EEDEMS 2022

Fouilles de données videotracking massives pour l'identification d'empreintes comportementales de l'exposition aux contaminants en écotoxicologue aquatique : application a 3 invertébrés pour la surveillance des rejets

George Ruck (2eme année de thèse) : george.ruck@inrae.fr

Encadrants :

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La Région Auvergne-Rhône-Alpes

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deep

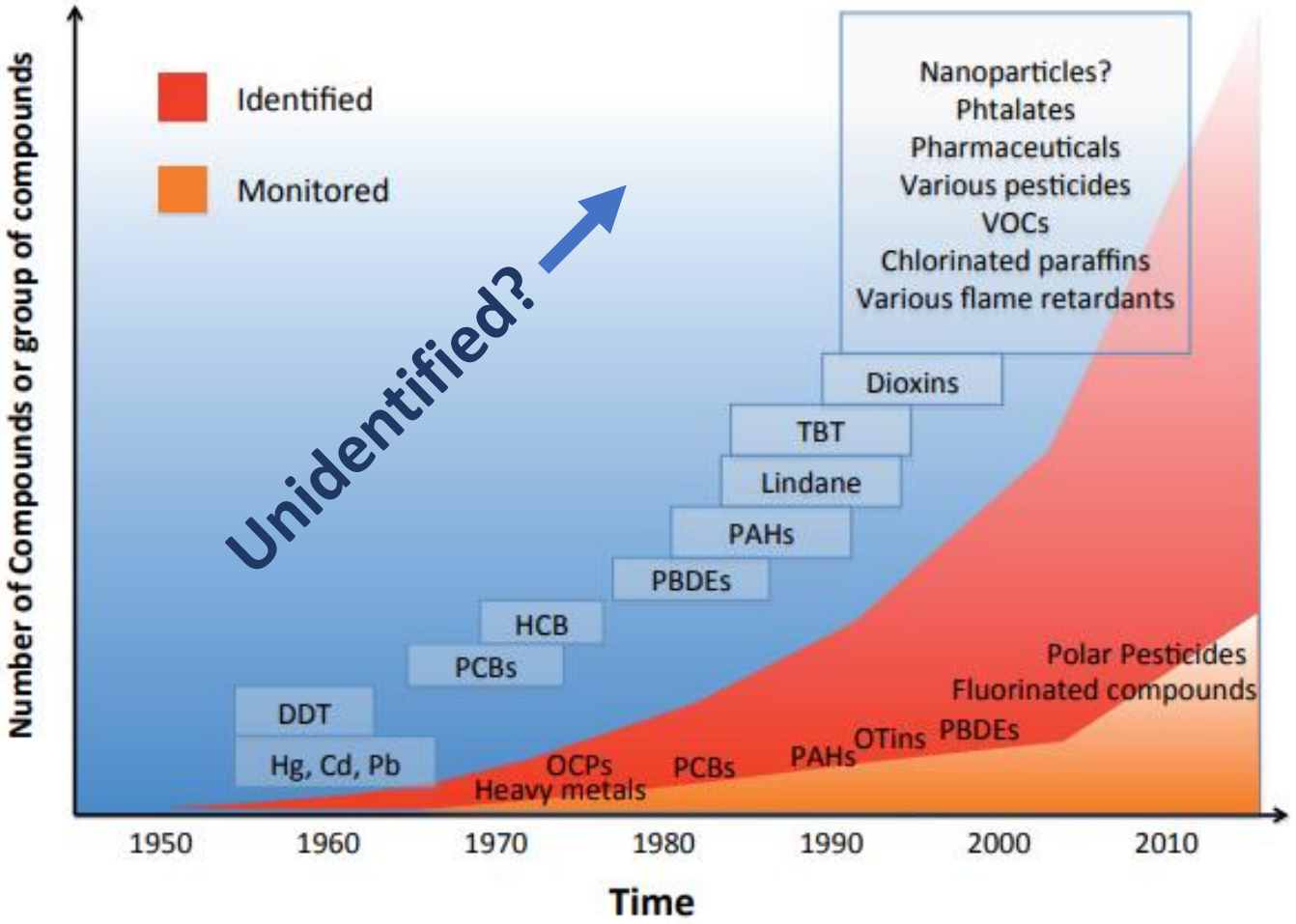
ViewPoint
Biosurveillance de l'eau

- PhD Context and Objectives
- Methodology
- Results
- Outlook

Context

Emerging Aquatic Micropollution

- Negative CEC impact often poorly understood
- Absence of CEC monitoring in wastewater management (**WWTPs**)
  - One shot campaigns
  - Grab sampling
- Temporal variability in discharge



Source : Chemical Pollution in Europe's Seas : Programmes, Practices and Priorities for Research, Marine Board Poosition Paper 16. Calewaert J.B. and McDonough N. Marine Board-ESF Ostend, Belgium.

Context

Emerging Aquatic Micropollution

- Negative CEC impact often poorly understood
- Absence of CEC monitoring in wastewater management (**WWTPs**)
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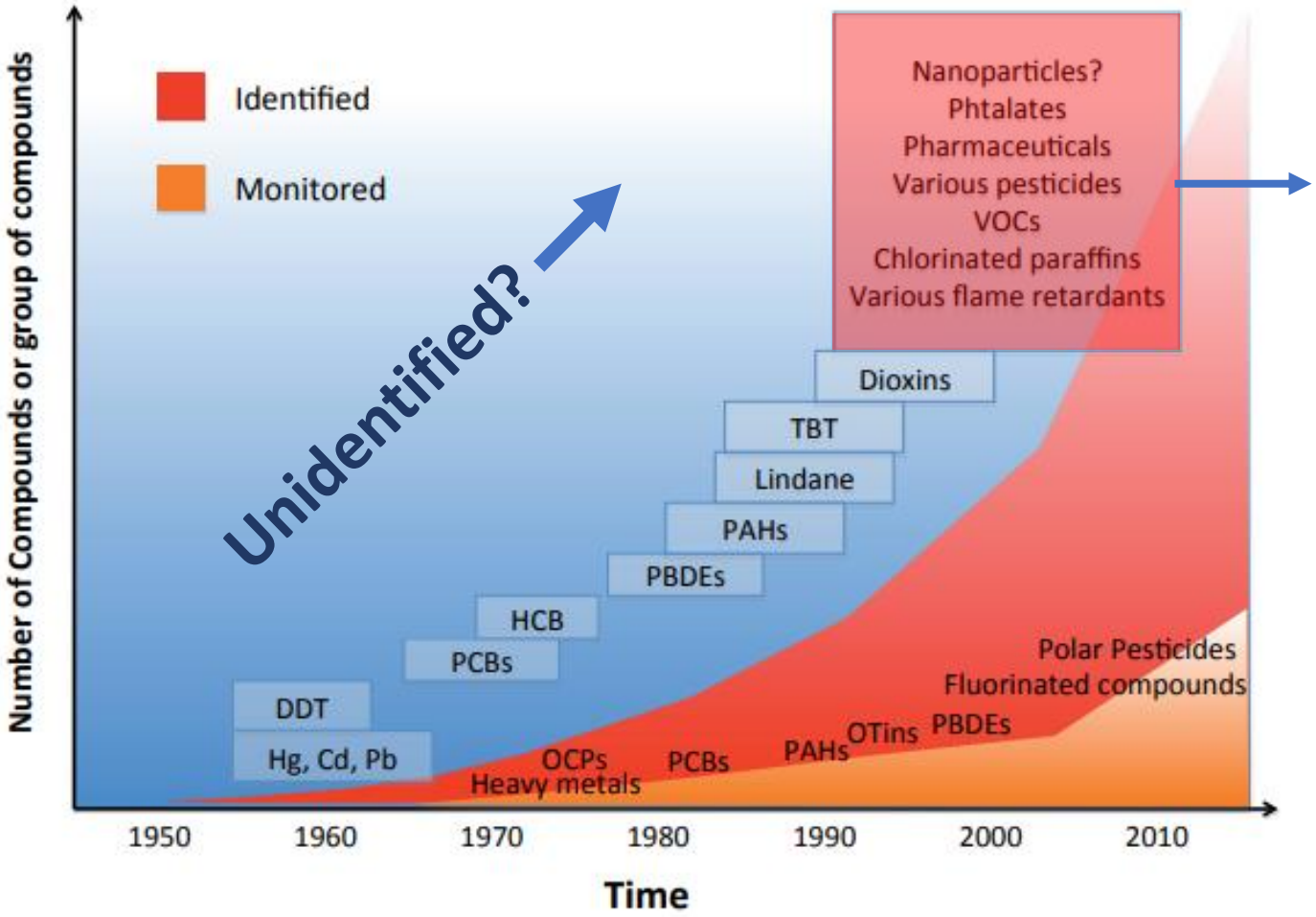
  - Grab sampling
- Temporal variability in discharge
- Objective : **Real-time CEC identification**



Non-targeted CEC detection?

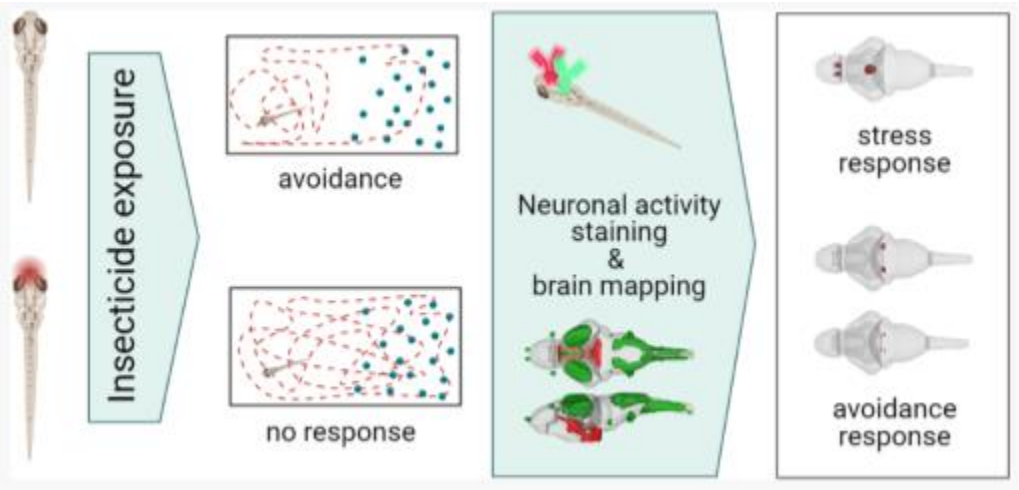
Source : Chemical Pollution in Europe's Seas : Programmes, Practices and Priorities for Research, Marine Board Poosition Paper 16. Calewaert J.B. and McDonough N. Marine Board-ESF Ostend, Belgium.

Context

Effect Based Wastewater Surveillance

- Known ecotoxicology biomarker : **Avoidance Behaviour**
  - Sensitive bio-activity measure
  - Quick response time

- Challenge : Quantify avoidance behaviour to indicate **micro-pollution presence** :
  - Centre of gravity tracking
  - Parallel organism tracking (ToxMate)



Source : Sub-Lethal Peak Exposure to Insecticides Triggers Olfaction-Mediated Avoidance in Zebrafish Larvae/ Konemann et. Al.

Low activity ***Avoidance***

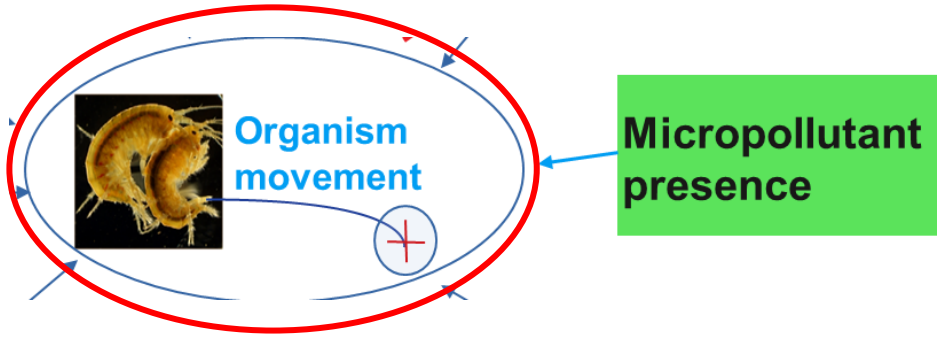
2 Gammarus fossarum tracked in the ToxMate over 2 seconds

Context

Hypotheses

1. Avoidance behaviour response to micropollutants

- Reproducible testing protocol
- External bias testing
- Testing of robustness



2. Multi-dimensional testing for pattern identification

- Difference in responses to chemicals
- Machine learning testing

3. Data-Mining and AI improvements

- Massive testing
- Targeted industrial testing
- Links to chemical structure

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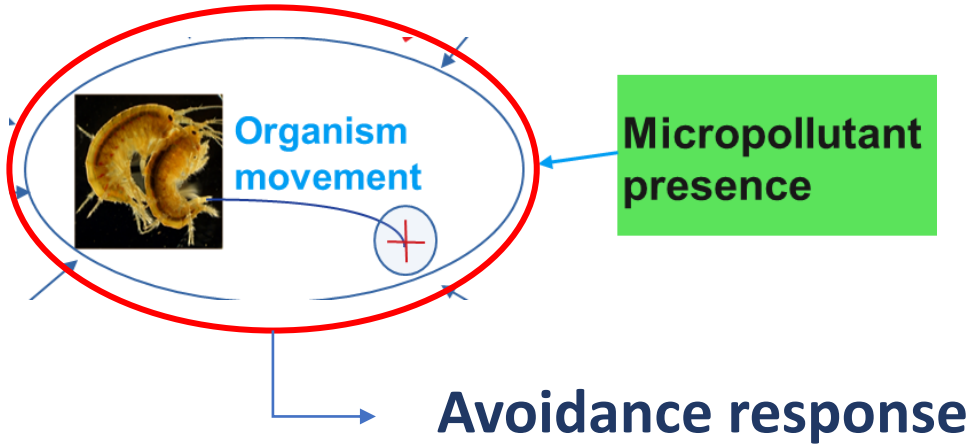

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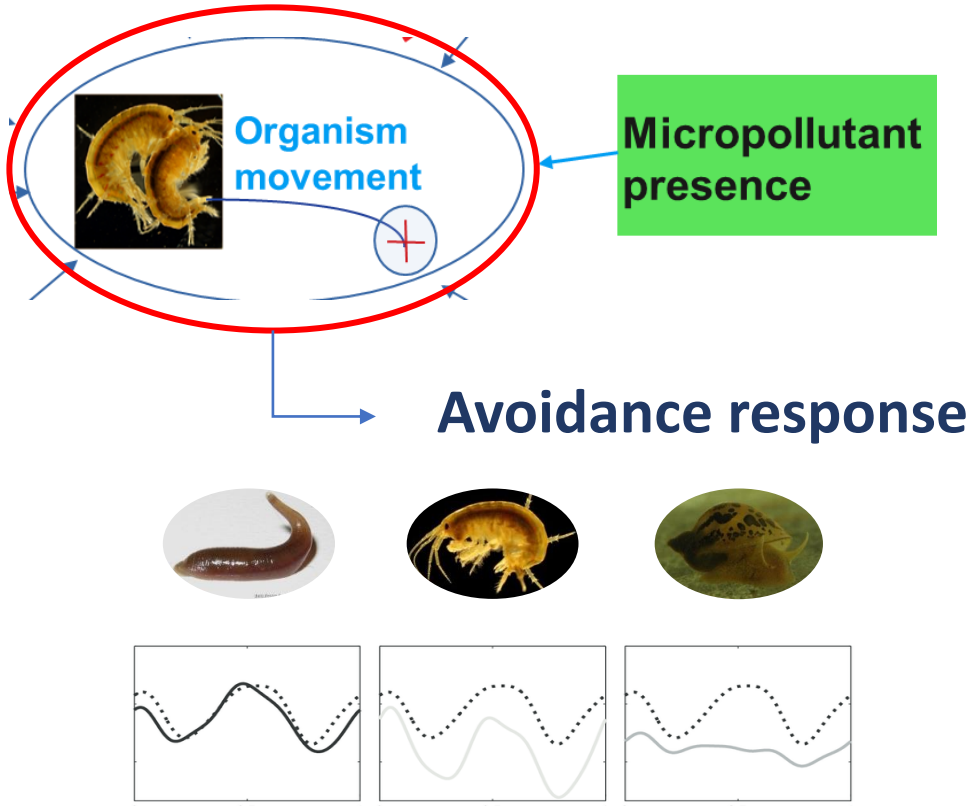

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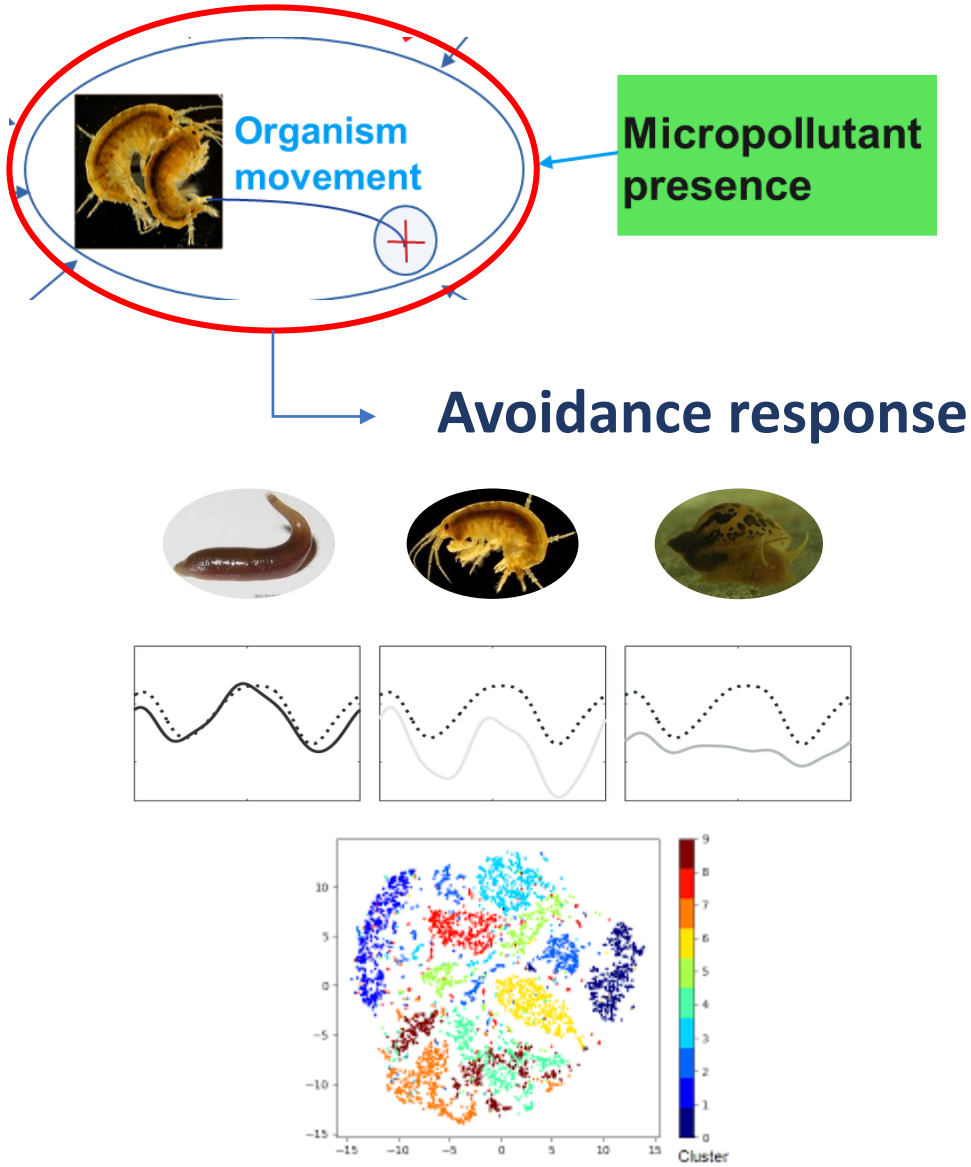
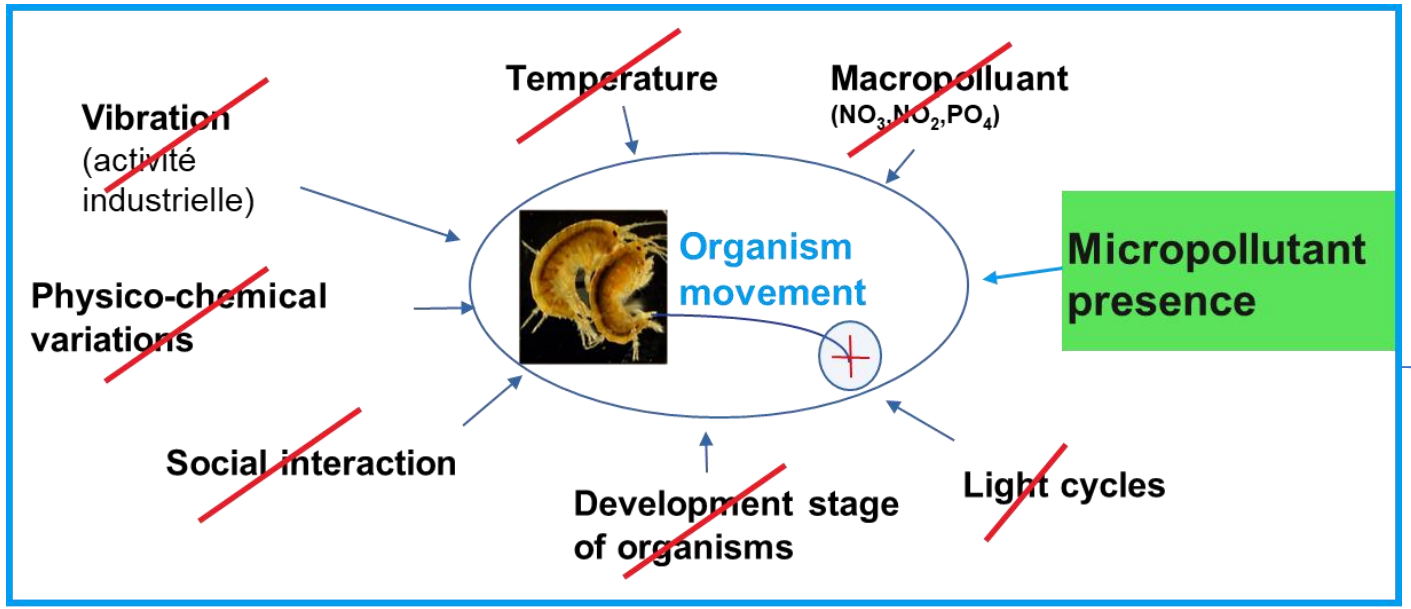


Objectives

Lab Testing

- Conditioning of organisms in lab conditions to reach a **minimal activity reference**
- Avoidance behaviour to detect CEC presence



Model macro-invertebrates

Gammarus fossarum

Erpobdella testacea

Radix auricularia

- Pharmaceuticals
- PAHs
- Solvents / Flame retardants

(Dangerous substances for the aquatic environment found in WWTP outlets. Technial report 2021 - INERIS)

- >NOEC Gammarus

(No observed effect concentration)

Industrial Application

- Validation for operational use in industry

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Methodology

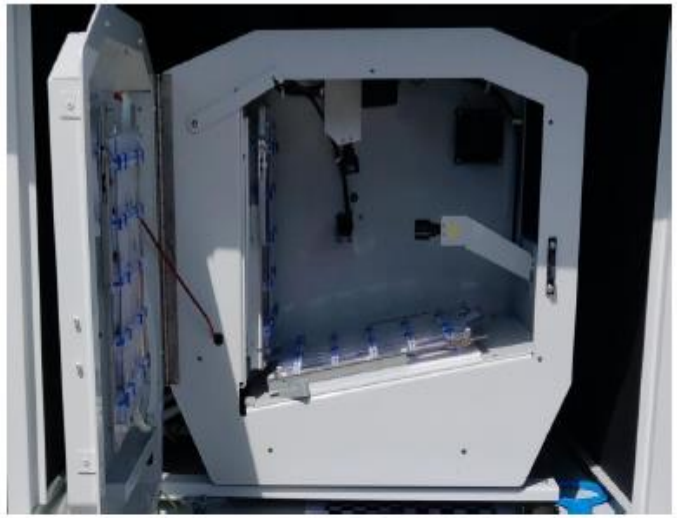
Methodology

ToxMate Surveillance

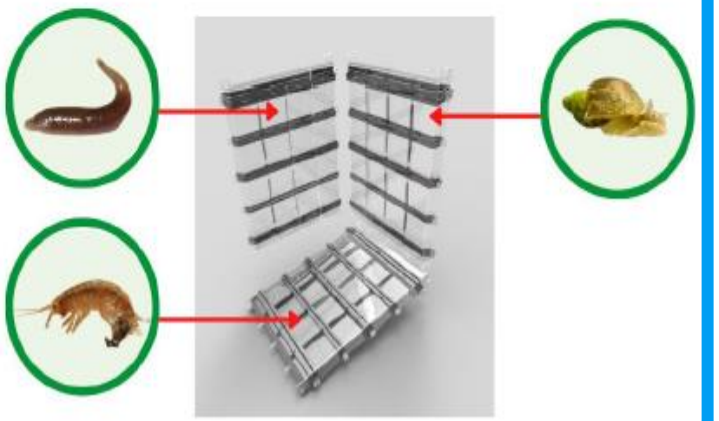
- 2014 — Development of ToxMate surveillance station
- 2016 — **Lab Testing** first data collection
- 2018 — Industrial adaptation for long-term operational use

Videotracking software

Sampling	< 40 ms
Repetability	16 organisms, 3 species
Data Output	~ 300 000 datapoints / minute
	RAW – C.O.G. : (x, y) + Area
	XLS – Automatic agregation
	AVI– images XVID



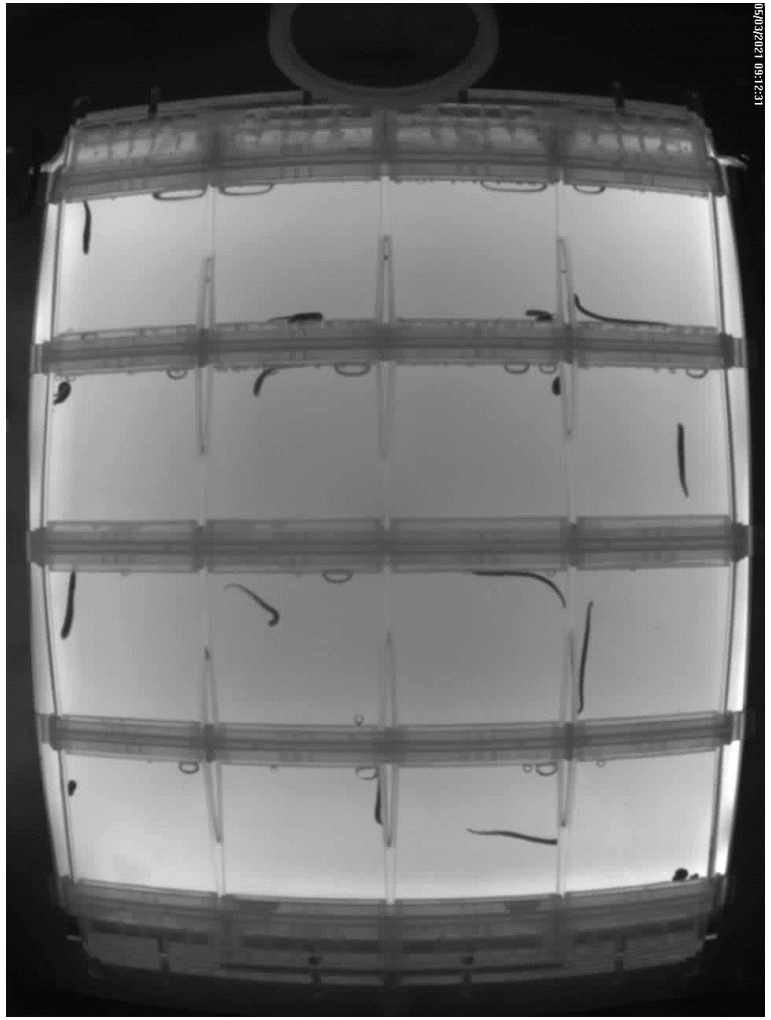
Interior of ToxMate surveillance station with observation cameras for videotracking



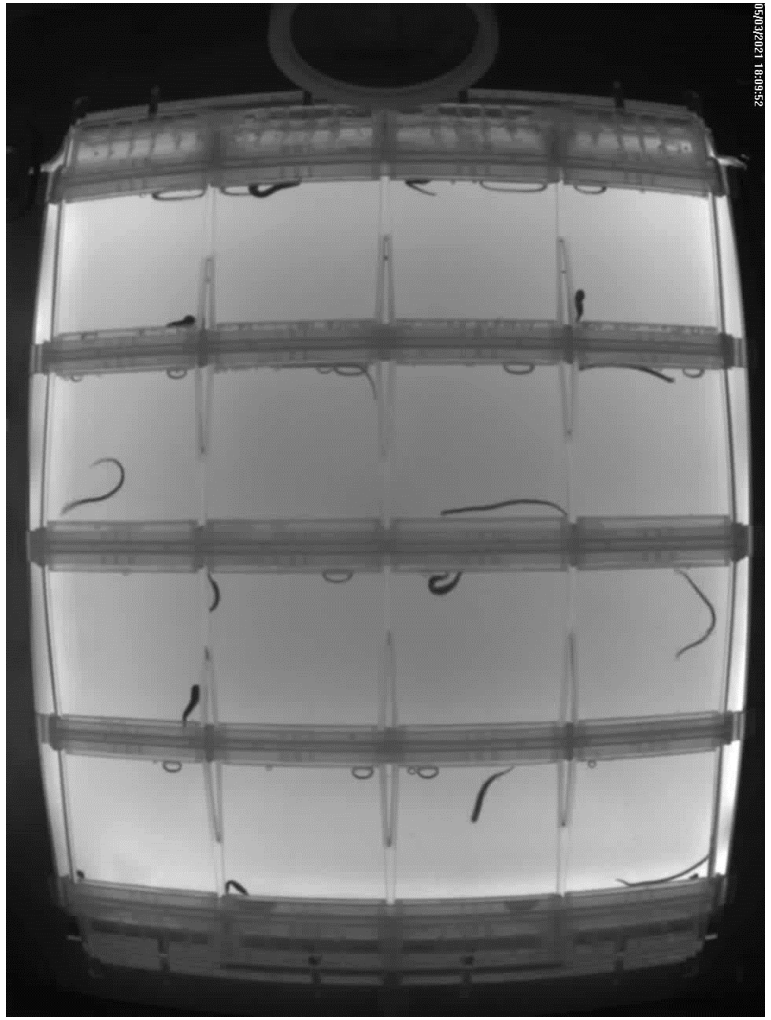
3 observation panels for 3 bio-model species with constant water current.

Methodology

Minimal activity state



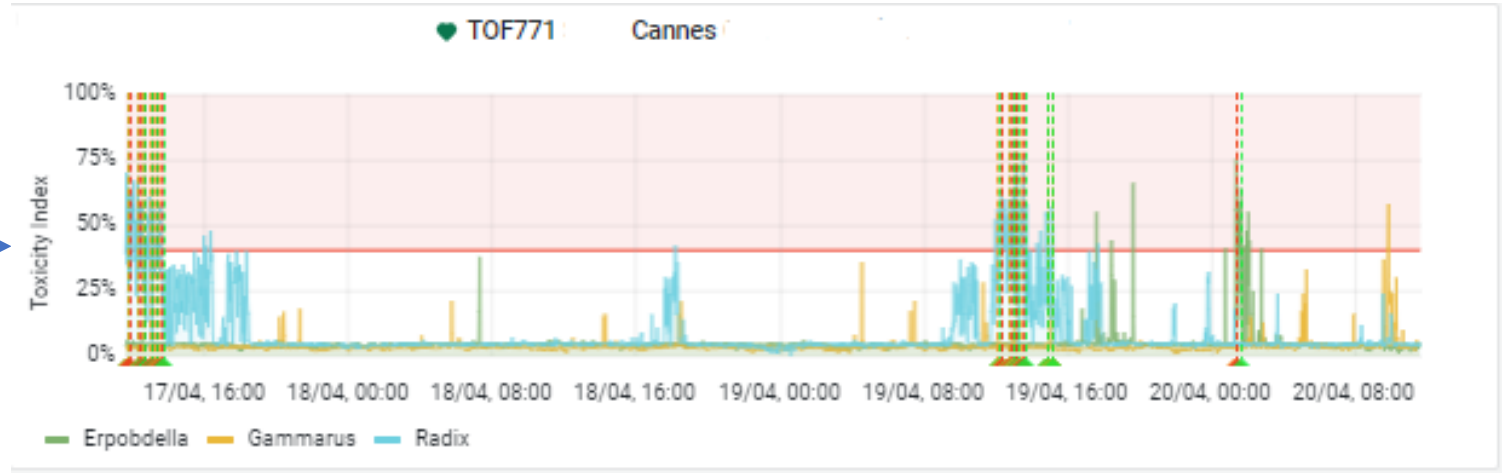
Avoidance



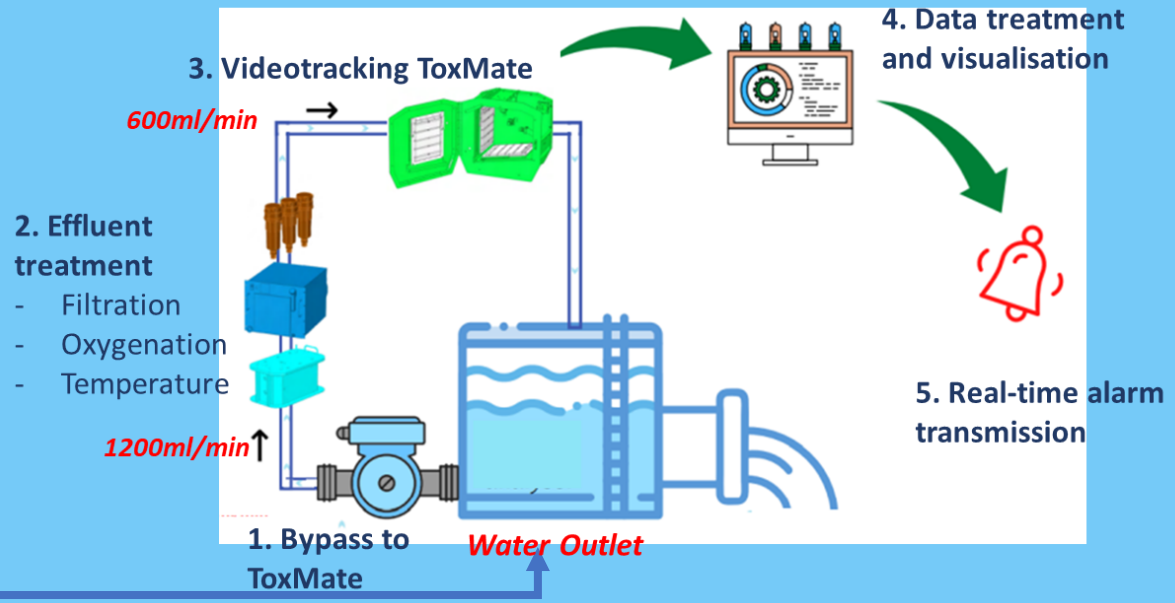
Methodology

WWTP operational surveillance

- WWTP outlet bypassed to **ToxMate**
- Continuous surveillance (>2years)
  - **Critical moment detection**
- **2019-present** : >20 ToxMates deployed for continuous surveillance across Europe



Alert Panel for industrials at WWTP site in Canne France.



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Results

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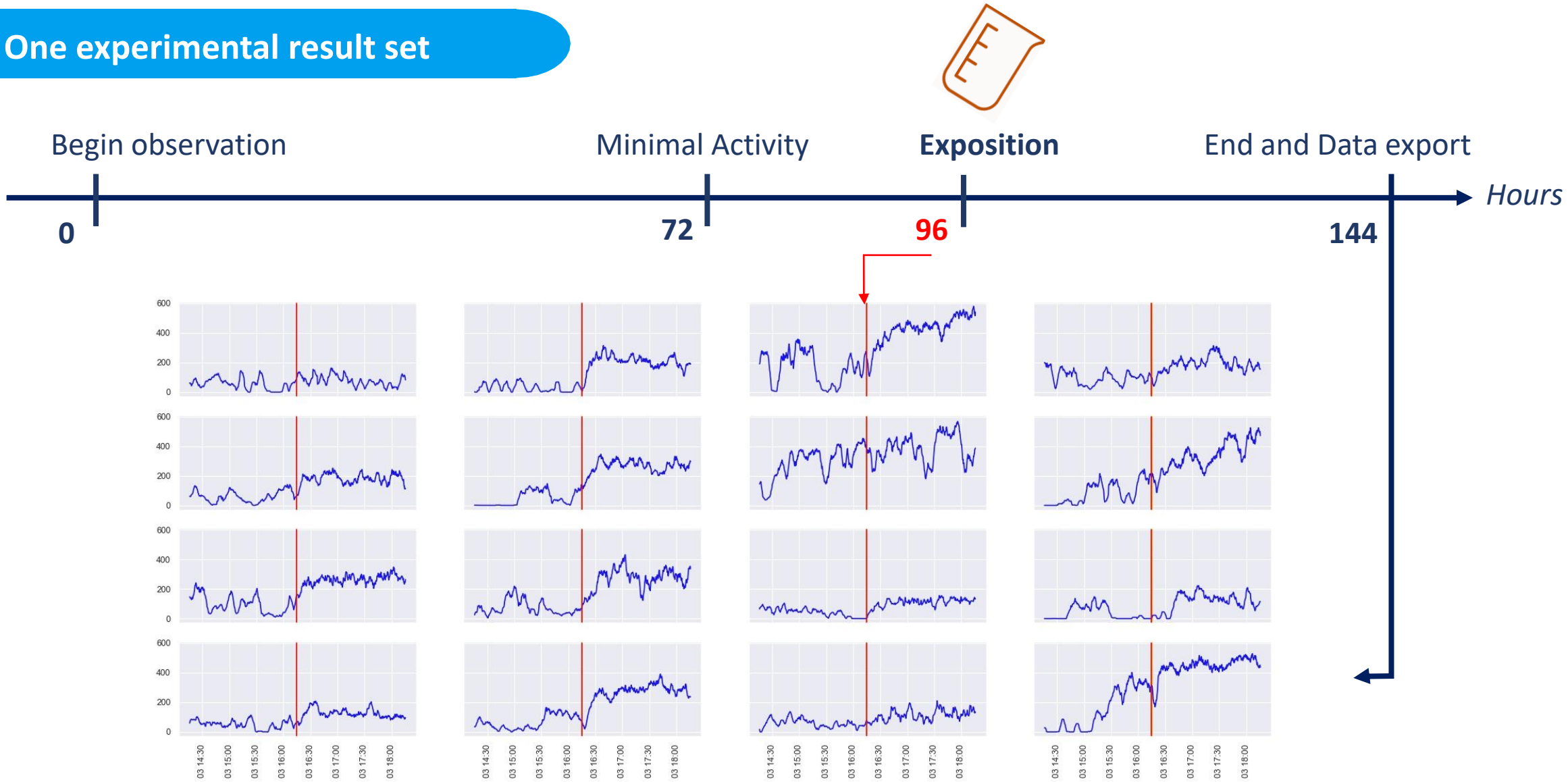
One experimental result set



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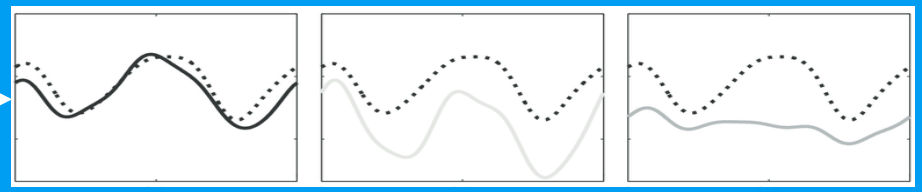
Signal processing

- Accumulation of 16 individual trajectories

Movement curves



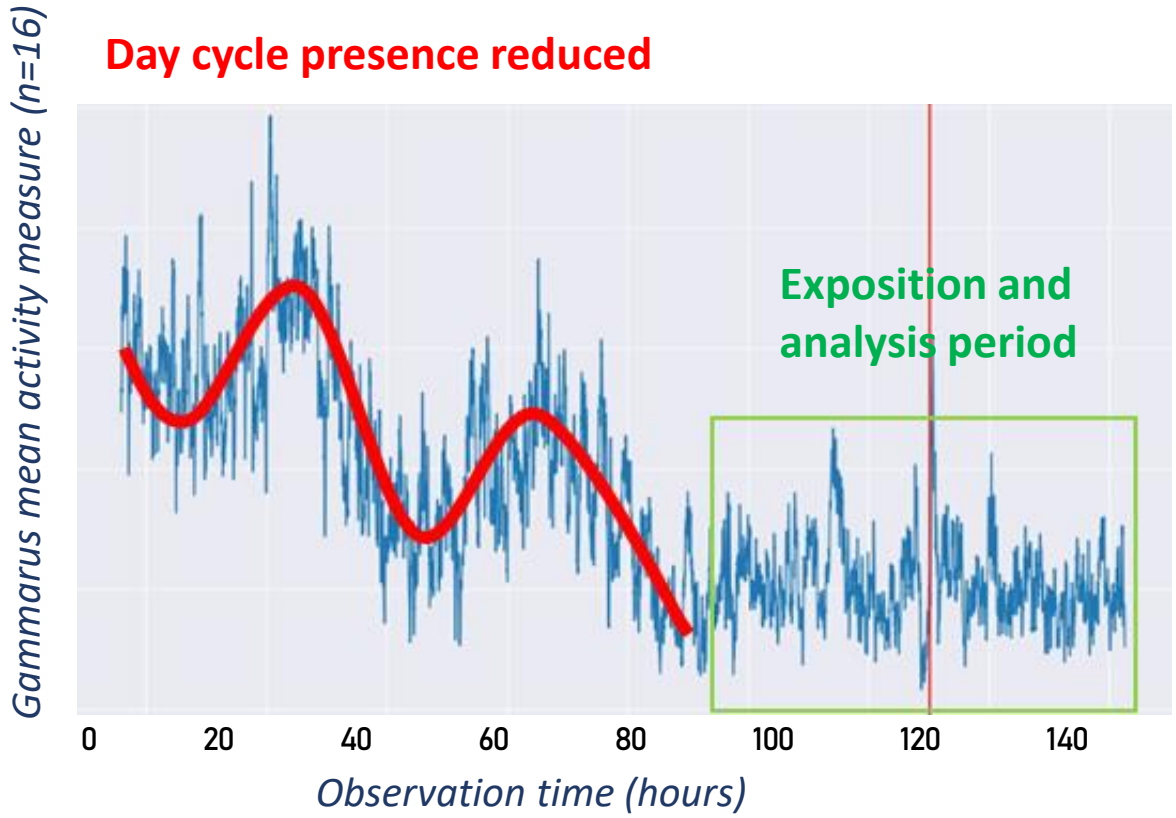
Experimental Protocol Definition

Acclimation

- ToxMate conditioning reduces external confusion
- CEC exposition after 72 hours

Minimal activity

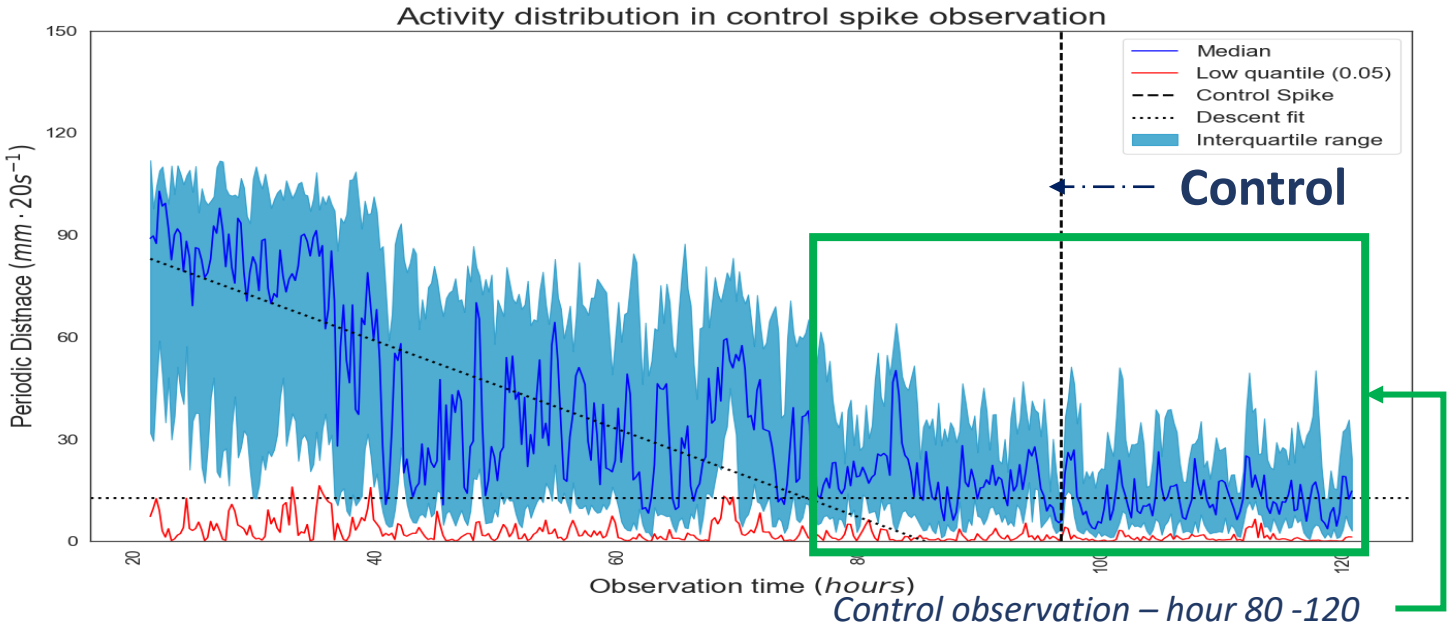
- Reference behaviour (close to zero)



Signal processing

Reproducibility

- Distribution shows **minimal activity** in lower quantile movements
- Observation period after 3 days



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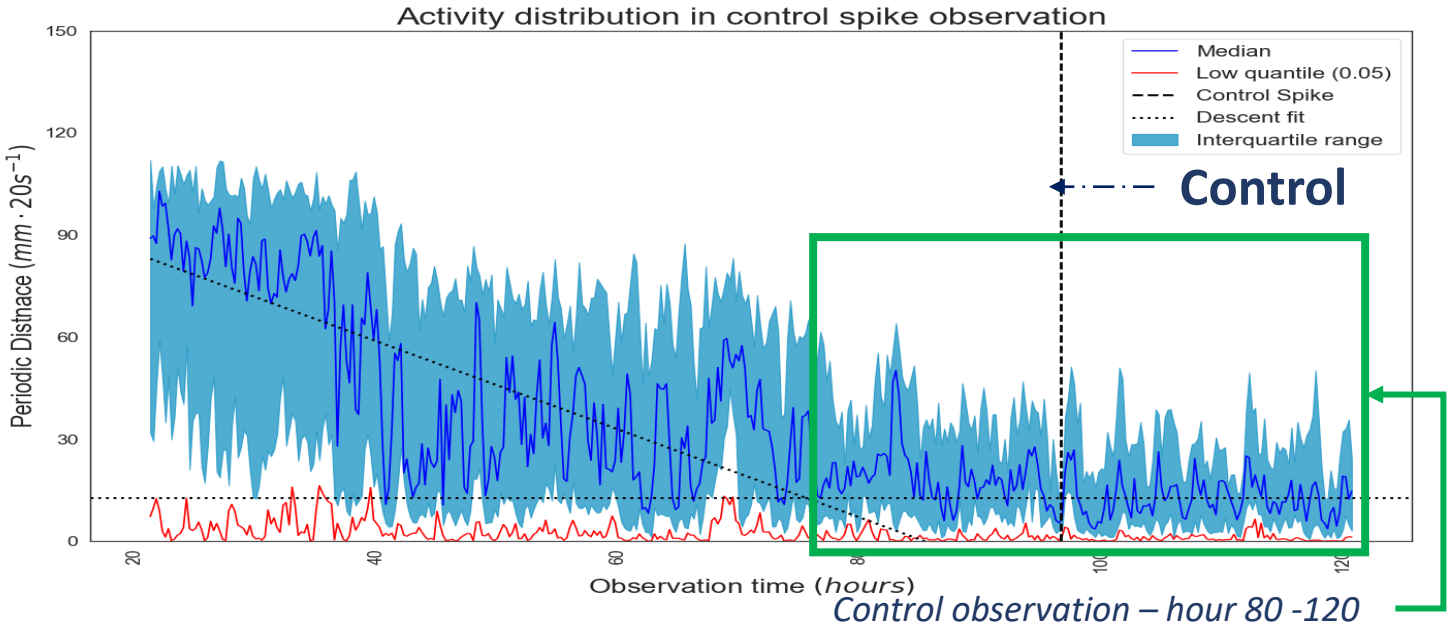
Signal processing

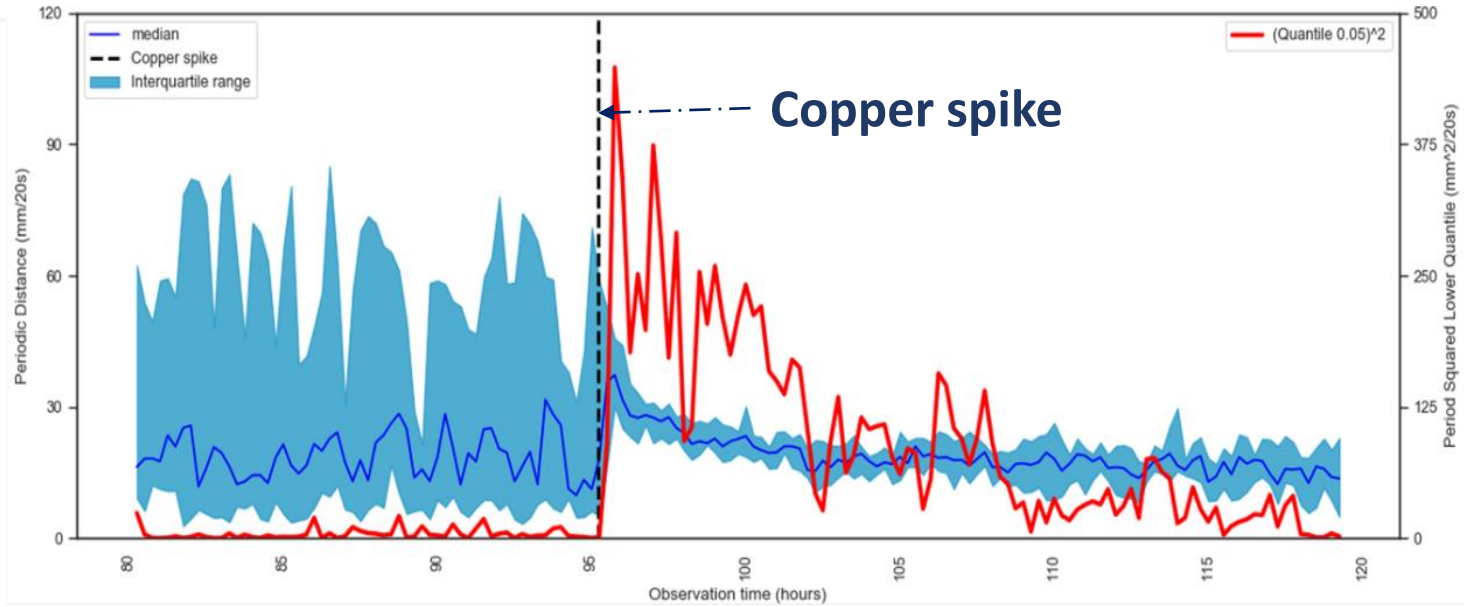
Reproducibility

- Distribution shows **minimal activity** in lower quantile movements
- Observation period after 3 days

- Instantaneous avoidance reaction in activity signal upon introduction of chemical



Control observation – hour 80 -120

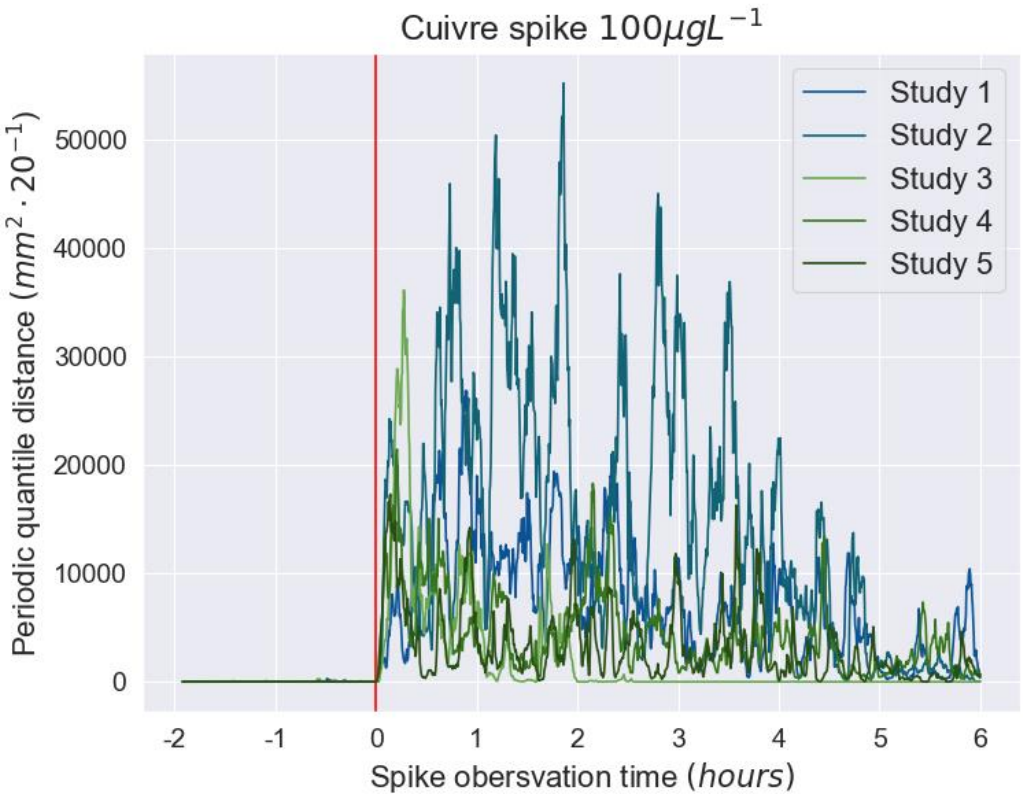


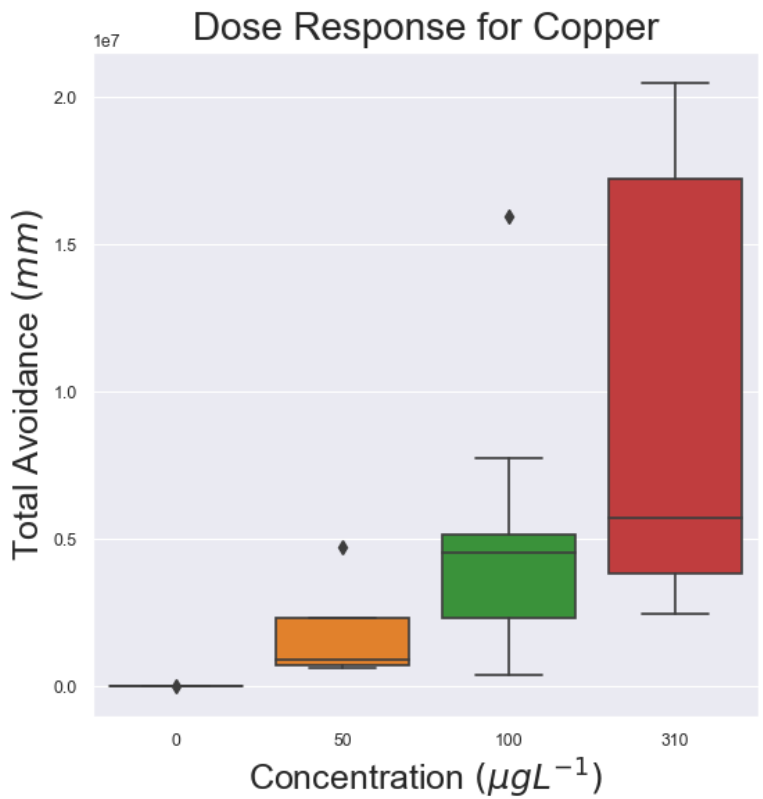
Micropollutant observation – hour 80 -120

CEC exposition spikes

Repetitions for reference chemicals

- 5 repetitions for copper (100ug/L)
- Dose response in avoidance behaviour?





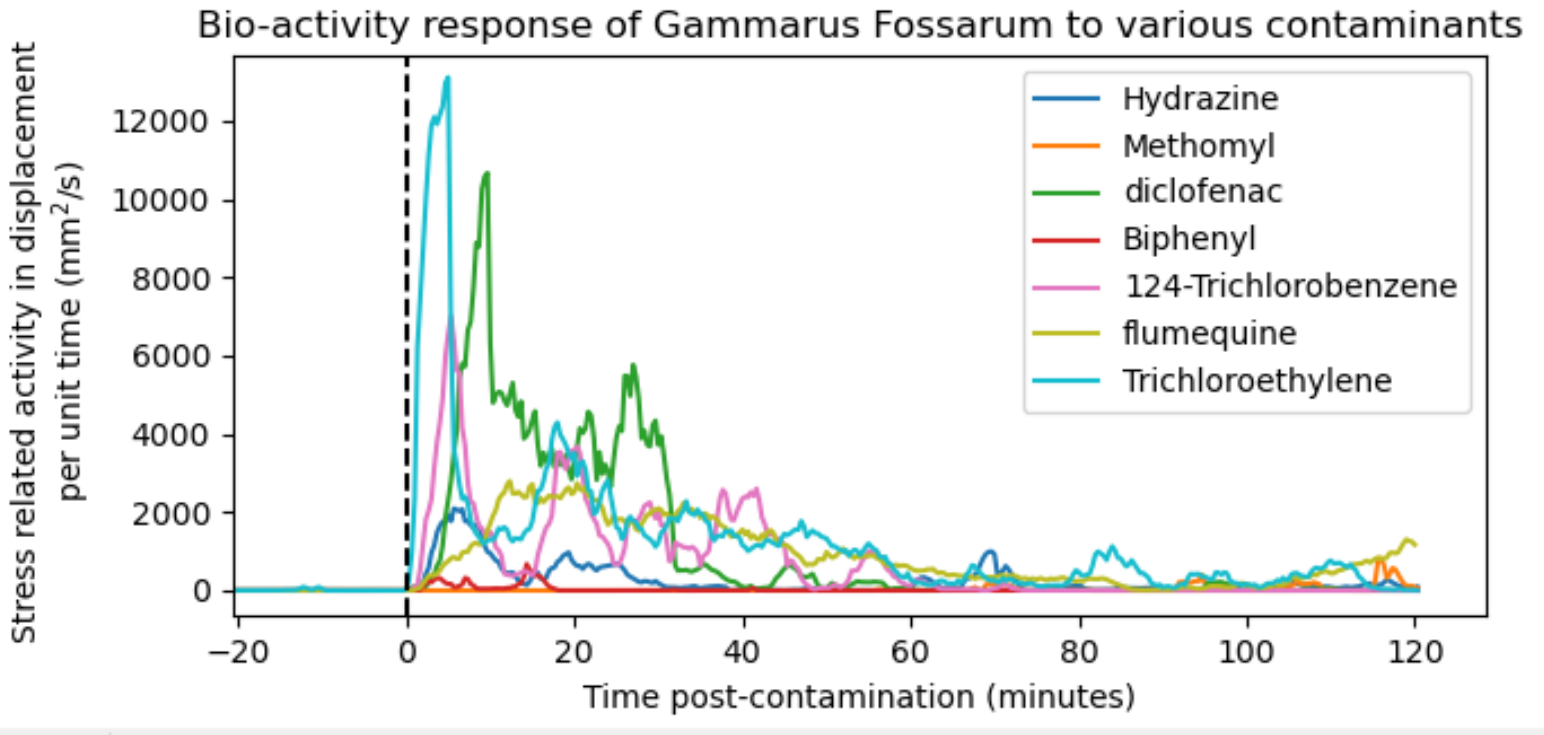
CEC exposition spikes

Diverse molecule selection

- Molecules of concern in WWTP across France selected

Varied response patterns (*Gammarus*)

- Avoidance observed for numerous micropollutants (>50)
- Differences in Gammarus response



Gammarus avoidance bio-activity profiles for 7 CEC spikes

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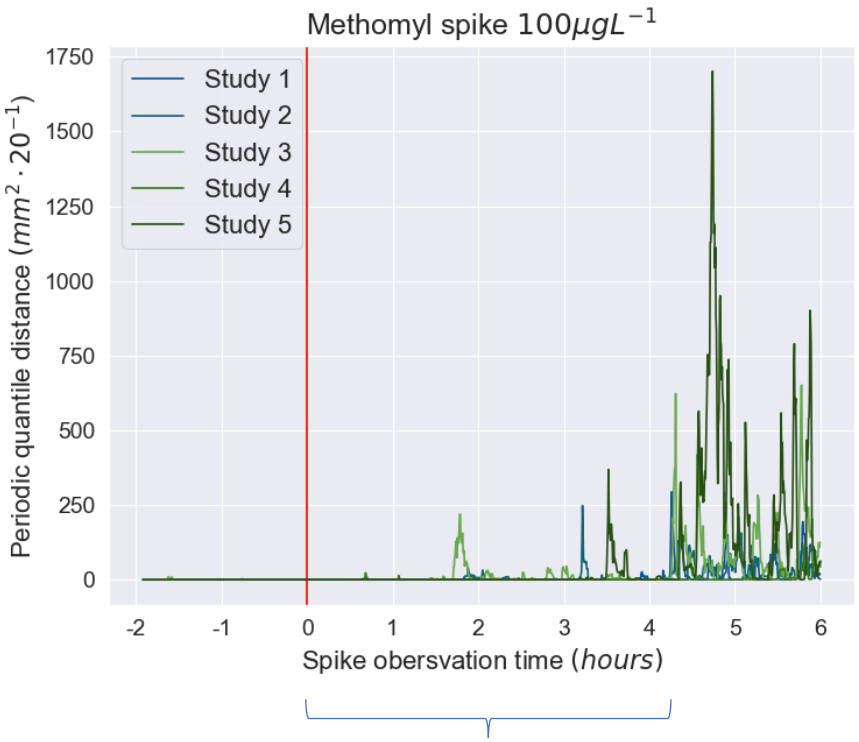
CEC exposition spikes

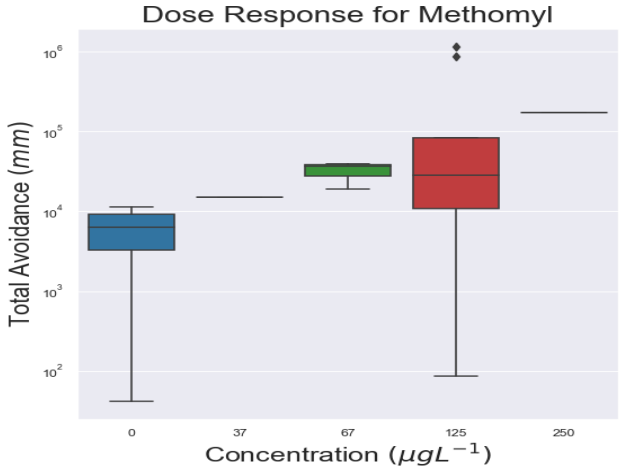
Repetitions for reference chemicals

- 5 repetitions for methomyl (125ug/L)



Delayed response? – 4 hour avoidance?

- Dose response in avoidance behaviour



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CEC exposition spikes

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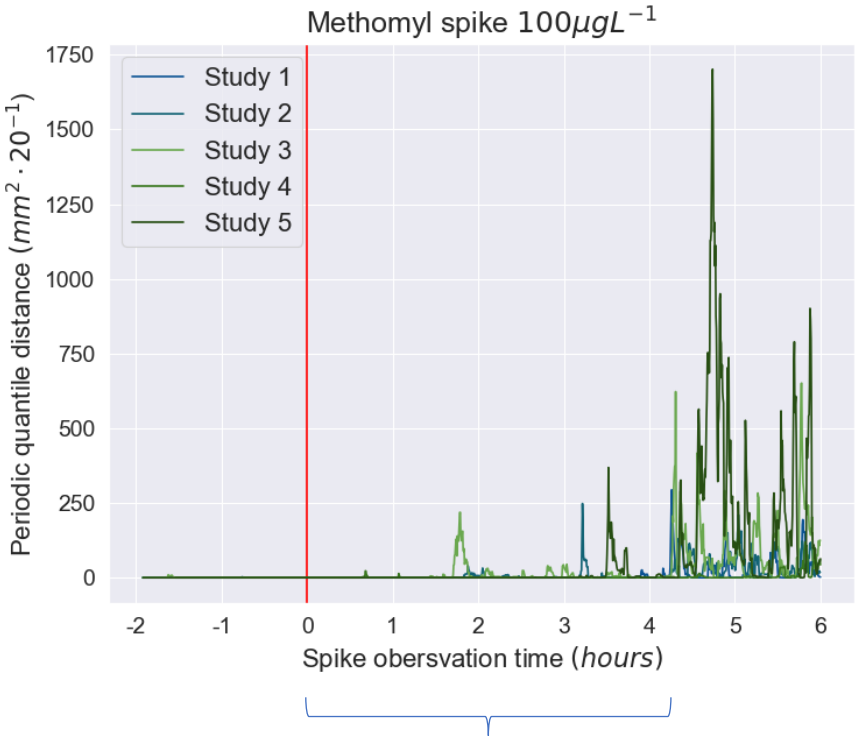

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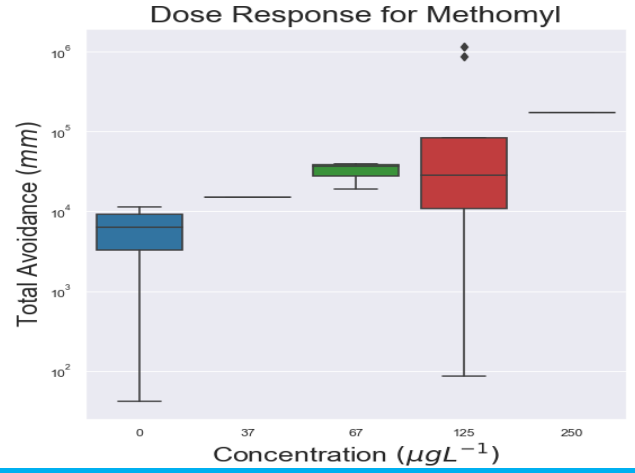
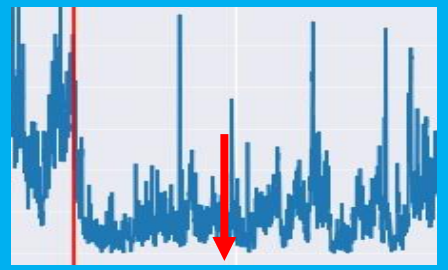
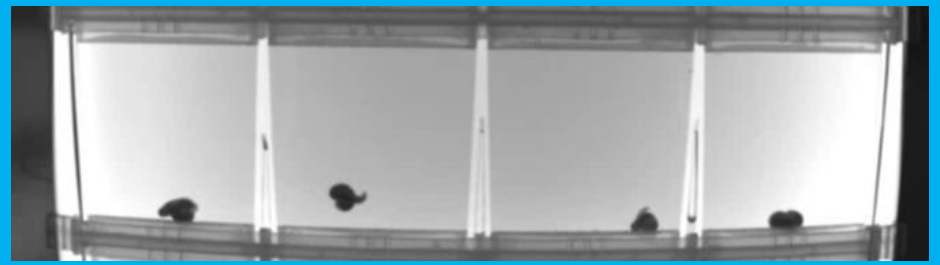


- Multi-species advantage, erpobdella response :



Immediate drop in activity to zero movement



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CEC exposition multi-spikes

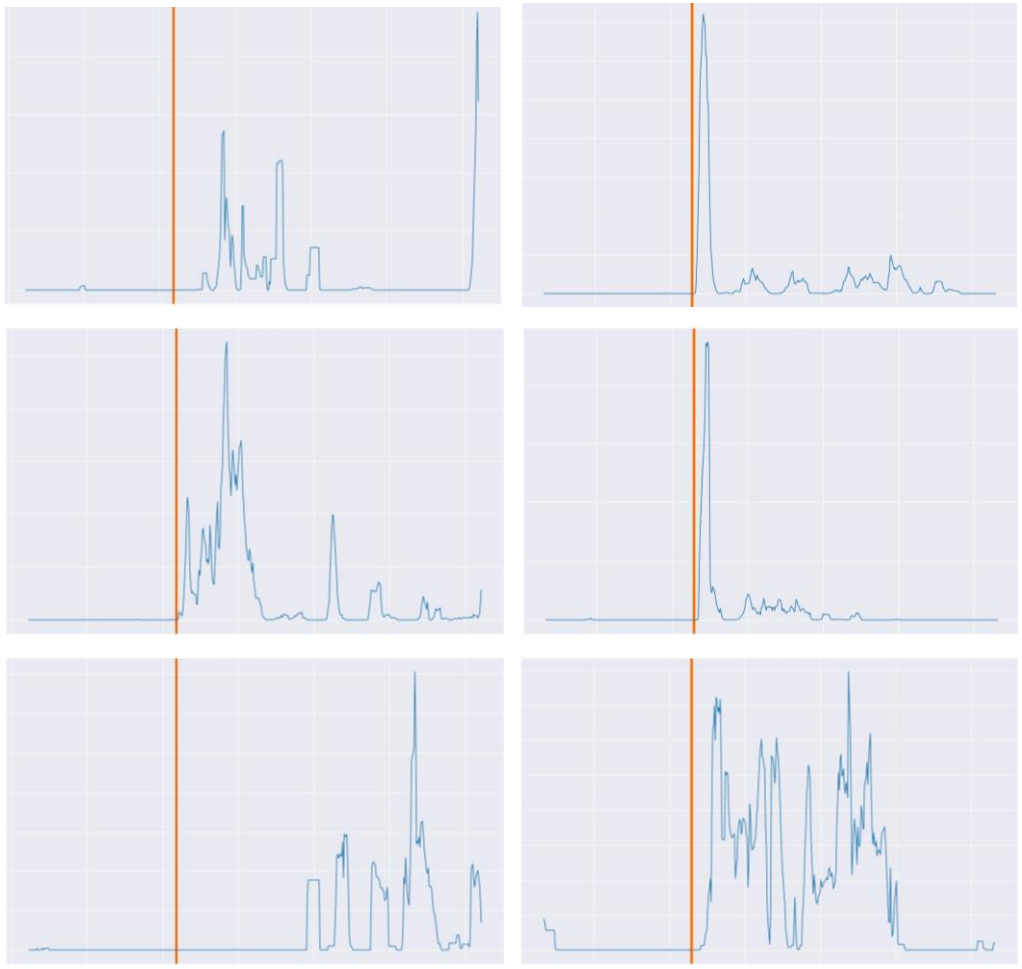
Fingerprint detection

- Better response definition through multi-dimensional signal

Response patterns

- Initial classification method developed for a group of substances :
  - ACP fonctionnelles
  - Classification de courbes

- Further clustering may reveal links between contaminants (>100 reponses)



Varying multispecies response for two solvent micropollutants

Current classification models

Curve description

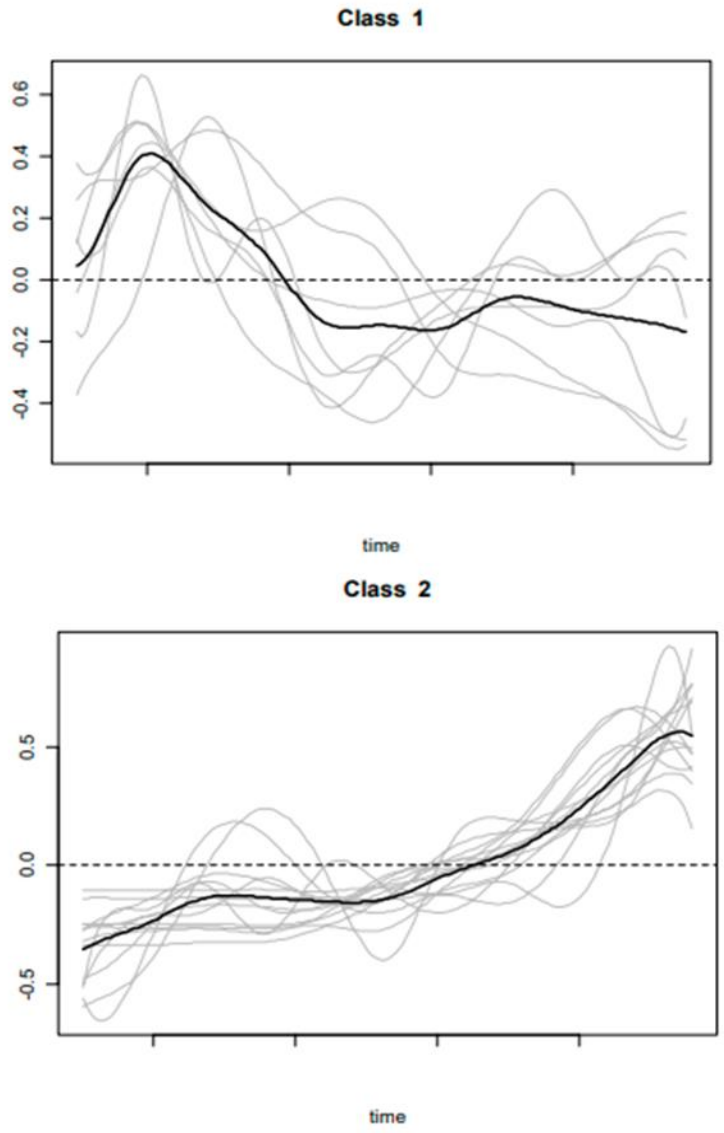
- Functional Principal Component Analysis (FPCA)
- Curve Classification methods

Machine Learning

- Supervised classification
  - Type random Forest
- Unsupervised classification
  - Type hierarchical clustering

Future work.

- Neural network techniques



Classes of mean activity response for the model substances

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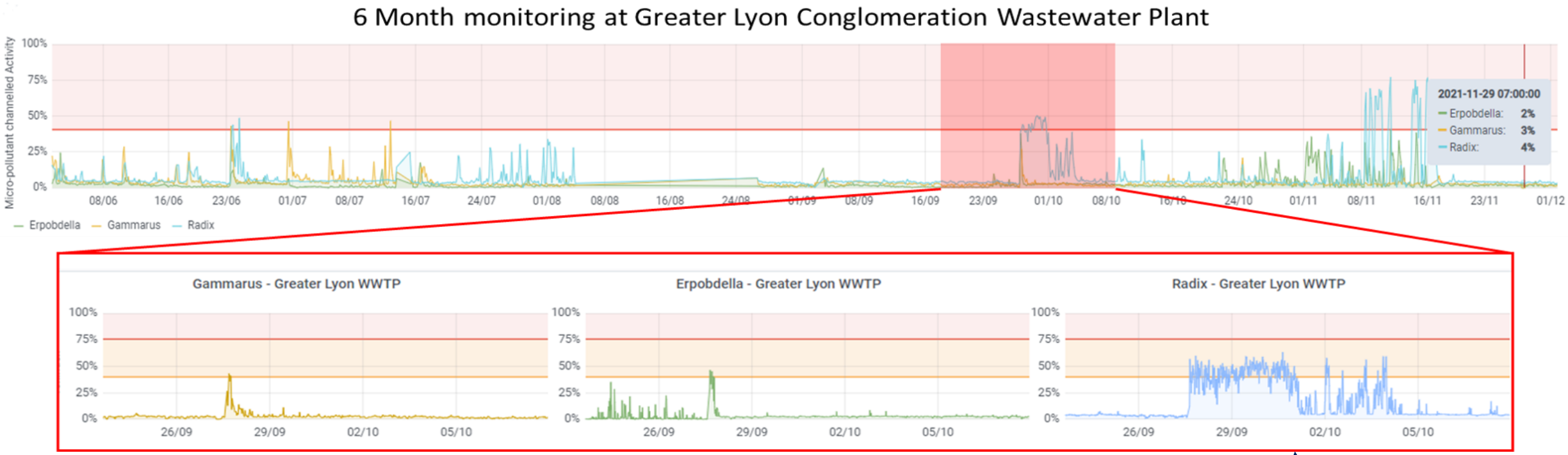
Critical moment detection in industry

Observation over long periods in WWTPS



- Difference in activity profile for the 3 species
- **Behavioural fingerprinting?**

Merci

Directeurs	-	A. Chaumot, JB Aubin, JL Bertrand-Krajewski, O. Geffard, A. Decamps, D. Neuzeret
Equipe expérimentale	-	L. Garnero, H. Queau, K. Montalbano, T. Cavanna, C. Grant
Equipe technique	-	M. Dauphin, A Deletang,

Questions?