

Water Recycling Toolbox

Recycling treated wastewater for agricultural use

Bornholm's Energy & Utility Co. A/S



Introduction to the pilot measure **Recycling treated wastewater for agricultural use** Bornholm's Energy & Utility Co. A/S

15 March 2023



Program

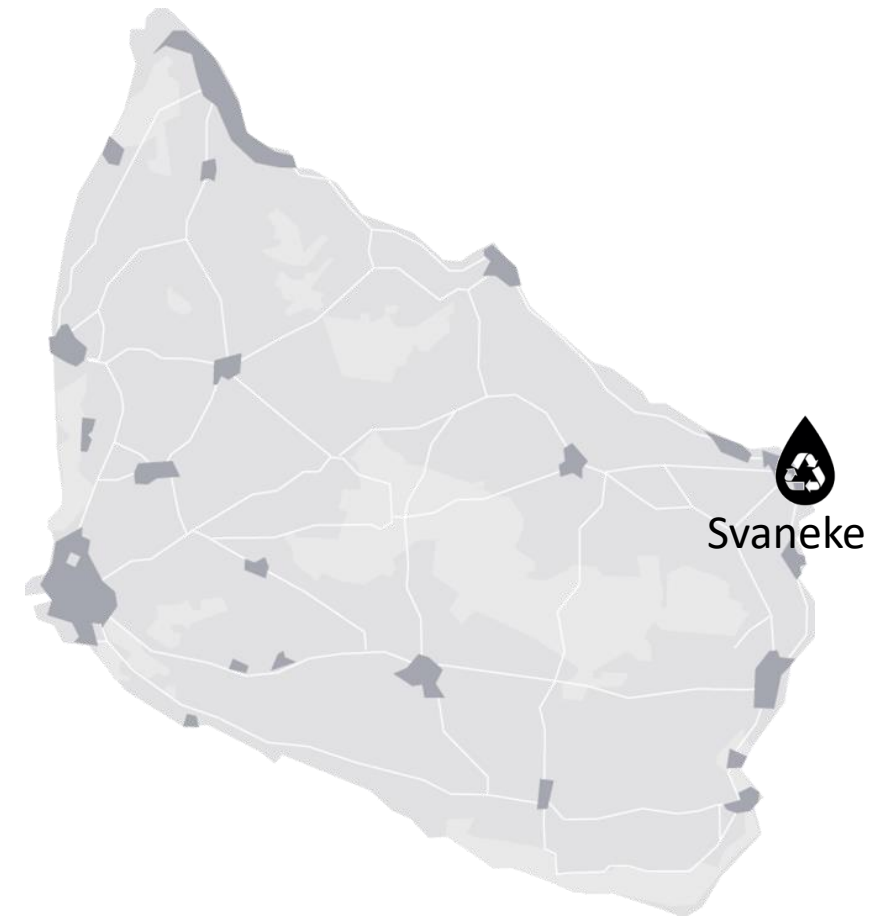
Local water management situation

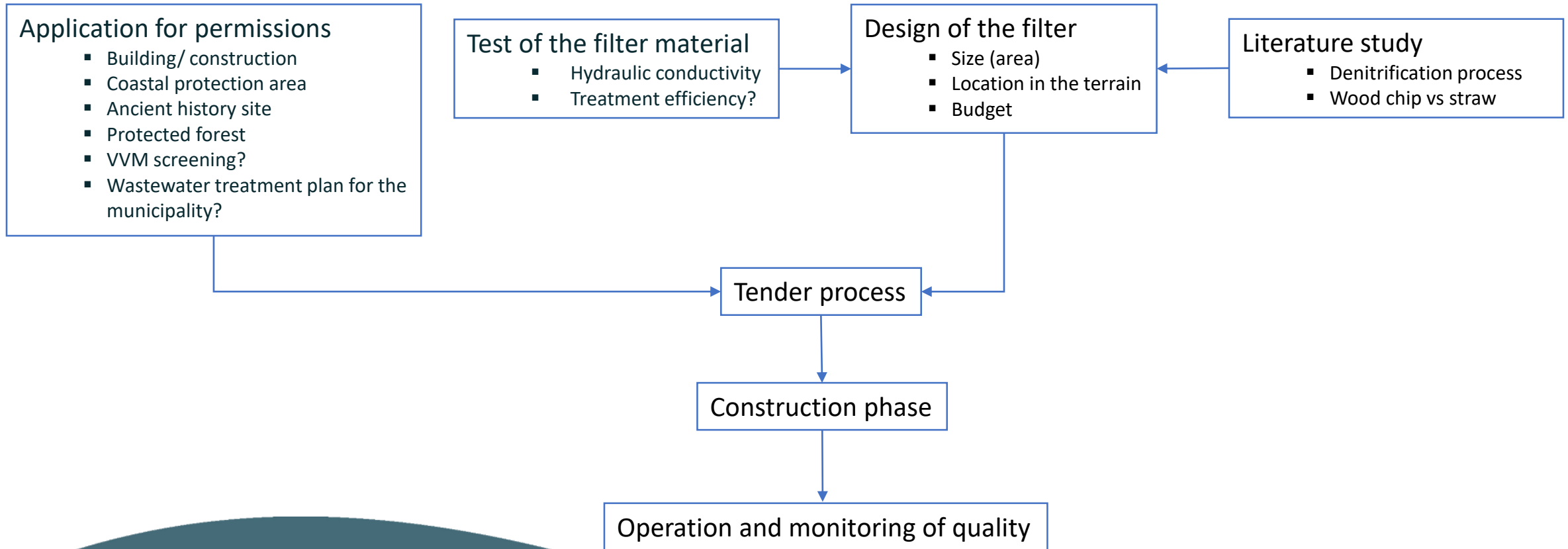
Pilot: Reuse of WWTP effluent for agricultural irrigation



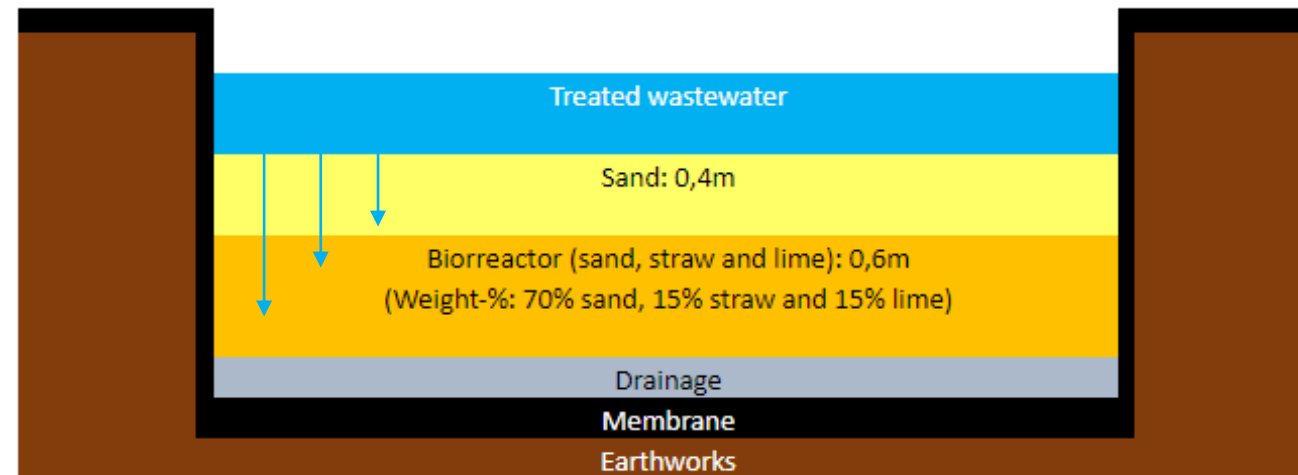
- Heavy rainfall – overflow of sewage system and nutrient outflow to the Baltic sea
- Draughts – impacting the agriculture and groundwater formation
- Tourist season puts a pressure on the wastewater treatment plants and drinking water supply
- Challenges with drinking water quality – organic micropollutants

- Low-tech water filter for purification of WWTP effluent
- Filter consisting of sand, straw (or wood chip) and lime
- Water quality monitored to investigate if the water is suited for agricultural irrigation (Regulation (EU) 2020/741)
- Idea stems from a similar filter built on Bornholm in the 1990ies





- Anaerobic filter – treatment process
 - Denitrification: straw acts as C-source for the process, lime will prevent the water from getting too acid
 - P and organic micropollutants expected to settle with the suspended solids on top of the filter
 - Bacterial degradation expected
- Anaerobic filter – size
 - Preliminary area: 250 m²
 - Velocity of water: 5-10 cm/hours (to be determined)
 - Treatment capacity: to be determined (hydraulic conductivity)



- Water quality monitoring (tentative list)
 - Nutrients (N and P)
 - Microorganic pollutants
 - Physical-chemical parameters
 - Parameters according to EU Regulation 2020/741, class D, se table below

Reclaimed water quality class	Indicative technology target	Quality requirements				
		E. coli (number/100 ml)	BOD ₅ (mg/l)	TSS (mg/l)	Turbidity (NTU)	Other
A	Secondary treatment, filtration, and disinfection	≤ 10	≤ 10	≤ 10	≤ 5	<i>Legionella</i> spp.: < 1 000 cfu/l where there is a risk of aerosolisation Intestinal nematodes (helminth eggs): ≤ 1 egg/l for irrigation of pastures or forage
B	Secondary treatment, and disinfection	≤ 100	In accordance with Directive 91/271/EEC (Annex I, Table 1)	In accordance with Directive 91/271/EEC (Annex I, Table 1)	-	
C	Secondary treatment, and disinfection	≤ 1 000			-	
D	Secondary treatment, and disinfection	≤ 10 000			-	

REUSE OF WWTP EFFLUENT FOR AGRICULTURAL IRRIGATION



Picture taken in February 2023



Visualization of the filter



- Any ideas and inputs are welcome!
 - Does someone have experience with this type of filter/bioreactor? (Denitrification, formation of dinitrogenoxide etc.)
 - Regulation (EU) 2020/741 (Reuse of water for irrigation)

Thanks!

Sara and Daniel can be contacted at sb@beof.dk and dsl@beof.dk

We are looking forward to the collaboration!

1st Peer-review session

Recycling treated wastewater for agricultural use

Bornholm's Energy & Utility Co. A/S

5 Sept 2023

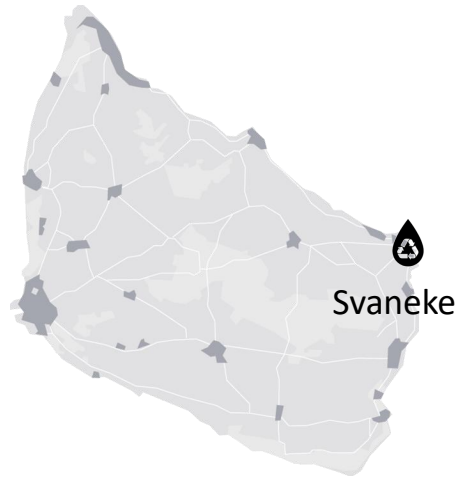


WaterMan – Pilot status

WATERMAN PILOT STATUS

- Agenda
 - Reminder
 - New situation
 - Monitoring of source water
 - Stakeholders
 - Risk assessment & monitoring
 - Work done since the kick-off
(literature review and experimental work)
 - Future plans

REMINDER – GOALS, LOCAL CONDITIONS AND CIRCUMSTANCES



■ Original plan:

- Full-scale low-tech media filter consisting of sand, straw (or wood chip) and lime for purification of WWTP effluent (slow sand filter)
- Idea based on similar filter built on Bornholm in the 1990ies
- Intended use for both reuse (irrigation of farmlands) and as a method to reduce nutrients to the Baltic sea at periods when irrigation is not needed



REMINDER – WATER REUSE SCHEME AND LEGAL REQUIREMENTS



- Local farmer who is interested in using the filtered WWTP-water for irrigation of plants grown for spinach seeds
- Class D water would be required for this use (EU 2020/741), plus potentially requirements regarding e.g. organic pollutants

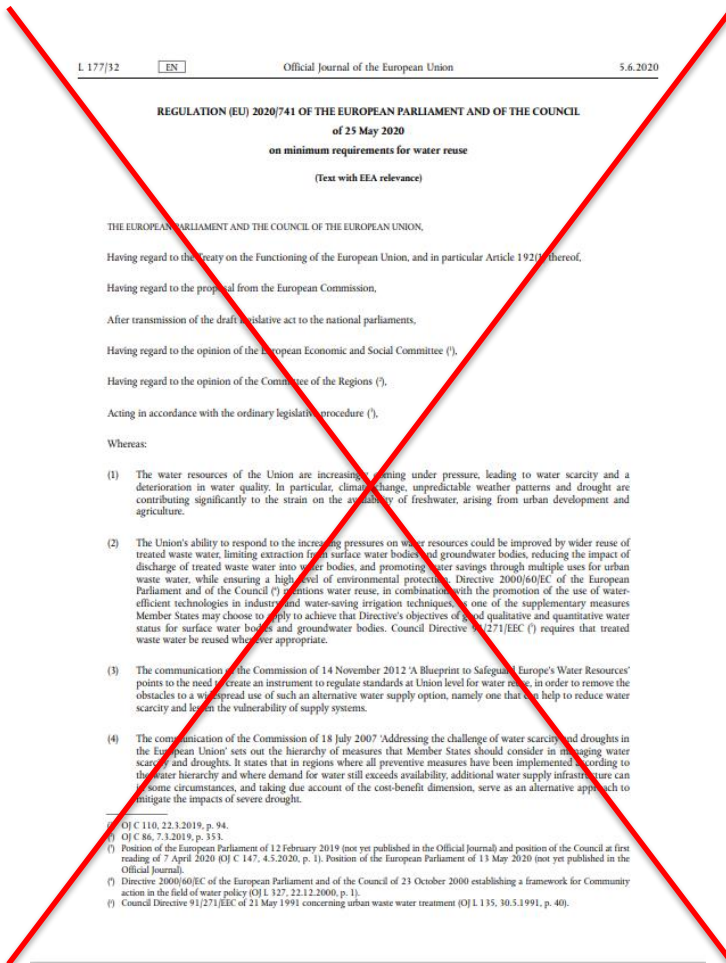
Table 2 – Reclaimed water quality requirements for agricultural irrigation

Reclaimed water quality class	Indicative technology target	Quality requirements				
		E. coli (number/100 ml)	BOD ₅ (mg/l)	TSS (mg/l)	Turbidity (NTU)	Other
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EU 2020/741 – [EUR-Lex - 32020R0741 - EN - EUR-Lex \(europa.eu\)](https://eur-lex.europa.eu/eli/dir/2020/741/oj)

Directive 91/27 EEC – [EUR-Lex - 01991L0271-20140101 - EN - EUR-Lex \(europa.eu\)](https://eur-lex.europa.eu/eli/dir/1991/27/oj)

NEW SITUATION – CHANGE OF PLANS



- EU 2020/741 will not be used in DK



We will conduct a feasibility study:

- Testing the filter in small scale
- Assessment of water quality and quantity, operation of the filter, the economy and the business case
- Results used for dialog with the Environmental Ministry about the future of the regulation in DK



Furthermore we will only focus on the reuse case, omitting the nutrient reduction (straw and lime), as this was a legacy from the seed project which was to start focusing on nutrient reduction, and as the filter is now down-scaled.

STAKEHOLDERS

- Environmental Ministry
- Local farmer
- The local farmers association
(Bornholms Landbrug of Fødevarer)
- BEOF's department of wastewater operation
 - operational requirements – as little contact with wastewater and manual work as possible when/if filter needs to be cleaned

RISK ASSESSMENT & MANAGEMENT

- On our To-Do-list!
We have had a brief discussion on the topic, started identifying hazards, risks, exposure scenarios, risk measures and tools/methods
- Will be done by the project team

MONITORING OF SOURCE WATER

- Regular monitoring of WWTP-effluent, flow proportional 24h



Eurofins Miljø A/S
Ladelundvej 85
6600 Vejen
Danmark
Telefon: 7022 4266
CVR/VAT: DK-2884 8196

Bornholms Spildevand A/S
Skansevej 2
3700 Rønne
Att.: Torben Jørgensen

Rapportnr.: AR-23-CA-23067834-01
Batchnr.: EUDKVE-23067834
Kundenr.: CA0017497
Modt. dato: 10.08.2023

Analyserapport

Provested:	Svaneke Renseanlæg - u020217 / 14050003						
Prøvetype:	Spildevand						
Prøveudtagning:	12.07.2023	til	13.07.2023				
Prøvetager:	Rekvirenten	PMS					
Analyseperiode:	10.08.2023 - 22.08.2023						
Kunde Ref.:	Svaneke rens ud						
Prøvemærke:	Udløb 004006960003637751						
Lab prøvenr.:	835-2020-80893466	Enhed	Kravværdier		DL.	Metode	Urel (%)
			Min.	Max.			
Konduktivitet (Ledningsevne)	1000	µS/cm			5	DS/EN 27888:2003	15
Uorganiske forbindelser							
Total Nitrogen	6.5	mg/l			0.05	DS EN ISO 11905-1:1998,ISO 15923-1:2013 mod.	15
Total Phosphor	1.6	mg/l			0.01	DS/EN ISO 6878:2004 part 7 + ISO 15923-1:2013	15
Organiske samleparametre							
BIS (med ATU)	2.4	mg/l			0.5	DS/EN 1899-1	20
COD, kemisk forbrug	32	mg/l			5	ISO 15705	15
Oplysninger fra rekvirent							
Prøvetagningsmetode	Mgd.prop.					*	
Prøvetagningsudstyr	Eget					*	
Vandmængde	1737	m ³ /døgn				*	
Vandtemp. i dunk v. nedtagning	3.8	°C				*	
Nedbør	10	mm				*	
Nedbør, døgn for prøvetagning	10	mm				*	

Batchkommentar:

Analysen er udført på prøve der er modtaget frosne.

- One E. Coli/ Total coliform measurement of WWTP-effluent, grab sample in May
 - E. Coli: approx. 27.000 CFU/100 ml
 - Total Coliform: approx. 271.700 CFU/100 ml

SLOW SAND FILTER (SSF) LITERATURE REVIEW – WASTEWATER APPLICATIONS

- SSF widely used for drinking water applications – first installation in London in 1829
- Sand filters are also applied for **wastewater applications**, but primarily rapid sand filters (RSF) are used.
- Experience with SSF and wastewater are mainly from pilot scale tests
- Pilot studies on wastewater show efficient removal of TSS and E. coli:
Effluent: TSS 1.2–2.3 mg/l and <100 E. coli / 100 ml
- Simple configuration with very low energy usage
- No pumping if landscape allows for it.
- Modular solution
- No back washing

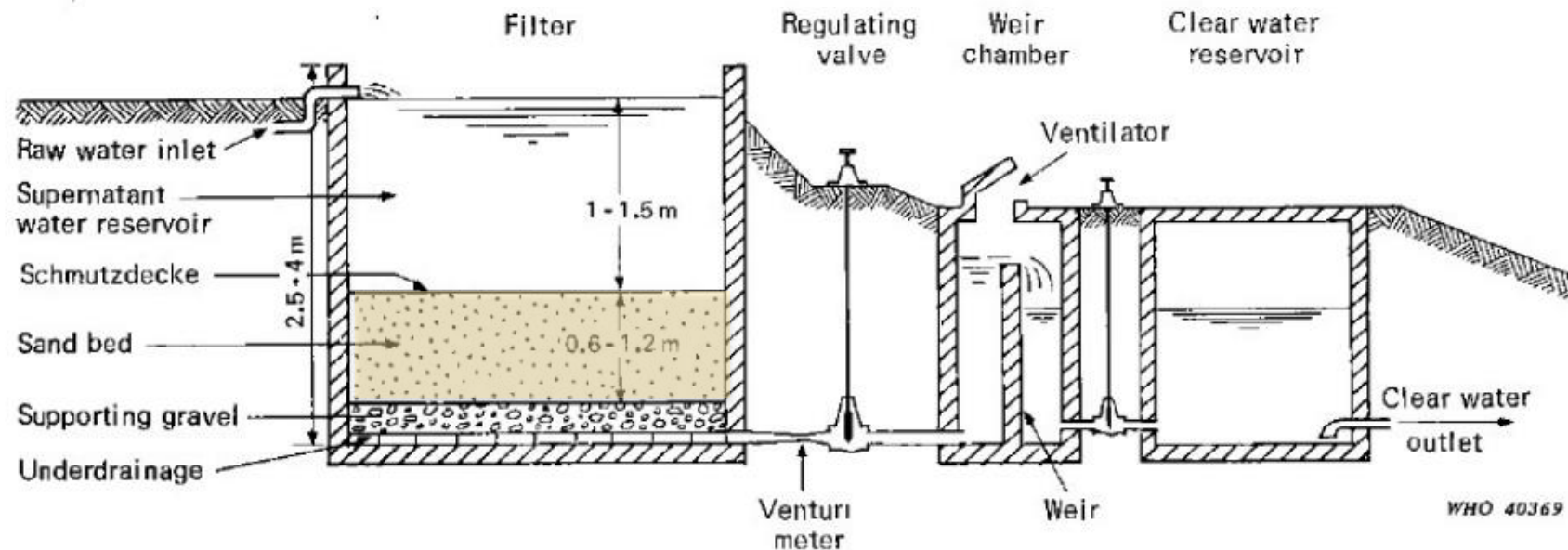
Attention to:

- Highly complex biological processes (Schmutzdecke)
- Requires scraping of surface at regular intervals (to remove Schmutzdecke)
- Requires a lot of land (surface area) to achieve high outputs due to low flow rates
- Storage
- Disinfection downstream (if required)



OUR TECHNOLOGY: SLOW SAND FILTER AS TERTIARY TREATMENT OF WASTEWATER

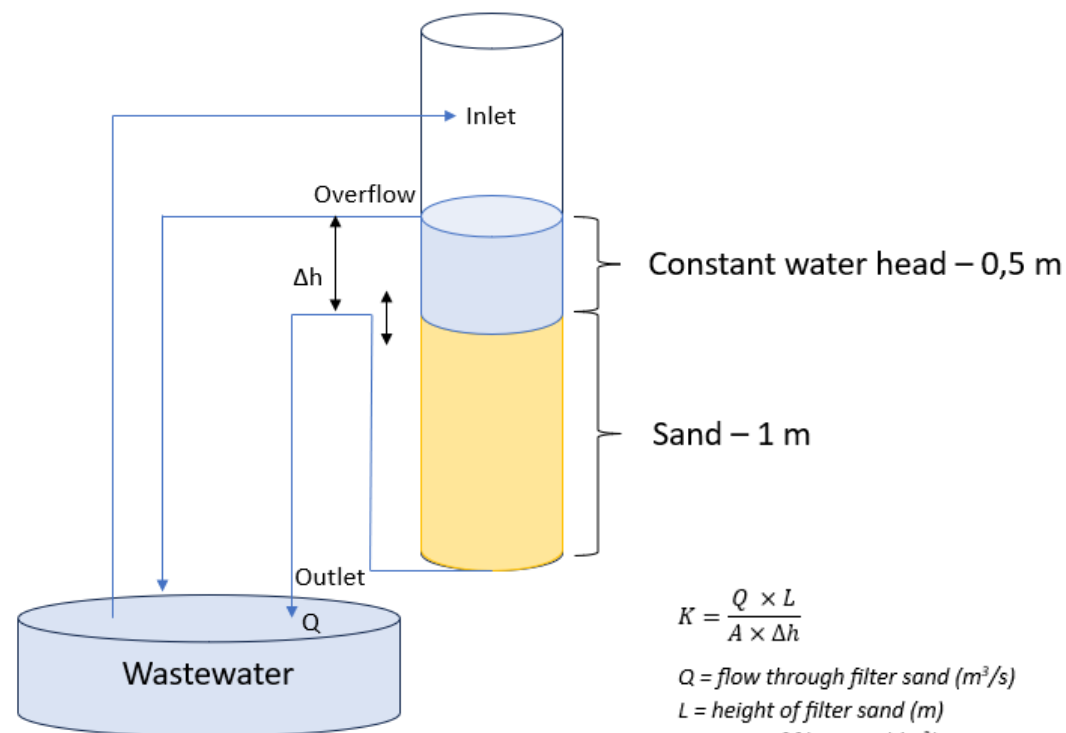
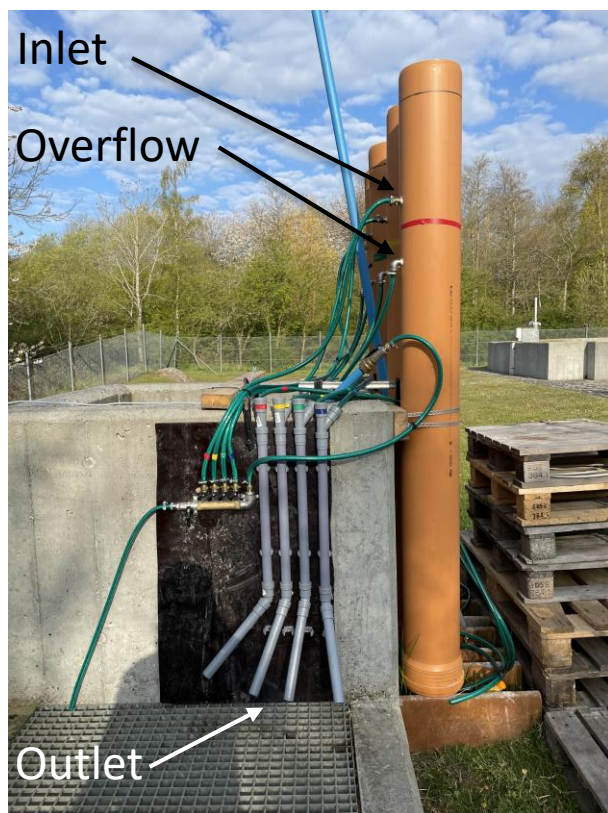
Slow sand filter (SSF)



•This is a schematic from the 1974 World Health Organization (WHO) “Slow Sand Filtration” design manual (Huisman & Wood, 1974. pg 18).

WORK DONE SINCE THE KICK-OFF

- Testing the hydraulic capacity of different sands



$$K = \frac{Q \times L}{A \times \Delta h}$$

Q = flow through filter sand (m^3/s)

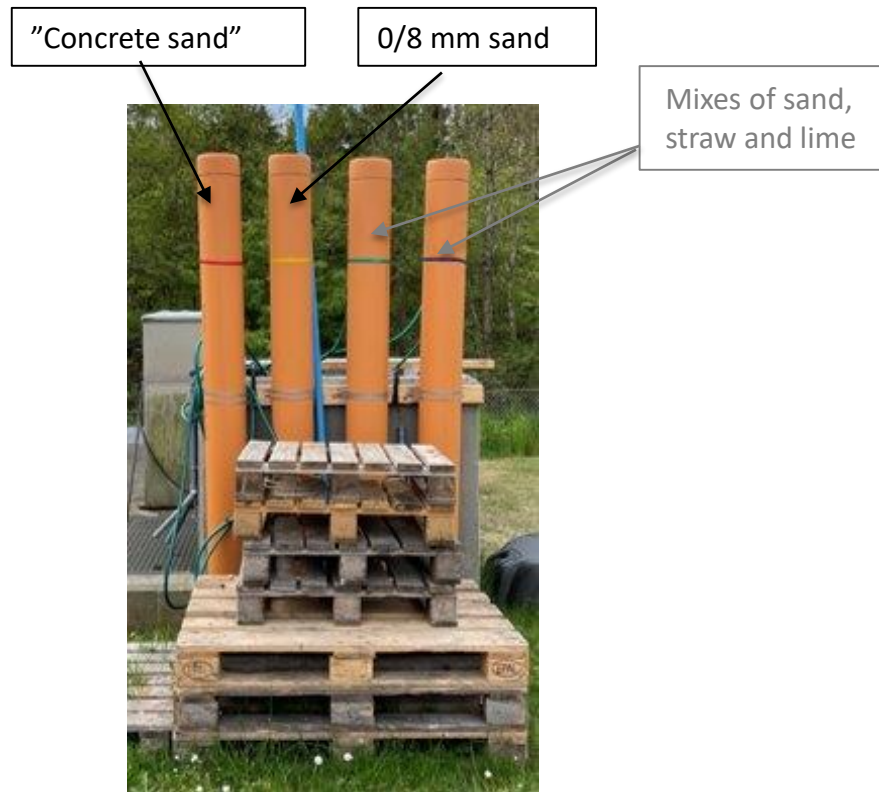
L = height of filter sand (m)

A = area of filter sand (m^2)

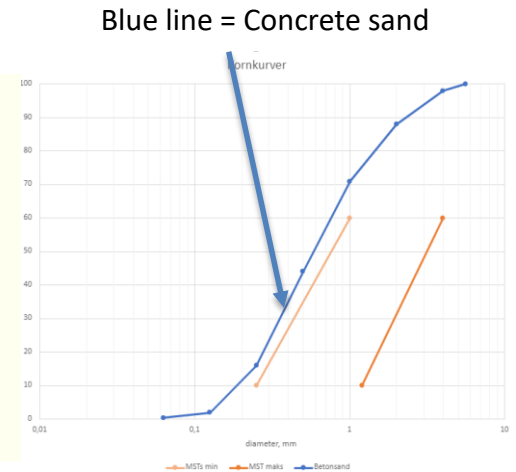
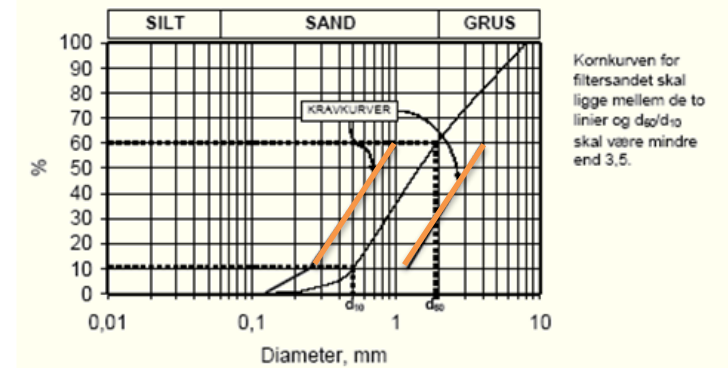
Δh = distance between height of outlet and overflow (m)

WORK DONE SINCE THE KICK-OFF

Hydraulic capacity of sand



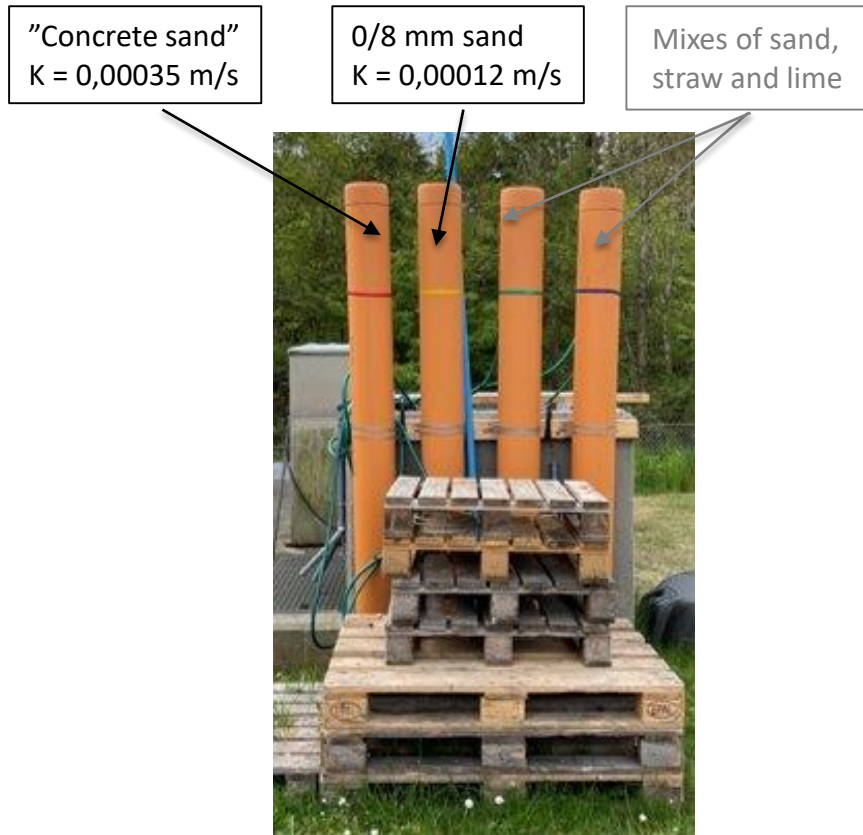
- Sand for test columns selected on basis of the Danish Environmental Protection Agency's recommended grain size distribution profile for biological sand filters.



- Sand from local gravel mine on Bornholm. Sand is processed (separated by particle size and washed)

WORK DONE SINCE THE KICK-OFF

■ Results hydraulic capacity



- Test indicate no change in K values over time = no clogging of the sand filter
- We will later decide what type of sand to use for the feasibility study
- Aiming for a traditional SSF– filter flow 5-10 cm/hours
Preliminary data calculated:
= equal to permeate flow of 1,2-2,4 m³/m²/day
= After Schmutzdecke built up: **0,2 m³/m²/day**
- => 5 m² filter area to produce 1m³ water/day (with Schmutzdecke)

WORK DONE SINCE THE KICK-OFF

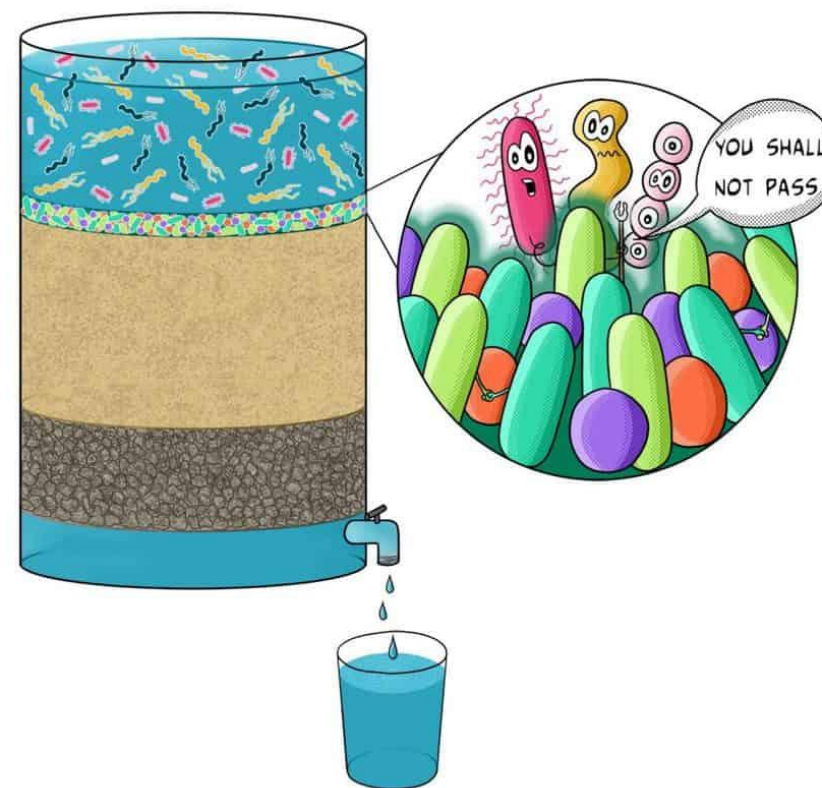
- Observations hydraulic capacity – the Schmutzdecke



- Reduces the flow significantly
- Needs to be removed from time to time, due to it acting as plug reducing the flow
- Schmutzdecke is removed by scraping top layer of sand after draining the filter

WORK DONE SINCE THE KICK-OFF

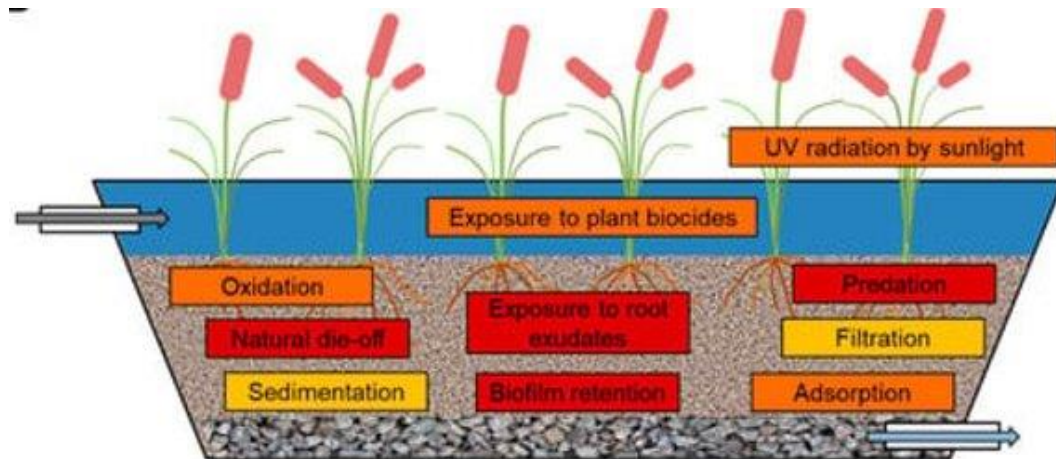
- The microbial biodegradation is taking place mostly in the Schmutzdecke
- We need the Schmutzdecke!
- Compromise between water quality and quantity



Nomi

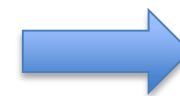
WORK DONE SINCE THE KICK-OFF

- Literature study – SSF and Schmutzdecke



- Schmutzdecke is complex!
- Is composed of algae, bacteria and protozoans
- Temperature critical for good activity; minimum 10-15 °C
- Oxygen, water quality etc.
- We can't control these processes...

[Water | Free Full-Text | Removal of Pathogens in Onsite Wastewater Treatment Systems: A Review of Design Considerations and Influencing Factors \(mdpi.com\)](#)

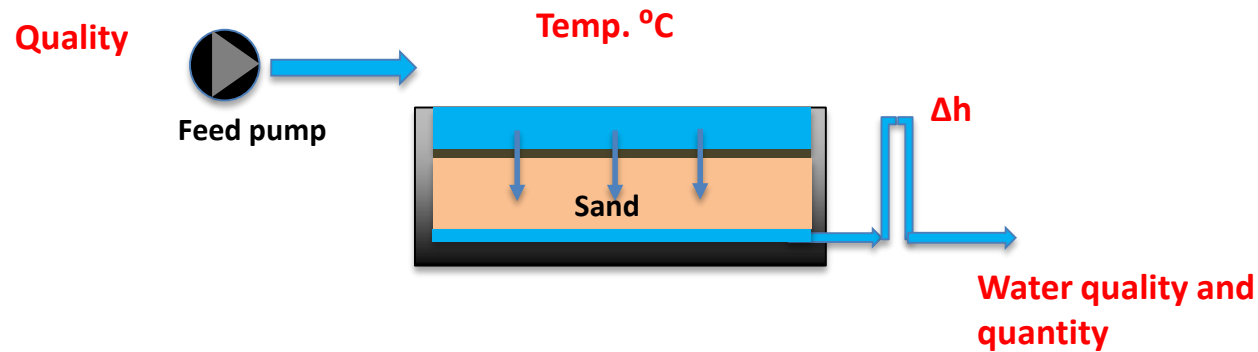
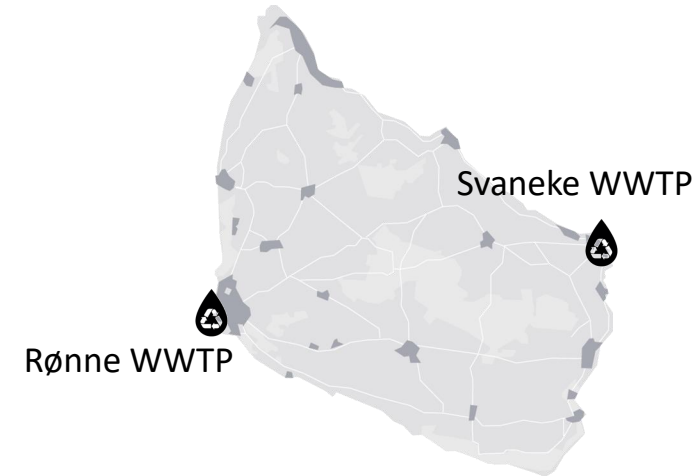


Add disinfection to stabilize the water quality?

Feasibility study– preliminary design

Design and materials for experimental setup

- Feed pump: Submersible pump
- Tank: Plastic, size 5-10m²
- Sand layer: 100cm
- Drain layer: 20cm (crushed granite)
- Drain pipes: Plastic, perforated



Location of sand filter

- Svaneke WWTP: Original location, but WWTP consists only of biological treatment, and no clarification tank.
- Rønne WWTP: Alternative location, Rønne WWTP has a traditional setup consisting of biological treatment + clarification step.

PLANS

■ To-do – Phase 1

- Continue tests with the test columns ("Schmutzdecke", E. Coli, hydraulic capacity)
- New plans
- New design/ technical drawings
- New budget
- Monitoring plan
- Risk assessment & management

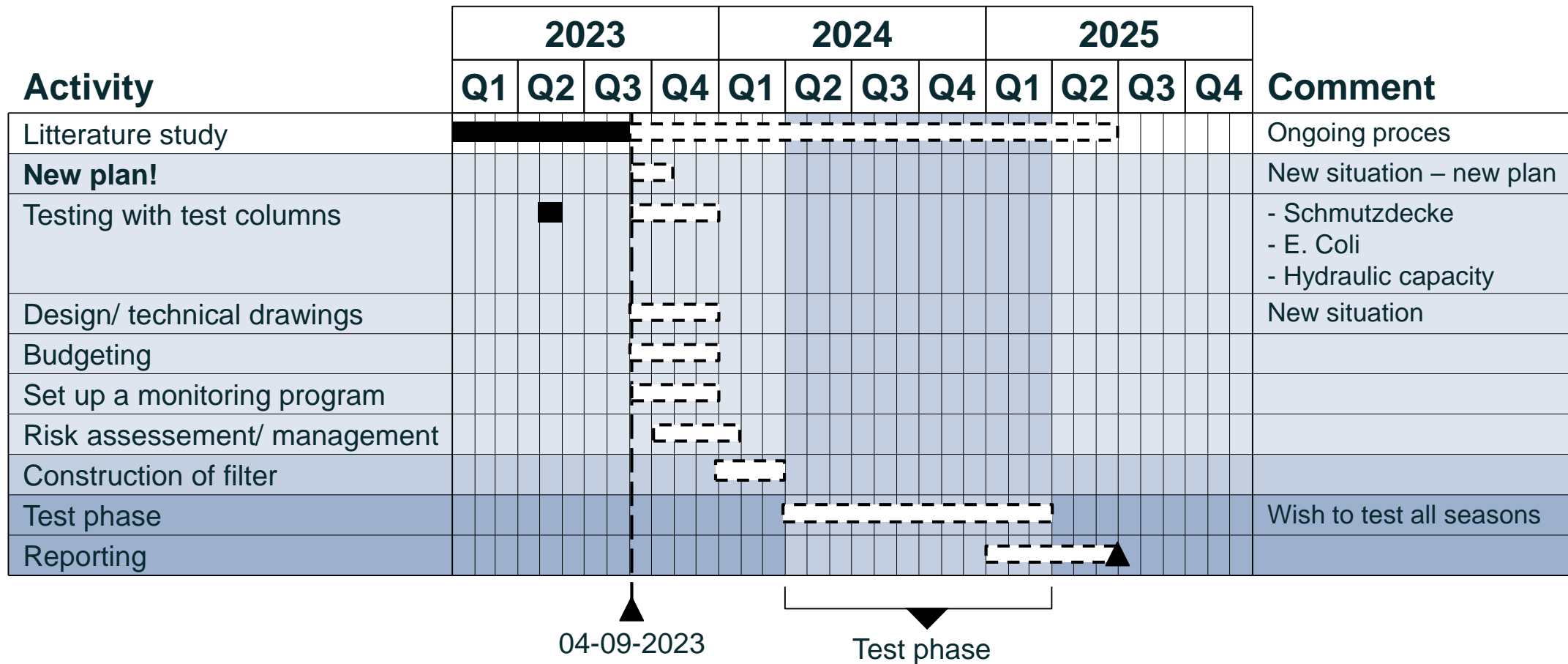
■ To-do – Phase 2

- Construction of the filter

■ To-do – Phase 3

- Test phase (water quality and quantity, filter operation)
- Reporting the results

PRELIMINARY PLANS



Selected literature

Slow sand filtration of secondary effluent for wastewater reuse: Evaluation of performance and modeling of bacteria removal

Kilian M. W. Langenbach

[INTRODUCTION \(tum.de\)](#)

SSF Training material from Oregon Drinking Water Services.

[Oregon Health Authority : Slow Sand Filtration : Surface Water Treatment : State of Oregon](#)

Schmutzdecke- A Filtration Layer of Slow Sand Filter

[Schmutzdecke- A Filtration Layer of Slow Sand Filter \(ijcmas.com\)](#)

1st Peer & expert review session: Recommendations & conclusions

- Keep in mind the feedback of your ministry to your pilot measures: It claims that water reuse is no “business case” in Denmark, and that the application of EU Regulation 2020/741 has therefore limited added value in DK. In order to enable water reuse according to the EU Regulation 2020/741 in Denmark (or at least an exception for Bornholm, like it is in place for Samsø), you will have to demonstrate to the ministry that there is a “business case” in water reuse. It is therefore not sufficient to create a low-tech filter & treatment process of high quality. What has to be proven by your pilot measure is that water reuse from WWTP for agricultural irrigation can be cost efficient and a business case for the farmers. Economic calculations & aspects are, therefore, essential parts of your pilot measure and its evaluation.
- Considering this strategic focus of your pilot action (> proving the need, feasibility & cost efficiency of water reuse for agricultural irrigation on Bornholm / in DK), it could be considered to involve further parties & stakeholders into the activities. For example, the Farmers’ Association may become a partner in the lobbying towards the ministry, and back-up the view of the single farmer taking part in the pilot, who wants to be a pioneer and to show that there is a business case (economic potential).
- Technical design of the low-tech filter:
 - Isolate the slow sand filter to optimize the temperature for microbial degradation. You can dig your filter in the ground (half on ground / half underground). Then you would have a construction that has better prospect to keep the temperature.
 - You could use some insulation material and / or soil to keep the filter warmer. A temperature of more than 5°C is still safe for the Schmutzdecke (biofilm). It still works then, though not as effectively as in case the temperature is higher.
 - With your planned concept, there may occur the necessity to remove the Schmutzdecke (biofilm) manually. This may be avoided by installing 2 sand filters that operate interchangeably (one working, other resting). to keep the balance between build up of the Schmutzdecke during operation and degradation of the Schmutzdecke when the filter is not in use. Alternatively, you may also operate the sand filter intermittently – and use the dry periods for removing / degradation of the Schmutzdecke. Some literature says that an intermittent operation is better than continuous. Have also a look into the concept of French-constructed wetlands (but keep in mind that it is a different process / no sand filter).
 - Some parts of the process will be out of your control as biological processes are complex. After the planned year of testing & sampling of the water, you may gain more knowledge and insights if you need a disinfection step to stabilise the water quality.

Absorption report Recycling treated wastewater for agricultural use Bornholm's Energy & Utility Co. A/S

07 November 2023

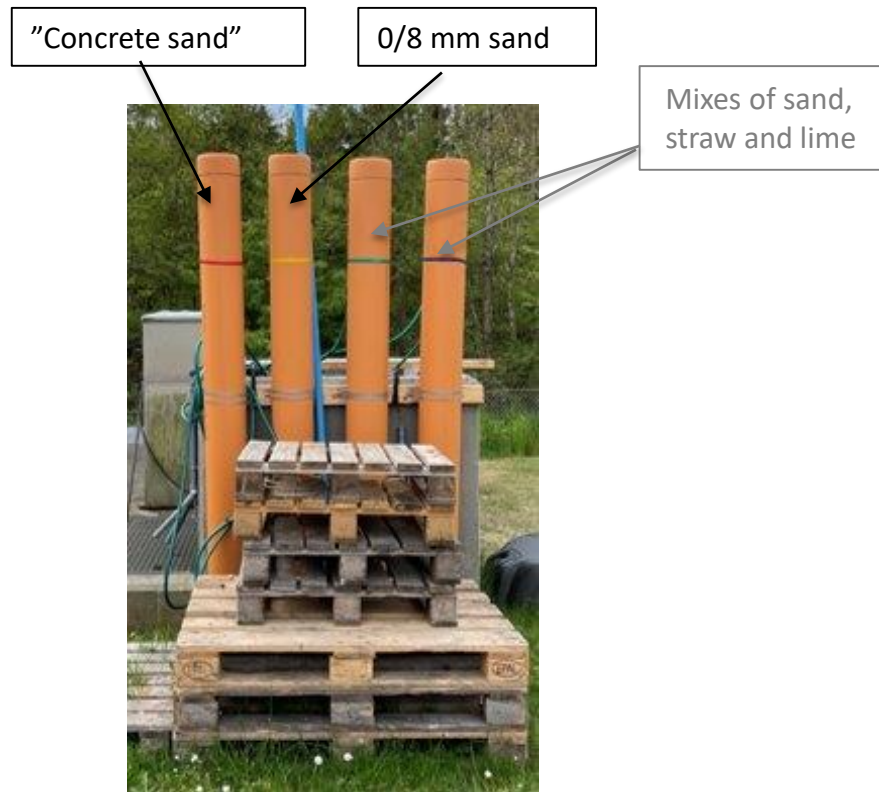


WaterMan – Pilot status

E. Coli results Absorption report

PRELIMINARY RESULTS – E. COLI

Concrete sand to be used for the feasibility study



E.Coli

	Feed (CFU/100ml)	Concrete sand (CFU/100ml)	0/8mm sand (CFU/100ml)
23-10-2023	142900	100	No flow
24-10-2023	19500	5400	500

Schmutzdecke stirred the day before and Δh adjusted

Coliforme

	Feed (CFU/100ml)	Concrete sand (CFU/100ml)	0/8mm sand (CFU/100ml)
23-10-2023	1000000	4000	No flow
24-10-2023	1000000	289600	26900

Need to work further on sampling and analysis procedures to get good quality results

PEER & EXPERT REVIEW

- Business case: Economic calculations will be part of the feasibility study
- Involvement of stakeholder Farmers Association – to have a stronger voice towards the authorities.
- Construction for better insulation:
 - Half in ground, cover piping with soil.
 - Polypropylene or fiberglass tank for better insulation
- Only one sand filter - Intermittent operation. Two in parallel will not be a solution for upscaling.

2nd Peer-review session

Recycling treated wastewater for agricultural use

Bornholm's Energy & Utility Co. A/S

7 November 2024

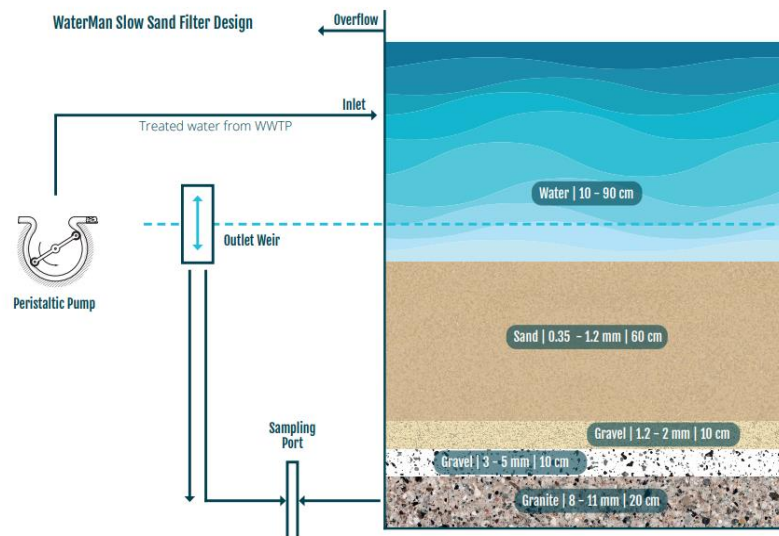


WaterMan – Pilot status

WATERMAN BORNHOLM PILOT

- Agenda
 - Status
 - User groups of the recycled water
 - Stakeholders engagement
 - Evaluation methodology

PILOT STATUS - SSF



SSF STATUS – operation & results

■ Results:

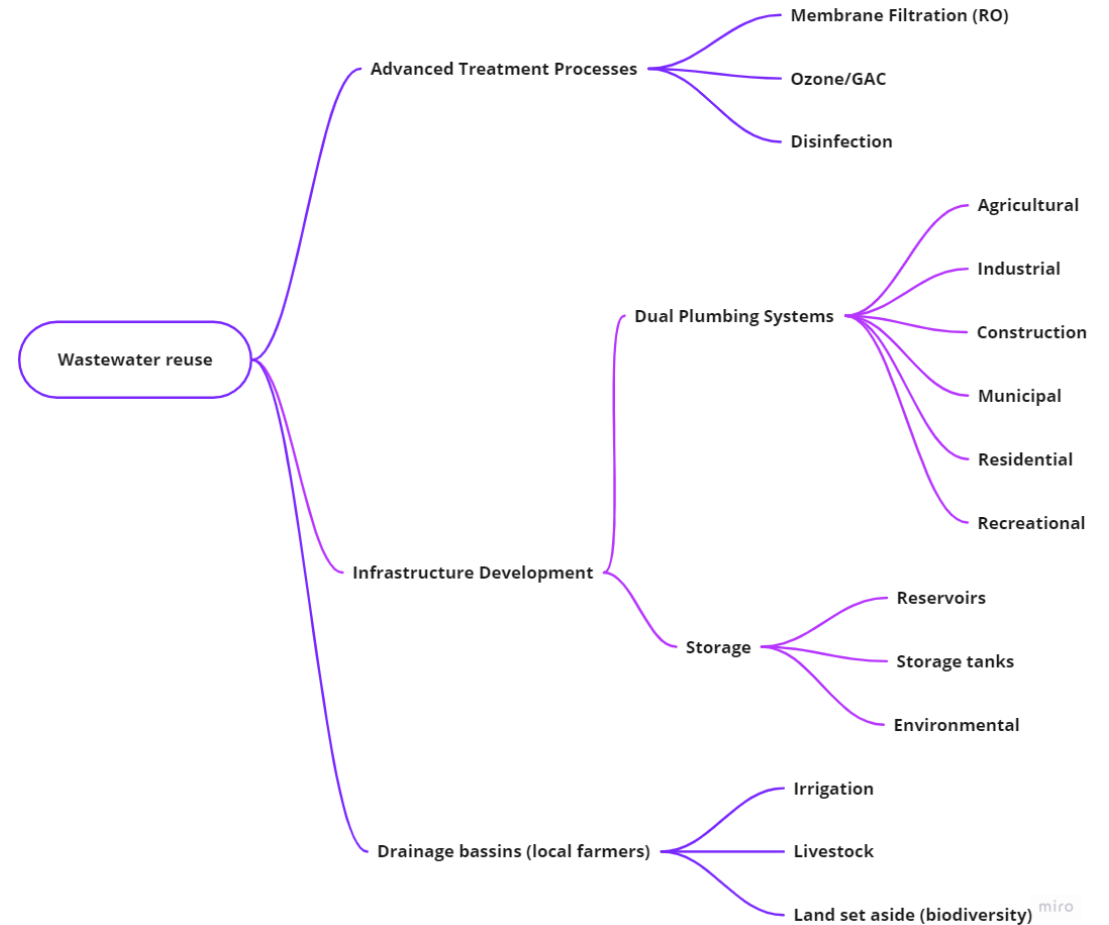
Date	Pump C value	Effluent flow (l/h)	A	B	C	D	Feed		Filtrate	
			Sand-Top (cm)	Water level-Top(cm)	Weir chamber-Top (cm)	dH Driving pressure	E.Coli CFU/100 ml	Total Coliforms CFU/100 ml	E.Coli CFU/100 ml	Total Coliforms CFU/100 ml
21-10-2024	300	260	95	33	47	14				
22-10-2024	345	285	95	11	47	36				
24-10-2024	345	120	95	11	47	36				
25-10-2024	345	271	95	26	82	56				
28-10-2024	345	225	95	11	82	71	17000	795400	370	10000
30-10-2024	345	171	95	11	82	71	34000	1000000	972	10000
31-10-2024	345	225	95	17	82	65				

■ Operation:

- Unstable flow (changed piping system)
- Filter overflow
 - Cleaning the sand (harrowing)
- Fast decline of the outflow
- Potential decrease of biological activity during winter

USER GROUPS FOR TECHNICAL WATER

- Envisaged:
 - Local farmers
 - Nearby (pumping; gravity)
 - Distant (pumping; dual plumbing systems)
- Potential:
 - Industry (process water)
 - Cleaning, manufacturing, aquaculture...
 - Municipal (irrigation)
 - Residential (irrigation; toilet flushing)
 - Recreational (golf courses; wetlands (nature parks))
 - Storage (reservoirs; tanks; wetland restoration)



STAKEHOLDER ENGAGEMENT

Strategy & motivation

Workshop jointly with SYMSITES Q1 2025

- **Objective:** To educate, explore challenges, brainstorm solutions, and promote acceptance of wastewater reuse.
- **Focus:** Treated wastewater for Agriculture
- **Themes:** Technology, innovation, implementation, regulatory considerations, sustainability, stakeholder roles.
 - **Public Perception & Acceptance:** Strategies to engage the community and enhance awareness.

Potential agenda:

- Introduction and Objectives
- Keynote or Expert Presentation
- Session 1: Technical Aspects of Wastewater Reuse
- Session 2: Regulatory and Policy Frameworks
- Session 3: Stakeholder Engagement & Public Acceptance
- Session 4: Case Study Breakouts – small groups activities
- Session 5: Implementation Challenges & Solutions
- Wrap-up and Takeaways



WATER USAGE – EVALUATION METHODS

Multi-step evaluation approach

1 - Water Quality Monitoring

- Physical Parameters
- Chemical Analysis
- Microbial Testing

2 - Agronomic Impact Studies

- Soil Testing
- Crop Health and Yield Assessment

3 - Irrigation Efficiency Evaluation (future)

- Drip and Surface Irrigation Performance
- Application Consistency Tests (nutrient deficiency areas)

4 - Long-Term Environmental Monitoring (future)

- Groundwater Testing
- Runoff Analysis

5 - Economic and Social Impact Assessment (future)

- Economic viability (potential yield improvements or savings from water reuse)
- Conduct surveys or interviews with end-users (farmers) to gauge satisfaction, adoption rates, and any challenges faced in using the treated water

Scenarios: greenhouse with growbeds, or farmland (open for discussion with lead partner)

Thank you



Paulo Silva

WaterMan Project manager

pas@beof.dk, +45 40243932



Torben Jørgensen

WaterMan Co-Project Manager

toj@beof.dk, +45 60262410



Sara Björkqvist

Water quality specialist

sb@beof.dk, +45 50495728



Daniel Sereth Larsen

Project Manager

dsl@beof.dk, +45 21636487



Anne Mette Glarbo

Communications consultant

amg@beof.dk, +45 56900083

2nd Peer & expert review session: Recommendations & conclusions

- Investment, but no real-world testing in the case of Bornholm. The proposed considered extension of water use to greenhouse vegetation is a step into very good direction.
- Results of the planned workshop talk with future potential users should feed into local model strategy.

Status updates

Recycling treated wastewater for agricultural use

Bornholm's Energy & Utility Co. A/S

30 April 2025



Pilot unit - Slow Sand Filter

• Operations

- Reduction in coliforms and nutrients.
- High maintenance due to clogging. Reduced water flow.
- Algae formation, but recently stabilized, perhaps because of a biocide. Water became clear. But still with reduced flow.

• Sampling/monitoring program (1X week)

- Sampling coliforms
- Monitoring water level and flow
- Monitoring water temperature
- *Further analysis to be made:*
 - Medicine & PFAS
 - TSS (inlet and effluent)

• Cleaning program

- For a period (1x week) we “scratched” the top layer with a rake and pumped water out, due to clogging. After cleaning, coliforms level increases, so as water flow, but back to normal in 2 days.
- At the moment (12/05/25), we are stressing the system (no cleaning) and conduct tests.
- After further analysis, we intend to replace the sand top layer.



Greenhouse

Plant (spinach) irrigation with water (polished) derived from the WaterMan slow sand filter, and water (nutrient loaded) from the Symsites project. Two separate feeding lines with drip irrigation into capillary boxes, to avoid spilling.

Key Points

- **Positive Impacts of Interaction:**
 - Enhances **awareness** and **acceptance** of innovative practices among potential users.
 - Provides valuable **exposure to the WaterMan project** among farmers.
- **Joint Efforts with Symsites Project:**
 - The initiative was established as a **collaborative task** alongside the ongoing Symsites project.



Workshop with potential users

Key Points

- Information on possibilities and need for reuse of treated wastewater
- Promote stakeholder & consumer acceptance for water reuse

Workshop

- Agriculture irrigation
- Water storage/retention
- Stakeholder engagement
- Potential users
- Discussion on concerns & requirements
- Future water demand; new crops
- Supply options

Local strategy

- Supplement to BEOFs internal strategy "The future wastewater system" and "Wastewater as a resource".

Baltic Sea Region Toolbox

- Results presentation



Final review

Recycling treated wastewater for agricultural use

Bornholm's Energy & Utility Co. A/S

24 September 2025



The Challenge

What was the problem / need / opportunity?

- **Problem:** Increasing pressure on water resources due to climate change.
- **Need:** Explore sustainable alternatives to freshwater use in agriculture.
- **Opportunity:** Reuse treated wastewater from WWTPs for irrigation, especially during dry periods.

Who / what is affected and in what way?

- **Farmers:** Face water scarcity during droughts, impacting crop yields.
- **WWTPs:** Reduce the load on the surrounding waterbodies as nutrients would be kept on land instead of discharged.

Underlying causes

- **Environmental:** Climate variability (e.g. droughts).
- **Systemic:** Lack of national regulation supporting water reuse (EU 2020/741 not applied in DK).
- **Technical:** Existing WWTPs not designed for reuse; need for low-tech, cost-effective treatment solutions.
- **Economic:** Perception that water reuse lacks a viable business case in Denmark.



Objectives of the Pilot Measure

What did the pilot aim to test or prove?

➤ Technical Feasibility

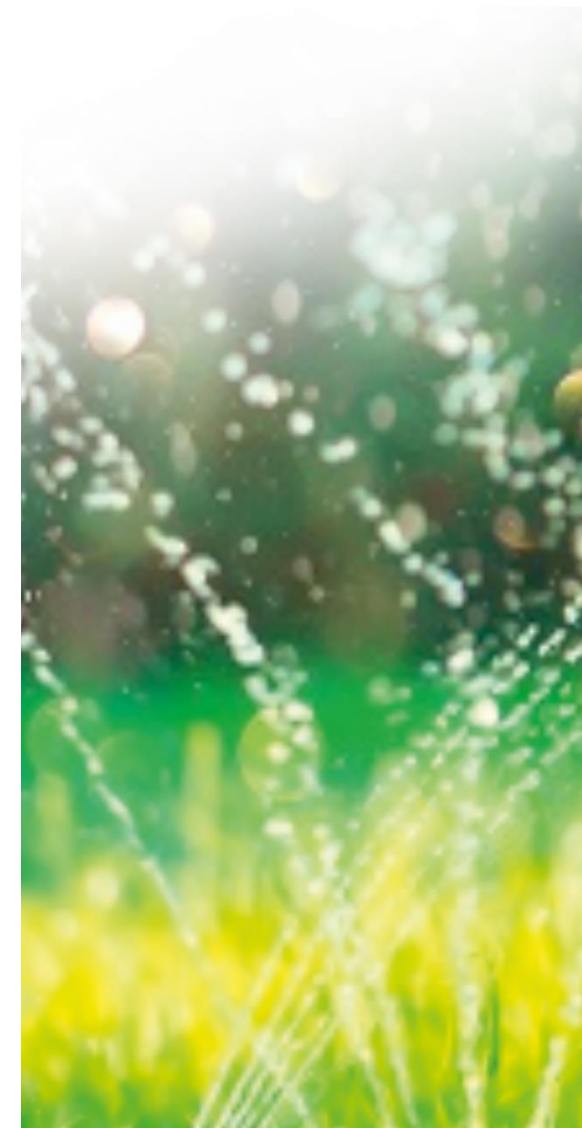
- Can a low-tech slow sand filter effectively treat WWTP effluent for irrigation?
- Is the system operationally stable under local conditions (e.g. winter temperatures, flow rates)?
- Can the system meet basic water quality standards (e.g. E. coli, nutrients, micropollutants)?
- Determine clogging frequency and maintenance intervals; assess micropollutant removal efficiency.

➤ Cost Effectiveness

- Is water reuse economically viable for farmers?
- Can the system be built and operated at low cost?
- Does it offer a business case strong enough to influence Danish regulation?
- Estimate Operation & Maintenance (O&M) costs and evaluate ease of use for farmers.

➤ Social Acceptance

- Will farmers adopt treated wastewater for irrigation?
- Engage farmers in co-measuring soil moisture and crop yield for long-term adoption.
- Can stakeholders (e.g. Farmers' Association, local authorities) support and promote the concept?
- How can public perception be improved through engagement and education?



Context & Background

➤ Why this specific location/site?

- Bornholm faces droughts that stress the water systems.
- A local farmer, located next to Svaneke WWTP, was interested in using treated water for spinach seed irrigation, providing a real-world test case.

➤ Policy / Industry Background

- EU Regulation 2020/741 on water reuse is not applied in Denmark.
- The Danish Environmental Ministry sees no business case for water reuse.
- The pilot aims to demonstrate feasibility and economic potential to influence future policy.

➤ Conditions

- Economic: Need for cost-effective irrigation solutions; pilot must prove financial viability.
- Environmental: Climate variability, nutrient runoff to the Baltic Sea.
- Institutional: Limited regulatory support; pilot must build a case for change.
- Socio-political: Public perception and farmer acceptance are key; stakeholder engagement is essential.



Stakeholders

➤ Key Stakeholders & Their Roles

- **Environmental Ministry**
Regulatory authority; key decision-maker on national water reuse policy.
- **Local Farmer (Frennegaard)**
Initial End-user of treated water; Interested in using the treated water.
- **Bornholms Landbrug & Fødevarer (Farmers' Association)**
Advocacy and stakeholder engagement; potential lobbying partner.
- **BEOF – Wastewater Operations Department**
Technical implementation and operation of the pilot system.
- **SYMSITES Project Partners**
Co-organizers of stakeholder workshops and knowledge exchange.
- **Bornholm Municipality (BRK)**
 - Regulatory authority.
- **DANVA – Danish Water & Wastewater Association**
 - Wastewater representative - significant advisory and influencing role in shaping water and wastewater policy in Denmark.

➤ Stakeholder Engagement

- **Initial Engagement**
One-on-one meetings with the local farmer and BEOF operations team.
- **Workshops**
Joint workshop with SYMSITES (Q1 2025) to:
 - Educate stakeholders
 - Explore challenges and solutions
 - Promote acceptance of wastewater reuse
- **Visits**
 - Municipality's environmental department pilot visit – regulatory advisory. Promote acceptance.
- **Strategic Involvement**
 - Environmental ministry engaged to strengthen the case for policy change - email conversations, Teams-meetings and phone calls.
 - Farmers' involvement in monitoring soil moisture and crop yield is recommended for future pilots



The Solution

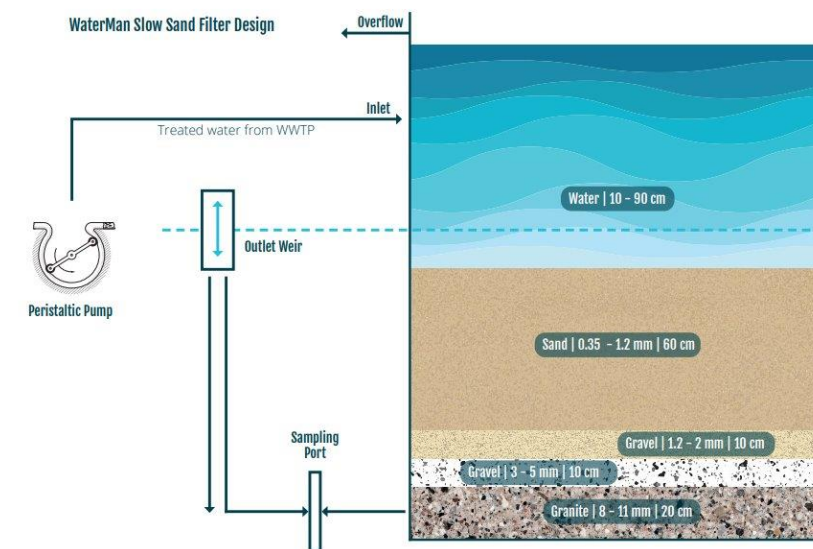
➤ Technical-Organisational Solution Applied

- **Location:** Svaneke WWTP
- **System:** Low-tech Slow Sand Filter (SSF)
- **Design:**
 - Sand layer (80 cm) + crushed granite drainage layer (20 cm)
 - Peristaltic pump and insulated tank
 - Monitoring operation to manage Schmutzdecke buildup
- **Focus:** Water reuse for agricultural irrigation, not nutrient reduction
- **Startup timeline:** Schmutzdecke formation requires ~10–14 days before stable operation.
- **Maintenance interval:** Surface scraping every 2–3 weeks under normal conditions.
- **Requirements:** WWTP must provide secondary-treated effluent; farmer needs land for filter and access to treated water.



➤ How It Works – Overview

1. **Effluent Collection**
Treated wastewater from WWTP is pumped into the filter system.
2. **Filtration Process**
Water passes slowly through sand, forming a Schmutzdecke (biofilm) that removes:
 - Suspended solids
 - Nutrients (N, P)
 - Microorganisms (e.g. E. coli)
3. **Drainage & Collection**
Filtered water is collected at the effluent end pipe after the outlet weir. Did not make use of the sampling port.
4. **Monitoring & Maintenance**
 - Regular water quality testing
 - Occasional surface scraping to remove clogged biofilm
 - Flow rate adjusted based on Schmutzdecke development



Development & Implementation

➤ Development Process

- **Initial Concept:** Inspired by a 1990s filter on Bornholm
- **Kick-off Activities:**
 - Literature review on slow sand filter (SSF) and Schmutzdecke
 - Hydraulic testing of local sand
- **Design Evolution:**
 - Shift from nutrient reduction to reuse-only focus
 - Downscaled to small-scale feasibility study

➤ Tools, Technologies & Methods

- **Slow Sand Filter (SSF):**
 - Sand layer + crushed granite drainage
 - Peristaltic pump, insulated tank
- **Monitoring Tools:**
 - E. coli and coliform testing
 - Nutrient and micropollutant analysis
- **Operational Methods:**
 - Harrowing and scraping of Schmutzdecke
 - Manual scraping manageable for small farms but challenging for large-scale use.
 - Monitoring operation to balance biofilm buildup

Micropollutant Removal Performance (SSF Inlet → SSF Outlet)

- **Suspended solids:** 6.44 mg/L → 2.33 mg/L (~64% reduction)
- **Turbidity:** 1.6 FNU → 0.3 FNU (~81% reduction)
- **E. coli:** 11,400 MPN/100 ml → 410 MPN/100 ml (~96% reduction)
- **PFAS compounds:** Most below detection limits; slight reductions observed (e.g., PFBA: 0.66 → 0.26 µg/L).
- **Pharmaceuticals:**
 - **Citalopram + escitalopram:** 0.072 µg/L → <0.010 µg/L (>86% reduction)
 - **Clarithromycin:** 0.07 µg/L → <0.01 µg/L (>85% reduction)
 - **Diclofenac:** 0.72 µg/L → 0.26 µg/L (~64% reduction)
 - **Hydrochlorothiazid:** 0.17 µg/L → <0.01 µg/L (>94% reduction)
 - **Venlafaxin:** 0.58 µg/L → 0.09 µg/L (~84% reduction)

Phase	Milestone	Status
Phase 1	Feasibility study & lab testing	✓ Completed
Phase 2	Filter construction	✓ Completed
Phase 3	Field testing & monitoring	✓ Completed
Q1 2025	Stakeholder workshop. Promote awareness	✓ Completed
End 2025	Final reporting & evaluation	🔄 In Progress

Lessons Learned

➤ What Did Not Go as Planned?

- **Unstable flow** due to initial piping setup
- **Filter overflow** during early operation
- **Fast decline in outflow** linked to Schmutzdecke buildup
 - Unexpected clogging frequency required more frequent maintenance than planned.
- **Winter performance** concerns due to reduced biological activity

➤ Adjustments Made

- **Changed piping system** to stabilize flow
- **Sand selection refined** based on hydraulic testing and clogging resistance
- **Filter design updated:**
 - Polypropylene tank for thermal stability

➤ Key Takeaways for Future Implementations

- **Smaller-scale farms** can benefit from modular, low-tech systems
- Intermittent **operation** is preferable to continuous for managing biofilm
- **Thermal insulation** is critical for year-round performance
- **Stakeholder involvement** (e.g. farmers' associations) strengthens policy impact
- **Economic viability** must be demonstrated early to support regulatory change



- **If starting again:** Include influent pre-treatment (drum filter), real-time monitoring, and automated scraping.
- **Future pilots** (scaling up): Co-measure soil moisture and crop yield with farmers; share results at seasonal workshops.

Scalability

➤ Can the Measure Be Scaled Up?

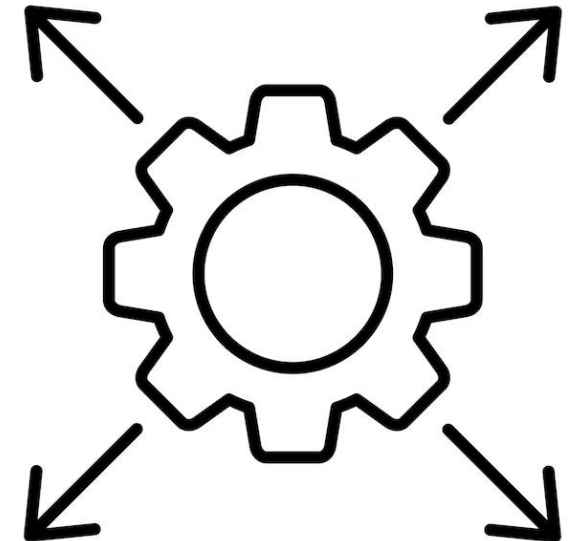
- Technically possible, but with significant limitations
- Scaling within the region would require large land areas and intensive maintenance

➤ Required Adaptations for Larger Scale

- Larger filter surface area to handle higher water volumes
- Scaling requires automation to reduce manual maintenance and improve farmer usability.
- Improved insulation and temperature control for year-round operation
- Efficient sludge and Schmutzdecke management systems

➤ Financial Viability

- Not viable in our case due to:
 - High volume of water requiring treatment
 - Large land footprint needed
 - Increased operational complexity and maintenance costs
- More suitable for small-scale farms or modular applications with lower water demand



Transferability

➤ Adaptability to Other Regions or Systems

- Modular design allows scaling up or down based on local needs
- Can be applied in:
 - Rural areas with limited infrastructure
 - Small-scale farms needing alternative irrigation sources
 - Municipal or industrial reuse (e.g. parks, cleaning, process water)
- Suitable for regions with:
 - Seasonal water stress
 - High nutrient runoff
 - Interest in circular water solutions

➤ Preconditions for Successful Replication

- WWTP effluent availability with basic treatment
- Land availability for low-flow filtration systems
- Stakeholder buy-in (farmers, municipalities, regulators)
- Monitoring capacity for water quality and system performance
- Regulatory flexibility or pilot-friendly frameworks
- Economic feasibility: Must demonstrate cost-effectiveness for end-users
- Precondition: Clear O&M cost estimates and farmer-friendly operation protocols.



Final Reflections

➤ Biggest Surprise

- The impact of cold weather on biological activity was less significant than expected.
- Schmutzdecke performance dropped during winter, affecting flow and treatment efficiency. But still good removal rates of coliforms.
- Overall removal rate – Class D

➤ “This Might Not Work...” Moment

- During early spring, outflow declined rapidly, raising concerns about system viability.
- Solution: performed regular cleaning/racking to increase flow.

➤ Key Tips & Recommendations

- Design for seasonal variation – insulation and flexible operation are essential.
- Start small – modular systems are ideal for pilot testing and small farms.
- Engage stakeholders early – farmer buy-in and ministry dialogue are critical.
- Plan for maintenance – biofilm management is a recurring task.

➤ Wish List for Future Pilots

- Automatic maintenance system for Schmutzdecke management
- Real-time monitoring sensors for flow and water quality
- Drum filter at influent to reduce solids load
- Integrated backwash system (though it may compromise the “low-tech” nature of SSF)
- Future pilots should include soil moisture and crop yield monitoring, shared at seasonal farmer workshops.
- Real-time sensors, influent drum filter, automated Schmutzdecke management.





Helpdesk / Contacts for further information:

Paulo Silva

pas@beof.dk

+45 40 24 39 32

Torben Jørgensen

toj@beof.dk

+45 60 26 24 10

Sara Björkqvist

sb@beof.dk

+45 50 49 57 28

Daniel Sereth Larsen

dsl@beof.dk

+45 21 63 64 87

Anne Mette Glarbo

amg@beof.dk

+45 56 90 00 83

The „BSR Water Recycling Toolbox” was elaborated as part of the WaterMan project, which is co-financed by the European Union (European Regional Development Fund) and implemented within the Interreg Baltic Sea Region Programme. More information:

eurobalt.org/WaterRecyclingToolbox

interreg-baltic.eu/project/waterman

WaterMan promotes a Baltic Sea Region-specific approach to water recycling, which makes use of the alternation of too much and too little water that has become typical for humid areas in the EU to strengthen the resilience of local water supply. Building on this approach, the project supports municipalities and water companies in adapting their water supply strategies.

The contents of „BSR Water Recycling Toolbox” are the sole responsibility of the authors and can in no way be taken to reflect the views of the European Union, the Managing Authority or the Joint Secretariat of the Interreg Baltic Sea Region Programme.

