Life cycle assessment at the scale of France on Human health and aquatic environment of micropollutants released by wastewater treatment plants

Quentin Aemig, Dominique Steyer, Arnaud Hélias

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Micropollutants : an old story !

Industries
Cities

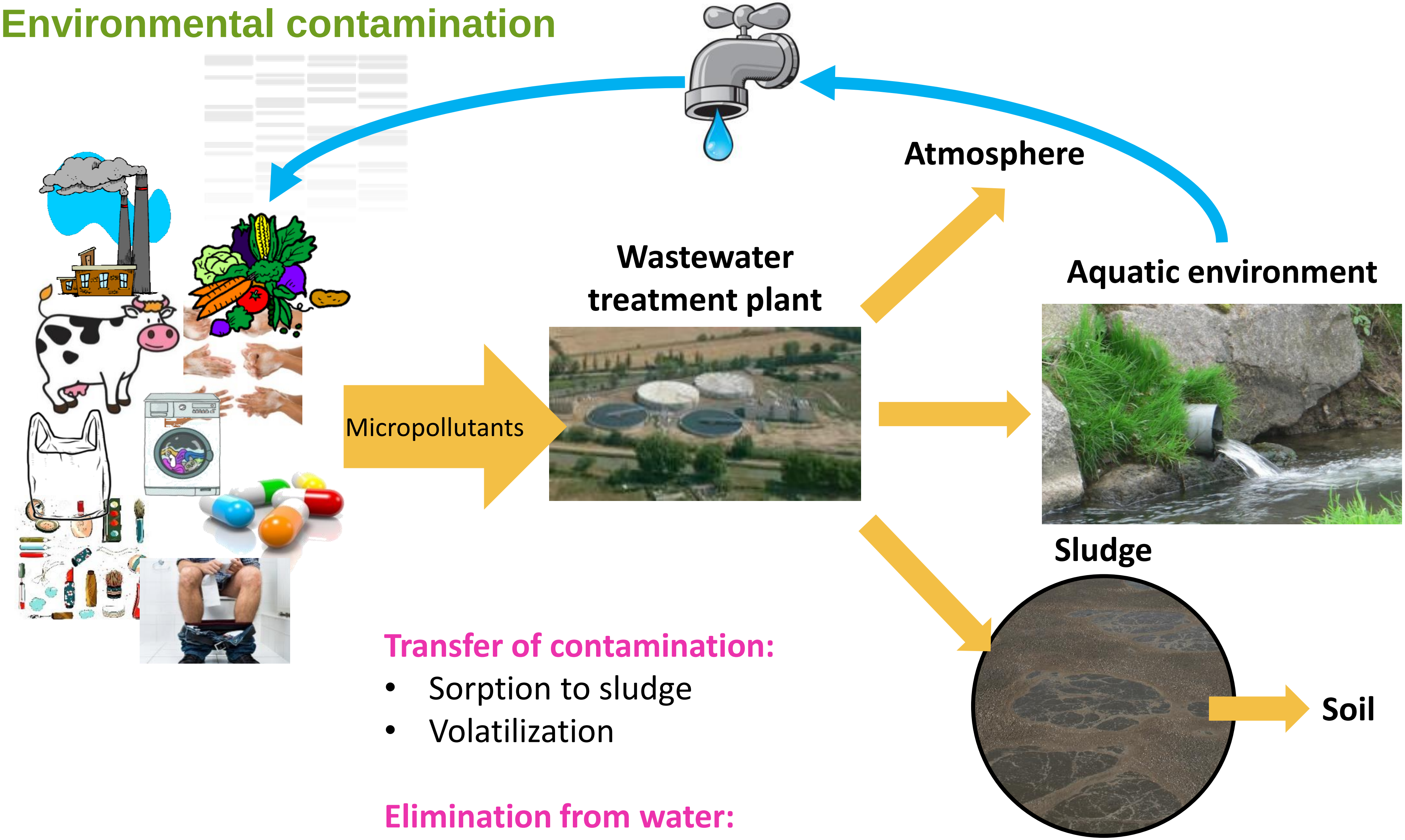
Agriculture
Food

Plastics
Drugs
Household products
Cosmetics

1970 1980 1990 2000 2010

Briand et al. 2018

Environmental contamination



Transfer of contamination:

- Sorption to sludge
- Volatilization

Elimination from water:

- Physicochemical or biological transformation
- Mineralization

Adapted from : Barret M., 2009.

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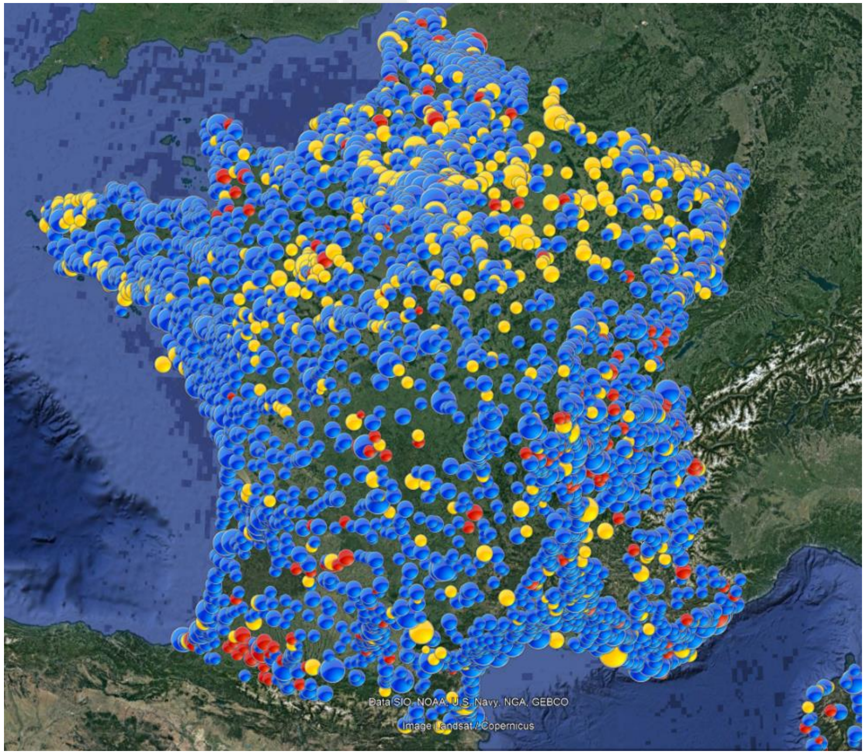
Environmental contamination



More than 20,000 WWTP in France:
Each day, around 14 millions m^3 of water containing a huge diversity of micropollutants released in the environment

What is the potential impacts of these micropollutants on Human health and aquatic environment?

Substances selection

European policies

Monitoring in aquatic environment

Studies with **quantification in WWTP effluents**

Studies considering **emerging contaminants**

Water Framework Directive

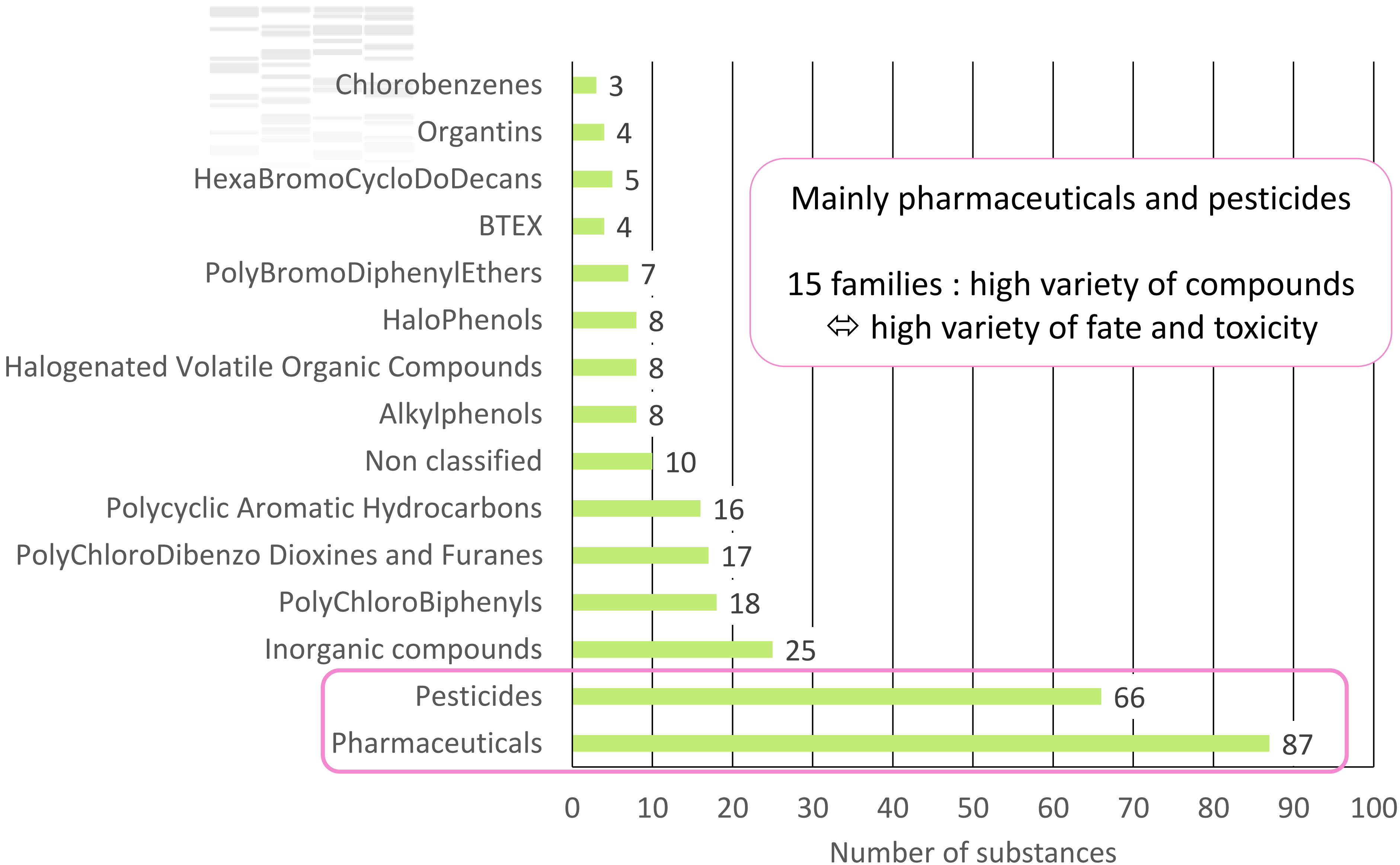
French National Action RSDE

French projects and studies

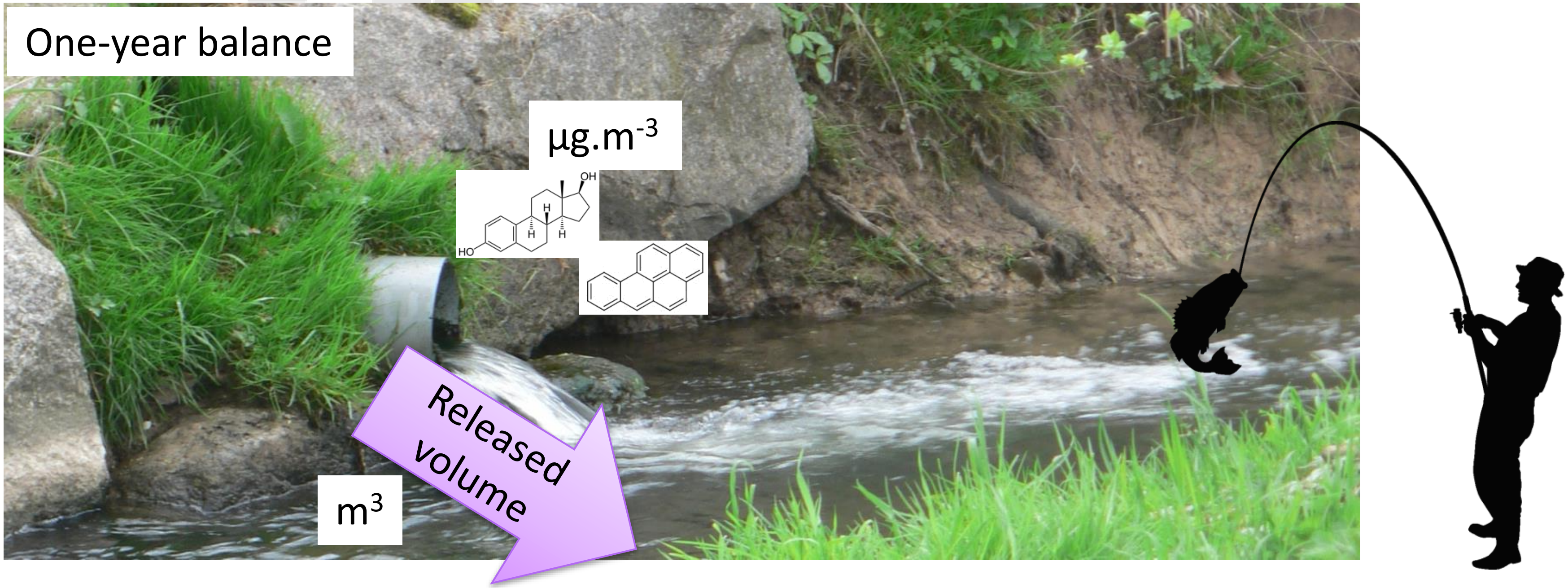
Expert assessment of Synteau and INRA

286 substances selected: 261 organic compounds and 25 inorganic compounds

Selected substances



Calculation



Concentration
x
Volume
=
Mass released to aquatic environment

Potential impacts on Human health and aquatic environment

x characterization factor (USEtox 2.1 ®)

Concentrations and annual masses released to aquatic environment

Data representative of the whole WWTPs

C° < Quantification Limit = QL/2

$\overline{C^\circ}$ = geometric mean + 95 % confidence interval

One-year volume = 5 billion m^3

One-year mass

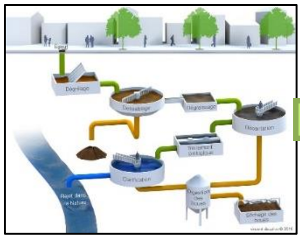
=

one-year volume x concentration

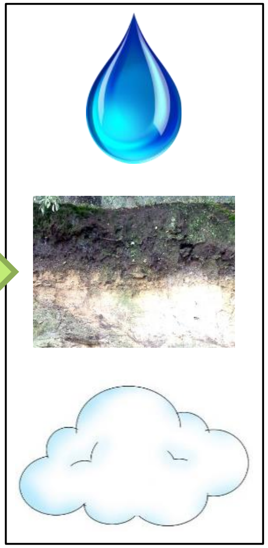
Characterization factor

USEtox®

Reference method in Life Cycle Assessment for assessing human toxicity and freshwater ecotoxicity

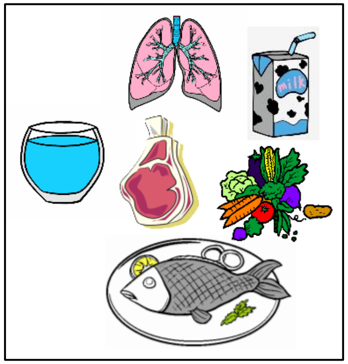


Emission



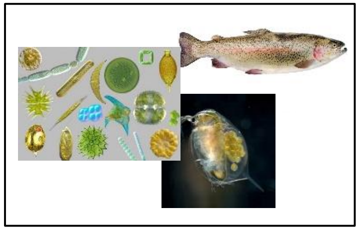
Fate

Intake fraction



Human toxicity characterization factor:
$DALY.kg_{emitted}^{-1}$ in fresh water

Exposure



Ecotoxicity characterization factor:
$PDF.m^3.d.kg_{emitted}^{-1}$ in fresh water

DALY = Disability Adjusted Life Years = number of life years « lost » because of illness, handicap or death

$PDF.m^3.j$ = Potentially Disappeared Fraction x cubic meter x day = fraction of species potentially disappeared integrated to volume and time

Potential impacts calculation

Potential impact

=

one-year mass x characterization factor

Total impact = ∑ impacts

Organic and inorganic compounds treated separately:

≠ concentrations

≠ USEtox 2.1 ®

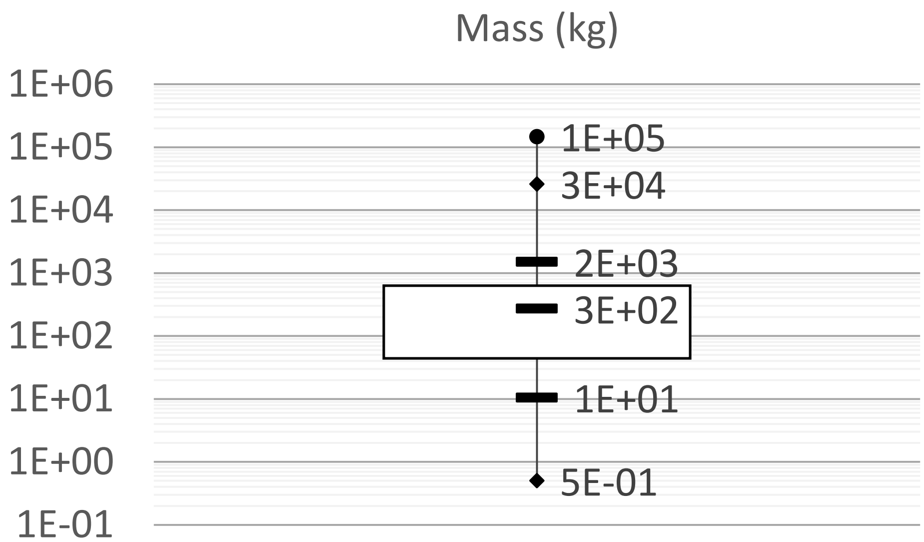
≠ fate

Available data and selecting

261 organics (100 %)	**List**	**25 inorganics (100 %)**
225 (86 %)	Compounds with at **least one concentration available**	**25 (100 %)**
153 (59 %)	Compounds with more than **10 % data > QL**	**24 (96 %)**

- Selecting allows to eliminate:
  - Non precise data
  - Substances poorly quantified with high QL which overestimate concentration

153 organic micropollutants mass released into aquatic environment



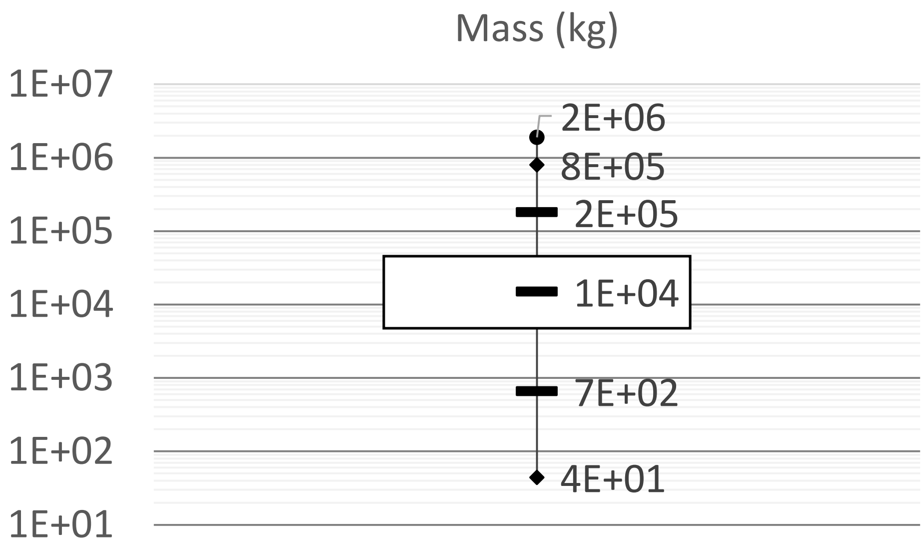
- Concentrations range : 0.1 $ng.L^{-1}$ to 5 $\mu g.L^{-1}$
- **90 % micropollutants: $ng.L^{-1}$ < C° < $\mu g.L^{-1}$**
- Mass range : kg to tons
- **∑153 ≈ 150 tons**

- 15/153 micropollutants represent 70 % of the mass:
  - **9 pharmaceuticals ⇔ 48 % of mass:**

    atenolol, carbamazepine, furosemide, sotalol, chlordiazepoxide, hydrochlorothiazide, ranitidine, irbesartan, valsartan
  - **6 other compounds ⇔ 22 % of mass:**

    tetrachloroethylene, trichloromethane, dichloromethane, NP1EC, DEHP, AMPA

24 inorganic substances mass released into aquatic environment

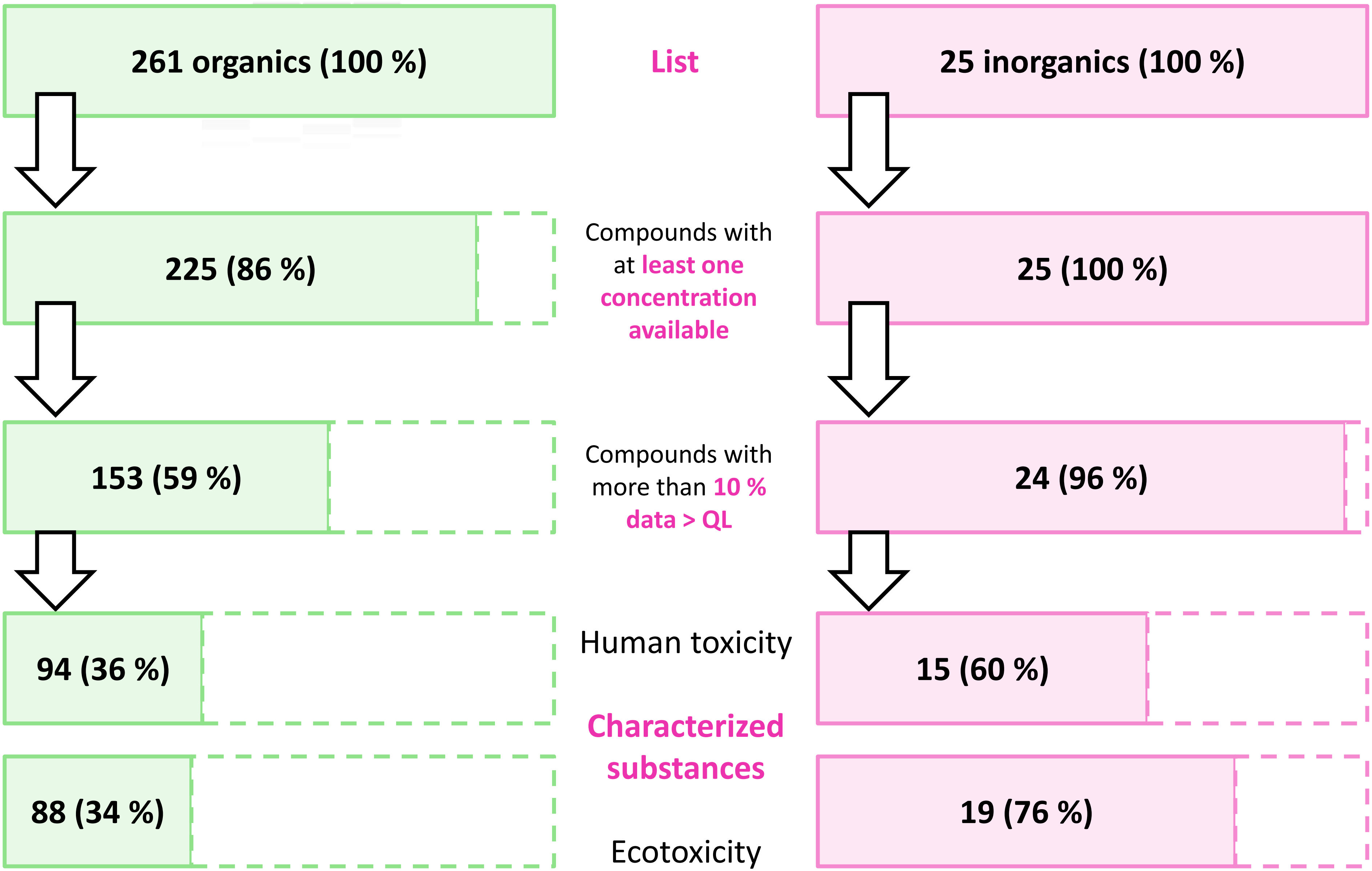


- Concentrations range : 9 ng.L^{-1} to 200 µg.L^{-1}
- **90 % micropollutants: 0.1 < C° < 40 µg.L^{-1}**
- Mass range : 10^1 kg to 10^3 tons
- **∑24 ≈ 2 000 000 tons**

- 5/24 micropollutants represent 85 % of the mass :
  - Iron, boron, aluminum, zinc and manganese

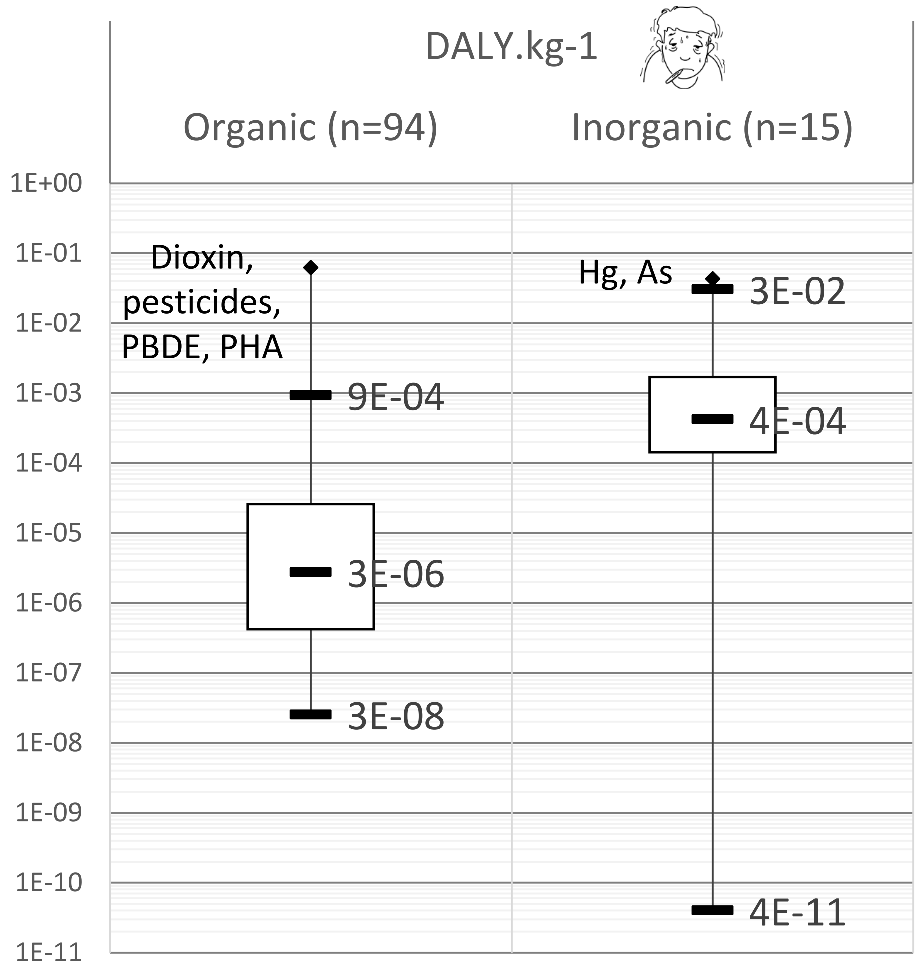
- Concentrations and mass in general **higher than** those of **organic micropollutants:**
  - Use in wastewater treatment (Fe)
  - Naturally present in water
  - No biodegradation

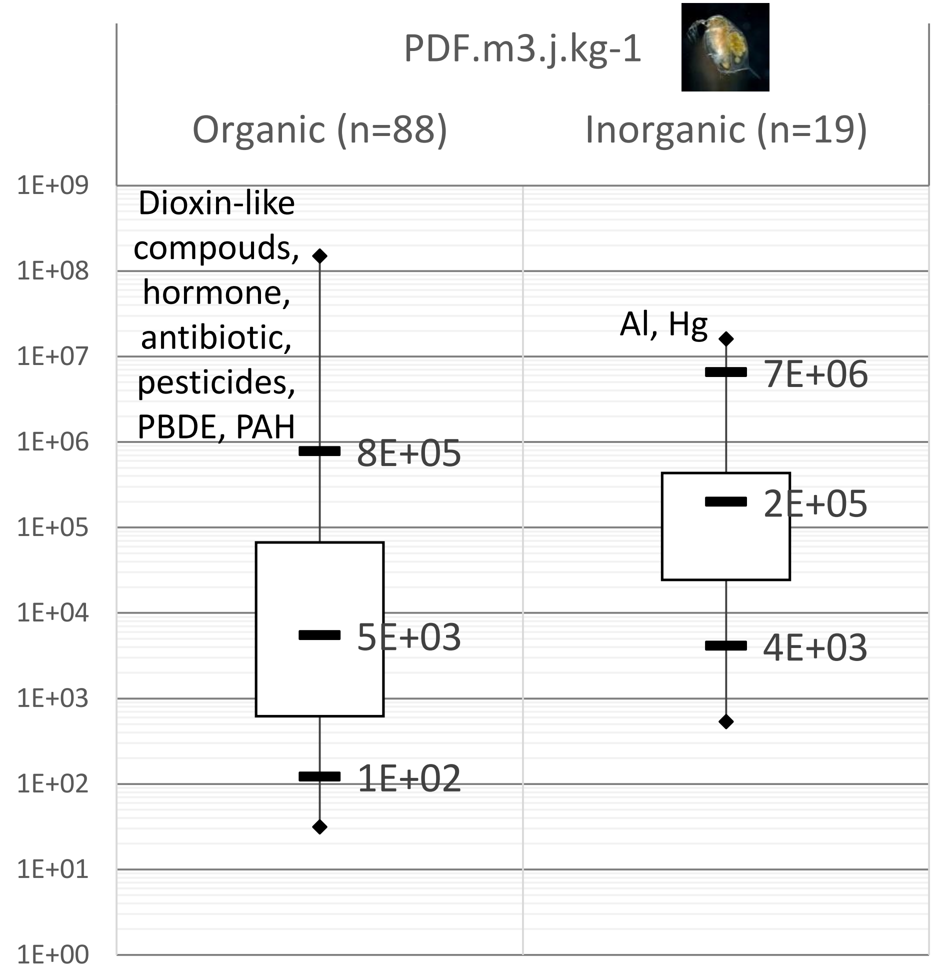
Available data and selecting



Lack of characterization factors (especially for pharmaceuticals)

Characterization factors

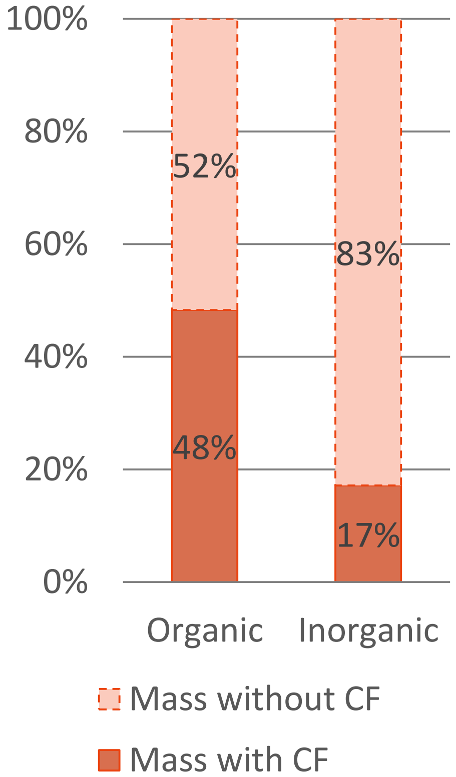


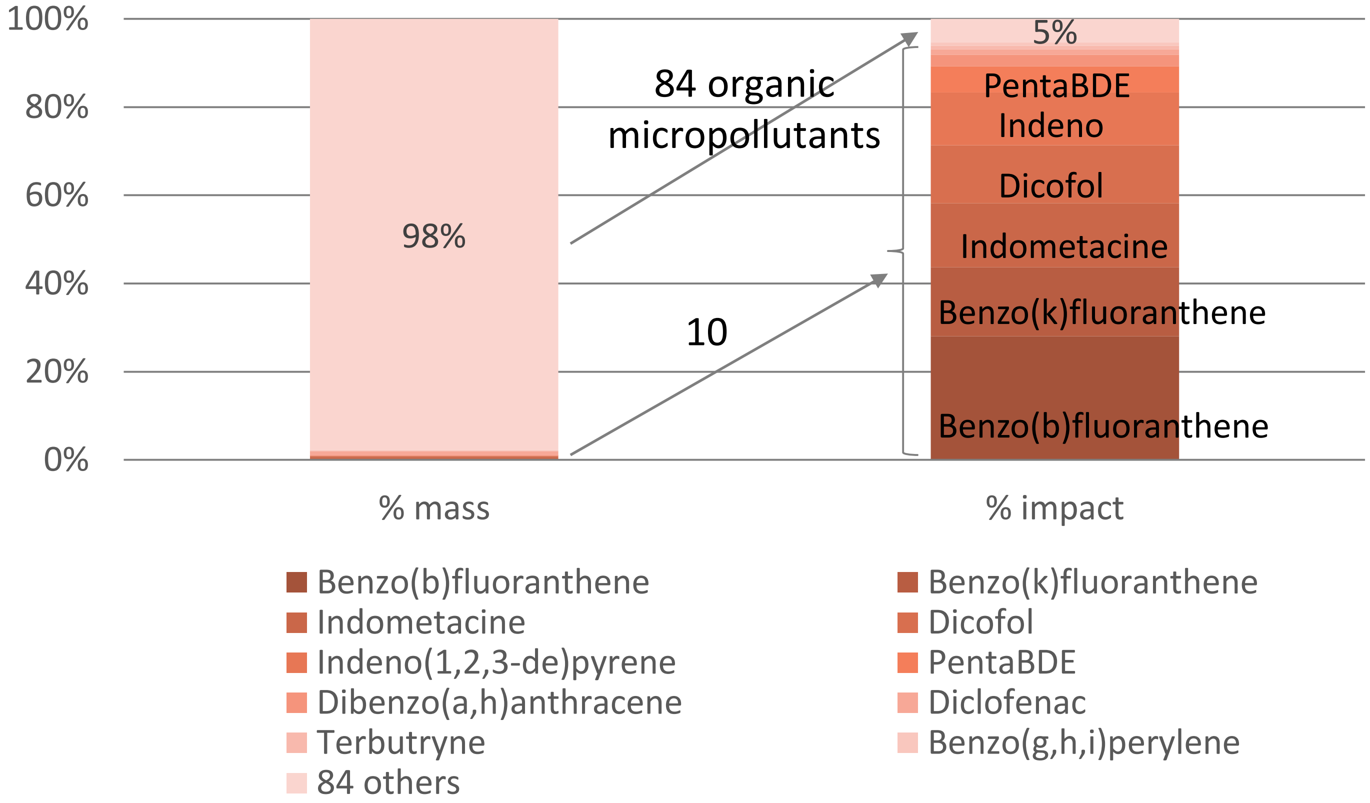


- **Inorganic micropollutants CFs > Organic micropollutants CFs** in general (no biodegradation)
- Inorganic micropollutants CFs **less precise**
- **Fate**: use of mean speciation for inorganic compounds

Potential impacts of micropollutants on Human health

- **9/15 organic micropollutants with highest mass have CFs** (atenolol, carbamazepine, furosemide, sotalol, hydrochlorothiazide, tetrachloroethylene, trichloromethane, dichloromethane and DEHP)
- **1/5 inorganic micropollutants with highest mass has CF** (Zn)





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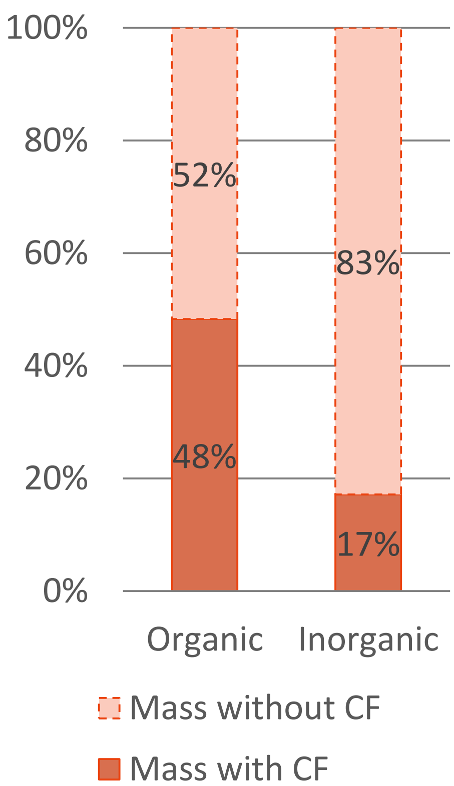

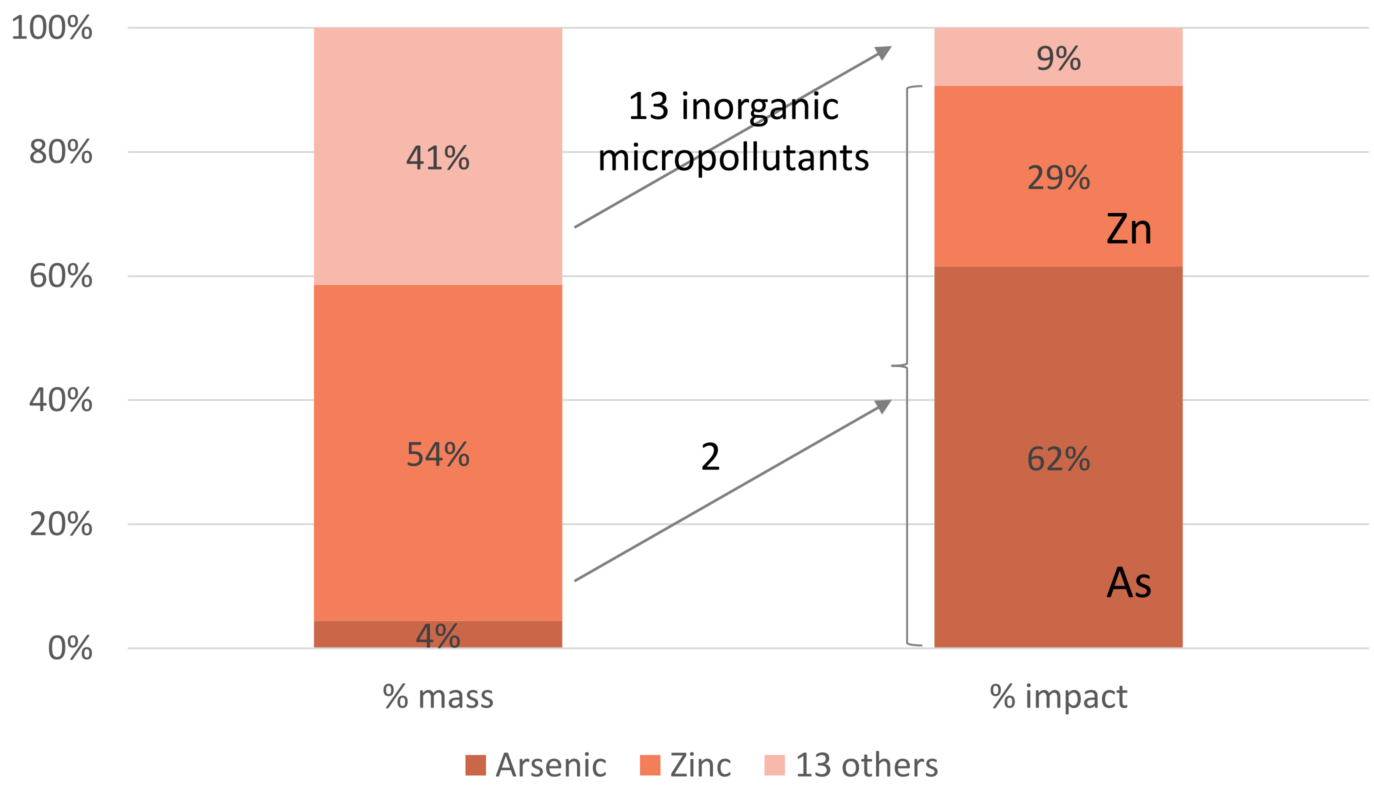

Potential impacts of micropollutants on Human health

- **Toxicity is very important when estimating potential impacts**

	94 organic micropollutants	15 inorganic micropollutants
Potential impact on Human health (DALY – number of year lost)	6 (≈ 3 s/year/inhabitant)	818 (≈ 6.4 min/year/inhabitant)

- **Potential impacts on Human health low**
- No direct exposure (dermal exposure not considered in USEtox ®)
- Drinking water treatment before consumption (ozonation, active carbon)
- Missing CFs for **emerging compounds** (31/59 pharmaceuticals) and for **highly concentrated inorganic micropollutants** (iron, aluminium, etc.)

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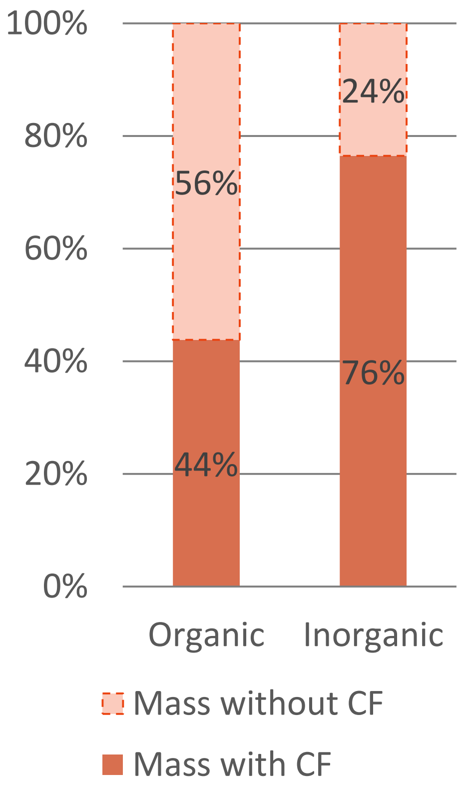
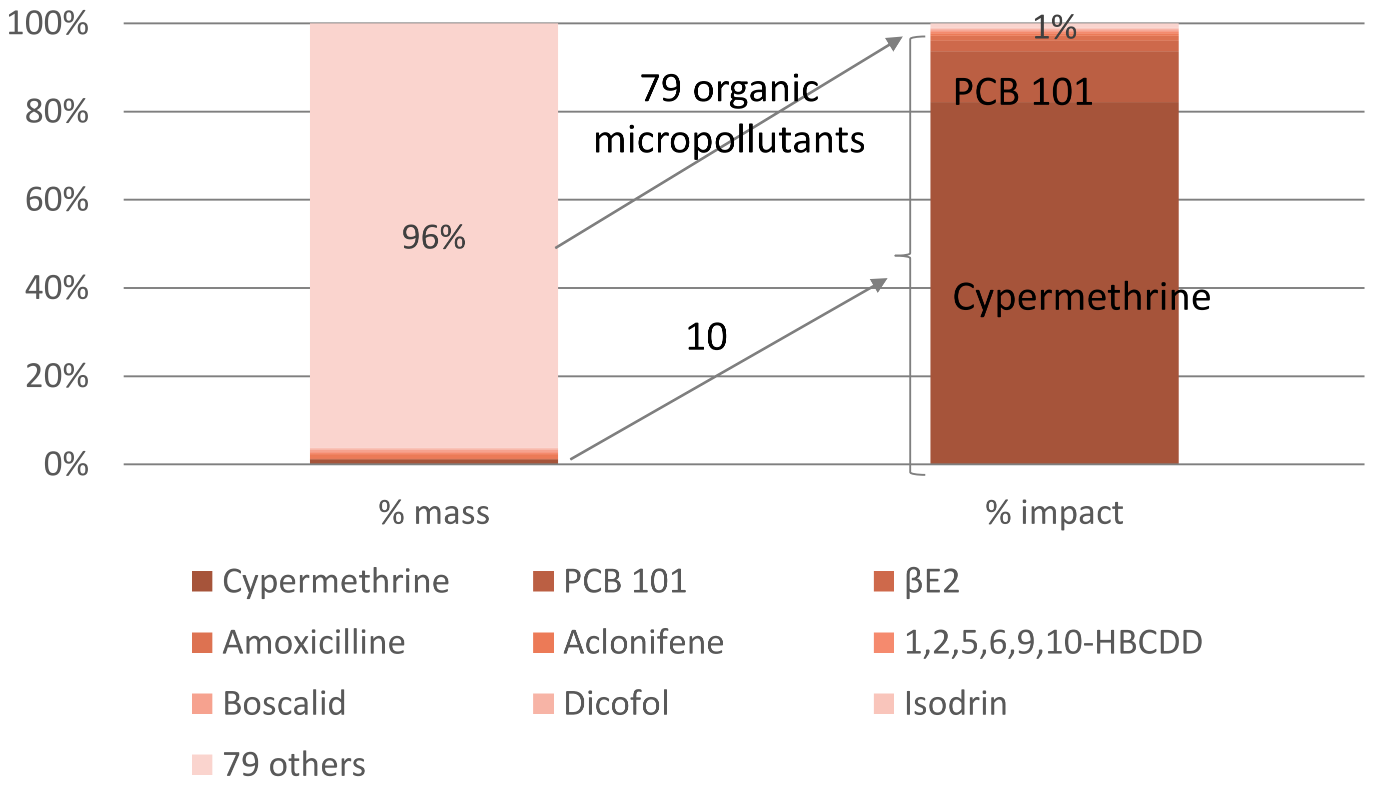
Potential impacts of micropollutants on Aquatic environment

- **8/15 organic micropollutants with highest mass have CFs** (sotalol, atenolol, carbamazepine, tetrachloroethylene, dichloromethane, trichloromethane, NP1EC, DEHP,)
- **4/5 inorganic micropollutants with highest mass has CF** (iron, aluminum, zinc, manganese)





Potential impacts of micropollutants on Aquatic environment

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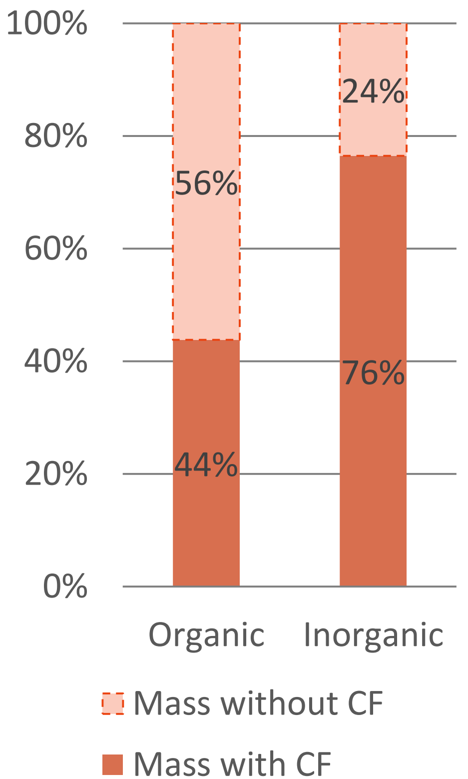

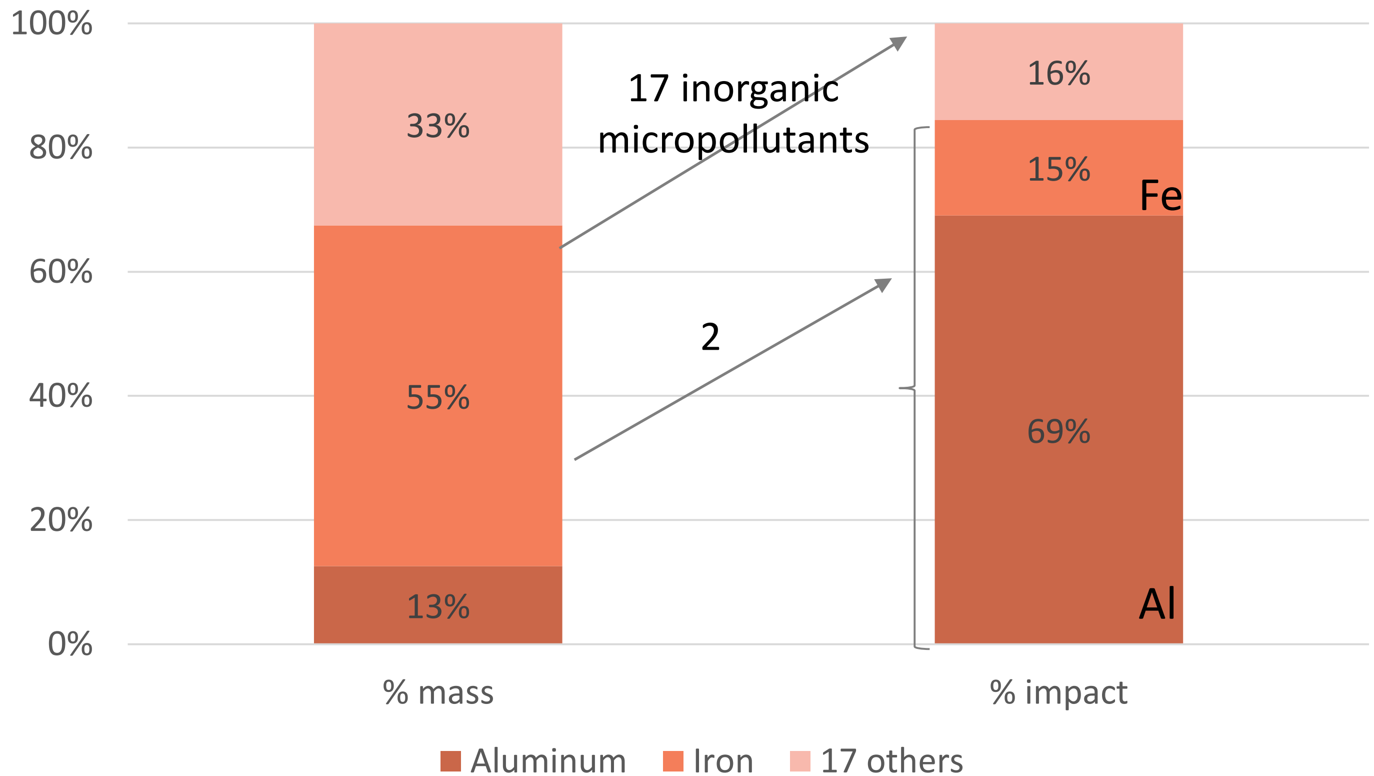

Potential impacts of micropollutants on Aquatic environment

	88 organic micropollutants	19 inorganic micropollutants
Potential impact on Aquatic environment (10^9 PDF.m^3.d)	61 (≈ 0.1 species potentially disappeared/year)	2 858 (≈ 6 species potentially disappeared/year)

- **Micropollutants does have an impact on aquatic environment**
- WWTP effluents versus **other emissions in aquatic environment?**
- Not taken into account: **antiobioresistance, endocrine disruption, cocktail effect, etc.**
- Number of studied compounds <<< **number of existing compounds**

Conclusions

- Potential impacts:
  - **Low on Human health**
  - **Noticed on Aquatic environment → comparison needed**

- **Toxicity generally more important than concentration for impacts**

- **Impacts calculated with 1/3 of selected micropollutants**:
  - Lack of concentration data
  - Lack of toxicological and ecotoxicological data

- With our data, possible to estimate impacts linked to micropollutants in WWTP effluents

- **Restricted number of substances** compared to existing ones

- **Restricted knowledge** on the effects on Human health and aquatic environment

- **Nanomaterials, nanoplastics, resistance genes** present in WWTP effluents not taken into account

- **Mean data** at the scale of France and only **additive effects** considered

Perspectives

- **Comparison at WWTP scale**:
  - Other emissions (air, sludge)
  - Different treatments (e.g. tertiary treatments)

- **Comparison at catchment basin scale**: emissions from WWTP effluents, agriculture, industries, etc. ➔ **identify the main source of impact**

- **Comparison** of concentrations/masses **with values from other countries** (Europe, United States)

- Toxicity and LCA studies to **obtain missing characterization factors**

Thank you to Synteau for their scientific and financial support…

… and thank you for your attention !

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