Modell med bio-P och fällning för hela avloppsreningsverket

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Outline

- Introduction
- New and extended process models
- Full-scale validation at Hammarby-Sjöstad and Henriksdal
- Conclusions
- Perspectives

Introduktion

- Bio-P i aktiv slam "hyggligt" modellerat sedan 1995 (ASM2d modellen)
- Fortfarande diskussion avseende PAO o GAO
- Kemisk fällning oerhört förenklat i ASM2d
- ADM1 modellen (2002) beskriver inte fosfor
- ADM1 dock en del kemi (ex grunder till weak acid-base och pH)
- Senaste 10 åren full physico-chemical modelling
- Utnyttja databaser från geologi/geokemi (MINTEQ, PHREEQC)

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Introduktion

- Tillägg av enbart P ganska rättframt
- Fällning med Fe kräver mer
- Svavel måste inkluderas (biologiskt o kemiskt)
- Komplexitet ökar dramatiskt
- Beskrivning av ett stort antal anjoner o katjoner samt deras interaktion i alla delprocesser
- Fällningsreaktioner centrala för resource recovery
- Pandoras box öppnar sig
- Numeriska problem dessutom

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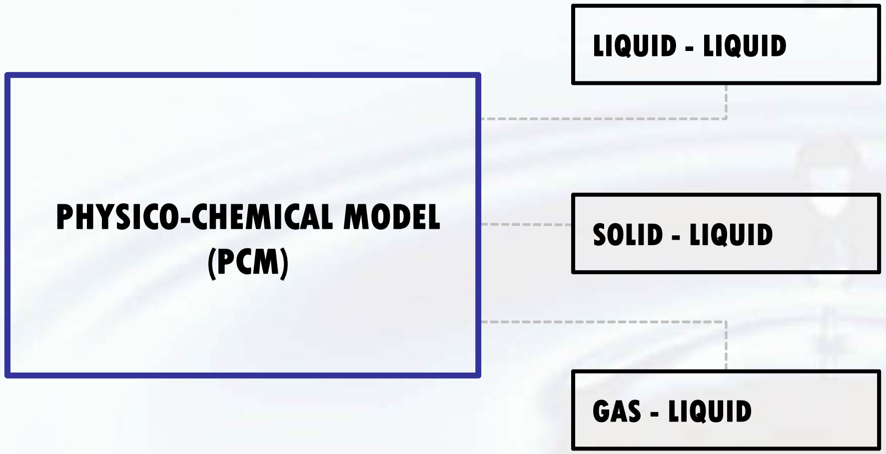
Processutvidgning



- Aqueous phase chemical equilibria
- Ion pairing
- Ion activity correction
- Precipitation
- Redissolution
- Stripping/Volatilization
- Absorption

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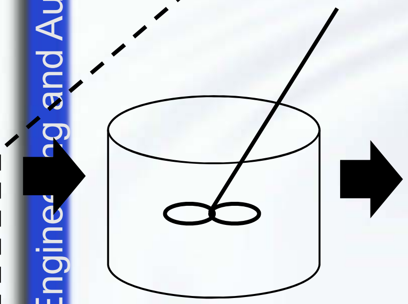
Modell med bio-P och fällning för hela reningsverket

New physicho-chemical description: Weak acid-base chemistry module

FULL CATIONIC / ANIONIC DESCRIPTION



Tot_Na
Tot_K
Tot_iNH
Tot_Cl
Tot_Ac
Tot_Pro
Tot_Ca
Tot_Mg
Tot_iC
Tot_SO
Tot_iP
Tot_SH
Tot_Fe2
Tot_Fe3
Tot_Bu
Tot_Va

EQUILIBRIUM MODELLING

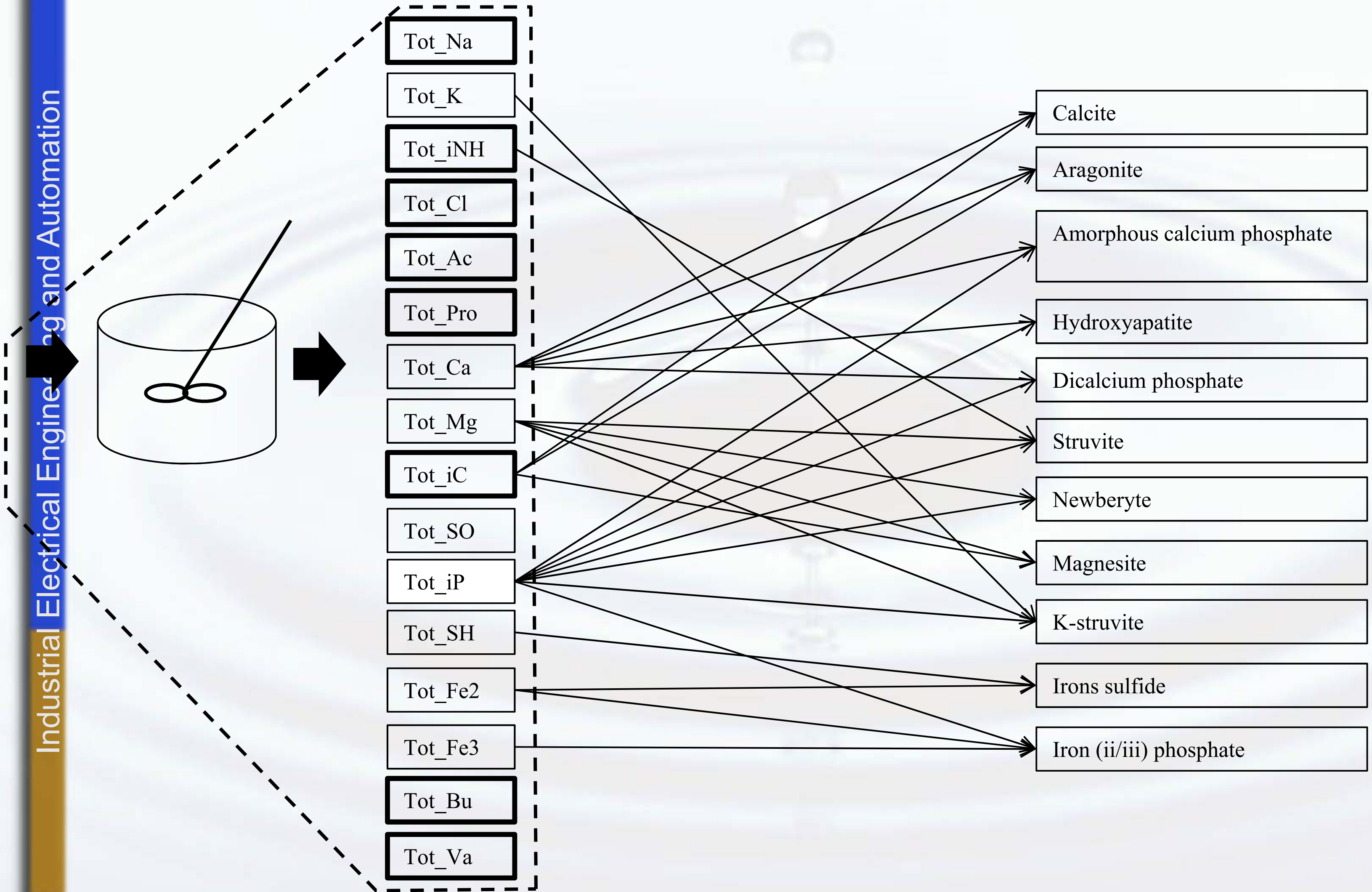
PO4 | HPO4 | H2PO4 | H3PO4

Al2PO4 | AlHPO4 | CaH2PO4 | CaHPO4 | CaPO4 | FeH2PO4
FeH2PO4(2) | FeH2PO4 | FeHPO4 | K2HPO4 | K2PO4 | KH2PO4
KHPO4 | KPO4 | MgHPO4 | MgPO4 | Na2HPO4 | Na2PO4
NaH2PO4 | NaHPO4 | NaPO4

Acid-base chemistry (pH)
Ion speciation / pairing
Ionic strengh / activity corrections

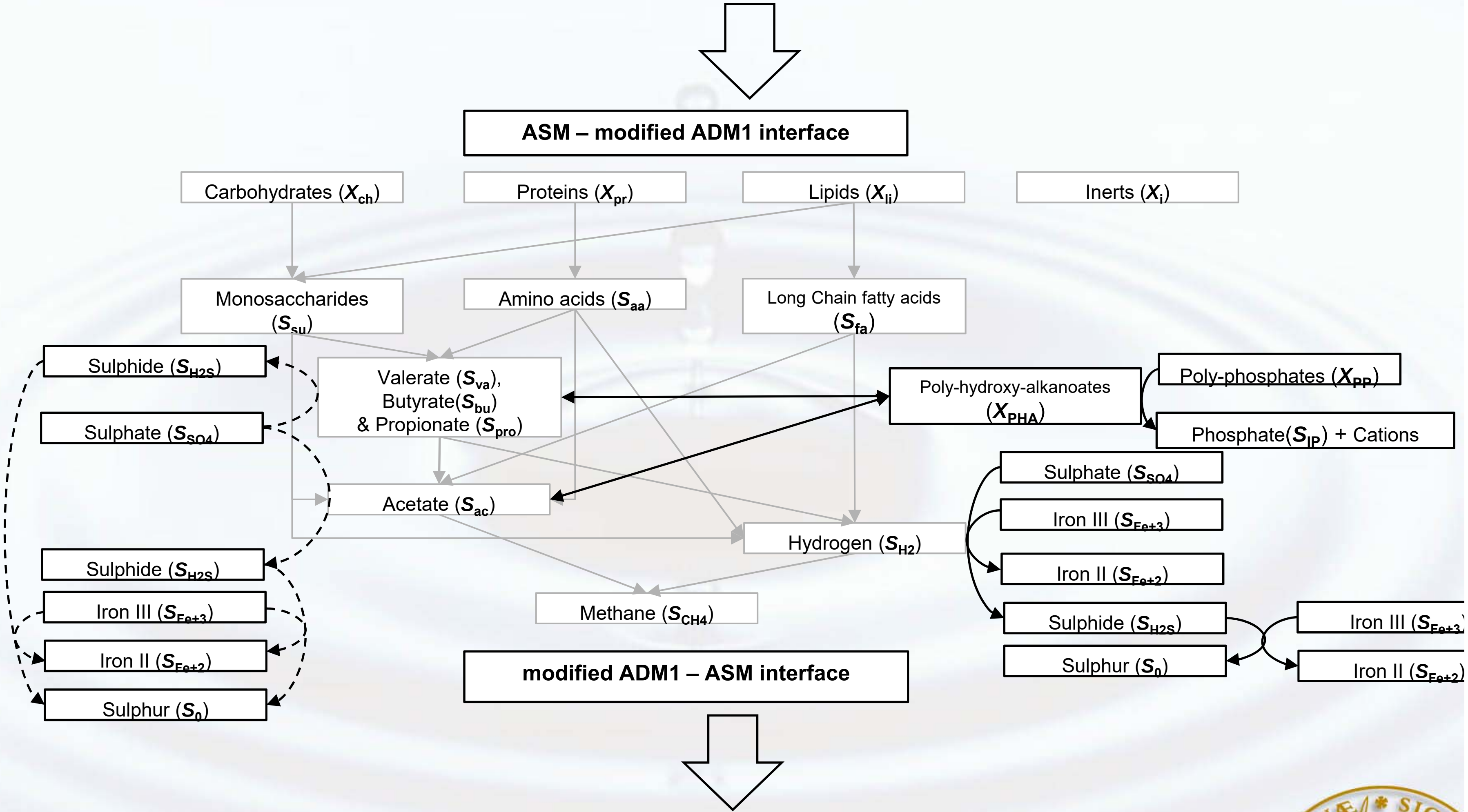
Solon K, Flores-Alsina X , Kazadi Mbamaba C., Gernaey K. V, Tait S., Batstone D. and Volcke E. I. P. Jeppsson U. (2015) Effects of ion strength and ion pairing on plant wide modelling on anaerobic digester. **Water Research** 70,235-245

New physicho-chemical description: Identification of potential precipitates



Kazadi-Mbamba C., Flores-Alsina X., Batstone D. & Tait, S. (2015a). A generalized chemical precipitation modelling approach in wastewater treatment applied to calcite. **Water Research**, 68(1), 342-353.

New biochemical description (e.g. AD)

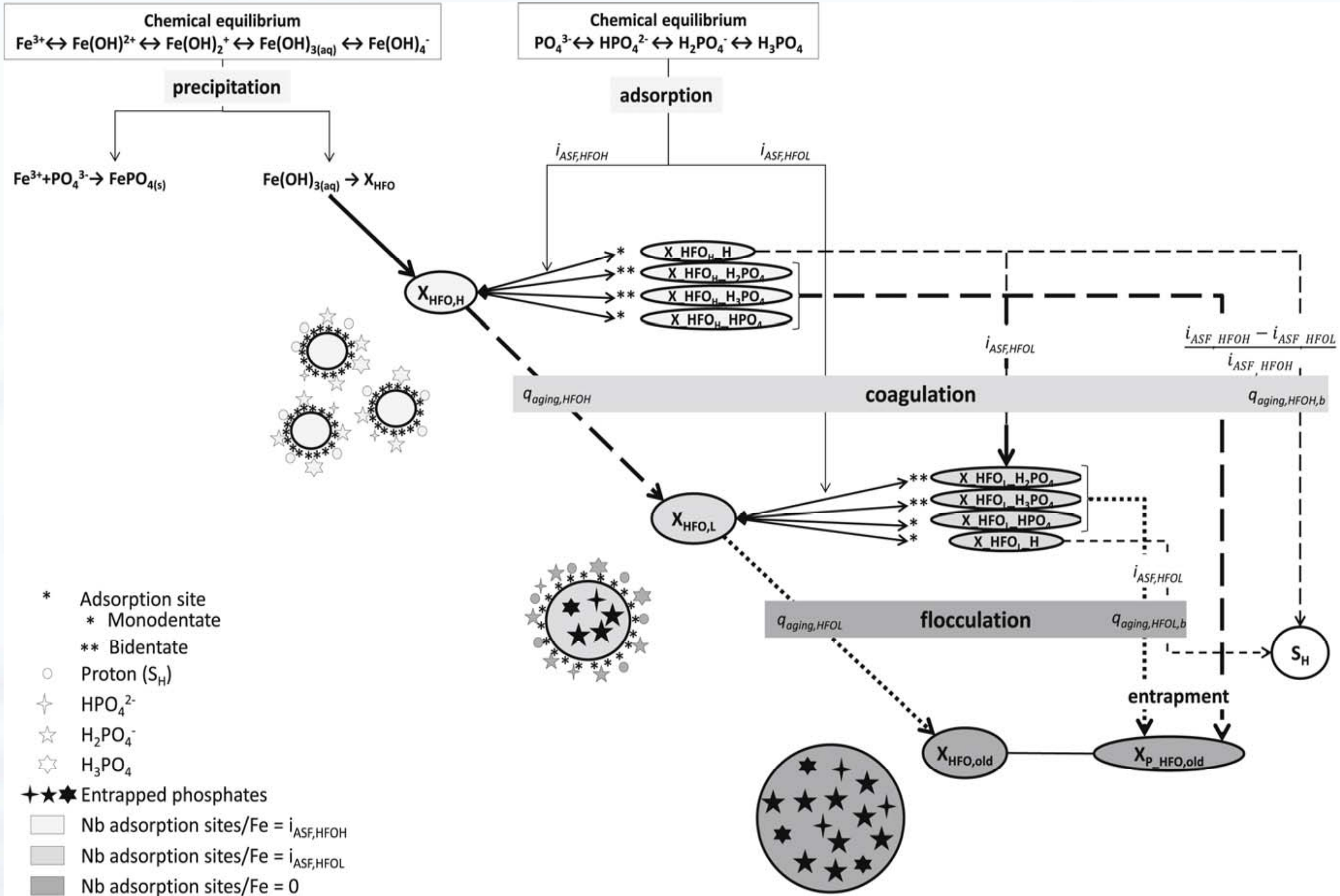


Ikumi, D.S., Brouckaert C.J. & Ekama G.A. (2011). Modelling of struvite precipitation in anaerobic digestion. Proc. **IWA Watermatex2011**, San Sebastian, Spain, 20-22 June 2011.

Batstone, D.J., Puyol, D., Flores-Alsina, X., Rodriguez, J. (2015). Mathematical modelling of anaerobic digestion processes: Applications and future needs. **Reviews on Environmental Science and Biotechnology** (accepted)

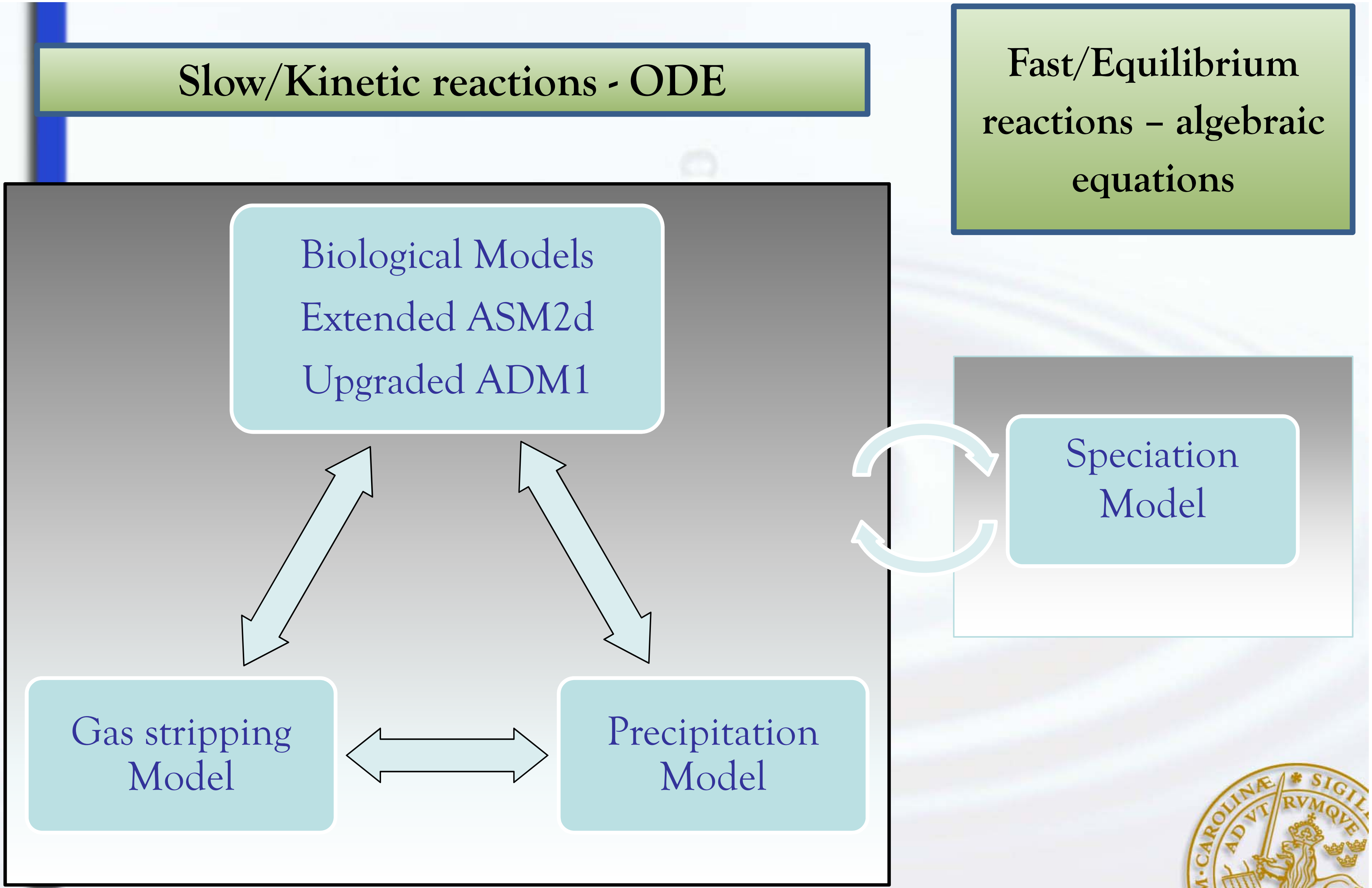
Barrera, E.L., Spanjers, H., Solon, K., Amerlinck, Y., Nopens, I. & Dewulf, J. (2015). Modeling the anaerobic digestion of cane-molasses vinasse: Extension of the Anaerobic Digestion Model No. 1 (ADM1) with sulfate reduction for a very high strength and sulfate rich wastewater. **Water Research**, 71, 42-54.

Chemical precipitation modelling

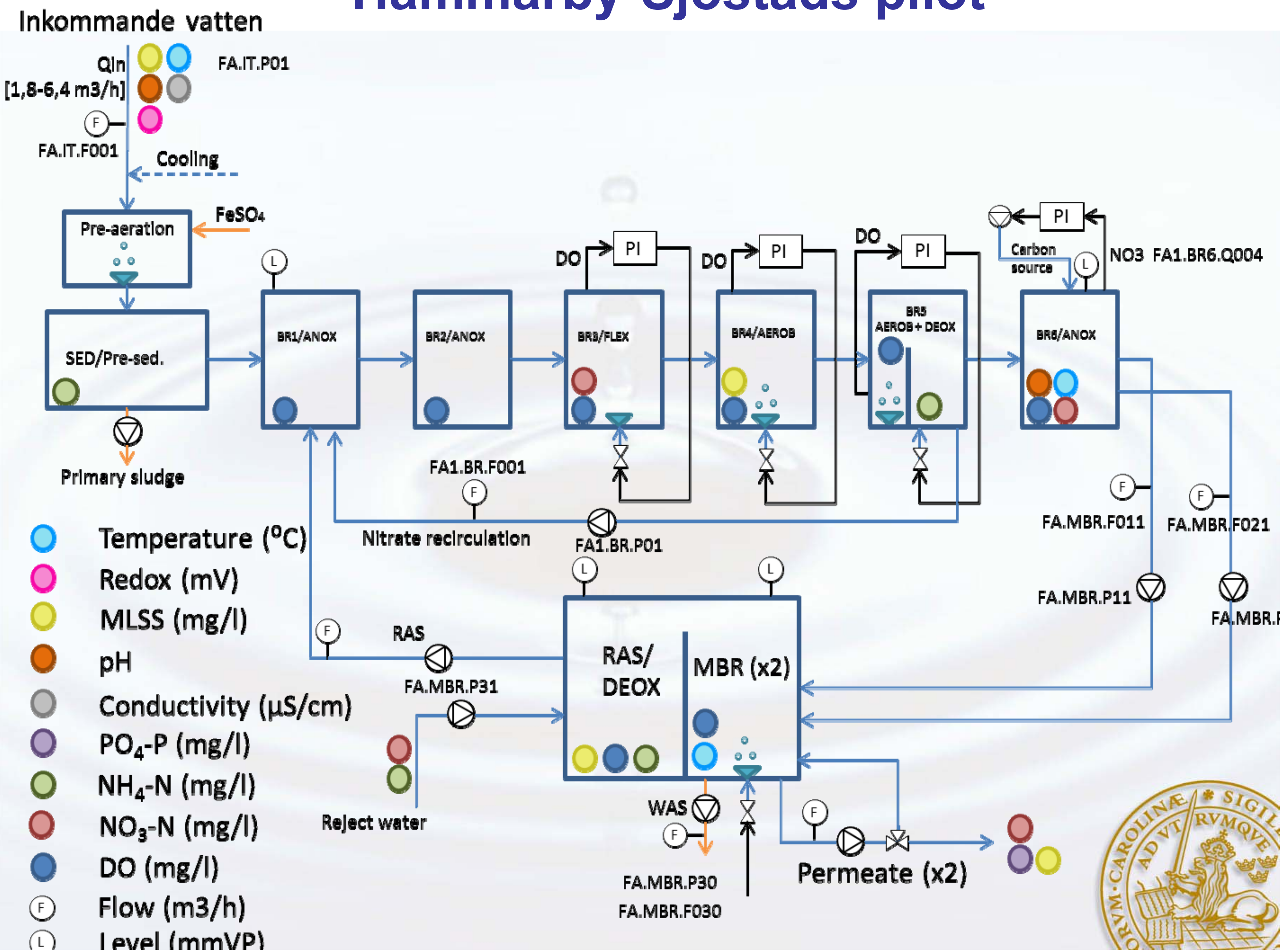


Hauduc et al. (2015)

Plant-wide modelling framework



Hammarby-Sjöstads pilot



Bio-P nätverksträff, Lund, 24-25 oktober 2017

Influent

	Measured
Flow (m^3)	71.13 ± 05
PO4-P ($gP.m^{-3}$)	2.06 ±0.04
NH4-N ($gN.m^{-3}$)	37 ± 0.12
Fe (tot $gFe.m^{-3}$)	1.35± 0.04
TSS ($g.m^{-3}$)	249 ± 2.87

Primary effluent

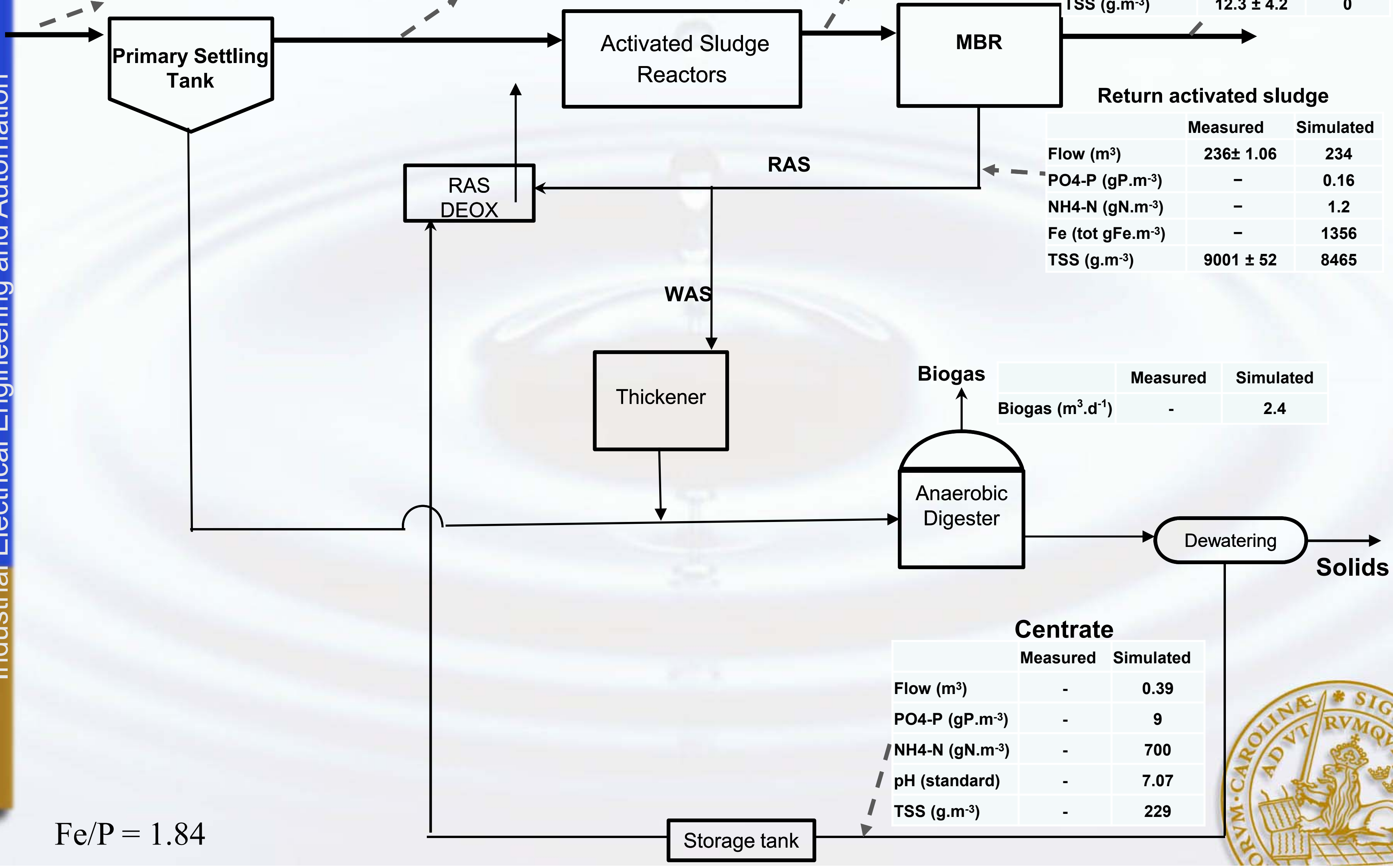
	Measured	Simulated
Flow (m^3)		71.9
PO4-P ($gP.m^{-3}$)	1.23± 0.03	1.3
NH4-N ($gN.m^{-3}$)	36.8 ± 0.12	36.5
Fe (tot $gFe.m^{-3}$)	9.6 ± 0.15	11.1
TSS ($g.m^{-3}$)	180 ± 16	175

Mixed liquor

	Measured	Simulated
Flow (m^3)	-	308
PO4-P ($gP.m^{-3}$)	-	0.17
NH4-N ($gN.m^{-3}$)	-	7.23
Fe (tot $gFe.m^{-3}$)	-	1041
TSS ($g.m^{-3}$)	7174± 31	7113

Effluent

	Measured	Simulated
Flow (m^3)		71.1
PO4-P ($gP.m^{-3}$)	0.24 ± 0.01	0.16
NH4-N ($gN.m^{-3}$)	1.25 ± 0.34	1.2
NO3 – NO2	3.13 ± 0.02	3.1
Fe (tot $gFe.m^{-3}$)	0.12 ± 0.001	0.23
TSS ($g.m^{-3}$)	12.3 ± 4.2	0



Return activated sludge

	Measured	Simulated
Flow (m^3)	236± 1.06	234
PO4-P ($gP.m^{-3}$)	–	0.16
NH4-N ($gN.m^{-3}$)	–	1.2
Fe (tot $gFe.m^{-3}$)	–	1356
TSS ($g.m^{-3}$)	9001 ± 52	8465

Biogas

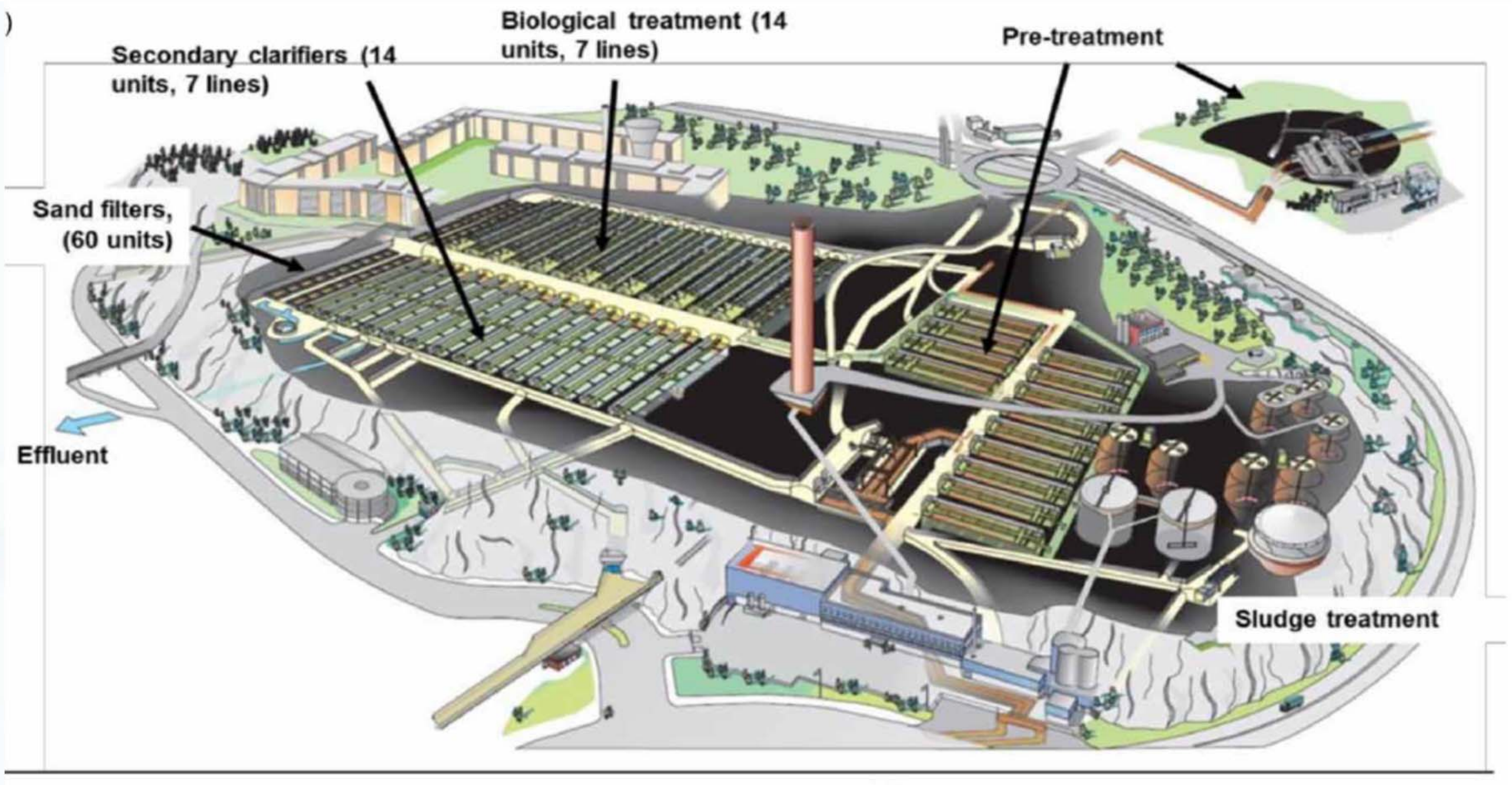
	Measured	Simulated
Biogas ($m^3.d^{-1}$)	-	2.4

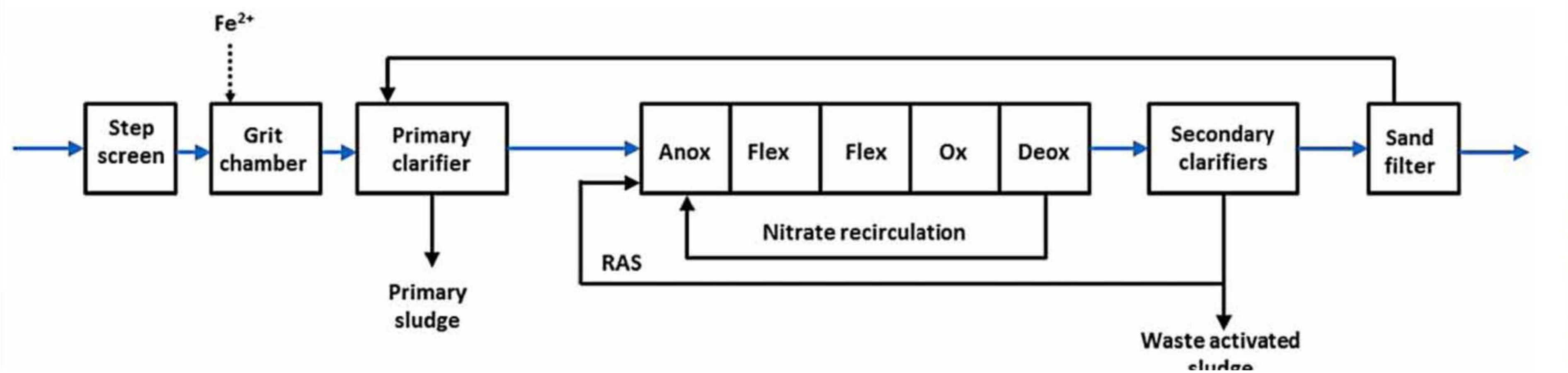
Centrate

	Measured	Simulated
Flow (m^3)	-	0.39
PO4-P ($gP.m^{-3}$)	-	9
NH4-N ($gN.m^{-3}$)	-	700
pH (standard)	-	7.07
TSS ($g.m^{-3}$)	-	229

Fe/P = 1.84

HENRIKSDAL CONFIGURATION





Bio-P nätverksträff, Lund, 24-25 oktober 2017

	Measured	Simulated
Flow (m^3)		255820
PO4-P ($gP.m^{-3}$)	-	1.95
NH4-N ($gN.m^{-3}$)	35.1	35.5
Fe (tot $gFe.m^{-3}$)	9.8	10.6
TSS ($g.m^{-3}$)	141 ± 2	139

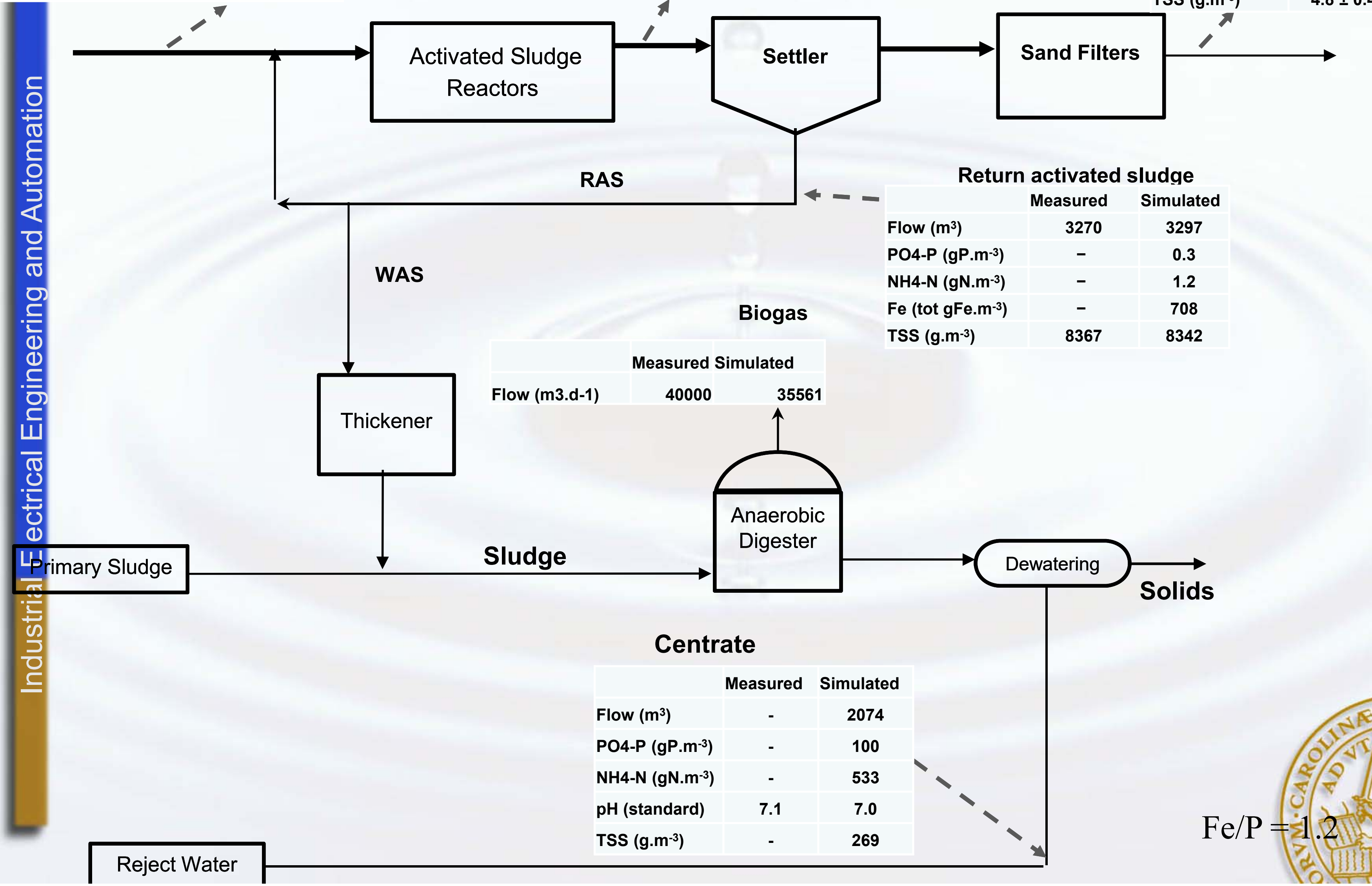
Mixed liquor

	Measured	Simulated
Flow (m^3)	-	1265701
PO4-P ($gP.m^{-3}$)	-	0.31
NH4-N ($gN.m^{-3}$)	-	1.17
Fe (tot $gFe.m^{-3}$)		239
TSS ($g.m^{-3}$)	2750	2810

	Measured	Simulated
COD ($g.m^{-3}$)	2316	2662
VSS ($g.m^{-3}$)	1767	1817

Effluent

	Measured	Simulated
Flow (m^3)		252520
PO4-P ($gP.m^{-3}$)	0.24 ± 0.01	0.3
NH4-N ($gN.m^{-3}$)	1.25 ± 0.34	1.2
NO3 – NO2	3.13 ± 0.02	3.76
Fe (tot $gFe.m^{-3}$)	0.7	2.7
TSS ($g.m^{-3}$)	4.8 ± 0.4	3.1



Return activated sludge

	Measured	Simulated
Flow (m^3)	3270	3297
PO4-P ($gP.m^{-3}$)	–	0.3
NH4-N ($gN.m^{-3}$)	–	1.2
Fe (tot $gFe.m^{-3}$)	–	708
TSS ($g.m^{-3}$)	8367	8342

Biogas

	Measured	Simulated
Flow (m3.d-1)	40000	35561

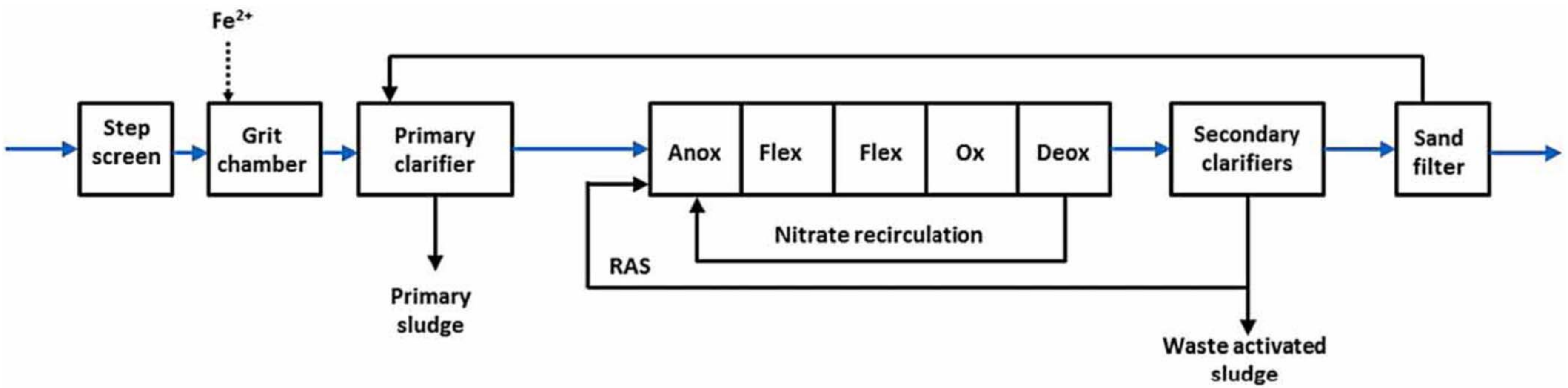
Centrate

	Measured	Simulated
Flow (m^3)	-	2074
PO4-P ($gP.m^{-3}$)	-	100
NH4-N ($gN.m^{-3}$)	-	533
pH (standard)	7.1	7.0
TSS ($g.m^{-3}$)	-	269

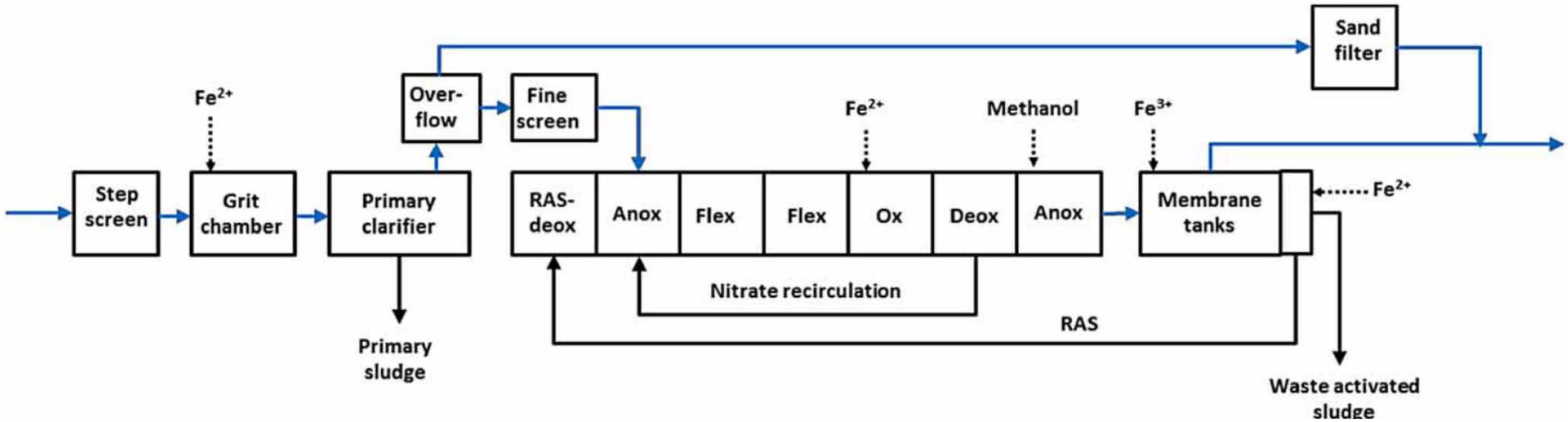
Fe/P = 1.2

Scenario Analysis

Scenario 1: Current configuration



Scenario 2:Future configuration



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Conclusions

- Simultaneous (bio and chem) C, N and P descriptions require substantial model (ASM, ADM) modifications/upgrades
- P, S, Fe modelling requires a dramatic (and unavoidable) increase in **physico-chemical model complexity** (speciation / precipitation)
- Special **solving routines** needed to handle the systems of ODE and DAE with multiple algebraic inter-dependencies
- Full-scale model validations (Stockholm and Australia) have provided very promising results

Perspectives

- BSM2-P, BSM2-PSFe (and other variations) free software available (Matlab/Simulink)
- Important for future recovery processes
- More collaboration between groups on plant-wide/system-wide model development needed
- Integration of C, N, P, S, PCM, precipitation with X (micro pollutants) and GHG?
- Integration with BSM3 – catchment, sewer, plant, recipient?
- IWA Working Group a suitable platform for collaboration