Dynamic Modelling of Heavy Metals Behavior in Whole Wastewater Treatment Plants

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Overview

- Problem statement
- Objectives
- Materials and methods
- Modelling
- Results
- Conclusion

Problem statement

- Influent of a wastewater treatment plant
  - Traditional pollutants
    - Organic matter (excrements, food wastes, leaves)
    - Nitrogen (urine, fertilizer)
    - Phosphorus (detergent, fertilizer)
  - Toxic compounds
    - Xenobiotic organic compounds
    - Heavy metals

Micropollutants
Emerging pollutants
Priority pollutants

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Problem statement

- Effluent of a wastewater treatment plant
  - A certain amount of pollutants will be rejected
  - But how much?
  - How can we improve the situation?
    - Limit the use of certain products
    - Modify the plant configuration/operation

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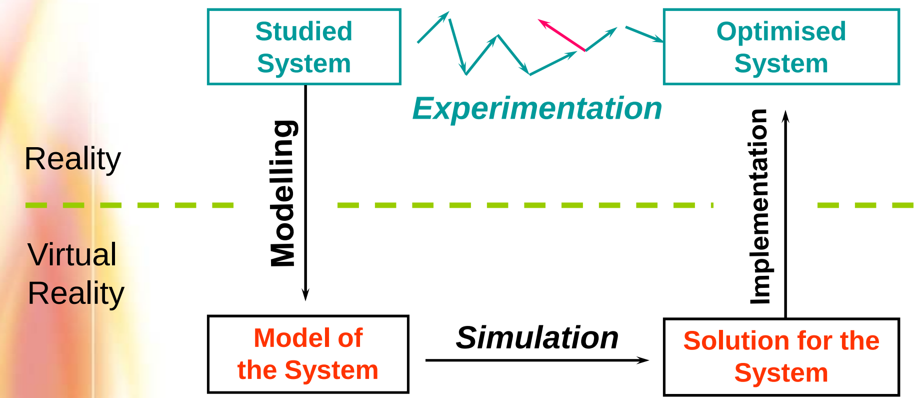
Problem statement



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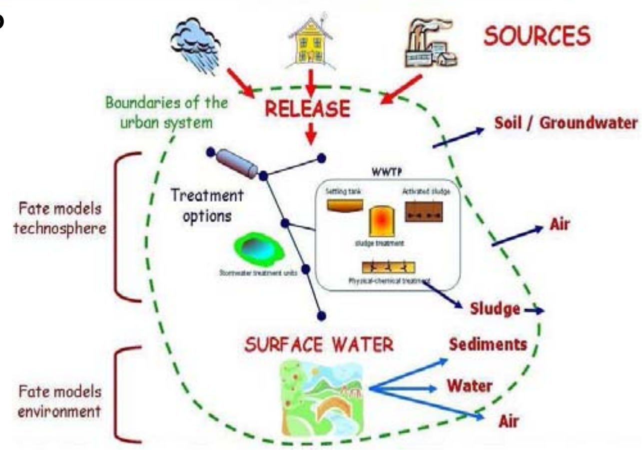
Objectives

- Develop a model able to describe the fate of micropollutants and traditional pollutants in a WWTP
- ScorePP
  - Source Control Options for Reducing Emissions of Priority Pollutants

Objectives

- ScorePP



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Objectives

- Example: Heavy metals
  - Origin
    - Tires (Zinc, Copper, Chromium)
    - Car parts (Lead, Cadmium)
    - Roofs (Zinc, Copper)

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Materials and methods

- Case study: WWTP of Norwich, UK
- Activated sludge with anaerobic digestion
- Data collected in 1986
  - COD, SS, NH_4, heavy metals
  - 10 days, 3h interval
  - Different sample locations in the WWTP
  - Unique data set in the world

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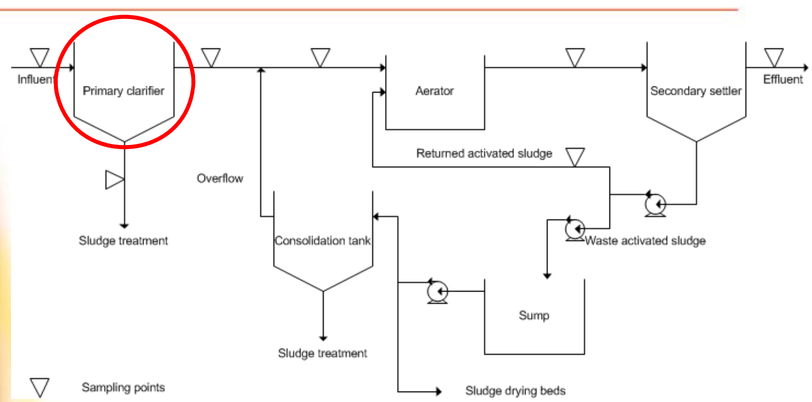
Materials and methods



Activated sludge system at the Norwich WWTP (Lessard and Beck, 1993)

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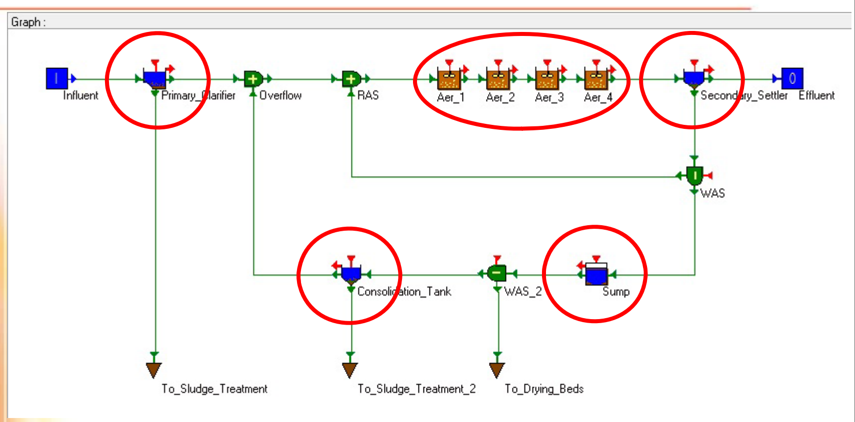
Materials and methods

- WEST® simulator
  - Developped by:
    - MOSTforWATER
    - BIOMATH

  - Functionality:
    - Dynamic simulation
    - Add/extend models yourself
    - Extensions for sewers (KOSIM) and rivers (RWQM1)

Materials and methods



The Norwich WWTP in the WEST simulator

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Modelling

Transport

Reactions

- Mass balance

$$\frac{dMetal}{dt} = \frac{Q_{in}}{V}\left(Metal_{in} - Metal_{out}\right) - \cancel{\text{Bio. Deg.}} - \text{"Sorption"} - \cancel{\text{Volatilization}}$$

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Modelling

- Describe sorption:

$$S_{Metal} + X_{TSS} \xrightarrow{k_{sorption}} X_{Metal}$$

$$X_{Metal} \xrightarrow{k_{desorption}} S_{Metal} + X_{TSS}$$

$$S_{Metal} + X_{TSS} \underset{\frac{k_{sorption}}{K_D}}{\overset{k_{sorption}}{\rightleftarrows}} X_{Metal}$$

$$K_D = \frac{k_{sorption}}{k_{desorption}}$$

$$\text{Rate} = k_{sorption} \cdot \left(S_{Metal} \cdot X_{TSS} - \frac{X_{Metal}}{K_D} \right)$$

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Modelling

Transport | Reactions

- Mass balance

$\frac{dMetal}{dt} = \frac{Q_{in}}{V}(Metal_{in} - Metal_{out})$ − ~~Bio. Deg.~~ − "Sorption" − ~~Volatilization~~

$$\frac{dS_{Metal}}{dt} = \frac{Q_{in}}{V}(S_{Metal,in} - S_{Metal,out}) - k \cdot \left(S_{Metal} \cdot X_{TSS} - \frac{X_{Metal}}{K_D} \right)$$

$$\frac{dX_{Metal}}{dt} = \frac{Q_{in}}{V}(X_{Metal,in} - X_{Metal,out}) + k \cdot \left(S_{Metal} \cdot X_{TSS} - \frac{X_{Metal}}{K_D} \right)$$

Transport | Sorption/Desorption

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Modelling

- Importance of TSS:

$$\frac{dS_{Metal}}{dt} = \frac{Q_{in}}{V}\left(S_{Metal,in} - S_{Metal,out}\right) - k \cdot \left(S_{Metal} \cdot X_{TSS} - \frac{X_{Metal}}{K_D}\right)$$

$$\frac{dX_{Metal}}{dt} = \frac{Q_{in}}{V}\left(X_{Metal,in} - X_{Metal,out}\right) + k \cdot \left(S_{Metal} \cdot X_{TSS} - \frac{X_{Metal}}{K_D}\right)$$

  - We need good quality TSS simulations
  - We need a model that describes growth/decay of biomass and the accumulation of org. matter

ASM1
(Activated Sludge Model No.1)

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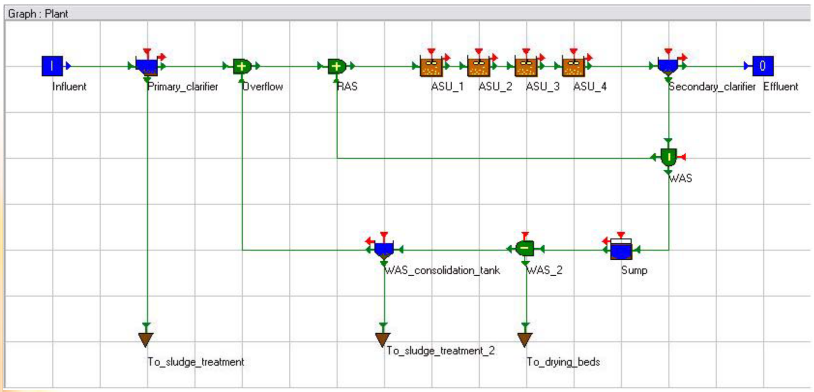
Results



The Norwich WWTP in the WEST simulator

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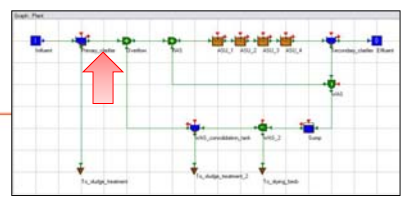
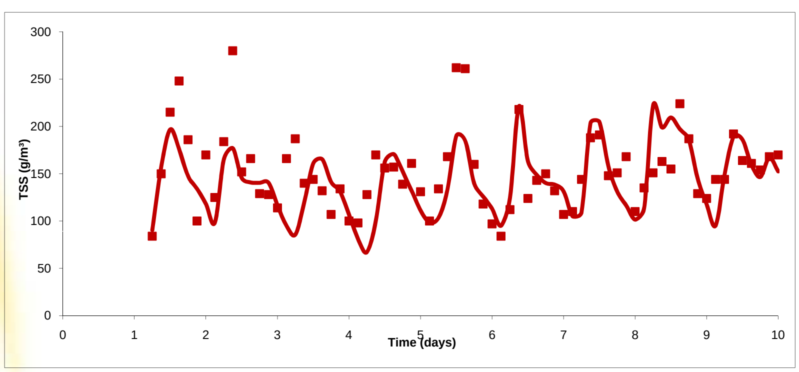
Results

- Primary clarifier: TSS





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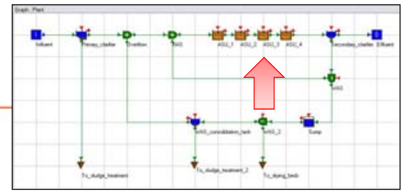
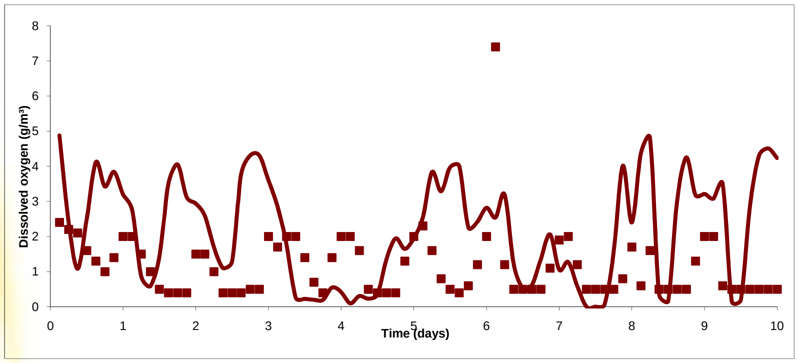
Results

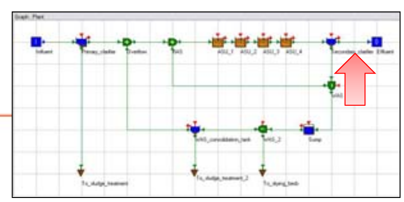
- Dissolved oxygen

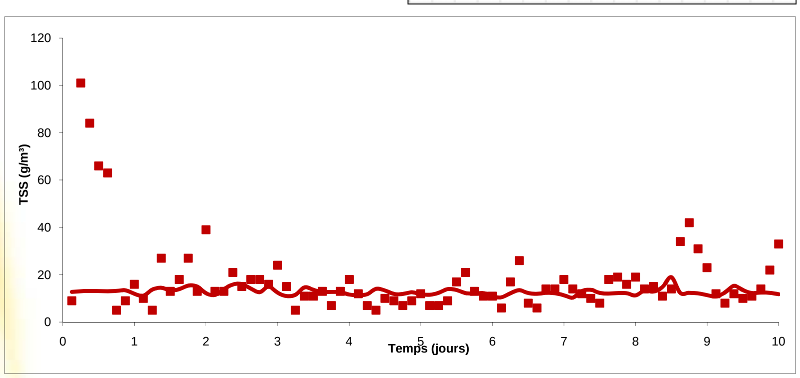




Results

- Effluent: TSS





Results

- Studied heavy metals

Parameters	Units	Copper	Zinc	Lead	Cadmium	Chromium	Nickel
$k_{sorption}$	L/mg.d	0.0002	0.0001	0.002	0.0002	0.0013	0.0008
$Log(K_D)$	L/kg	3.7 (3.1 – 6.1)	5.1 (3.5 – 6.9)	4.6 (3.4 – 6.5)	4.6 (2.8 – 6.3)	4.4 (3.9 – 6.0)	3.9 (3.5 – 5.7)
Removal	%	88.6	82.4	93.1	86.2	86.5	69.1

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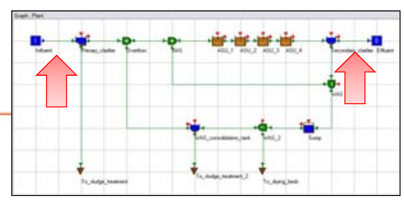
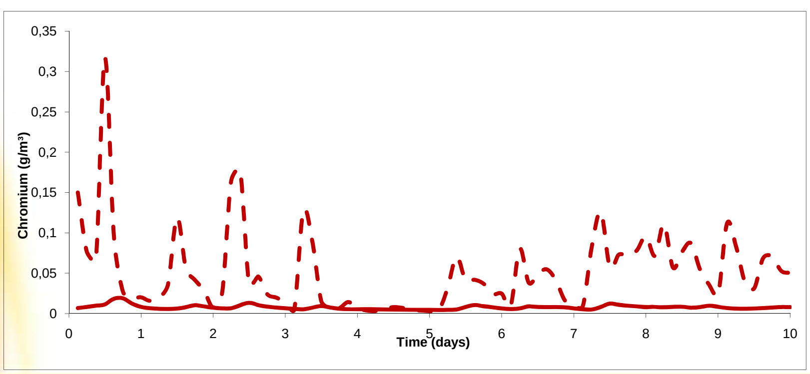
Results

- Chromium: In - Out





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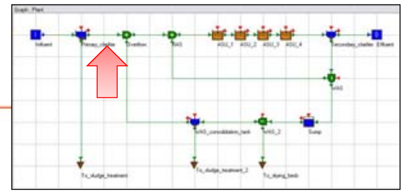
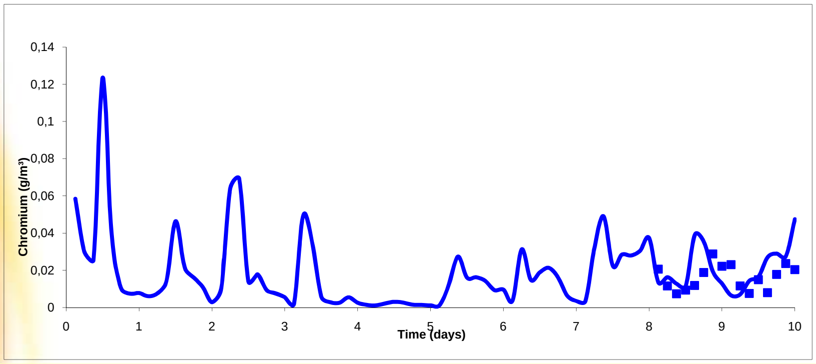
Results

- Chromium: PC effluent





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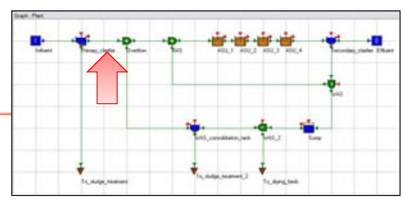
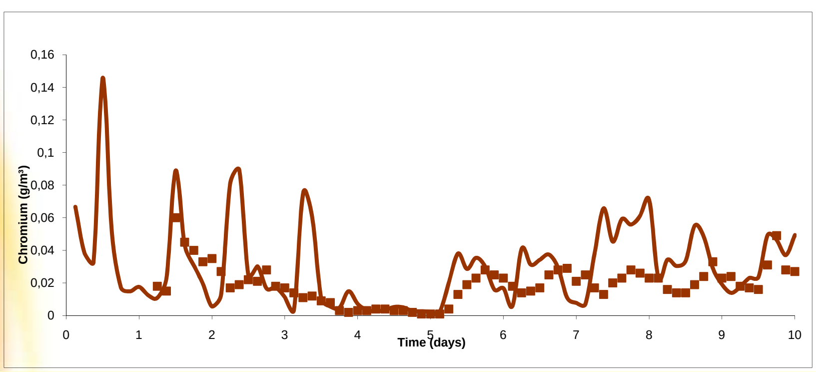
Results

- Chromium: PC effluent





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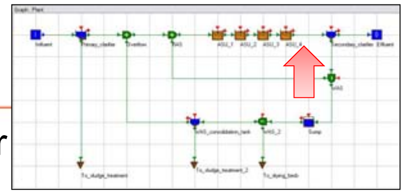
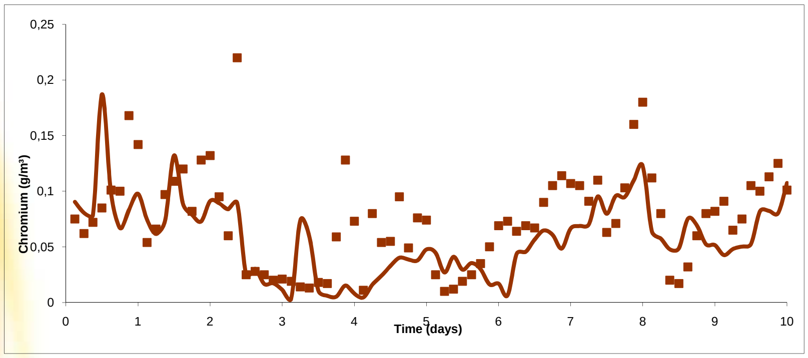
Results

- Chromium: Mixed liquor





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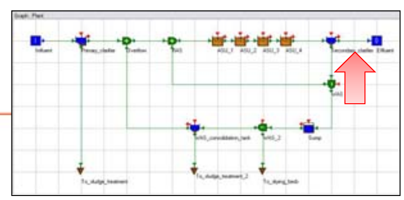
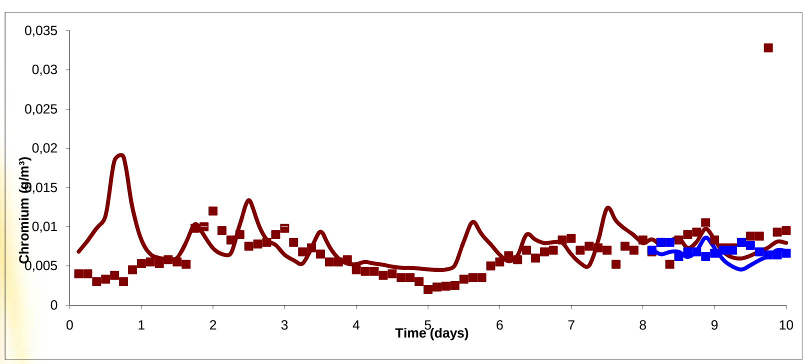
Results

- Chromium: Effluent





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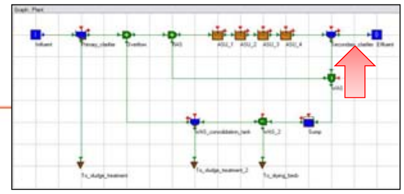
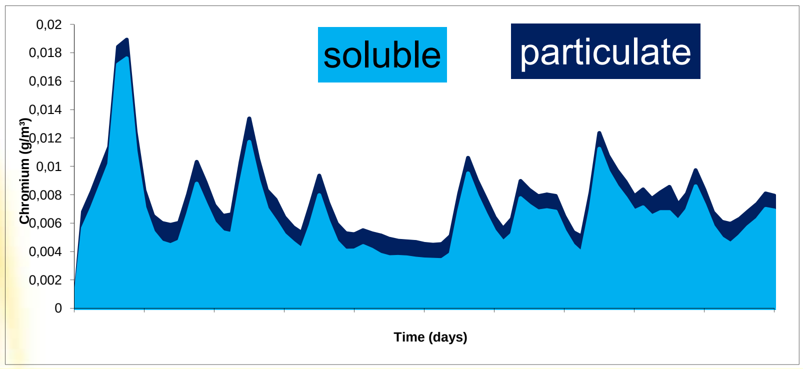
Results

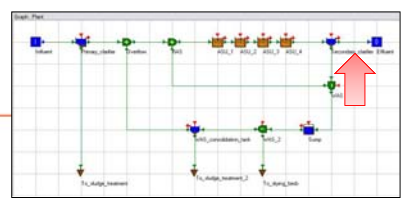
- Chromium: Partitioning

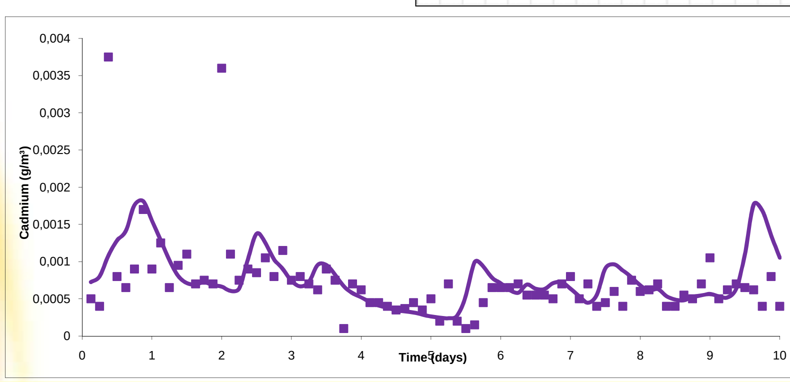




Results

- Cadmium: Effluent





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Conclusion

- Development of a model that deals with:
  - Traditional pollutants
  - Heavy metals

$$k_{sorption} \cdot \left(S_{Metal} \cdot X_{TSS} - \frac{X_{Metal}}{K_D} \right)$$

- Potential of the model
  - Optimising the design/operation of WWTPs

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Conclusion

- Perspectives
  - ScorePP
    - Developed a model for micropollutants (runoff, sewer network, wwtp, river)
  - Pancanadian study
    - Efficacy of emerging contaminants removal
    - Assess its impact on aquatic species

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Conclusion

- Acknowledgement

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  - Peter Vanrolleghem
  - Paul Lessard

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