# Innovative rain gardens to filter microplastics from stormwater

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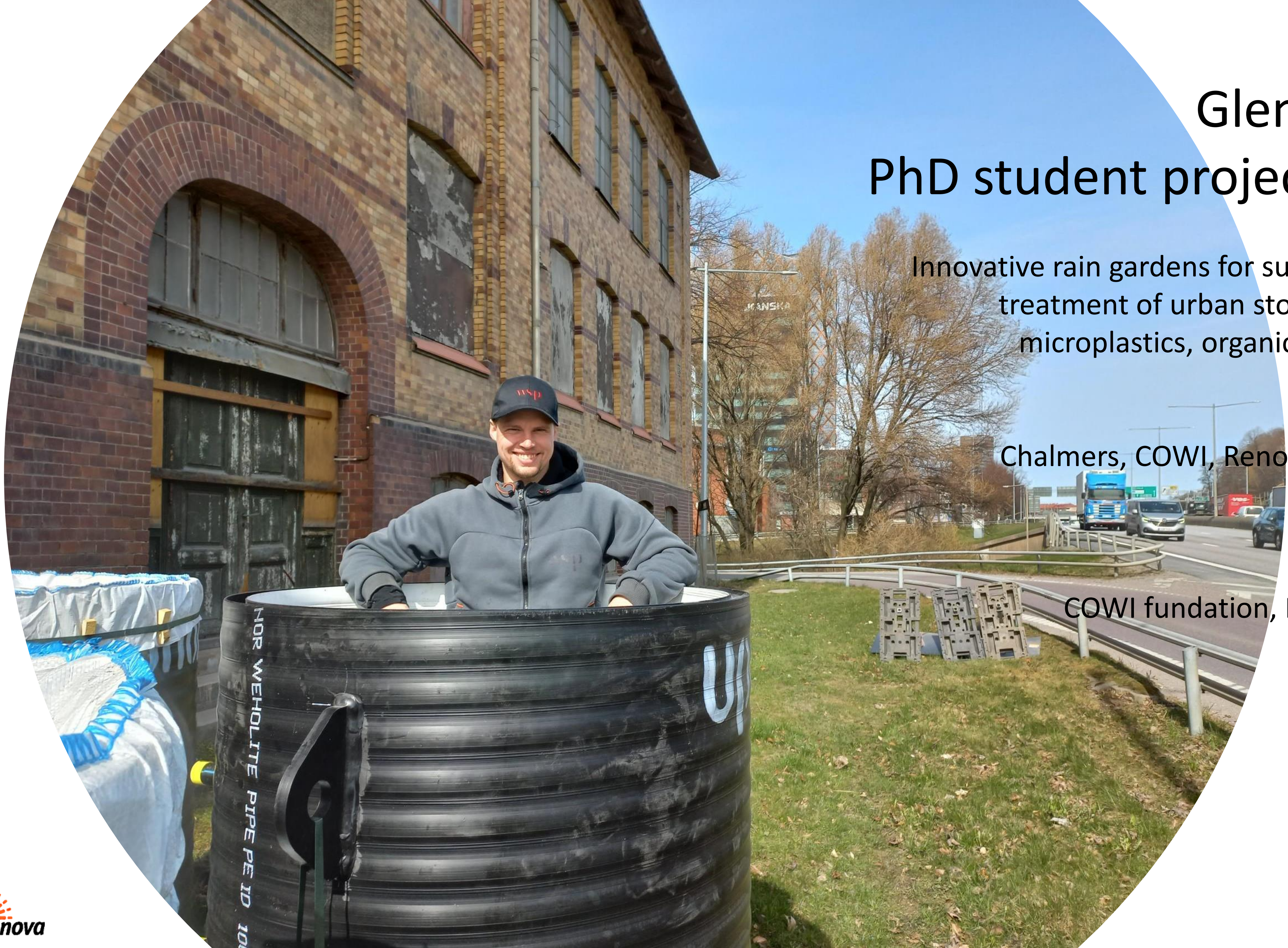

# Glenn Johansson
# PhD student project 2021-2026

Innovative rain gardens for sustainable and effective treatment of urban stormwater polluted with microplastics, organic pollutants and metals

Participants:

Chalmers, COWI, Renova, AquaTeam, and VTI

Funding:

COWI fundation, FORMAS, and Immerse

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# Flooding…

www.stockholmvattenochavfall.se

https://www.svt.se/vader/manadskronikor/juni2007

www.gp.se

# ...and pollution!

Traffic is the major source of microplastics

https://research.chalmers.se/publication/532025/file/532025_Fulltext.pdf

To reduce the spread of pollutants, stormwater should be treated as close to the source as possible.

-City of Gothenburg



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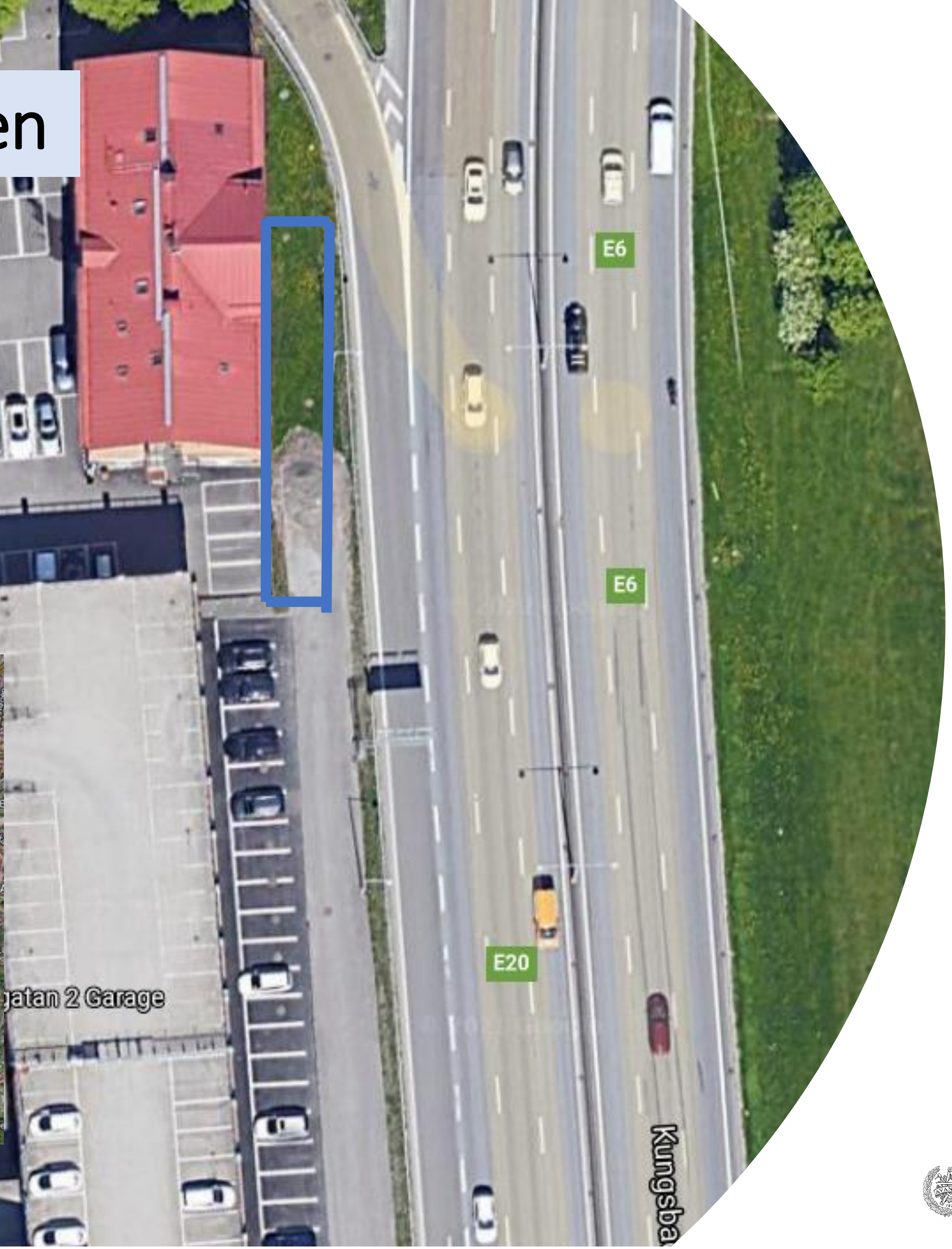
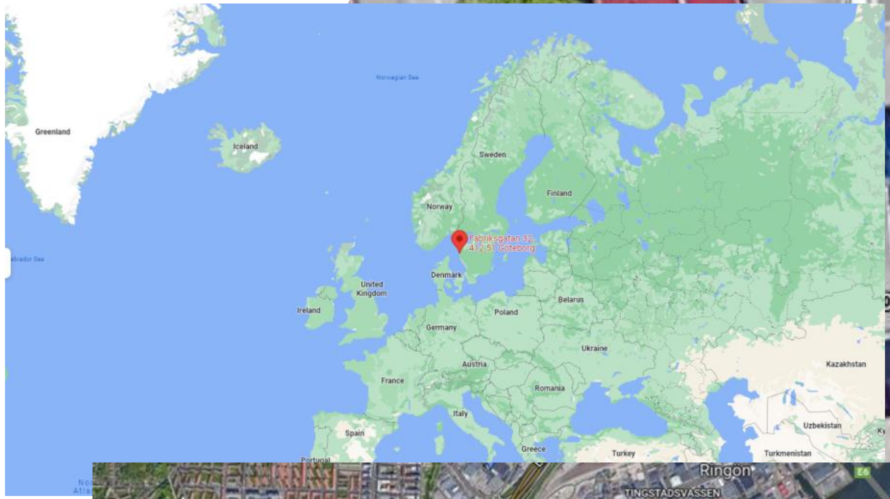
# Highway E6, Gothenburg, Sweden





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# Microplastics in urban stormwater

The size fraction of microplastic analyses influence the results

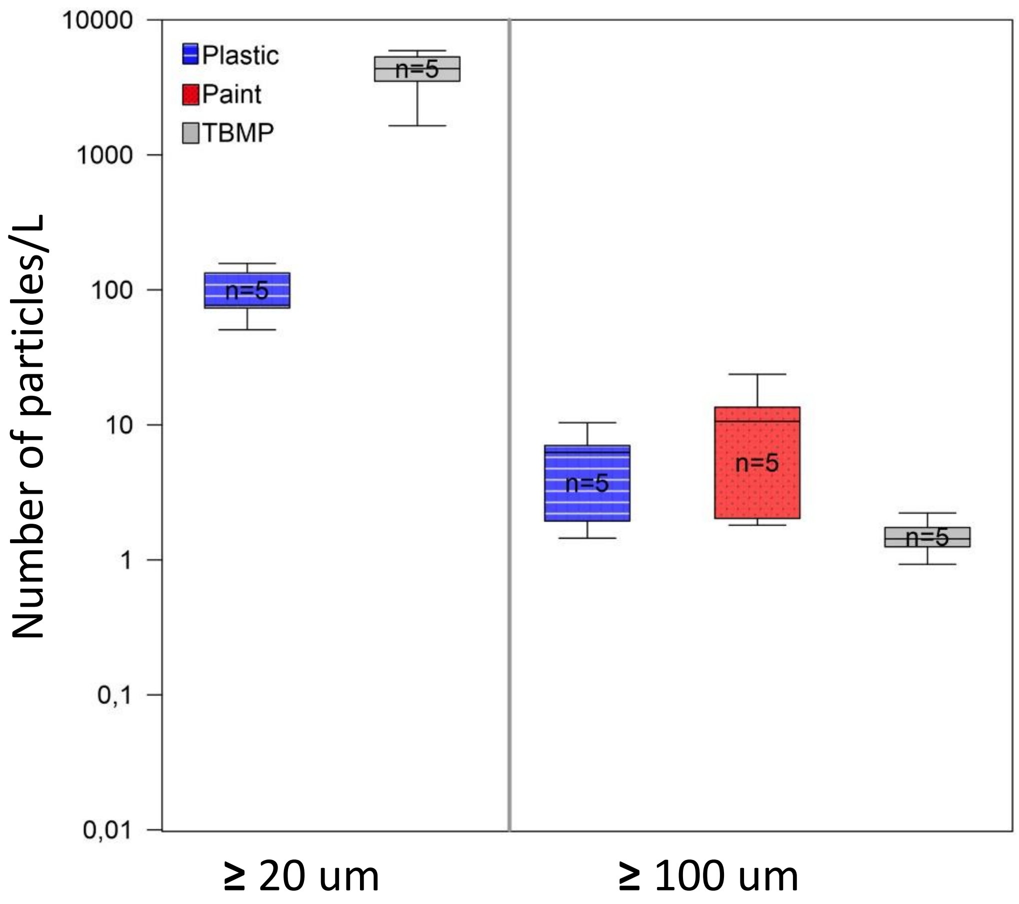



Fig. 11. Plastic, paint and TBMP in stormwater, measured as flow-weighted rain event mean concentration. Boxes to the left relate to particles ≥20 μm and boxes to the right show particles ≥100 μm.

Ref: Järlskog I., Strömvall A-M., Magnusson K., Gustafsson M., Polukarova M., Galfi H., Aronsson M., Andersson-Sköld Y. (2020). Occurrence of tire and bitumen wear microplastics on urban streets and in sweepsand and washwater. https://doi.org/10.1016/j.scitotenv.2020.138950

# Microplastics in urban stormwater (≥10um)

| | Stormwater sediment E6, µg/kg DS | Stormwater E6, µg/L |
|---|---|---|
| **Polyisoprene (PI)** | 142 000 | 130 |
| **Polybutadiene (PB)** | 11 500 | 90 |
| **Polyethylene (PE)** | 67 700 | 140 |
| **Polypropylene (PP)** | 11 800 | 12 |
| **Polyvinylchloride (PVC)** | 10 200 | 120 |
| **Polystyrene (PS)** | 6 700 | 10 |
| **Polymethylmetacrylate (PMMA)** | 2 000 | <1,0 |
| **Polyeteneterphthalate (PET)** | 750 | <1,0 |
| **Polyamide 6 (PA6)** | <30 | <1,0 |
| **Polycarbonate (PC)** | <30 | <1,0 |

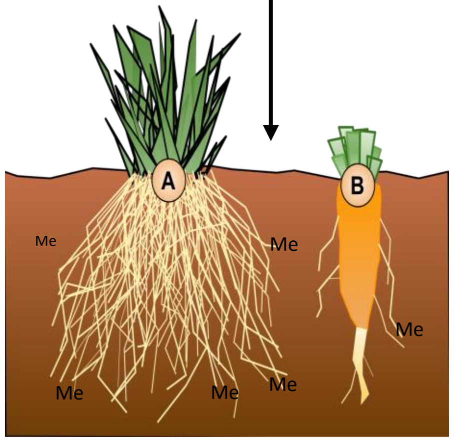
**PI and PB**: mainly TRWP (tire and road wear particles)
**PE, PP, PVC, and PS**: e.g. car bumpers, food packaging, pipes
**PMMA** (Plexiglas): e.g. exterior vehicle lights
**PET**: e.g. bottles

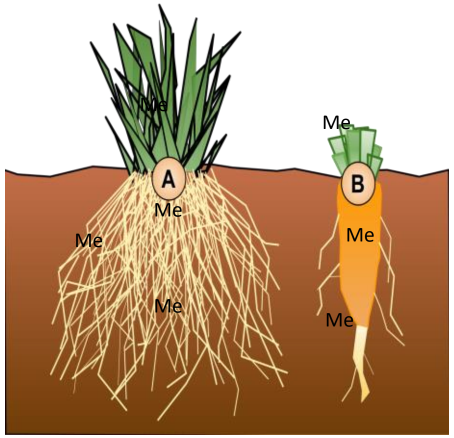
# Phytoremediation and filters

Phytoremediation
=
The plants are doing the job!


Stormwater from E6 in Gothenburg
- Metals (Cu, Zn)
- **Microplastics**
- Organic pollutants
- (Nutrients)

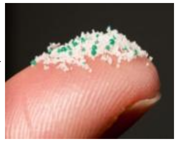
Soil
**Peat**
**Bio char**
**Ash***





Zinc recovery



Plastic recovery?

Cleaner water and material?!

*Sorted and aged bottom ash from waste-to-energy incineration



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# Aim

**Value**

Reduce the spreading of pollutants

**Techniques**

Develop environmentally adaptable techniques

**Green economy**

Contribute to a green and circular economy

**Green infrastructure**

Contribute to a green infrastructure

# Scientific questions



- Can raingardens in combination with different filter material and plants purify polluted stormwater?
  - ❖ With and without plants
  - ❖ Control with plants
- How are the pollutant adsorption processes working in the different filters?
  - ❖ Metals
  - ❖ Microplastics
  - ❖ Nutrients
  - ❖ Organic pollutants
- What and how much of the pollutants are extracted by the plants?
- Is it possible to recycle the metals?
- Can an optimal layout be designed?

# Demands on plants

- Extract and/or degrade
  - ❖ Metals
  - ❖ Microplastics
  - ❖ Organic pollutants
- Nordic climate
- Dry and rainy periods
- Large biomass


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# Filters

**Control**

1. Sandy loam with pumic stone (Top layer)
2. ***Sandy loam mixed with 15% compost***
3. Coarse sand
4. Fine gravel

**Peat and Bio char**

2a. Soil mixed with peat/bio char (40%)

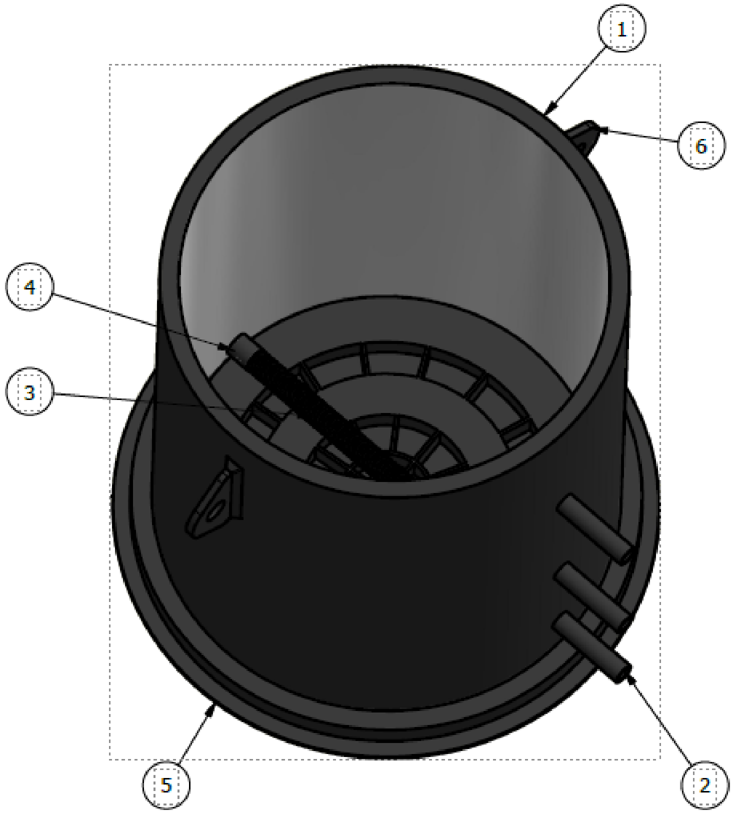
2b. Peat/bio char

**Ash**

2a. Soil mixed with ash (50%) and compost (15%)

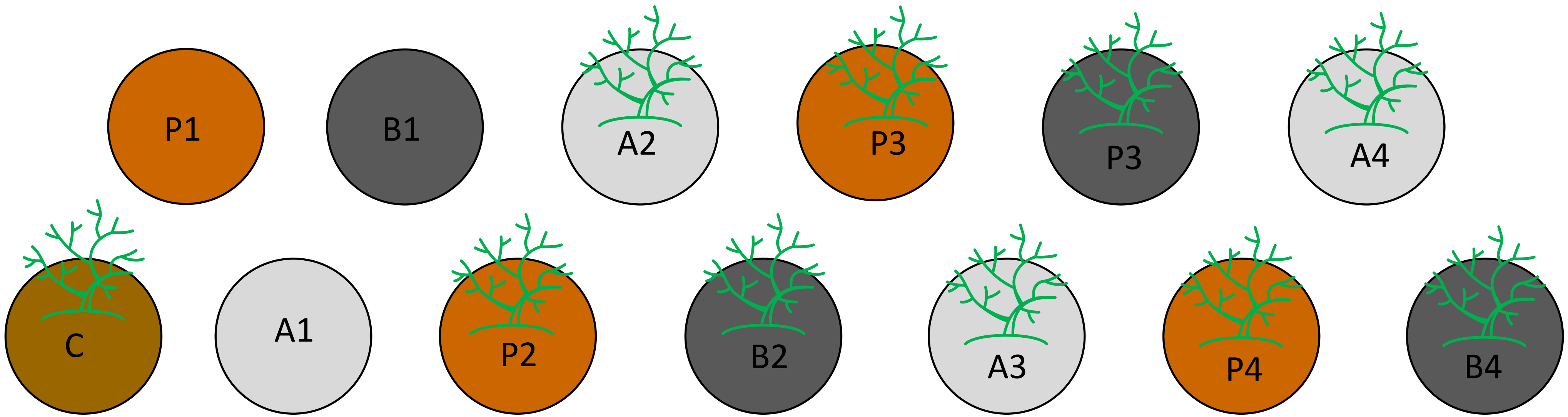
2b. Peat

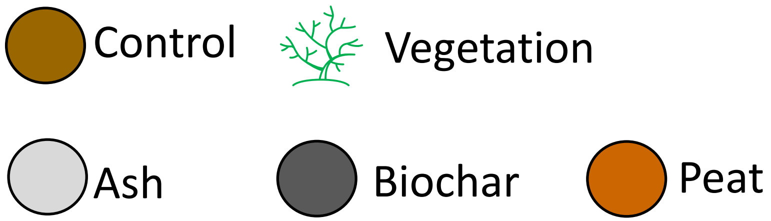
2c. Bio char




Height: 125 cm    Diameter: 100 cm

# Setup

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# Results


May 2022


October 2022

- The plants are growing!
- Mainly water analyses
  - Fundamental characterization e.g. pH, redox, DOC,…
  - Metals, nutrients, organic pollutants, and microplastics

- Variations in untreated stormwater
- No differences with and without plants

# Results
# Particulate matter and nutrients

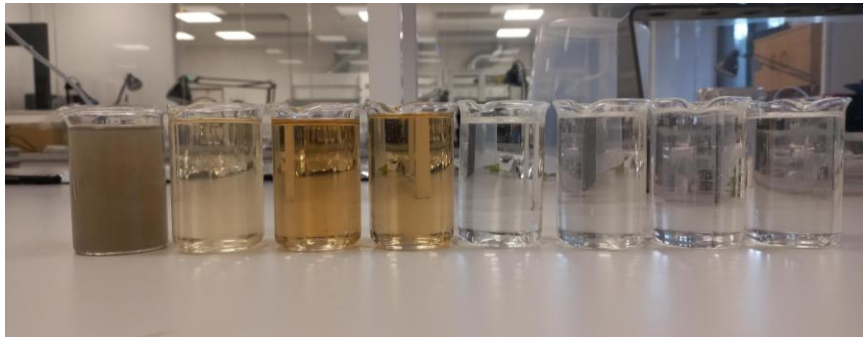
**Particulate matter**
- Particulate matter decreases
- Difference between filter types

**Nutrients**
- High in the beginning
- Concentrations in effluents decrease with time
- Biochar → lowest release

Original stormwater

**July 2022**

control peat ash biochar

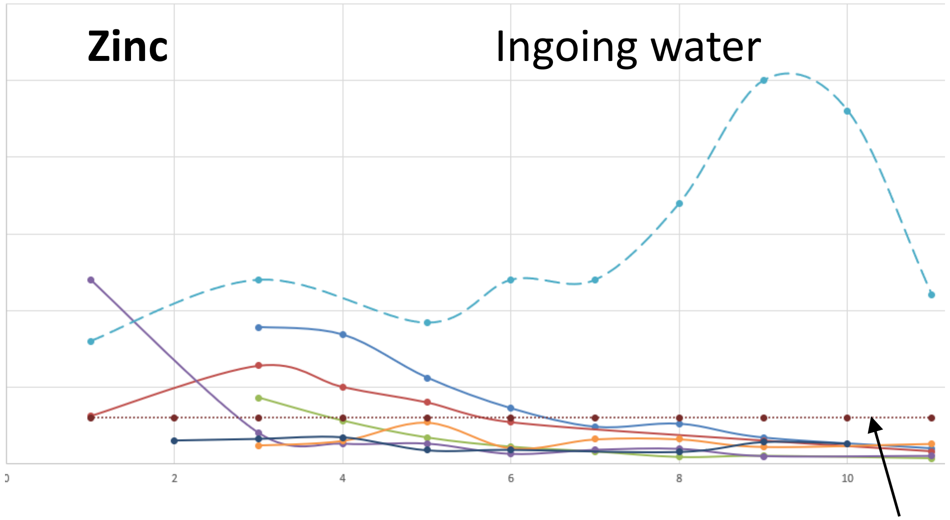


**January 2023**

# Results
# Organic pollutants and metals

**Organic pollutants** (aliphates and PAHs)
- Decreased concentrations with time in all filters (Often <detection limit)
- Approx at least 10 times reduction in effluent vs influent
- Long aliphates (>C16-35) highest in biochar and peat
- PAHs highest in ash

**Metals** (e.g. Zn, Cu, Pb, Co, and Ni)
- Decreased concentrations with time
- Efficient reduction
- Variation between filters and metals
- All metals <guidelines except Cu
- Only biochar reduces Cu to <guideline




Guideline stormwater
(City of Gothenburg)

# Results
# Microplastics (<10 um)

Reduction of all microplastics!

| | Influent<br>% quantified >1.0 µg/L, n= 7[b] | Effluent<br>% quantified >1.0 µg/L, n= 34 | Filter types, >1,0 µg/L |
|---|---|---|---|
| **Polyisoprene (PI)** | 57 | 6 | Ash and peat |
| **Polybutadiene (PB)** | 57 | n.a. | |
| **Polyethylene (PE)[a]** | 100 | 71 | All filter types incl control |
| **Polypropylene (PP)[a]** | 86 | 71 | All filter types incl control |
| **Polyvinyl chloride (PVC)** | 43 | n.a. | |
| **Polystyrene (PS)** | 57 | 15 | All filter types incl control |
| **Poly(methyl methacrylate) (PMMA)** | n.a.[c] | 3 | Peat |
| **Polyethylene terephthalate (PET)** | 14 | n.a. | |
| **Polyamide 6 (PA6)** | n.a. | n.a. | |
| **Polycarbonate (PC)** | 14 | 9 | Ash, peat, and control |

[a]Potential contamination from filter materials; [b]Total number of samples analyzed; [c]Under the limit for quantification

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# Results
# Microplastics

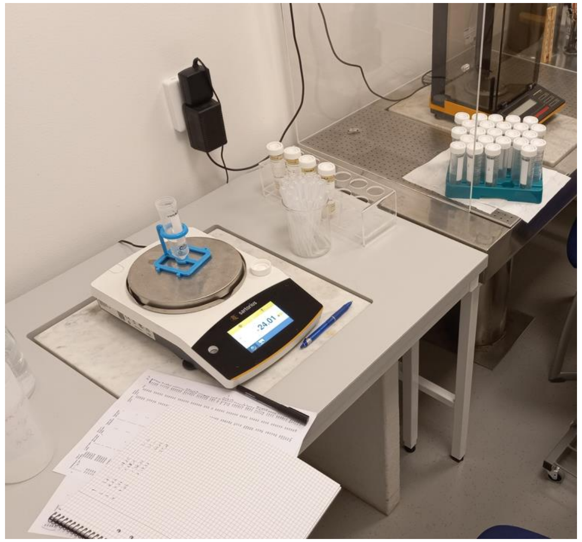
February 2023

| | Influent, ug/L | Control, ug/L | Ash, ug/L | Biochar, ug/L | Peat, ug/L |
|---|---|---|---|---|---|
| **PI** | 460 | <1.0 | <1.0 | <1.0 | <1.0 |
| **PB** | 250 | <1.0 | <1.0 | <1.0 | <1.0 |
| **PE** | 130 | <1.0 | <1.0 | 1.5 | 2.9 |

**Good cleaning of microplastics!**

# Conclusions, this far…

- Pollutants i.e. metals, organics and microplastics, and nutrients are identified in urban stormwater
- All plants survived the first cultivation season
- All filters work well
- Pollutants are efficiently removed from the stormwater
- Small microplastic particles may pass the filters



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# Continued research

2023

- <10 um microplastic particle size analyses

- Performance under non-favourable conditions
  - Wet periods and low temperatures (winter)
  - More pollutants in the stormwater
  - Less active plants

  - Dry periods and high temperatures (dry summer)

2024

- The processes in soil, microbiology, mycorrhiza, and plants
- Analyses of filter materials
- Recycling of metals
- Performance over time

# Thank you for your attention!


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