Use of down-flow dual media granular filters to obtain strict discharge limits at Bekkelaget WWTP in Norway

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ABSTRACT

The new Bekkelaget wastewater treatment plant in Oslo, Norway is designed to treat wastewater from the eastern parts of Oslo, with a total load of 280.000 pe. The maximum hydraulic load is 260.000 m^3/d. The plant was built to meet new and more restrict discharge limits on phosphorous and nitrogen. The average discharge limit for phosphorous is 0.2 mg P/l. The plant is an activated sludge plant with simultaneous precipitation and pre-denitrification. To meet the discharge limits, dual-media downstream sand filters with Filtralite MC is built as a final polishing step. The reduction of phosphorous and suspended solids over the filters is about 80%. The experiences with sand filters at Bekkelaget WWTP are very good, the need of coagulants are limited and operation is to a great extent automised.

INTRODUCTION

The new Bekkelaget wastewater treatment plant (BRA) was finished in fall 2001. The plant was built to meet the demands in the North Sea Treaty, and replaced the old Bekkelaget WWTP at the same location, approximately 3 kilometres south of the city centre of Oslo, Norway. The plant treats wastewater from about 280.000 people (TN_{12} pe) living in the eastern parts of Oslo. The effluent from the plant goes to the Oslo fjord, which is a threshold fjord with low water replacement. The new plant is built in rock caverns, except for storage tanks for chemicals and biogas. The total area of the caverns are 40.000m^2 .Oslo municipality owns the treatment plant and Bekkelaget Water Inc. handles the operation on a 15 years contract. Bekkelaget Water Inc. is a part of Anglian Water Group

The plant has a mean flow of 100.000m^3/d and the maximum capacity is 260.000m^3/d.

The inlet water goes to primary sedimentation before the biological treatment step, based on activated sludge with pre-denitrification. Maximum capacity in the biological treatment step is 147.000 m^3/d. In the biological step, ferrous sulphate is used for simultaneous precipitation at a dose of approximate 10g Fe/m^3. After biological treatment and secondary sedimentation, the water is led to the dual media sand filters for final polishing. When the inlet flow exceed this the excess water volume, limited to 113.000 m^3/d, will only be treated by precipitation with ferric chloride and dual media filtration, shown in figure 1. The dosage of ferric chloride in the precipitation is 20-25g Fe/m^3 .The maximum hydraulic capacity of the dual media filters is 260.000 m^3/d. In periods of high P loads or high hydraulic loadings, increased removal of P can be accomplished by dosing coagulant before the sand filters with a dose of 0.5-1.0 g Fe/m^3

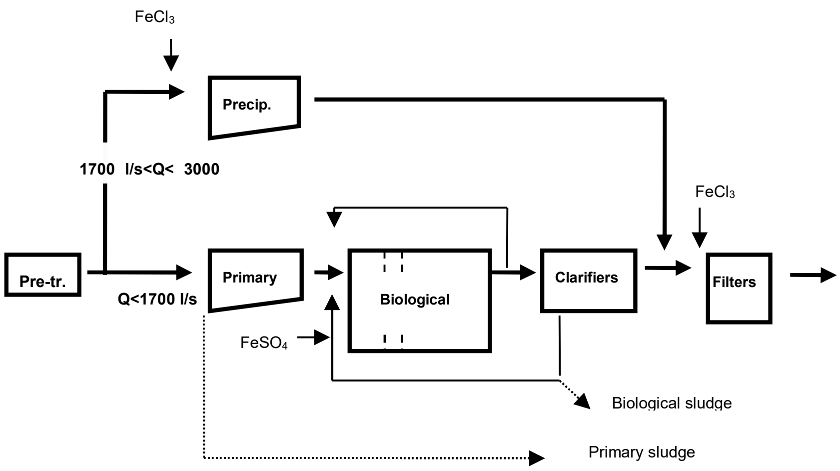

Figure 1 Flowchart Bekkelaget WWTP, water processes

The sludge treatment is thermophilic digestion, dewatering with centrifuges and sludge drying.

On a yearly basis the discharge limits (without overflows) are:

Tot-P	9.6 ton/year	→ ~ 0.2 mg P/l
BOD_7	455 ton/year	→ ~ 10 mg BOD_7/l
Tot-N	456 ton/year	→ ~ 10 mg N/l

There are no discharge limits on SS or COD

Filter design and operation

The filters at Bekkelaget WWTP are dual media filters. The filters are designed with 1.8 metre of filter-material in each filter; 1.2 metre of Filtralite® MC (Medium density, Crushed quality) size 2.5 mm – 4 mm.(top-layer), and 0.6 metres of fine-grained sand 1.2 – 1.8 mm (bottom-layer). Each of the 16 filters have a surface area of 50 m^2, total area is 800 m^2. In the bottom of the filters, there are 55 nozzles per square metre with 0.7 mm slits.

The filters are designed to treat the total incoming flow, both biologically treated and direct-precipitated water. Normal hydraulic load is 5.7 m/h, and max load is 14.4 m/h with 15 filters in operation; (one filter is always in backwash mode during max load periods).

To improve the performance it is possible to add coagulants before the filters, either $FeSO_4$ or $FeCl_3$ can be used.

The filters are operated with a constant water-level. When the filter accumulates sludge the outlet valve gradually opens to keep this level constant. If the valve is >90% open, the filter is considered to be clogged, and a backwash is automatically started. If the load is low, the filters are backwashed after a preset runtime, about once a day. Under normal conditions, the fixed run-time initialises the backwash-cycle.

A backwash-cycle consists of a washing-sequence and a stratification-sequence, it can be repeated three times, and is as follows:

- Filter shut down
- Air is blown into the filter to rub off sludge particles from the material.
- Water is pumped in to wash the filter and remove the sludge.
- Removal of supernatant back to inlet

After washing the filter, the material must be stratified so that the Filtralite MC is layered above the sand. This is done by fluidizing the material at a water velocity of 70-80 m/h. Total time to wash one filter with 3 sequences is normally 25-35 min.

It is critical that there is sufficient pause time between filter backwash and discharge of supernatant. If not, there is risk of loosing the filter material.

The water used for backwashing, in total 175 m^3 when backwashed with three sequences, is effluent water from the outlet-channel. The supernatant is decanted from the filter and pumped back to the inlet of the plant.

Even though the filters are dimensioned to treat the whole incoming flow, there are situations when this is not possible (breakdown of backwash-equipment, failure in the control system, heavy clogging of filters etc). In these situations there is a possibility to bypass the filters, and let unfiltered water to the outlet.

One can divide the filter operation into two main situations; normal flow, and high flow conditions. Normal flow is experienced during dry weather periods with an average flow of 1200 l/s to the plant. A high flow situation is due to rain and/or snow melting, with a flow between 2200 l/s and up to 3000 l/s.

High filter loads results, of course, in more frequent backwashing, a higher consumption of effluent water for backwashing , higher electricity-consumption and a high amount of particles back to the inlet. The SS that is returned to the inlet can represent a considerable amount due to frequent filter-backwash.

RESULTS

Dry-weather results

The flow to the plant is approximately 100.000m^3/day during dry weather periods. The concentration of P is 3.5-4 mg/l, COD 350-400 mg/l and SS 220 - 250 mg/l. The whole flow is simultaneous precipitated in the activated sludge step.

The results from the test period are typical for the plants normal performance. As shown in Table 1, the filters receive a SS concentration of about 20 mg/l. The concentration in the outlet is 2,6-2,9 mg SS/l. The phosphorous concentration is lowered from about 0.5 mg/l to <0.1 mg/l. Adding of coagulant under dry-weather conditions does not seem to have a significant effect. In these periods the filters remove most of the remaining SS, P and COD without addition of chemicals.

Because the water is precipitated with Fe (direct and/or simultaneous precipitation) there is no ortho-P left. What is left of P is in particulate form. Therefore the correlation between SS and Tot-P is very good. If the SS is high in the outlet, the P-removal is low. If the SS is between 2-4 mg/l we know that the P-removal meets the discharge limits.

Figure 2 shows a typical dry-weather situation concerning SS and flow. Inlet flow is constant from day to day, SS to the filters varies a little, but the outlet concentrations are stable and low.

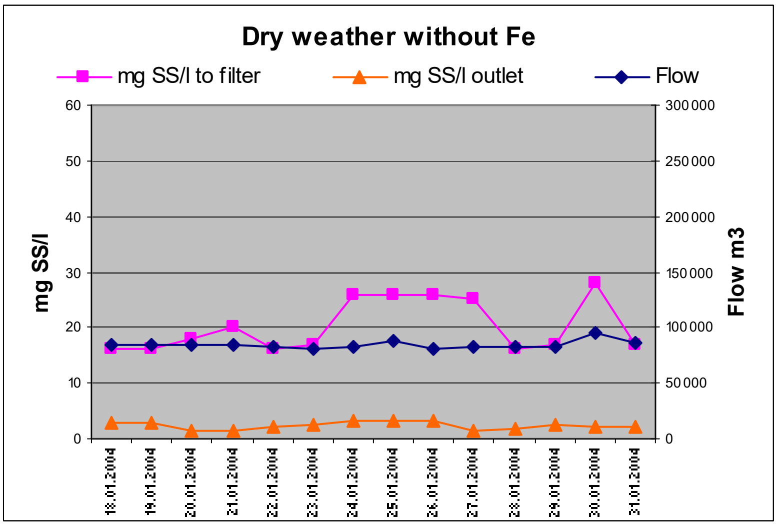

Figure 2. Dry weather loading

High flow results

A high flow period can last for a few hours up to two weeks. There are seldom periods of high flow longer than two weeks. High flow can be everything from a short intense summer-rain to rain combined with snowmelt for several days. In high-flow periods, the inlet concentrations to the plant of P varies from 0,9-1,5 mg/l, COD 80-150 mg/l and SS 60-150 mg/l. The inlet water is usually more concentrated in the beginning than at the end of a high flow period. The first day of high flow after a longer dry period often gives a “first flush” effect.

As shown in Table 1, this period has an average concentration of 30.9 mgSS/l and 0.45 mg P/l to the filters, and 12.5 mg SS/l and 0.19 mg P/l out of the filters. In the beginning of a period like this, the filters are backwashed every 5-10 hrs. When the high hydraulic load to the plant continues the filters are backwashed more frequently and filter run times are only 1-2 hrs. The reason for this is that the sludge-settling is poorer when the basins have been heavily loaded for a long period resulting in an increased particle load to the filters. When the filters clog this fast, they queue up for backwashing since one backwash-cycle takes about 30 min. If many of the filters are clogged, the water level in front of them rise, and a bypass-penstock opens to avoid flooding of the plant. It is not unusual that 10-20 % of the incoming water bypasses the filters under these conditions. To improve the P-removal efficiency $FeCl_3$ is added to the filters at high flow.

Figure 3 below shows a typical wet weather situation. The first day the flow is high, but the filters only receive biologically treated water (plant is not yet max. loaded). SS to the filters are high because sludge which has settled in channels during low flow is washed out. The second day, the flow increases to max. loading and a part of this is only direct-precipitated water. As the high load continues, the filters have problems treating the whole flow, and bypass some of the water. Problems with filters failing (fails during backwash because of high pressure) have also caused water to bypass and increase SS in the effluent.

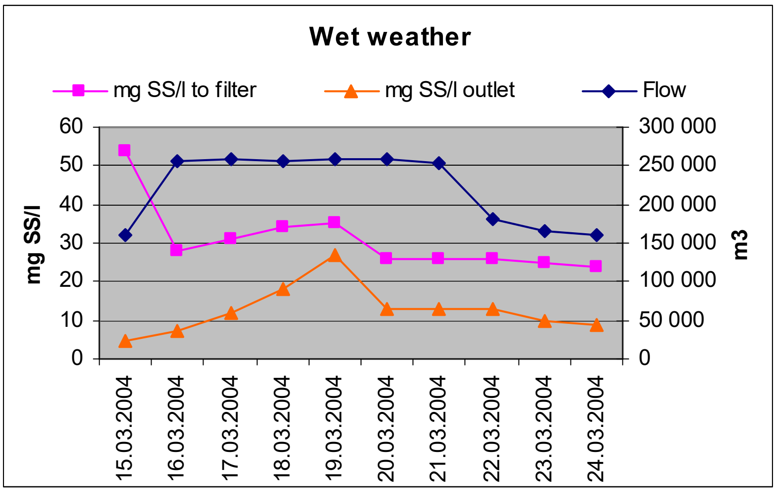

Figure 3. Wet weather loading.

Table 1 Data from three typical periods, period average in and out of filter.

	In mg/l	*Out mg/l*	*Kg removed*	*Efficiency %*
Dry weather with coagulant (0.5 g Fe/m3)				
Suspended solids	21.3	2.6	1674	87
Total - phosphorous	0.404	0.062	31	79
Dry weather no coagulant				
Suspended solids	22.1	2.9	1919	87
Total - phosphorous	0.609	0.092	47.6	83
Rain/snowmelt with coagulant (0.7 g Fe/l)				
Suspended solids	30.9	12.5	3848	57
Total - phosphorous	0.45	0.19	70	60

Figure 4 shows two different head loss curves for the same filter under different conditions. The figure shows the head loss (HL) development when the load is low (SS1 and HL1), and backwash after a fixed run-time, and a situation with high load (SS2 and HL2) when backwash is carried out after about 7 hrs. The low-load situation has a flow between 600 and 1350 l/s (a normal 24 hrs variation) and SS load about 13 mg/l. The head loss curve (HL1) shows little decrease due to clogging for the first 19 hrs of the runtime. Then the filter is saturated with deposits in only a few hours and finally backwash when it has reached its set point for run-time (23 hrs). The high-load situation has a flow of 2500 – 3000 l/s. The SS load varies from 14 to 27 mg/l, and gives the filter a shorter run-time before clogging.

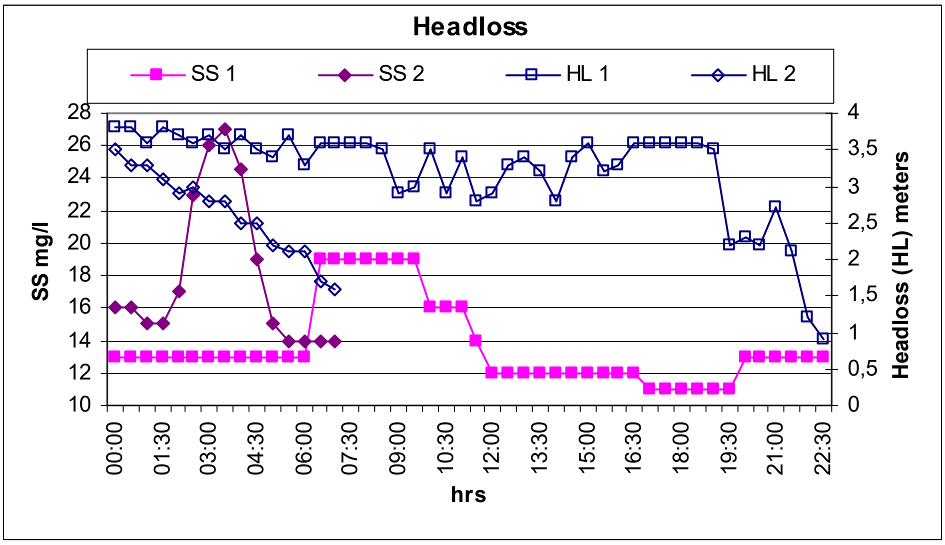

Figure 4. Headloss curves for a filter under different conditions. SS – mg/l HL – m 1–dry-weather period, 2-high load period

EXPERIENCES AFTER 3 YEARS OF OPERATION:

Operating sand filters is not very complicated, but still experiences are important to improve the operation and get better and more stable results.
During the first three years of operation getting experience on how to handle high flow periods has been of great importance. High flows give a higher concentration of SS and thus a higher load to the filters. Also the sludge-separation is somewhat poorer in the clarifiers, and there is risk of sludge washout, especially when the high flow continues for several days. Therefore it is important to control the sludge blanket in the clarifiers regularly. There has been very few periods of sludge washout from the clarifiers when the sludge blanket is regularly controlled.

Furthermore adjustments have been made to the back wash sequence. The backwash speed has been increased, and this is of course important to make sure that the filter sand is properly cleaned, but also important to avoid clogging of the nozzles. Clogging of the nozzles has been a problem, probably caused by iron precipitates and low backwash velocity. To avoid these problems the nozzles were replaced with new nozzles having larger slits (0.5 mm replaced by

0.7 mm,). In addition to use an increased backwash velocity also the dosage of chemicals was reduced.

The first two years $FeSO_4$ was used as a coagulant before the filters. After the problems with the nozzles, we changed to $FeCl_3$, and coagulant has only been used during high flow periods. After one year of this new operational regime, the nozzles have been controlled, and there is no sign of deposits inside the nozzles. The results on removal of SS and P are still very good, but the dosing is more difficult to optimise when using ferric chloride instead of ferrous sulphate.

The supernatant from the backwash sequence is pumped back to the inlet of the plant to be treated together with the incoming flow. When the filters are backwashed once a day this load contributes about 5% to the incoming SS-load. During high load periods, this fraction can be as high as 20% of incoming water. The SS loading from supernatant from filter back wash can be comparable to the supernatant from the sludge dewatering centrifuges. At Bekkelaget the treatment of filter supernatant have caused some problems. The particles would not easily settle, and created a blanket above the bottom in the settling tanks. During high flow conditions this blanket was flushed out and clogged the filters. Separate treatment was considered, but instead the point of addition was rebuilt. The water is now more completely mixed with the inlet water, and settles more easily.

The filters capacity to accumulate sludge has been measured by analysing the SS in the backwash-water. Earlier investigations showed that the capacity was between 3-4 kg SS/m2. Investigations done in 2004 shows that the capacity is only ~2 kg/m2. There are at least two reasons why the capacity is lowered: -loss of filter material, -lack of structure in the filters (Backwash-speed is not high enough). Filter-material has been lost because of to short pause after backwash, so that filter material followed the supernatant from back wash water.

Power consumption from filter operation is basically from back wash water pumps, and blowers. During dry weather periods the consumption is 300 kW/day. With continuously high flow, the power consumption is 1000 kW/day.

CONCLUSIONS

- During three years of operation of the sand filters at Bekkelaget WWTP, there is no doubt that the plant would not fulfil the discharge limits for phosphorus without the dual media granular filters.
- With sand filters as a final polishing step, the levels of both phosphorus and suspended solid are reduced with approximate 80% under normal conditions and about 60% during high flow situations.
- The need of coagulants is limited, but a small dose, 0.5-1.0 g Fe/m^3 is needed during rain weather and increased flows.
- The velocity of backwash water is important both to avoid clogging of the nozzles and to get the right structure of the filters
- The SS loading from supernatant from filter back wash can be comparable to the supernatant from the sludge dewatering centrifuges, and up to 20% of incoming water

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