

# MBR modelling: hands-on

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# WEST-MBR model (with fouling)

- Resistance across the membrane surface:

$$R = R_m + R_c + R_{irr}$$

- Intrinsic resistance of the membrane ( $R_m$ )
- Cake resistance (reversible):

$$R_c = \alpha \cdot \frac{M_c}{A_0} \quad \Rightarrow \quad \frac{dM_c}{dt} = C_c \cdot Q_{permeate} \quad C_c = SMP \cdot \left( \frac{J}{J_{crit}} \right)^\beta$$

- Irreversible resistance:

$$R_{irr} = R_m \cdot \left( \frac{A_0}{A} - 1 \right) \quad \Rightarrow \quad \frac{dA}{dt} = \sigma \cdot SMP \cdot Q_{permeate}$$

- Actual flux through the membrane:

$$J = \frac{Q_{permeate}}{A}$$

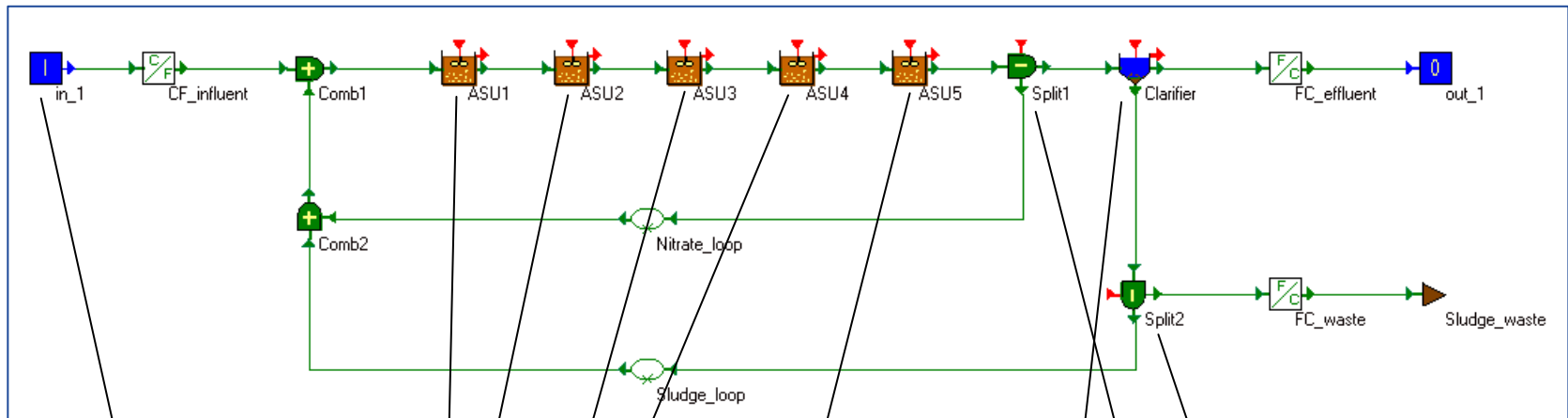
- Trans-membrane pressure:

$$\Delta P = J \cdot \varepsilon \cdot R$$

- Model parameters:

- $A_0$  : initial membrane surface ( $m^2$ )
- $\eta_{20}$  : viscosity of the permeate at 20 °C ( $Pa \cdot d$ )
- $R_m$  : intrinsic membrane resistance ( $1/m$ )
- $J_{crit}$  : critical filtration flux ( $m/d$ )
- $J_{12}$  : filtration flux ( $m^3/m^2/d$ )
- $u_{14}$  : backwash flux ( $m^3/m^2/d$ )
- $\alpha$  : specific cake resistance ( $m/g$ )
- $\beta$  : semi-empirical exponent for solid deposition (-)
- $\sigma$  : irreversibly blocked membrane area per unit SMP ( $m^2/g$ )
- Temp : operating temperature ( $^{\circ}C$ )

# Benchmark (BSM2)



- $Q_{ave}$  : 18,446 m<sup>3</sup>/d
- COD : 360 g/m<sup>3</sup>
- NH : 30 g/m<sup>3</sup>

- Anoxic**
- $V$  : 1,000 m<sup>3</sup>
  - $K_{La}$  : 0 d<sup>-1</sup>

- Aerobic**
- $V$  : 1,333 m<sup>3</sup>
  - $K_{La}$  : 240 d<sup>-1</sup>

- Aerobic**
- $V$  : 1,333 m<sup>3</sup>
  - $K_{La}$  : 84 d<sup>-1</sup>

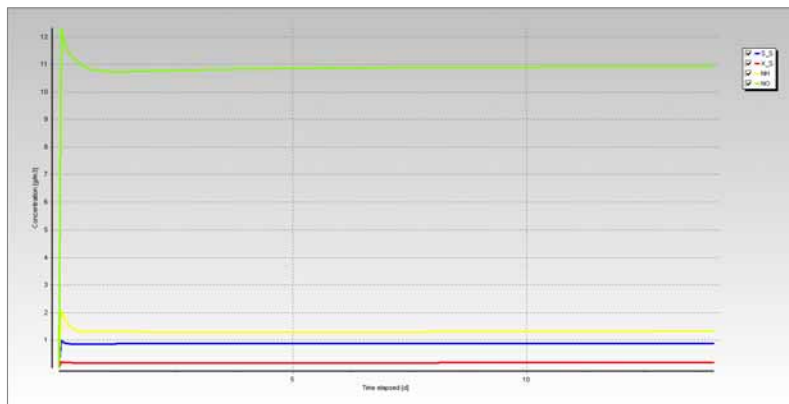
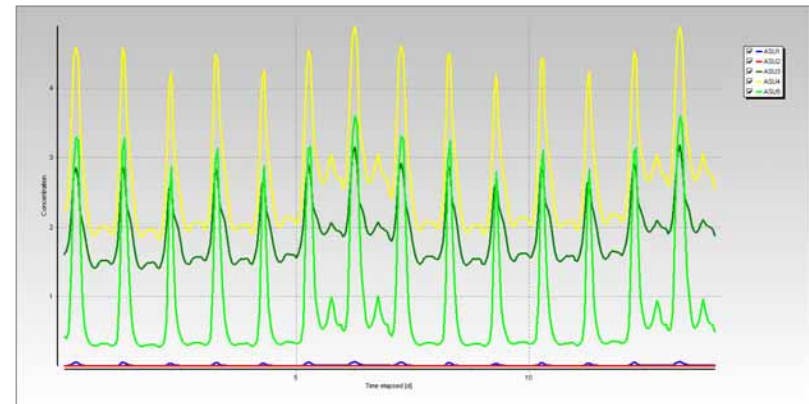
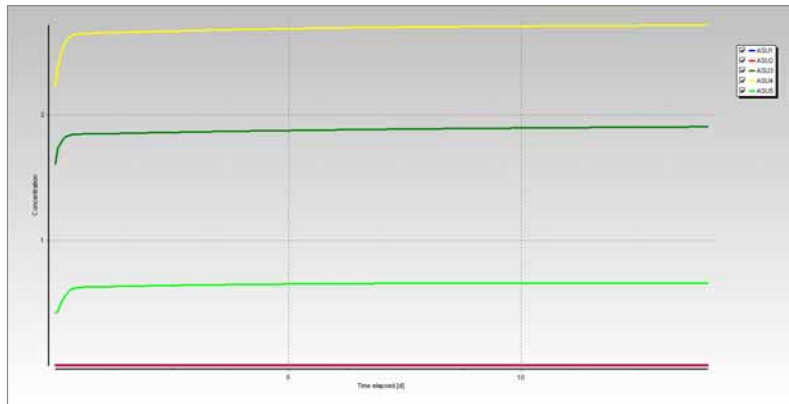
- Clarifier**
- $V$  : 4,500 m<sup>3</sup>
  - $Q_{under}$  : 18,831 m<sup>3</sup>/d

- Sludge wastage**
- $Q_{waste}$  : 385 m<sup>3</sup>/d

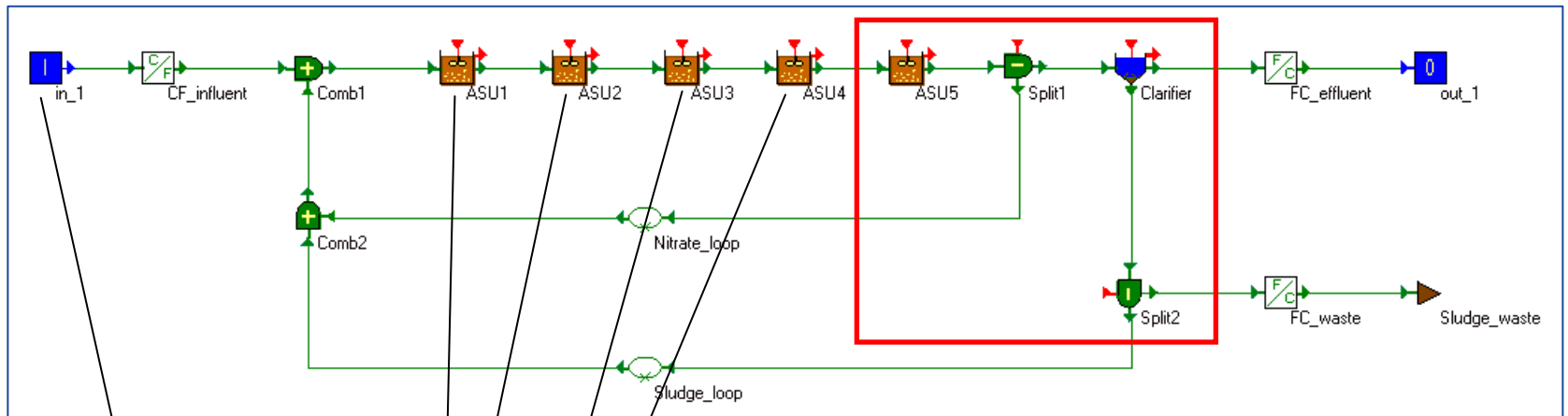
- NO recycle**
- $Q_{NO}$  : 55,338 m<sup>3</sup>/d

## Steady-state

## Dynamic



# Benchmark with MBR



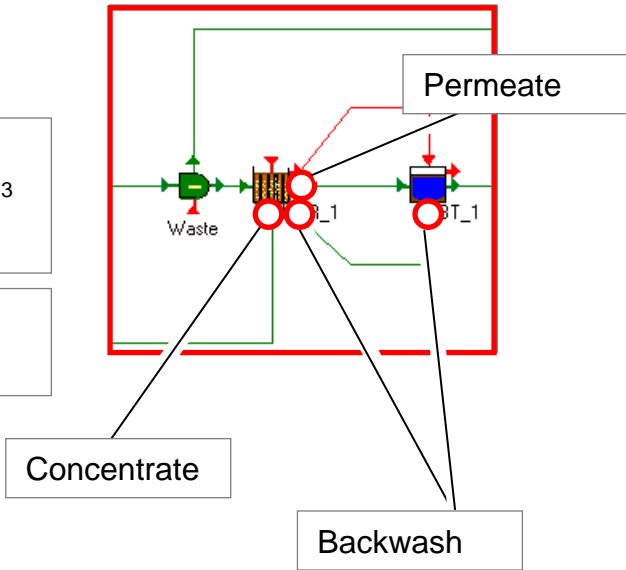
- $Q_{ave}$  : 18,446 m<sup>3</sup>/d
- COD : 360 g/m<sup>3</sup>
- NH : 30 g/m<sup>3</sup>

- Anoxic**
- $V$  : 1,000 m<sup>3</sup>
  - $K_{La}$  : 0 d<sup>-1</sup>

- Aerobic**
- $V$  : 1,333 m<sup>3</sup>
  - $K_{La}$  : 240 d<sup>-1</sup>

- MBR**
- $V$  : 445-450 m<sup>3</sup>
  - $K_{La}$  : 240 d<sup>-1</sup>

- Buffer tank**
- $V_{max}$  : 2,000 m<sup>3</sup>



# Model settings

- Plant:

Flow rate

$Q_{ave}$      $m^3/d$

Waste

$Q_w$      $m^3/d$

(recycle rate)

$r$     -

$$Q_e = Q_{ave} - Q_w$$

- Membrane

Cycle length

$T$     min

Backwash length

$T_{bw}$     min(s)

Filtration flow

$J$     Lmh

Backwash flow

$J_{bw}$     Lmh

$$T_{filtr} = T - T_{bw}$$

$$J_{net} = J_e \cdot \frac{T_{filtr}}{T} - J_{bw} \cdot \frac{T_{bw}}{T}$$

$$A = \frac{Q_e}{J_{net}}$$

- Influent characterisation (BSM2)

- Plant:

Flow rate

18446 m<sup>3</sup>/d

Waste

120 m<sup>3</sup>/d

(recycle rate)

10 -

$$Q_e = 18326 \text{ m}^3 / \text{d}$$

- Membrane:

Cycle length

10 min

Backwash length

10 s

Filtration flow

15 Lmh

Backwash flow

17 Lmh

$$T_{filtr} = 9.83 \text{ min}$$

$$J_{net} = 0.360 \cdot 0.98$$

$$- 0.408 \cdot 0.02 = 0.347 \text{ m/d}$$

$$A = 52782 \text{ m}^2$$

- ASM1 parameters (modif. MBR set-up):

Decay rate for autotrophic biomass ( $b_A$ )	0.003	1/d
Ammonia half-saturation for autotrophic biomass ( $K_{NH}$ )	0.2	gN/m <sup>3</sup>
Oxygen half-saturation for autotrophic biomass ( $K_{OA}$ )	0,2	gO <sub>2</sub> /m <sup>3</sup>

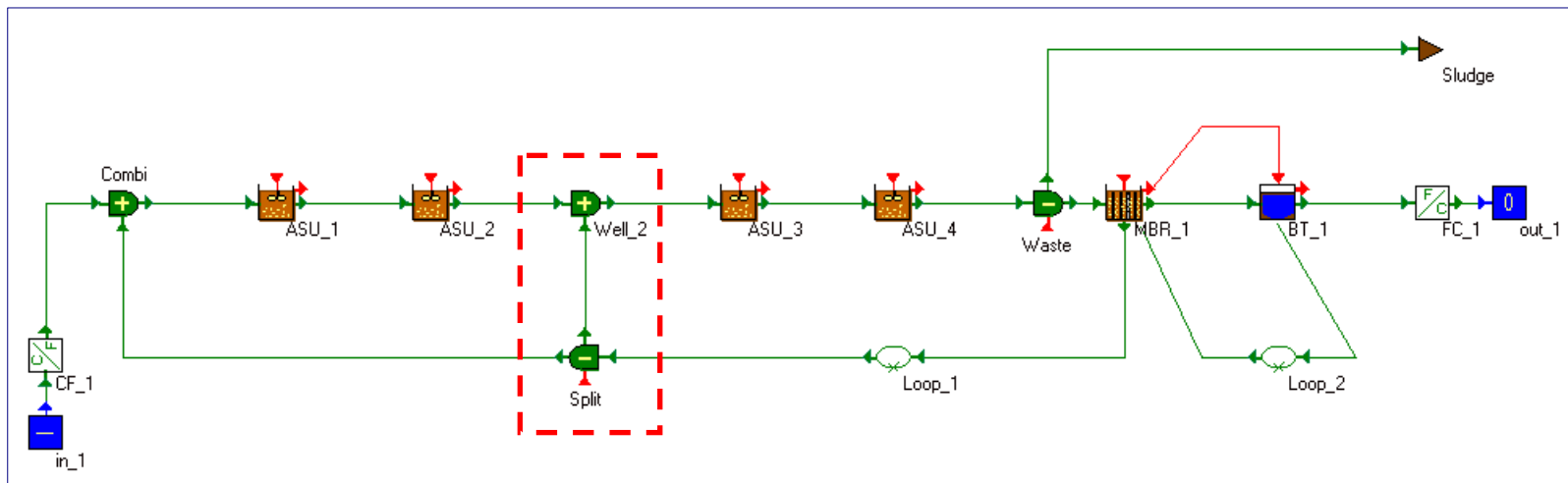
- Membrane model settings (Jiang, 2007):

Specific cake resistance ( $\alpha$ )	3.6	10 <sup>12</sup> m/g
Exponent for solid deposition ( $\beta$ )	3.5	
Irreversibly blocked membrane area per unit SMP ( $\sigma$ )	3	10 <sup>-4</sup> m <sup>2</sup> /g
Critical flux ( $J_{crit}$ )	2.3	m/d
Ave. SMP concentration ( $C_{SMP}$ )	100	mg/ℓ

- Other settings:

Recycle ( $Q_{\text{pump, MBR}}$ )                      55,000 m<sup>3</sup>/d

Backwash ( $Q_{\text{pump, buffer}}$ )                    21,535 m<sup>3</sup>/d    \*\*\* controlled \*\*\*



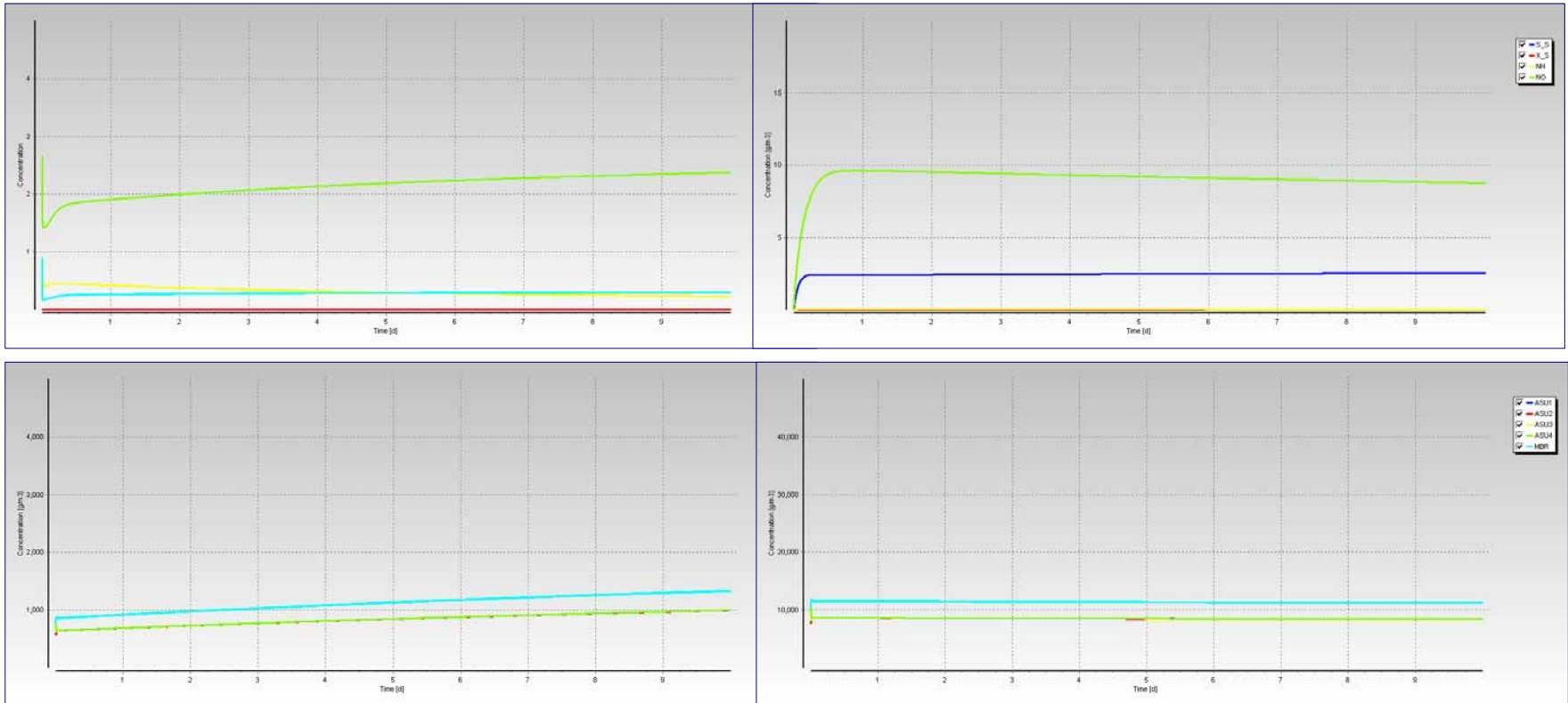
# Outline

- Base simulation
  - Compare effluent quality to BSM2
- Turn off the recycle
  - Discussion
- Discuss effect of aeration
  - Can we find a balance between ... ?
- Effect of model parameters on TMP

## Base simulation:

MBR:  $K_{La}$  240 1/d,  $Q_{recycle}$  55000 m<sup>3</sup>/d  $\sigma$  3 10<sup>-4</sup> m<sup>2</sup>/g, SMP 120 mg/l

Kinetics:  $b_A$  0.003 1/d,  $K_{NH}$  0.2 g/m<sup>3</sup>,  $K_{OA}$  0.2 g/m<sup>3</sup>



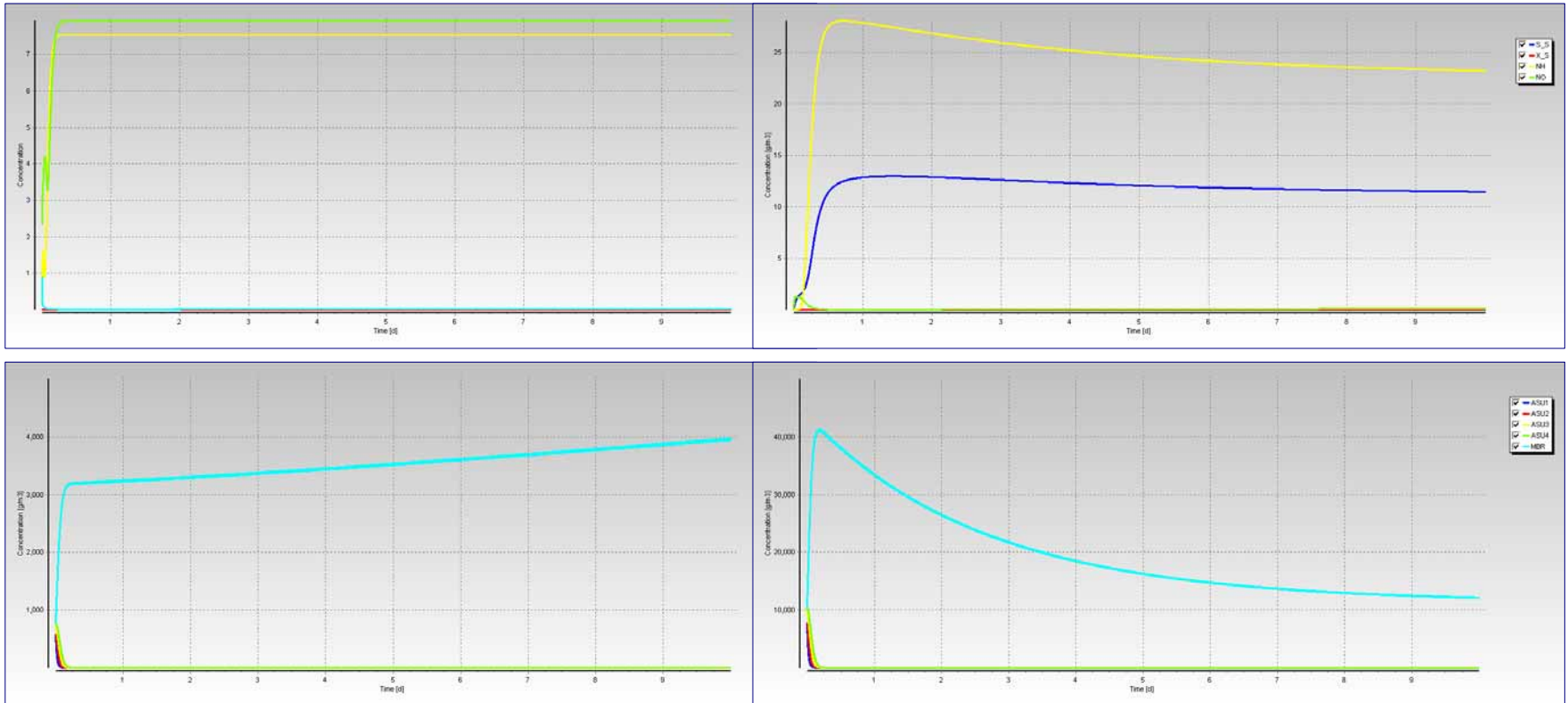
Oxygen (top left), Effluent (top right), Autotrophic (bottom left) and Heterotrophic biomass (bottom right) concentrations.

## Simulation-A:

MBR:  $K_{La}$  240 1/d, **no recycle**

$\sigma$   $3 \cdot 10^{-4}$  m<sup>2</sup>/g, SMP 120 mg/l

Kinetics:  $b_A$  0.003 1/d,  $K_{NH}$  0.2 g/m<sup>3</sup>,  $K_{OA}$  0.2 g/m<sup>3</sup>

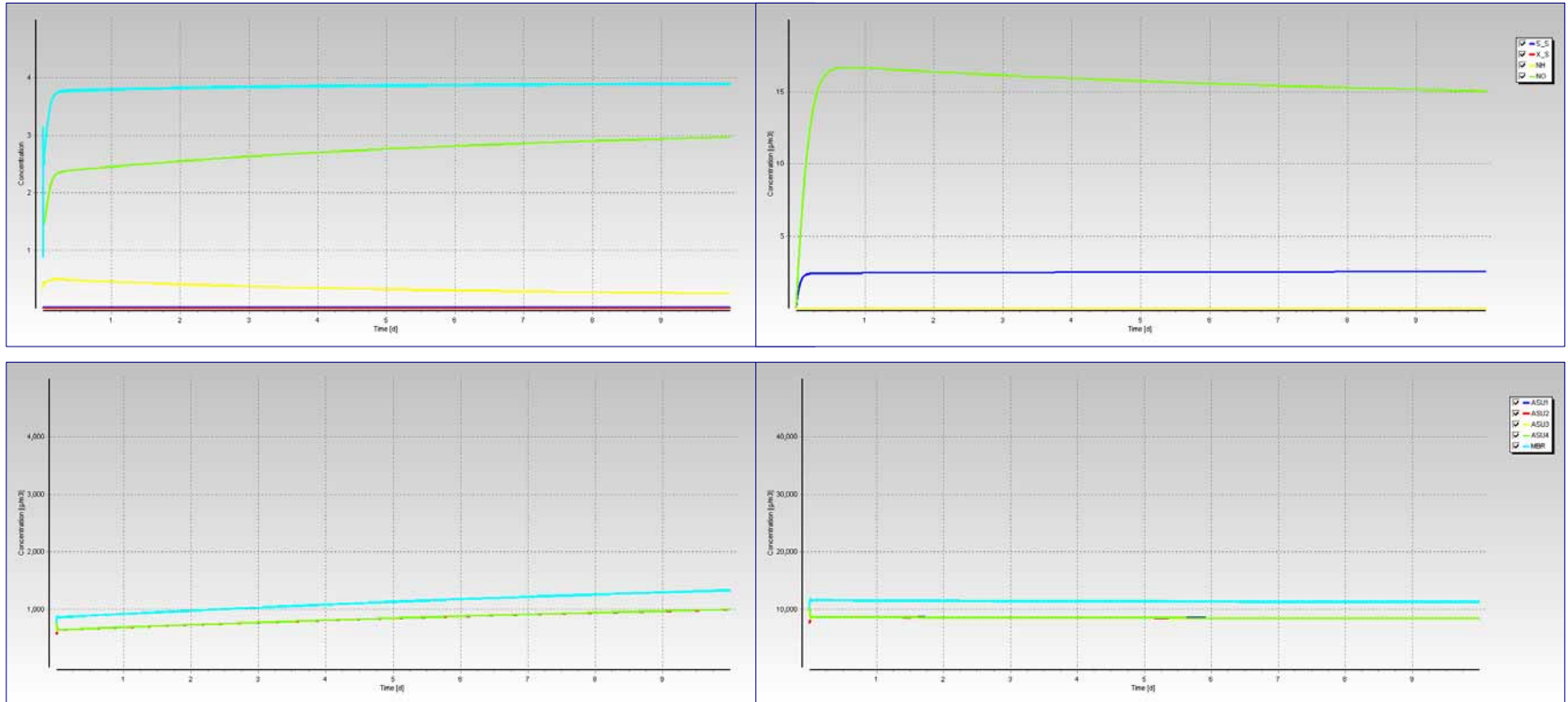


Oxygen (top left), Effluent (top right), Autotrophic (bottom left) and Heterotrophic biomass (bottom right) concentrations.

## Simulation-B:

MBR:  $K_{La}$  780 1/d,  $Q_{recycle}$  55000 m<sup>3</sup>/d  $\sigma$  3 10<sup>-4</sup> m<sup>2</sup>/g, SMP 120 mg/l

Kinetics:  $b_A$  0.003 1/d,  $K_{NH}$  0.2 g/m<sup>3</sup>,  $K_{OA}$  0.2 g/m<sup>3</sup>

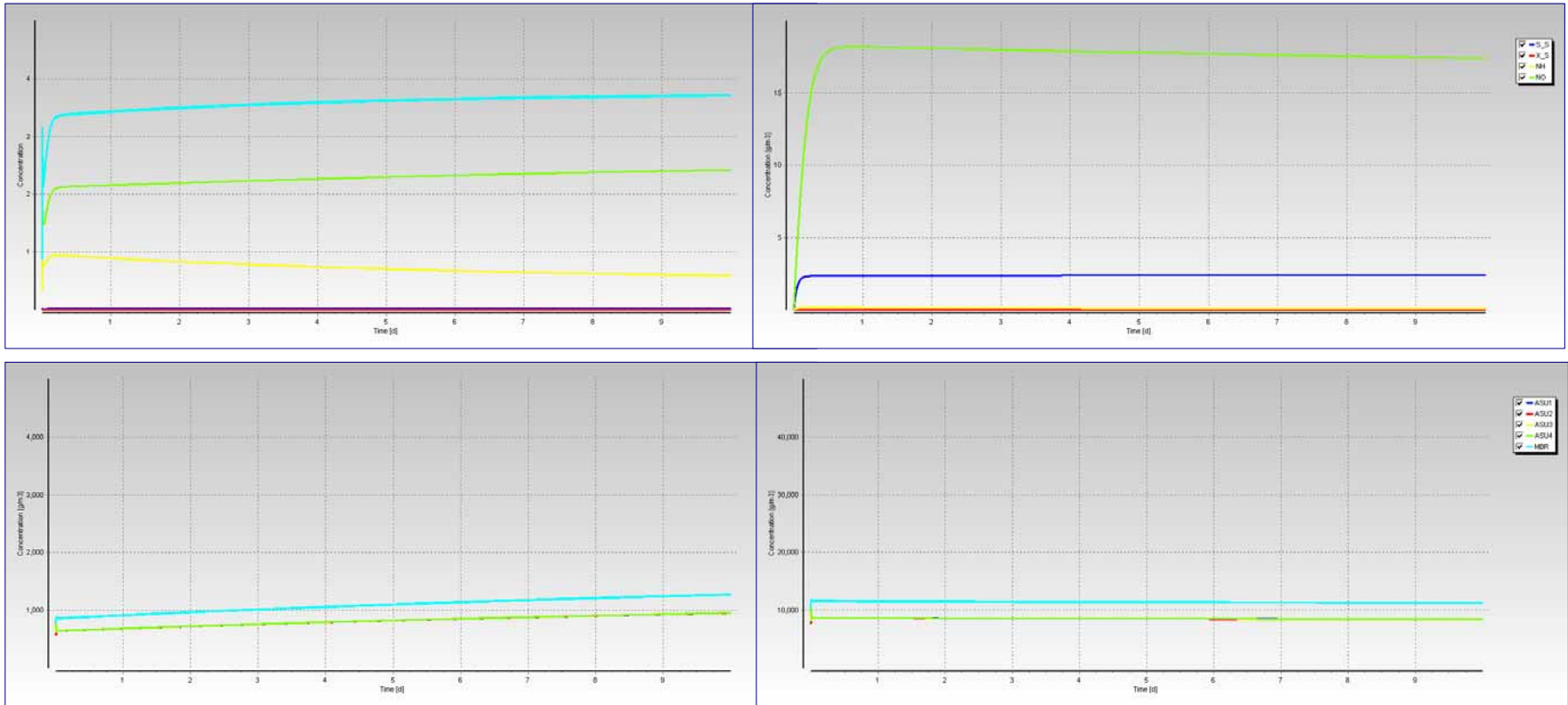


Oxygen (top left), Effluent (top right), Autotrophic (bottom left) and Heterotrophic biomass (bottom right) concentrations.

## Simulation-C:

MBR:  $K_{La}$  780 1/d,  $Q_{recycle}$  55000 m<sup>3</sup>/d  $\sigma$  3 10<sup>-4</sup> m<sup>2</sup>/g, SMP 120 mg/l

Kinetics:  $b_A$  0.01 1/d,  $K_{NH}$  1.0 g/m<sup>3</sup>,  $K_{OA}$  0.4 g/m<sup>3</sup>

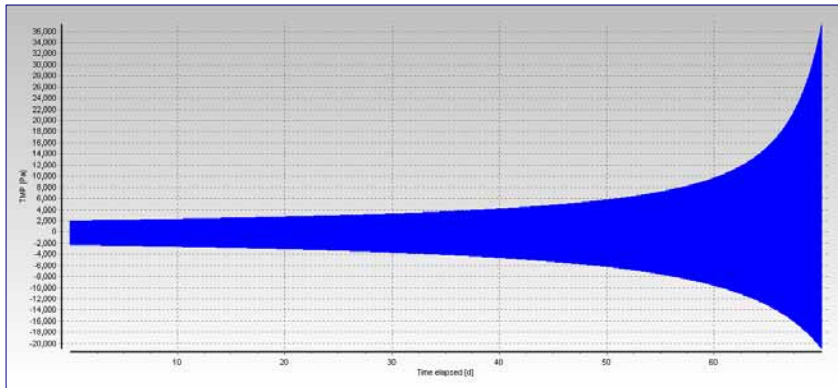


Oxygen (top left), Effluent (top right), Autotrophic (bottom left) and Heterotrophic biomass (bottom right) concentrations.

## Simulation-D:

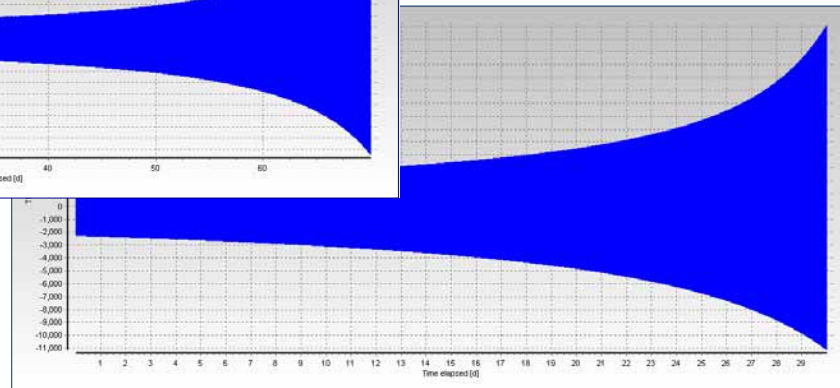
MBR:  $K_{La}$  780 1/d,  $Q_{recycle}$  55000 m<sup>3</sup>/d  $\sigma$  6 10<sup>-4</sup> m<sup>2</sup>/g, SMP 250 mg/l

Kinetics:  $b_A$  0.003 1/d,  $K_{NH}$  0.2 g/m<sup>3</sup>,  $K_{OA}$  0.2 g/m<sup>3</sup>



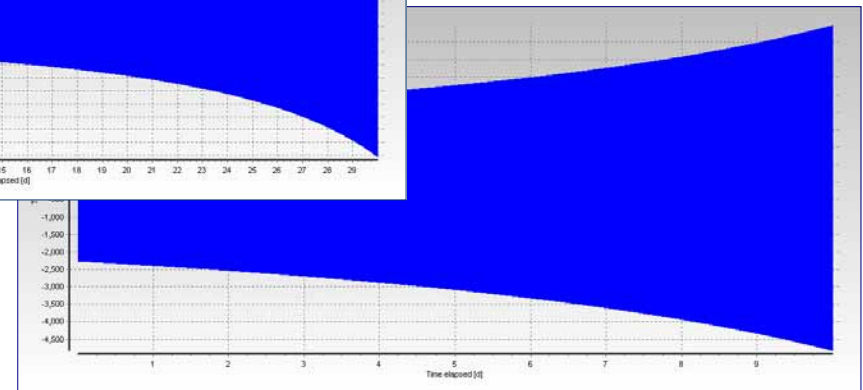
$\sigma$  3 10<sup>-4</sup>, SMP 120  
(TMP 37 kPa in 70 days)

Simulation: 3,950 s



$\sigma$  3 10<sup>-4</sup>, SMP 250  
(TMP 14 kPa in 30 days)

Simulation: 1,402 s



$\sigma$  6 10<sup>-4</sup>, SMP 250  
(TMP 20 kPa in 15 days)