Removal of contaminants of emerging concern (CECs) during primary, secondary and tertiary wastewater treatment steps

Zeina Baalbaki*

Co-authors: Thomas Maere**, Elena Torfs**, Peter A. Vanrolleghem** and Viviane Yargeau*

* Yargeau 3Cs Laboratory, Chemical Engineering Department, McGill University

** modelEAU, Département de génie civil et de génie des eaux, Université Laval

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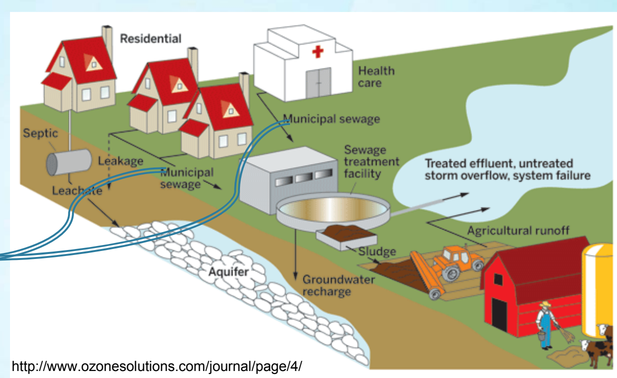
Contaminants of Emerging Concern (CECs)

Background | Methodology | Hydraulics | Removals | Fate Modelling | Conclusion

Pharmaceuticals and drugs

Personal care products

Hormones



http://www.ozonesolutions.com/journal/page/4/

- Wastewater treatment plants (WWTPs) are not designed to remove CECs
- CECs get discharged in receiving streams

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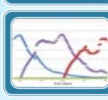
Research question and objectives

- **Research Questions: How efficient are different treatment technologies at treating CECs? What is the predicted efficiency of activated sludge in treating CECs?**
- **Research objectives:**
  - Obtain reliable CECs removal data along the treatment train of a full-scale WWTP
  - Understand the fate of CECs in WWTP by carrying out mass balances accounting for metabolites
  - Build and calibrate a model predicting the fate of CECs in WWTPs

General approach

1. Electrical conductivity (EC) probes deployment



2. Hydraulic calibration using EC data

3. Sampling: 24-h composite samples over 3 or 4 consecutive days

4. Solid-phase extraction and Chemical analysis by LC-HRMS for a list of 25 CECs

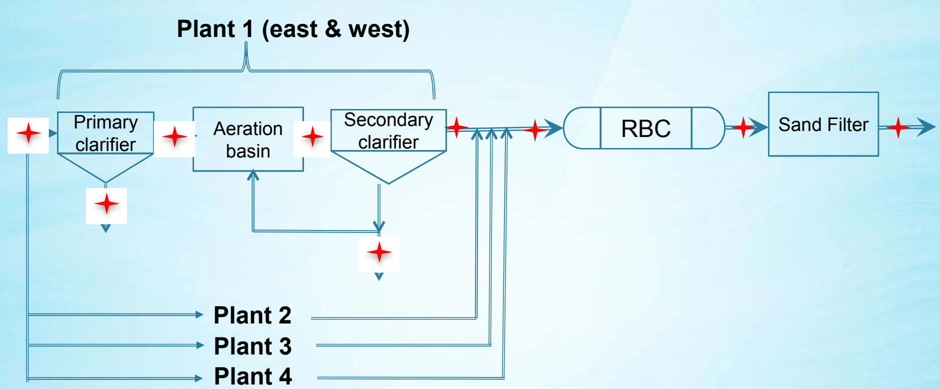
5. Calculation of reliable removal data of CECs

6. Calibration of conventional pollutant model and CECs fate model in WEST software

Sampling Site

- **Guelph WWTP**
  - Located in Guelph, ON, Canada
  - Serves population of ~120,000
  - Receives mainly municipal wastewater
  - Employs primary clarification, activated sludge, rotating biological contactors (RBCs), sand filters and chlorination
  - Effluent is discharged into Speed River

Sampling points in Guelph WWTP



Conductivity probes were deployed (3 weeks)
Samples collected (4 consecutive days)

Modelling approach (WEST)

Background | Methodology | Hydraulics | Removals | Fate Modelling | Conclusion

Hydraulic modelling

Hydraulic modelling:
- Plant layout

Conventional pollutant modelling (over one year)

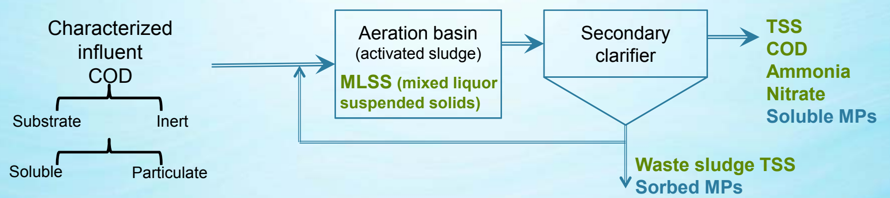
Solids balance:
- Settling parameters

Pollutant calibration:
- Biokinetic parameters

Micropollutant (MP) modelling (over sampling period)

Biodegradation:
- MP degradation half life

Sorption:
- MP sorption parameters



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Best-fit hydraulic models

Background | Methodology | Hydraulics | Removals | Fate Modelling | Conclusion

Primary clarifier
Calibrated volume = actual total volume

Aeration tanks
Two series of 3 aeration tanks in series
Calibrated volume= actual total volume

Secondary clarifier
Calibrated volume = actual total volume

Rotating biological contactor
Calibrated volume = actual total volume

Sand filter
Calibrated volume = 1800 m^3

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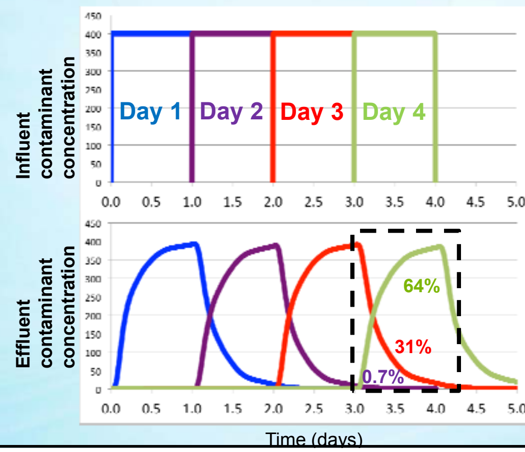
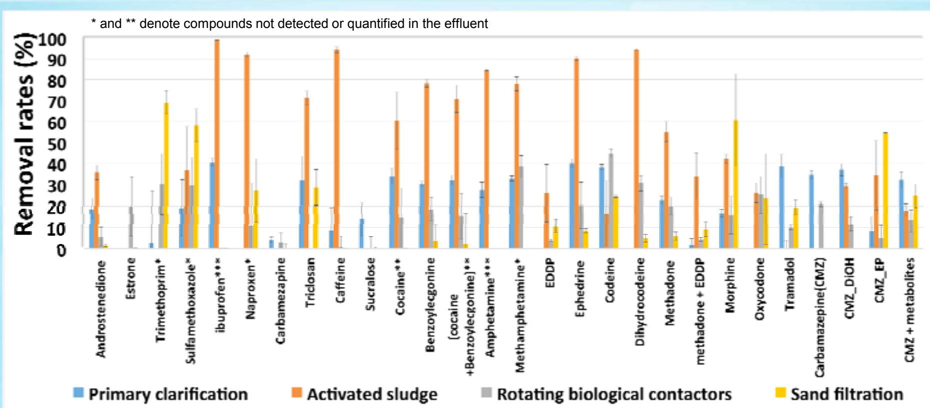
Improved strategy to calculate removals (Fractionated approach)

- Due to the residence time distribution one day in the effluent contains influent load of previous days described by load fractions (Majewsky et al., 2011)
- Best-fit hydraulic model is used to obtain the load fractions of each unit



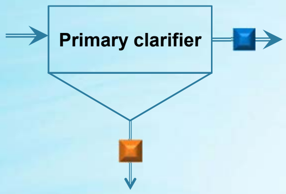
Observed CEC removal rates



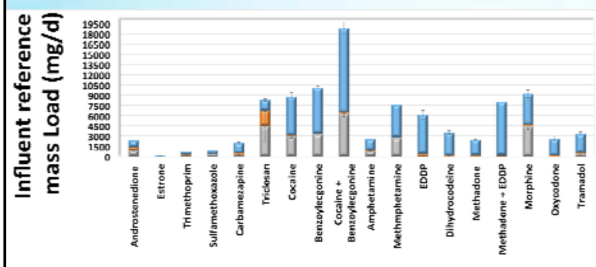
- Highest removal for most CECs takes place in activated sludge unit
- Sand filtration is efficient at removing some of the CECs

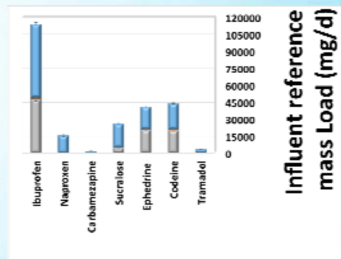
Mass balance around the primary clarifier

Background Methodology Hydraulics **Removals** Fate Modelling Conclusion



- Primary effluent (measured)
- Primary sludge (measured)
- Degraded (by difference)





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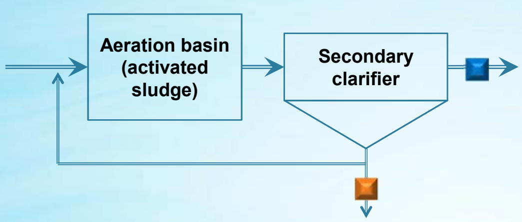
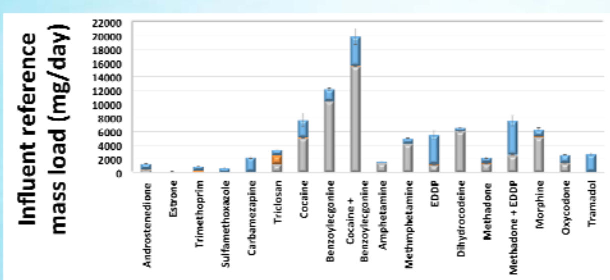
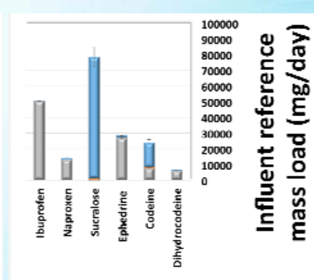
Mass balance around the biological treatment

Background Methodology Hydraulics **Removals** Fate Modelling Conclusion



- Secondary effluent (measured)
- Waste sludge (measured)
- Biodegraded (by difference)





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Conventional pollutant model calibration

Background | Methodology | Hydraulics | Removals | Fate Modelling | Conclusion

- **Start from the best-fit hydraulic model**
- **Aeration:** The oxygen transfer coefficient was found to be 300 d^{-1} and 360 d^{-1} for east and west trains to match actual dissolved oxygen
- **Solids balance:** The Burger Diehl model contains extra layers at the top and bottom that contribute to producing a match with the actual effluent TSS

Parameter in secondary clarifier	Description	Value	Solids variables most sensitive
rP (m^3/g)	Low concentration parameter	0.05	Effluent TSS, Effluent COD
rH (m^3/g)	Hindered settling parameter	0.000576	MLSS, WAS TSS
f-ns(m/d)	Non-settlable fraction	0.00228	Effluent TSS, Effluent COD
Voo (m/d)	Maximum practical settling velocity	250	Effluent TSS, Effluent COD

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Conventional pollutant model calibration

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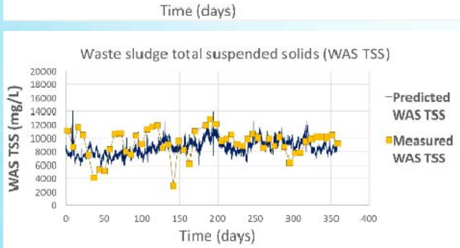
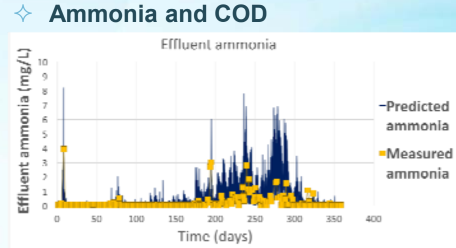
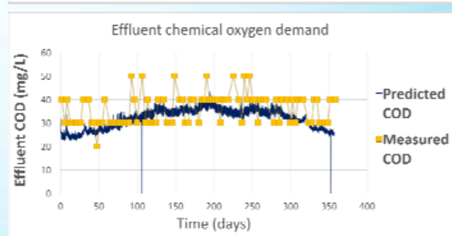
Good match is achieved between measured and predicted data

- **Solids**



- **Ammonia and COD**





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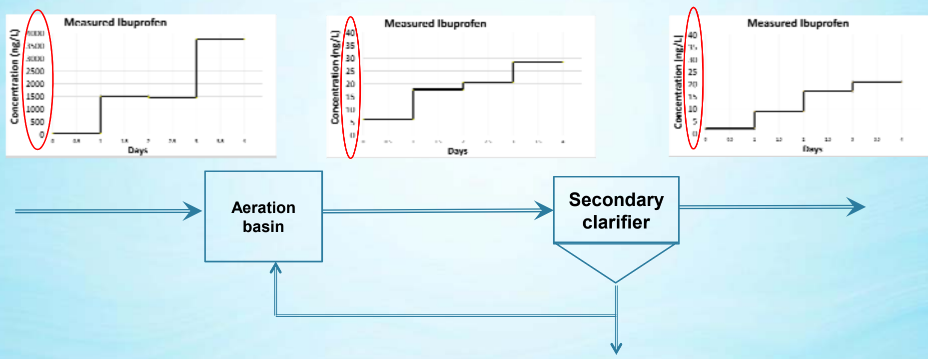
Predicting Micropollutant Removal - Ibuprofen

Background | Methodology | Hydraulics | Removals | Fate Modelling | Conclusion

- Measured Ibuprofen concentrations were used for model input (at primary influent) and calibration (at secondary effluent)



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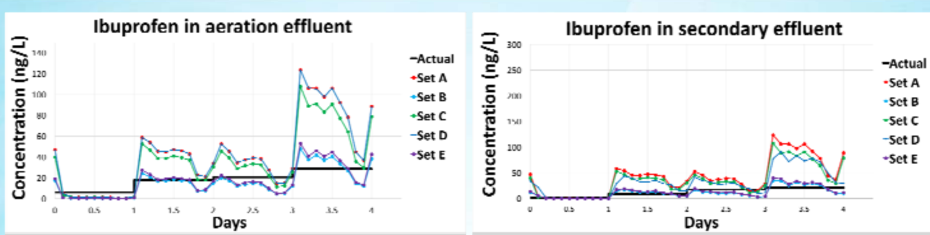
Predicting Micropollutant Removal - Ibuprofen

Background | Methodology | Hydraulics | Removals | Fate Modelling | Conclusion



Parameters set	K_{bd} (m^3/(day*gCOD)) Biodegradation first-order rate constant	K_{ads} (m^3/(day*gCOD)) Sorption rate constant	K_d (g/m^3) Sorption equilibrium constant
A	0.05	0.06	10,000
B	0.08	0.06	10,000
C	0.05	0.06	100,000
D	0.05	6	10,000
E	0.07	0.06	100,000

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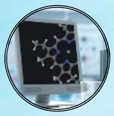
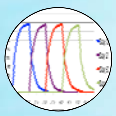
Conclusion

Background | Methodology | Hydraulics | Removals | Fate Modelling | **Conclusion**



- **Optimized collection of samples**
- **Aqueous and sludge samples analyzed**
- **Quantification of CECs and their major metabolites**



Understanding the residence time distribution of WWTPs:
- **Hydraulic model**
- **Advanced sampling strategy**

Conventional pollutant modelling to calibrate for solids and pollutants removal

Experimental CEC removals and mass balance

Model that predicts the fate of CECs can be used for optimization

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Acknowledgements

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Questions?

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