds, and three days in maturation ponds.**
- If the calculated value of θ in the latter is less than this minimum value (θmin), then the pond volume or area is recalculated from:
- $V = Q\theta_{min}$
- $A = Q\theta_{min}/D$

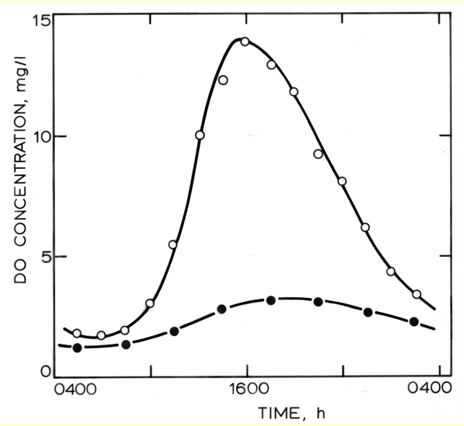
Management & optimization

Mixing & Stratification

- Wind-induced vertical mixing promotes uniform vertical distribution of algae (esp. non-motile species), bacteria, BOD, dissolved oxygen, etc.
- Conventionally thought to be good for efficient operation, but….????
- In absence of wind, thermal stratification occurs:

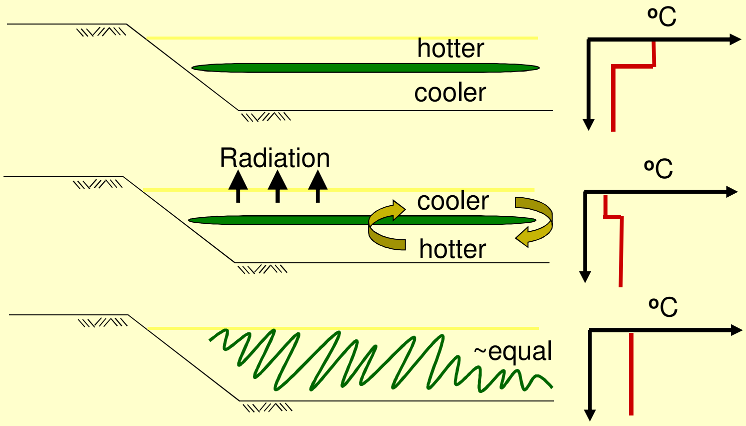
Diurnal variation in DO

Algae produce O_2, but only during daylight hours



○ ~10 cm
● ~80 cm
below surface

Stratification destroyed by wind, or by cooling of upper layers in the evening:



- non-motile algae (if there are any) sink below thermocline, where they exert O_2 demand (too dark for them to photosynthesise)

❖ algal stratification → physicochemical stratification (e.g. pH, DO, BOD etc.)

∴ need to study pond profiles (parameter variation with depth)

Design 2 : WSP in series

- Why?
- Different ponds have different functions
- BOD removal poor in maturation ponds, but faecal bacterial removal is high
- Theory indicates that a series of small ponds outperforms a single pond of same overall size
- also observed in practice

Performance of Five Ponds in Series

Northeast Brazil, 25 ºC

Experiment 1

June 1977 – May 1979

$\Sigma\theta$ = 29.1 days

	Retention time (d)	BOD out (mg/l)	SS (mg/l)	FC (/100ml)
Raw	–	240	305	4.6×10^7
A1	6.8	63	56	2.9×10^6
F1	5.5	45	74	3.2×10^5
M1	5.5	25	61	2.4×10^4
M2	5.5	9	43	450
M3	5.8	17	45	30

Pathogen Removal in WSP

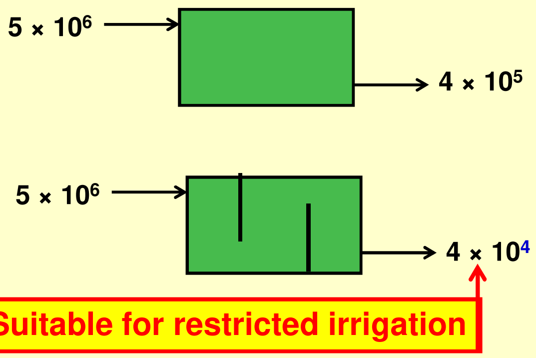
- Helminth eggs & protozoan cysts:
  - sedimentation
- Viruses:
  - Adsorption & sedimentation (probably)
- BACTERIA:
  - Several possible responsible factors – eg:
  - * Time & Temperature * UV radiation
  - * Algal toxins * High DO
  - * Low CO2 * High pH
  - * Predation by protozoa and micro-invertebrates

Design optimization (baffles)

- Pretreatment in 1-day anaerobic pond
- 4-day secondary fac. pond at 25ºC:

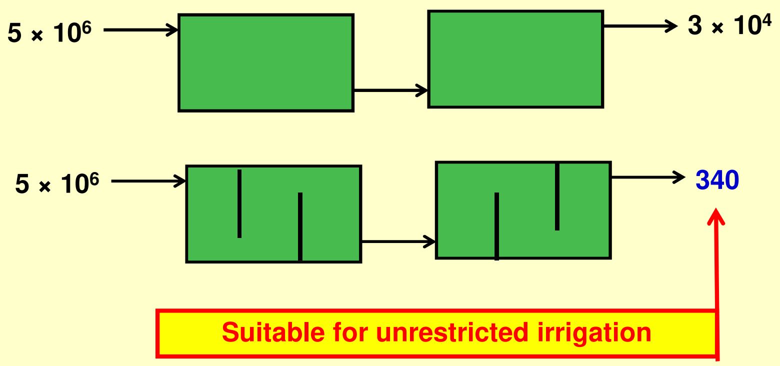
A. Un-baffled

B. Two equally spaced 70%-width baffles



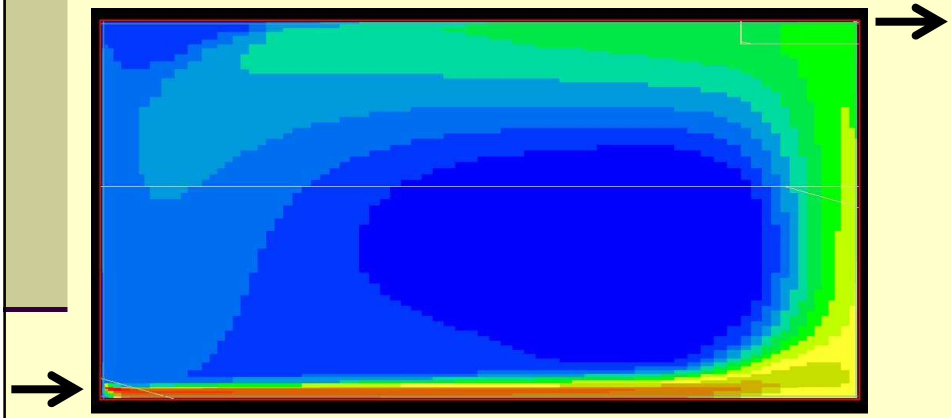
Effect of baffles

- **Pre-treatment in 1-d anaerobic pond**
- **4-d sec. fac. pond + 4-d mat. pond at 25ºC:**



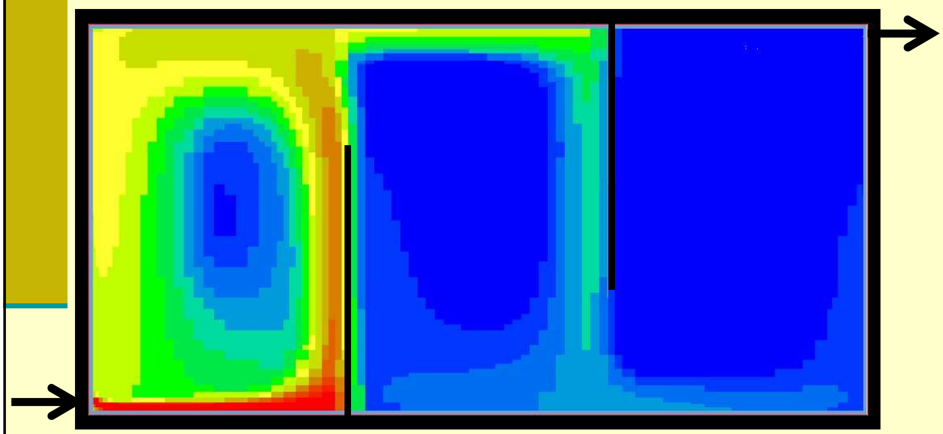
Wind effect

Un-baffled sec. fac. pond



Red: high *E. coli*; blue: low *E. coli*

Twin-baffled sec. fac. pond

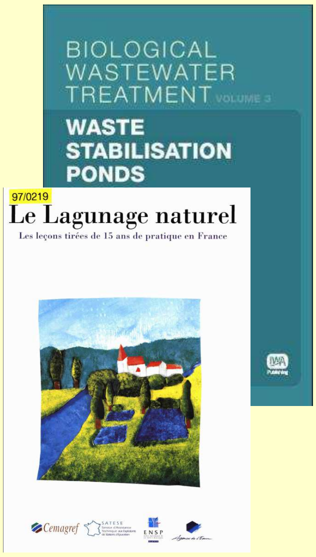


CONCLUSIONS

Advantages of WSP

- Usually the CHEAPEST option – both in terms of capital and O&M costs.
- VERY simple O&M –
  only unskilled (but supervised) labour needed.
- Good resistance to shock hydraulic & organic loads.
- Good resistance to heavy metals.
- VERY HIGH removals of excreted pathogens:
- up to 6 log10 unit reduction of excreted bacteria
- Up to 4 log10 unit reduction of excreted viruses
- 100% removal of helminth eggs & >90% of protozoan cysts

References



Waste Stabilisation Ponds
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2004