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A Tire Industry Project Initiative

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Micropollutants loads in the road runoff

Importance, nature and efficiency of
runoff source control measures

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Context

Traffic area runoff (roads, streets, parking lots)

a non-point source of micropollutants for surface waters

... only partially diagnosed

- a complex mixture of pollutants
- important site to site variability

... and yet often uncontrolled.



Control of these contaminant loads is needed

- a range of innovative runoff control approaches available
- SUDS, sustainable urban drainage systems
- need to adapt to different contexts (urban context, pollutant type and level, socio-technical context)

The French ROULEPUR project (2016-2020)

Objectives

- Diagnosing the composition and toxicity of road runoff, and better identification of primary sources
- In situ evaluation of several innovative treatment solutions
- Analyzing the overall environmental performance (LCA)
- Evaluate solutions ownership conditions



Project funding:

Ministry of Ecological Transition
French Water Agencies
French office of biodiversity

Project partners:

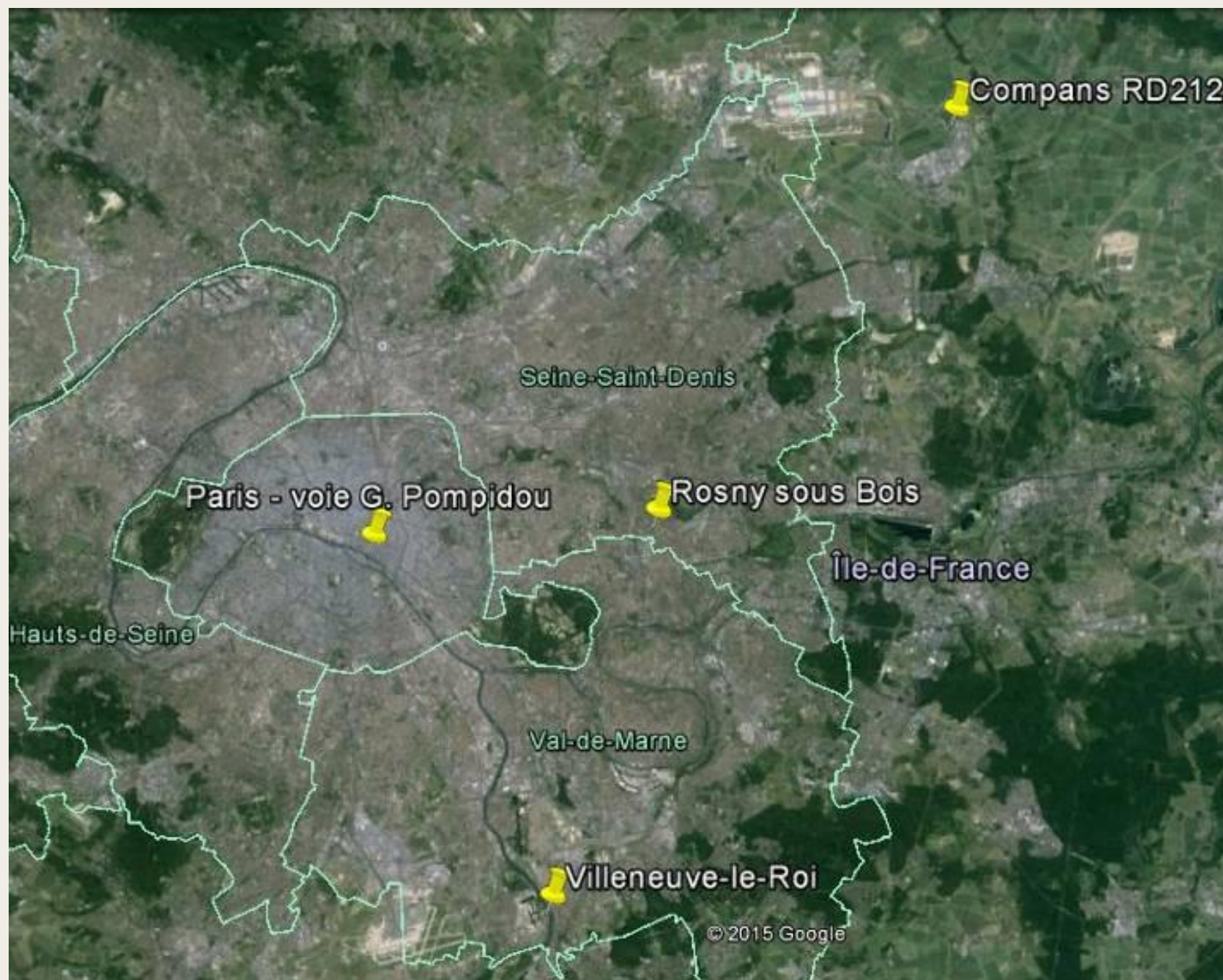
3 research centers
2 private companies
3 local authorities

In partnership with OPUR, observatory of urban hydrology



Experimental sites

Four contrasted road / car park situations in Paris conurbation



Villeneuve-le-Roi	Rosny-sous-Bois	Compans	Paris
Residential area, suburbs, close to Orly airport	Town center, suburbs	Industrial and agricultural suburban area, close to Roissy airport	Central Paris
Residential car park	Urban street 2x1 lanes	Departmental road 2x2 lanes	One way urban boulevard 2 lanes
Very low traffic (1 to 3 rotations per day)	Low and variable traffic (< 3000 veh/day) Traffic light 50 km/h	High traffic, many lorries (2×1000 veh/day) Smooth traffic flow 90 km/h	High traffic ($40\,000$ veh/day) Traffic jams 50 km/h
730 m ²	3 410 m ²	945 m ²	1 045 m ²



Increasing traffic level

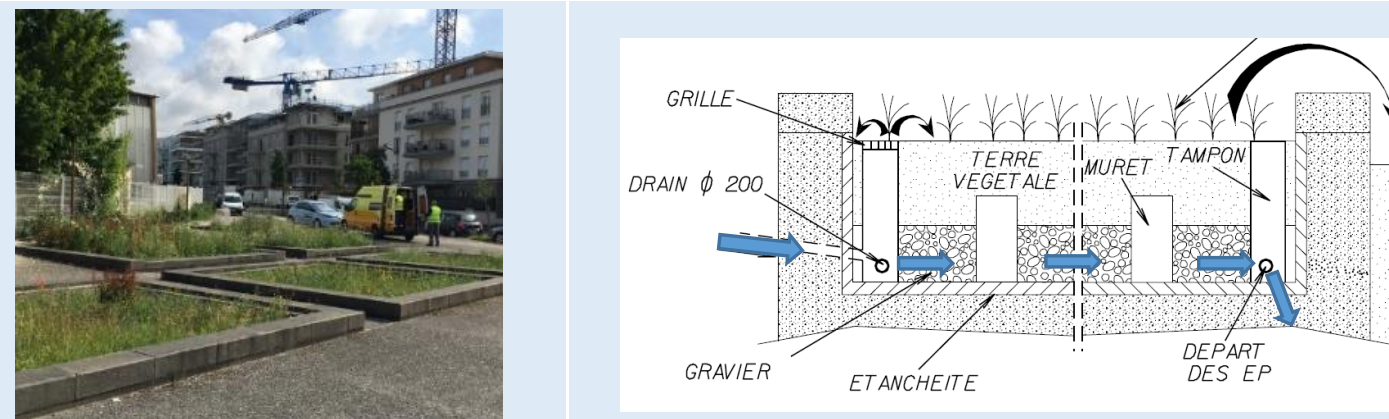
Associated runoff source control measures

Five contrasted runoff control facilities

Permeable parking lot



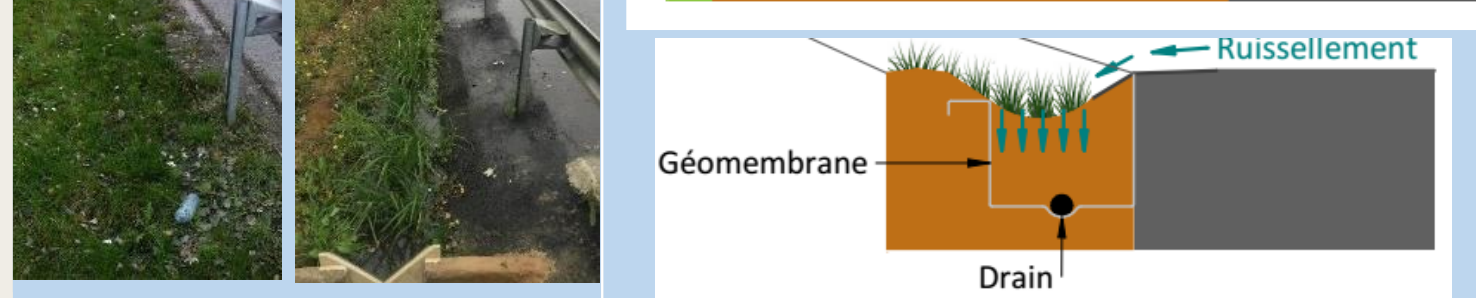
Horizontal sand filters



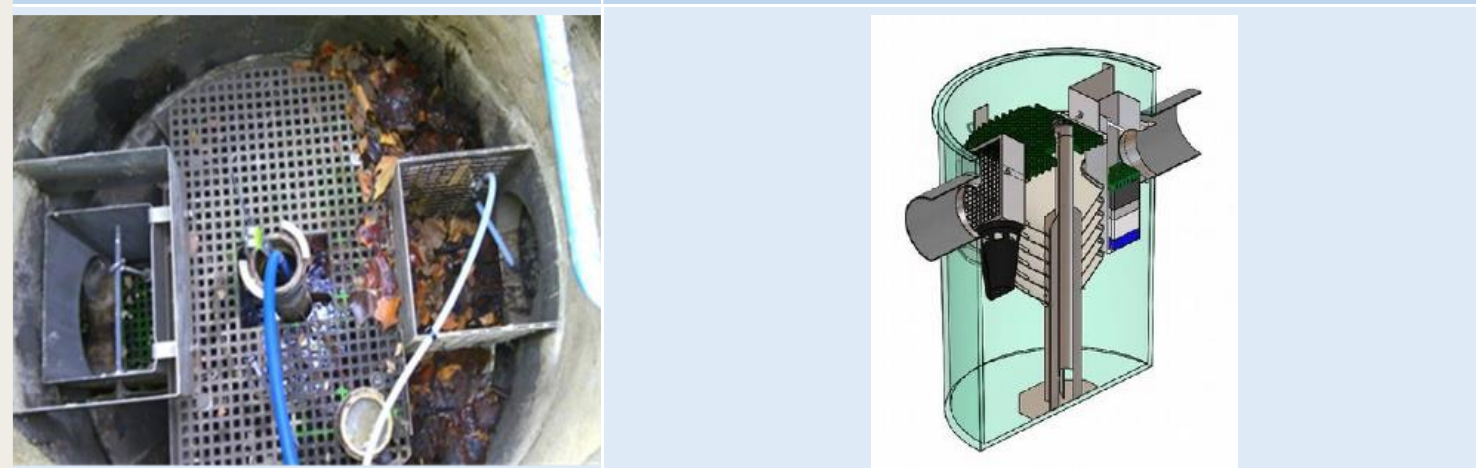
Biofiltration strip



Biofiltration swale



Compact settler



	Villeneuve	Rosny	Compans	Paris
Type of area	Car park	Low traffic street	High traffic road	
Concentration levels	●	●●	●●●●●	
Type of SCM	Pervious vegetated parking	Horizontal sand filters	Biofiltration swale Filtration strip	Compact settler
Designed for	Runoff volume mitigation	Flow regulation Poll. mitigation	Pollutant concentration mitigation	
Hydraulic loading	●	●●●●	●●	●●●●●●
Hydrologic processes	Retention / Evapotranspiration / Infiltration	Detention and flow regulation	Detention / retention / evapotranspiration	-
Treatment processes	Filtration (adsorption)	Filtration	Filtration + adsorption	Settling (Filtration + adsorption)

- Both nature-based and technological devices
- Main design target : runoff volume control and/or pollutant control
- Main treatment processes: settling, filtration, adsorption
- Very different hydraulic loadings
- Very different inflow water qualities

Roulépur – methodological approach



Limited number of study sites / facilities

But holistic and pluridisciplinary evaluation approach

Pollutant fluxes and fate in SCMs

- Field monitoring
 - rainfall, in/out flow, water level, soil water content
 - sampling (water, sediment, soil)
- Lab analyses
 - target and non target screening
 - ecotoxicity tests
- Hydrological modelling

Environmental impact of SCMs

- Life cycle analysis (LCA)

Obstacles and levers to innovation

- Socio-technical analysis

Primary sources identification

(alkylphenols and phthalates)

- Lab experiment
 - simulated rainfall on car built parts, analysis of automotive fluids, exhaust particles and tire extractions

Production of technical guidelines and recommendations (in French)

- <https://www.leesu.fr/opur/syntheses-operationnelles>
- <https://professionnels.ofb.fr/fr/doc-guides-protocoles/guide-methodologique-levaluation-performances-ouvrages-maitrise-source-eaux>



Performance evaluation of SCMs

- Global parameters: SS, POC, DOC, N, P, 11 major elements, total hydrocarbons (HC)
- Micropollutants: 10 trace metals (As, Cd, Cr, Co, Cu, Mo, Ni, Pb, V and Zn), 19 PAHs, 7 alkylphenols (APs), bisphenolA (BPA), 15 phthalic acid esters (PAE)
- Ecotoxicity tests

Screening of road runoff contamination

- Targeted screening
 - poorly documented regulated compounds: 9 PBDE, DEHP, 3 organotins, nickel, HBCDD, PFOS
 - non regulated compounds :
 - 3 benzotriazoles, TBBPA, benzophenone, 17 PFAS, 3 oxygenated ethers, LAS
 - Sb, Ag, Cs, Rb, Se and 15 rare earth elements (REE), *platinoïds*
- Non targeted screening
- Ecotoxicity

Event mean concentration (EMC)
Dissolved and particulate phases
Concentrations, flows, loads

Sources of contamination



Anthropic activities,
street furnitures
?

Guardrail
Zn
Road paint
Ti
Road wear



Paint, lacquer , varnish
APs, **BPA, PAE (DEHP, DIBP)**

Engine and vehicle
body wear
Cr, Ni

Windshield washer,
anti freeze, polish, ...
Zn, Cu
APs, BPA, PAE

Exhaust
PAH, PAE



Polymers : optics, bumper,
plastic bodywork
APs, BPA, PAE

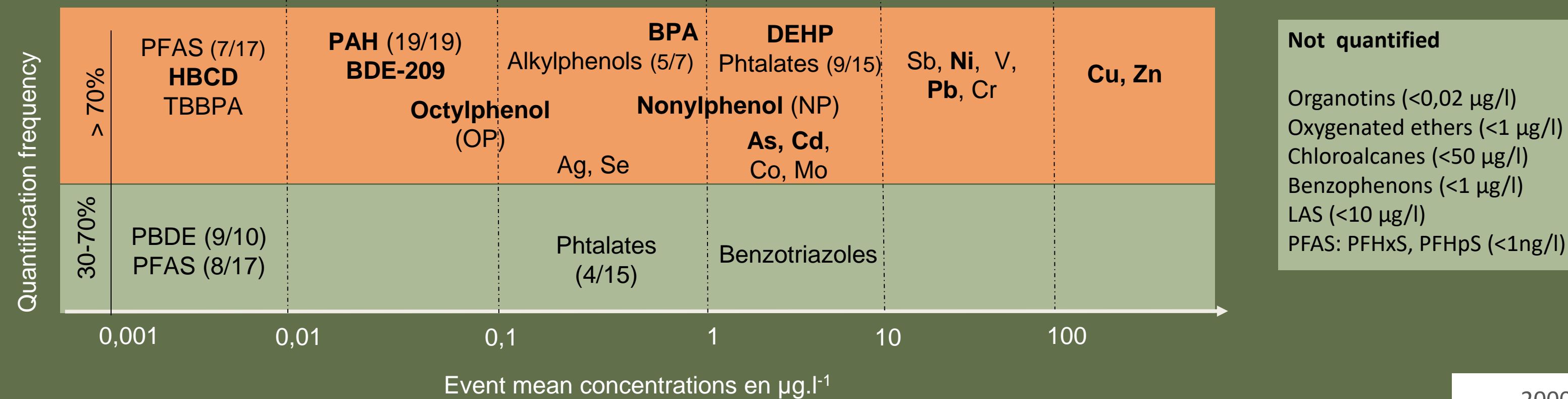
Brake pads
**Cu, Zn, Ni, Pb,
Sb, Cd**

Leaks : fuel, oil, break fluid,
coolant ...
HC, Zn
APs, BPA, PAE

Tires
Zn, (Cu, Pb, Cd)
PAH
APs, BPA, PAE

Runoff contamination profiles

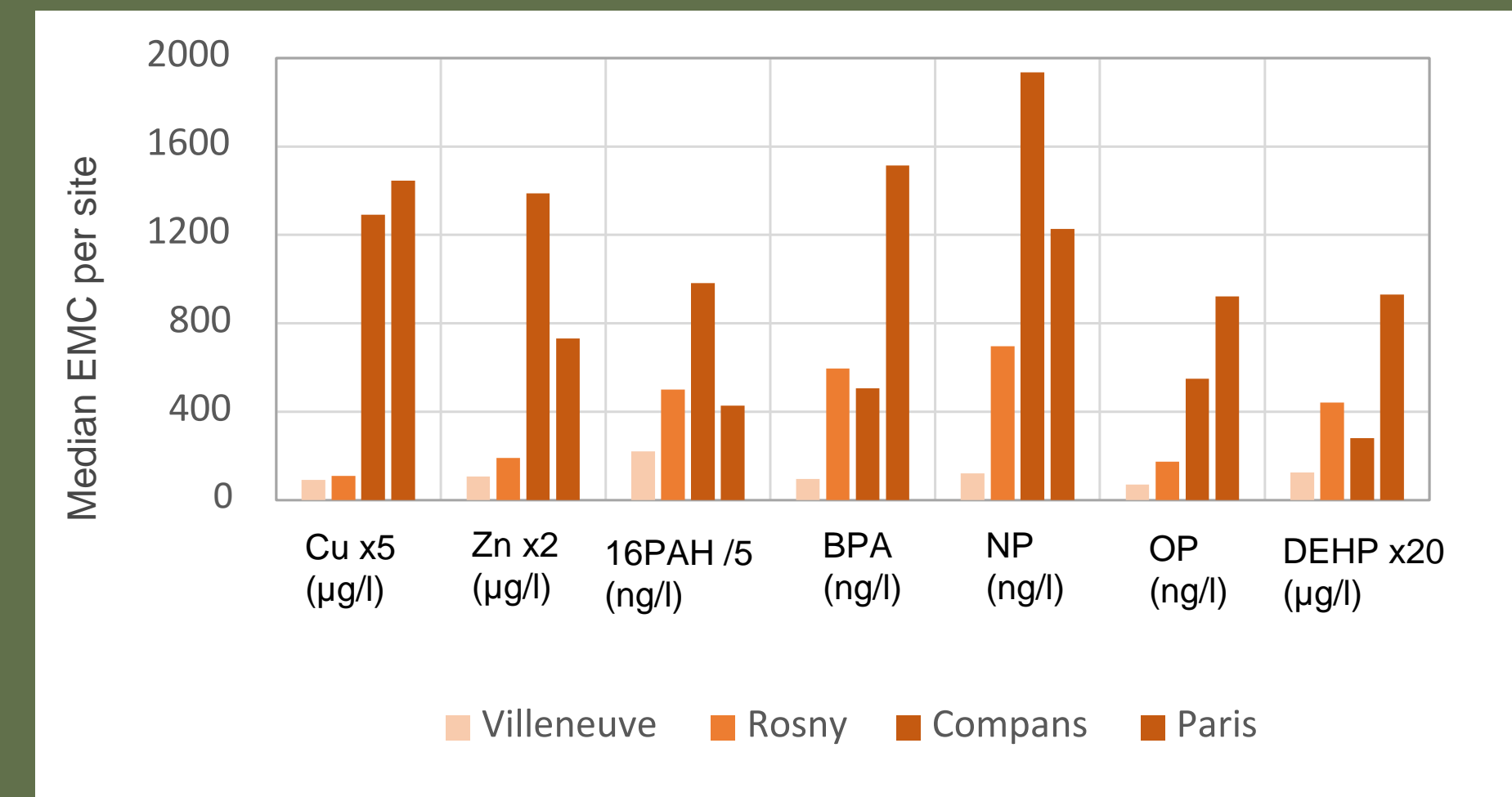
Targeted screening



Not quantified

- Organotins (<0,02 µg/l)
- Oxygenated ethers (<1 µg/l)
- Chloroalcanes (<50 µg/l)
- Benzophenons (<1 µg/l)
- LAS (<10 µg/l)
- PFAS: PFHxS, PFHpS (<1ng/l)

- Similar contamination profiles on all 4 sites but
- Important difference in concentrations levels, function of traffic level but also urban context



Runoff contamination profiles

Relevant contaminants and link with traffic

	Villeneuve parking	Rosny street	Compans road	Paris road
Traffic level	+	++	++++	+++++
Cd, Ni	+/-	+/-	+	+
Cr, Pb	+	+	++	++
Zn	+	++	++++	+++
Cu	++	++	++++	++++
PAH, Alkylphenols, PBDE	+	++	+++	+++
Phtalates	+	++	++	+++
Benzotriazole, HBCDD, TBBPA	+/-	+	+	+
PFAS	+/-	++	+	+

- Some micropollutants are clearly corelated to traffic
- Some are probable related to the urban context

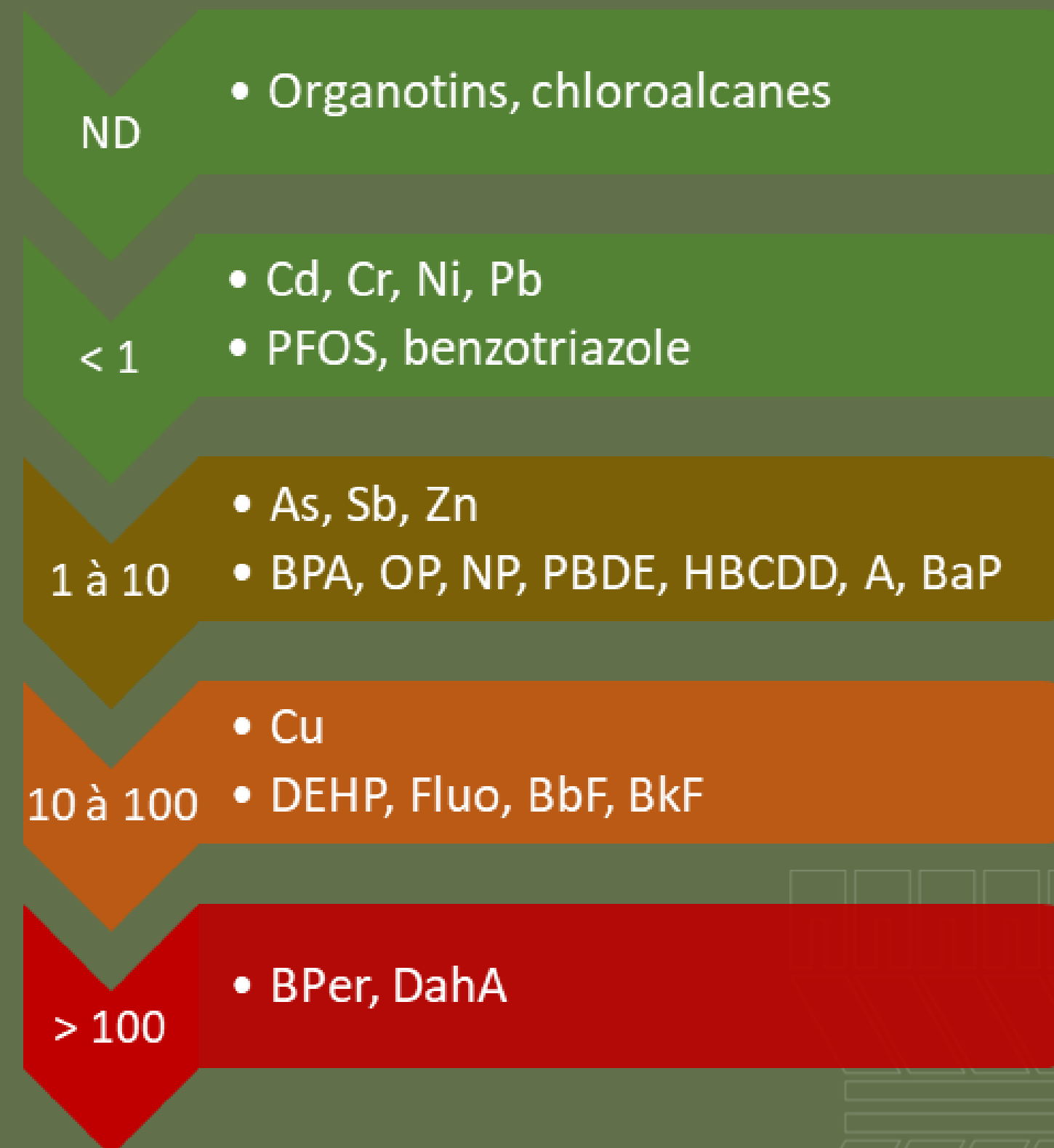
Runoff contamination profiles

How relevant is the contamination ?

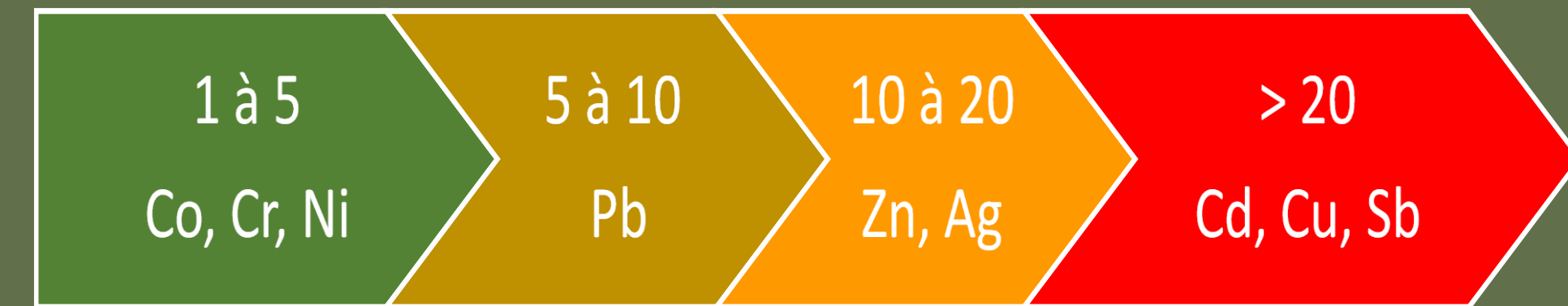
Comparison to EQS for surface waters

EMC / AA-EQS

(total concentration for organics and dissolved concentration for metals)



Enrichment factor of suspended solids compared to geological background



Pollutants of major concern in the target screening:

PAHs

DEHP (phtalate)

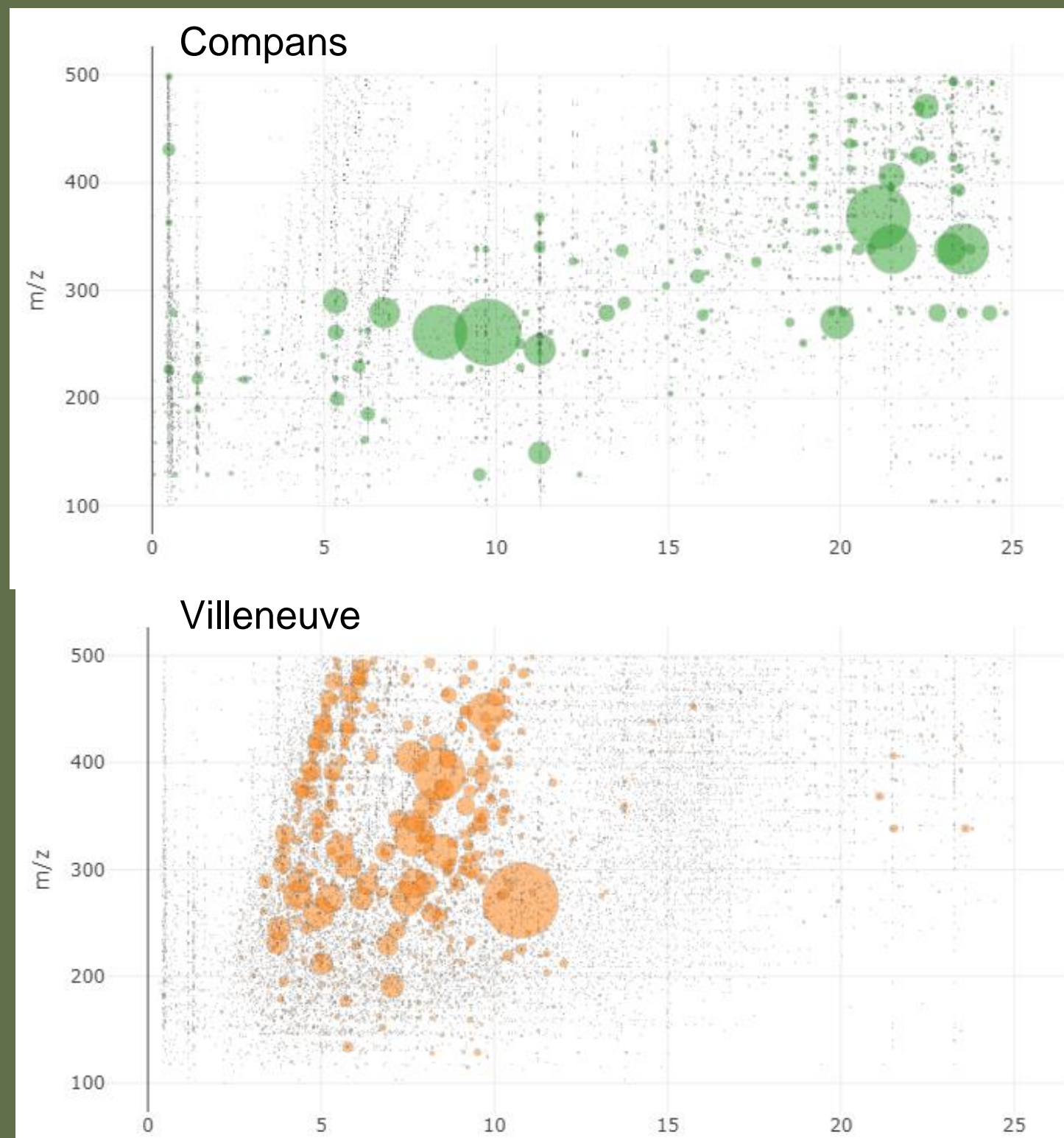
Metals (Cu, Sb)

Runoff contamination profiles

We usually only find what we are looking for ...

Non target screening opens new perspectives, and rises new concerns

- HRMS analysis of the dissolved phase (Le Roux et al. 2020, Gasperi et al. 2020, Sandré et al 2022, Huynh et al. 2023)



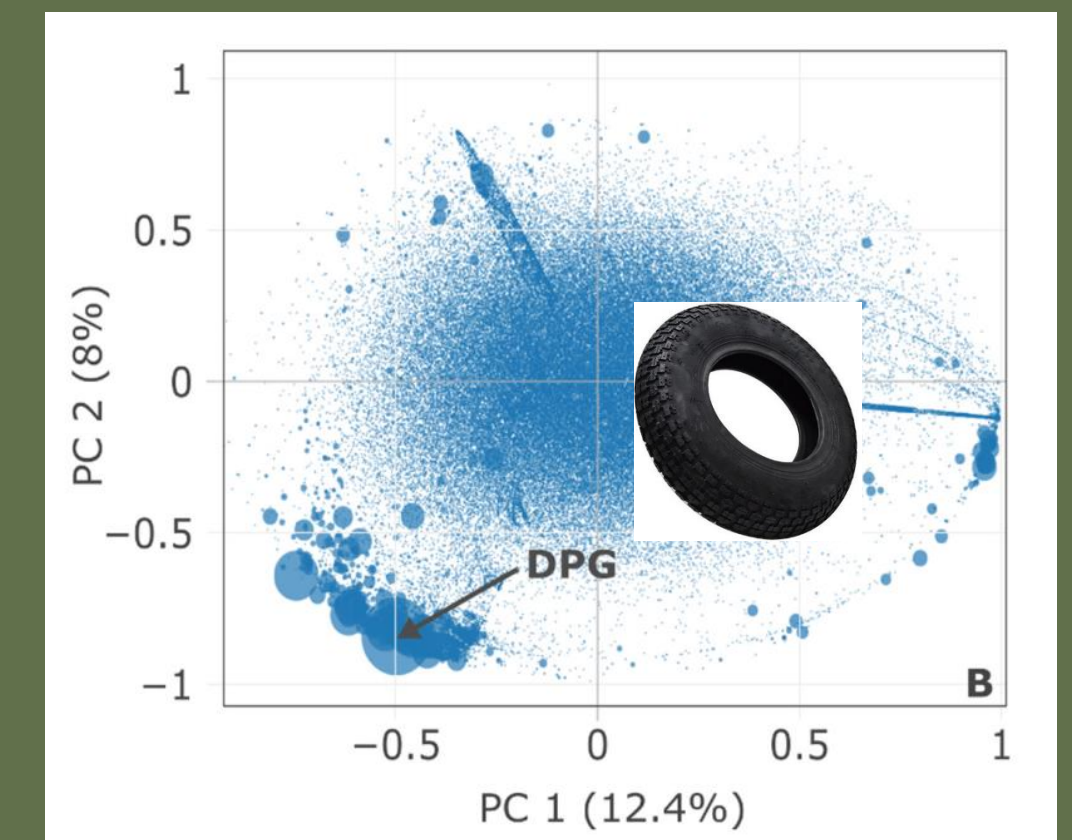
« Finger prints » : similar between the two high traffic roads,
very different between road and car park

Compounds with high intensities in Compans
runoff :

- Suspected : 6PPD quinone,
- Confirmed : DPG (1,3 diphenylguanidine),
1,3benzothiazole 2 sulfonic acid, benzotriazole
- Not detected : 6PPD, benzothiazole, HMMM

Confirmed in tire leaching :

- DPG (1,3 diphenylguanidine) → tire vulcanisation
- 6 PPD → rubber antioxidant



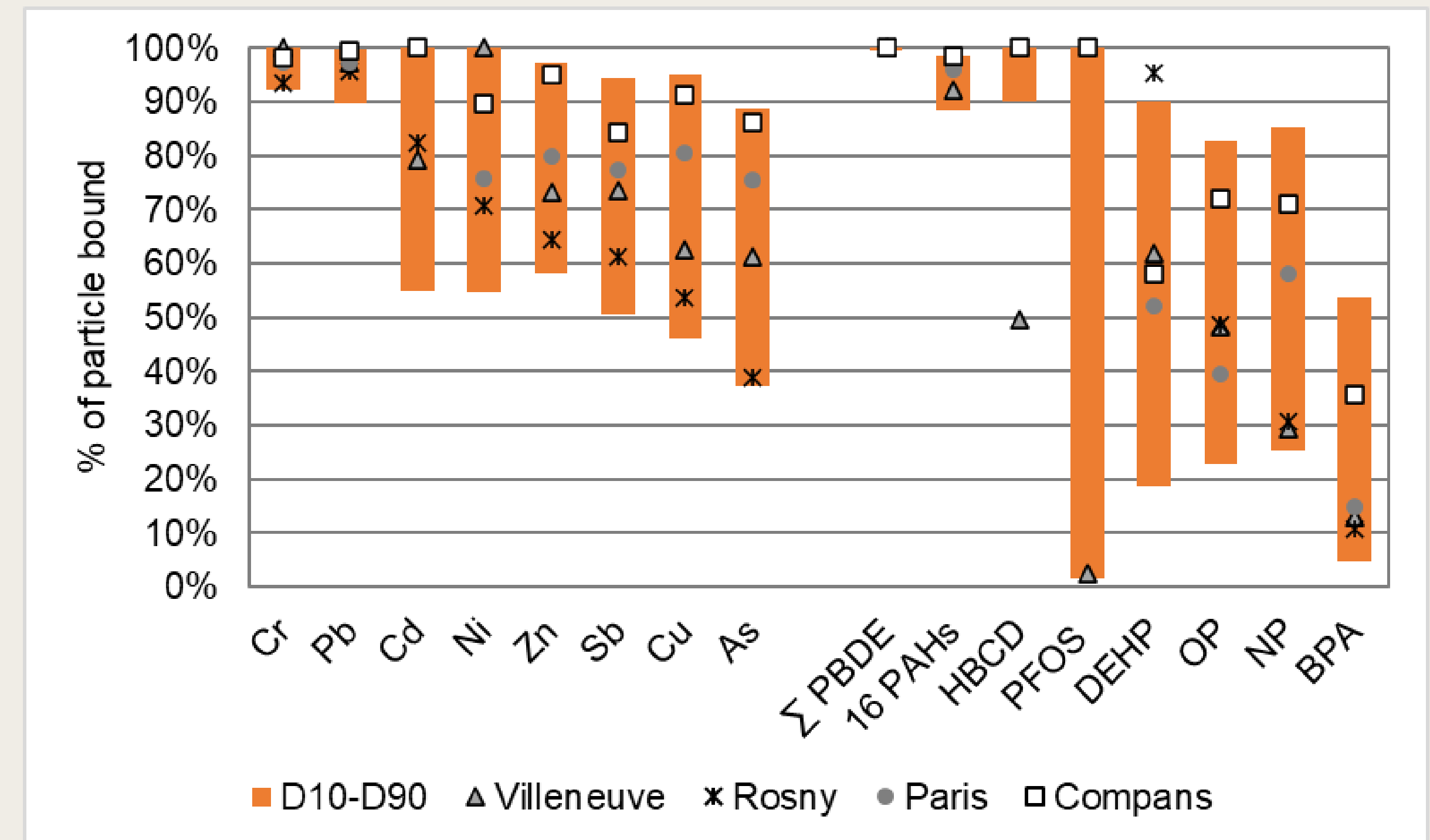
Distribution between dissolved and particulate phase

Is it true that stormwater contamination is mainly particle bound?

- Yes, when considering
 - Discharges from stormsewer system
 - “Conventional” pollutants (metals, PAH, hydrophobic contaminants)
- But it can be different from road runoff

Dissolved fraction can be significant in the road runoff

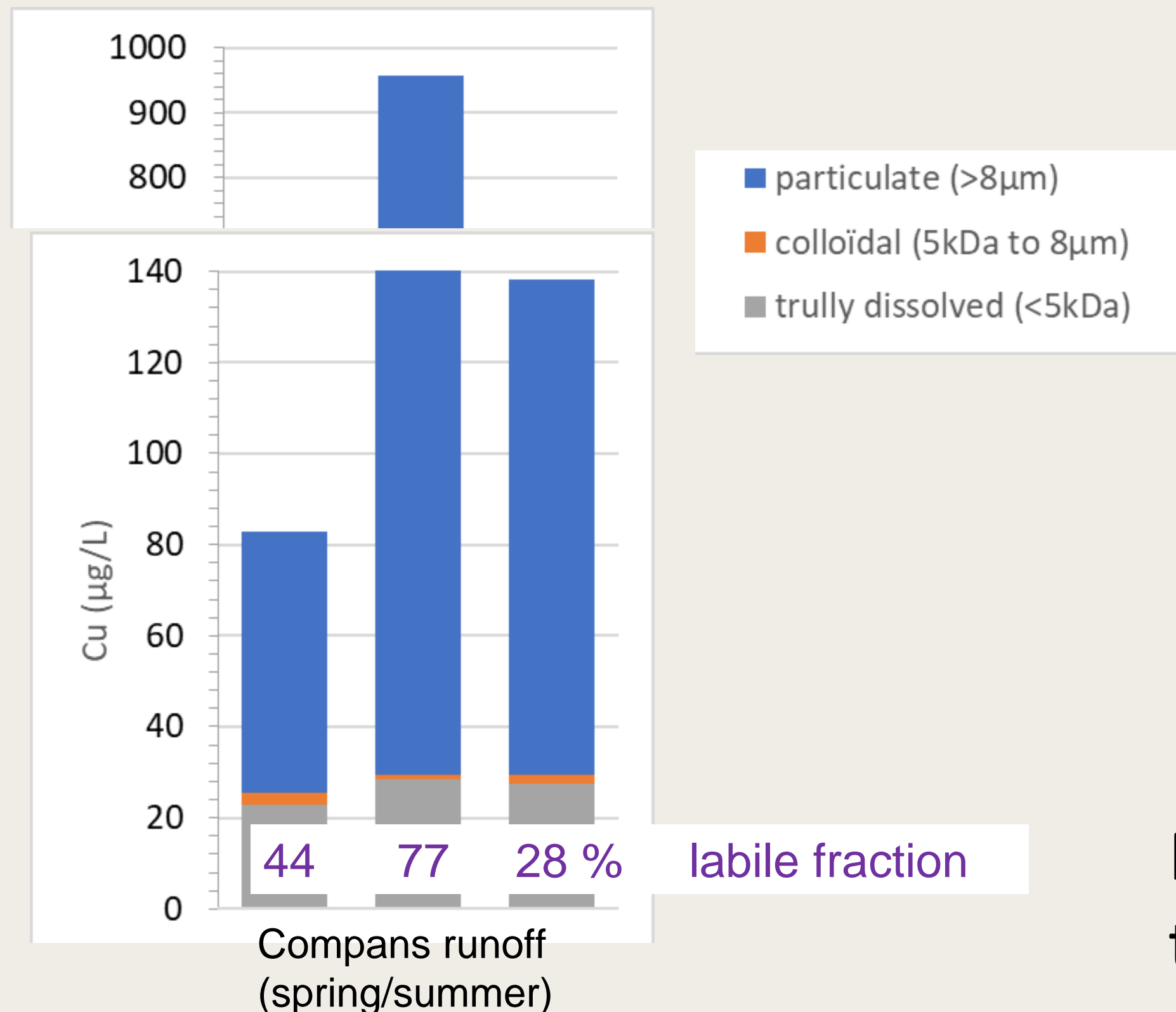
- For less hydrophobic pollutants
- or
- When SS concentrations are low



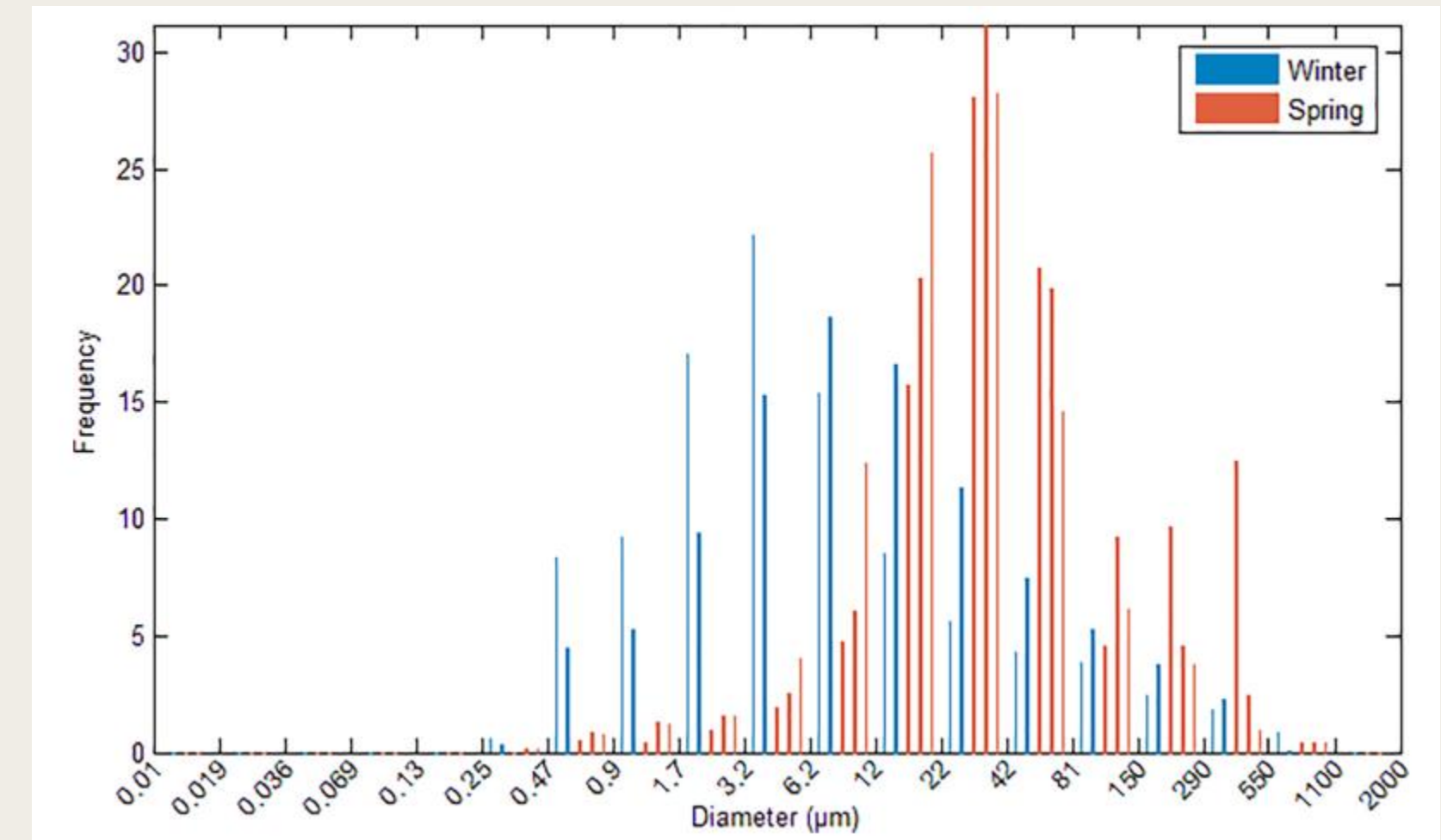
Suspended solids characteristics

How settlable are the suspended solids?

- Very fine particles for most part
- D50 = 10 to 30 μm
- (very) low settlability expected



Compans runoff



Flanagan et al. (2019), STOTEN 656, 1178-1190

What about colloids (5 kDa to 8 μm) ?

- Limited importance of the colloidal form of metal in the Compans runoff
- Consistent with other studies (Tucillo 2006, Lindfors et al. 2021)

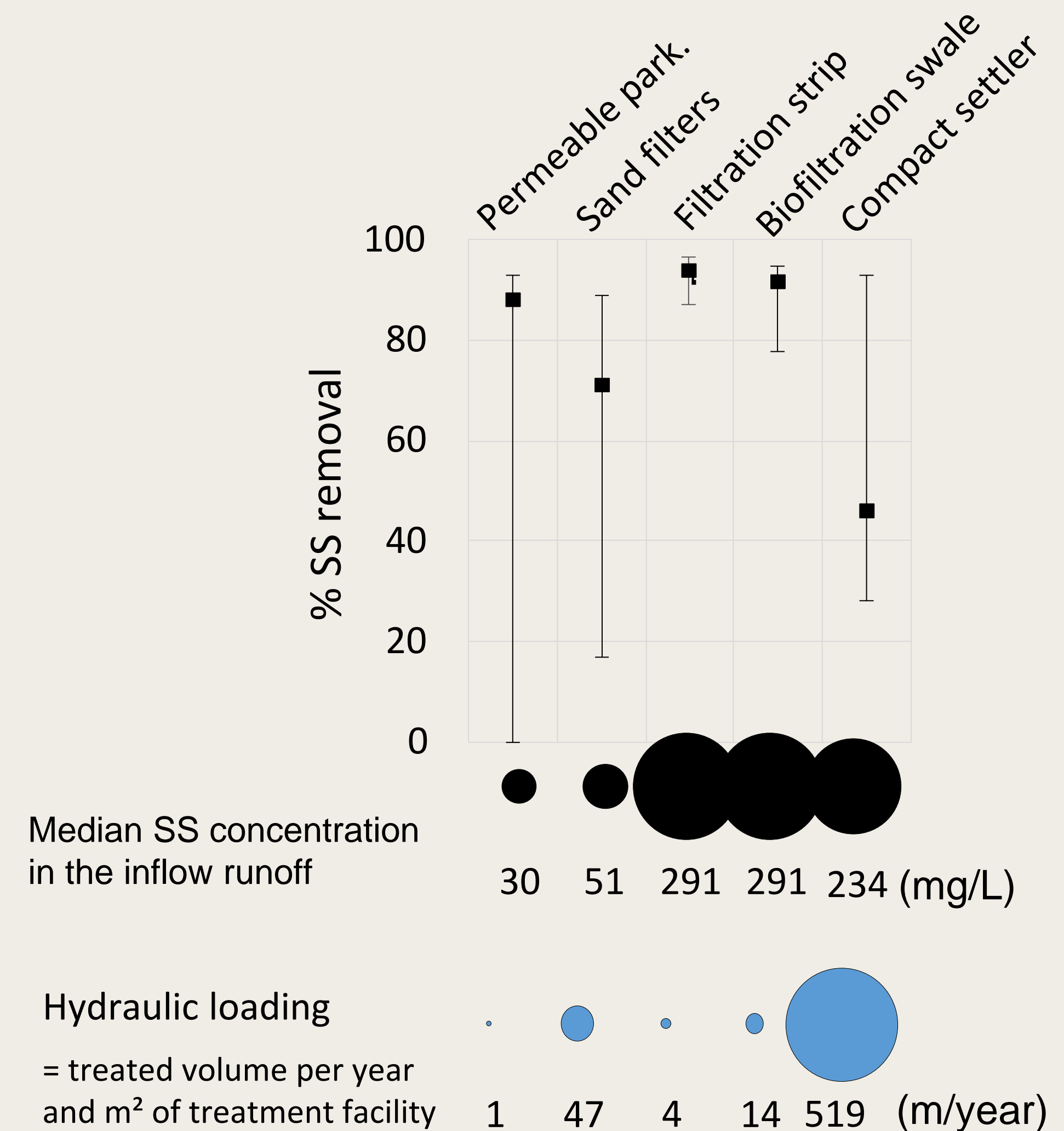
Part of the “truly dissolved” is not labile (complexed by DOM ?) → this may limit adsorption

Efficiency of runoff source control measures (SCMs)

Suspended solids

Event mean concentration reduction

- Important SS reduction for all 4 facilities but
- Efficiency is lower and/or more variable when
 - Low input concentration
 - Strong hydraulic loading (ie high catchment area over treatment area ration)



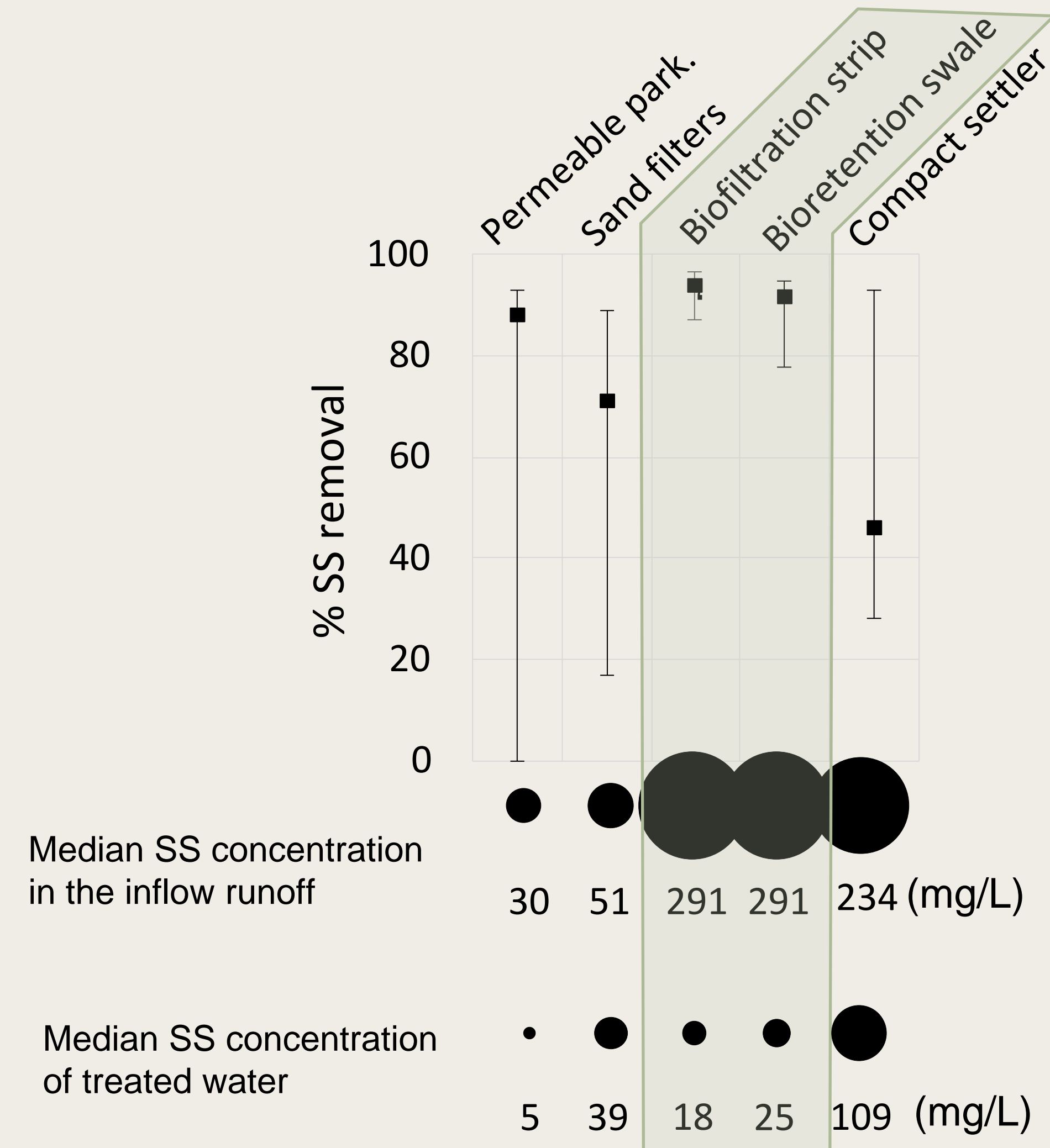
Efficiency of runoff source control measures (SCMs)

Suspended solids

Event mean concentration reduction

- Important SS reduction for all 4 facilities but
- Efficiency is lower and/or more variable when
 - Low input concentration
 - Strong hydraulic loading (ie high catchment area over treatment area ration)

- Outlet SS concentration < 30 mg/L is only achieved with vegetated filtration systems

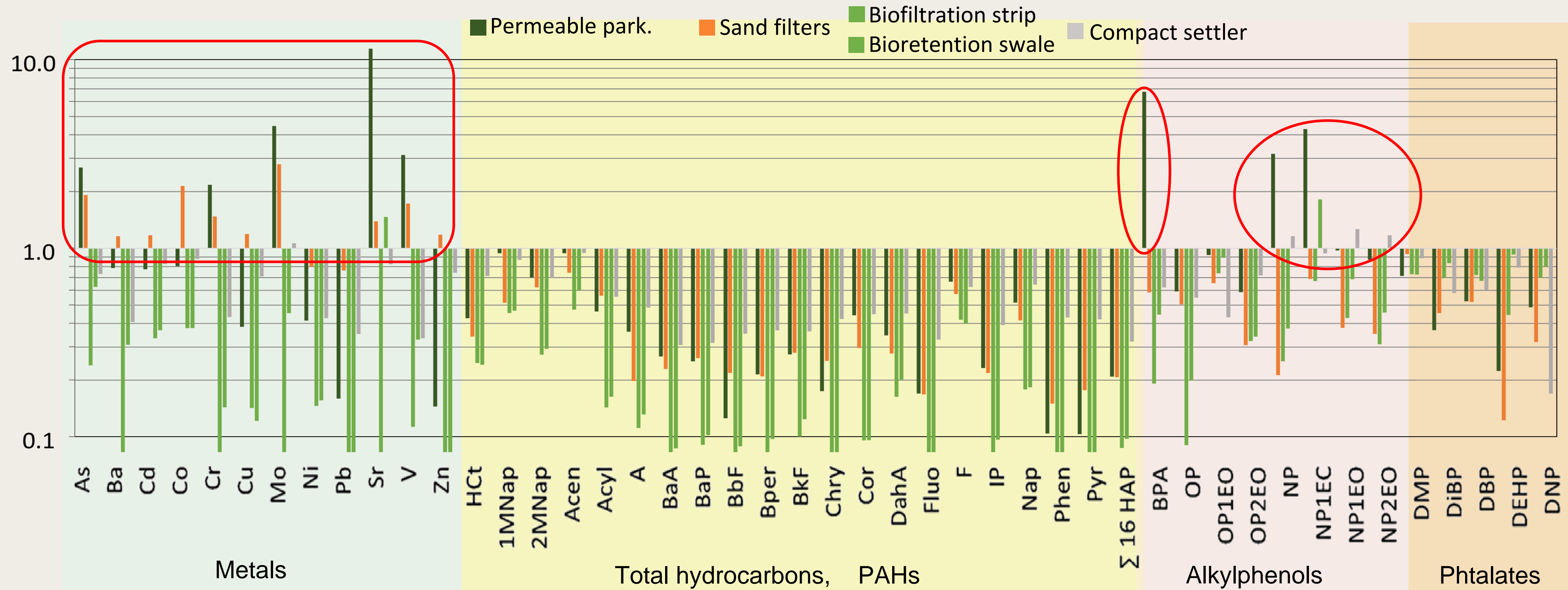


Efficiency of runoff source control measures (SCMs)

What about the micropollutants?

Median outflow / median inflow concentration

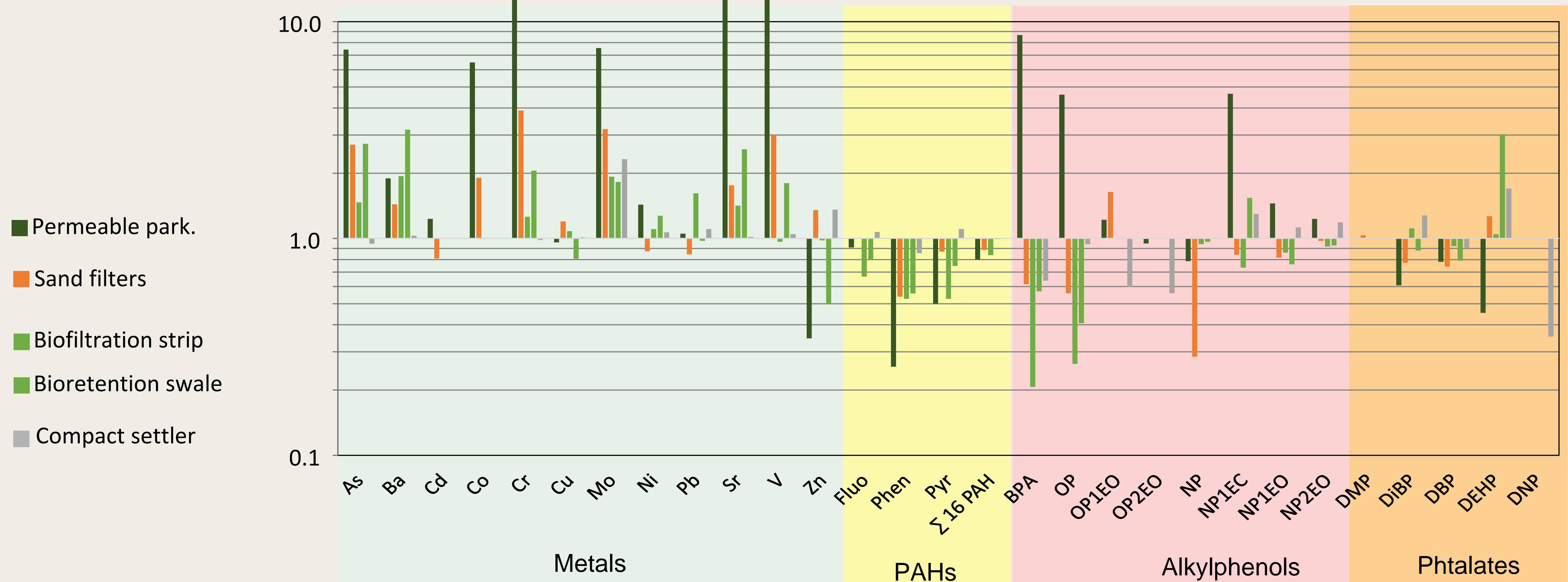
- Variable efficiencies, generally lower than SS
- Better for micropollutants that are mainly particle bound
- Over contaminations observed in some cases (BPA, APs, metals)



Efficiency of runoff source control measures (SCMs)

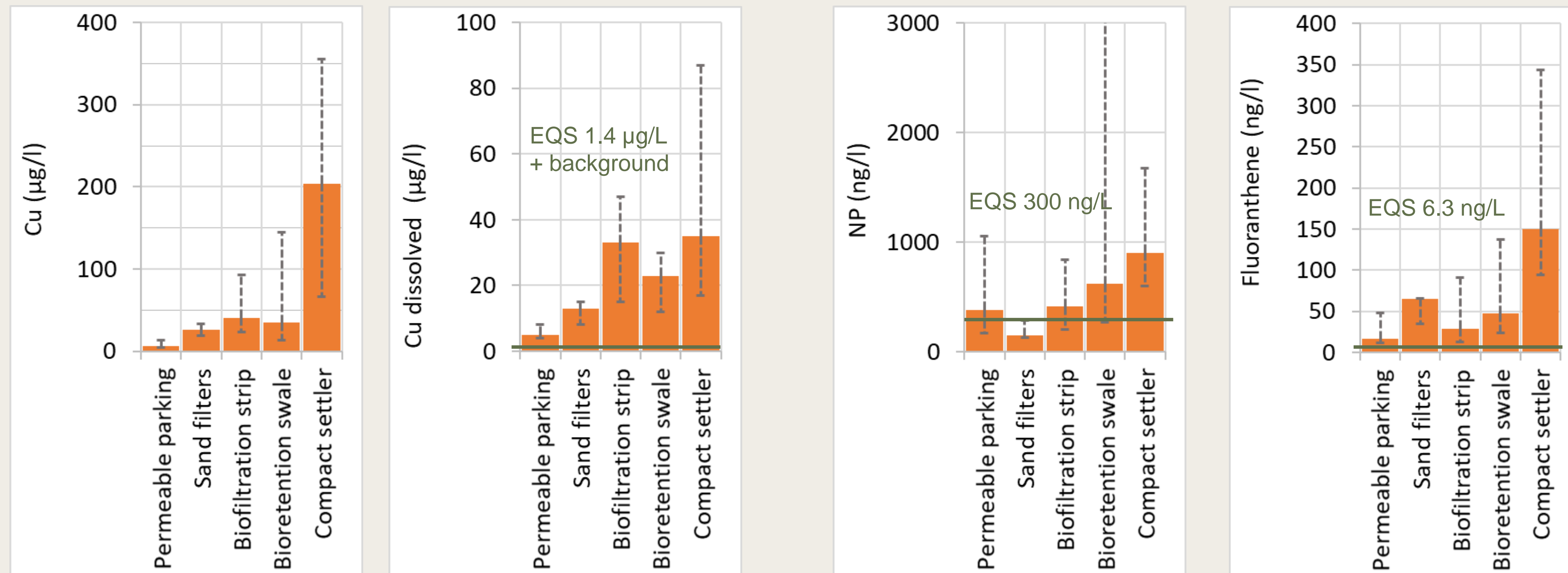
Focus on the dissolved micropollutants Median outflow / inflow concentrations

- None of the devices is really efficient for dissolved metals...
 - Possible leaching from previously accumulated metals
 - Increased colloidal forms in the outlet
- For organics : limited and variable efficiencies
- Emissions from construction materials



Efficiency of runoff source control measures (SCMs)

Level of outflow concentrations ?



Efficiency of runoff source control measures (SCMs)

But we should focus on load reduction rather than concentration reduction !



- Load reduction is very depend on volume reduction
- “Depollution” (ie concentration reduction) systems may be needed for heavy traffic roads or specific contexts
- For many area pollutant loads discharged to surface waters can be mitigated by mitigating runoff volumes

Efficiency of runoff source control measures (SCMs)

Vigilance points

- Be careful of non treated overflows !

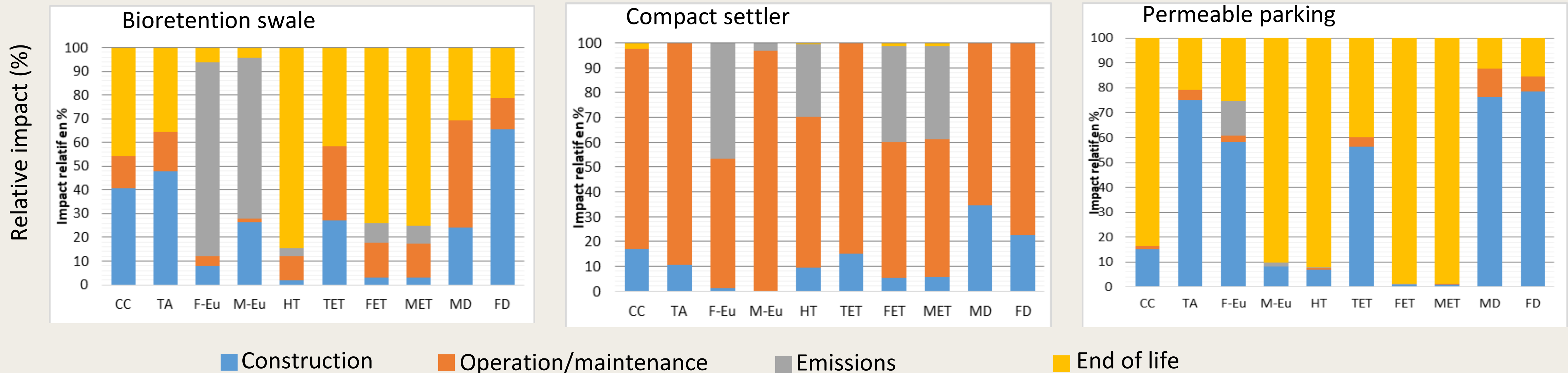
Compans biofiltration swale	SS treatment efficiency	Annual overflow volume	Global SS load reduction
1rst year	92%	35%	60%
After increase in surface storage	92%	10%	81%

- Ensure sufficiently sizing of the structure (to treat at least 80% of the annual volume), allow for sufficient sediment storage capacity
 - Respect maximum catchment size for prefabricated structures,
 - Anticipate sediment build up (heavily contaminated sites only) and associate storage volume
 - Need for continuous hydrological modeling on rainfall chronicles for the design of *ad-hoc* facilities and nature-based solutions
- Ensure sufficient and adapted maintenance (especially for heavily contaminated sites)
 - Industrialised structures: sediment removal and replacement of filters
 - Nature based facilities : need to control at regular intervals sediment accumulation, permeability, and every few years substrate contamination level. Pre-treatment system might be needed.

Global environmental impact of SCMs

Runoff is treated at the cost of other environmental impacts

Construction, operation, maintenance, dismanteling → life cycle assessment



Life cycle steps with the highest environmental impact :

- Filtration systems = end of life → fate of the contaminated filtration substrates
- Compact settler = maintenance → sediment and filtration cartridge removal and fate,
- Permeable parking = end of life + construction → polymeric construction materials

Design systems as simple as possible

- The more complicated, the less readable it is, and the more difficult it is to ensure appropriate maintenance

Consider operation and maintenance from the design phase

Pay attention to the construction materials used !

- They can be sources of micropollutants (drains, geomembranes, geotextiles).
- Check the absence of initial contamination of the substrates

Need for treatment and/or valorization sectors of by-products to improve the overall environmental assessment

The major challenge for SCMs deployment is not only technical

- Need to involve from the start a wide range of stakeholders (road services, water and sanitation department, landscapers, green area department, cleanliness agents)
- Allow for effective collaboration between different urban/road services

Extend the range of studied micropollutants, and assess their fate in the treatment facilities

- TWR particles, associated additives and degradation products
 - OPUR6, Leesu (starting) : mapping of SUDS soil contamination
plastics + non target screening + bioindicators of soil health
- Biodegradation potential of trapped micropolluants
 - SUDs soils are highly biologically active
 - Limited by pollutant biodisponibility?

Long term efficiency ?

- Leaching from accumulated particules?
- Saturation of adsorption capacity?

What should we do with the polluted sediments / substrates ?

- Remediation possibilities?

Thanks

And thanks to all the Roulépur team !

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