

Interreg

North Sea Region

NuReDrain

European Regional Development Fund



EUROPEAN UNION



Webinar, 24 November 2022

Practical issues

- Please mute yourself.
- Feel free to ask questions in the chat.
- The webinar will be recorded.
- Handouts will be put available afterwards.

NuReDrain -> NureDrain 2.0

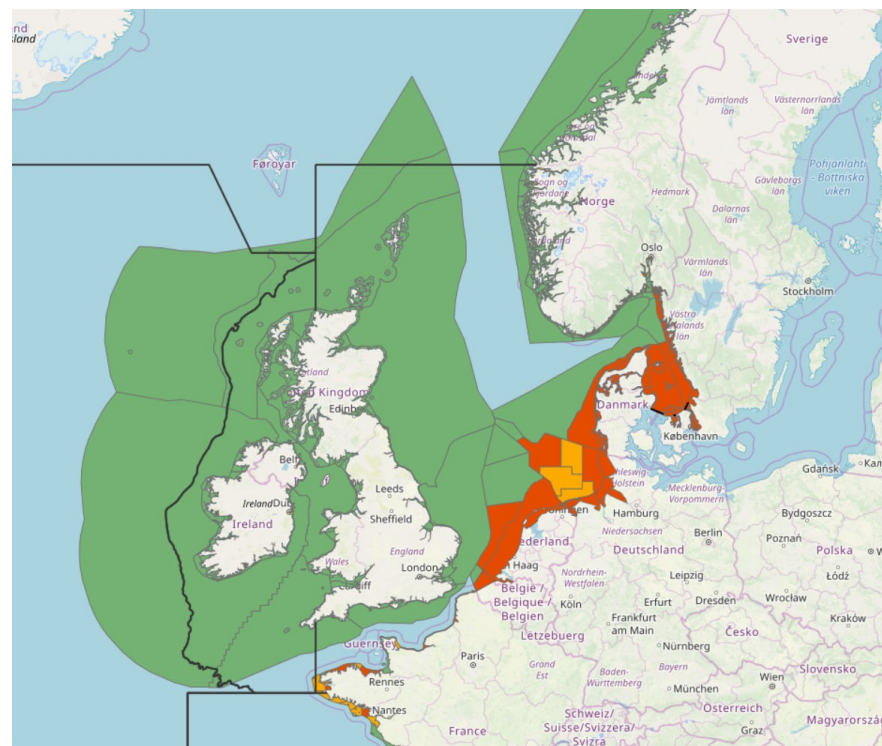
- Nutrient Removal and Recovery from Drainage water
- 1/3/2017 – 30/9/2021 -> 30/6/2023
- Interreg North Sea Region
- Project cost: € 3.516.378 - Fund: € 1.758.187
- 11 partners in 3 countries -> 7 partners in 3 countries (BE, DE, DK)



Eutrophication status

Interreg VB North Sea Region
Programme Area 2014-2020

Regions within the NSR programme area



- Red : problem areas
- Orange : potential problem areas
- Green : non-problem areas

Source: OSPAR

- **Point sources:**

- Discharge municipal effluent
- Discharge industrial effluent



Pressure on surface water

18%

- **Diffuse sources:**

- Agricultural activities
- Combined sewer overflow events



38%

Nutrient sources

- **Point sources:**

- Discharge municipal effluent
- Discharge industrial effluent



Pressure on surface water

18%

- **Diffuse sources:**

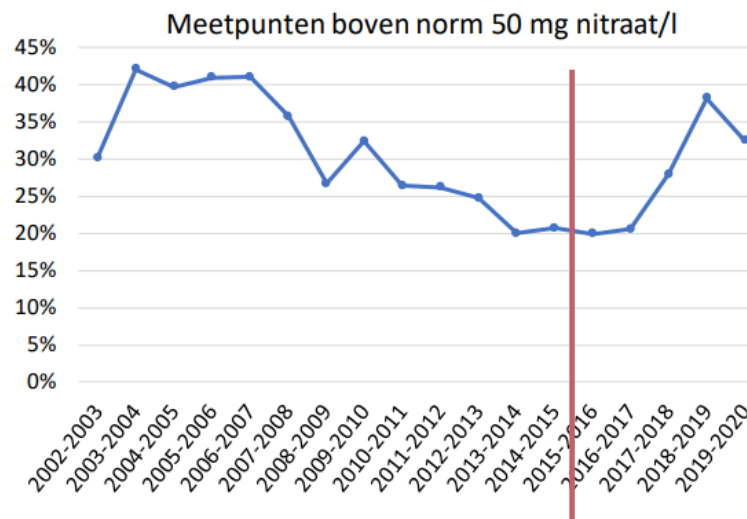
- Agricultural activities
- Combined sewer overflow events



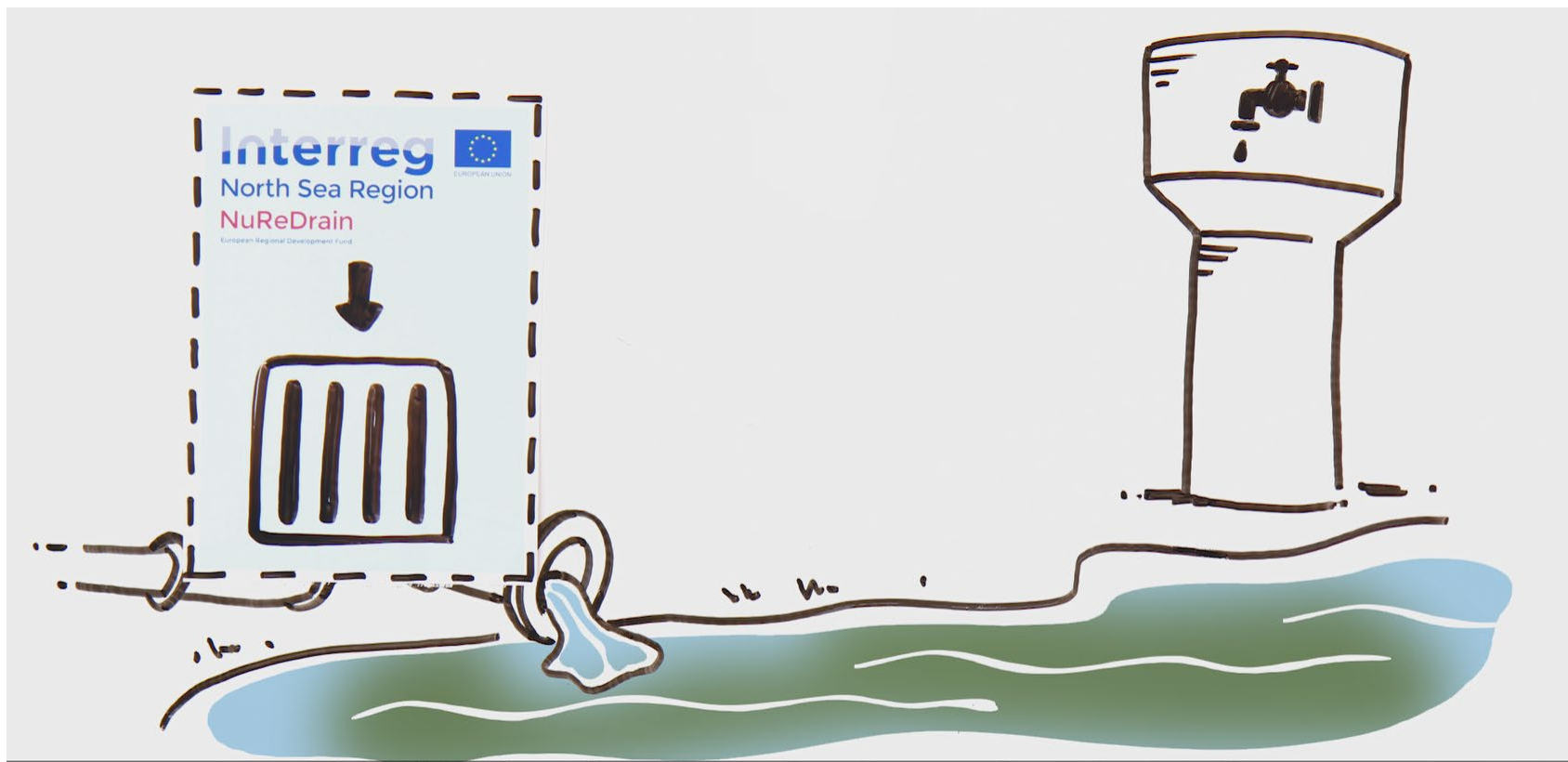
38%

I. Source based measures

- Reduce nutrient input (optimize fertilization)
- Reduce losses from soil (adapt rotations, grow catch crops, manage crop residues, ...)



End-of-pipe filter systems



2 water types

1. Drainage water



Bigger volumes

Low N and P concentrations

Rain dependent

Periodic

2. Greenhouse effluent



Smaller volumes

High N and P concentrations

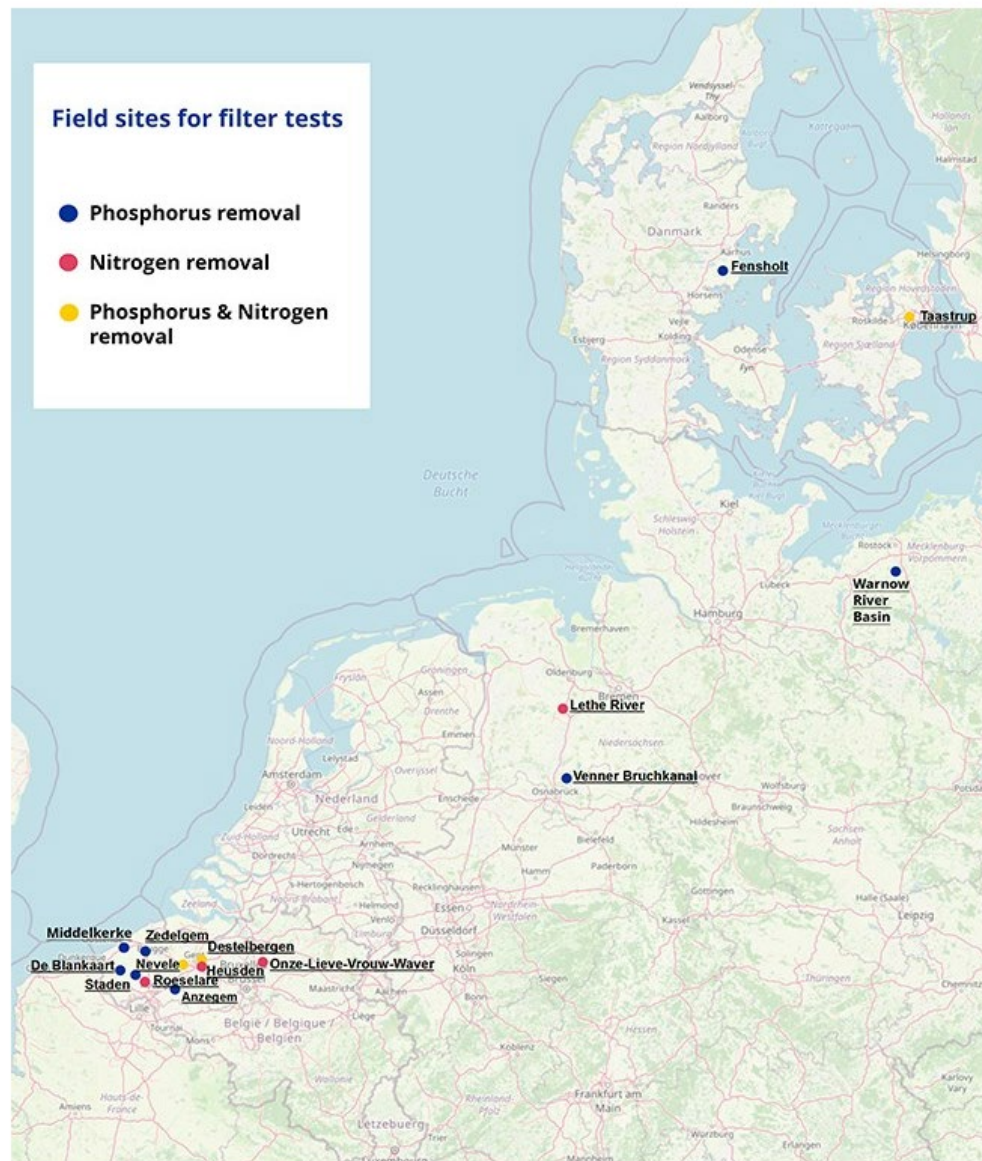
Controllable

Continuous or periodic

Field cases

Field sites for filter tests

- Phosphorus removal
- Nitrogen removal
- Phosphorus & Nitrogen removal



1. Long term evaluation and upscaling of iron coated sand filters for P removal from agricultural drainage water

Junwei Hu (Ghent University)

2. Can filter materials be regenerated and reused?

Jef Bergmans (VITO)

3. Combining filter systems for N and P removal from greenhouse wastewater

Els Pauwels (PCS Ornamental Plant Research)

4. Cost effectiveness of nutrient removal filters at a catchment scale

Andreas Bauwe (Rostock University)

5. Nutrient filter systems in practice: construction manuals, fact sheets and cost assessment

Charlotte Boeckert (VLAKWA/VITO)

Long term evaluation and upscaling of iron coated sand filters for P removal from agricultural drainage water

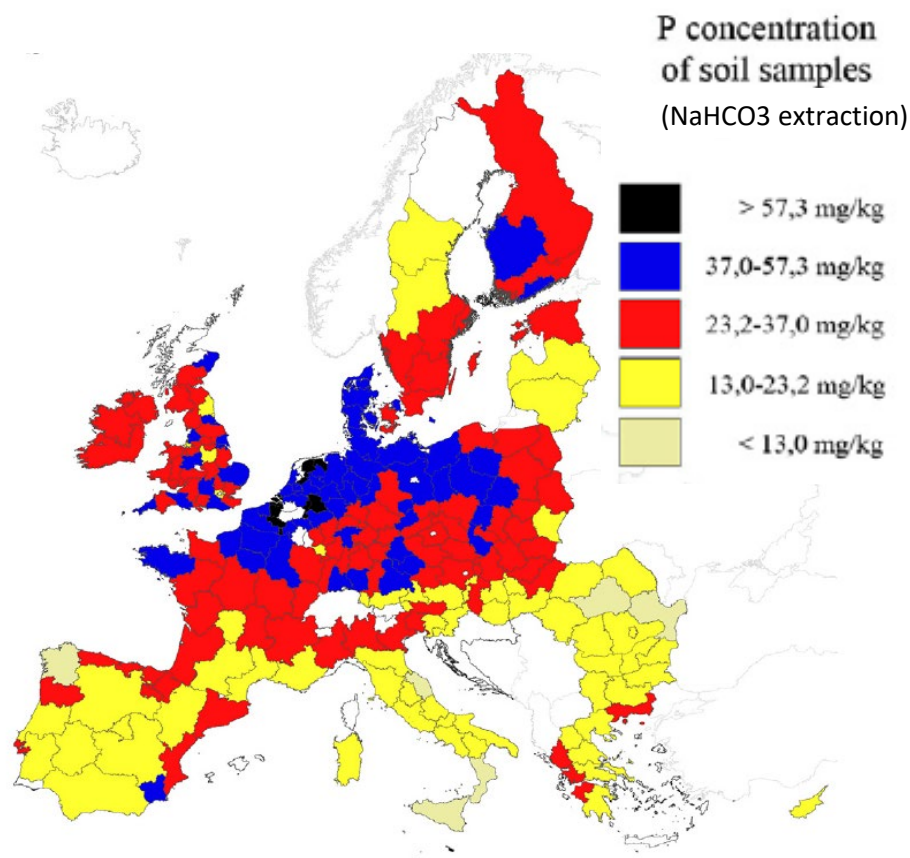
Junwei Hu, Hui Xu, Stany Vandermoere, Stefaan De Neve

Department of Environment

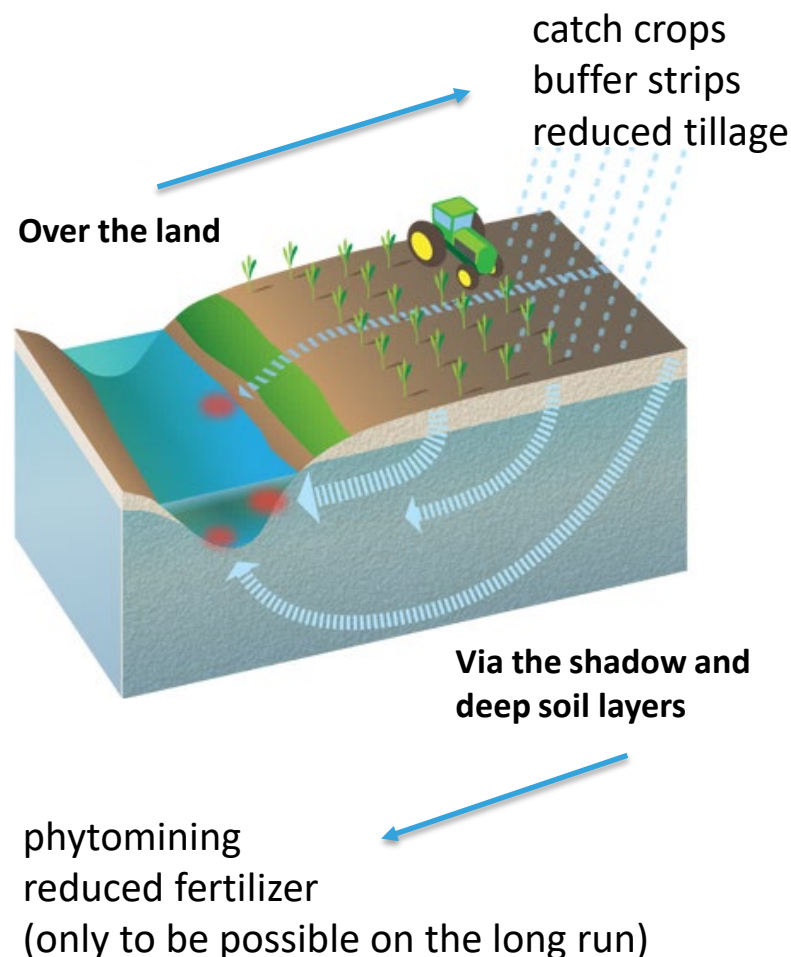
Ghent University

Why is P removal important?

Agricultural intensification resulted in high soil P content

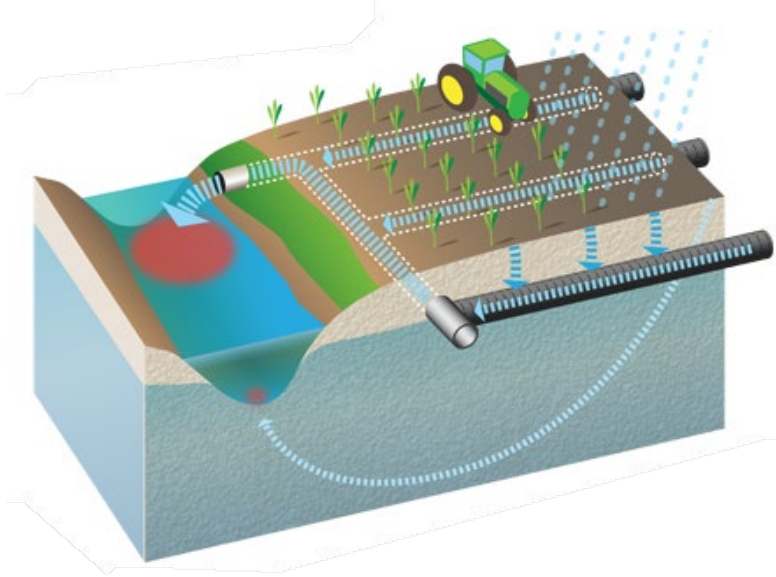


In Northwest Europe, agricultural P losses are a major cause of eutrophication problems in surface water



What do we need?

There are no efficient management practices to reduce P leaching on the short term.



17—40 % is drained in NW Europe
a large mitigation potential

installing P filters at the end of the drains could be potential solution

- Reduce P loads as much as possible (< 0.1 ppm, Water Framework Directive)
- Process discontinuous and peak flows
- Low cost and easy to be installed

Phosphorus Filter Development

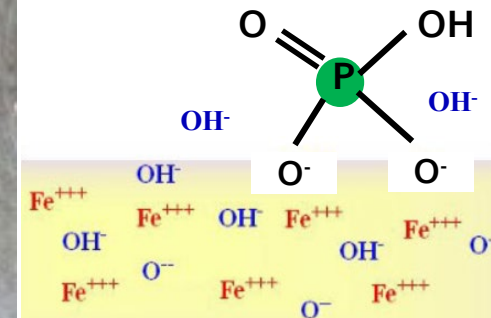
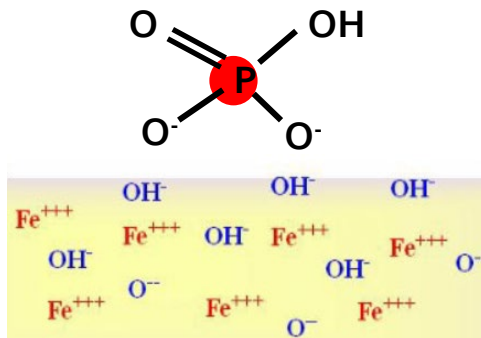
Phosphorus Sorbing Materials: Iron coated sand (ICS)

Lab scale

P sorption capacity and speed:

ICS > bauxite > glauconite > olivine = biotite.

- Saturated hydraulic conductivity
(K_{sat}) ≥ 0.00045 m/s
- Sufficient P removal ($\geq 74\%$)

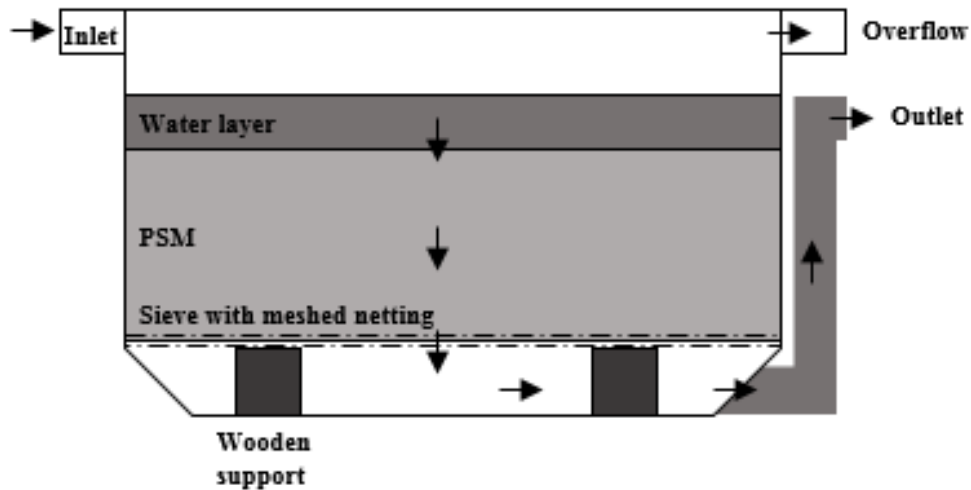


By-product from drinking-water industry

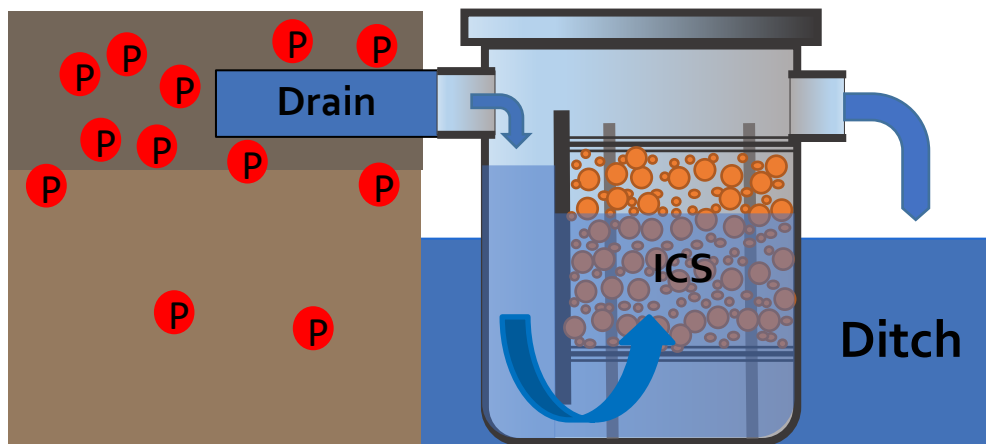
Vandermoere S., Ralaizafisolaoarivony N., Van Ranst E., De Neve S. (2018). Reducing phosphorus (P) losses from drained agricultural fields with iron coated sand (- glauconite) filters. Water Research, 141, 329–339.

Simple bucket filter and prototype

Simple bucket filter

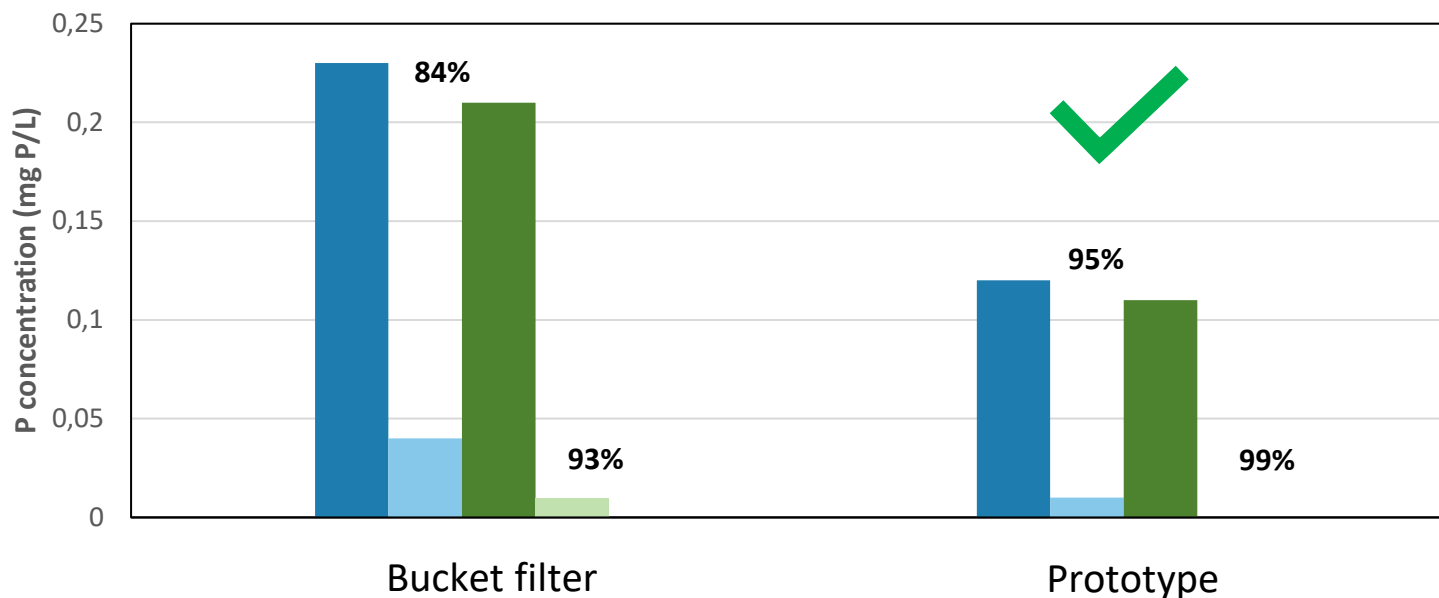


Prototype



P removal efficiency

- Volume weighted average TP concentration inlet
- Volume weighted average TP concentration outlet
- Volume weighted average DRP concentration inlet
- Volume weighted average DRP concentration outlet



Water flow: **0.04-4.3 m³/day**

0.04-3.6 m³/day

TP: total phosphorus

DRP: dissolved reactive phosphorus

Cost estimate

	Price [€]	Life span [years]
Filter bucket	600	15
ICS materials	50	2
Labor for installation	50 (self-installation) /100 (external-installation)	2
Total [€/year]		90-115

Evaluation of the filter

- + Low-tech solution: easy installation and operation
- + High P removal efficiency
- + Low cost of filter materials
- + Causes no other contaminations
- + No impact on accessibility and landscape

- + Only applicable for individual drain
- + Mostly remove dissolved reactive P

Recent Progress



Long term performance of filter box for single drain



Dig-in filter box for single drain



Upscaled filter box for larger volume of water

Long term performance

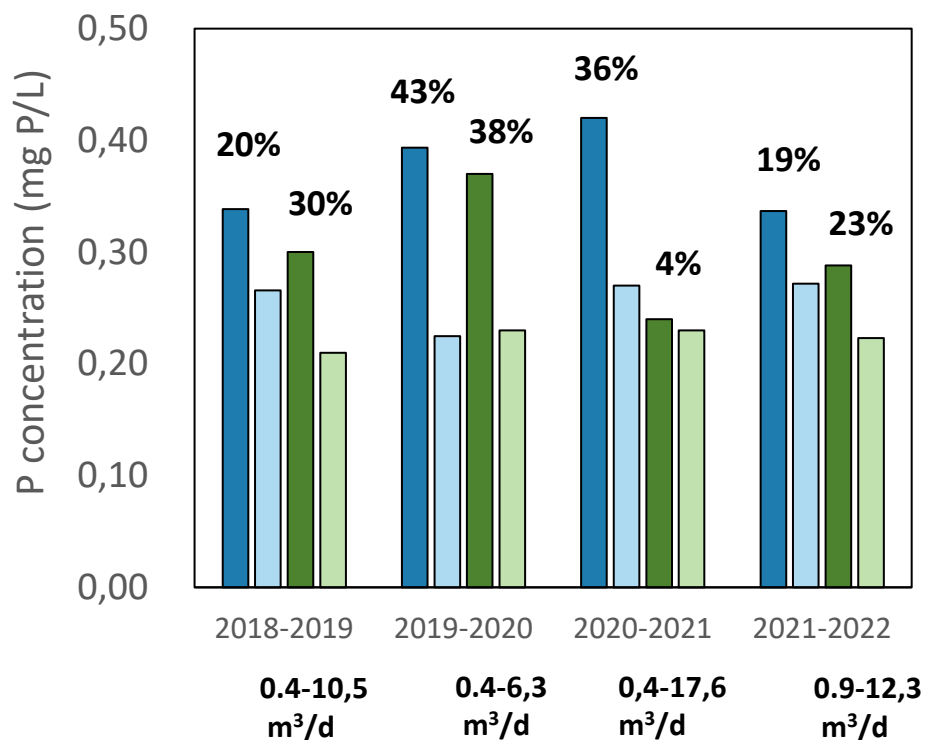
- 4 existing P filter boxes
- Anzegem, 2018-11-29
- Zedelgem, 2018-11-30
- Zedelgem 1mm (2), 2020-1-10
- Zedelgem 2mm (3), 2020-1-10

Long term performance

P removal efficiency

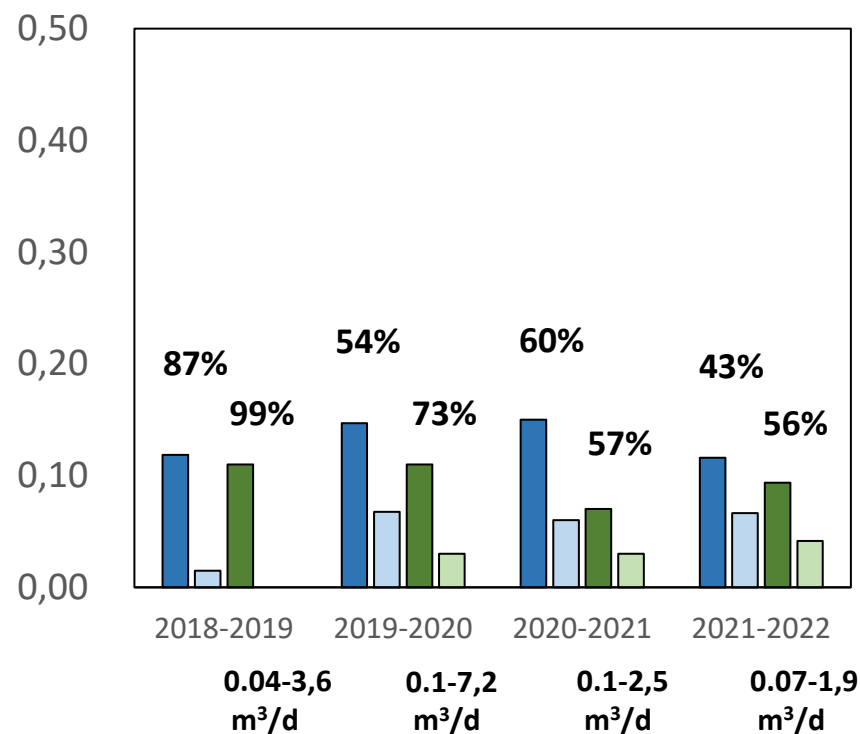
Anzegem

TP-in TP-out DRP-in DRP-out



Zedelgem

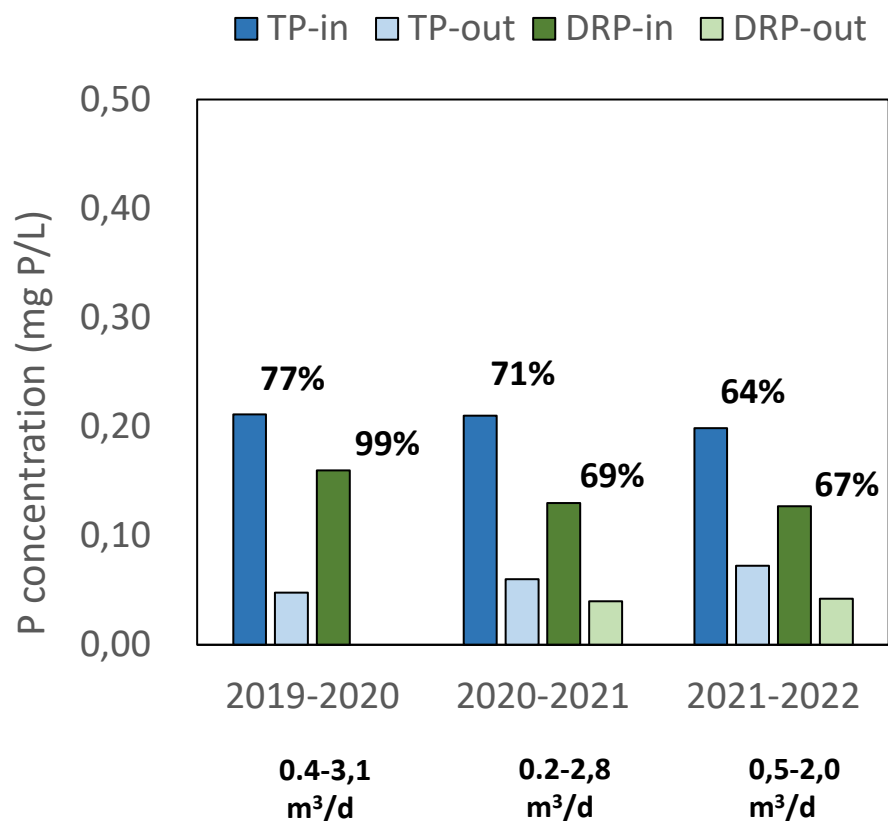
TP-in TP-out DRP-in DRP-out



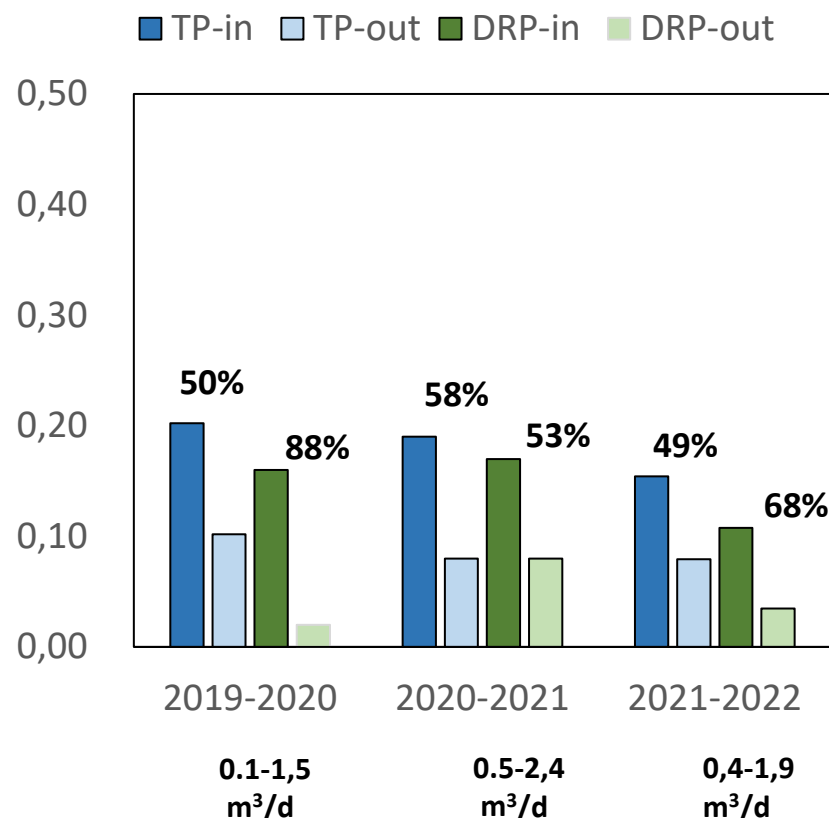
Long term performance

P removal efficiency

Zedelgem 1mm

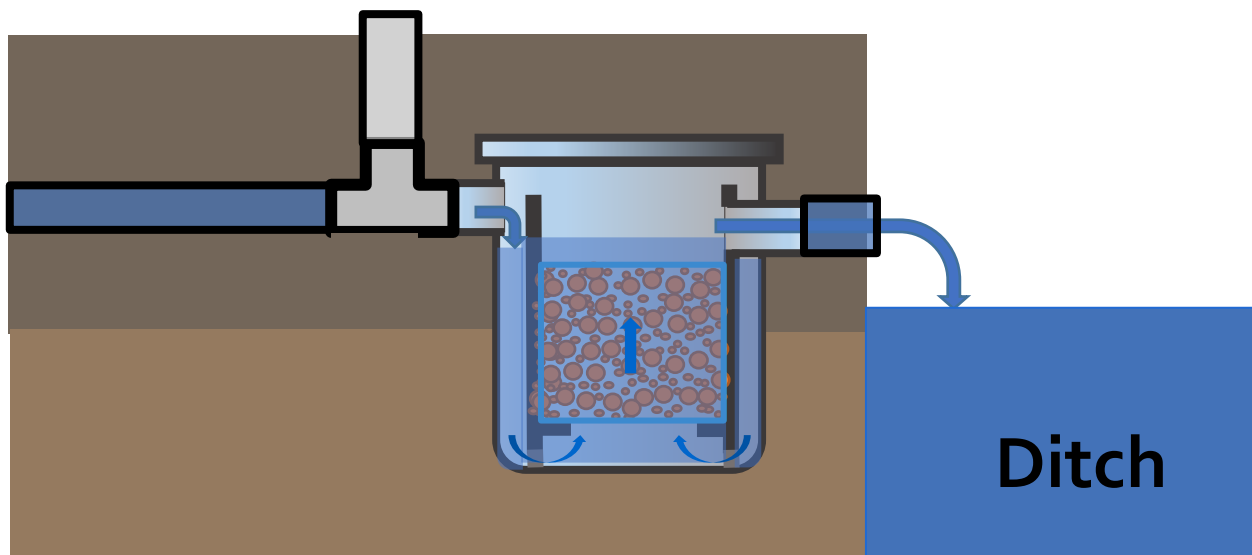


Zedelgem 2mm



Dig-in filterbox

The P filterbox is currently placed in the ditch but ideally the ditch is not to be obstructed.



Dig-in filter box

Staden dig-in (1)



Staden dig-in (2)

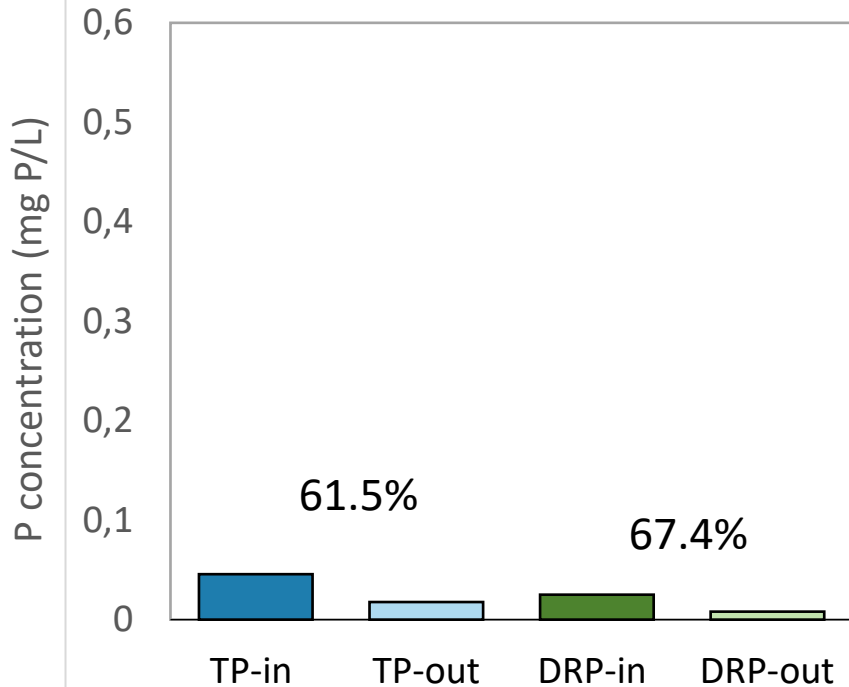


The installation was proven to be feasible

Dig-in filterbox

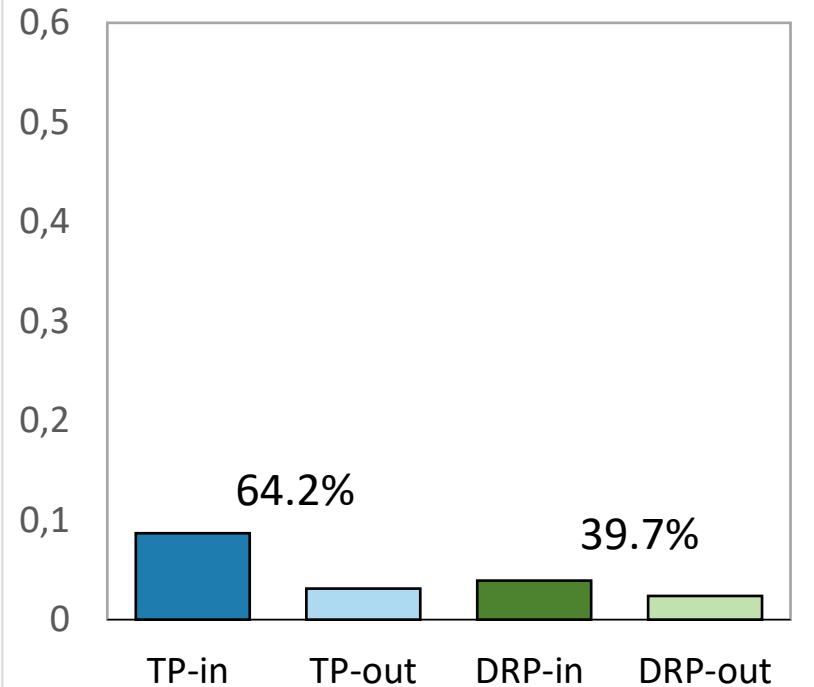
P removal efficiency

Staden dig-in (1)



Flow: 1.4-4.2 m³/d

Staden dig-in (2)



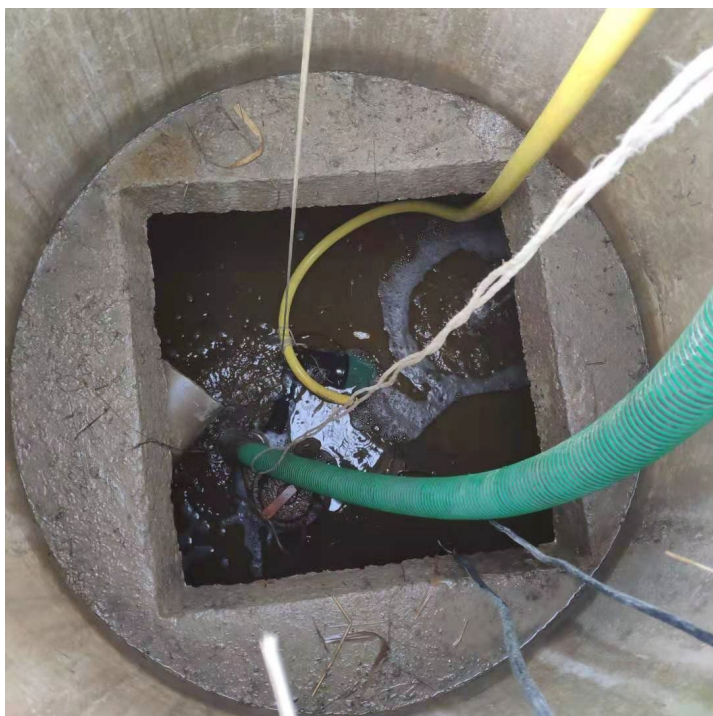
Flow: 3.4-8.3 m³/d

Given the P concentration is low, the dig-in P filter boxes are functioning

Upscaled P filterbox

- To treat bigger volume of drainage water

Collector drain

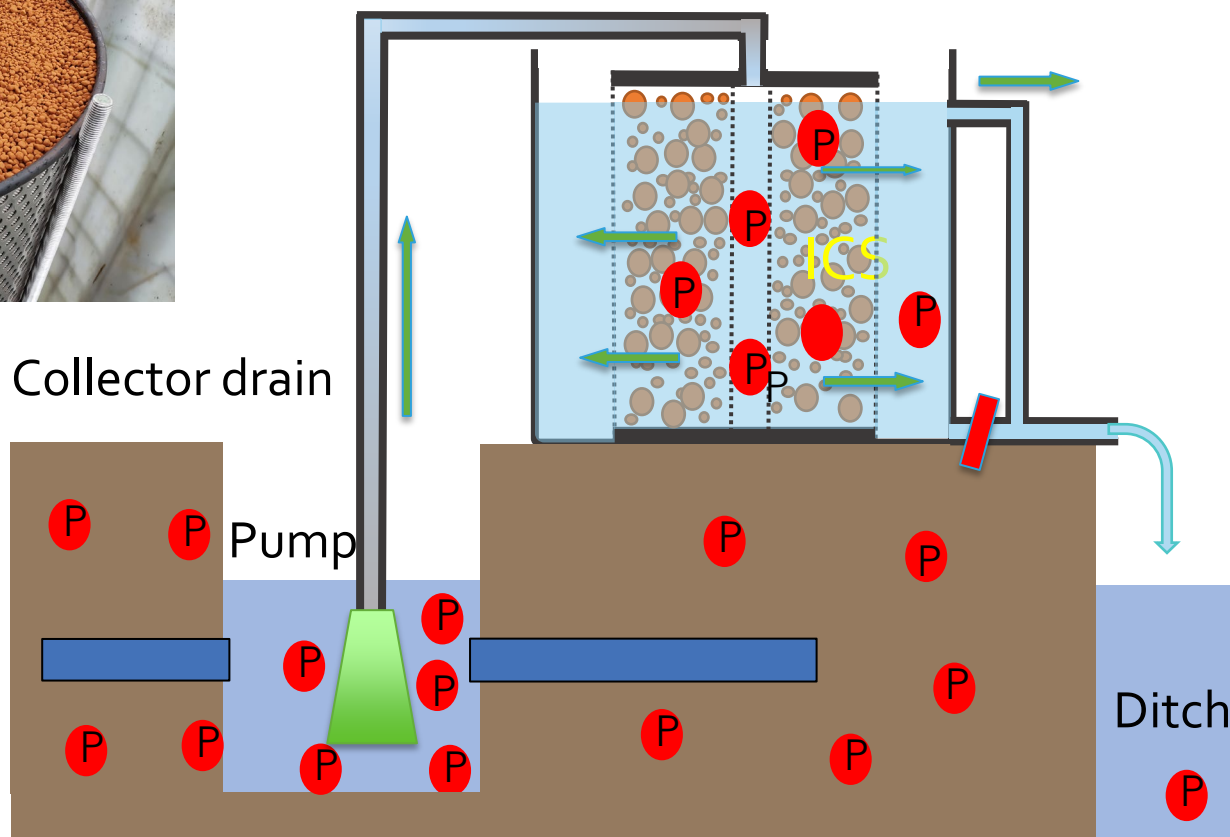


Open pond



Upscaled P filterbox

- Capable of treating bigger volume of drainage water
- 140 L iron coated sand



Upscaled P filterbox

Godelieve fields of Inagro

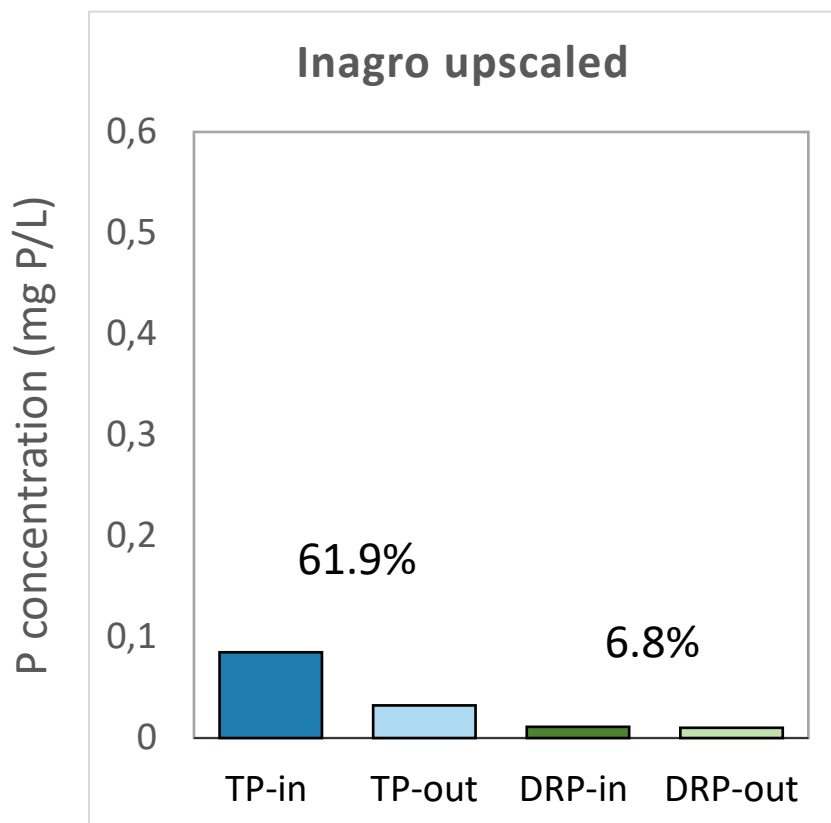


Middelkerke (Belgian coast)

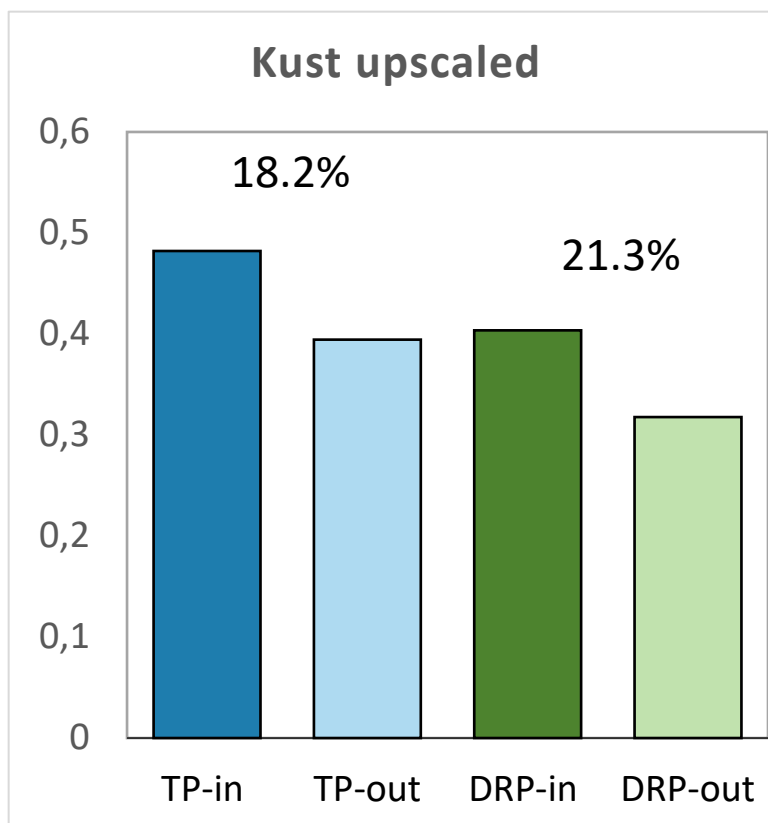


Upscaled P filterbox

P removal efficiency



Flow: 7.2-16.9 m³/d



Flow: 17.0-36.2 m³/d

The next

- Effectiveness vs flow
- Clogging of water from open pond
- Electricity supply



Thanks!

Q & A

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Jef Bergmans (VITO)

3. Combining filter systems for N and P removal from greenhouse wastewater

Els Pauwels (PCS Ornamental Plant Research)

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Charlotte Boeckert (VLAKWA/VITO)



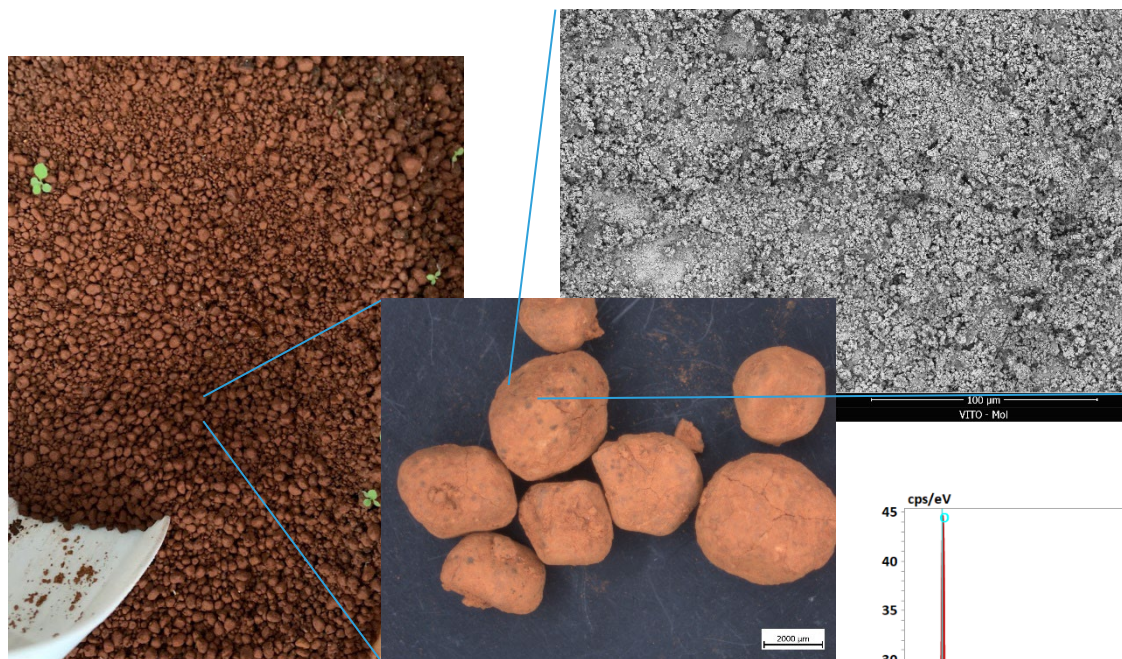
Desorption of ICS grains

Jef Bergmans – VITO

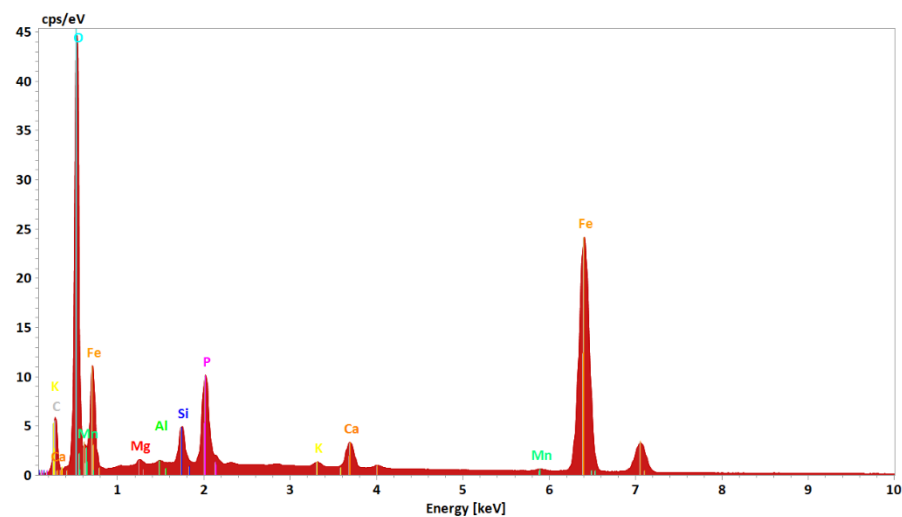
The opportunity to regenerate filter material enables that high-cost materials can be reused several times decreasing the total cost of operation.

- protocol for the regeneration P saturated filter material
- scale-up of the process

Characterisation of saturated ICS grains



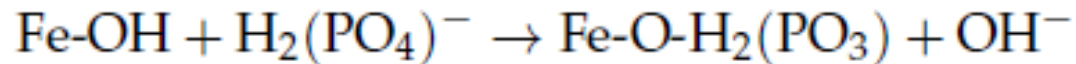
Mostly Fe, Si and P
Also C, Mg and Ca found



Different strategies are available in literature

- Acidic route → focus on P recovery
- Alkaline route → focus on **filter material recovery**

The alkaline route regenerates the hydroxyl groups

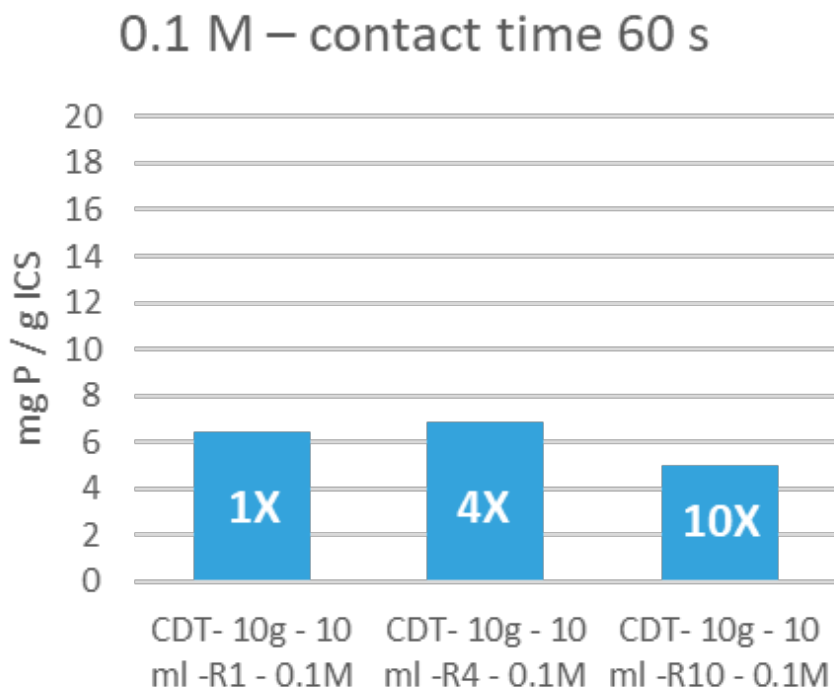
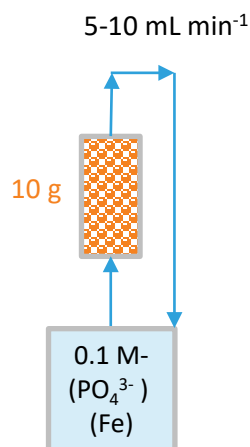


A significant amount of OH⁻ ions are needed to reverse the equilibrium and the excess OH⁻ ions are slowly release afterwards changing the pH of the eluate

Several studies available in literature providing valuable information,
However:

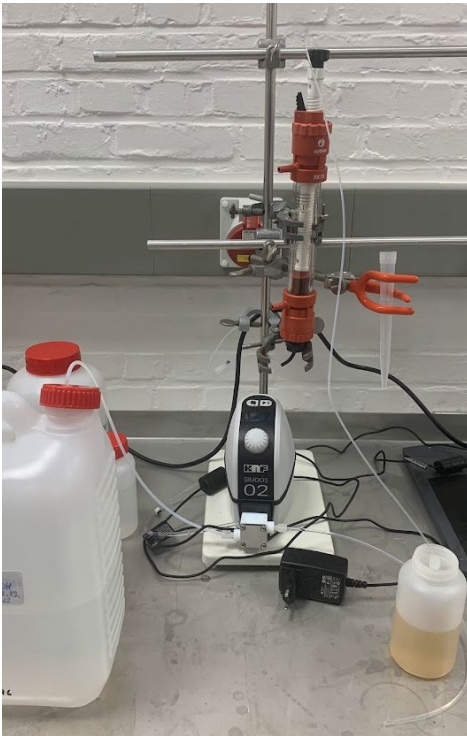
- Static small scale desorption experiments
- Test performed on artificially loaded sorbents

Optimisation of regeneration protocol



Re-use of the stripping solution also gives similar results for lower base concentration
Improved P desorption by changing contact time needs further investigation

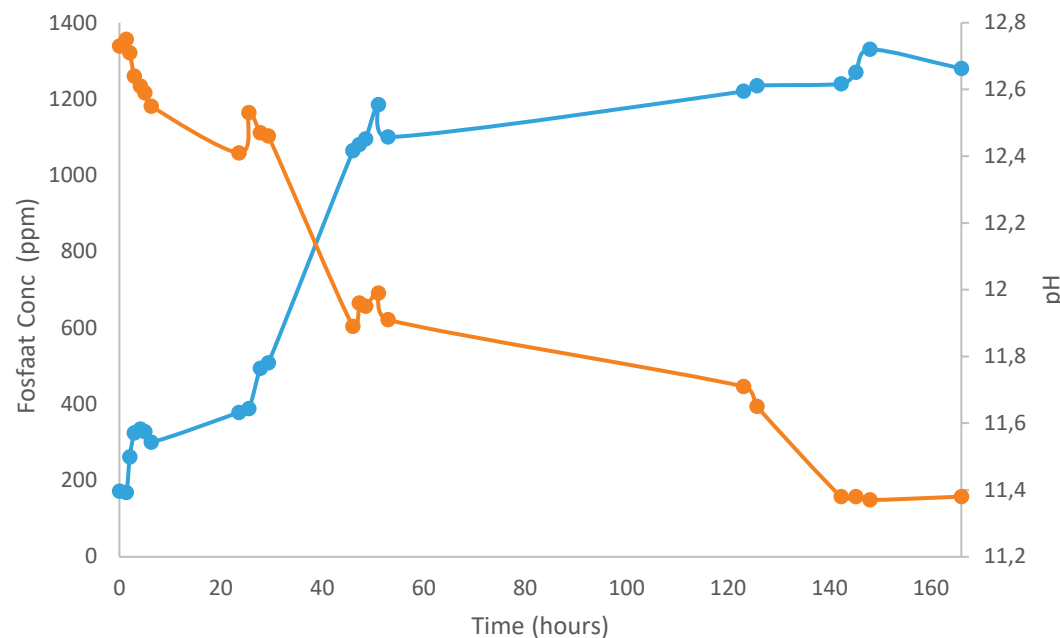
Scale-up



Optimisation at small scale
(10 g)

Larger scale
(1000 g)

Recirculation with 0.1 M NaOH
Liquid/Solid (L/S) ratio = 10
Flow 60 ml/min



5.2 mg P desorbed per g ICS
Equilibrium after 18 recirculations
< 1 ppm Fe in the solution

Scale-up

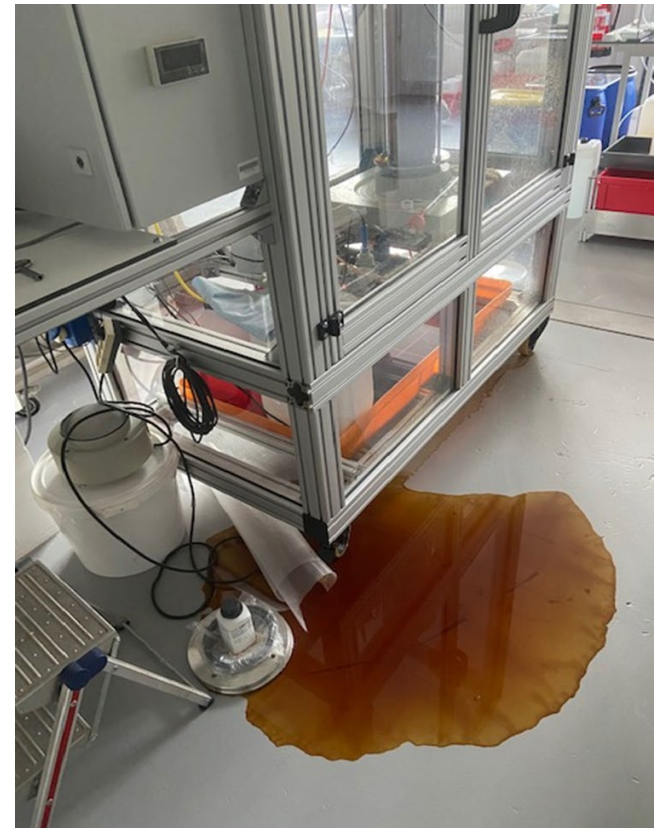


Larger scale
(12 kg)

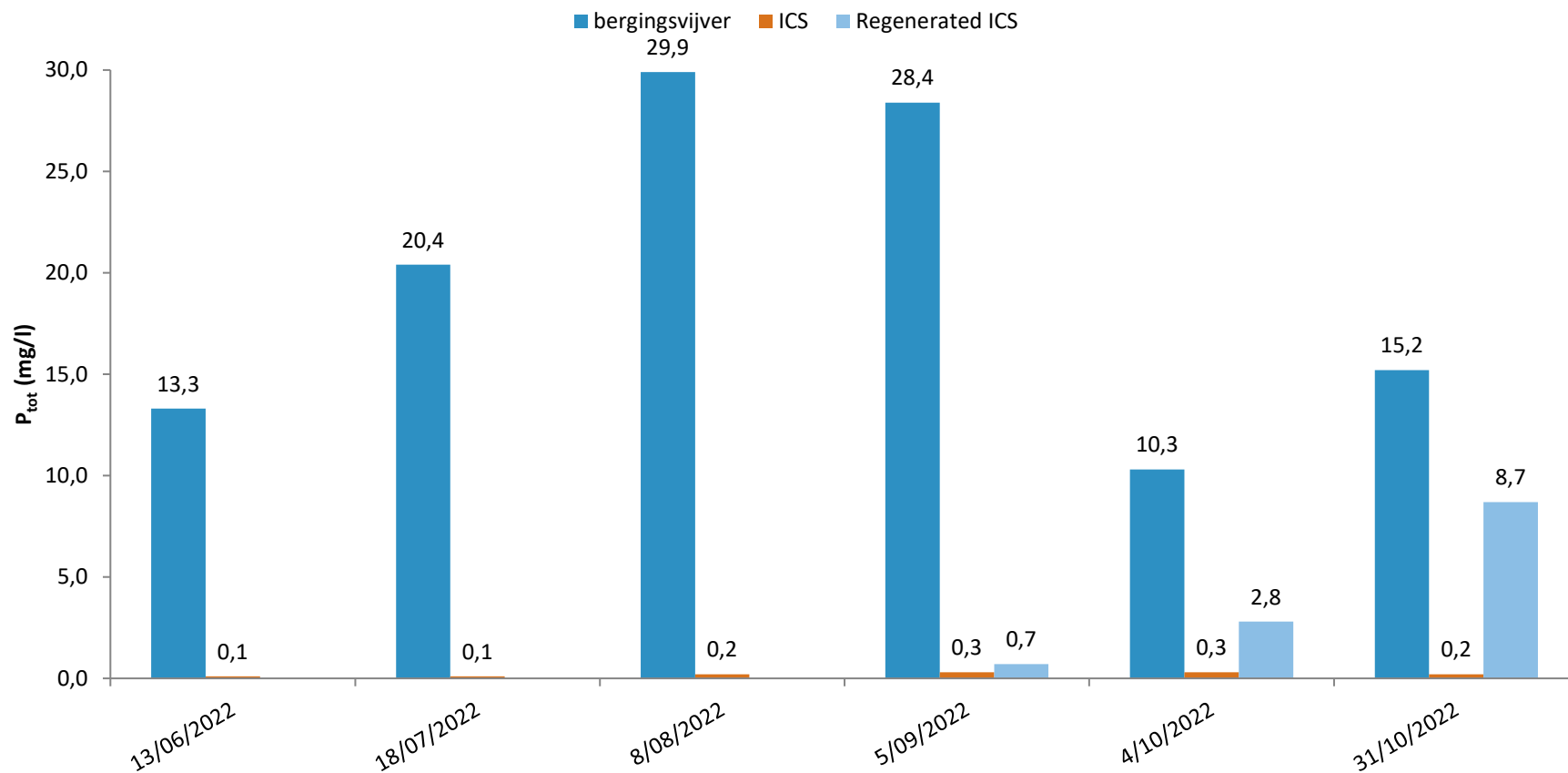


- Keeping pH at pH 12.5
- 25 liter for 12 kg

- Desorption of ± 6.0 g P /kg sorbent
- Desorbed sorbents sent to PCS after washing step (water) and pH decrease

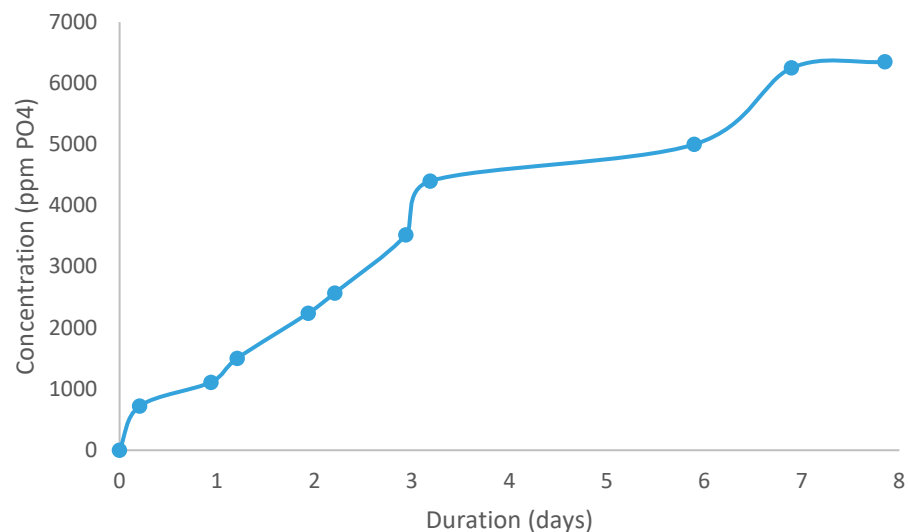


NuReDrain: results 2022



Sorption at pH = 12.5

- $L/S = 5$
- Desorption of 10.7 g P /kg sorbent
- Higher pH: damaging ICS grain integrity



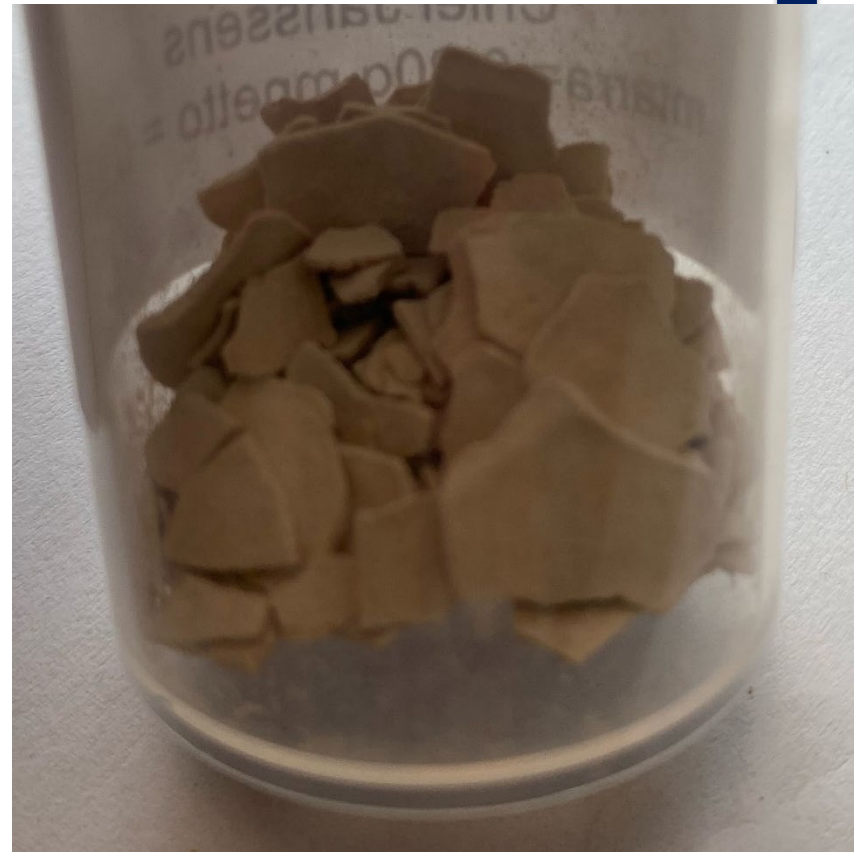
Scale-up: precipitation

Precipitation of phosphate
With 1 g $\text{Ca}(\text{OH})_2$ per liter

⇒ Precipitation product over filtration: 0.96 g

First analysis results:

- Mainly calcium phosphate carbonates
 $[\text{Ca}_5(\text{PO}_4)_3(\text{CO}_3)_{0.5}]$: $\pm 75\%$
- About 25% $\text{CaCO}_3/\text{Ca}(\text{OH})_2$
- Trace levels of Fe, Si, Zn



Is precipitation necessary?

- High pH solution: ± 12.5 or lower (mixing with washing and/or acidic solution)
 - Phosphate: 25 g/l
 - Calcium: 0.7 g/l
 - Iron: 0.3 mg/l
 - Trace levels of Si, Zn
- Sodium?
- Desorption is also possible with KOH

- Desorption of P is possible for the saturated ICS
 - Type of base has negligible influence (KOH vs NaOH)
 - Recirculation of solution is possible
 - Automated addition of extra alkaline solution
- Higher alkalinity gives better P removal but
 - A balance will have to be found between ICS integrity and P recovered capacity

Q & A

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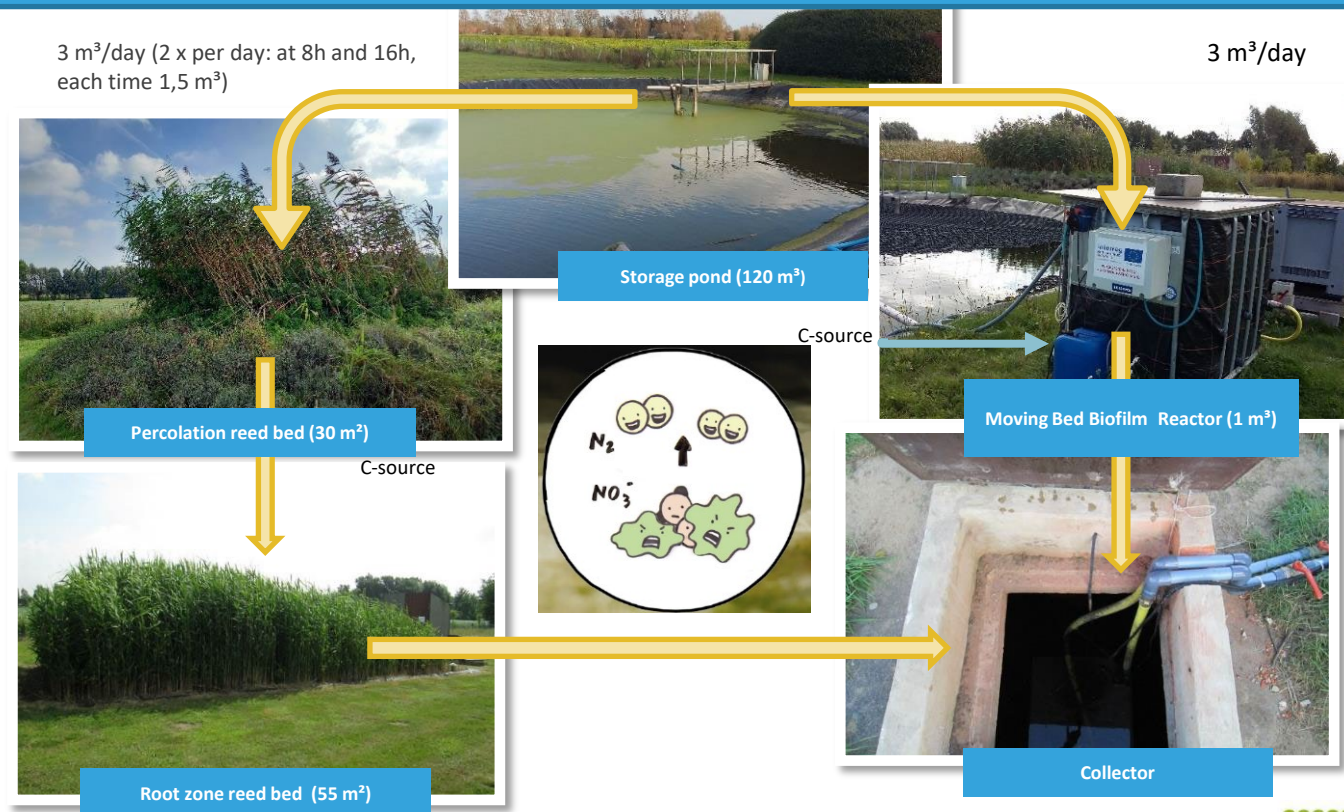


NuReDrain 2.0 Webinar:

Combining filter systems for N and P removal from
greenhouse wastewater

Els Pauwels (PCS Ornamental Plant Research)

N-removal: constructed wetlands + MBBR



MBBR: Biological denitrification on bio-carriers

- Carbon-source
- Aeration pump



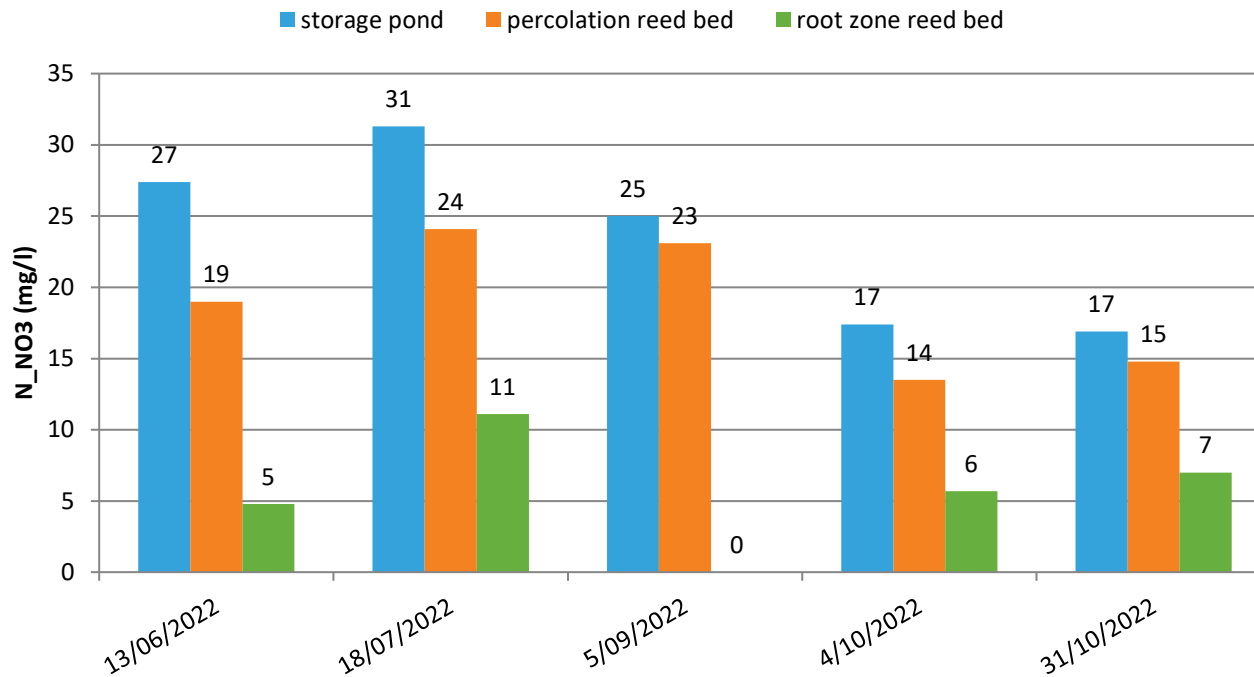
Carbon-source



AnoxKaldnes K5 carriers

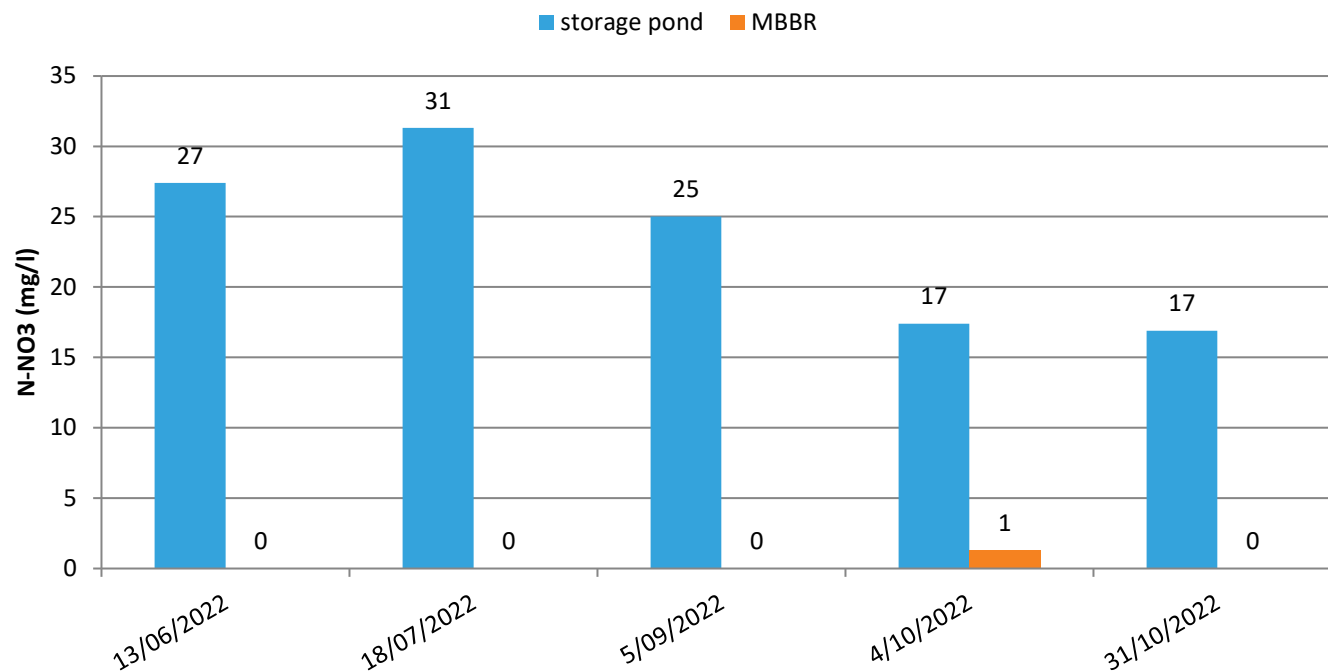
NuReDrain: results 2022

- PCS: constructed wetlands



NuReDrain: results 2022

- PCS: MBBR

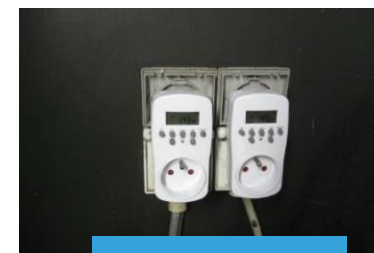


P-Removal P-filters

- Testing capacity saturated ICS grains from UGent
- Testing regenerated ICS grains from VITO

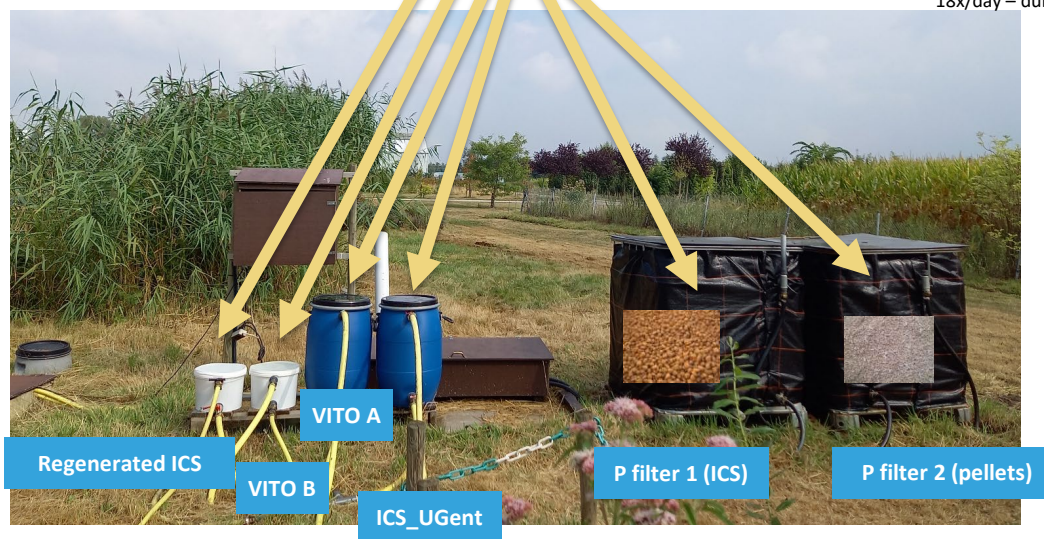


Collector



Time switch

18x/day – during 2 min



Filter-material P-filters



Iron Coated Sand korrels (ICS)



Pellets



VITO A



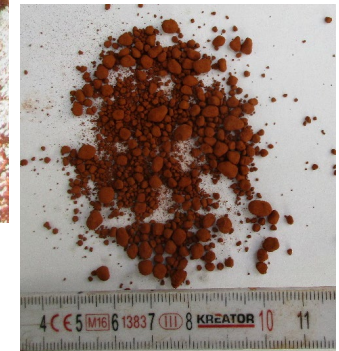
VITO B



Regenerated ICS



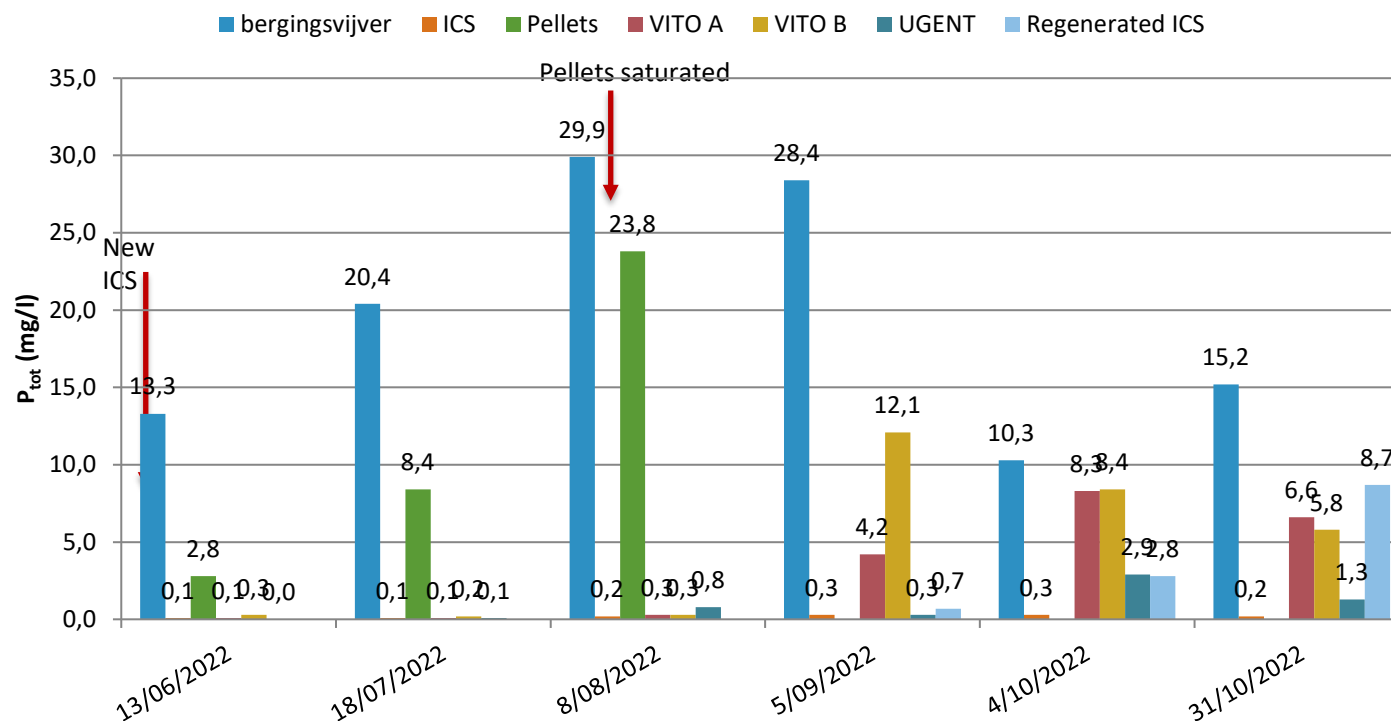
Regenerated ICS



ICS

NuReDrain: results 2022

• PCS: P-Filters

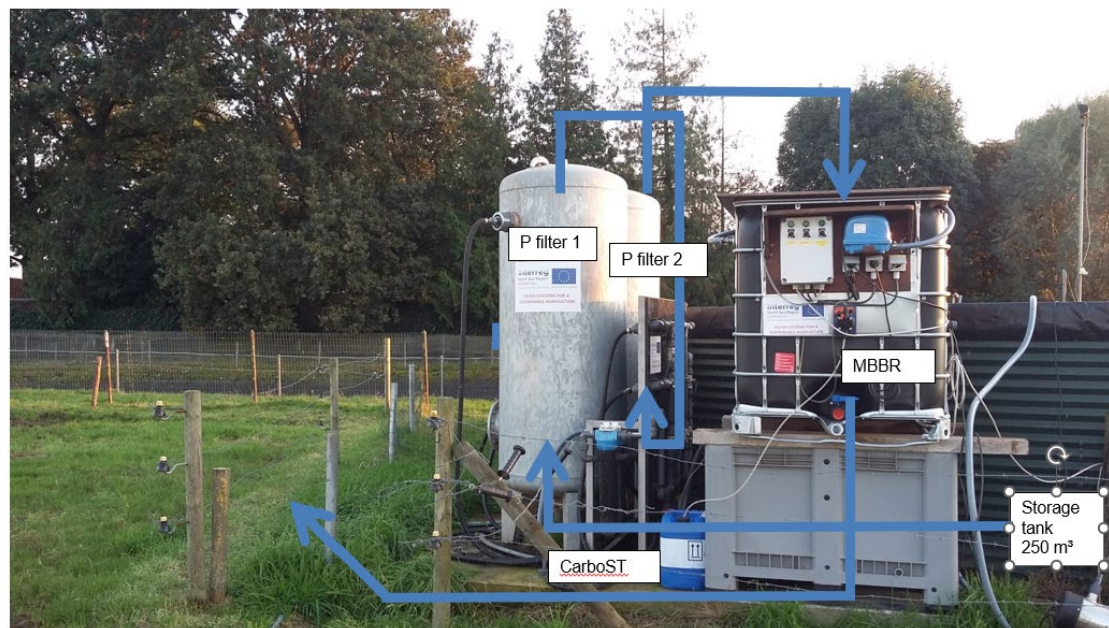


Grower potted plants (Meuninck) - P-filter + MBBR

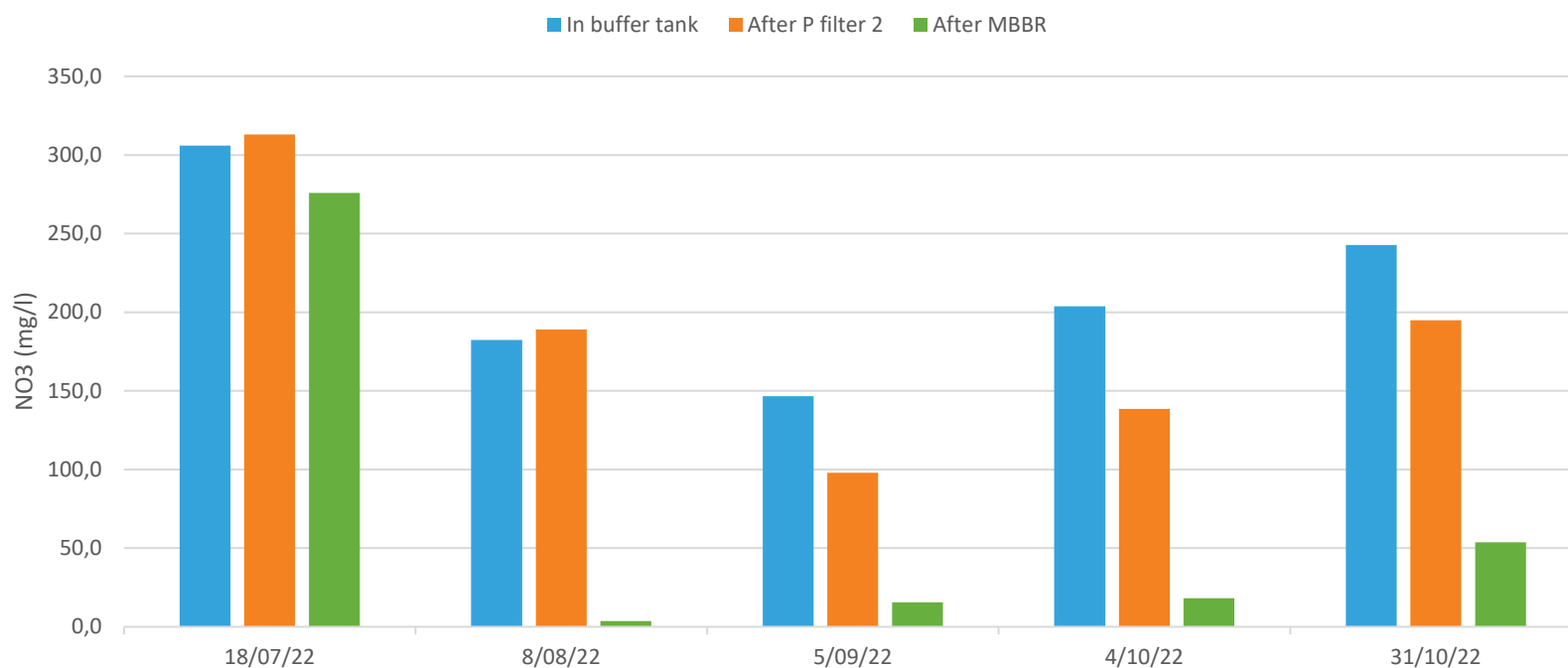
Waterflow in 2022

In 2020-2021:
MBBR + P-filter - adaptations were needed

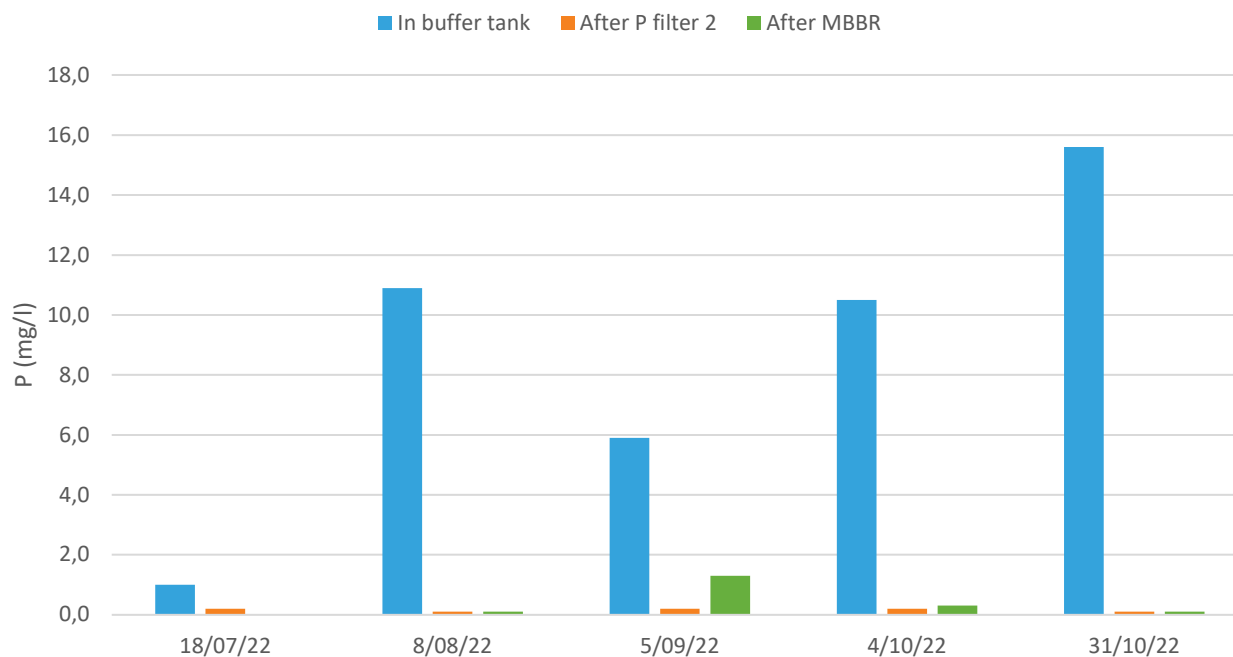
In 2022:
first P-filter and then N-filter
ICS were replaced



Results 2022 (Meuninck) - P-filter + MBBR



Results 2022 (Meuninck) - P-filter + MBBR



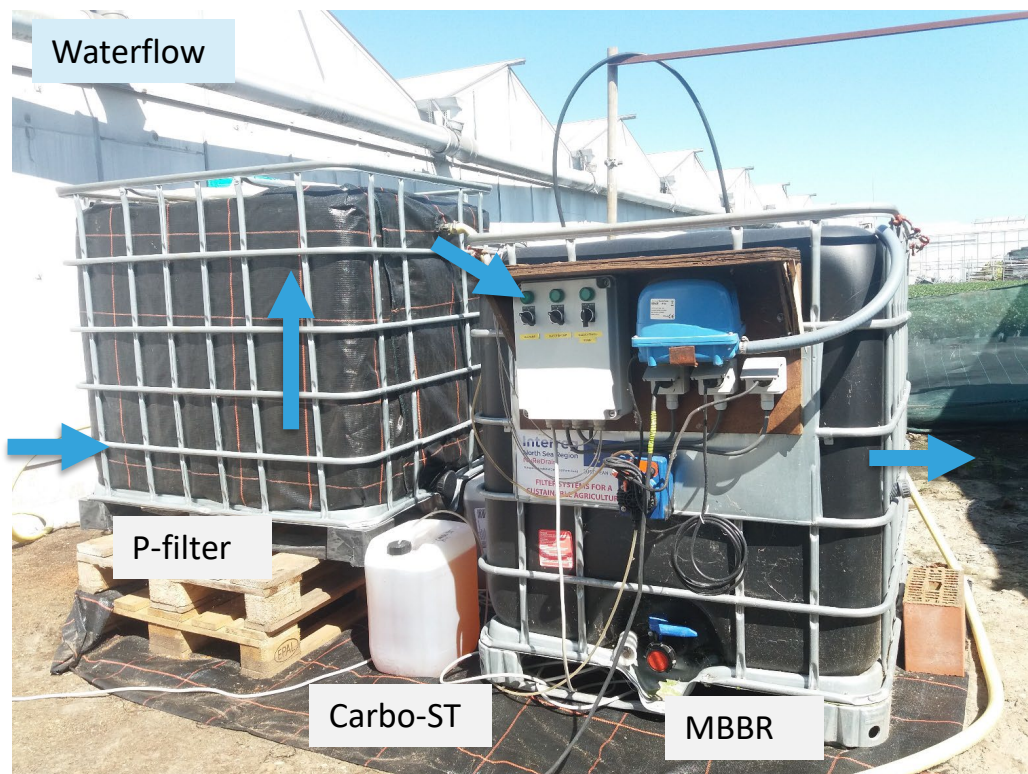
New ICS grains in both filters!!

Grower azalea (VDS Plant) - P-filter + MBBR

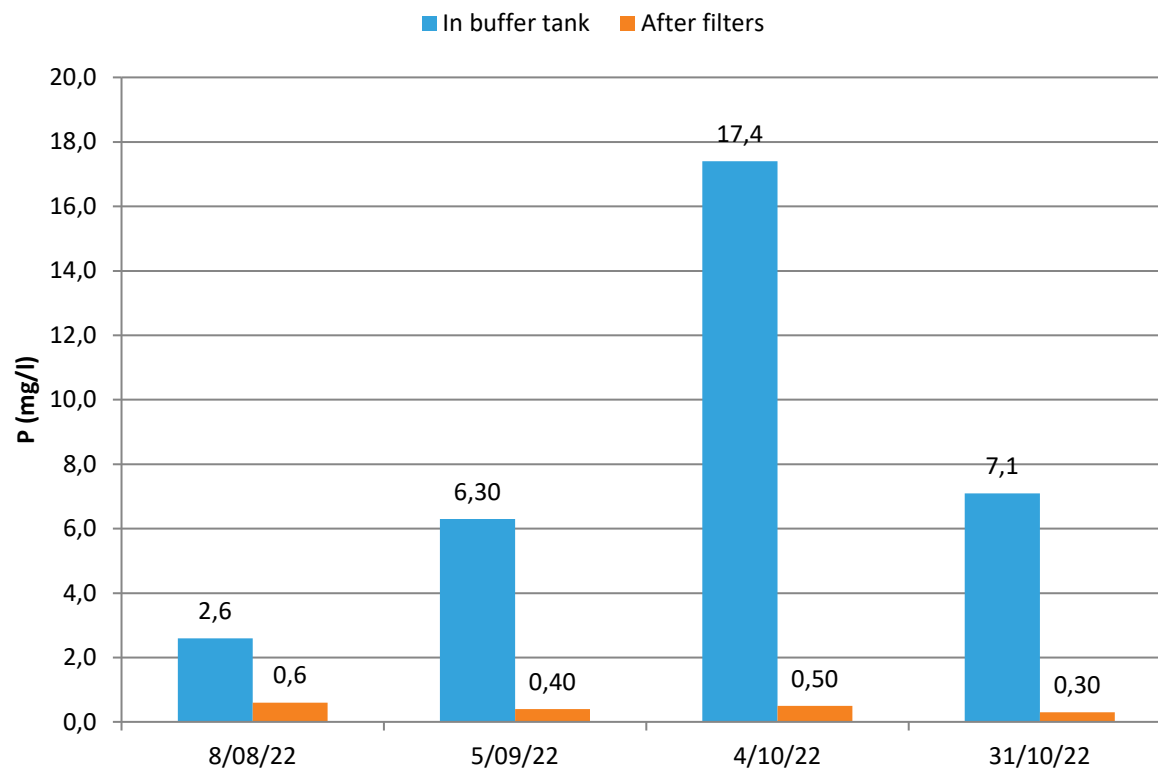
Drainwater from greenhouse with azalea

- Buffer tank 5 m³
- P filter
- MBBR
- Daily volume: 1,5 m³

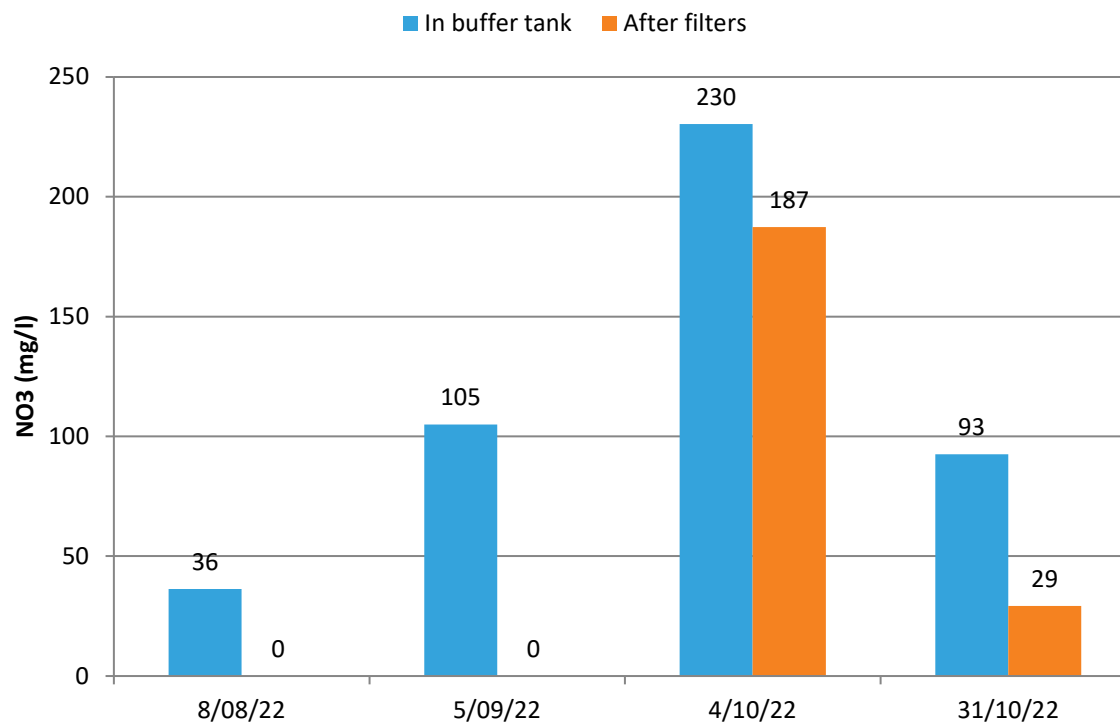
Buffer tank



Results 2022 (VDS Plant) - P-filter + MBBR



Results 2022 (VDS Plant) - P-filter + MBBR



Microflor - Orchid



MBBR: Biological denitrification on bio-carriers



Manual available: Dutch and English

1. What is a MBBR?

A Moving Bed Biofilm Reactor (or MBBR for short) removes nitrogen from water by converting nitrate into nitrogen gas by means of biological processes. A MBBR consists of a tank filled with water, in which plastic carriers are located that are set in motion (Photo 1/Photo 2). The irregular and large specific surface area of the carriers forms an ideal habitat for various micro-organisms (Photo 2/Photo 2). On these carriers grows active sludge (biofilm) and this carries out the denitrification.

A MBBR requires little maintenance and is simple to construct yourself with the help of this information sheet.



Photo 1: Set-up of Moving Bed Biofilm Reactor (MBBR) at PCS Ornamental Plant Research

- ✓ Simple and compact
- ✓ Processes 3 m³/day
- ✓ Robust
- ✓ Cheap
- ✓ No recovery

- ✓ Add C-source (5-8%)
- ✓ Difficult operation in winter

Information sheet: "How do I build my own MBBR?" - Version date 28/05/2020
Drawn up in connection with the Interreg North Sea Region project NuReDrain.
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Questions?

Thanks to:
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Bruno Jacobson Da Silva

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Cost effectiveness of nutrient removal filters at a catchment scale

Andreas Bauwe, Bernd Lennartz – University of Rostock

NUREDRAIN 2.0 WEBINAR

November 24 2022

Filter types

a) NuReDrain applications

Moving Bed Bioreactor (MBBR) **N**



Phosphorus filter **P**



b) other applications

Woodchip filter **N + P**



Constructed Wetland **N + P**



The main study questions were:

1. What is the **nitrate removal potential** using filters at catchment scale and
2. what are the **annual costs**?

Necessary data

- Mean annual waterflow of the drainage pipe Q (m³/yr)
- Mean annual NO₃⁻-N concentration in the drainage water C (mg/L)
- Removal efficiency of the filter (%)
- Costs (€/ kg N reduction)

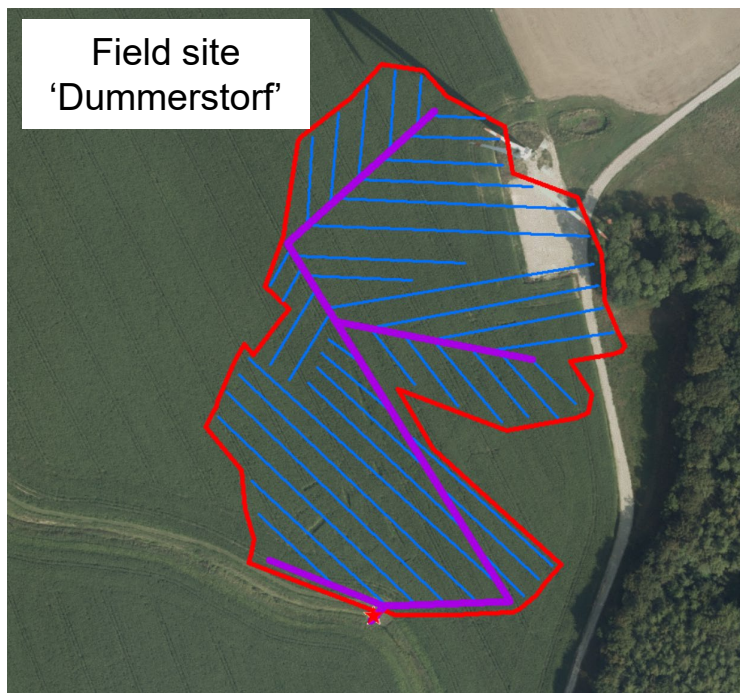
Calculations

$$F_{actual} \left(\frac{kg}{yr} \right) = Q \left(\frac{m^3}{yr} \right) * c \left(\frac{kg}{m^3} \right)$$

$$F_{filter} \left(\frac{kg}{yr} \right) = F_{actual} \left(\frac{kg}{yr} \right) * \left(1 - \frac{Removal\ efficiency\ (\%)}{100\ (\%)} \right)$$

$$Costs \left(\frac{€}{yr} \right) = (F_{actual} \left(\frac{kg}{yr} \right) - F_{filter} \left(\frac{kg}{yr} \right)) * Costs \left(\frac{€}{kg} \right)$$

Example 1: Drainage plot



Drain plot characteristics

Size: 4.2 ha

$Q = 39 \text{ m}^3/\text{d}$ or $7056 \text{ m}^3/\text{yr}$

$c = 9.6 \text{ mg NO}_3^-/\text{L}$

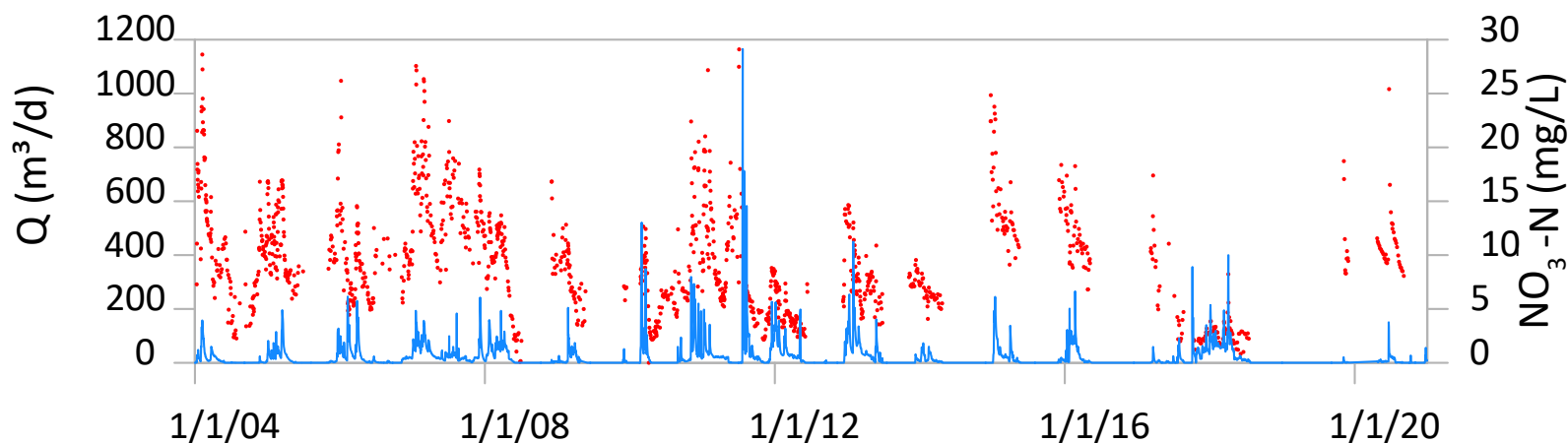
Assumptions

Removal efficiency: 30 – 90%

Costs: MBBR: 50 – 500 €/kg reduction

WF: 2 – 20 €/kg reduction

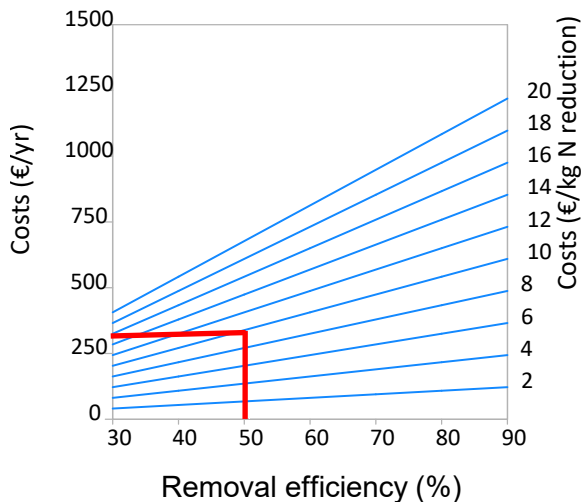
SFW: 5 – 95 €/kg reduction



Example 1: Drainage plot

Nomograms to calculate annual costs based on varying removal efficiencies and installation/maintenance costs

Woodchip filter



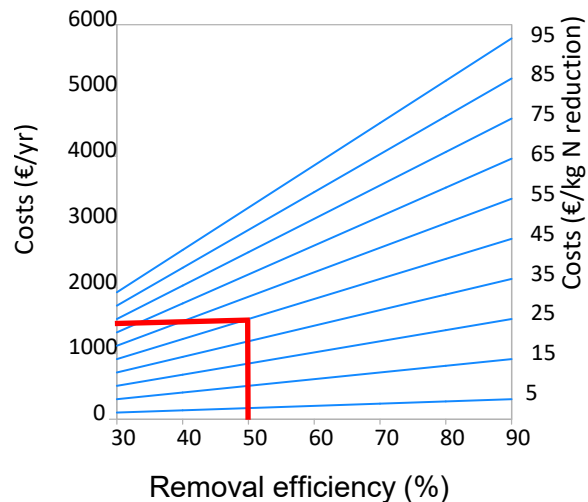
Reading example

removal efficiency: 50%

Costs: 10 €/kg N red.

Total Costs: 339 €/year

Constructed Wetland

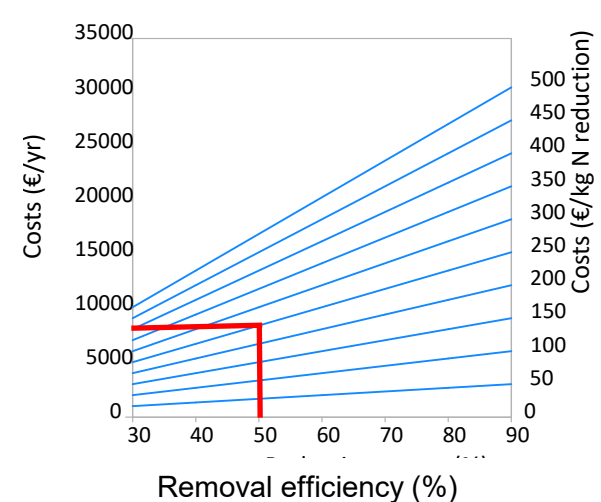


removal efficiency: 50%

Costs: 45 €/kg N red.

Total Costs: 1524 €/year

MBBR



removal efficiency: 50%

Costs: 250 €/kg N red.

Total Costs: 8467 €/year

Example 2: Catchment



Example 2: Catchment

Assumptions

Annual discharge: 80 - 150 mm/yr

NO₃⁻-N concentrations: 3 - 15 mg/L

Implementation of filter technologies: NO₃⁻-N concentrations >10 mg/L

- MBBR: small-sized drainage plots (<2 ha) at costs of 50 - 500 €/kg N reduction
- Woodchip filters: medium-sized drainage plots (2-10 ha) at costs of 2 - 20 €/kg N reduction
- Surface-flow constructed wetlands: large-sized drainage plots (>10 ha) at costs of 5 - 95 €/kg N reduction

Removal efficiencies: 30 - 90%

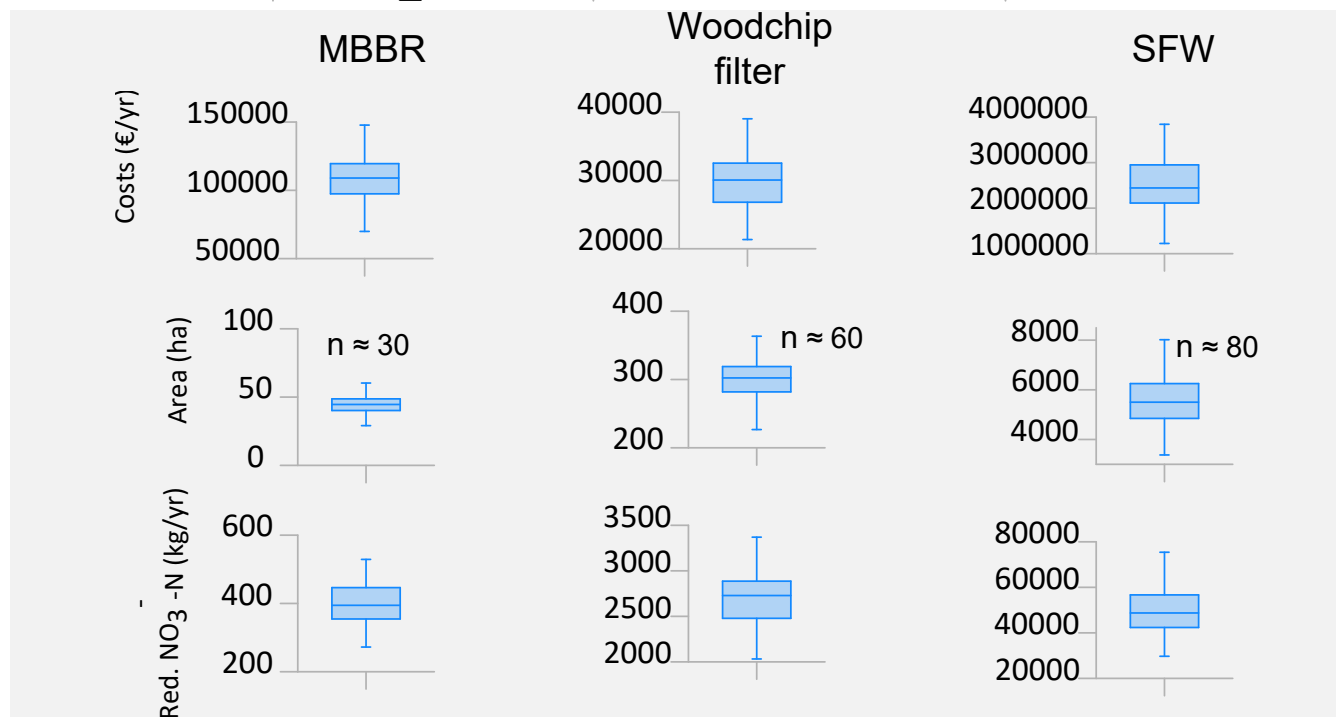
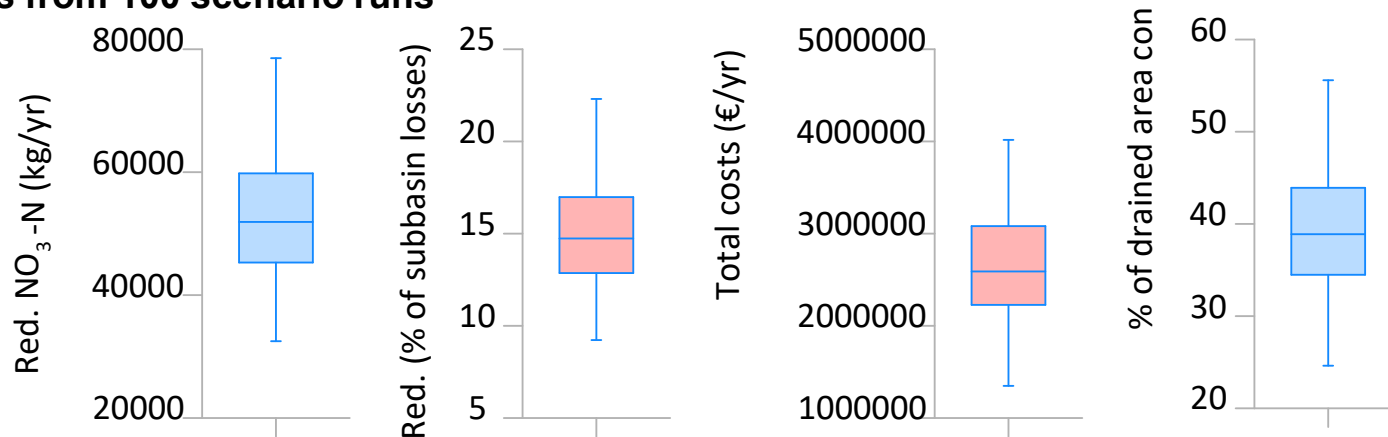
Calculations

All values will be randomly selected within the given ranges

100 runs were conducted

Example 2: Catchment

Results from 100 scenario runs



- Due to many hardly predictable costs and necessary simplifications, **single calculations** are mostly to be understood as rough estimates.
- Therefore, scenario analyses using **multiple calculations** can provide a realistic range of expected costs and nutrient reductions that policymakers and stakeholders can work with at the watershed level.
- The results suggest that filter systems, if installed widely, can help to reduce nutrient pollution in surface waters significantly.
- The installation and maintenance of filter systems can be very costly.
- Filter systems will always be side-measures and will not replace the necessity of sustainable agricultural systems.



Thank you for your attention

Q & A

1. Long term evaluation and upscaling of iron coated sand filters for P removal from agricultural drainage water

Junwei Hu (Ghent University)

2. Can filter materials be regenerated and reused?

Jef Bergmans (VITO)

3. Combining filter systems for N and P removal from greenhouse wastewater

Els Pauwels (PCS Ornamental Plant Research)

4. Cost effectiveness of nutrient removal filters at a catchment scale

Andreas Bauwe (Rostock University)

5. Nutrient filter systems in practice: construction manuals, fact sheets and cost assessment

Charlotte Boeckert (VLAKWA/VITO)

Interreg

North Sea Region

NuReDrain

European Regional Development Fund



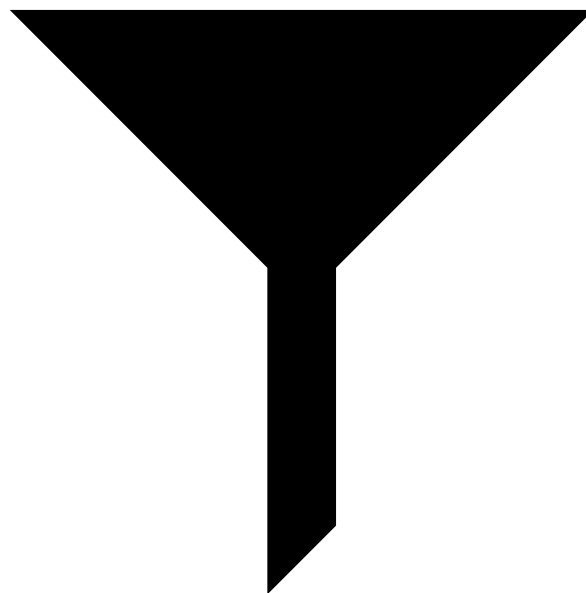
EUROPEAN UNION

Nutrient filter systems in practice: construction manuals, fact sheets and cost assessment

Charlotte Boeckaert, Vlakwa

Nuredrain information

field descriptions
sheets case videos
manuals materials
filter fact articles

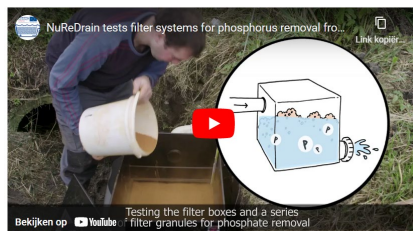


[NuReDrain, Interreg VB North Sea Region Programme](#)

Project videos

Phosphorus filter box for drainage water in agricultural fields

Tests on filter systems for phosphorus removal from drainage water in agricultural fields by [Ghent University](#) and [Inagro](#)



Nitrogen and phosphorus removal in horticulture

Filter systems for Nitrogen and Phosphorus removal in horticulture by [PCS](#) and [KU Leuven](#)



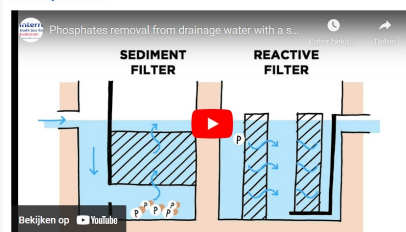
Phosphorus filter system for a water production centre

Video about tests on a phosphorus filter system in a water production centre by [De Watergroep](#) and [VITO](#)



Phosphorus filtering with a sediment and reactive filter in Denmark

Video about the phosphorus removal filter system of [Aarhus University](#) and [Copenhagen University](#) in [Eensholt](#)



Mobile constructed wetland for nitrate removal

Video about the field test of a denitrification filter system by [QOWV](#) at Lethe river in Lower Saxony



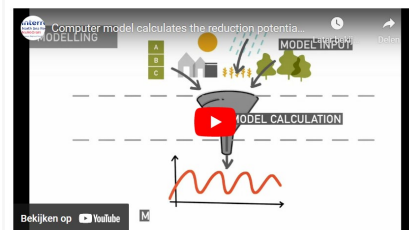
Inline phosphorus filter system for drainage water

Video about the field test of a phosphorus filter system by [LWK Niedersachsen](#) for drainage water at Venner Bruchkanal in Lower Saxony



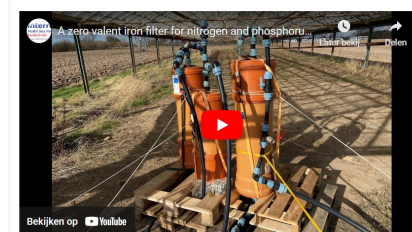
Modelling the reduction potential of filters at catchment scale

Video about [Rostock University](#)'s model that estimates the reduction potential of nutrient removal filters at catchment scale



A zero valent iron filter for drainage water

[Copenhagen University](#) is testing an experimental Zero Valent Iron filter for the removal of phosphorus and nitrogen from drainage water.



Relive the NuReDrain webinars

NuReDrain Webinars

In September and October 2020 NuReDrain organised a series of webinars about the research results.

Webinar 1: phosphorus filter systems for drainage water



Fact sheets

Iron coated sand filter

Phosphorus removal from drained agriculture fields

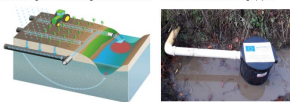
Price: € 1.000-6.000 + € 600
Flow: 3-6 m³/d
PO ₄ -P removal
NO ₃ -N removal
OM removal

Problem

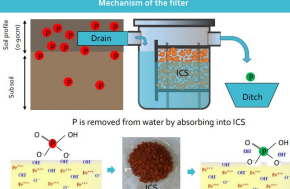
Direct phosphorus (P) discharge towards the surrounding water due to high P content in soil

Solution

To install iron coated sand (ICS) filter at the end of drainage pipes



Mechanism of the filter



P is removed from water by absorbing into ICS

interreg North Sea Region

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Paul Ra (paul.ra@ugent.be)

Iron coated sand filter

Phosphorus removal from drained agriculture fields

Price: € 1.000-6.000 + € 600
Flow: 3-6 m³/d
PO ₄ -P removal
NO ₃ -N removal
OM removal

Conditions for installation and application

Woodchip Bioreactor

Nitrate removal by biological denitrification

Price: € 70.000 - 90.000 + € 3000
Flow: 3-30 m³/d
NO ₃ -N removal
Plant Protection Product removal
OM removal

Benefits

- Edge of field and low tech measure
- Low maintenance
- Effective nitrate remediation
- Moderate temperature fluctuations favor microbial activity even in winter

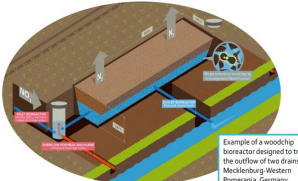
Limitations

- Construction work for excavation and diversion of drainage pipes necessary
- Substance release (e.g. TPC) from the woodchips, in particular in the beginning of drainage season

Working principle and installation

Mechanism

Nitrate-enriched drainage water is diverted through a bioreactor filled with woodchips, which provides anoxic and carbon-enriched conditions. Microorganisms in the bioreactor break down nitrate to nitrogen gas, which is released in the atmosphere. As nitrate represents the major form of nitrogen in drainage water, nitrogen loads to the aquatic ecosystems are significantly reduced.



Example of a woodchip bioreactor designed to treat the outflow of two drains in Mecklenburg-Western Pomerania, Germany

interreg North Sea Region

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Bened Lennartz (bened.lennartz@nordsee-netz.de)

Moving Bed BioReactor

Nitrate removal by biological denitrification

Price: € 3.000-10.000 + € 1.000 - 3.000
Flow: 0-15 m³/d
NO ₃ -N removal
Plant Protection Product removal
OM removal

Benefits

- Compact and straightforward design
- Easy to operate
- Withstands temperature fluctuations and peak loads
- No sludge disposal
- Customized design for each application is possible

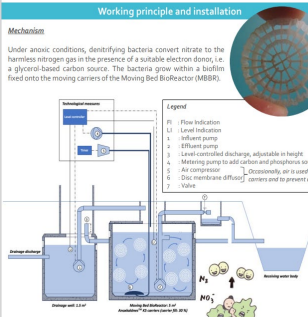
Limitations

- Energy supply is necessary
- Low water temperatures affect the removal efficiency in the MBBR system
- Residues of pesticides can negatively influence the efficiency
- No recovery

Working principle and installation

Mechanism

Under anoxic conditions, denitrifying bacteria convert nitrate to the harmless nitrogen gas in the presence of a suitable electron donor, i.e. a glycerol-based carbon source. The bacteria grow within a biofilm fixed onto the moving carriers of the Moving Bed BioReactor (MBBR).



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Piet Van den Broek (piet.vandenbroek@klu.ac.be)
Raf David (raf.david@klu.ac.be)

Zero-valent iron and zeolite filter

Phosphate and nitrate removal and nitrogen recycling

Price: € 40k
Flow: 1-5 m³/d
PO ₄ -P removal
NO ₃ -N removal
Plant Protection Product removal
OM removal

Benefits

- Nitrate can be completely removed, even at low concentrations and low temp.
- Ammonium can be recovered enabling nitrogen to be recycled
- Phosphate is fully removed
- Iron(II) formed during ZVI corrosion contributes to further increase the reactivity of the system

Limitations

- Nitrate removal efficiency decreased due to passivating ZVI corrosion layers
- Oxygen in drainage water will also consume ZVI
- Reduction of water consumes ZVI and generates H₂
- Maintenance requires aeration (pump)

Working principle and installation

How is ZVI working with nitrate and phosphate?

- Nitrate removal:** The ZVI reduces nitrate to gaseous nitrogen (N₂) and/or ammonium. Ammonium is captured in another medium to enable recycling of nitrogen.
- Phosphate removal:** When nitrate is reduced ZVI corrodes and "rust" is produced. Rust (iron oxide) is a super filter for phosphate



Schematic diagram of the filter system and field filter installation in Taastrup, Denmark

interreg North Sea Region

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Hans Christen (hans.christen@klu.ac.be)

Zero-valent iron and zeolite filter

Nitrate removal by biological denitrification

Price: € 40k
Flow: 1-5 m³/d
PO ₄ -P removal
NO ₃ -N removal
Plant Protection Product removal
OM removal

Inline P-Filter

Removal of phosphorus by adsorption on iron

Price: € 10k
Flow: 1-5 m³/d
PO ₄ -P removal
NO ₃ -N removal
Plant Protection Product removal
OM removal

Benefits

- Can be used on existing collector tile drain systems
- Long-term filter effect
- Easy to operate, to maintain & to renew
- Cheap filter material (only transportation costs)
- Limited space needed
- No energy supply necessary

Limitations

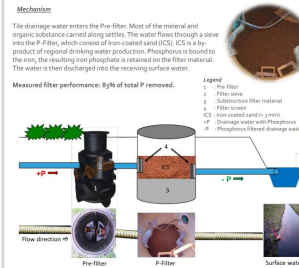
- Additional material & installation costs
- Maintenance work necessary
- Filter effect reduced by clogging (see Pre-Filter)
- Reduced flow when low gradient

Working principle and installation

Mechanism

The drainage water enters the Pre-Filter. Most of the mineral and organic substance carried along settles. The water flows through a sieve into the P-Filter, which consist of iron-coated sand (ICS). ICS is a by-product of regional drinking water production. Phosphate is bound to the iron, the resulting iron phosphate is retained on the filter material. The water is then discharged into the receiving surface water.

Measured filter performance: 80% of total P removed.



interreg North Sea Region

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Remond Eick (remond.eick@nordsee-netz.de)

Inline P-Filter

Removal of phosphorus by adsorption on iron

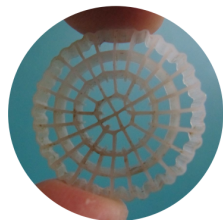
Price: € 10k
Flow: 1-5 m³/d
PO ₄ -P removal
NO ₃ -N removal
Plant Protection Product removal
OM removal

Conditions for installation and application

Filter construction manual

Denitrifying MBBR Guide

DENITRIFYING MBBR GUIDE	1
1 CHOICE OF MBBR TECHNOLOGY	2
2 CARBON SOURCE DOSAGE	2
3 THE CARRIER MATERIAL	7
3.1 FILLING FACTOR	8
3.2 AERATION SYSTEM AND MECHANICAL MIXING APPARATUS	9
4 DIMENSIONING OF MBBRS	11
4.1 INFLUENCE OF THE WATER TEMPERATURE ON THE DENITRIFICATION SPEED	11
4.1.1 CHOICE OF OVERGROUND OR UNDERGROUND MBBR	12
4.1.2 CHOICE OF A CARBON SOURCE THAT IS WINTER-PROOF	13
4.2 INFLUENCE OF THE INFLUENT CONCENTRATION ON THE DENITRIFICATION YIELD	14
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5 FAQ	17



1

1. Working principles

2. Dimensioning

Excel - mbb-design-tool - Saved					
File Home Insert Draw Page Layout Formulas Data Review View Help					
MBBR design tool					
1	Influent NO ₃ concentration	(mg NO ₃ -N/L)	150		
2	Influent NO ₂ concentration	(mg NO ₂ -N/L)	34		
3	Target NO ₃ concentration	(mg NO ₃ -N/L)	0		
4	Target NO ₂ concentration	(mg NO ₂ -N/L)	0		
5	Water temperature	(°C)	6		
6	Filling grade MBBR AnoxKaldnes KS	(%)	30		
7	Design flow MBBR	(m ³ /day)	12	→ Needed MBBR volume	(m ³)
8	Design mass flow MBBR	(kg NO ₂ -N/day)	1.8	Total volume AnoxKaldnes KS	(m ³)
9	Design mass flow MBBR	(kg NO ₂ -N/day)	0.41	Total surface area AnoxKaldnes KS	(m ²)
10				HRT	(h)
11	Design Volume MBBR	(m ³)	4.5	→ Maximum mass flow MBBR	(kg NO ₂ -N/day)
12	Total volume AnoxKaldnes KS	(m ³)	1.35	Maximum flow MBBR	(m ³ /day)
13	Total surface area AnoxKaldnes KS	(m ²)	1080	HRT	(h)
14					
15	Maximum denitrification rate @ influent temperature	(g NO ₂ -N/m ² ·day)	0.38		
16	Maximum denitrification rate @ influent temperature	(g NO ₂ -N/m ² ·day)	302		
17	Carbon source demand (mass flow)	(kg CO ₂ /day)	3.254		3.264
18	Carbo ST consumption per day	(L/day)	2.169		2.176
19	Selenoid dosing pump setting	(%)	18%		18%
20	Carbo ST cost per day	(€/day)	2.346		2.353
21		(€/m ³)	0.20		0.19
22	Minimal P concentration of influent	(mg PO ₄ -P/L)	0.030		
23	P concentration of influent	(mg PO ₄ -P/L)	0.000		
24	P demand (mass flow)	(kg PO ₄ -P/day)	0.000356		
25	Carbo ST vessel volume	(L)	60		
26	mL of 75% H ₃ PO ₄ addition to Carbo ST vessel	(mL)	10.2		



1. What is a MBBR?

A Moving Bed Biofilm Reactor (or MBBR for short) removes nitrogen from water by converting nitrate into nitrogen gas by means of biological processes. A MBBR consists of a tank filled with water, in which plastic carriers are located that are set in motion (Photo 1/Photo 2). The irregular and large specific surface area of the carriers forms an ideal habitat for various micro-organisms (Photo 2/Photo 3). On these carriers grows active sludge (biofilm) and this carries out the denitrification.

A MBBR requires little maintenance and is simple to construct yourself with the help of this information sheet.



Photo 1: Set-up of Moving Bed Biofilm Reactor (MBBR) at PCS Ornamental Plant Research

Information sheet: "How do I build my own MBBR?" - Version date 28/05/2020
Drawn up in cooperation with the Interreg North Sea Region project NuReDrain
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3. DIY building

Cost filterbox - P filter

Water	Filter	CAPEX	OPEX	Yearly cost	Total P removal (kg P)	Cost effectiveness (€/kg P)
Drainage (0,25 mg P/l)	P filterbox	€ 635	€ 8,62	€ 702	0,06	1.304
	Drainage water (0,46 mg P/l)				0,19	↓
	Drainage water (0,12 mg P/l)				0,02	↑
Greenhouse (15 mg P/l)	DIY	€ 690	€ 9,10	€ 291	1,94	327

Cost MBBR - N filter

	Application	CAPEX	OPEX	Yearly cost	Total N removal (kg P)	Cost effectiveness (€/kg N)
DIY	Greenhouse effluent	€ 3.000	€ 1.131	€ 1.400	12,44	113
Subsoil	Drainage	€ 30.000	€ 3.260	€ 6.000	52,84	114
Containerized	Drainage Off-grid	€ 50.000	€ 1.867	€ 6.034	44,44	136
	Drainage	€ 40.900	€ 2.967	€ 6.315	44,44	142

Approach

1. Source based measures
2. Identification of nutrient hot spots
3. Set reduction goals
4. Calculate costs
5. Prioritize locations
6. Install filter systems

Acknowledgements

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Provincie
Antwerpen



Provincie
Oost-Vlaanderen
Voor ieder van ons



west-vlaanderen
de gedreven provincie

Thank you for your attention!

