Bornholms Energi & Forsyning A/S

BEOF, Langsomt sandfilter WaterMan

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1. Background

Within the WaterMan project, Bornholm Energi & Forsyning (BEOF) has conducted a feasibility study on use of slow sand filtration (SSF) for polishing the Svaneke Wastewater Treatment Plant (WWTP) effluent.

WaterMan promotes a region-specific approach to water recycling, which intends to use the occurrence of both too much and too little water that has become typical in the Baltic Sea Region, to make the local water supply more resilient, and supports municipalities and water companies in adapting their strategies. The project is co-financed by the European Union (European Regional Development Fund) and implemented within the Interreg Baltic Sea Region Programme.

eurobalt.org/WaterRecyclingToolbox interreg-baltic.eu/project/waterman

A pilot plant study was conducted to investigate whether slow sand filtration can produce a filtrate that complies with the minimum requirements for agricultural irrigation, specifically the microbial requirements of Reclaimed water quality class D. The minimum requirements for class D reclaimed water are shown in Table 1.

Table 1: Reclaimed water quality requirements for agricultural irrigation (EU, 2020)[1].

Reclaimed water quality class	*E. coli*	BOD_5	TSS	*Legionella spp.
D	≤ 10.000 cfu/100 ml	25 mg/l	35 mg/l	< 1.000 cfu/l

* Only if risk for aerosol formation

Another objective was to investigate the operational parameters, such as possible filtration rate and requirement for manual cleaning.

Envidan has helped BEOF with planning the pilot tests, designing the pilot plant and evaluating the results.

2. Pilot-scale slow sand filtration

The slow sand filter consisted of a Ø2000 mm plastic well, placed next to the outlet water chamber at Svaneke WWTP. The filter had a solid bottom and was filled with approximately 60 cm of sand, on 40 cm of gravel. In the gravel, a drainpipe collected the filtrate. A peristaltic pump, installed in a shed, ensured a steady flow of treated wastewater into the SSF. The weir in the weir chamber was adjusted so that the water level in the filter would remain above approximately 10 cm over the sand surface at all times, even without flow through the system. The driving pressure for filtration was up to 72 cm, when the feed side overflowed. A simple process flow diagram is shown in Figure 1 and a photo of the actual pilot scale setup can be seen in Figure 2.

As many input parameters varied uncontrollably (e.g. weather conditions, feed concentration of suspended solids) the feed flow was kept constant, at approximately 314 L/h. This corresponded to a filtration rate of 0.1 m/h, when the feed side was not overflowing.

Two cleaning methods were applied:

1) During wet-harrowing, the filter bed was scraped with a rake.

2) During thorough cleaning, the top layer (Schmutzdecke) was removed (approx. 3 cm).

[1] EU. (25. May 2020). REGULATION (EU) 2020/741 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 25 May 2020 on minimum requirements for water reuse. Official Journal of the European Union, s. 33-55.

During the year of pilot plant operation, Total Suspended Solids (TSS) concentration in the feed was 25 mg/l on average (median 12 mg/l, max 224 mg/l).

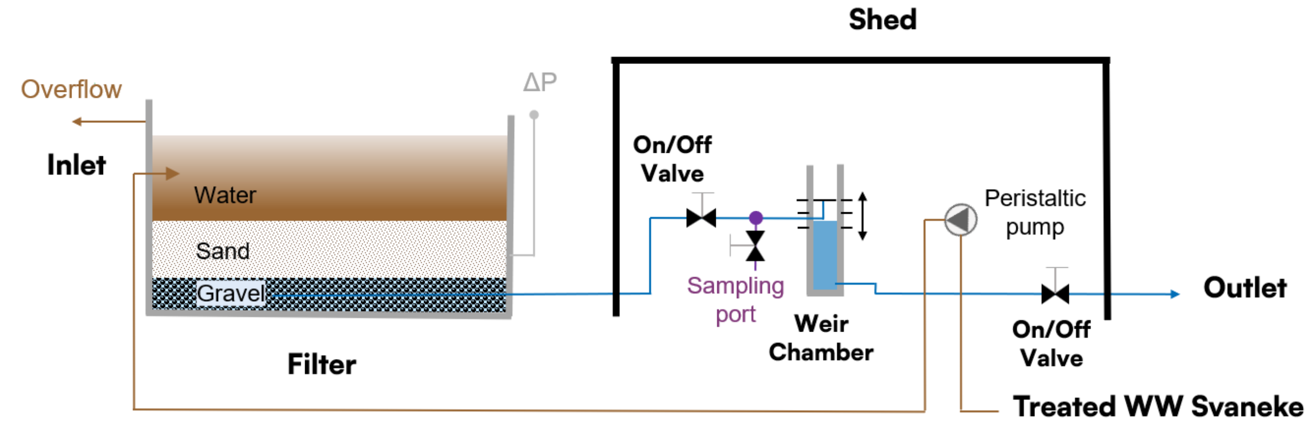

Figure 1: Process Flow Diagram Slow Sand Filter (SSF)

Figure 2: Photo of pilot-scale Slow Sand Filter (SSF) installation at Svaneke WWTP.

3. Main results

It was difficult to maintain the target filtration rate of 0.1 m/h (314 L/h) due to clogging. During Spring and Summer, there was algae growth in the water column. Wet-harrowing with removal of the dirty water restored the filter's hydraulic capacity partly, for a limited time, approximately one week. Thorough cleaning with removal of the top layer restored the filtration rate.

Reduction of E.Coli concentration was normally in the range 90-99,9 % (1-3 $\log_{10}$) with effluent concentrations below 1000 in most samples. Wet-harrowing affected microorganism removal for one to two days. After thorough cleaning, it took more than four days to reach 1 $\log_{10}$ E.Coli removal.

SSF had no effect on chemical oxygen demand (COD), total phosphorus, ammonium and nitrate.

The pilot plant functioned well technically, but the filter clogged rapidly, resulting in very low filtration rates. Thorough mechanical cleaning was required to restore the intended filtration rate. A theoretical estimate is that feed TSS values should be kept low (max 6 mg/l) to restrict the increase in filter resistance to 2 cm/day (increase of water level), corresponding to a cleaning interval of once a month.

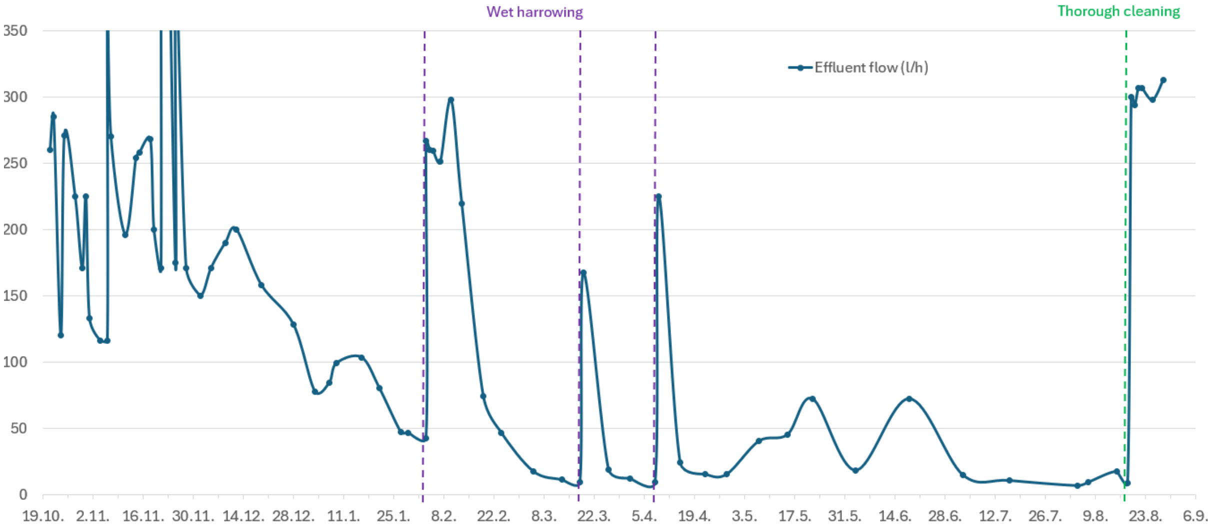

Figure 3: Effluent flow rate over the first year of operation

The filter developed considerable biological activity, including larger animals such as worms and bugs. Growth of algae may become an operational nuisance in a full-scale plant.

The process investigated in this study, with slow sand filtration directly fed WWTP effluent has doubtful perspective in a full-scale application, as the filtration rate is low and thorough cleaning with removal of the top layer required frequently. This would be a serious practical and economic constraint. To achieve operational conditions with mechanical cleaning not more than every three months, the feed probably would have to be pre-treated to TSS values around 1 mg/l. This could be obtained by installing a mechanical filter prior to SSF.

When mature, the filter achieved reasonable $\log_{10}$-removals of E.Coli and coliform bacteria. After thorough cleaning however, there were some days with close to zero reduction. In a full-scale application, some days of maturing the filter would be required before the filtrate is used again. Alternatively, UV-disinfection could be added to the treatment chain as a microbial barrier, to secure consistently low bacterial concentrations.

Slow sand filtration for polishing treated wastewater demands a large filter area. At a filtration rate of 0.1 m/h, it would take 10 m^2 for each 1 m^3/h wastewater to be polished. The economic suitability of SSF needs to be investigated, including investment and operational costs. Other processes such as backwashed rapid sand filters should be compared as an alternative for polishing treated wastewater for reuse as technical water or in agriculture.

Further investigations of SSF for polishing treated wastewater should include a pre-treatment process to reduce Total Suspended Solids in the feed to reduce the need for mechanical cleaning. Also, the hydraulic resistance of the filter bed should be investigated in depth, to make sure that fine particles from the treated wastewater do not accumulate deep in the bed, where they are difficult to remove with mechanical cleaning. Other issues that should be investigated are possible esthetic issues with large-scale slow sand filter fed treated wastewater, such as odor or breeding of insects, such as mosquitoes.