SYSTEM-WIDE MODELLING FOR FUTURE WASTE AND RESOURCE RECOVERY FACILITIES

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SYSTEM –WIDE WRRF MODELLING

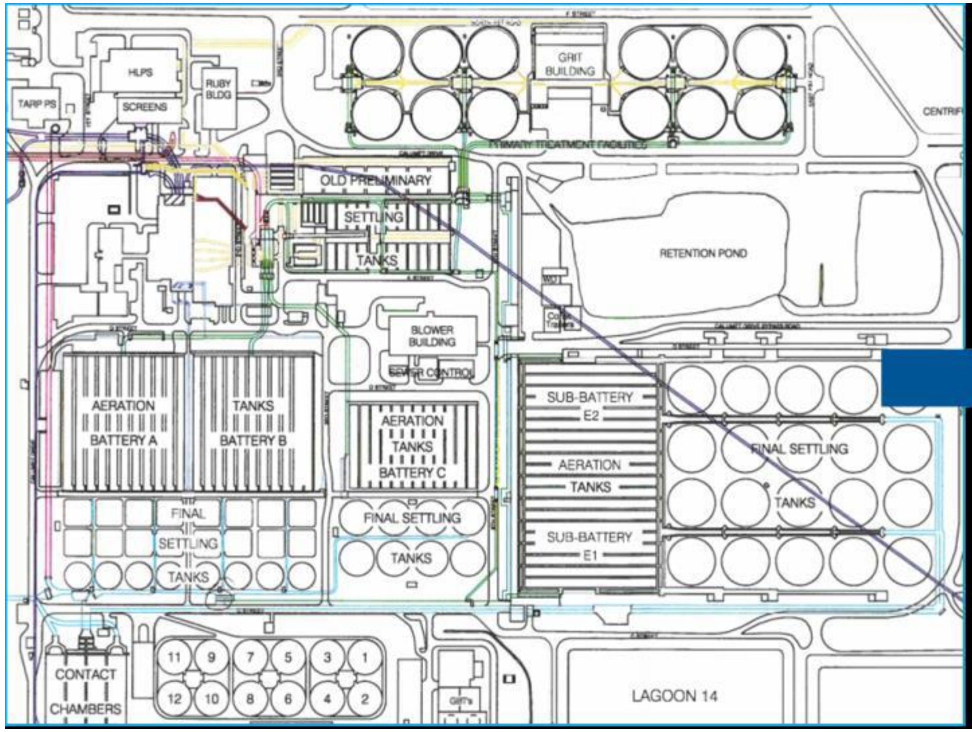
~~WASTEWA~~TER TREATMENT FOR EFFLUENT QUALITY

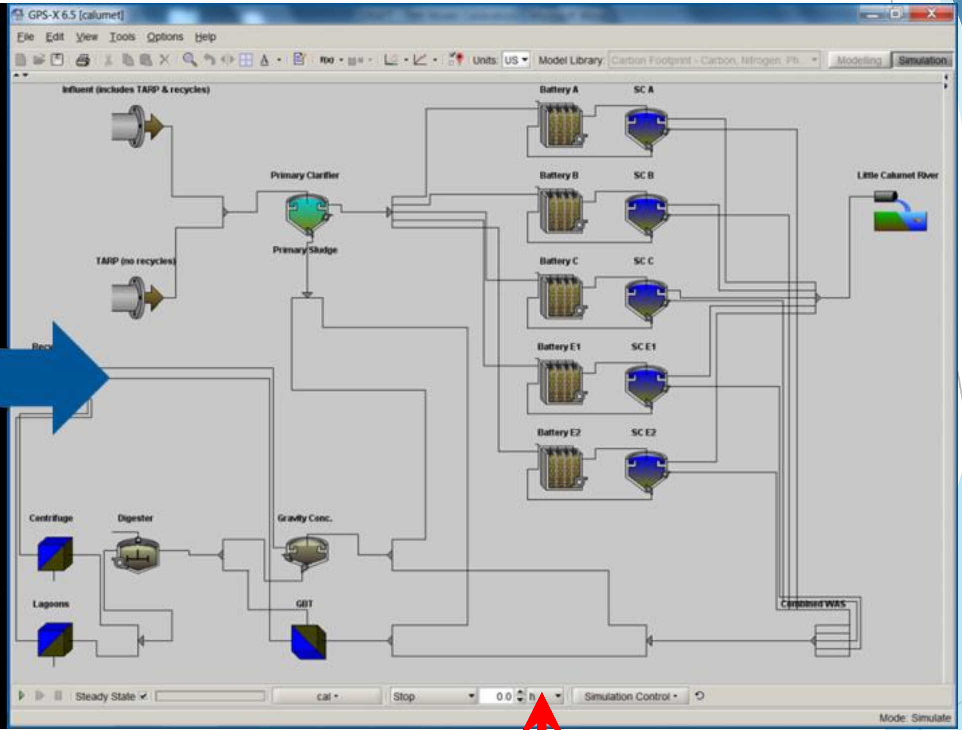
WATER AND RESOURCE RECOVERY – OPTIMISED GENERATION OF **PRODUCTS**

(UTILISATION OF MODELS FOR PREDICTED SYSTEM PERFORMANCE)

Performance Data

Modelling Socially, Economically and Environmentally Sustainable Waste Treatment Systems of the Future:





- **Include, Evaluative Performance Indices for Effluent Quality (EQI) and Cost (OCI) at System-Wide Level.**

Recovered Products (i.e., Nitrogen, Methane, Organic fertiliser, Phosphorus, Water, etc).

OBJECTIVES

Generate experimental data that can answer questions raised from modelling of phosphorus (P) removal systems.

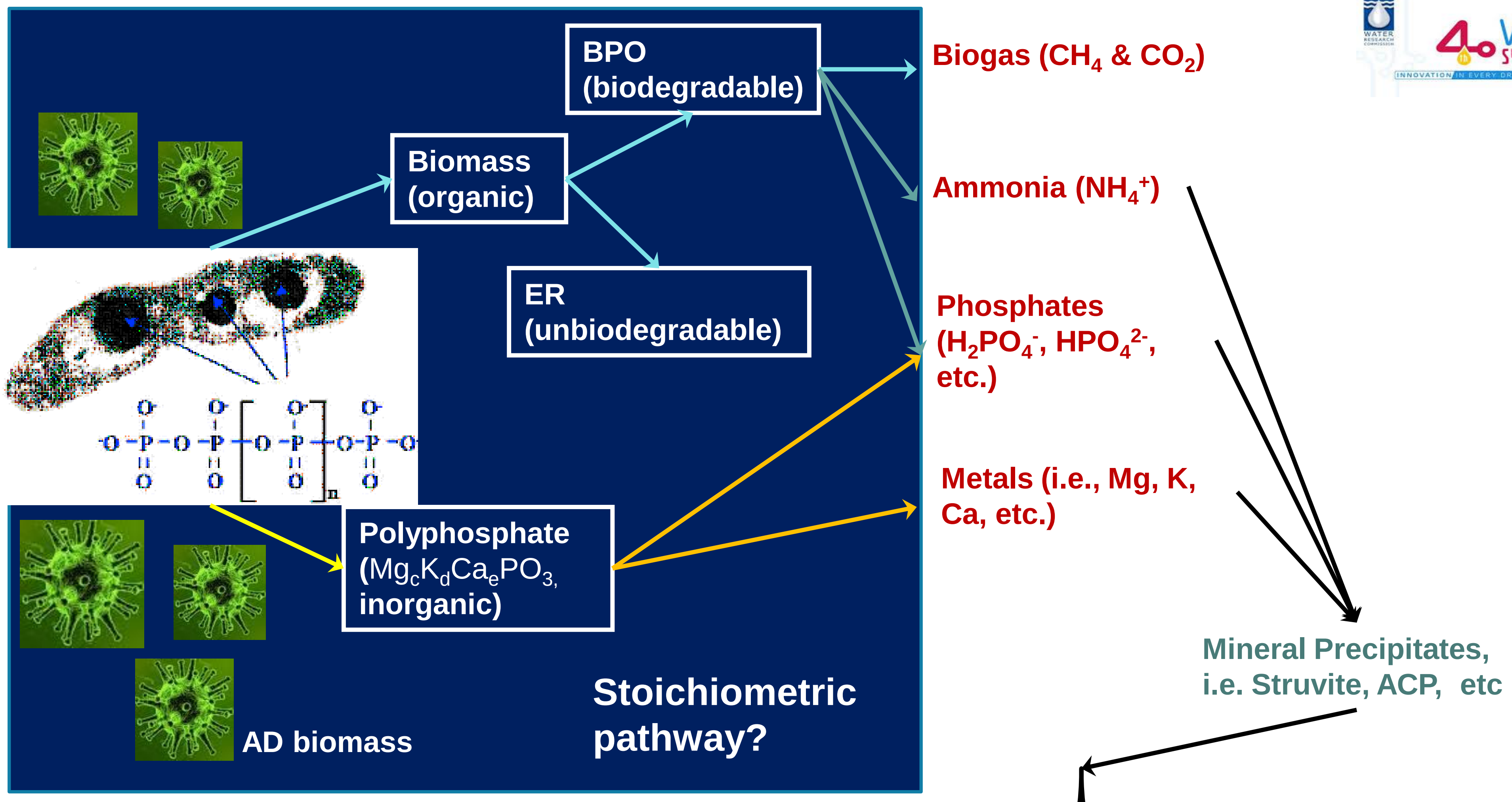
Requires:

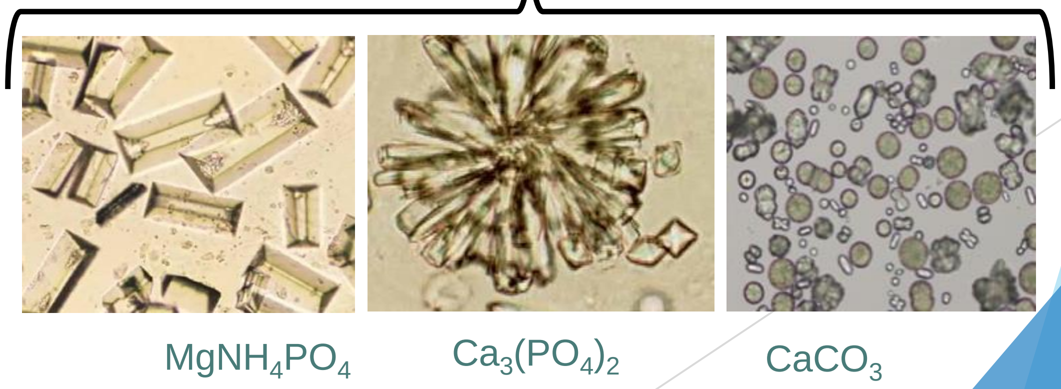
- PAO behaviour (mainly anaerobic polyphosphate release)
- Chemically dosed components

UCT plant wide dynamic model (PWM_SA) be utilised towards transforming WWTPs to WRRFs

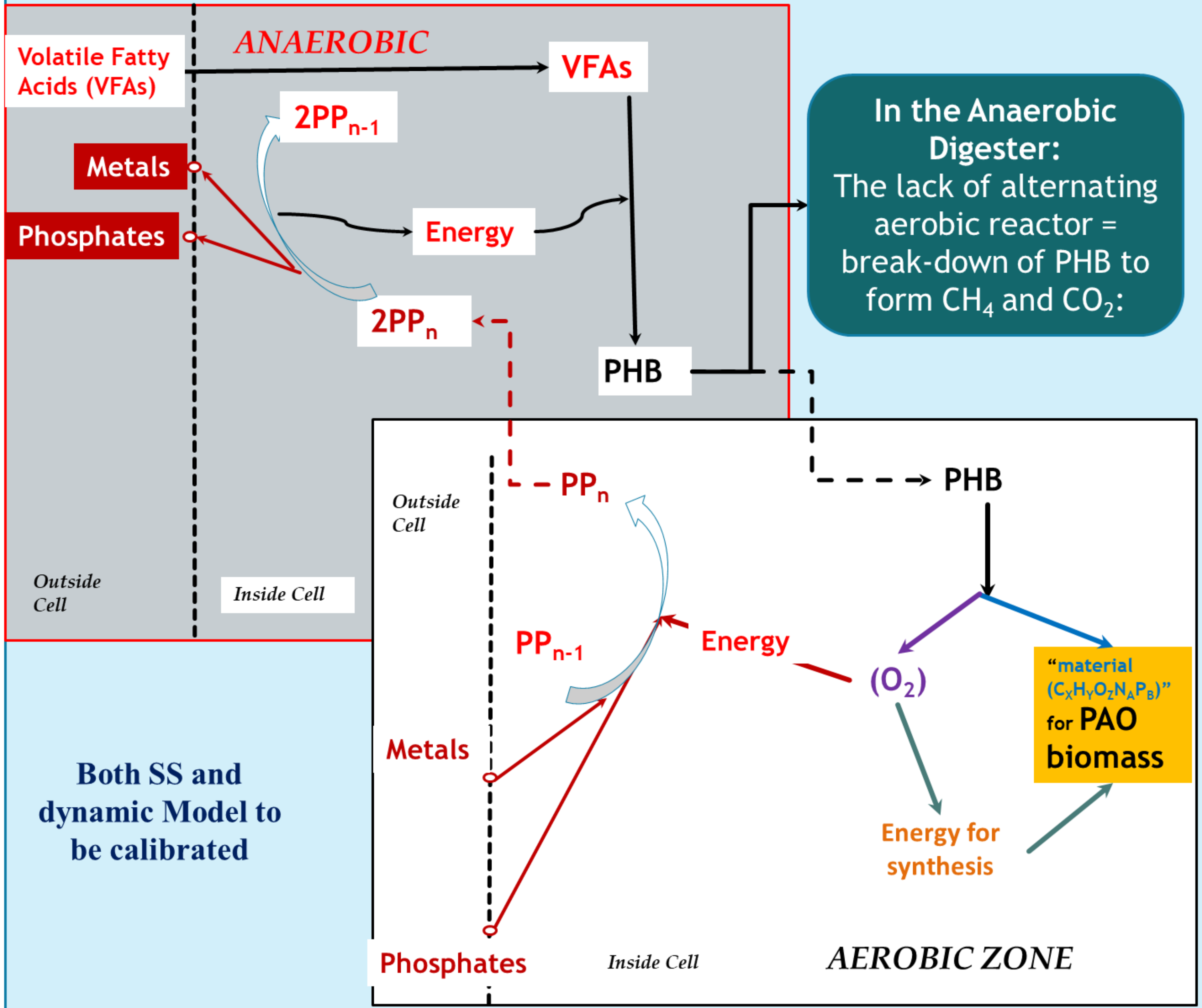
- Review fate of WWTP products
- Develop evaluative protocol for entire system (including fate of products)
- Case Studies on evaluation of full scale systems

Anaerobic Digester System Products





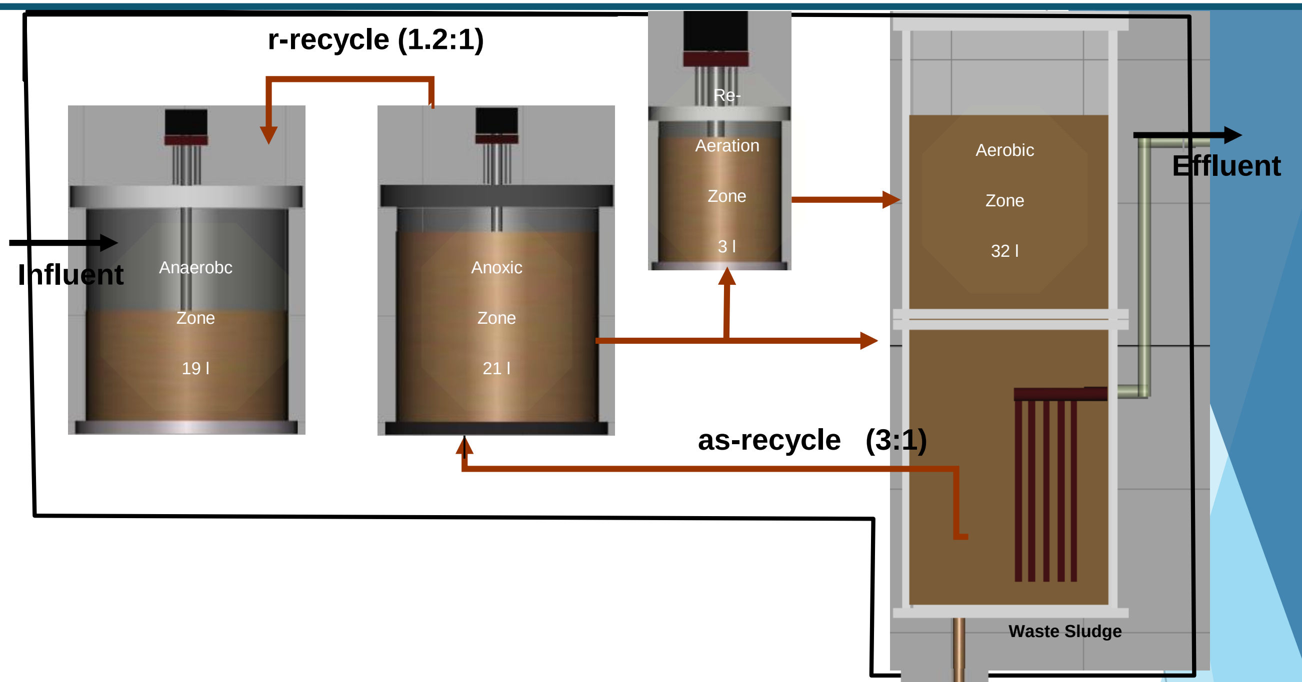
PAO BEHAVIOR IN AS AND AD SYSTEMS

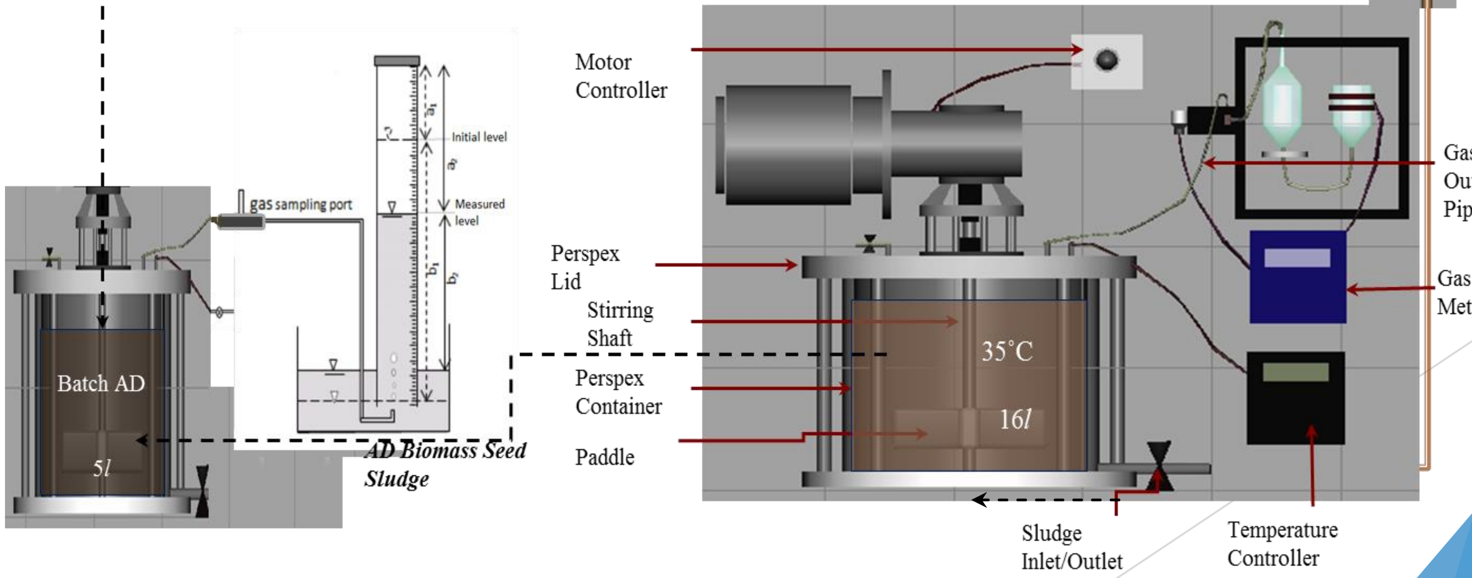


Both SS and dynamic Model to be calibrated

EXPERIMENTS TO MODEL P REMOVAL

The AD system fed enhanced culture of PAO's to **(1)** Identify correct **AD stoichiometric Pathways for PAOs**; **(2)** Measure **PAO ER fraction; (3)** Determine **Kinetics of PAO breakdown** in AD **(4)** Generate data to **Validate AD model**.





Modelling Chemical Precipitation Processes

Research Questions

- Are Mathematical models that include biological and chemical P removal sufficient to inform optimal design?
- Should chemical P removal using ferric and/or Aluminium ions be used to supplement biological P removal in activated sludge system?
- Is it cost effective and efficient to remove P biologically without chemical addition (ferric and/or Aluminium ions) in activated sludge system?
- What is the fate of the resulting chemicals binding phosphorus in the waste activated sludge?

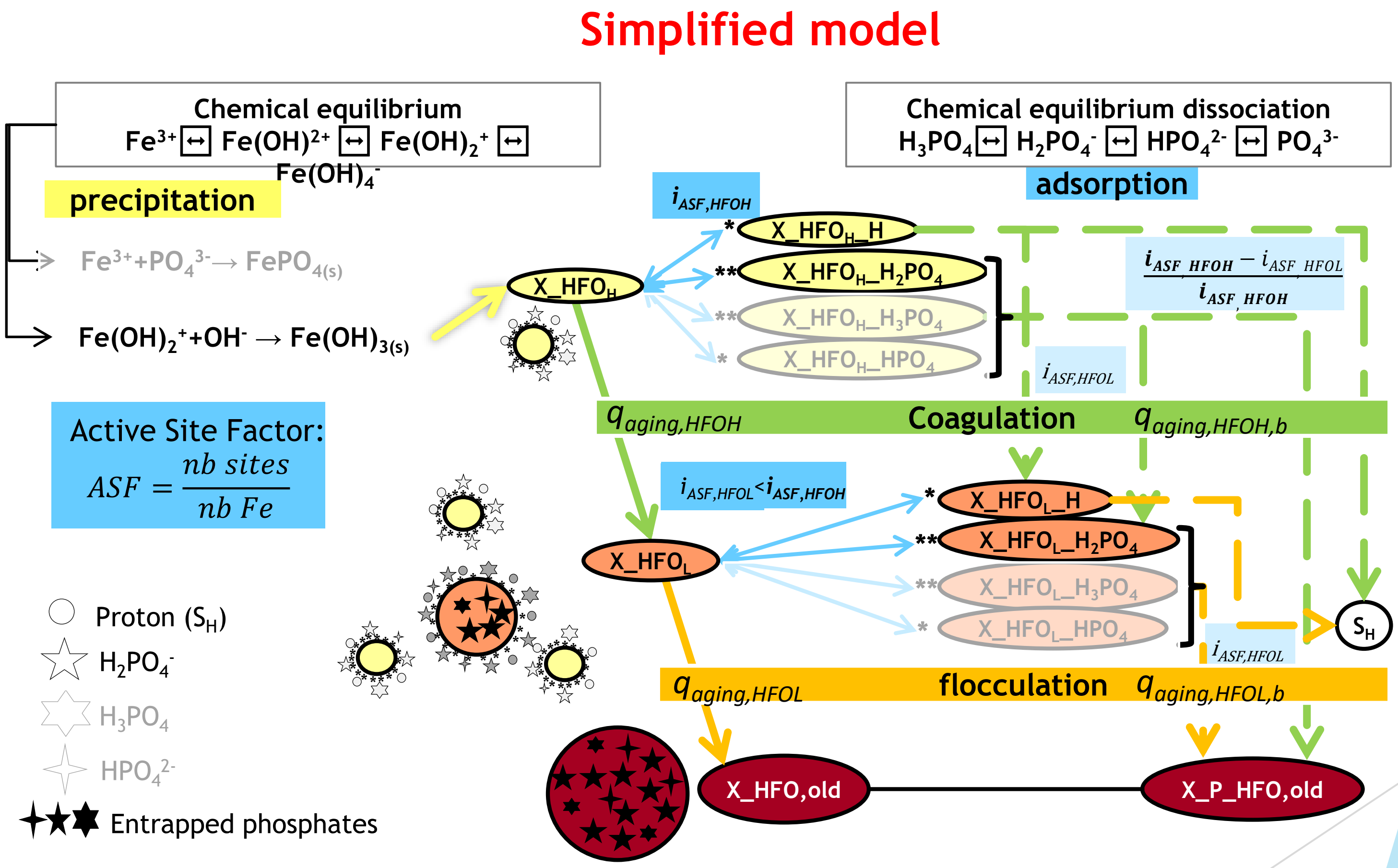
Research Approach:

- Extend Model and utilize data from Literature to explore the chemical P removal via pre-precipitation, co-precipitation and post-precipitation
- Experiments used where research gaps identified (i.e., data unavailable)

Modelling Chemical Precipitation Processes

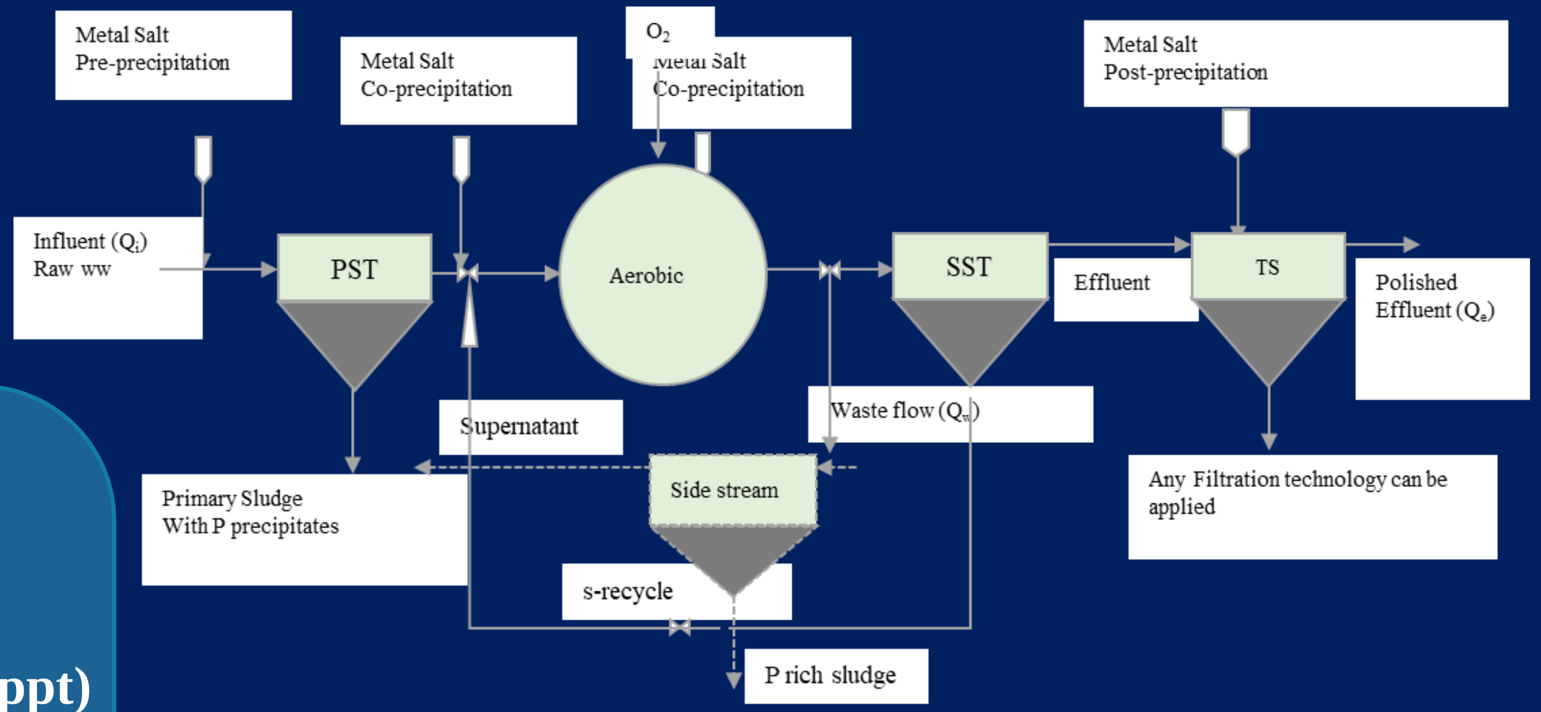
Hauduc et al., 2015

- 2/1 Precipitation Processes
- 8/4 Adsorption Processes
- 4 Aging Processes
- 12/8 State Variables



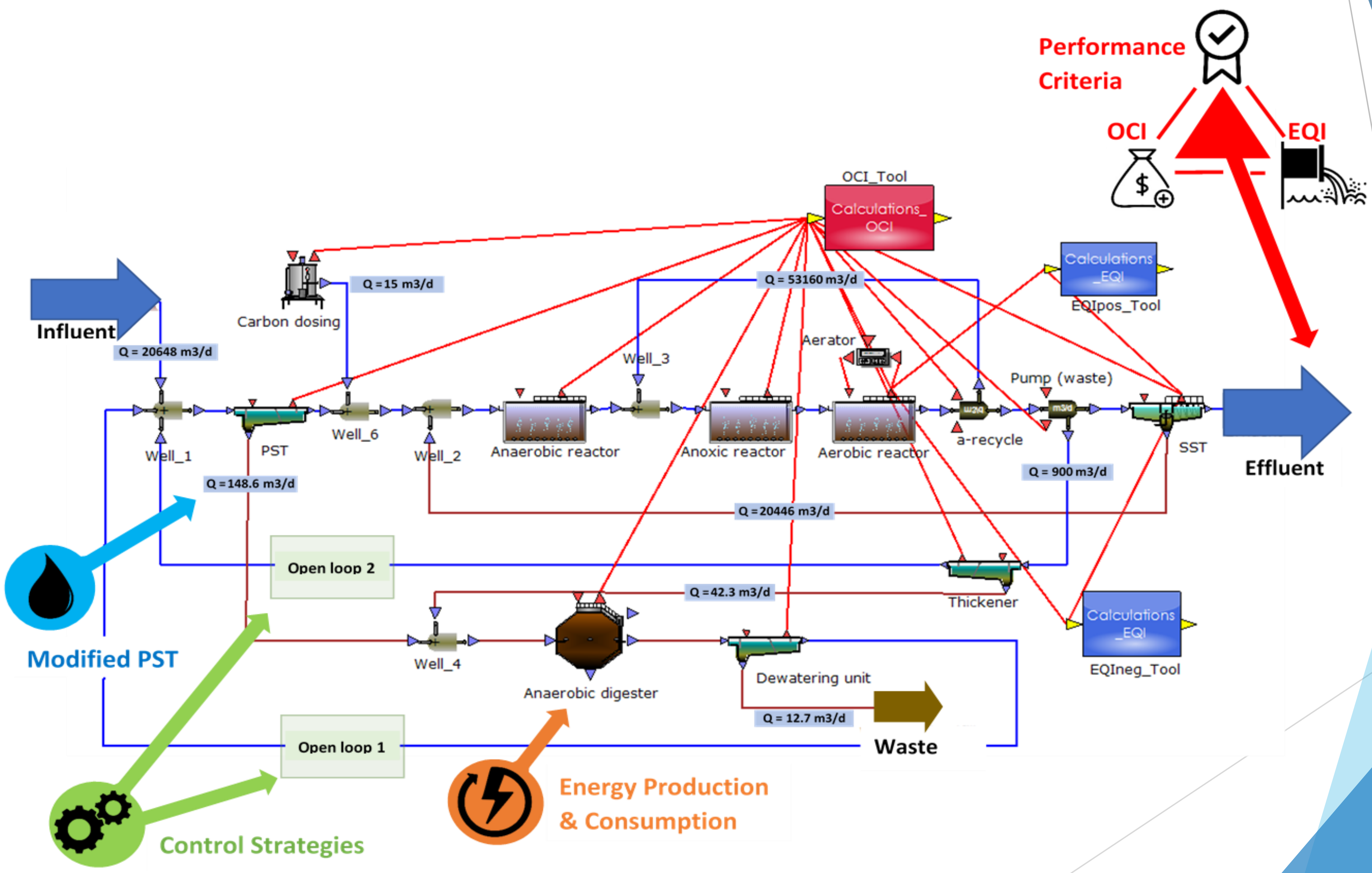
Extension of PWMSA model to include above chemical precipitation model

Calibrating Chemical Precipitation Processes



- Calibration of the **model (E.M.) with data from (De Haas; FeCl co precipitation), (Power, 1991; $AlSO_4$ ppt)**
- Evaluate model predictions of P removal, when done (i) biologically, (ii) chemically for co-precipitation, and (iii) when (i) and (ii) are combined
- Assess impact of pre-precipitation

Developing an Evaluative Protocol



Effluent Quality Index

$$EQI_{water} = \frac{1}{T \cdot 1000} \int_{t_0}^{t_{end}} \left(\beta_{TSS} \cdot TSS(t) + \beta_{COD} \cdot COD(t) + \beta_{FSA} \cdot FSA(t) + \beta_{NO} \cdot NO(t) + \beta_{OP} \cdot OP(t) + \beta_x \cdot X(t) \right) \cdot Q_e(t) \cdot dt$$

Eq. 1

- X(t): Any other pollutant considered in future evaluations
- Flexibility in the weighting factors

$$EQI_{gas} = \frac{1}{T \cdot 1000} \int_{t_0}^{t_{end}} \left(\beta_{CO_2} \cdot FCO_2(t) + \beta_{CH_4} \cdot FCH_4(t) + \beta_{N_2O} \cdot FN_2O(t) \right) \cdot dt$$

Eq. 2

T	: Total length of evaluation period (days)
β	: Pollutant weighting factor (β_{CO_2} =1; $\beta_{CH_4} = 32$; $\beta_{N_2O} = 281$)
F	: Flux of gas evolved (kg/d)

Works in Progress: Formulation for EQI Sludge?

Operational Cost Index

$$OCI = (AE + PE - MP + ME + HE) \cdot Energy\ cost + SP \cdot Sludge\ disposal\ cost + EC \cdot Carbon\ cost + Metals\ dosed \cdot Metal\ cost + Lime\ dosed \cdot Lime\ cost - NR \cdot Market\ price + Fines$$

Eq. 3

AE	: Aeration energy (kWh/d)
PE	: Pumping energy (kWh/d)
SP	: Sludge produced (kgTSS/d)
EC	: External carbon addition (kgCOD/d)
ME	: Mixing energy (kWh/d)
MP	: Energy from methane produced (kWh/d)
HE	: Total heat energy required be anaerobic digester for sludge treatment (kWh/d)
NR	: Nutrient recovered; e.g Struvite (kg/d)

Delivering a new generation of engineering tools to simulate resource recovery options and to evaluate these novel technologies in line with the circular economy paradigm

Development and validation of engineering tools for resource recovery technologies for South African treatment plants

Interfacing engineering tools within system-wide modelling approaches

Demonstrating novel process simulation and scenario analysis options using full-scale case studies

Promote the development of a WRRF mathematical modelling community