



EUROMEMBRANE

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Integrated Model for Simulation of Super-Large Scale Membrane Bioreactor Process and Energy Consumption

Modelling of Seine Aval MBR plant (2nd largest in Europe)

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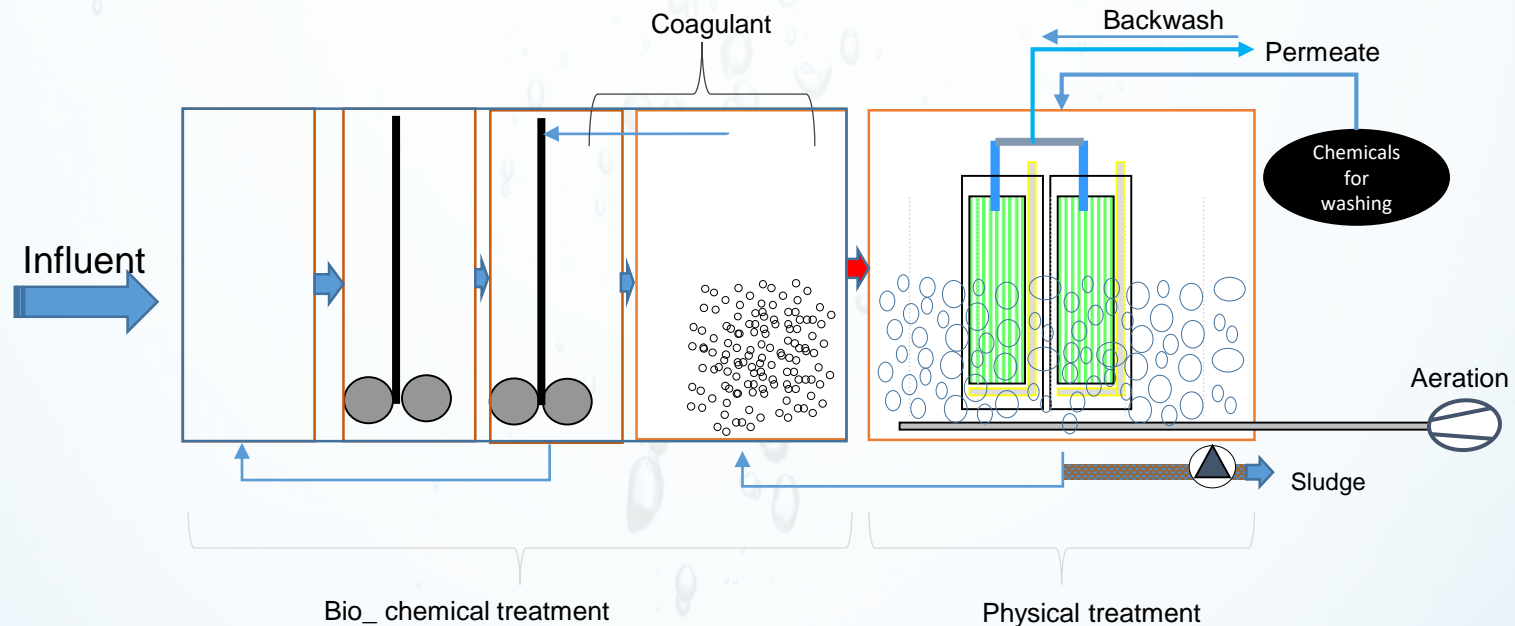
CONTEXT: Modeling super-large-scale MBR

- Superior and consistent effluent quality
- Membrane fouling
 - Loss of membrane permeability
 - Loss of productivity
 - Fouling abatement (relaxation -backwashing -scouring)
 - Higher aeration cost
 - Higher chemical consumption

} Need optimization

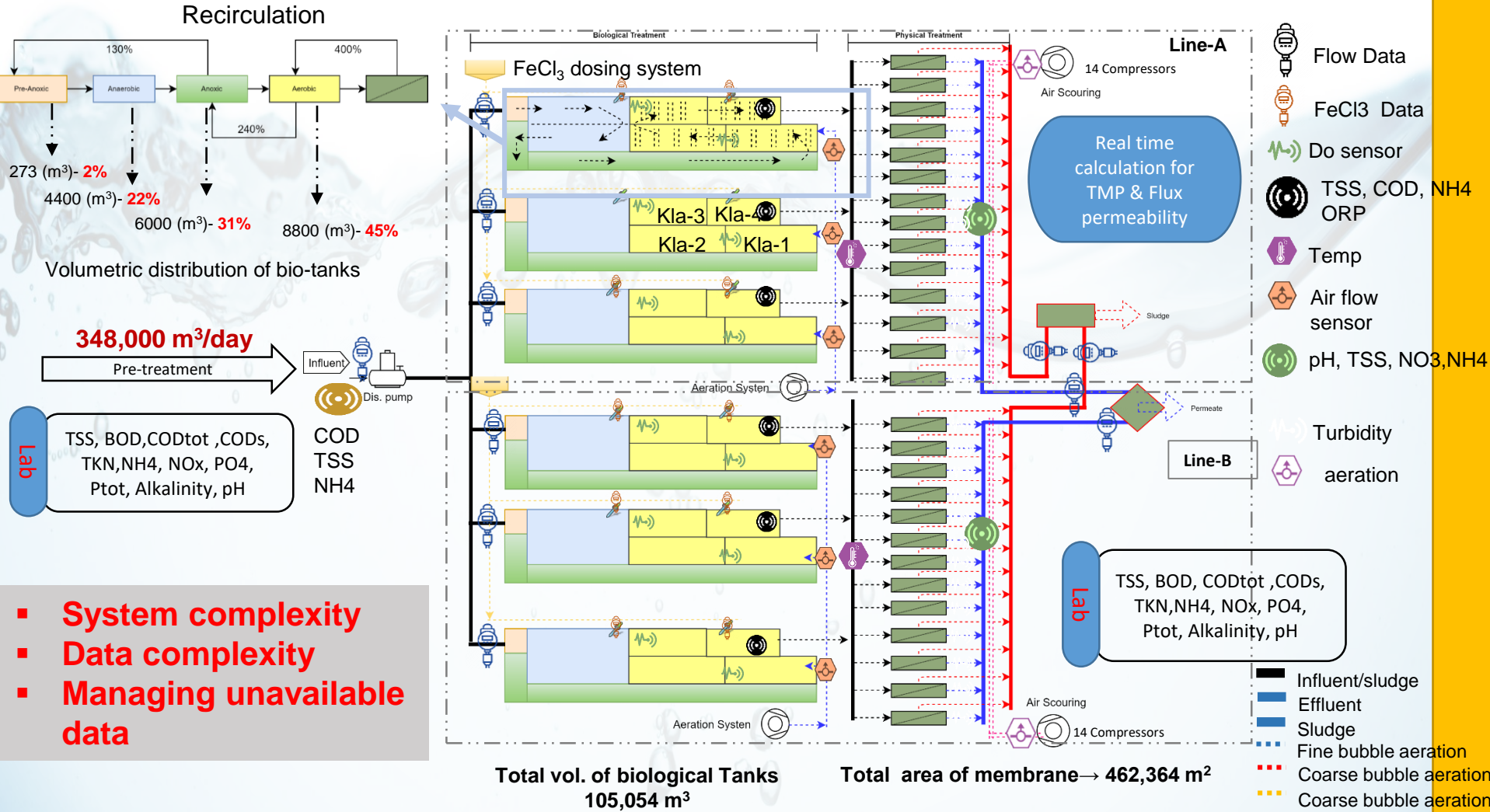
Integrated modelling

No super-large-scale modeling study till date



CONTEXT: Modeling super large scale MBR

Understanding of the system and its complexity



- System complexity
- Data complexity
- Managing unavailable data

50 Swimming pools

65 Football grounds

Data acquisition, treatment and experimentation

- 3 months data collection < **1st Nov 2018 to 31st Jan 2019** > SCADA system, lab-data
- **1st experimental campaign < 13th May 2019 to 17th May 2019 >**
- 2nd experimental campaign < 21st Sep 2020 to 2nd Oct 2020 >

Data ready for modelling use

Matlab
R-studio

Basic Treatment

- Data treatment using statistical tools like box & time series plots to see the unexpected peaks /outliers

- Removal of the outliers/ faulty sensor data points and replacing the missing data with rolling averages

Basic Checks

- Influent & effluent
e.g. COD/BOD, COD/N, COD:TN:TP
- Logical order check –Influent
 - e.g. $TKN > NH_4$, $P_{tot} > P$, $COD_{tot} > BOD_5$, $N_{tot} = TKN + NO_2 + NO_3$

Comparison with literature data-IWA guidelines

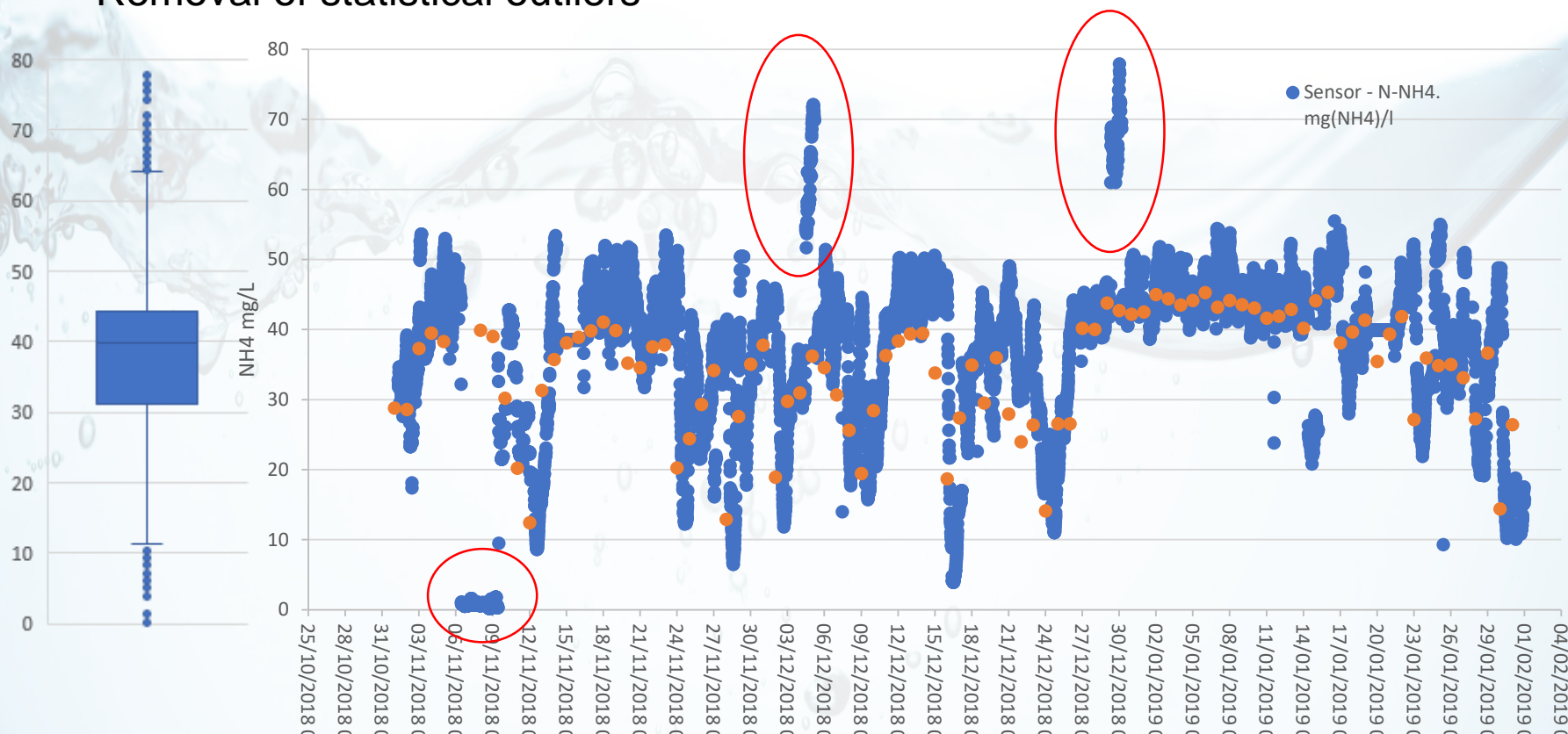
Advanced Checks

- Influent & effluent
- Hydraulic & mass balances

Data Treatment

- Removal of unexpected peaks/technical outliers
- Removal of statistical outliers

Before Treatment



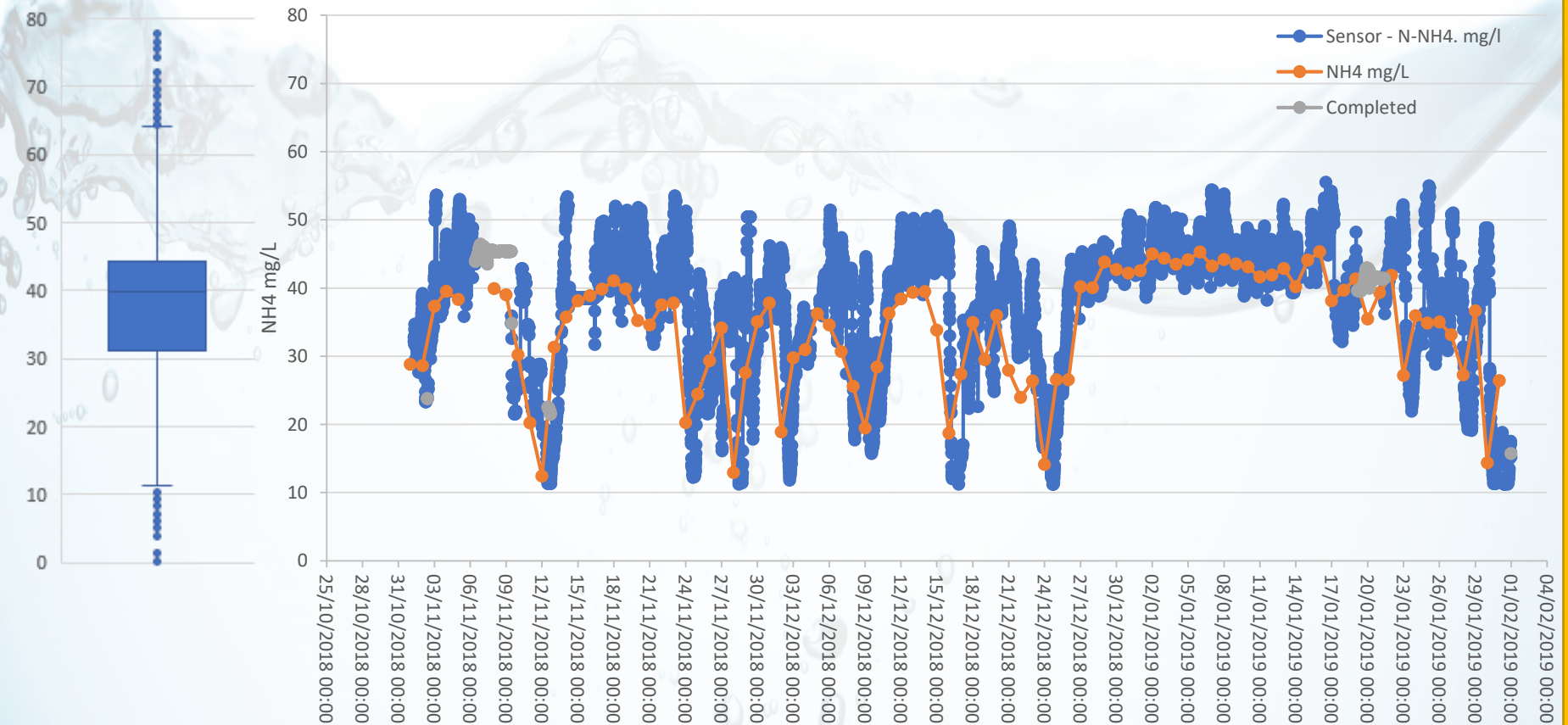
Influent sensor data for NH₄

Identification of the technical outliers > time series Analysis (sensor errors)

Identification of statistical outliers > box plots

Data treatment & reconciliation

After treatment



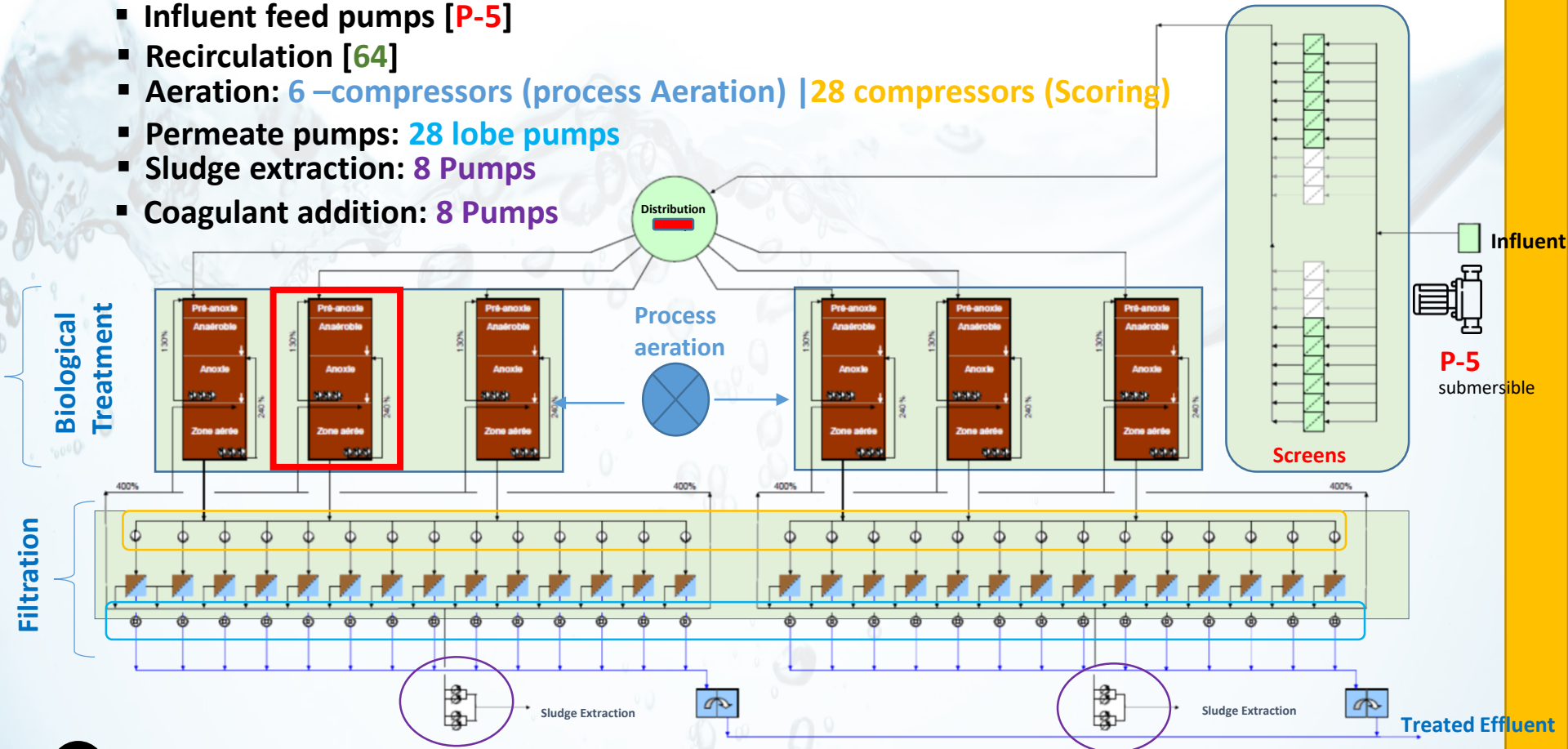
Influent sensor data for NH_4

Energy Consumers

1

Energy consumers dynamically integrated into model

- Influent feed pumps [P-5]
- Recirculation [64]
- Aeration: 6 –compressors (process Aeration) | 28 compressors (Scoring)
- Permeate pumps: 28 lobe pumps
- Sludge extraction: 8 Pumps
- Coagulant addition: 8 Pumps



2

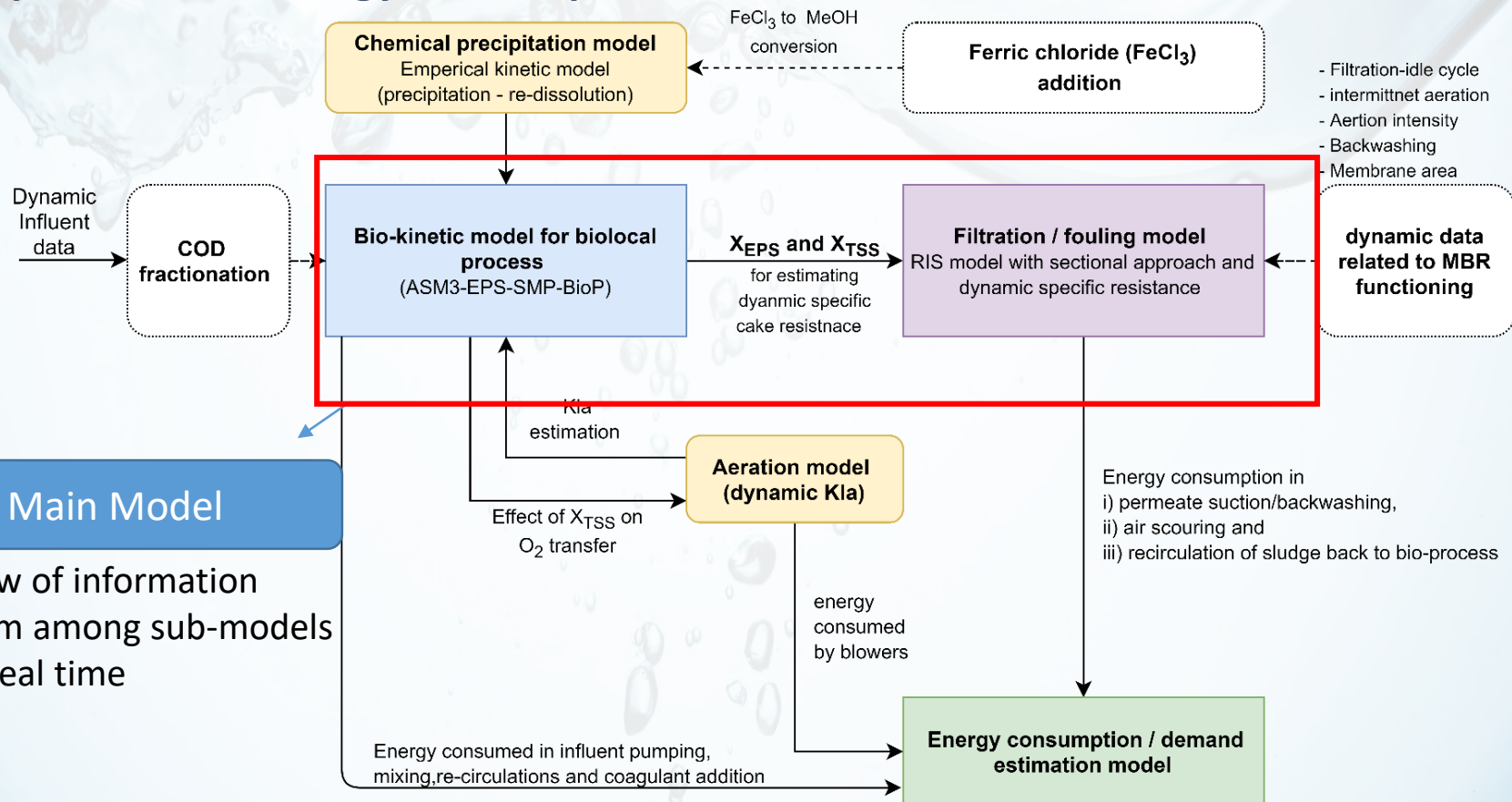
Fixed energy consumers

- Agitators : 36 (anaerobic and anoxic reactors)
- Foam breaking pumps: 06

Mechanistic model structure

Modeling super large scale MBR (>100,000 m³/day)

- Validated model as a digital twin for C-N-P removal performance evaluation of the plant and filtration/fouling behavior of membrane
- Development of a model based tool to further use it for optimisation of process and energy consumption



Integrated mechanistic model structure

Filtration Sub-Model (RIS- Model)

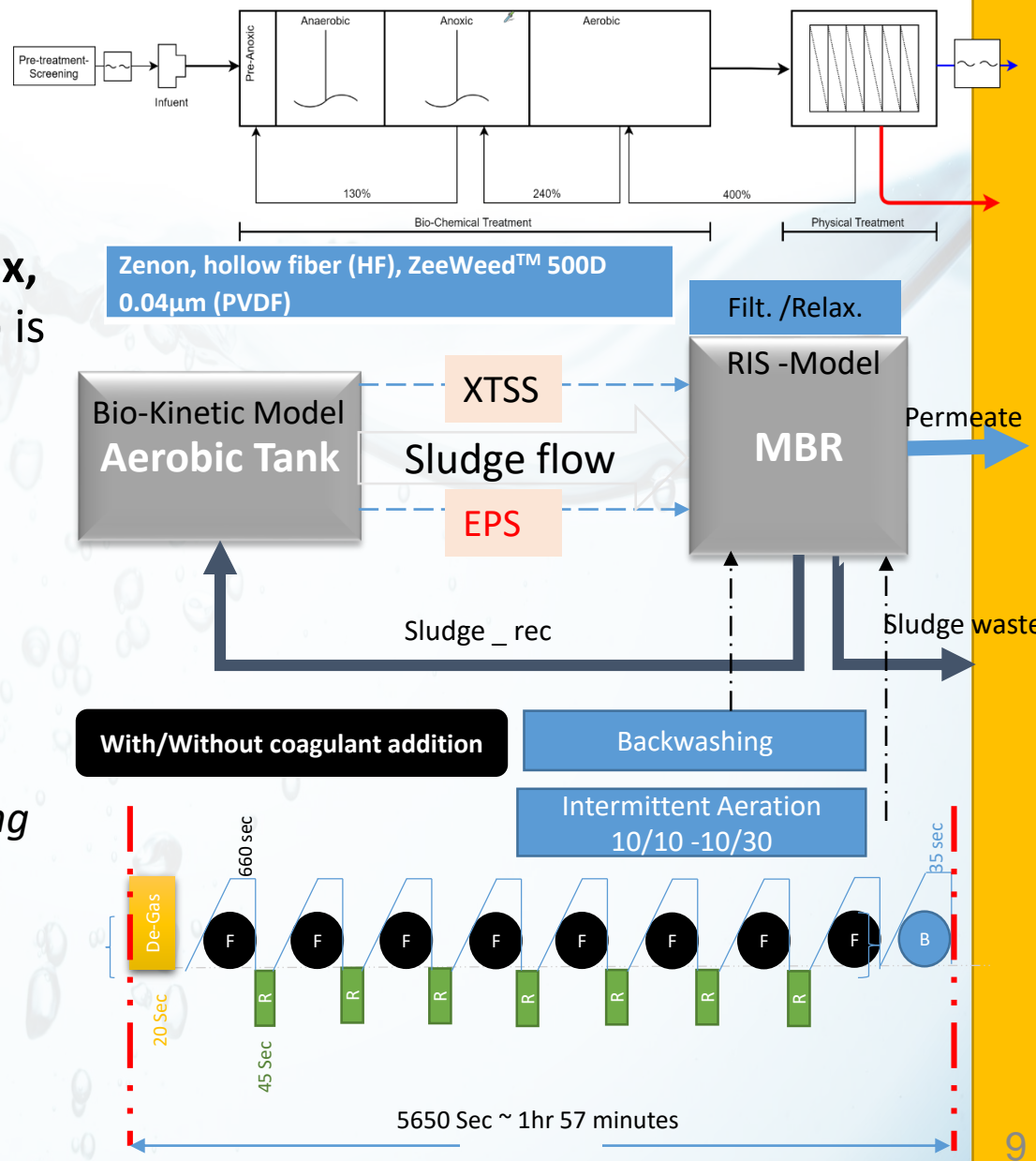
Model assumptions

RIS model with sectional approach

- Given flow rate that **fixes the Flux**, **TMP** evolution (linked to fouling) is modeled
- Dynamic specific cake resistance
- Dynamic cake layer
- Static cake layer
- Pore fouling resistance

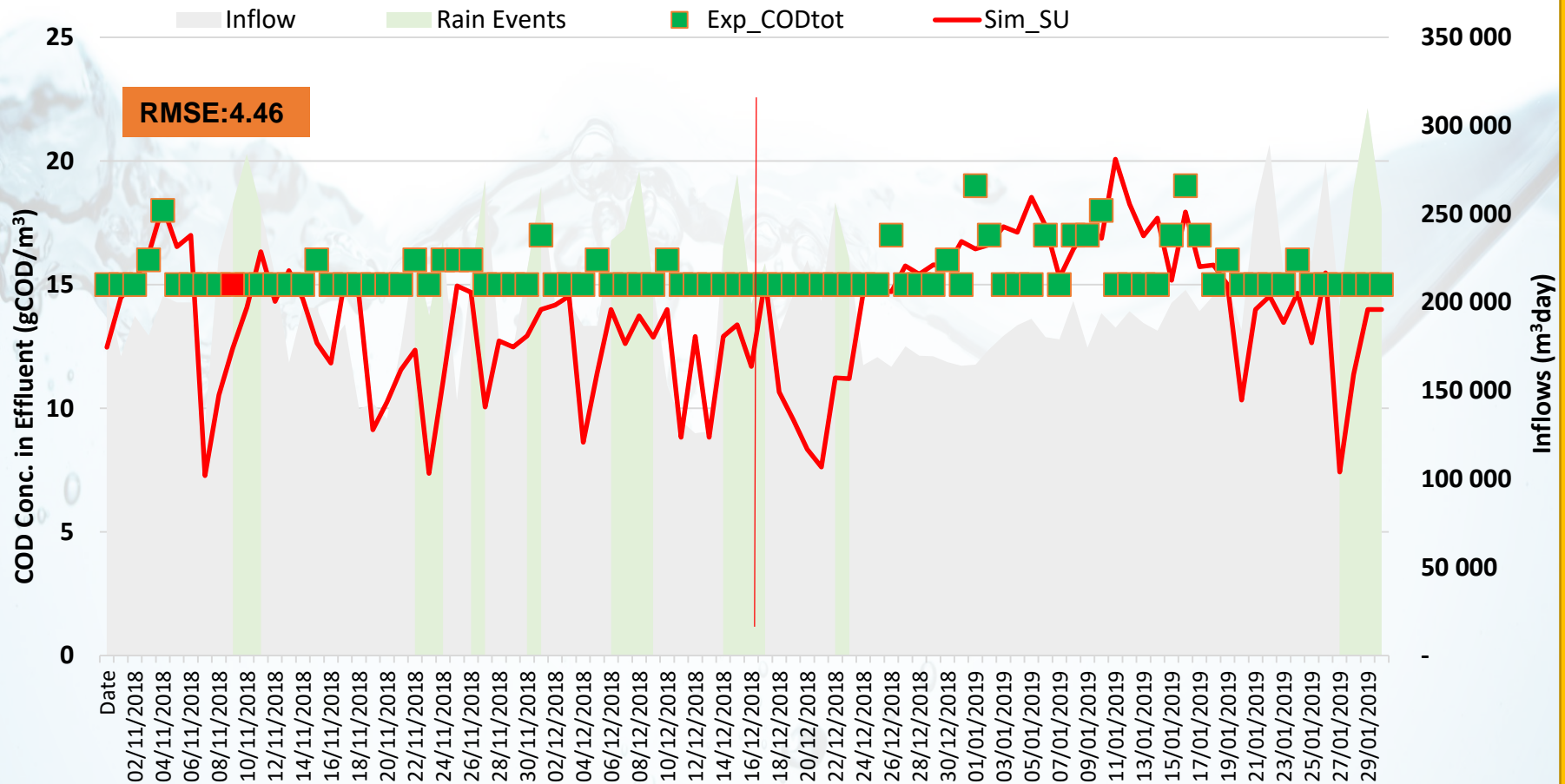
Not considered:

- Chemical cleaning*
- Role of coagulant addition in fouling*





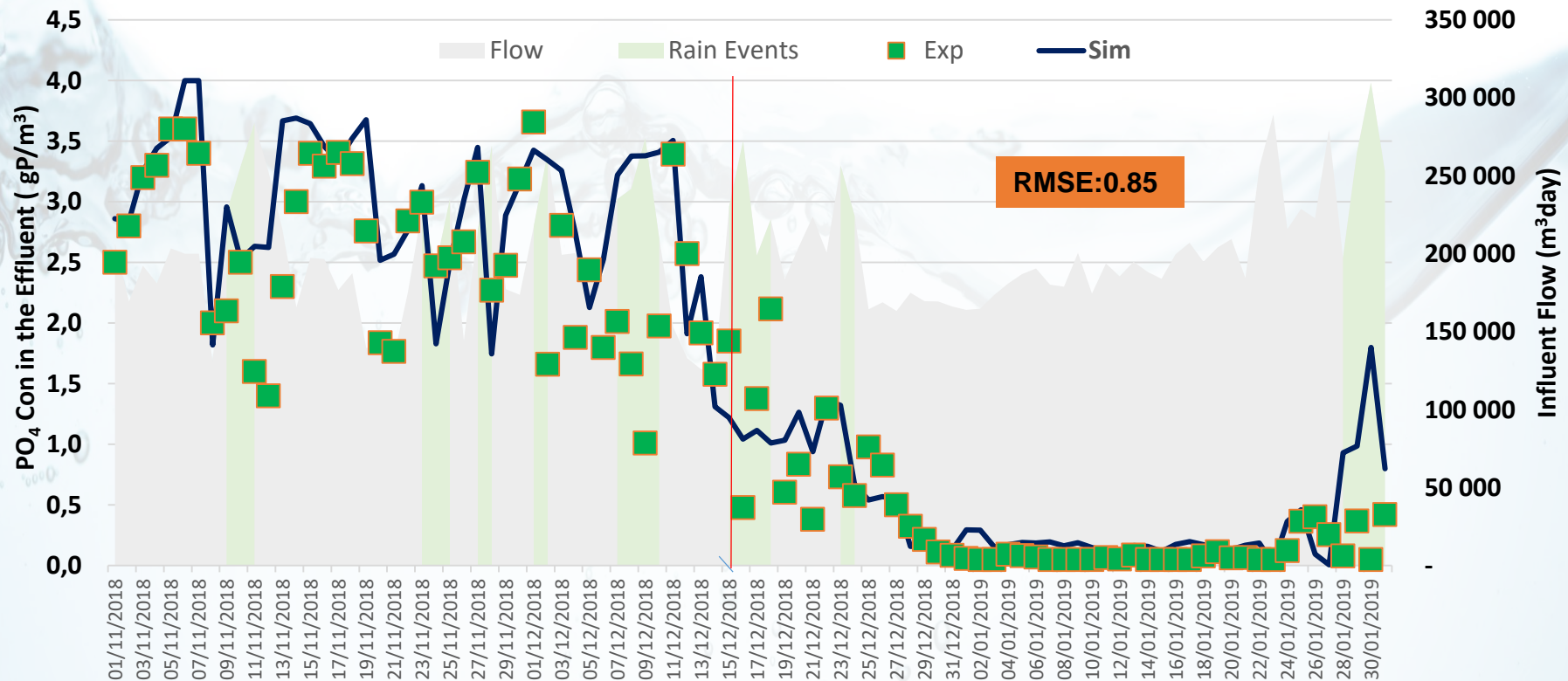
Simulation Results vs Experimental Data: COD (S_U)



- Baseline of experimental data is due to range of the lab measurement.
- Simulated results are good and can even predict below the measurement detection limits.



Simulation Results vs Experimental Data: PO₄

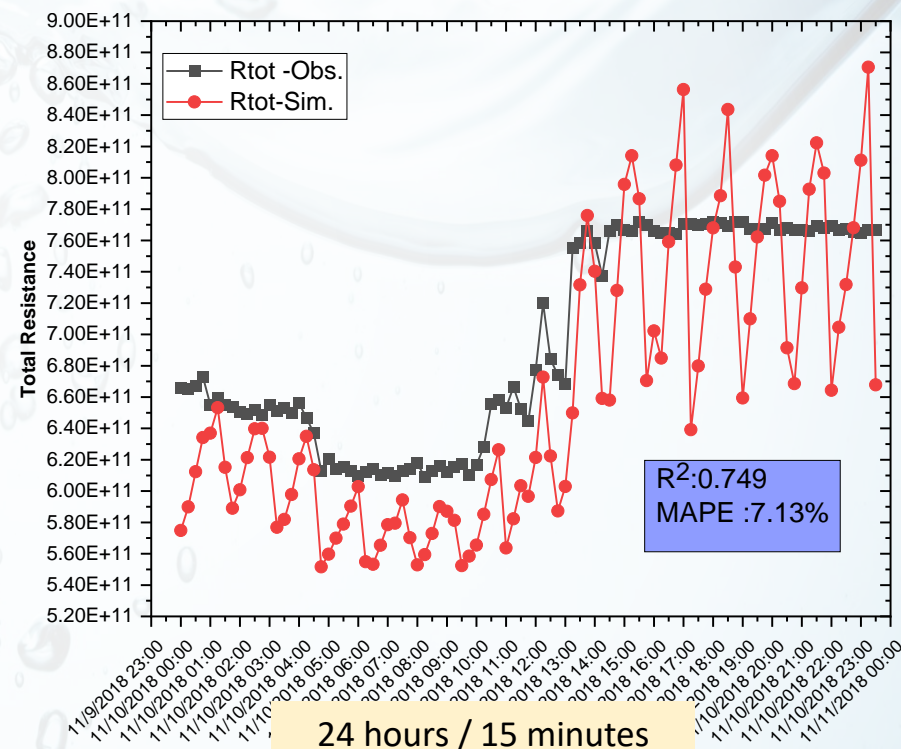
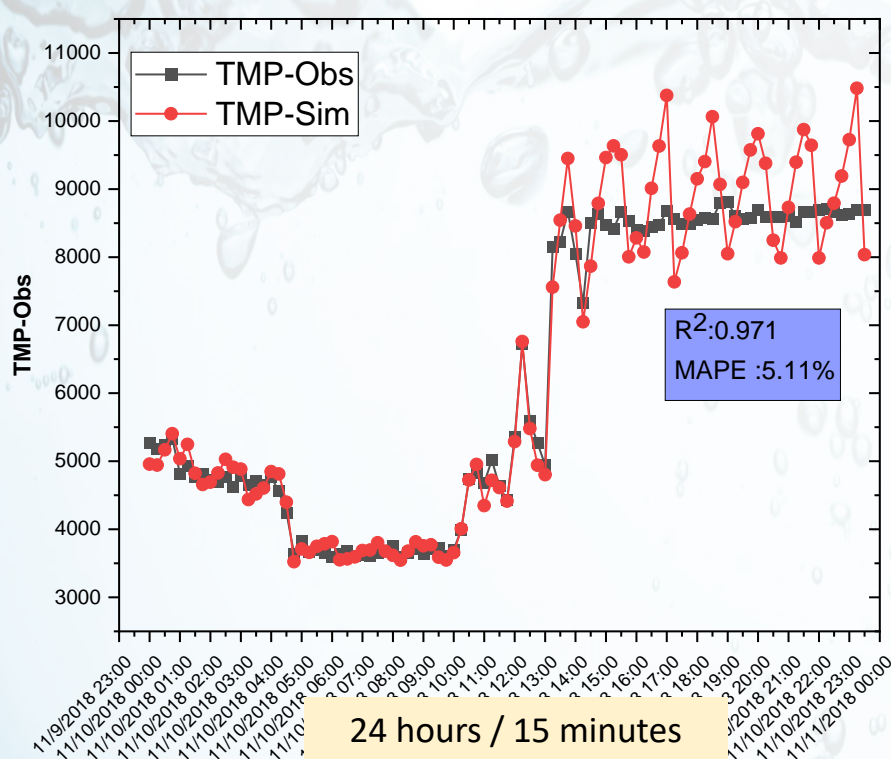


- Kinetic and stoichiometric parameters for Bio-P have been adopted from Rieger et al., 2001.
- Few of the kinetic parameters (bio-P) are adjusted based on MBR specific literature data



Results for Entire Plant: One-Day Simulations

- 28 tanks operating in parallel
- TSS/EPS data from bio-chemical kinetic model
- Actual filtration-relaxation, backwashing, aeration sequencing data

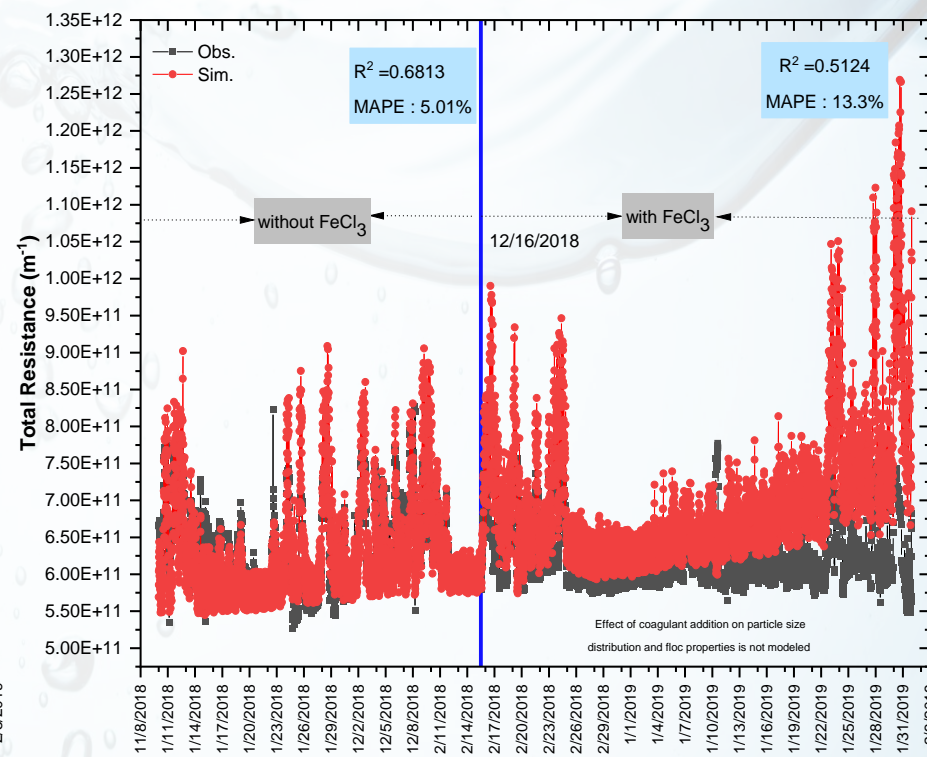
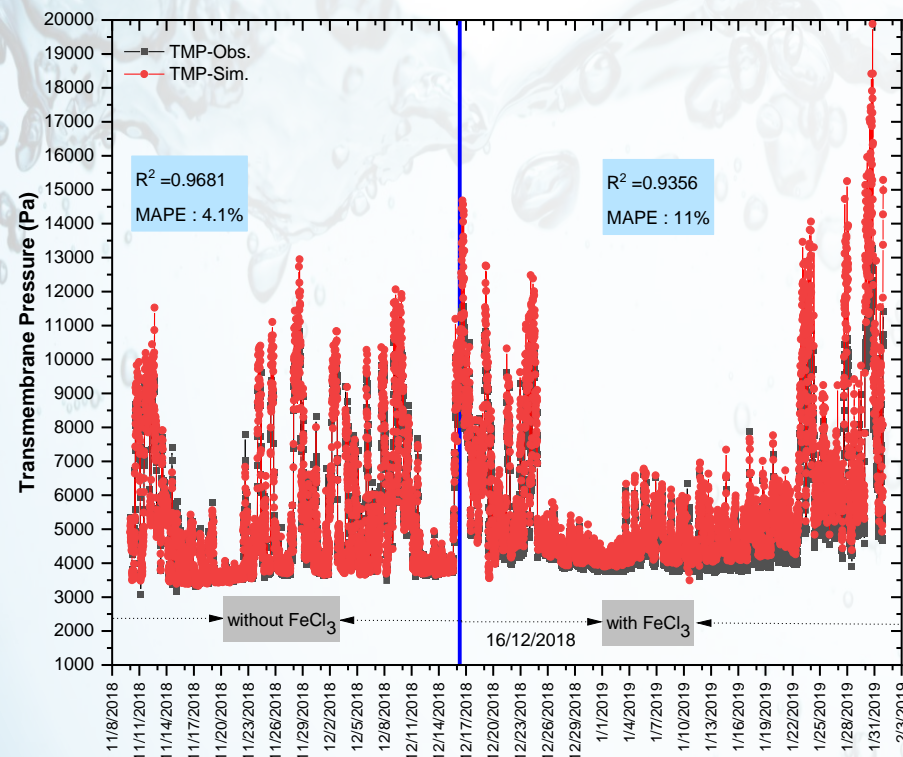


- Good fit between simulated and measured TMP (with average flux)
- TMP fluctuations due mainly to flux changes and few to resistance evolution (good functioning conditions)



Results for Entire Plant:3- Months long simulations

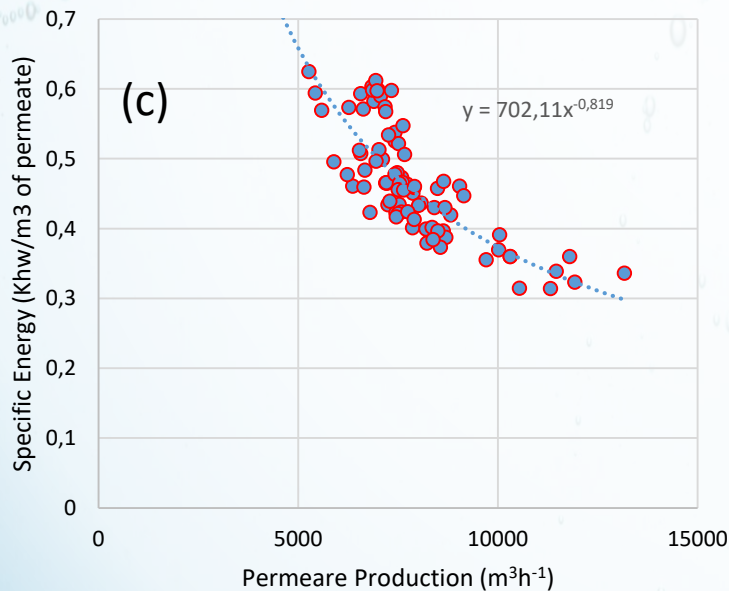
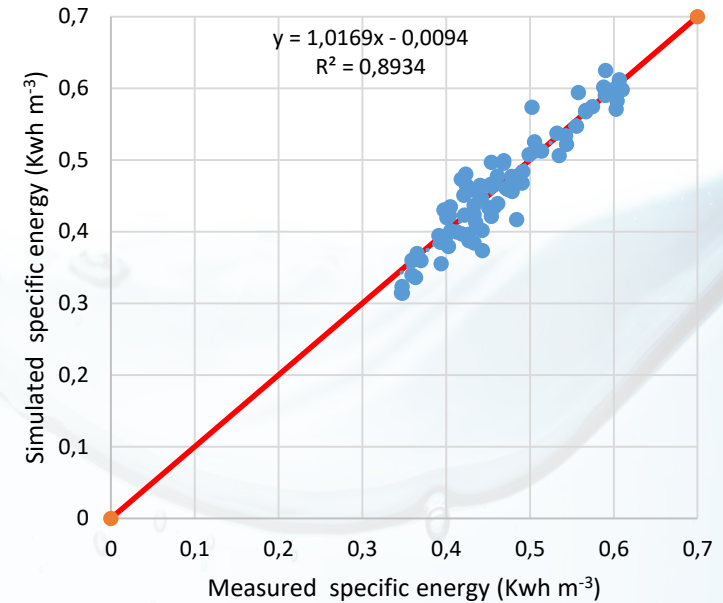
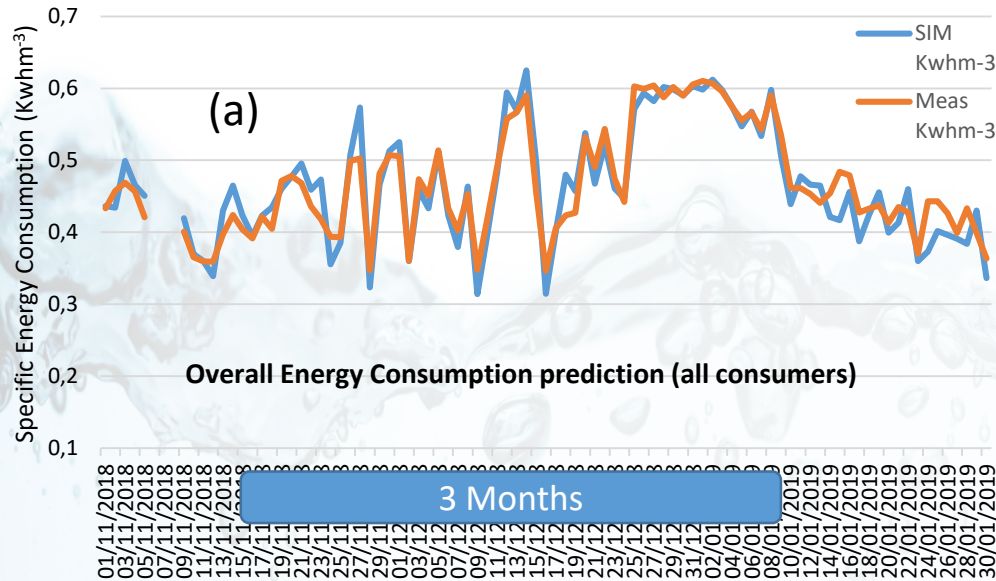
- FeCl_3 addition starts on 16/12/2018
- Higher precision for simulating TMP evaluation (with flux) and associated total resistance before adding coagulant
- Model accuracy declined after addition of coagulant.



Processes not modeled:

- Chemical cleaning effect to remove pore-fouling and static cake layer
- Effect of coagulant on PSD and other properties like stickiness of the sludge particles among each other and with the membrane surface

Specific Energy Consumption



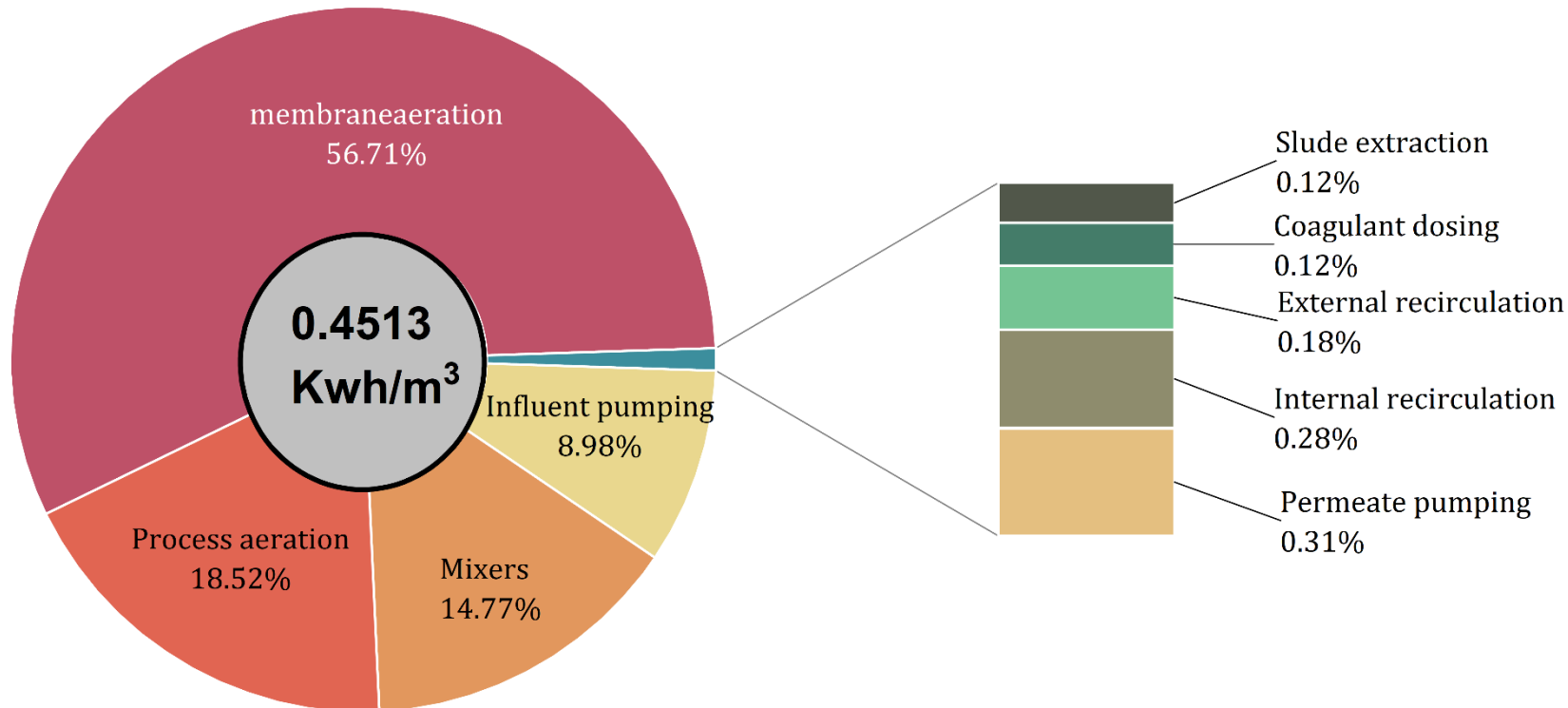
The model dynamically simulated the energy consumption in:

- Influent pumping
- Recirculation
- Biological process and membrane aeration
- Permeate production
- Sludge extraction

Fixed energy consumers

a) Taken into account the fixed energy consumption

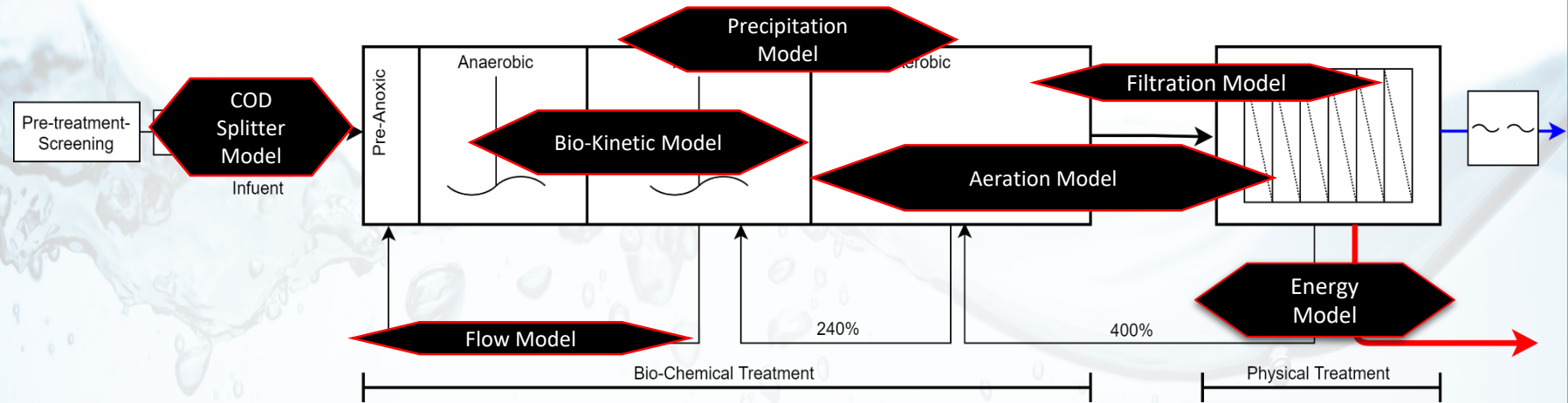
Energy Consumption distribution



- ❑ Membrane scouring, biological aeration, mixing, and influent pumping accounted for approximately 56%, 14%, 18%, and 9% respectively
- ❑ While the rest of 1.02 % is being consumed by other processes such as *recirculation*, *chemical dosing*, *permeate suction-backwashing*, and *sludge extraction*.

Conclusion & Perspective

Modelling super-large scale MBR (>100,000 m³/day)



Integrated model is successful in fairly simulating:

- Carbon-oxidation nitrification, denitrification, EBPR and chemical precipitation processes
- Transmembrane pressure (TMP) & total membrane resistance
- Energy consumed by the various processes

Perspective:

- The integrated comprehensive model presented can be used as digital twin by the process engineers and the plant operators in optimising the process parameters to predict the effluent quality and well as to predict the membrane fouling and energetic consumption
- Consideration of coagulant addition

Thank You

For your kind attention

