IWA TG on Benchmarking of Control Strategies for WWTPs

Plant-wide modelling and simulation The importance of interfaces

13 September 2006
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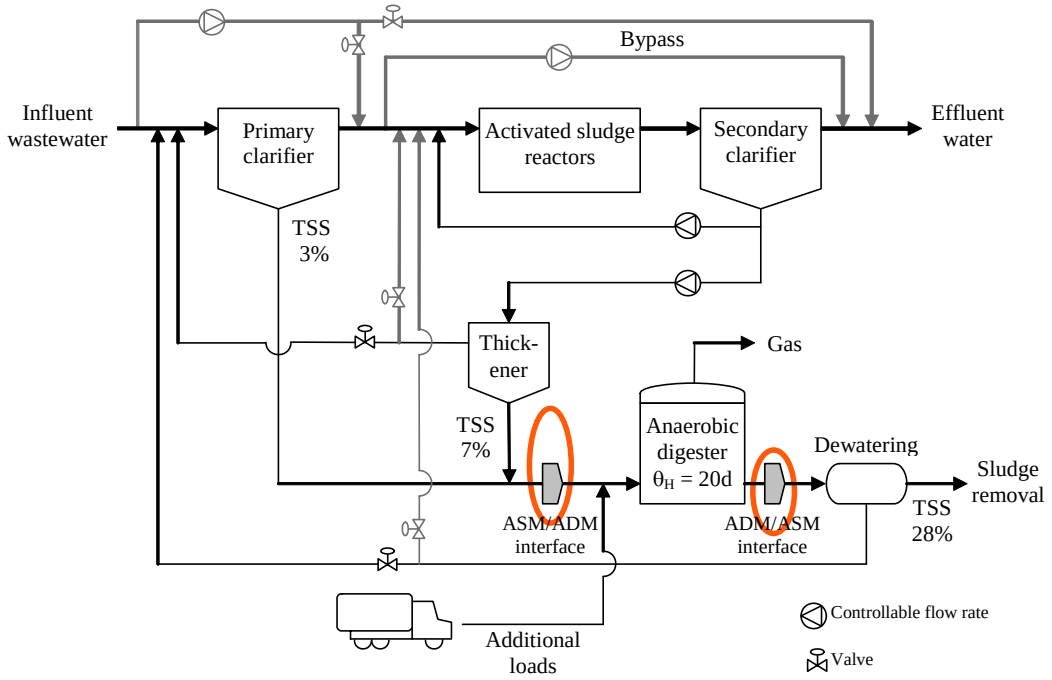
Outline

- Introduction
- Interface Copp et al. (2003)

- Performance of Copp interface
- Modified Copp interface for BSM2
- Performance of modified Copp interface

- Conclusions

Benchmark simulation model No. 2



ASM1 versus ADM1

- Incompatible variable lists
  - ASM1:
    - Soluble: S_S, S_I, S_O, S_{NO}, S_{NH}, S_{alk}, S_{ND}
    - Particulate: X_S, X_I, X_P, X_{BH}, X_{BA}, X_{ND}
  - ADM1:
    - Soluble: S_{su}, S_{aa}, S_{fa}, S_{va}, S_{bu}, S_{pro}, S_{ac}, S_{h2}, S_{ch4}, S_{IC}, S_{IN}, S_I, S_{cat}, S_{an}
    - Particulate: X_{xc}, X_{ch}, X_{pr}, X_{li}, X_{su}, X_{aa}, X_{fa}, X_{c4}, X_{pro}, X_{ac}, X_{h2}, X_I

ASM1 versus ADM1

- Example 1
  - X_{BA}: nitrifiers have no state variable in ADM1

Cell lysis / storage →

Cell components?
COD-fraction?
N-fraction?

International Water Association
IWA Task Group on "Benchmarking of Control Strategies for Wastewater Treatment Plants"
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ASM1 versus ADM1

- Example 2
  - ASM1
  - Separate particulate COD and N: X_S and X_{ND}
  - ADM1
  - Composites, carbohydrates, proteins and lipids: X_{xc}, X_{ch}, X_{pr}, X_{li}

PVR9

ASM1 versus ADM1

- Example 3
  - ASM1
  - Inerts: S_I and X_I
  - ADM1
  - Some aerobic inerts can be anaerobically degradable

$$S_{I,ASM} \neq S_{I,ADM} \quad \wedge \quad X_{I,ASM} \neq X_{I,ADM}$$

Folie 7

PVR9 Deze staat hidden in de presentatie...
Peter Vanrolleghem; 03.09.2006

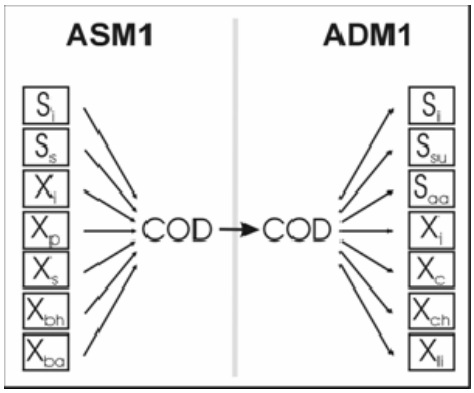
ASM1 versus ADM1

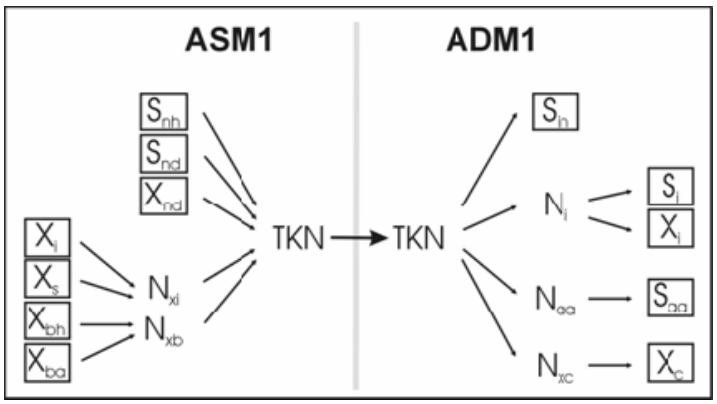
- Interfaces needed to convert COD and N components from ASM1 to ADM1 and vice versa

- History:
  - Copp et al. (2003)
    - WEFTEC-paper
  - Vanrolleghem et al. (2005)/ Volcke et al. (2006)
    - CBIM – continuity based interface methodology
    - Wat Sci Tech / Wat Res papers

Interface Copp et al. (2003): ASM-ADM

- Mass balancing crucial
- Emphasis on COD and TKN
- Lump – delump approach

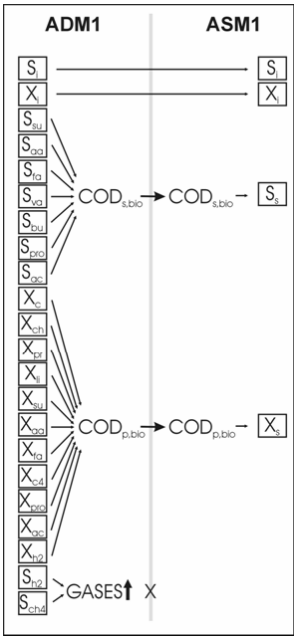


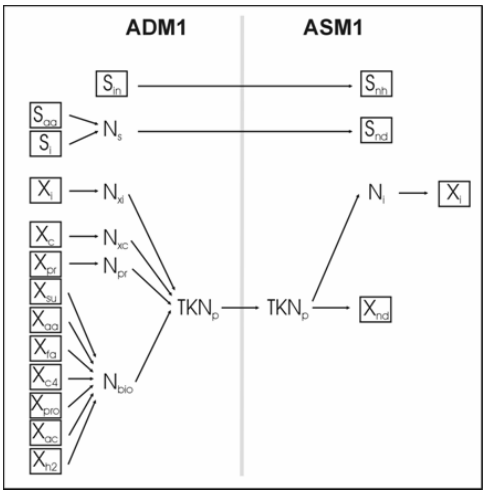


Interface Copp et al. (2003): ASM-ADM

- Step 1: COD-demand → S_S, X_S, X_{BH}, X_{BA}
- Step 2: S_{ND}, S_S → S_{aa}, S_{su}
- Step 3: S_I → S_I, S_{su}
- Step 4: X_I → X_I, COD
- Step 5: COD → max. X_C, X_{ch}, X_{li}
  org-N → S_{IN}

Interface Copp et al. (2003): ADM-ASM





Outline

PVR10

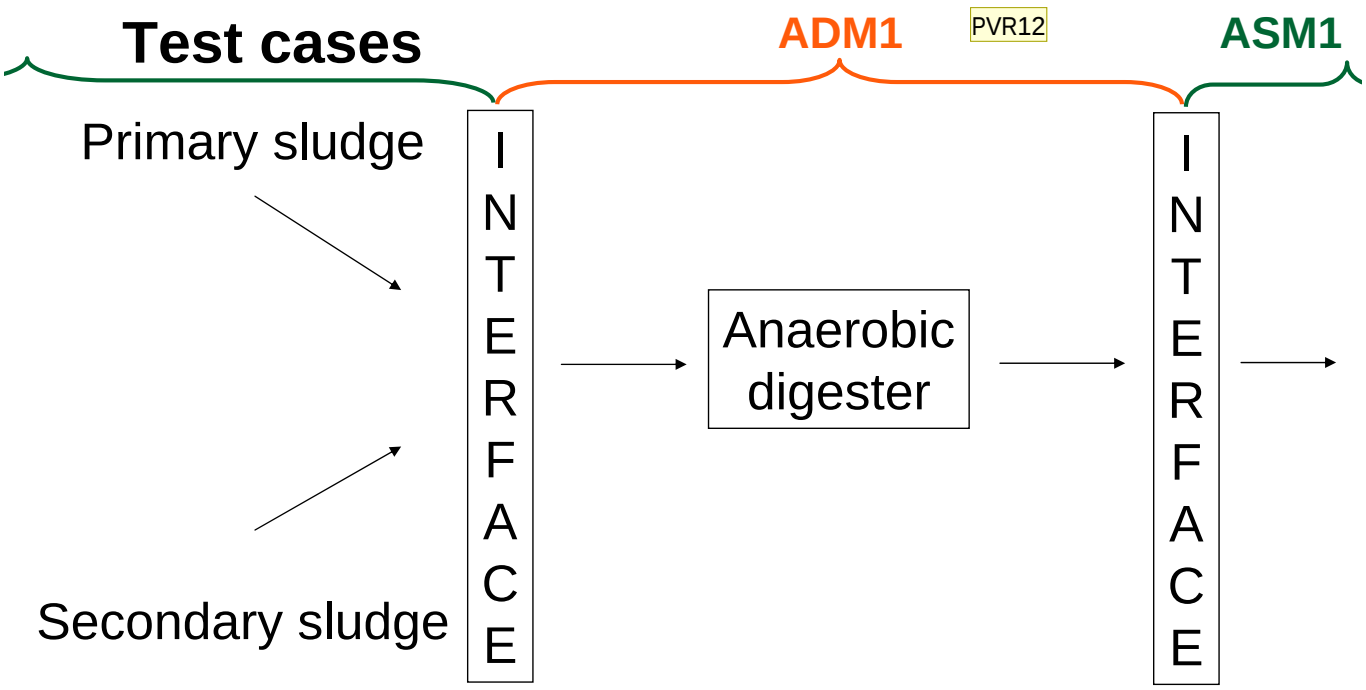
- Introduction
- Interface Copp et al. (2003)

- Performance of Copp interface
- Modified Copp interface for BSM2
- Performance of modified Copp interface

- Conclusions

Folie 12

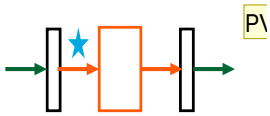
PVR10 'k heb eventjes de outline er weer bijgehaald...
Peter Vanrolleghem; 03.09.2006

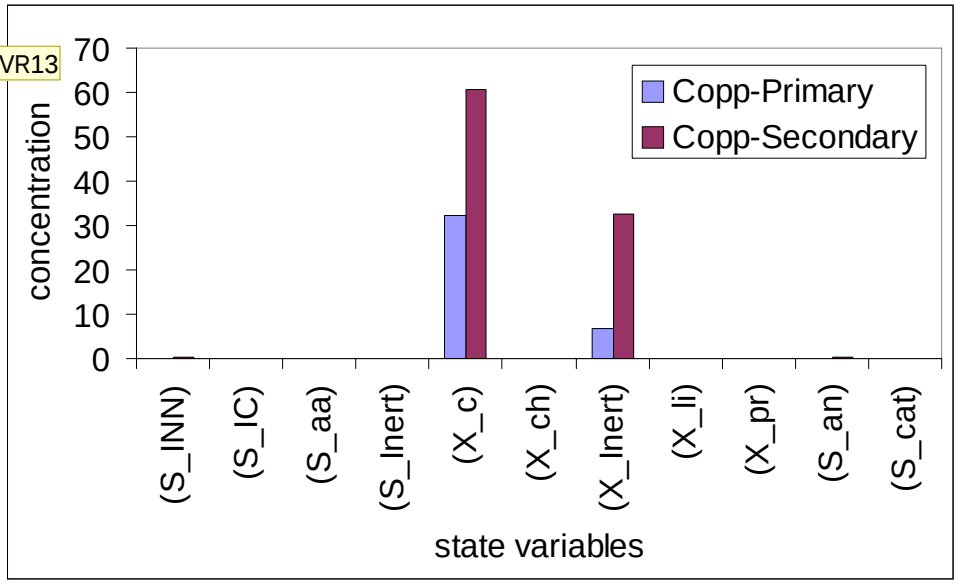


Folie 13

PVR12 Eventjes duidelijk aangeven welke variabelen waar gebruikt worden ...
Peter Vanrolleghem; 03.09.2006

Test cases: Copp interface output



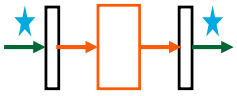


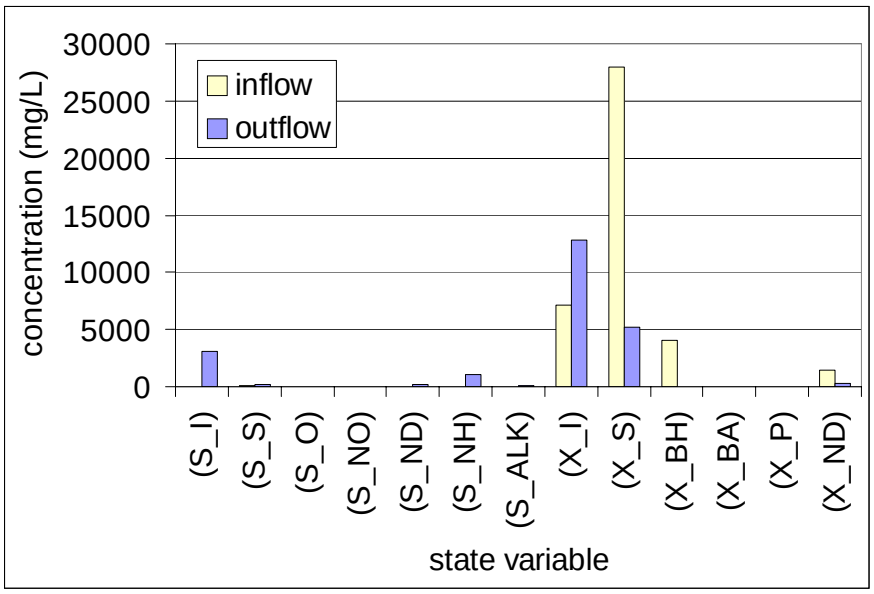
Folie 14

PVR13 Eenheid Concentratie ?
Peter Vanrolleghem; 03.09.2006

PVR14 Ik heb er zo'n schemaatje bijgezet om duidelijk te maken waar de variabelen getoond worden (in welke toestandsvariabelen dus)
Peter Vanrolleghem; 03.09.2006

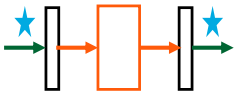
Test cases: Primary sludge

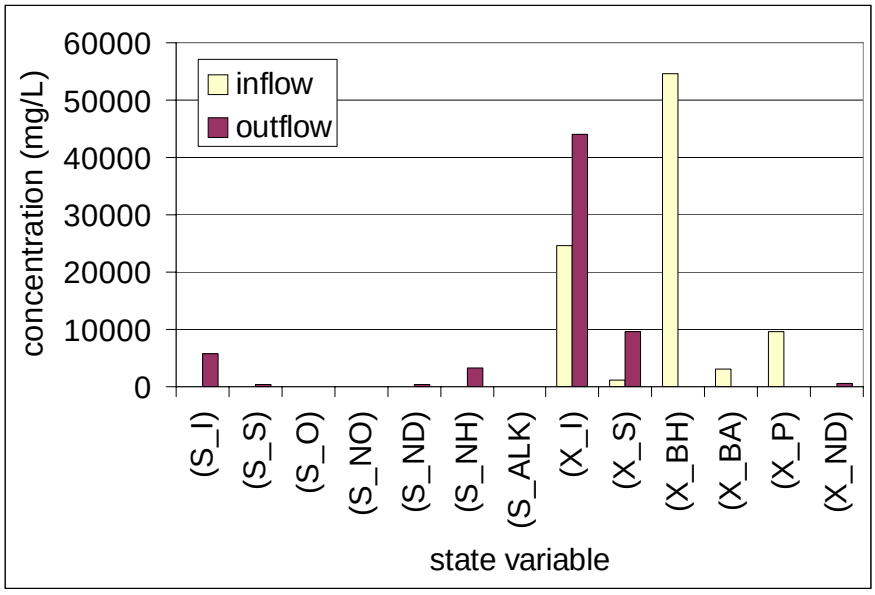




Lots of Inerts formed

Test cases: Secondary sludge





Lots of Inerts formed

Test cases: Gas production in digester

	Primary	Secondary
p_ch4 (%)	56 % PVR15	57 %
q_gas (m^3/d)	2184	3903
Methane production (kg/d)	758	1419
TSS (kg/m^3)	29.41	70
Methane production (kg CH4/kg TSS)	0.15	0.12

i1

Only 27% increase!

PVR16

Folie 17

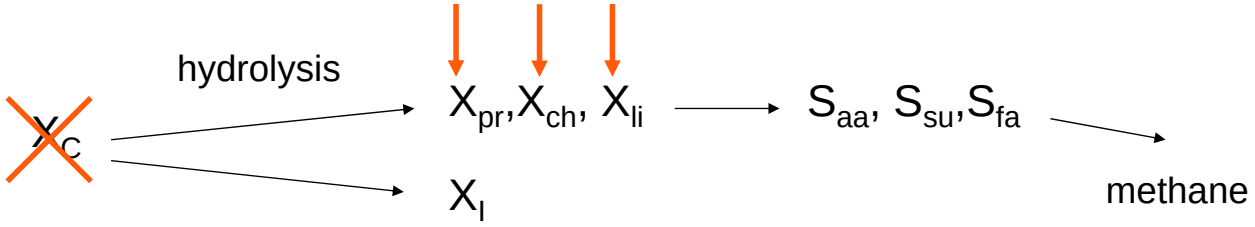
PVR15 Ik denk dat de meesten het beter begrijpen als je de partieeldruk van methaan gewoon uitdrukt als percent...
Peter Vanrolleghem; 03.09.2006

PVR16 Wat is er verhoogd ? over welke variabelen heb je het ?
Peter Vanrolleghem; 03.09.2006

i1 x4 for kg COD (1kg CH4 = 4 kg COD)
ingmar; 05.09.2006

Modified Copp interface for BSM2

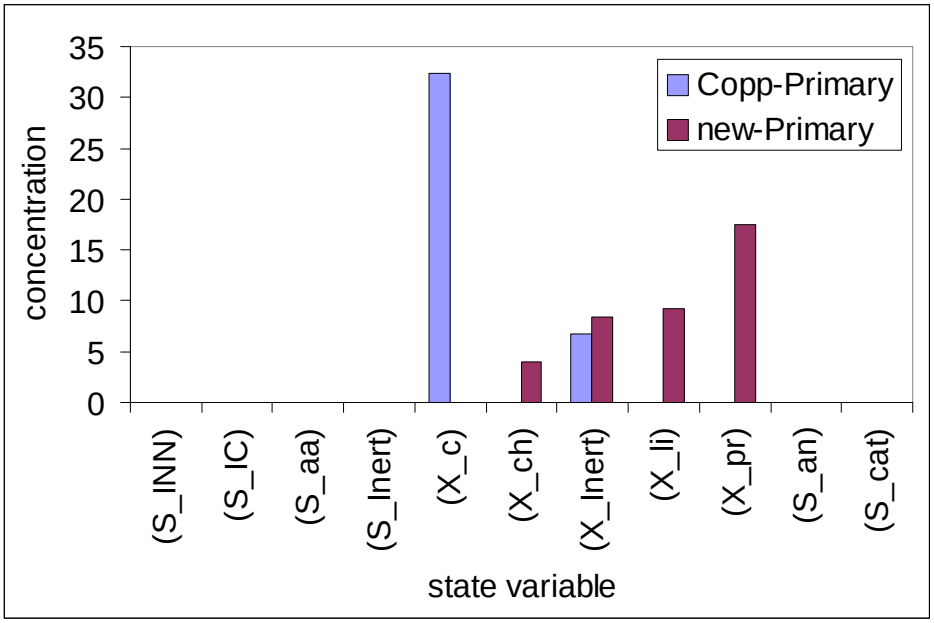
- S1: COD-demand → S_S, X_S, X_{BH}, X_{BA}
- S2: S_{ND}, S_S → S_{aa}, S_{su}
- S3: S_I → S_I, S_{su}
- S4: X_I → X_I, COD
- S5: COD → max. X_C, X_{ch}, X_{li}
  org-N → S_{IN}



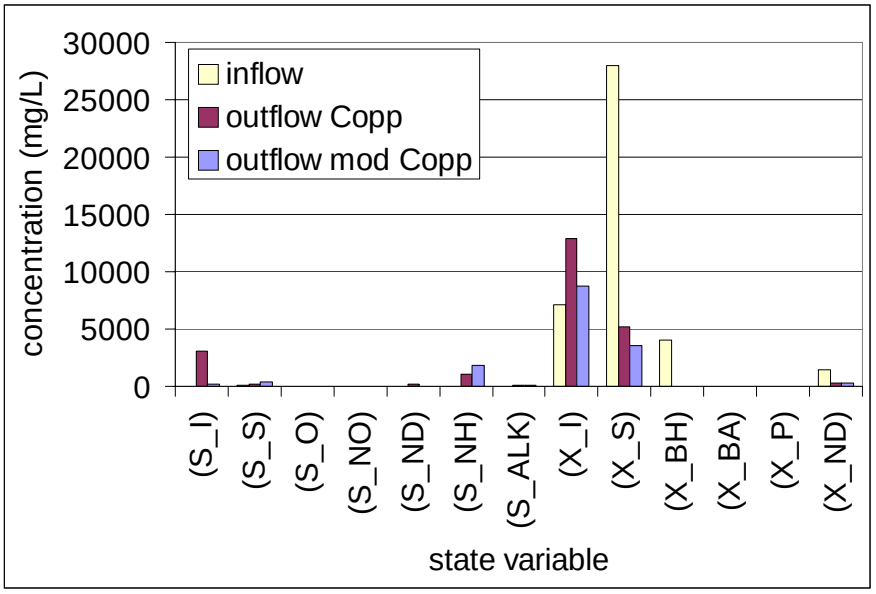
Modified Copp interface for BSM2

- S1: COD-demand → S_S, X_S, X_{BH}, X_{BA}
- S2: S_{ND}, S_S → S_{aa}, S_{su}
- S3: X_{ND}, X_S → X_{pr}, X_{ch}, X_{li}
- S4: X_{BH}, X_{BA} → X_{pr}, X_{ch}, X_{li}
- S5: S_{alk} → S_{IC}
  S_{NH} → S_{IN}
- S6: S_I → S_I
  X_I, X_P, X_{BH}, X_{BA} → X_I

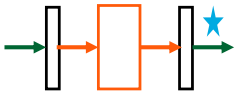
Test cases: Interface output (primary)



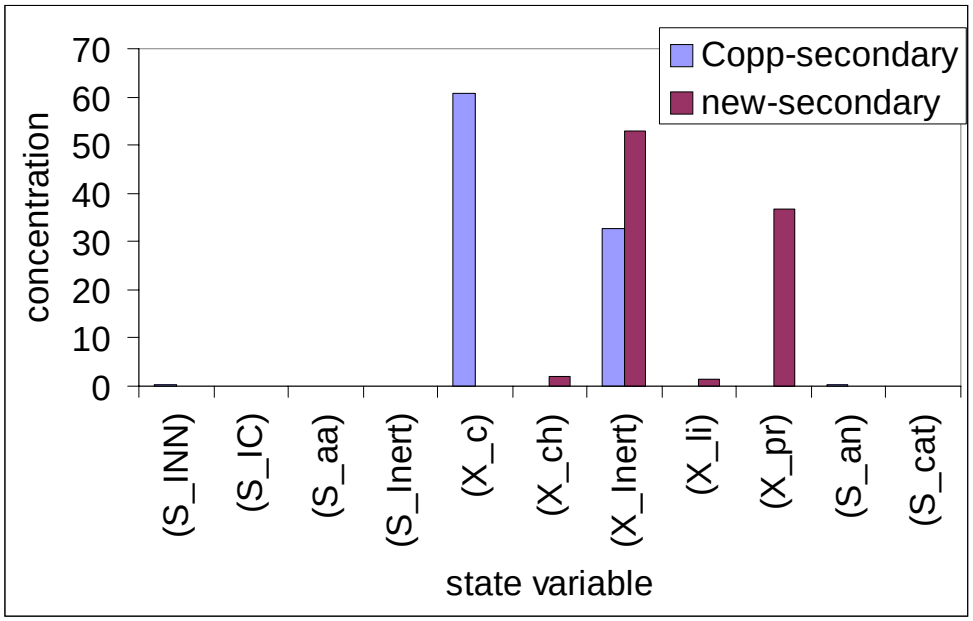
Test cases: output digester (primary)



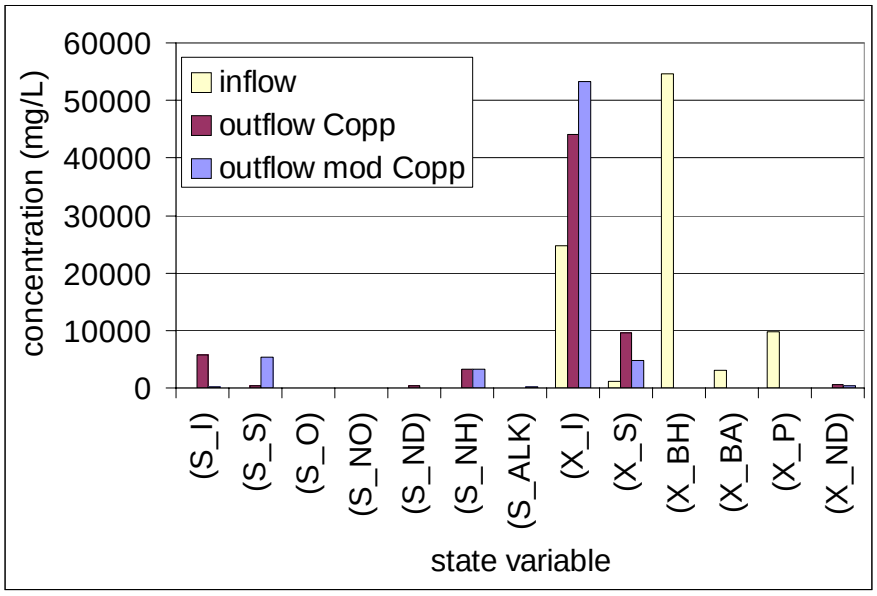
- Less inerts
- More NH4



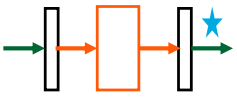
Test cases: Interface output (secondary)



Test cases: Output digester (secondary)



- Less S_I, more X_I
- More S_S



Test cases: Gas production in digester

PVR18

PVR17	Primary Copp	Primary Modified Copp	Secondary Copp	Secondary Modified Copp
p_ch4 (%)	56	67	PVR23	
q_gas (m^3/d)	2184	2630		
Methane production (kg/d)	758	1121		
TSS (kg/m^3)	29.41	29.41		
Methane production (kg CH4/kg TSS)	0.15	0.22		

PVR19

Folie 24

PVR17 Opnieuw in % gezet
Peter Vanrolleghem; 03.09.2006

PVR18 'k Heb alles gecentreerd. Ziet er beter uit
Peter Vanrolleghem; 03.09.2006

PVR19 Weet nog niet waarje 't over hebt.
Peter Vanrolleghem; 03.09.2006

PVR23 Heb dit geanimeerd: anders zitten ze toch al de kolommen van de secondary sludge ook te lezen...
Peter Vanrolleghem; 03.09.2006

Test cases: Gas production in digester

PVR21

PVR20	Primary Copp	Primary Modified Copp	Secondary Copp	Secondary Modified Copp
p_ch4 (%)	56	67	57	65
q_gas (m^3/d)	2184	2630	3903	3033
Methane production (kg/d)	758	1121	1419	1254
TSS (kg/m^3)	29.41	29.41	70	70
Methane production (kg CH4/kg TSS)	0.15	0.22	0.122	0.107

112% increase!
More realistic

PVR22

Folie 25

PVR20 Opnieuw in % gezet
Peter Vanrolleghem; 03.09.2006

PVR21 'k Heb alles gecentreerd. Ziet er beter uit
Peter Vanrolleghem; 03.09.2006

PVR22 Weet nog niet waarje 't over hebt.
Peter Vanrolleghem; 03.09.2006

Conclusions

- Interface is crucial for BSM2
- Copp interface had drawbacks
- Modified Copp interface allows for
  - using 1 interface for different inflows to digester
  - more realistic gas production
  - less inerts
  - faster kinetics