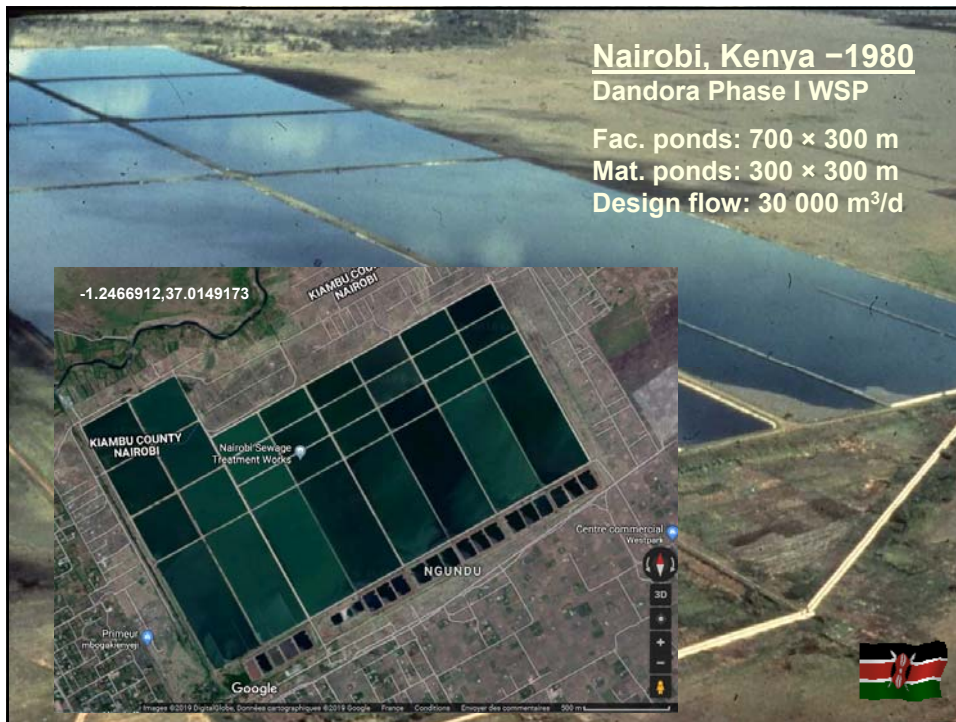


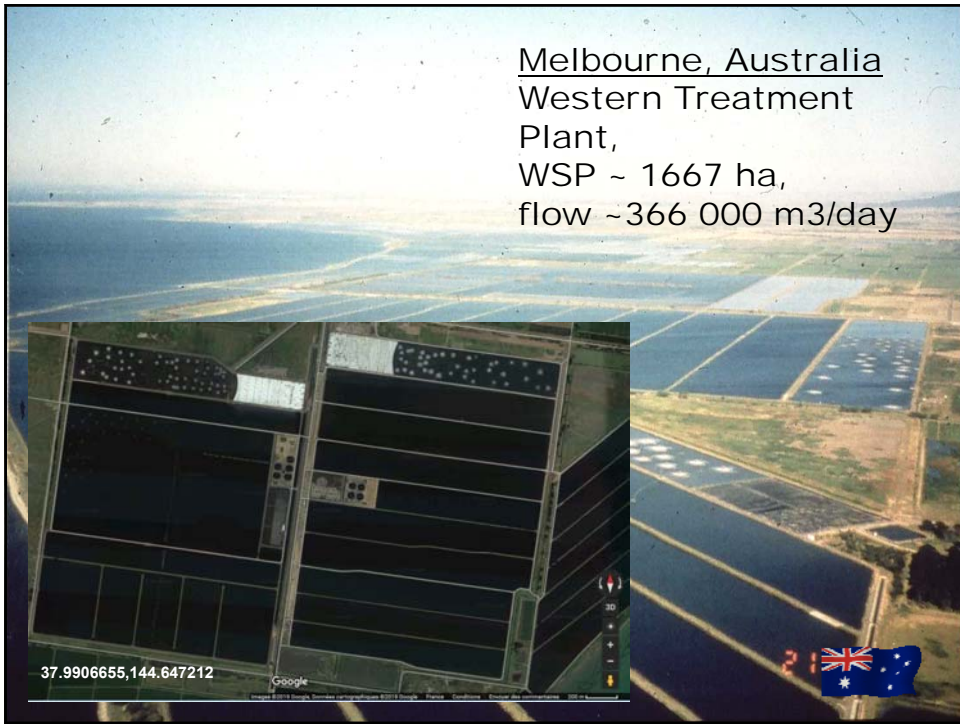
Natural Wastewater Treatment

INTRODUCTION TO WASTE STABILIZATION PONDS

Martin SEIDL v2019

after Duncan MARA







Ginebra Colombia
UASB post treatment



Brazlândia,
Federal District,
Brazil



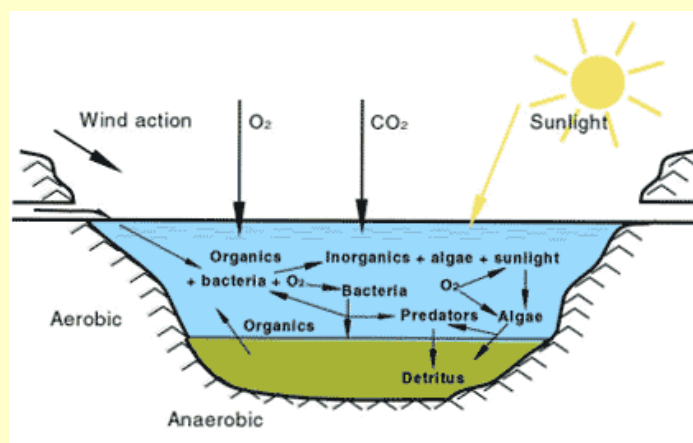
■ Wastewater Lagoon Mixing Case Study

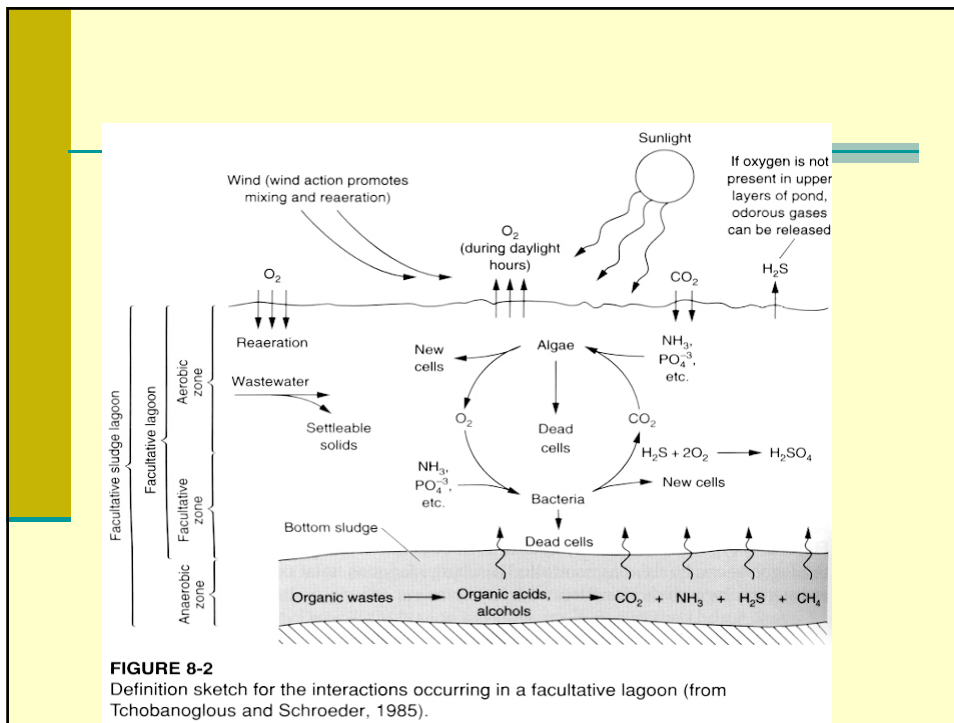
<https://youtu.be/vazxt0pSNGU>
off line



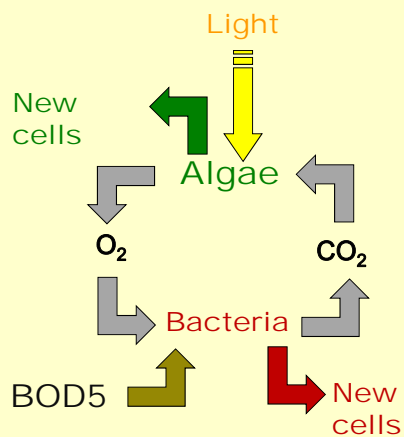
PRINCIPLES

The Cycle



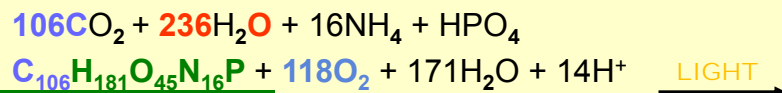


Algal-bacterial mutualism



Photosynthesis

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



↑
ALGAE

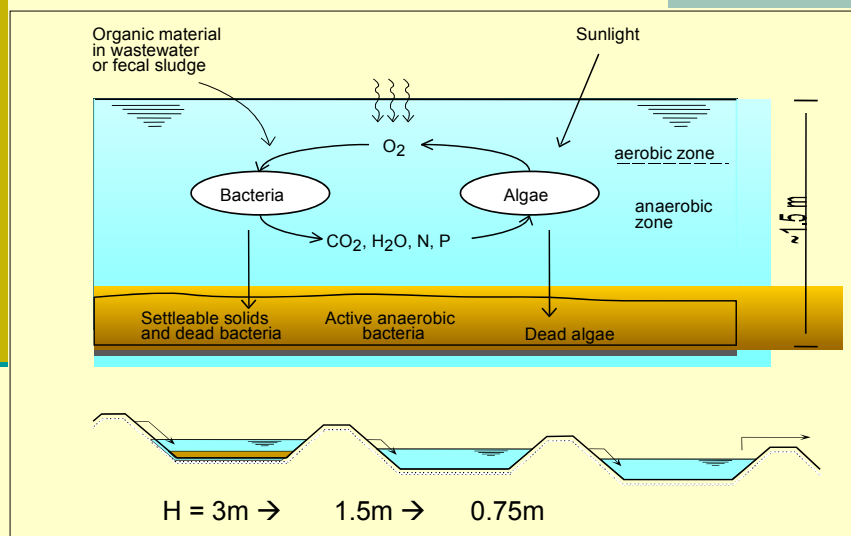
1 g algae produces ~1.5 g O₂ which ≈ 1.5 g BOD_u ≈ 1 g BOD₅

Advantages of WSP

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

PROCESS OPTIMIZATION

Spatial separation

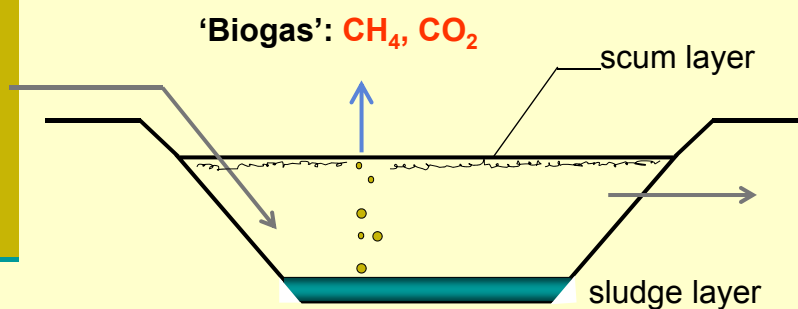


Types of WSP

- 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



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

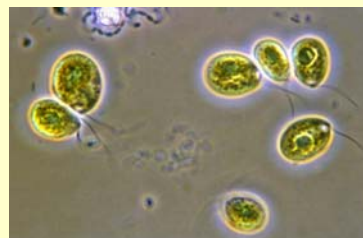
functions

- **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

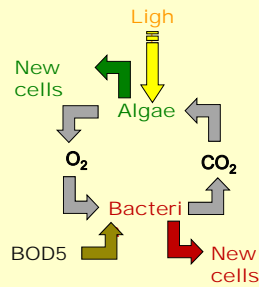
Operation

- 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*

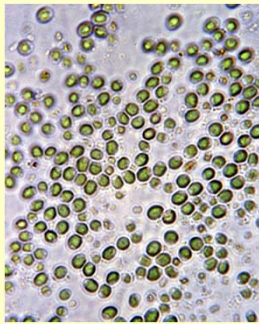


2) Facultative ponds

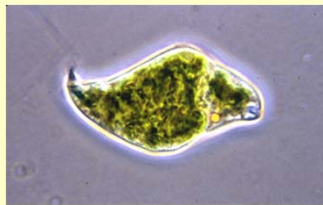


- **algal-bacterial mutualism:** algae produce O₂, used by heterotrophic bacteria which produce CO₂ which is used by the algae.
- Common facultative pond algae: *Chlorella*, *Euglena*, *Scenedesmus*.....
- can receive raw wastewater: “primary fac. ponds”; or settled wastewater : “secondary fac. ponds”

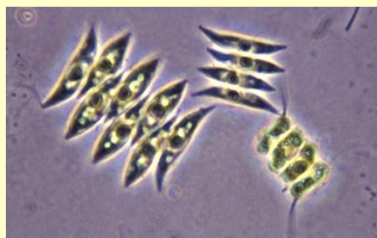
Chlorella spp.



Chlorella spp.



Euglena spp.

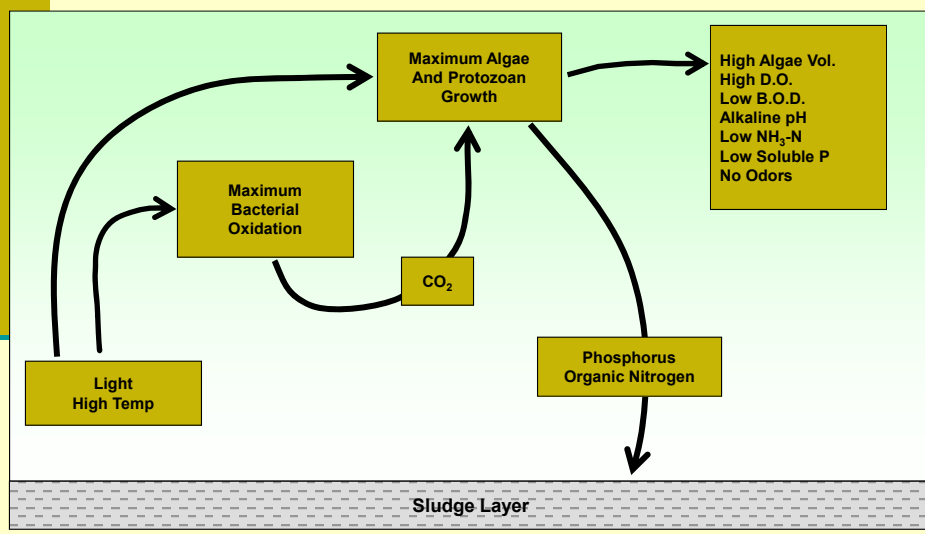


Scenedesmus quadricauda

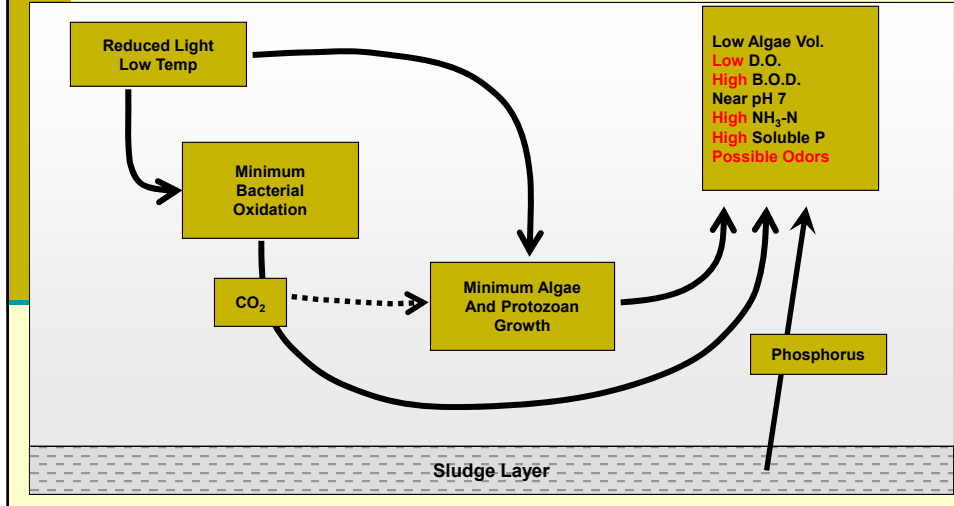
operation

- ❑ profuse presence of various species of mainly motile microalgae – around 500–2000 $\mu\text{g/l}$ 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

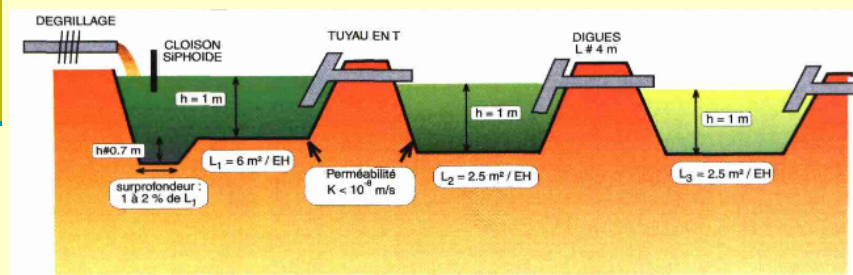
Basic

- 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
 - H1=2m / 50 %
 - H2=1m / 25 %
 - H3=1m / 25 %
 - T séjour ?
- 1er bassin dimensionné à 6 m² / EH, éventuellement doté d'une surprofondeur 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 (λ_v , g/m³ d) is given by:
- $\lambda_v = LiQ/Va$
- where Li is the BOD₅ of the raw wastewater (mg/l = g/m³), Q is the wastewater flow (m³/d) and Va is the anaerobic pond volume (m³).
- The permissible range of λ_v is 100 g/m³ d at temperatures $\leq 10^\circ\text{C}$, 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 λ_v is determined and the value of Va calculated.
- The anaerobic pond area is then determined by dividing Va by the pond depth (e.g., 3 m).
- BOD₅ removal is 40% at temperatures $\leq 10^\circ\text{C}$, increasing linearly to 70% at 25°C and above.

2. Facultative ponds

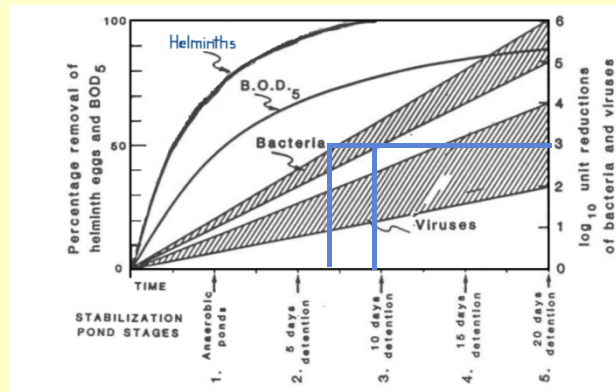
(Varon & Maara 2004)

- The surface BOD₅ loading (λ_s , kg/ha d) is given by:
- $\lambda_s = 10LiQ/Aaf$
- where Li is the BOD of the anaerobic pond effluent (mg/l) and Af is the facultative pond area (m²).
- The value of λ_s depends on the design temperature (T , °C), as follows:
- $\lambda_s = 350(1.107 - 0.002T)T^{-25}$
- The value of λ_s 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 (m^3), Q the wastewater flow through the pond (m^3/d), A is the pond area (m^2) 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 (θ_{min}), then the pond volume or area is recalculated from:
- $V = Q\theta_{min}$
- $A = Q\theta_{min}/D$

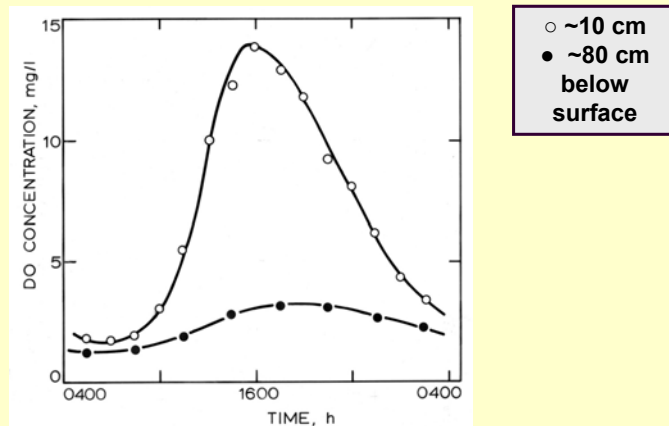
Management & optimization

Mixing & Stratification

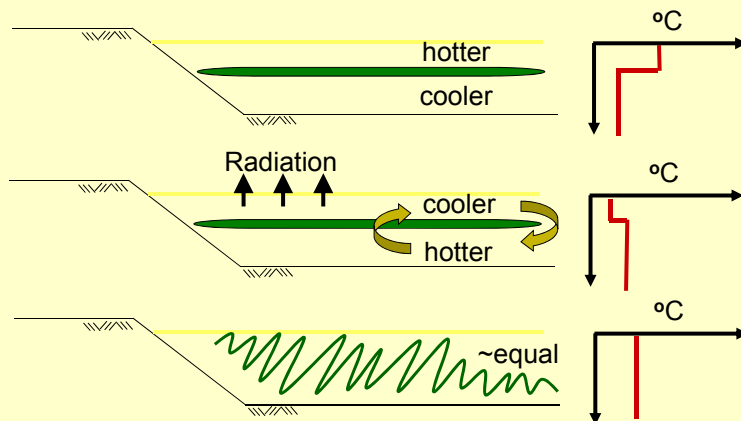
- Wind-induced vertical mixing promotes uniform vertical distribution of algae (esp. non-motile species), bacteria, BOD, dissolved oxygen, etc.
- Conventionally thought to be good for efficient operation, but....????
- In absence of wind, thermal stratification occurs:

Diurnal variation in DO

Algae produce O₂, but only during daylight hours



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 °C

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 25°C:

A. Un-baffled



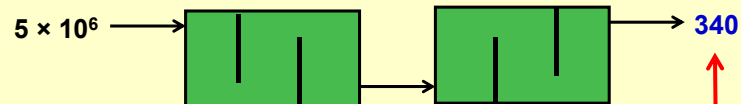
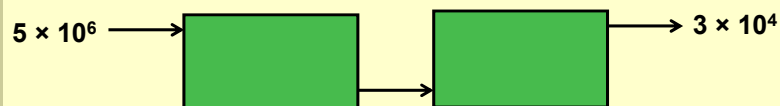
B. Two equally spaced 70%-width baffles



Suitable for restricted irrigation

Effect of baffles

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

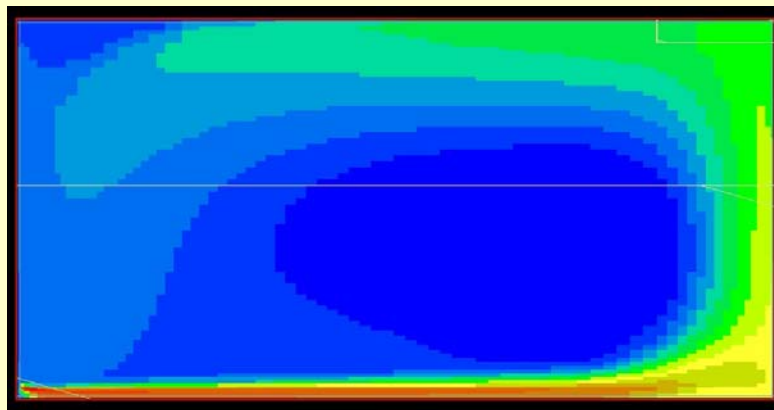


Suitable for unrestricted irrigation

Wind effect

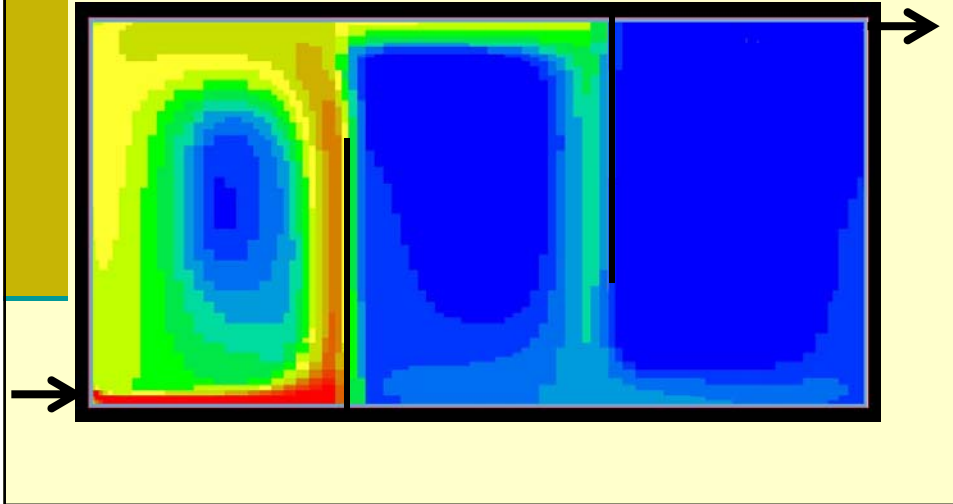


Un-baffled sec. fac. pond



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

By: Miguel Peña Varón
Universidad del Valle, Instituto
Cinara. Cali, Colombia
and
Duncan Mara
School of Civil Engineering,
University of Leeds. Leeds, UK
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