Feasibility study of biological wastewater treatment plants with Salsnes Filter™ fine mesh sieve primary treatment compared to plants without primary treatment

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Summary

Small biological treatment plants are often designed without primary treatment. This feasibility study looks at what effect primary treatment using Salsnes Filter fine mesh sieves, with 300 μm mesh size, will have on these smaller plants. One scenario was for plants required to remove organic matter only, while the other scenario was for plants that, in addition to removal of organic matter, also were required to nitrify. Calculations were made using activated sludge processes and a generic plant with an average flow of 2760 m^3/d and an 8280 population equivalent (PE) organic load. Either one (1) Salsnes Filter model 4000 sieve or two (2) Salsnes Filter model 2000 sieves were used for primary treatment. Cost and area requirement for activated sludge aeration basins without primary treatment, were compared to the cost and area requirement for Salsnes Filter primary treatment and activated sludge aeration basins. All other unit processes, like screens, grit chambers and secondary sedimentation, were considered equal. The cost comparisons were made for outdoor plants with open basins. The cost for land was set at zero.

For BOD-removal, the area requirement for Salsnes Filter primary treatment and activated sludge aeration tanks was about 60 % of the area requirement for activated sludge aeration tanks without primary treatment. Investment cost savings of about NOK 0.5 to 0.8 million were seen by using Salsnes Filter primary treatment. Energy and maintenance cost using one Salsnes Filter model 4000 sieve was the same as without primary treatment. Using two Salsnes Filter model 2000 sieves the energy and maintenance cost was higher than without primary treatment, but this was offset by the lower capital cost.

For BOD-removal and nitrification, the area requirement for Salsnes Filter primary treatment and activated sludge aeration tanks was about 55 % of the area requirement for activated sludge aeration tanks without primary treatment. Investment costs were reduced by more than NOK 1.7 million using two Salsnes Filter sieves, and more than NOK 2.0 million using one sieve. Compared to a process without primary treatment, energy and maintenance costs were lower using one sieve and somewhat higher using two sieves. Including capital costs, however, even the alternative with two Salsnes Filter model 2000 sieves showed annual cost savings of more than NOK 170 000.

Key words - English	Key words - Norwegian
Fine mesh sieve	Finmasket sil
Primary treatment	Mekanisk rensing
Biological treatment	Biologisk rensing
Costs	Kostnader

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1. Introduction

Salsnes Filter, with head office in Namsos, Norway, has developed a unique fine mesh sieve system for treatment of municipal and industrial wastewater. The first prototype was produced in 1992. Presently, about 40 units have been installed for treatment of municipal wastewater.

Traditionally fine mesh screens and sieves have been used for pretreatment, or as the only treatment at smaller plants that discharged wastewater to the ocean. Removal efficiencies reported for screens and sieves with less than 1 mm openings, were only 5 to 10 % for organic matter and only 10 to 20 % for suspended solids (SS) (Hansen, 1996). The effect was mainly aesthetic, as the sieves and screens only removed the most visible part of the pollution.

The European Union has defined primary treatment as removal of at least 50 % SS and at least 20 % BOD_5. This can normally not be achieved by just fine mesh sieves or screens. However, Salsnes Filter has achieved primary treatment performance at their installations. In addition to removing particulate material, the Salsnes Filter unit also dewaters the primary sludge, resulting in a very compact process for primary treatment. A test at the Tiendeholmen wastewater treatment plant (Rusten, 2000) showed that two Salsnes Filter fine mesh sieves in parallel (with mesh sizes of 300 μm and 350 μm) removed 59 % of the SS, 45 % of the COD and 36 % of the BOD_5. The primary sludge leaving the sieves had an average total solids (TS) concentration of 23 %.

Worldwide, most of the large biological wastewater treatment plants (WWTPs) have primary treatment. However, a lot of the smaller biological WWTPs are designed without primary treatment. This report will look at what effect primary treatment using Salsnes Filter fine mesh sieves will have on these smaller plants. One scenario will be for plants required to remove organic matter only, while the other scenario will be for plants that, in addition to removal of organic matter, also are required to nitrify.

The feasibility of using Salsnes Filter fine mesh sieves instead of conventional sedimentation for primary treatment at municipal wastewater treatment plants, has been presented in two previous reports (Rusten and Paulsrud, 2000 a, 2000 b).

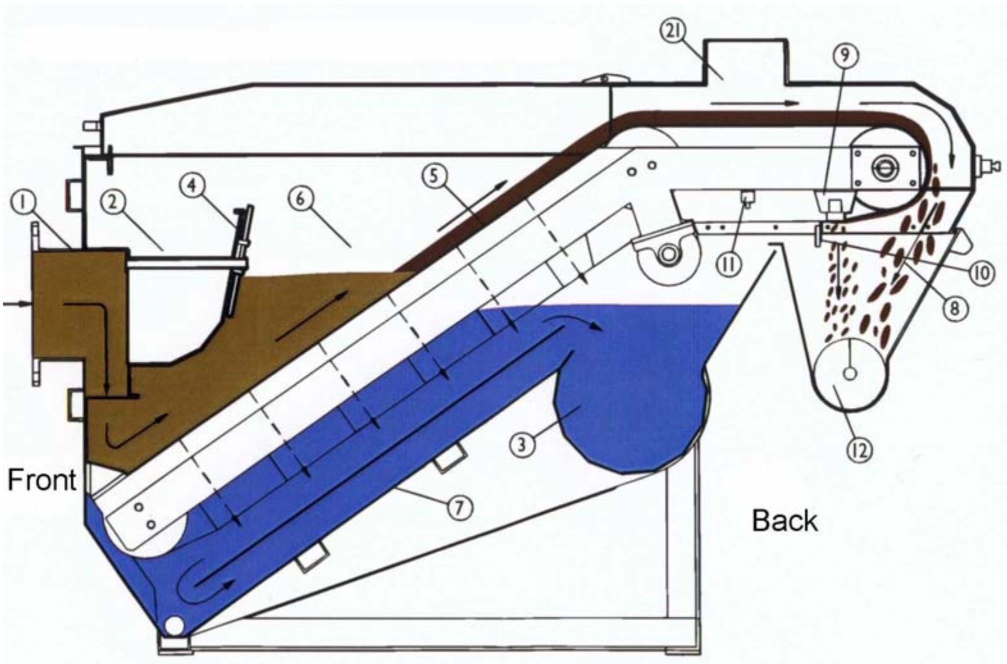
2. Description of the Salsnes Filter fine mesh sieves

The Salsnes Filter fine mesh sieves are compact units for mechanical separation of particulate materials from wastewater. Currently, models with capacities from 10 to 180 liters per second (36 to 648 m^3/h) and mesh sizes from 0.1 to 1.0 mm are available.

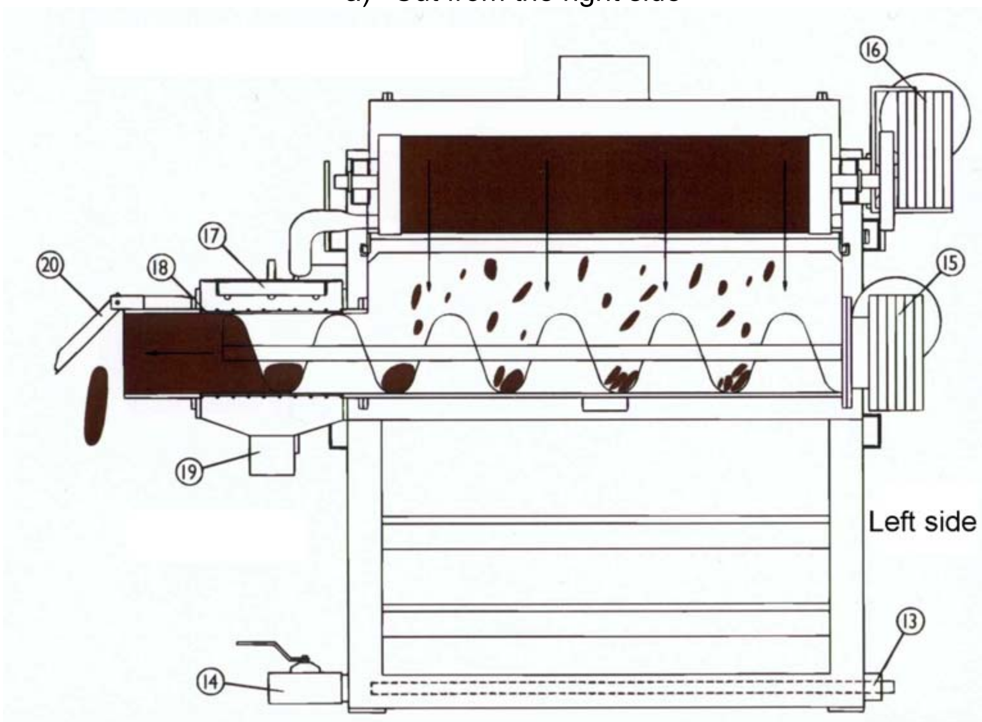
Sketches of a Salsnes Filter sieve unit are shown in Figures 1 a and b. The wastewater flows through the inlet tube (1), filters through an endless wire cloth and 40 to 80 % of the SS is removed. From the back of the wire cloth filtered water flows out through the outlet tube (3). The wire cloth rotates as the arrows show. The cloth transports the separated SS (sludge) to the air-cleaning device (9) where compressed air blows the sludge down into the sludge compartment (8). First stage of dewatering is done by gravity during transport to the screw compartment. The screw presses the sludge forward to a press cylinder (18) where further dewatering is done. The dry solids concentration of the sludge can be regulated by adjusting the tension on the spring-loaded lid (20).

The wire mesh cloth may be produced using different types of material, different thickness of the thread and different mesh sizes. For maintenance of the wire mesh cloth, it is flushed (11) with hot water twice a day (2 x 20 liters for the largest unit) to remove fat and grease.

A pressure transmitter (4) measures the level of incoming water and this information is used to vary the speed of the wire mesh cloth to achieve optimum performance at variable flow rates and variable influent SS concentrations. As long as the water level in the inlet chamber of the sieve is low, the wire mesh cloth is immobile. Eventually particles will accumulate on the cloth surface, the water level will increase and the pressure transmitter (4) will automatically start the motor (16) that moves the wire mesh cloth. If the water level keeps increasing while the cloth is moving, the speed will automatically increase. If the water level drops below a preset limit, the motor will stop until the level increases again.



a) Cut from the right side



b) Cut from behind

Figure 1. The Salsnes Filter fine mesh sieve.

Key:

1 Inlet	9 Air cleaning device	16 Gear/motor for wire cloth
2 Overflow	10 Rubber scraper	17 Hot water nozzles for cleaning press cylinder
3 Outlet	11 Hot water nozzles	18 Press cylinder
4 Level indicator	12 Screw	19 Reject from press cylinder
5 Wire cloth	13 Cold water pipe for settled waste removal	20 Spring-loaded lid
6 Wastewater	14 Drain valve for settled waste	21 Ventilation
7 Filtered water	15 Gear/motor for screw press	
8 Sludge compartment		

3. Design examples

Figure 2 shows simplified box diagrams of the four biological treatment processes that will be evaluated.

Process A is a conventional activated sludge system for removal of organic matter, with coarse screens and sand & grit trap, but no primary sedimentation. Process B is the same conventional activated sludge system for removal of organic matter, but with the addition of Salsnes Filter fine mesh sieves for primary treatment. Sand & grit traps are not necessary to achieve good removal efficiencies using the Salsnes Filter fine mesh sieves. However, they have been included because they are a standard feature of most WWTPs, and because they reduce the wear of the sieves and prolong the lifetime of the wire cloth. The primary sludge from the fine mesh sieves is dewatered to the desired solids content, up to a maximum concentration of approximately 25 % total solids (TS). Waste activated sludge (WAS) from the biological process will have a concentration of maximum 1 % TS.

Process C is basically the same as process A, but with a significantly larger activated sludge aeration tank to get a solids (or biomass) retention time (SRT) sufficiently long to achieve stable nitrification (oxidation of NH_4-N to NO_3-N) in addition to removal of organic matter. Likewise, process D is similar to process B, except for the larger activated sludge aeration tank necessary to achieve stable nitrification.

Comparison of the different processes will not include sludge handling and disposal. A multitude of different sludge handling techniques are available for small WWTPs, and the optimum solution will depend on the local situation and local rules and regulations. Processes A and C, without primary treatment, will produce approximately 15 % less sludge on a total solids mass basis than processes B and D. Prior to any further sludge treatment, however, the overall sludge volume will be significantly smaller for the processes with Salsnes Filter primary treatment (processes B and D), due to a primary sludge concentration of approximately 25 % TS. The volume of sludge from the processes with Salsnes Filter primary treatment will be approximately 50 % of the volume of sludge from the processes without primary treatment.

3.1. Wastewater flows and composition

The design example is done for a treatment plant with the following design flows:

- Average flow: Q_{avg} = 2760 m^3/d
- Design dry weather flow: Q_{design} = 160 m^3/h
- Design wet weather flow: Q_{max} = 230 m^3/h

This result in a ratio of 1.39 between the design dry weather flow and the average flow, and a ratio of 2.0 between the design wet weather flow and the average flow. These are normal ratios for a plant of this size.

Influent wastewater has the following composition:

SS = 250 mg/L
Total COD = 360 mg/L
Filtered COD = 100 mg/L
Total BOD_5 = 180 mg/L
Filtered BOD_5 = 60 mg/L
Total N = 33 mg/L
NH_4-N = 18 mg/L

The influent wastewater composition is assumed to be a typical medium concentration wastewater, based on data obtained by Aquateam from several plants in different parts of the world.

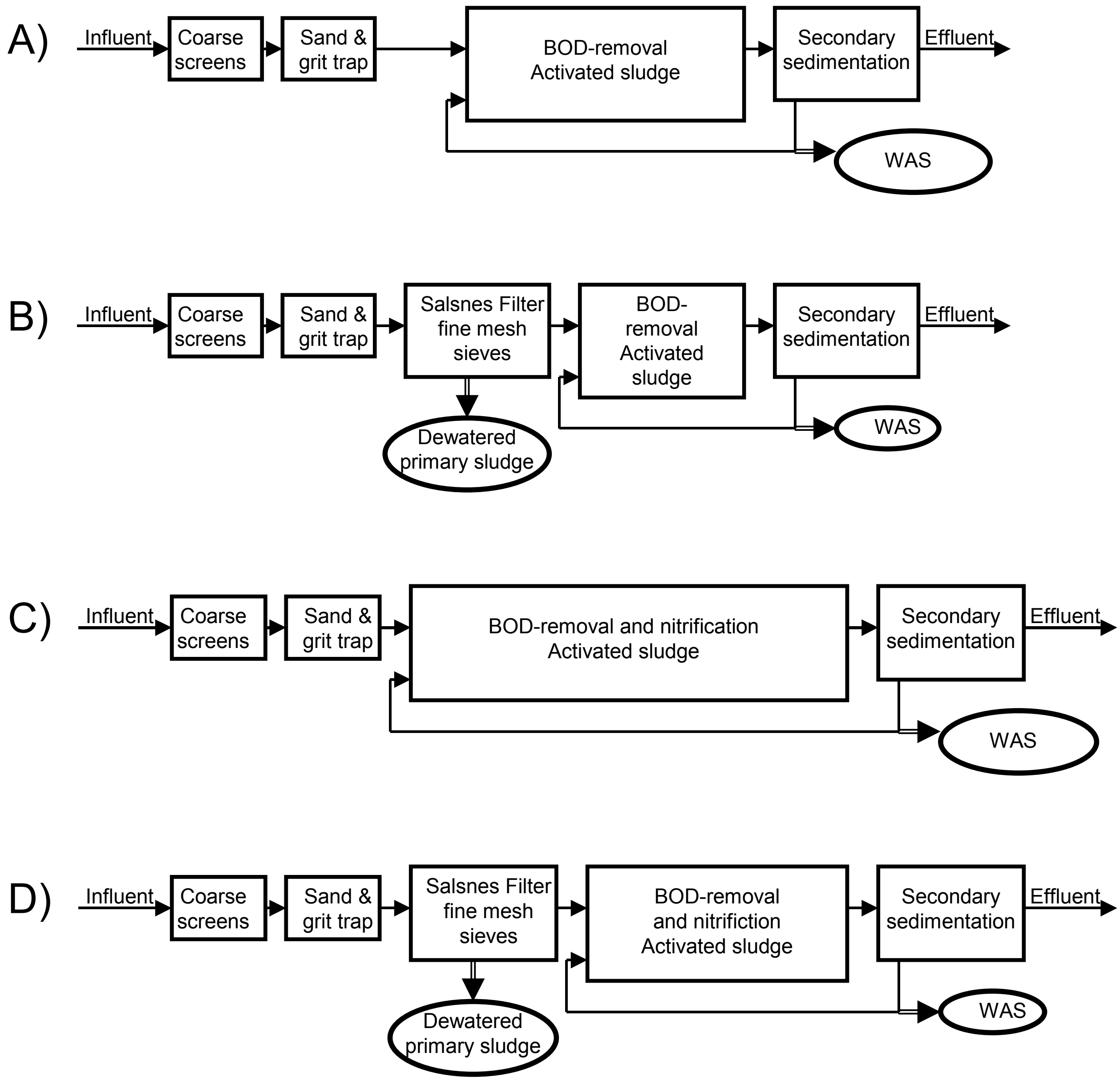


Figure 2. Simplified flow sheets for biological treatment plants. A: Activated sludge system for BOD-removal, without primary treatment. B: Activated sludge system for BOD-removal, with Salsnes Filter primary treatment. C: Activated sludge system for BOD-removal and nitrification, without primary treatment. D: Activated sludge system for BOD-removal and nitrification, with Salsnes Filter primary treatment.

3.2. Expected primary treatment performance

For primary treatment with Salsnes Filter fine mesh sieves, a filter cloth with a mesh size of 300 μm is chosen. For the given wastewater composition, the removal efficiencies shown in Table 1 are expected over the fine mesh sieves.

Table 1. Expected primary treatment performance, using Salsnes Filter fine mesh sieves with 300 μm mesh size.

Parameter	% removal
Suspended solids	60
Total COD	40
Total BOD_5	30
Total N	15

3.3. Design values

The design values used for the different processes are shown in Table 2. Only unit processes where the choice of primary treatment will influence either the size of the unit, or the operation cost of the unit, will be addressed. Coarse screens and sand traps, for example, will be the same in all alternatives and will therefore not be considered when comparing process alternatives.

Assuming the sludge settling characteristics for the activated sludge to be the same for processes A and B, the size of the secondary sedimentation tanks and the return activated sludge (RAS) flow rates will be identical for the two processes for BOD-removal. Even though it may be different than for processes A and B, the sludge settling characteristics for processes C and D are also assumed to be equal, resulting in identical secondary sedimentation tanks and RAS flow rates for the two processes for BOD removal plus nitrification. This means that the costs for secondary sedimentation and RAS pumping can be neglected when comparing process A to process B, and process C to process D.

Table 2. Design values used in examples.

Salsnes Filter, model 2000, 300 μm mesh size:	115 m^3/h capacity
Salsnes Filter, model 4000, 300 μm mesh size:	265 m^3/h capacity
Primary sludge dewatered in Salsnes Filter unit:	25 % TS
Activated sludge aeration tank design temperature:	12 °C
Activated sludge aeration tank MLSS concentration:	3000 mg/L
Activated sludge SRT for BOD-removal only:	5 days
Activated sludge SRT for BOD-removal + nitrification:	10 days
Activated sludge aeration tank water depth:	4.0 m
Activated sludge oxygen demand:	As per ATV guidelines (ATV, 1991)
Activated sludge aeration tank oxygen concentration:	2.0 mg O_2/L
Biological sludge production:	As per ATV guidelines (ATV, 1991)

Since sludge handling and disposal will not be included in this comparison of wastewater treatment processes, the size of the activated sludge aeration tanks and of the aeration systems and blowers, are the only elements that will be influenced by whether or not the plant has primary treatment.

3.4. Design of processes for BOD-removal

3.4.1. Process A

Key data for BOD-removal with an activated sludge system that does not have primary treatment, are shown in Table 3. The system is assumed to have two aeration basins in parallel, and the aeration basins are expected to cover an area of about 300 m^2.

Table 3. Key data for BOD-removal for a system without primary treatment.

Influent to biological stage:	250 mg SS/L 360 mg COD/L 180 mg BOD_5/L
Activated sludge aeration tanks:	2 x 539 m^3 volume, 303 m^2 area
Average oxygen demand:	18.7 kg O_2/h
Average secondary sludge (WAS) production:	619 kg TS/d

3.4.2. Process B

Key data for a system with Salsnes Filter primary treatment, followed by an activated sludge system for BOD-removal, are shown in Table 4. For primary treatment with Salsnes Filter fine mesh sieves, two units of the model 2000 will be needed to accommodate the peak hour flow. Alternatively, only one unit of the model 4000 can be used. Selecting only one unit will leave the plant without primary treatment when this unit is out of order. Scheduled maintenance stops, however, are short. The longest maintenance procedure is changing of the wire mesh cloth, which is expected to take about 4 hours once every 3 years.

Using two Salsnes Filter model 2000 units, primary wastewater treatment and primary sludge dewatering can be accomplished within an area of approximately 25 m^2. With this area, there is at least 0.6 m of free space outside the extremities of each machine on three sides, and 1.5 m of free space on the fourth side. Using one Salsnes Filter model 4000 unit, with the same free space around the machine, an area of approximately 15 m^2 will be needed. Area for sludge containers and sludge storage is not included for either alternative.

The biological treatment system is assumed to have two aeration basins in parallel, and the aeration basins are expected to cover an area of about 160 m^2.

Table 4. Key data for BOD-removal for a system with Salsnes Filter primary treatment.

Primary treatment equipment:	2 x Salsnes Filter model 2000, 25 m^2 shed or 1 x Salsnes Filter model 4000, 15 m^2 shed
Primary effluent quality:	100 mg SS/L 216 mg COD/L 126 mg BOD_5/L
Average primary sludge production:	414 kg TS/d
Primary sludge volume at 25 % TS:	1.66 m^3/d
Activated sludge aeration tanks:	2 x 274 m^3 volume, 161 m^2 area
Average oxygen demand:	12.9 kg O_2/h
Average secondary sludge (WAS) production:	301 kg TS/d

3.5. Design of processes for BOD-removal and nitrification

3.5.1. Process C

Key data for BOD-removal and nitrification with an activated sludge system that does not have primary treatment, are shown in Table 5. The system is assumed to have two aeration basins in parallel, and the aeration basins are expected to cover an area of about 550 m^2.

Table 5. Key data for BOD-removal and nitrification for a system without primary treatment.

Influent to biological stage:	250 mg SS/L 360 mg COD/L 180 mg BOD_5/L 33.0 mg N/L
Activated sludge aeration tanks:	2 x 1011 m^3 volume, 552 m^2 area
Average oxygen demand:	40.4 kg O_2/h
Average secondary sludge (WAS) production:	579 kg TS/d

3.5.2. Process D

Key data for a system with Salsnes Filter primary treatment, followed by an activated sludge system for BOD-removal and nitrification, are shown in Table 6. For primary treatment with Salsnes Filter fine mesh sieves, two units of the model 2000 or one unit of the model 4000, will be needed to accommodate the peak hour flow.

Primary wastewater treatment and primary sludge dewatering can be accomplished within an area of approximately 25 m^2, using two Salsnes Filter model 2000 units. With this area, there is at least 0.6 m of free space outside the extremities of each machine on three sides, and 1.5 m of free space on the fourth side. Using one Salsnes Filter model 4000 unit, with the same free space around the machine, an area of approximately 15 m^2 will be needed. Area for sludge containers and sludge storage is not included for either alternative.

Table 6. Key data for BOD-removal and nitrification for a system with Salsnes Filter primary treatment.

Primary treatment equipment:	2 x Salsnes Filter model 2000, 25 m^2 shed or 1 x Salsnes Filter model 4000, 15 m^2 shed
Primary effluent quality:	100 mg SS/L 216 mg COD/L 126 mg BOD_5/L 28.1 mg N/L
Average primary sludge production:	414 kg TS/d
Primary sludge volume at 25 % TS:	1.66 m^3/d
Activated sludge aeration tanks:	2 x 501 m^3 volume, 282 m^2 area
Average oxygen demand:	30.3 kg O_2/h
Average secondary sludge (WAS) production:	273 kg TS/d

The biological system is assumed to have two aeration basins in parallel, and the aeration basins are expected to cover an area of about 280 m^2.

4. Comparison of alternatives

4.1. Cost and area requirement

Cost figures for the Salsnes Filter fine mesh sieves are based on the year 2002 standard export price, plus 50 %. The additional 50 % is supposed to cover freight, other expenses and a normal profit margin for the local distributor. All other civil works, process equipment and operation cost figures are based on the cost level in the Norwegian market in year 2002.

The Salsnes Filter fine mesh sieves are placed inside a shed. Other than that, the treatment plant is supposed to be outdoors, with open basins.

An energy cost of NOK 0.40/kWh has been used. Maintenance cost for the Salsnes Filter fine mesh sieves is based on experience from plants operating in Norway, and includes all parts to be replaced every 3 to 4 years in a scheduled maintenance program. In this comparison the cost for spare parts for the Salsnes Filter fine mesh sieves has been set at 300 % of the cost in Norway, to make sure that all possible expenses associated with operating through a distributor in a foreign country are covered. For all other processes, annual maintenance cost is calculated as 1.5 % of the investment cost.

The cost for land has been set at zero. However, for a specific project where the cost of land is known, the difference in area requirements for the different alternatives can be used to enter this cost into the process evaluation.

Finally, all costs in our comparison exclude tax and engineering fees.

Table 7 compares the costs and area requirements for BOD-removal, according to process alternatives A and B shown in Figure 2, for plants with an average flow of 2760 m^3/d and a wastewater composition as described in paragraph 3.1.

Table 7. Comparison of plants for BOD-removal only. Comparing activated sludge aeration basins for process A, with Salsnes Filter primary treatment and activated sludge aeration basins for process B. Current exchange rate of NOK 7.30 per USD.

BOD-removal	Investment cost, 1000 NOK (%)*	Energy and maintenance cost, 1000 NOK/year	Area requirement, m^2
A: Activated sludge aeration basins	4327 (100)	110	303
B: Two (2) Salsnes Filter model 2000 + activated sludge aeration basins	3866 (89)	155	186
B: One (1) Salsnes Filter model 4000 + activated sludge aeration basins	3531 (82)	112	176

*) Relative investment cost shown as percent of cost for process alternative A.

For BOD-removal, the area requirement for Salsnes Filter primary treatment and activated sludge aeration tanks was about 60 % of the area requirement for activated sludge aeration tanks without primary treatment. Significantly lower investment costs were also seen by using Salsnes filter primary treatment, with savings of about NOK 460 000 for a process with two Salsnes Filter model 2000 sieves, and savings of about NOK 800 000 with one Salsnes Filter model 4000 sieve. Annual energy and maintenance costs were about the same for alternative B with one Salsnes Filter model 4000 sieve, and for alternative A without primary treatment. For alternative B with two Salsnes Filter model 2000 sieves, the annual energy and maintenance cost was NOK 45 000 higher than for alternative A. However, for a situation with 7 % APR financing and 15 years depreciation, the lower capital cost for alternative B with two Salsnes Filter model 2000 sieves will more than offset the higher energy and maintenance cost.

Table 8 compares the costs and area requirements for BOD-removal and nitrification, according to process alternatives C and D shown in Figure 2, for plants with an average flow of 2760 m^3/d and a wastewater composition as described in paragraph 3.1.

Table 8. Comparison of plants for BOD-removal and nitrification. Comparing activated sludge aeration basins for process C, with Salsnes Filter primary treatment and activated sludge aeration basins for process D. Current exchange rate of NOK 7.30 per USD.

BOD-removal + nitrification	Investment cost, 1000 NOK (%)*	Energy and maintenance cost, 1000 NOK/year	Area requirement, m^2
C: Activated sludge aeration basins	6955 (100)	204	552
D: Two (2) Salsnes Filter model 2000 + activated sludge aeration basins	5236 (75)	221	307
D: One (1) Salsnes Filter model 4000 + activated sludge aeration basins	4901 (70)	177	297

*) Relative investment cost shown as percent of cost for process alternative C.

For BOD-removal and nitrification, the area requirement for Salsnes Filter primary treatment and activated sludge aeration tanks was about 55 % of the area requirement for activated sludge aeration tanks without primary treatment. Significantly lower investment costs were also seen by using Salsnes filter primary treatment, with savings of more than NOK 1.7 million for a process with two Salsnes Filter model 2000 sieves, and savings of more than NOK 2.0 million with one Salsnes Filter model 4000 sieve. Annual energy and maintenance cost was NOK 27 000 lower for alternative D with one Salsnes Filter model 4000 sieve, than for alternative C without primary treatment. For alternative D with two Salsnes Filter model 2000 sieves, the annual energy and maintenance cost was NOK 17 000 higher than for alternative C. However, the lower capital cost for alternative D with two Salsnes Filter model 2000 sieves will more than offset the higher energy and maintenance cost. For a situation with 7 % APR financing and 15 years depreciation, looking at the annual capital cost plus the annual energy and maintenance cost, will result in savings of more than NOK 170 000 per year for process D with two Salsnes Filter model 2000 sieves, when compared to process C.

4.2. Discussion

It is important to note that the comparisons in paragraph 4.1 are for outdoor plants, with open basins. In Norway it is common to have treatment plants inside buildings and also have covered reactors. This will increase both the investment and operation costs, due to more civil works and the need for heating and ventilation. Costs are more or less proportional to the area requirement for the processes, and will significantly increase the advantage of using the Salsnes Filter fine mesh sieves.

The advantage of getting a dewatered primary sludge from the Salsnes Filter fine mesh sieves is not reflected in the cost and area requirement comparisons in Tables 7 and 8. For some potential applications, getting a dewatered primary sludge may be a significant benefit. However, if a primary sludge with a dry solids content of only 5-6 % is sufficient, the dewatering feature will not be necessary and the annual energy and maintenance cost for the sieves will be lower than shown in Tables 7 and 8.

The calculated data also indicate that introducing Salsnes Filter fine mesh sieve primary treatment may be a perfect upgrade to achieve full nitrification in an activated sludge system that currently removes BOD and has no primary treatment. The very compact Salsnes Filter primary treatment sieve(s) will remove so much SS and BOD that a sufficiently high SRT for complete nitrification will be achieved, without enlarging the volume of the existing aeration basins. However, the aeration system has to be upgraded to meet the added oxygen demand for the oxidation of ammonium to nitrate.

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