The EU funded SWIM-SM: developing capacity for Sustainable and Integrated Wastewater Treatment and Reuse

Online Course on Natural Treatment Systems: Phosphorus Removal

Phosphorus removal

SWIM OLC

on

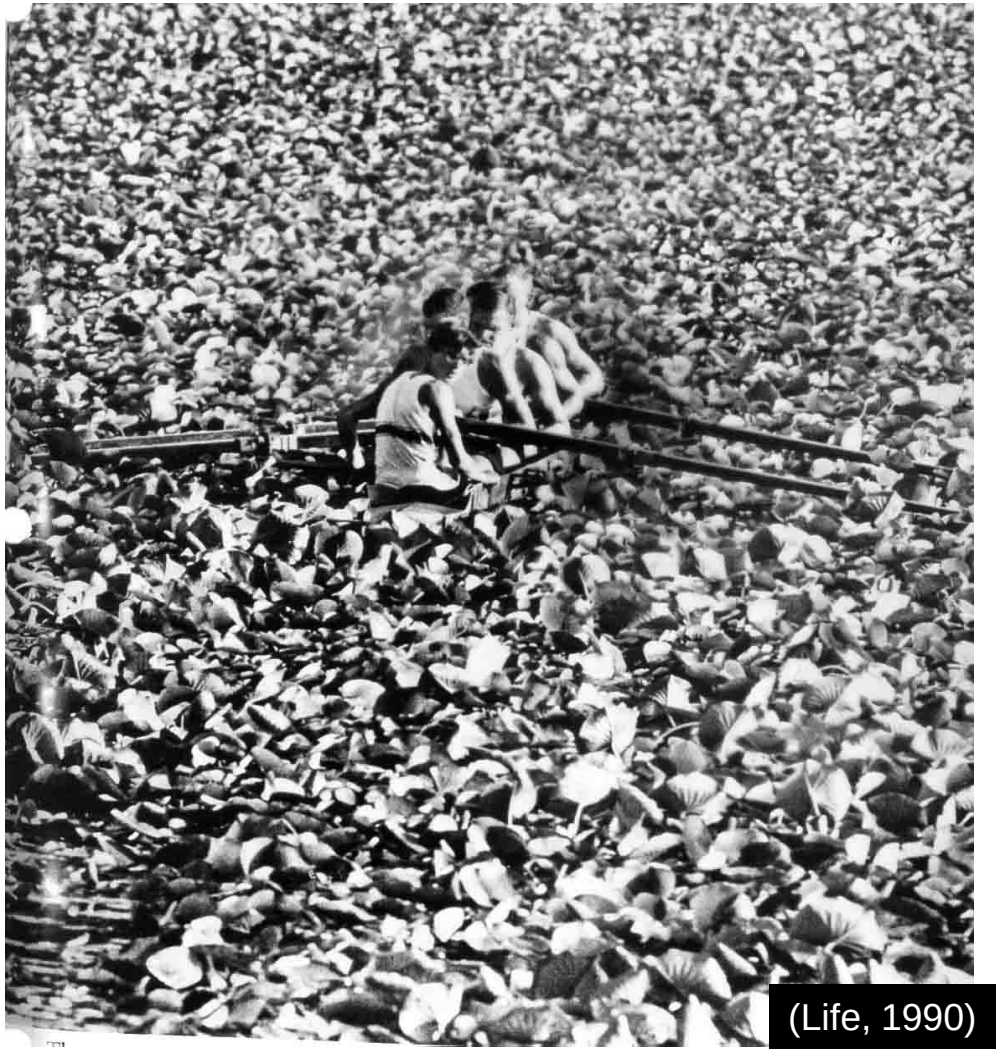
Natural Treatment Systems

Introduction: why P removal?

- Nitrogen (N) and phosphorus (P) discharges in water bodies lead to eutrophication:
    - excessive algae and plant growth
    - poor fish habitat
    - algal toxins production
    - more complex water treatment systems needed
    - reduced recreation uses
    - reduced (fresh) water availability

Eutrophication:

Water hyacinth bloom near Vancouver, Canada

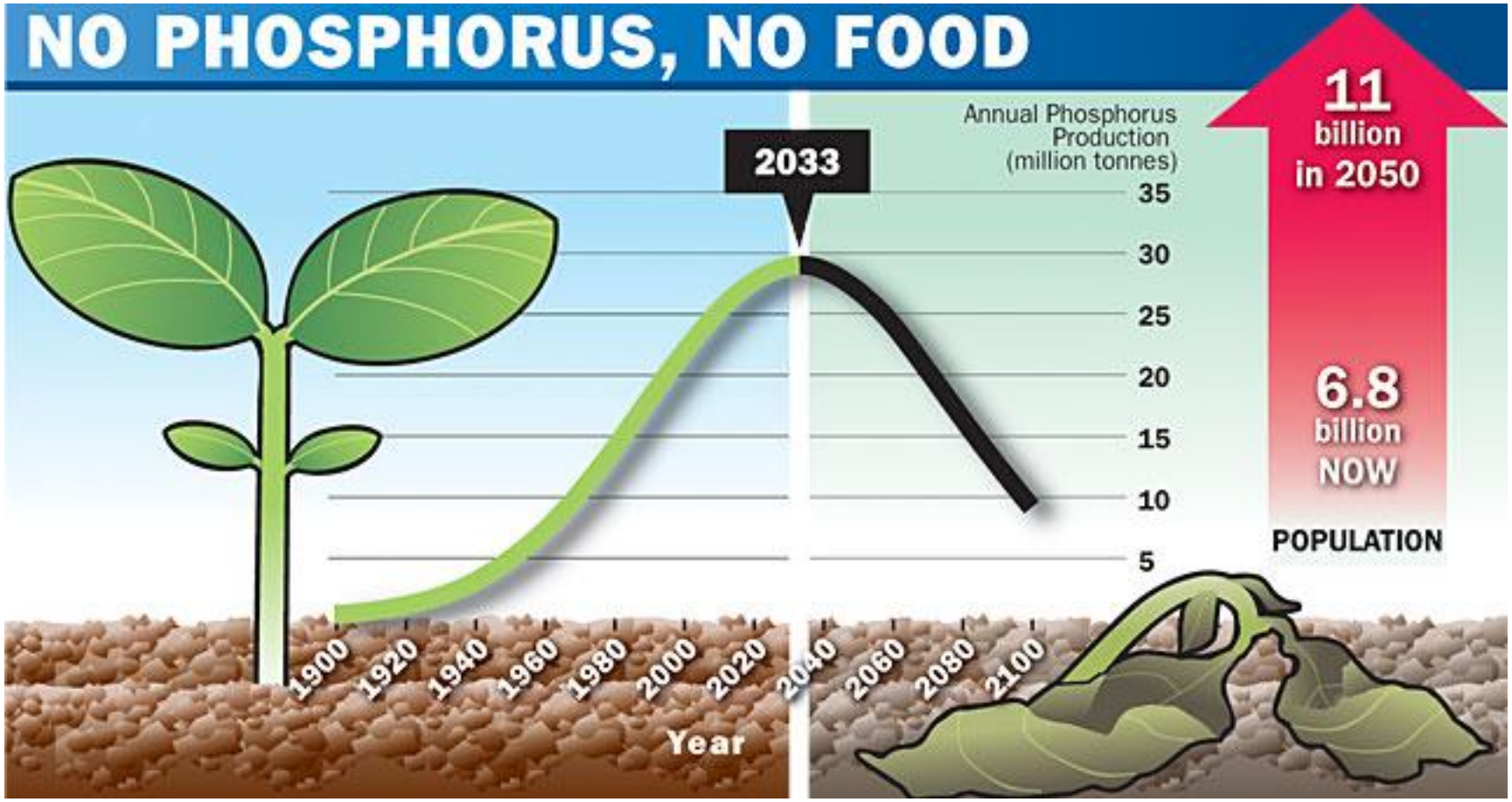


(Life, 1990)

Why P vs N removal?

- N removal can reduce eutrophication but if N becomes limiting, cyanobacteria can fix dinitrogen gas (N_2) from the air (containing ~ 20% O_2, ~ 80% N_2)
- Phosphorus removal is more efficient since P can only come from upstream
- Thus, P is the « key » nutrient to remove

phosphorus recycling



http://www.rainharvest.co.za/2010/07/peak-phosphorus-what-does-this-mean/

P-removal in natural systems

- Adsorption to sediment/ soil
- Plant uptake
- Algae uptake
- Bacteria uptake
- Photosynthesis leads to an increase in pH, if alkalinity is low, and this favours phosphorus precipitation as calcium phosphate

Maybe better: re-use nutrients in agriculture

How much P removal by primary settling and conventional AS?

- typical P removal efficiency
  - primary settling 15-20%
  - conventional activated sludge 30-40%
  - enhanced biological phosphorus removal (EBPR) activated sludge 90-99%

BPR – Advantages and Limitations

- Advantages
  - no chemical addition
  - no chemical sludge produced
  - more « ecological »
  - more economical
  - **potential P-recovery**
  - High efficiency (P_{eff} < 1 mgP/L)
- Limitations
  - Relatively complex process (greater operator expertise required)
  - risks of P release during sludge treatment

Principle of BPR

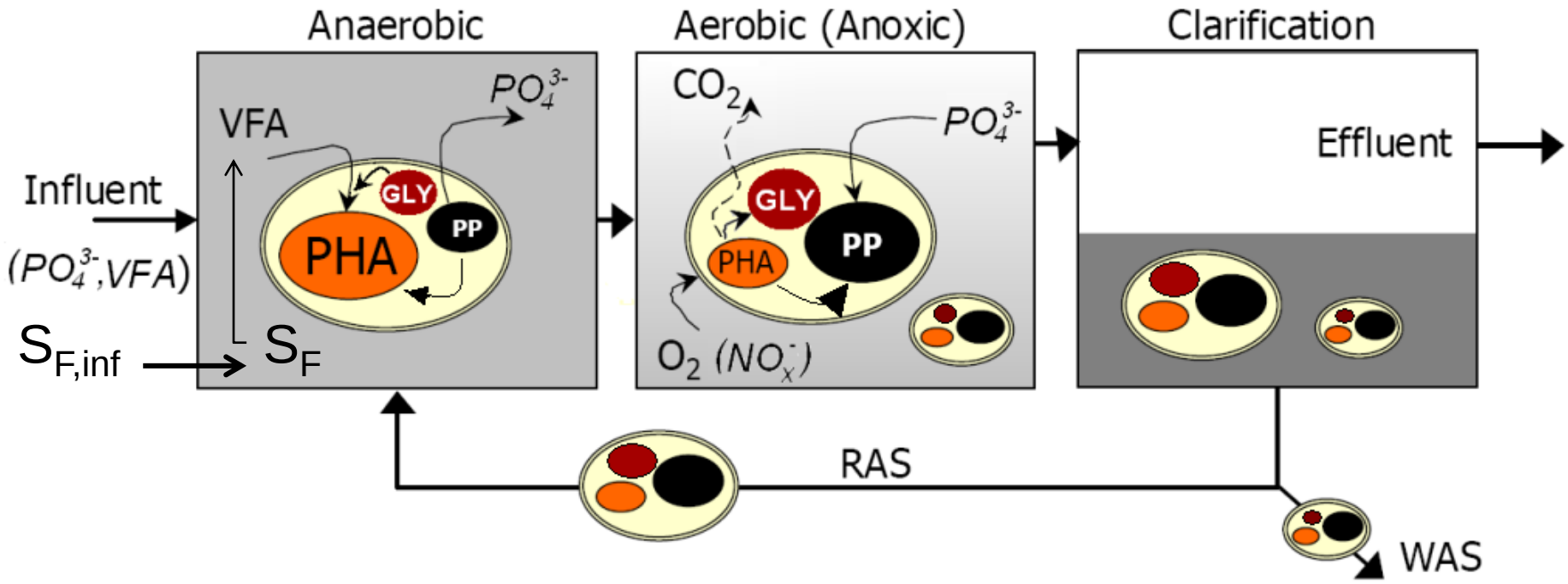
- BPR = accumulation of P beyond metabolic requirements
  - as intracellular polyphosphates reserves in phosphorus accumulating organisms (PAOs)
- Essential requirements to achieve BPR
  - exposure of PAOs to alternating anaerobic (AN) & aerobic (OX) (or anoxic) conditions
  - VFAs storage by PAOs in the AN reactor

BPR – Definitions of reactor conditions

- Conditions for a reactor
  (engineering definitions)
  - AN: anaerobic: neither O_2 nor NO_3^-
  - AX: anoxic: without O_2, with NO_3^-
  - OX: aerobic with O_2

BPR observations

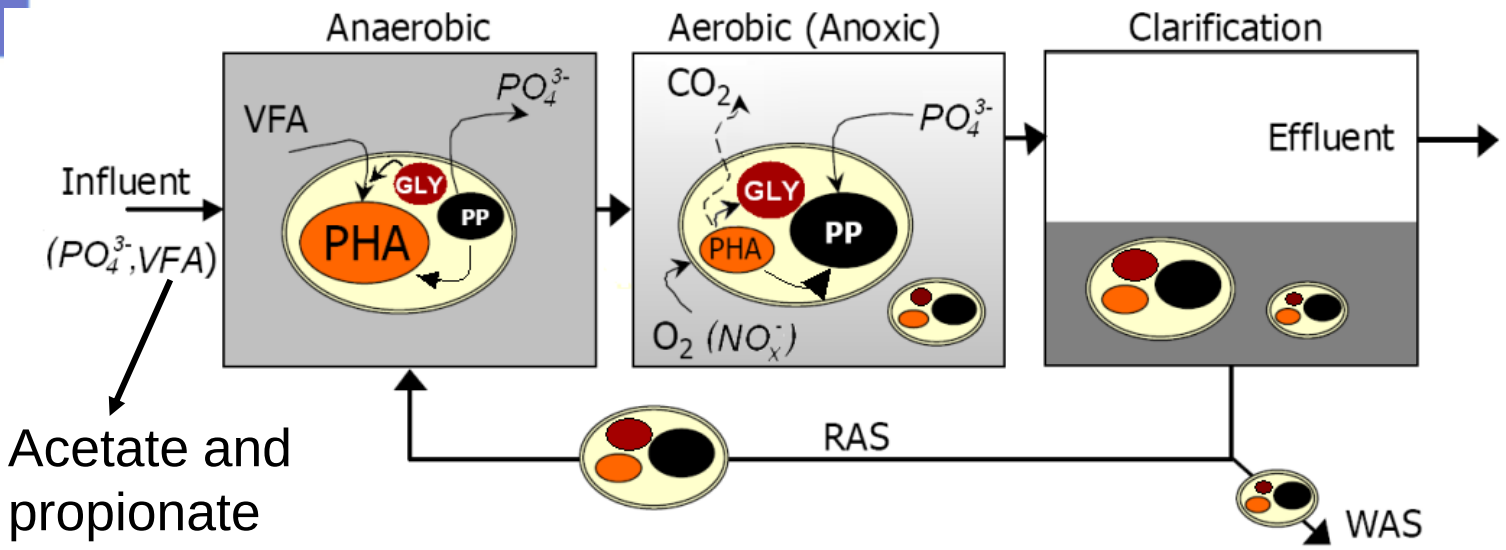
Polyphosphate-accumulating organisms (PAO)

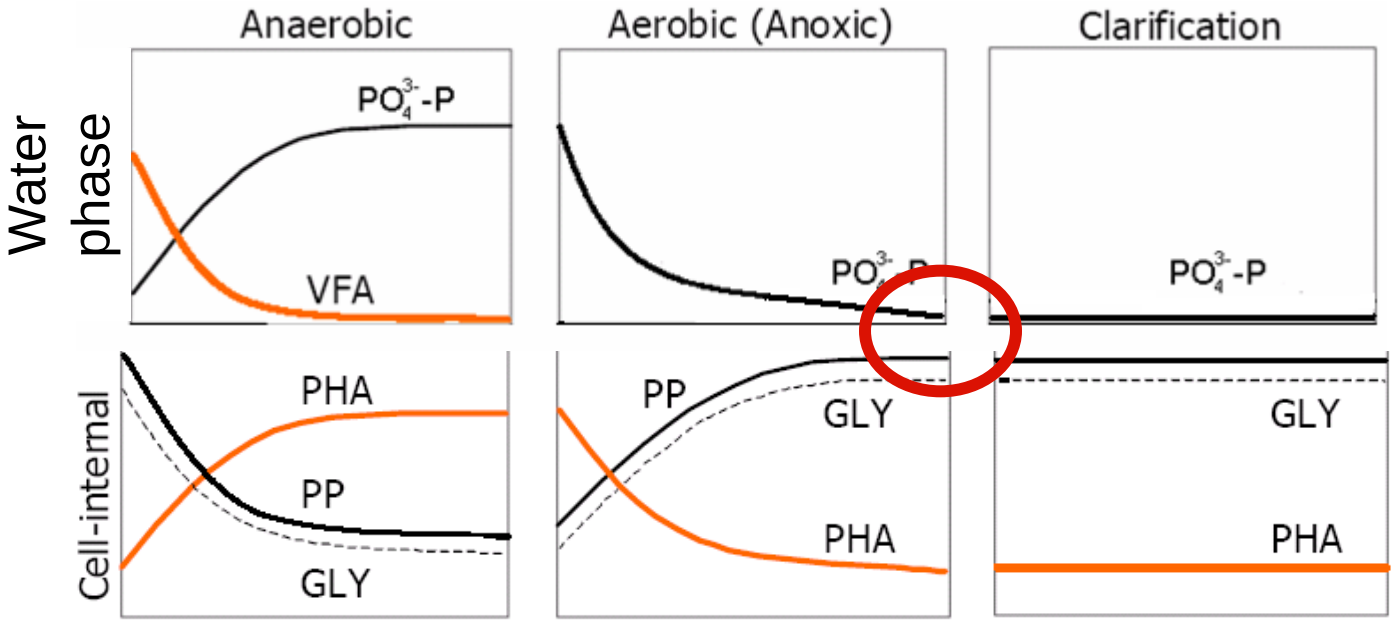


VFA: Volatile fatty acids such as acetate (HAc) and propionate (HPr)

$S_{F,inf}$: Fermentable organics present in the influent.

Polyphosphate-accumulating organisms (PAO)





How much P in PAOs?

- Maximum P content of PAOs
  = 0.38 g P/g AVSS (where AVSS = active VSS)

  $f_{VT,PAO}$ = 0.48 g AVSS/g TSS ➔ 0.18 g P/g TSS

- P content of PAOs (g P/g VSS) depends on the proportion of influent biodegradable COD (COD_b) stored by PAOs

Biological mechanisms of BPR

- PAO are heterotrophic organisms with unbalanced growth:
  - Uptake carbon source under anaerobic conditions
  - But grow under aerobic conditions
- no pure cultures of PAOs achieved yet!
- from molecular techniques:
  - NOT *Acinetobacter* which was first thought to be a PAO
  - but *Candidatus Accumulibacter Phosphatis*

- 3 intracellular storage compounds involved:

  - PP or poly-P (polyphosphates)

  - PHA (poly-β-hydroxyalkanoates)
    - PHB (poly-β-hydroxybutyrate) +
    - PHV (poly-β-hydroxyvalerate)….
    - Among others…

  - GLY or glycogen (a polymer of glucose)

BPR configurations

- Various configurations were developed to exploit various optimisation principles:

  - To protect the ANAEROBIC reactor from nitrate and oxygen recirculation

  - Maximize the consumption of S_{VFA} by PAO

Conclusions

- P removal vs eutrophication
- Low in natural systems
- BPR complements chemical P «ecologically»
- Not yet a PAO pure culture but enhanced cultures
- Biochemical mechanisms sufficiently well understood
- Various BPR configurations were developed