



RIVER BED-LOAD SEDIMENTS AND SUSPENDED PARTICLES: TWO DIFFERENT WORLDS FOR TRACE METALS

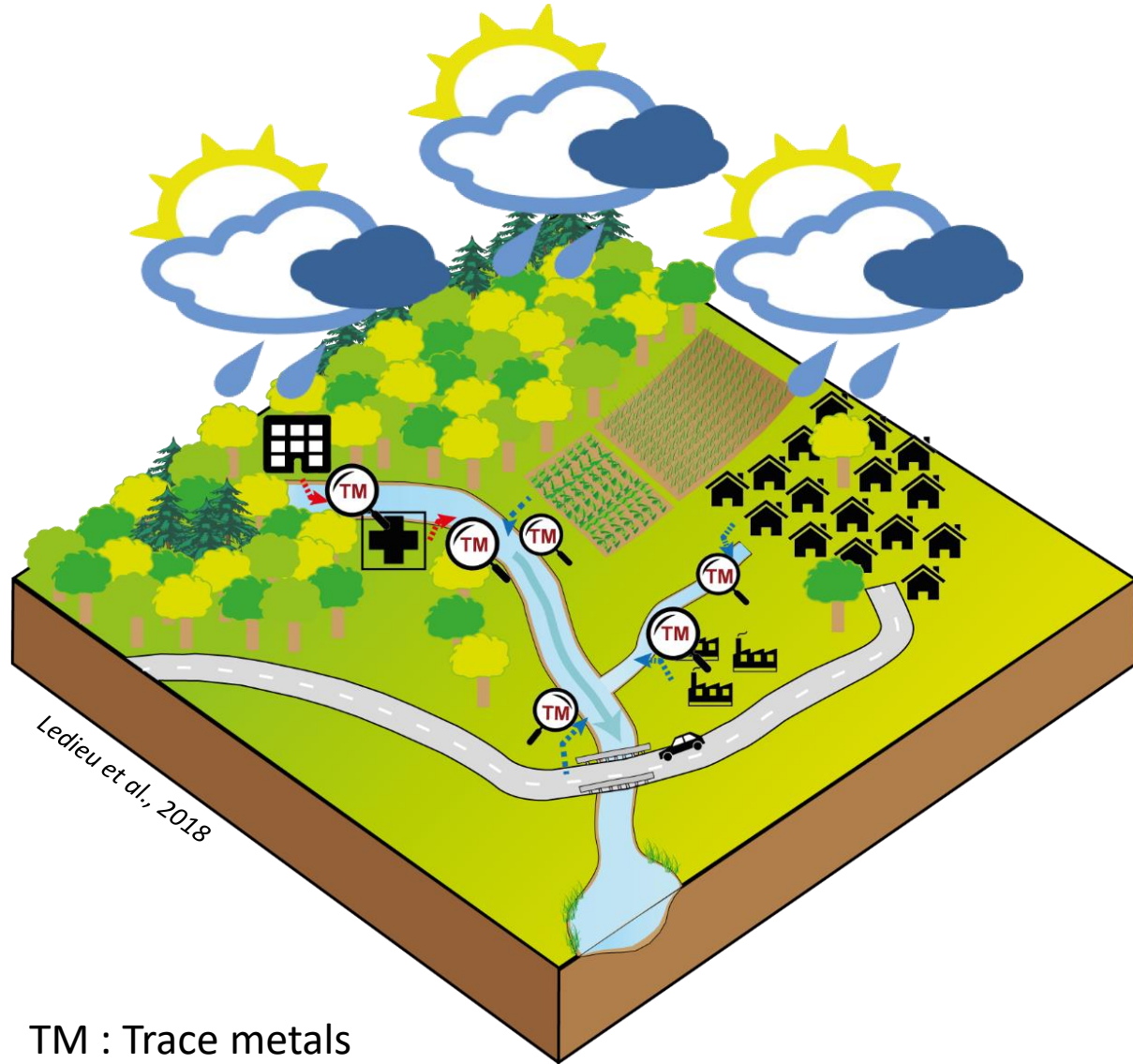
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Global context

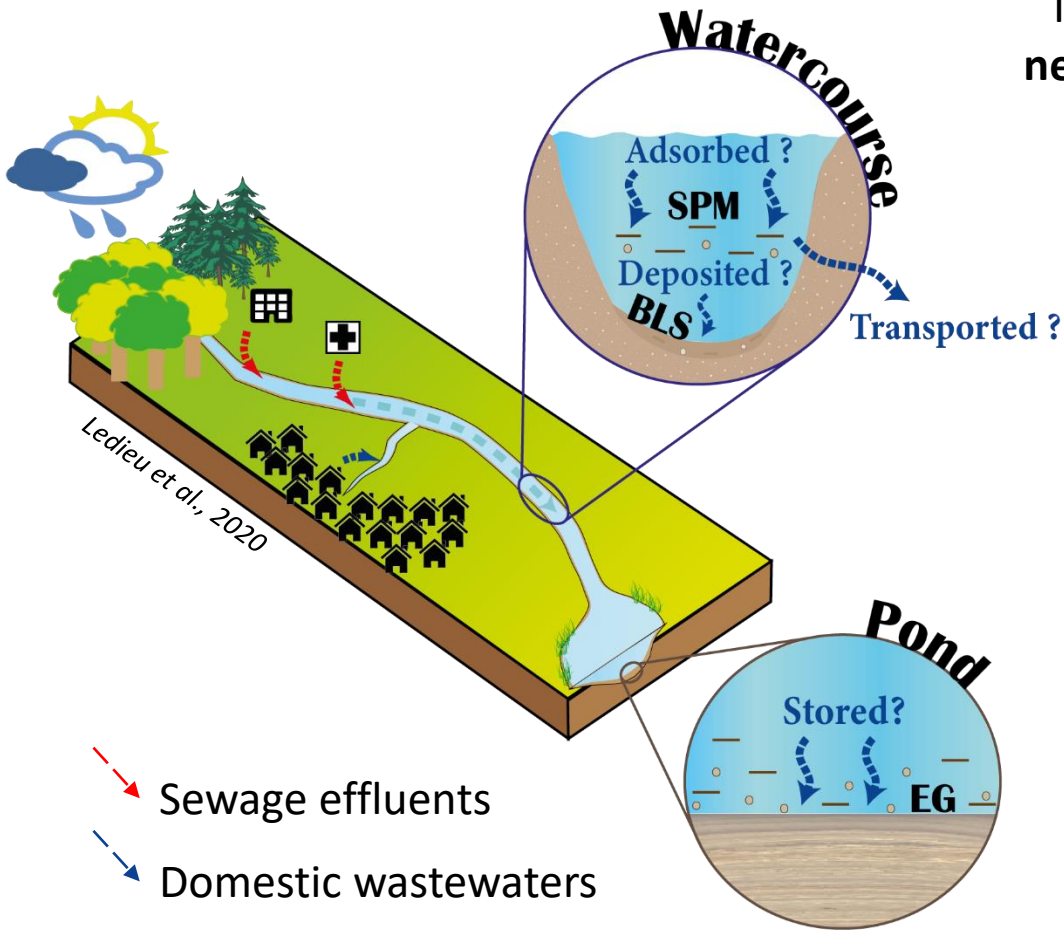


Widely used for anthropogenic activities, trace metals are highly emitted in the environment through **point** and **non-point sources** (Thévenot et al., 2009)

The **runoff** on **urban areas** constitute a **major source** (Briand et al., 2018) and expose several problems : **urbanisation is increasing** and this **source** is often **non-point**

Trace metals were therefore included in the targeted compounds by the Water Framework Directive

Scientific questioning



Trace metals are known to have an **affinity** with **particulate phases**, the **need to evaluate this fraction** was thus already demonstrated (Sutherland, 2000)

Fine grain-size particles (Grosbois et al., 2012) as well as **organic matter** and **metal oxides** (Bibby and Webster-Brown, 2006) can have a **role** in trace metals **sorption**

Being highly **toxic** and having long **residence time**, trace metals behavior **need to be well understood** in order to manage the **risks assessed** by these contaminants (Sharley et al., 2016)

One of the remaining question is **what compartment** of a river is the **better to monitor these risks**, and if there are **significant differences** between them (Mokwe-Ozonzeadi et al., 2019)

Are the parameters driving trace metals spatio-temporal dynamics in the different particulate phase compartments the same ?

Study site

Egoutier stream :

A bedrock composed by **Sologne sands and clays** and **Orleanais sands** (Berger and Desprez, 1969)

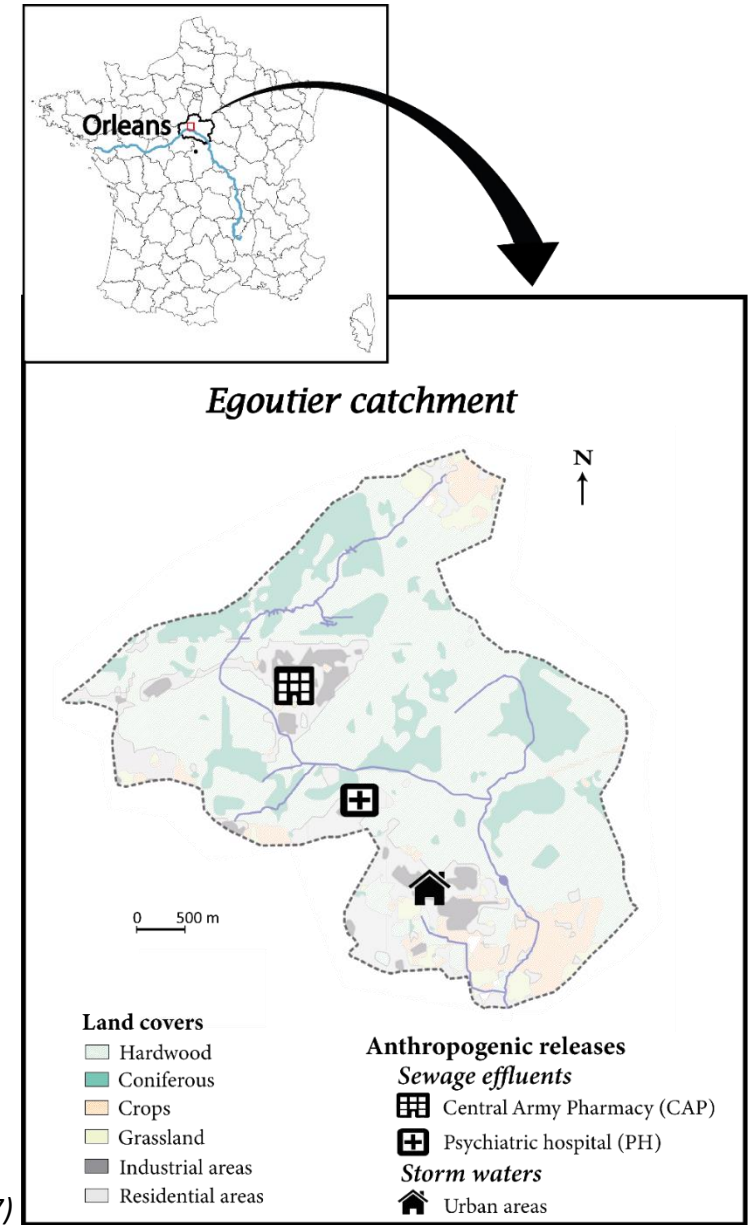
Tributary of the **Loire River** developed on **hydromorphic subsoils** (Soucémariadin and Verbèque, 2007)

Soil types are mainly **Redoxisols** (Soucémariadin and Verbèque, 2007)

Collects several anthropogenic effluents :

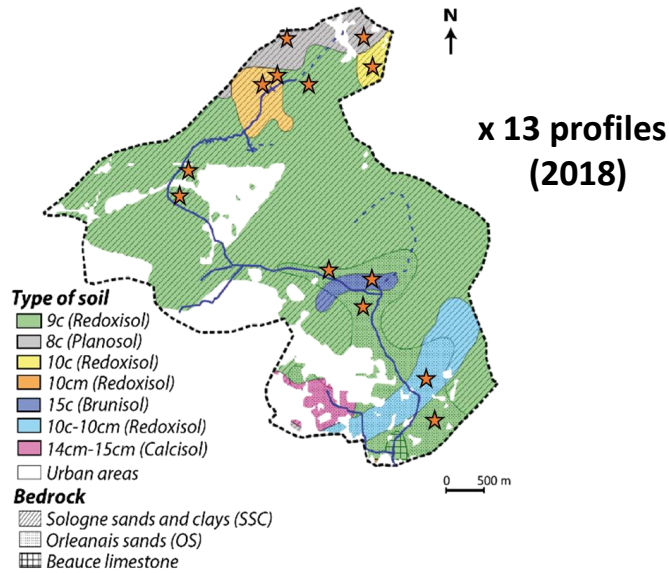
- ➔ • Two sewage effluents :
 - From a Central Army Pharmacy (CAP)
 - From a psychiatric hospital (PH)
- ➔ • One urban storm waters effluent

◻ Discharge into a **pond** (the Beulie pond) in its central part

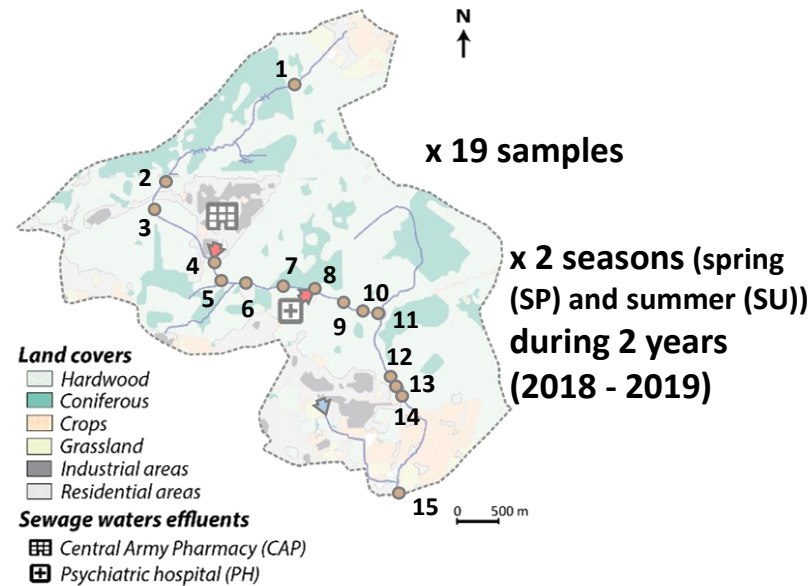


Sampling

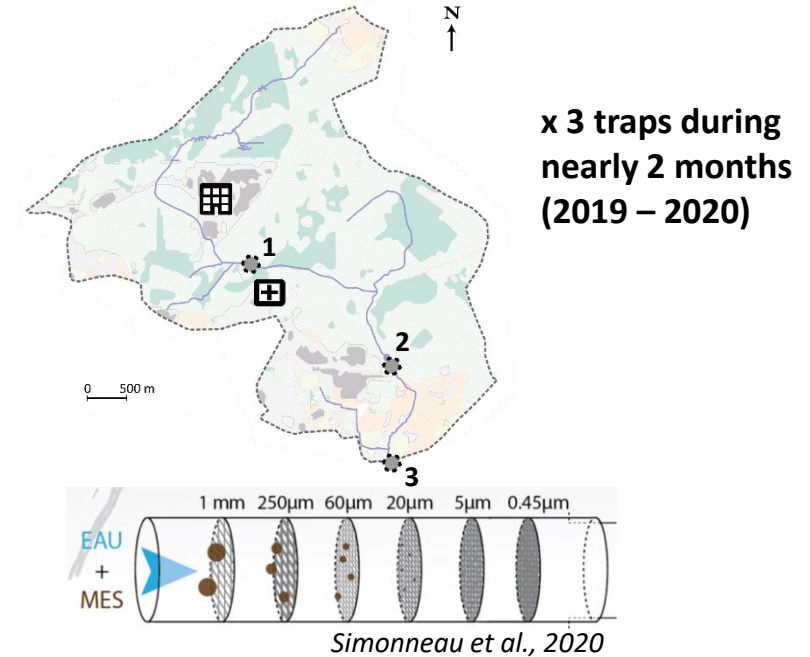
★ 1. Soil surveys: background levels



● 2. Bed-load sediments: accumulated levels



⚙ 3. Suspended particulate matter : transported levels



Different compartments sampled and analysed :

- **Soil types** to measure the **geochemical background**
- **Bed-load sediments** to quantify **contamination levels** and **accumulation zones**
- **Suspended particulate matter** to visualize **transported contaminants** orders of magnitude and **transfer distances**

Methods

In this context, the solid samples were analysed through different methods to quantify trace metals and their influencing factors

Global geochemistry and trace metals contents → *X-Ray fluorescence* → *Fe, Mn, Pb, Zn, Cu (µg/g)*

Characteristics of the particulate materials were also measured as they take role into trace metals sorption and transportation *(Bibby and Webster-Brown, 2006)*

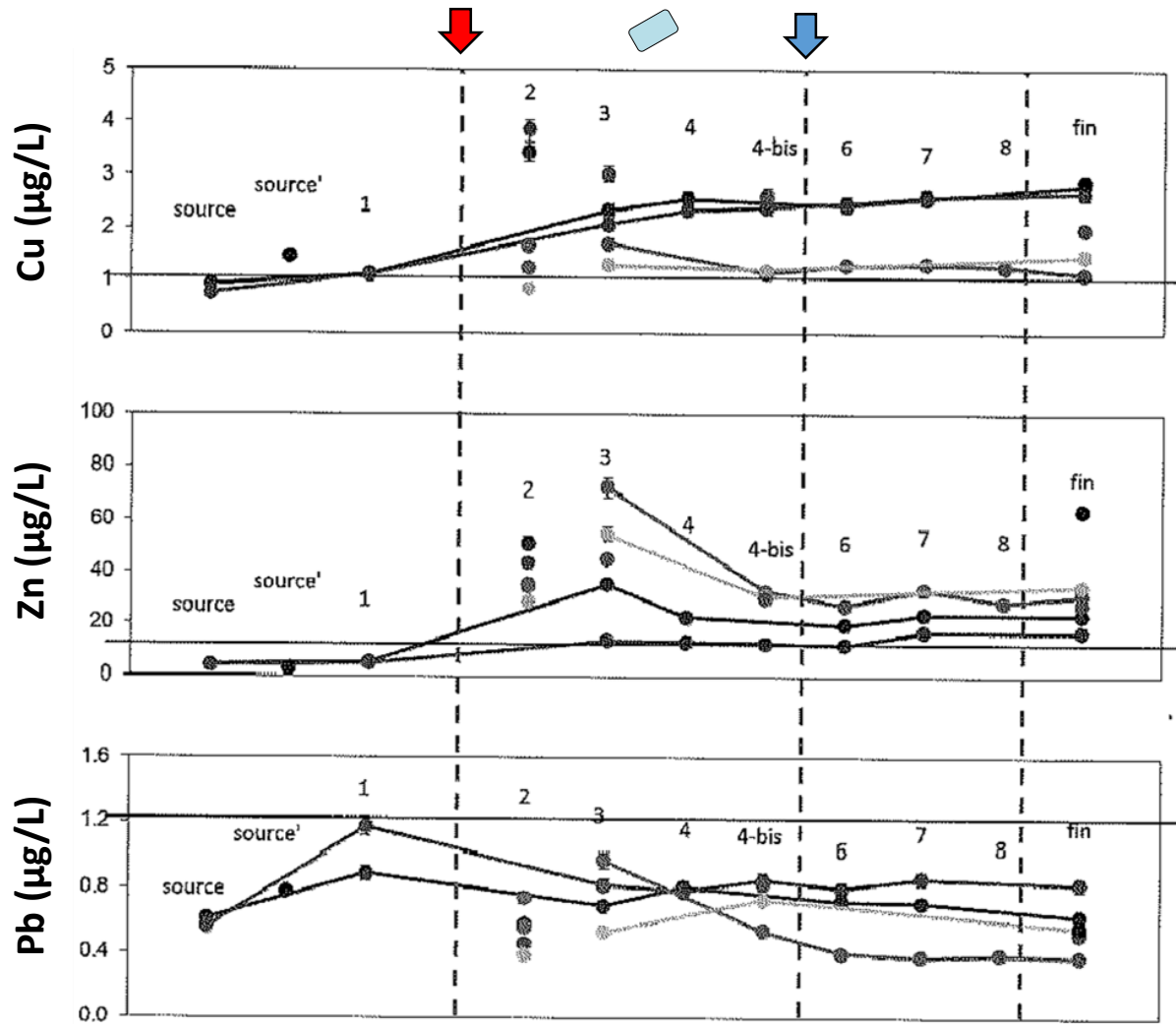
Mineralogy → *X-Ray diffraction*

Organic matter content → *Rock-Eval pyrolysis* → *TOC (%)*

Grain-size distribution → *Laser particle sizer* → *0 – 2 µm, 2 – 63 µm, 63 – 250 µm, 250 – 1800 µm (%)*

What is already know

Dissolved phase in the Egoutier stream :



Desaulty and Millot, 2017

Contamination levels : **Pb < Cu < Zn**

Variability : **Pb < Cu < Zn**

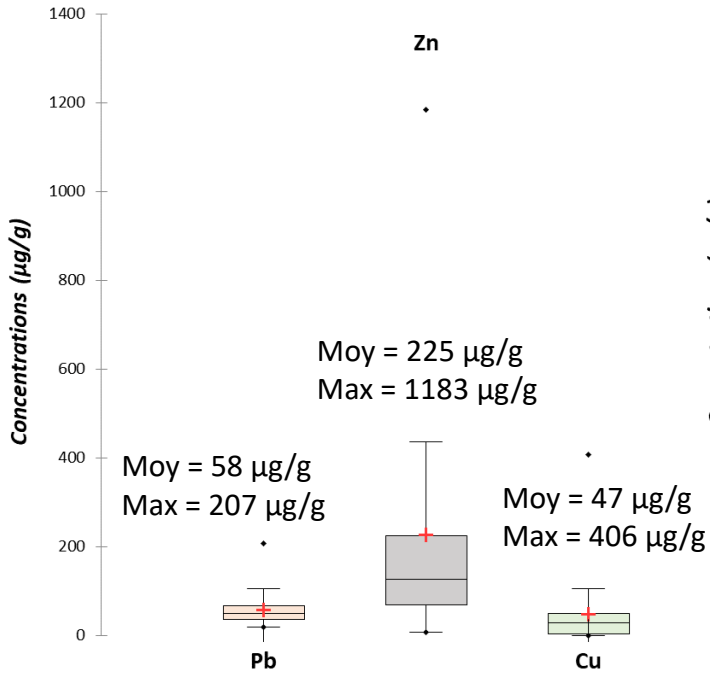
Anthropogenic releases :

- **Sewage effluents** are sources of **Cu** and **Zn**
- Impact of **urban storm waters** not significantly appear

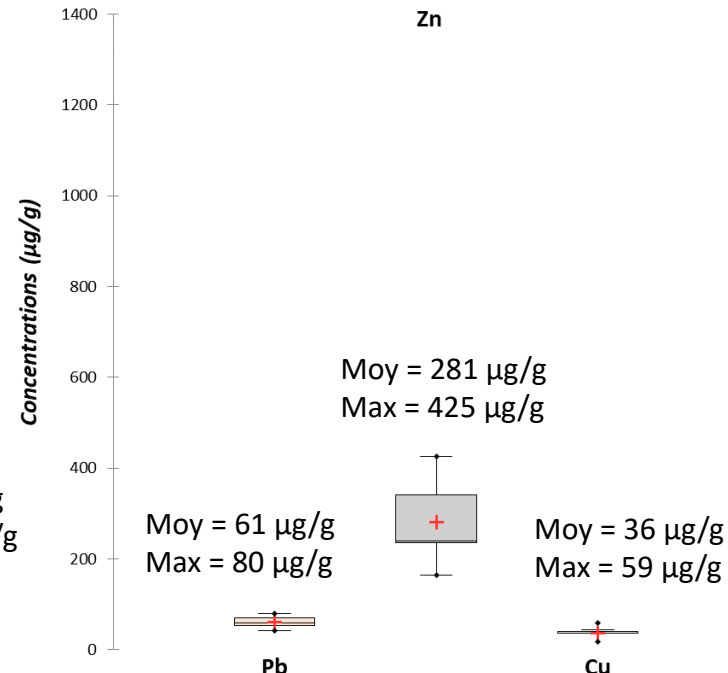
Results and discussion

Soil : $[Pb]_{moy} = 55 \mu\text{g/g}$; $[Zn]_{moy} = 36 \mu\text{g/g}$; $[Cu]_{moy} = 2 \mu\text{g/g}$

● *Bed-load sediments*



⚙️ *Suspended particulate matter*



Like in the dissolved phase, only **Zn** and **Cu** mean concentrations evidenced **anthropogenic contributions** in **both compartments**, average content of **Pb** correspond to the **geochemical background**

Despite that, high **accumulation levels** can be observed for **all investigated trace metals**, mainly in **bed-load sediments**

Contamination levels :

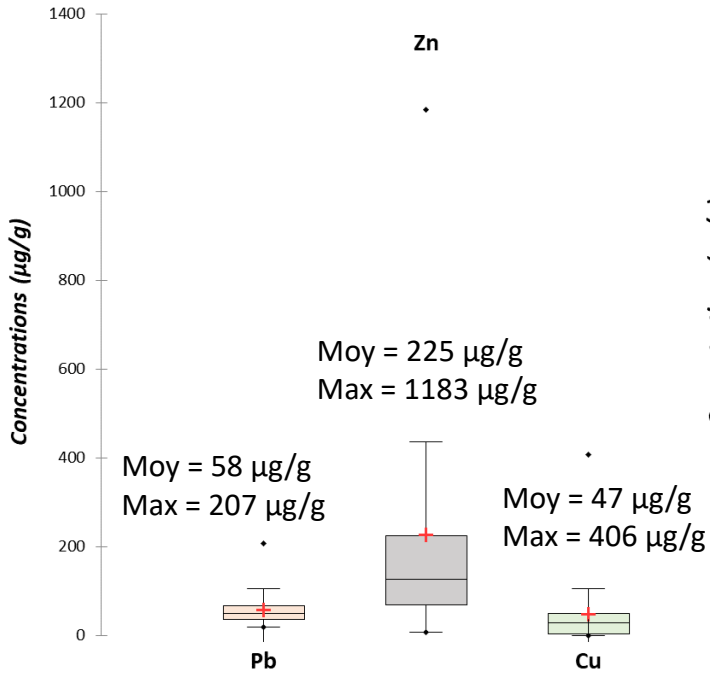
- **Bed-load sediments : Pb < Cu < Zn**
- **Suspended particulate matter : Cu < Pb < Zn**

Differences between average and maximum concentrations increase with increasing compound solubility

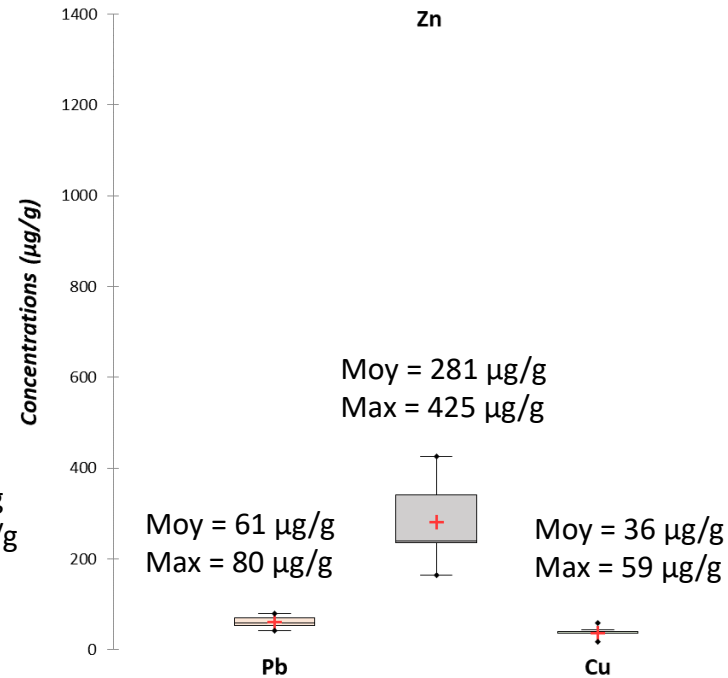
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● *Bed-load sediments*



⚙️ *Suspended particulate matter*



✓ **More soluble** (*Lazzari et al., 2000*), **Zn** stays rather in the **dissolved phase** but can be **strongly adsorb** too

✓ Contamination levels are **higher** in **bed-load sediments**, mostly for **Cu**

✓ Even if it seems to be in **lower amounts**, **anthropogenic effluents** are sources of **Pb** too

✓ **Less soluble** (*Lazzari et al., 2000*), **Pb** is already in a **particulate form** (*Briand et al., 2018*)

✓ With an **intermediate solubility** (*Durand, 2003*), **Cu** can already be in the **particulate fraction** but this latter can **adsorb** the dissolved phase levels **too**

Results and discussion

● *Bed-load sediments*

Indeed, both **sewage waters** and **urban storm waters** are sources of **Pb, Zn and Cu**

Pb seem mostly emitted by the **PH sewage effluent**

Storm waters releasing rates seem **lower** than **sewage waters** ones

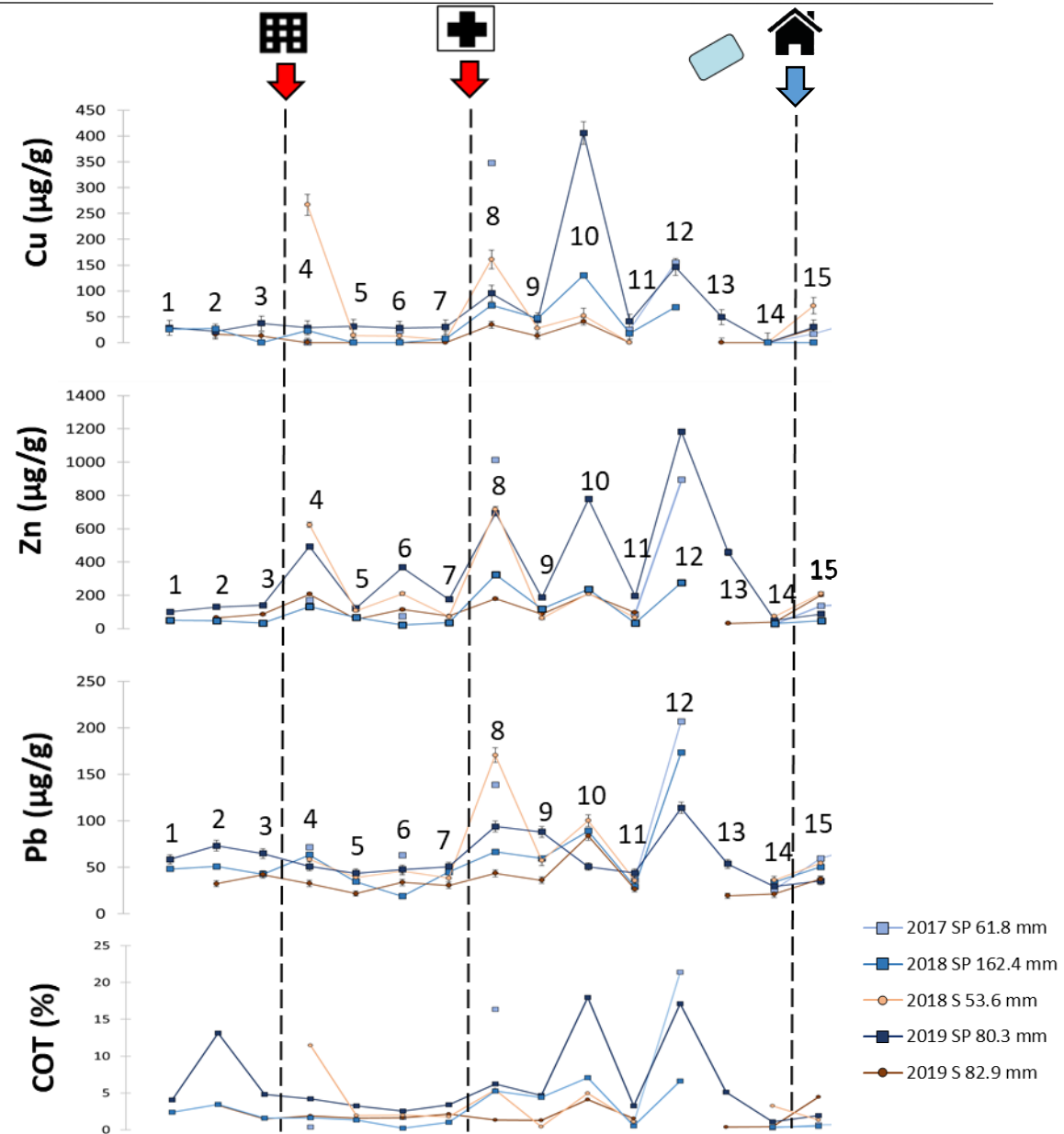
Their **spatial distribution** are highly variable with strong **accumulation zones upstream** the pond

The **accumulation zones** correspond to **discharging sites** and zones with large **organic matter** amounts

✓ **Trace metals have a good affinity with organic matter**

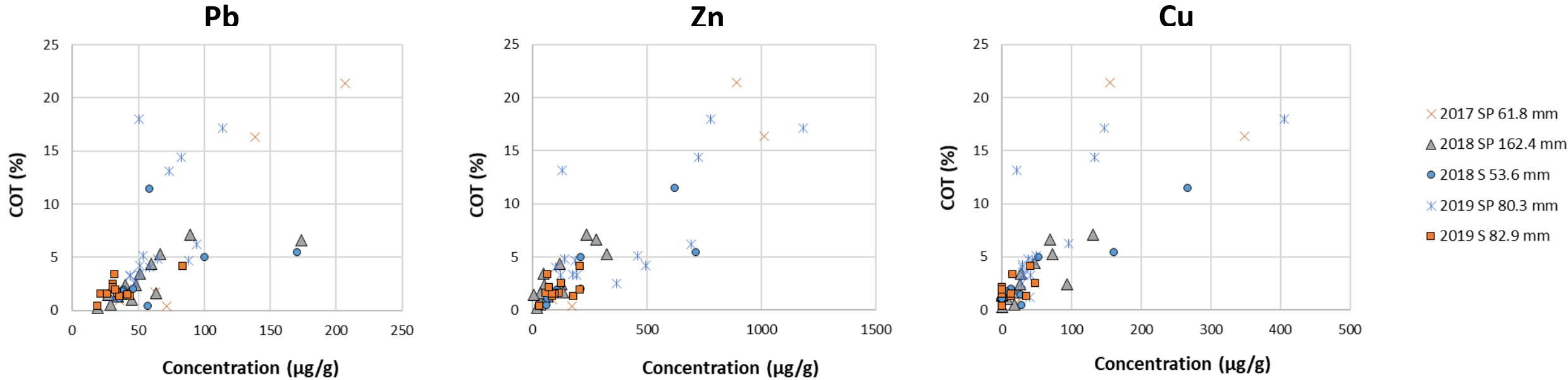
(Bibby and Webster-Brown, 2006)

✓ **Their spatial distribution reflect the sedimentary dynamic of the stream**



Results and discussion

● *Bed-load sediments upstream the Beulie pond*



Higher levels in trace metals were mainly observed in **spring**, when inputs in **organic matter** were **higher**

It was not the case in **spring** with the **higher rain amount** (2018), probably because of **higher flow rates** decreasing sediment accumulation

High levels were also quantified at **discharging sites** during the **summer** with the **lower rain amounts** (2018), which is probably the result of a **lower dilution** from storm events and **lower flow rates**

Temporal dynamics depend on both bearing phases (TOC) and rain amounts

Results and discussion

⚙️ *Suspended particulate matter*

In suspended particles, **contamination levels generally decreased after the Beulie pond** despite the adding contribution of the PH sewage effluent

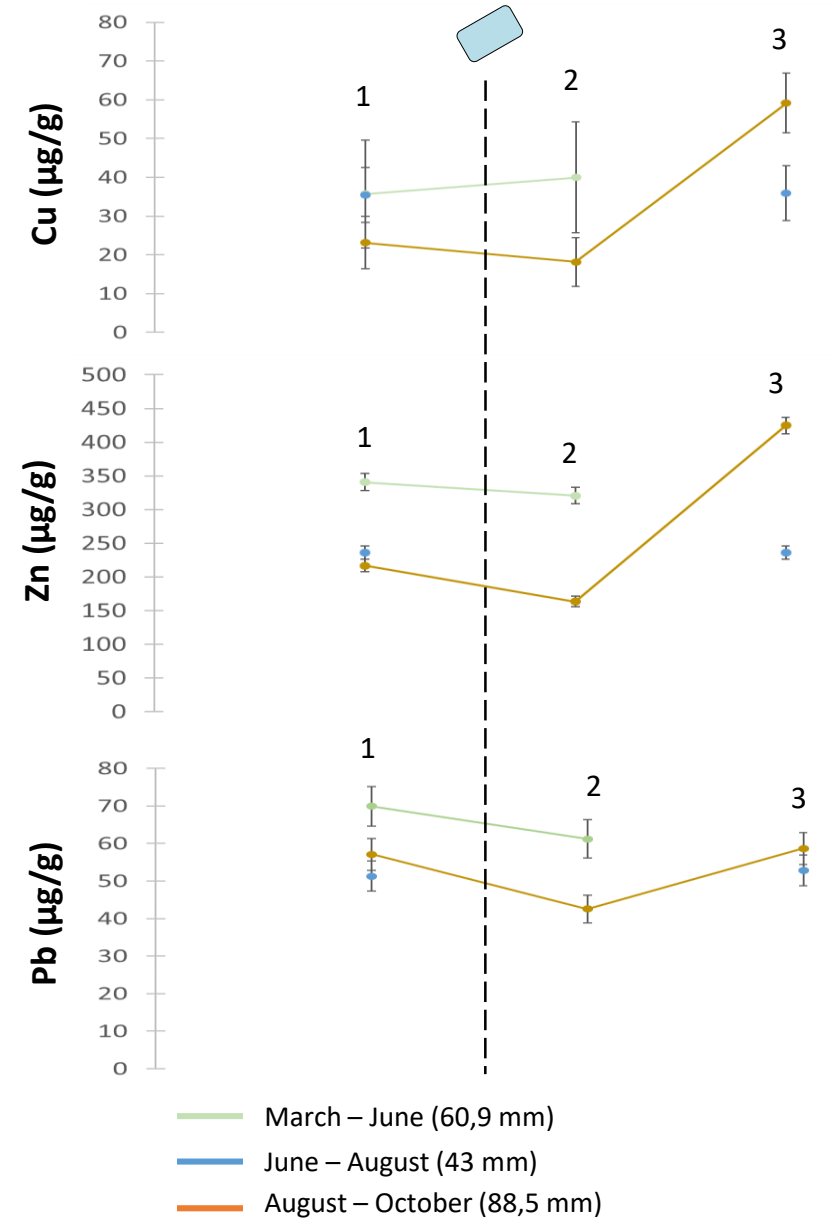
✓ **The Beulie pond have a good storage capacity**

In contrast to bed-load sediments, contents are **higher at the outlet**

✓ **The transportation capacity is higher downstream the Beulie pond**

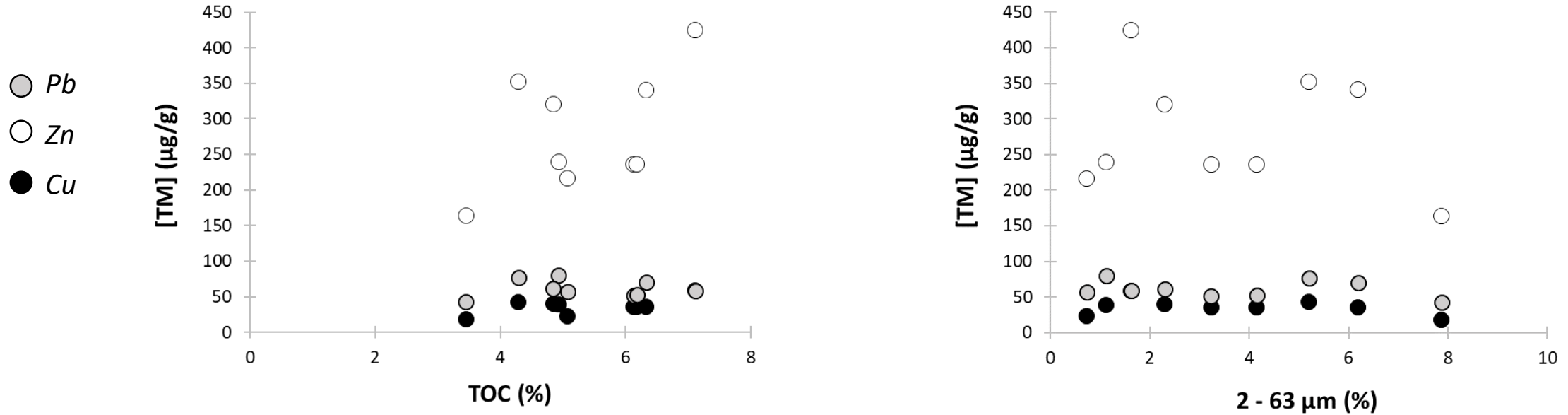
Contamination levels were higher in particles collected during the period between March and June with an intermediate rain amounts

-> **Because of higher rates in organic matter ?**



Results and discussion

⚙️ *Suspended particulate matter*

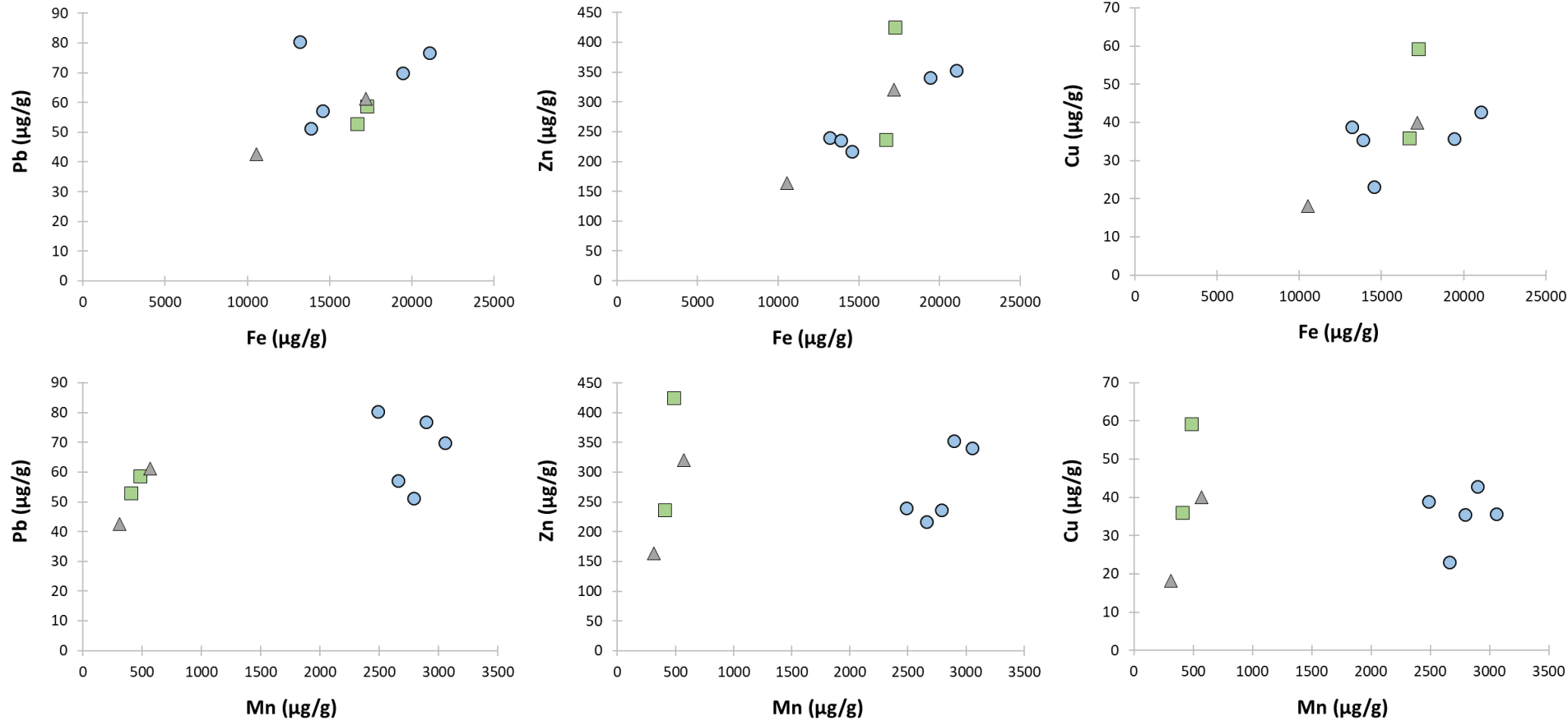


Contrary to bed-load sediments, trace metals seem **not bound** to **organic matter** in **suspended particles**

Trace metals can also have **fine particles** as bearing phases (*Hong et al., 2017*), but this grain-size fraction seem **not involved** in their distribution

Results and discussion

⚙️ *Suspended particulate matter*



- *Upstream*
- ▲ *Downstream the pond*
- *At the outlet*

Higher transportation rates in the downstream part of the catchment because of more particles involved in their sorption ?

Indeed, **trace metals** are in fact **bound to metal oxides**
(Bibby and Webster-Brown, 2006)

These interactions seem have **spatial variations** :

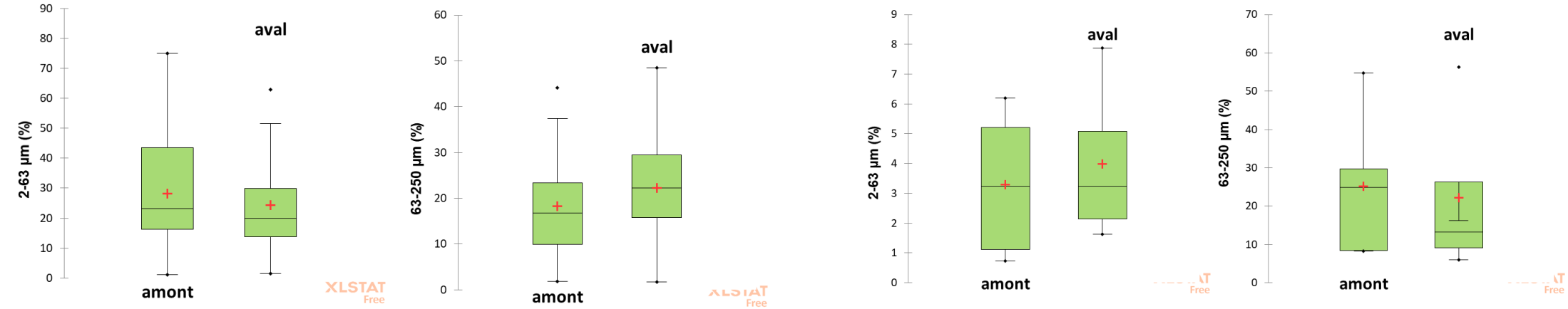
Fe oxides seem to play role in Pb, Zn and Cu transportation at **catchment scale**

In contrast, **Mn oxides** seem to be involved in Pb, Zn and Cu transportation only in the **downstream part of the catchment**

Results and discussion

● *Bed-load sediments*

⚙️ *Suspended particulate matter*



Bed-load sediments are coarser in the downstream part of the catchment

Suspended particles are finer in the downstream part of the catchment

Higher transportation rates mainly because of stronger carrying capacities of the stream in its downstream part

It can be the result of higher flow rates because of impermeable land covers in this part of the catchment

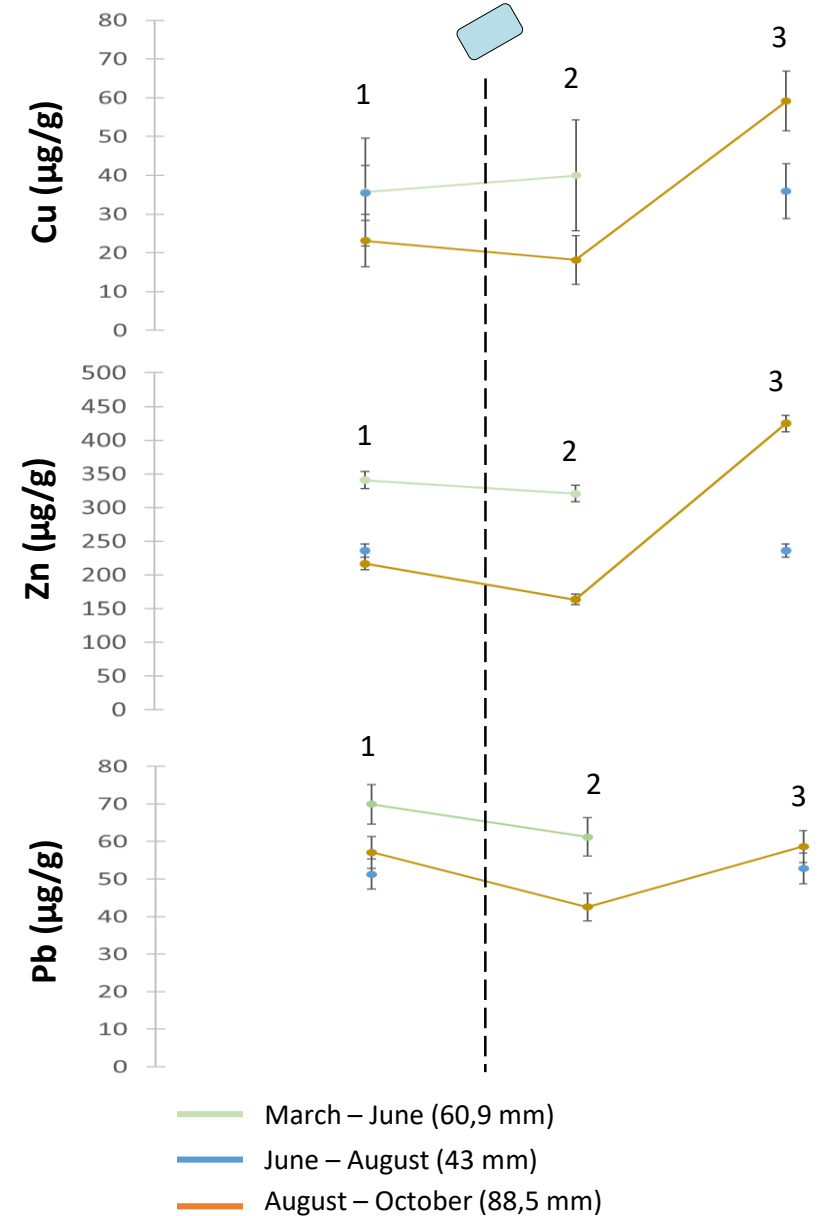
Results and discussion

⚙️ *Suspended particulate matter*

Contamination levels were **higher** in particles collected during the period **between March and June** with an intermediate rain amounts

It is the result of **higher contents** in **Fe** and **Mn oxides** during this period, which is probably linked to **larger erosion rates**

Despite a **higher rain amount** during the period **between August and October**, at the end of summer, **infiltration could be higher than runoff**



Conclusion

- ✓ Anthropogenic releases are in decreasing order : $Zn < Cu < Pb$, which is consistent with *Briand et al. (2018)*
- ✓ According to compound solubilities, some contamination only appeared in particulate phases
- ✓ Even if bed-load sediments well accumulate trace metals, they could have long transfer distances
- ✓ Main trace metals bearing phases are different between bed-load sediments and suspended particles with organic matter as a strong sink and a bounding to metal oxides, respectively
- ✓ Therefore, the spatial distribution of trace metals in both compartments do not vary according to the same parameters :
 - *In bed-load sediments* : contamination levels depend on discharging sites and the sedimentary dynamic of the stream
 - *In suspended particles* : the presence of the pond and the impermeable land cover of the downstream part of the catchment modify trace metals bearing phases and the carrying capacity of the stream downstream
- ✓ In the same way, dissimilarities in their temporal variabilities are observed :
 - *In bed-load sediments* : variations are linked to different seasonal bearing phases inputs and flow rates
 - *In suspended particles* : variations appeared consistently the result of erosion rates

Further investigations will be needed to identify trace metals spatial and temporal behaviors in suspended particles

Given the well storage capacity of the Beulie pond, its sediments could constitute a good archive of contamination levels temporal evolution through larger time scales

Collecting several specific anthropogenic releases, the Egoutier stream is a good candidate to investigate other groups of contaminants

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