Evaluation and testing of fine mesh sieve technologies for primary treatment of municipal wastewater

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Abstract Fine mesh sieve technologies were tested in full scale at several municipal wastewater treatment plants. A screening test was used to characterize wastewater and establish the design criteria for the sieves. To achieve high removal efficiencies it was crucial to operate the sieves with a filter mat. Rotating belt sieves performed best in the full-scale tests. A small dose of cationic polymer and a static flocculator ahead of a rotating belt sieve achieved excellent results on a wastewater that was originally found unsuitable for primary treatment with fine mesh sieves. Simple screw presses dewatered the sludge from the sieves to typically 25–30% total solids. Using fine mesh sieves with <500 microns openings was found to normally be the most economical process for primary treatment.

Keywords Filter mat; fine mesh sieves; municipal wastewater; primary treatment

Introduction

Due to the European Union (EU) requirements for wastewater treatment, the Norwegian State Pollution Control Agency (SFT) took an initiative to evaluate and test several different technologies for primary treatment. This R&D program was carried out with contributions from the Norwegian University of Science and Technology (NTNU), the national R&D organizations SINTEF and NIVA, the consulting companies Asplan Viak, Rambøll Norge and Aquateam, the cities of Bergen and Tromsø, and the regional water and wastewater utility company IVAR (Ødegaard, 2005).

The goal was to find dependable and cost efficient technologies that fulfilled the stringent EU criteria for primary treatment. The primary treatment requirements are at least 20% removal of organic matter (measured as BOD₅) and 50% removal of suspended solids (SS). For treatment plants with 12 control samples per year at least 10 samples must fulfill the requirements. For treatment plants with 24 control samples per year at least 21 samples must fulfill the requirements. This is a lot stricter than looking at average removal efficiencies and the R&D program showed that an average SS-removal of about 65% was necessary for enough samples to pass the 50% removal requirement.

Several types of sieves, large septic tanks, clarifiers, dissolved air flotation (DAF) and deep bed filtration were initially evaluated. Of the technologies that were considered fully developed, clarifiers and different types of fine mesh sieves were found most suitable for primary treatment. These technologies were then tested in full scale at several treatment plants, for both primary treatment and chemically enhanced primary treatment.

Historically, primary treatment has been synonymous with sedimentation in clarifiers. The R&D program revealed, however, that most primary clarifiers are unable to achieve primary treatment according to the EU requirements. Surveying of data from five treatment plants showed that only one plant fulfilled the EU requirements for primary
treatment, and this plant had an average surface area overflow rate \( (v_f) \) of only 0.36 m/h (Misund et al., 2004).

Often the particle size distribution of the wastewater was such that required primary treatment removal efficiencies could not be achieved by sedimentation, regardless of how low the surface area overflow was. Therefore, chemically enhanced primary treatment (CEPT) will normally be necessary to achieve the required primary treatment removal efficiencies in primary clarifiers. This has been done for decades in Scandinavia, by dosing precipitation chemicals and polymers to the wastewater and using aerated sand and grit traps for flocculation. The goal has been to remove phosphorus, but removal efficiencies have also been very high for both BOD and SS (Ødegaard, 1992). The drawback when using CEPT is the cost of chemicals and the increased sludge production.

The R&D program also revealed the great need for a better understanding of how to design and operate fine mesh sieves in order to optimize primary treatment performance. This became the main focus of the R&D program and is the topic of this paper.

**Fine mesh sieves**

A number of fine mesh sieves are on the market and were tested in the R&D program. They include stationary sieves, rotating drum sieves, rotating disc sieves and rotating belt sieves. Full-scale tests were carried out at 9 treatment plants with predominantly municipal wastewater. Six of these plants used rotating belt sieves (from two different manufacturers), two plants used rotating disc sieves and one plant had both a stationary sieve and a rotating drum sieve. Mesh sizes ranged from 80 to 850 microns.

**Screening tests**

Characterization of the wastewater is very important in order to predict what removal efficiencies and hydraulic capacities that can be expected for a given sieve. A simple screening test apparatus and procedure (Rusten, 2004) was used in the R&D program. A sketch of the equipment and photos of a 350 microns sieve cloth prior to testing and after development of a filter mat are shown in Figure 1.

A batch of wastewater with sufficient volume to run tests with several different sieve cloths was placed in a large tank. To ensure a homogenous distribution of particulate material the batch would be vigorously stirred prior to taking wastewater out of the tank for analysis or to put through the test apparatus. Samples of the wastewater filtered through the sieve cloths were taken of the first litre of wastewater filtered, when the sieve cloth was clean. Then more wastewater was added until a build-up of particles on the sieve cloth had formed a filter mat. Tests with a filter mat simulated operation of a fine mesh sieve with a significant pressure drop over the sieve cloth and a low hydraulic load.

![Figure 1 Sketch of screening test apparatus and photos of clean sieve cloth and sieve cloth with filter mat](https://iwaponline.com/wst/article-pdf/54/10/31/431033/31.pdf)
The transparent PVC tube of the apparatus had marks at 200 mm and 300 mm above the surface of the sieve cloth. After the first litre was filtered through the sieve cloth, the valve at the bottom of the apparatus was closed and more wastewater was added. Then the valve was partially opened, allowing the water level in the PVC tube to drop at a rate of 3 to 4 cm/s. When a proper filter mat had formed on the sieve cloth, the valve was opened all the way and filtered wastewater was collected while the water level dropped from the 300 mm mark to the 200 mm mark. The time it took for the water level to drop from 300 mm to 200 mm was also recorded. For most test runs this procedure was done repeatedly after more wastewater had been added and a thicker filter mat had developed, resulting in a longer period of time for the water level to drop from the 300 mm to the 200 mm mark.

All water samples were analysed for total COD (TCOD), filtered COD (FCOD) and SS. Dr. Lange technology (Dr. Lange, 2000) was used for COD analysis. Glass fibre filters (Whatman GF/C) were used for filtration and to measure SS.

**Screening test results**

The screening tests showed that required primary treatment removal efficiencies could be achieved with all tested wastewaters (from 11 different treatment plants), if the proper mesh size was used and a sufficiently thick filter mat was allowed to develop. However, use of sieves would not always be economical due to the low hydraulic loads necessary to achieve sufficiently high removal efficiencies with some of the wastewaters. Sieves that could not be operated with a significant filter mat would likely fail to meet primary treatment requirements, even with mesh sizes in the 50 to 100 microns range. To be considered suitable for primary treatment with fine mesh sieves the screening tests indicated that at least 20% of the SS in the wastewater should consist of particles larger than 350 microns and the ratio between FCOD and TCOD should be <0.4. Once a filter mat was formed on the sieves, there were practically no differences in the performances of sieve cloths with different mesh sizes, with regard to both % SS removal and filtration rate. This will normally favour the use of larger mesh sizes, like the 350 microns sieve cloth. However, if the wastewater has a very small amount of larger particles there may not be enough particles present to form a filter mat, and a smaller mesh size would be recommended to initiate the formation of the necessary filter mat.

Examples of screening test results are shown in Figure 2. As mentioned above, the mesh sizes of the sieve cloths had very little influence on the results, within the ranges tested. With a given wastewater the removal of SS was mainly a function of the hydraulic flow through the sieve cloth, referred to as sieve rate, which again was a function of the development of a filter mat on the sieve. At a low sieve rate of only 20 m³ per m²
submerged sieve cloth area per hour (m³/m²/h), more than 70% removal of SS was achieved with wastewater from the Nordre Follo wastewater treatment plant (WWTP). When the sieve rate was increased to 100 m³/m²/h, the removal efficiencies dropped to about 60%. The example from the Tiendeholmen WWTP shows a concentrated wastewater that was very well suited for fine mesh sieve treatment. Even at a sieve rate of 224 m³/m²/h, the removal of SS was 69% with a 350 microns sieve cloth.

**Full-scale primary treatment results**

Very good agreement was found between screening tests and full-scale tests. An example of this is shown in Figure 2 where the full-scale result for the Tiendeholmen WWTP is shown together with the screening test results. Figure 3 shows a photo of the rotating belt sieves at the Tiendeholmen WWTP. Full-scale testing demonstrated the importance of gentle handling of the particles to prevent them from breaking and then going through the sieve openings. It also verified the need for a filter mat. Only rotating belt sieves had the ability to control filter mat development in our tests.

Of all the sieves tested on predominantly municipal wastewater only rotating belt sieves fulfilled the EU primary treatment requirements. The Salsnes Filter rotating belt sieves performed extremely well at the Breivika WWTP in Tromsø (Berg, 2004). The results, summarized in Figure 4, show that every single sample fulfilled the EU primary treatment requirements. Average influent concentrations for 19 samples were 331 mg SS/L and 176 mg BOD₅/L, while average effluent concentrations were 34 mg SS/L and 36 mg BOD₅/L. This corresponds to average removal efficiencies of 90% for SS and 80% for BOD₅. The excellent results can be explained by operating the sieves with a very thick filter mat (Figure 5) and at a sieve rate of only 25 m³/m²/h.

At higher sieve rates the removal efficiencies will normally be lower. An example of good performance at a high sieve rate is the Guldholmstranda WWTP, where short term tests showed 78% removal of SS at 116 m³/m²/h on a Salsnes Filter SF 2,000 rotating belt sieve using a mesh size of 350 microns. For wastewater with a favourable particle composition very high sieve rates may be used. In cases where high removal efficiencies are not important and sieves can be operated without a filter mat, hydraulic capacities will depend on wastewater composition and sieve cloth properties and may be as high as 300 m³/m²/h.

A general observation from the full-scale plants was that the highest possible removal efficiencies were achieved if the plants were operated in such a way that they treated the least amount of water over the longest possible time. This means that fine mesh sieves

![Image](https://iwaponline.com/wst/article-pdf/54/10/31/431033/31.pdf)
with pumped influent should have frequency controlled pumps to avoid on/off operation. At plants with several sieves in parallel, all sieves should be running even at low water flows. This will enable operation with thick filter mats and high removal efficiencies.

**Chemically enhanced primary treatment**

Screening tests and full-scale tests at the Bangsund WWTP showed the wastewater to be unfavourable for primary treatment with conventional fine mesh sieves. Initial full-scale tests, with two rotating belt sieves in series and coagulant/flocculant addition and flocculation between the two sieves, showed that prior removal of particles smaller than 850 microns had a detrimental effect on the flocculation. Use of cationic polymer alone worked better than different combinations of metal salts and polymer, and the best results were obtained when the wastewater bypassed the first sieve. However, excellent results were achieved with a mesh size of 850 microns on the first sieve, addition of about 1 mg/L of a cationic polymer (Pemcat 163, medium charge density, high molecular weight), flocculation in a static flocculator and solids separation on a rotating belt sieve (Salsnes Filter SF 4,000 Fnokk) with a mesh size of 250 microns (Rusten and Lundar, 2004). Results achieved with a small dose of cationic polymer easily fulfilled the EU criteria for primary treatment and they are shown in Figure 6. For 5 of the 23 data points in Figure 6 the first sieve was bypassed. Average SS-removal was 66% at an average sieve rate of 25 m³/m²h.

Tests on a Sobye rotating belt sieve in Bergen, using ferric or aluminium coagulants, were unsuccessful and the performance was worse than without chemicals. Part of the reason for this is that chemical precipitation with metal salts produces more SS and if
this extra SS is not removed on the sieve cloth negative removal efficiencies may be observed. Neither with, nor without chemicals were the EU primary treatment criteria fulfilled. It was also observed that the cleaning of the belt on the Sobye unit was inadequate (Vogelsang, 2004).

Sludge dewatering

All the different sieves had simple screw presses for sludge dewatering, either integrated or as separate units. Dewatered primary sludge had total solids (TS) concentrations from 17 to 37%, with an average of 27%. There was no significant difference between the different types of sieves or between plants with or without chemically enhanced primary treatment. The volatile solids fraction was very high in all the sludge samples and averaged 90% (Paulsrud, 2005).

Operational experiences

Drum filters and disc filters failed to achieve EU primary treatment at all locations, even with sieve openings as small as 80 microns, probably due to lack of filter mats.

Rotating belt sieves from Sobye did not achieve EU primary treatment at the two locations tested (Akervold, 2004; Berg, 2004; Vogelsang, 2004), primarily because of no filter mat establishment due to high belt speeds. At the test site in Bergen the Sobye sieve experienced some mechanical problems with a warped and torn filter belt. Inadequate belt cleaning was also observed and this was believed to be due to the absence of hot water rinse and/or air-knife cleaning of the belt (Vogelsang, 2004).

The Salsnes Filter rotating belt sieves easily fulfilled the EU primary treatment requirements when treating predominantly municipal wastewater. These sieves have variable belt speed from zero and up, which made it easy to operate the sieves with a controlled filter mat. The Salsnes Filter rotating belt sieves also have patented air-knife cleaning of the belt, and tracks to keep the belt properly positioned at all times.

Cost comparison

A cost comparison of primary treatment, including sludge dewatering, was carried out for rotating belt sieves and clarifiers. The cost comparison was for a dry weather flow of 200 m$^3$/h and an influent concentration of 250 mg SS/L. The maximum wet weather flow was 400 m$^3$/h. The clarifier overflow rate was 1.2 m/h at dry weather flow and 2.4 m/h at maximum flow, as per Norwegian design guidelines (SFT, 1983). The sieve rate was 100 m$^3$/m$^2$/h at dry weather flow and 200 m$^3$/m$^2$/h at maximum flow. The cost of land
was set at zero and the clarifiers were not covered. A 7% annual interest rate and 15 years depreciation was used to calculate annual capital costs.

For the above conditions, savings will be substantial when using rotating belt sieves for primary treatment. Both investment costs and total annual costs (annual capital costs plus operation and maintenance costs) for the rotating belt sieves were about 50% of the costs for the primary clarifiers.

Conclusions

Clarifiers will normally not achieve the required EU removal efficiencies for primary treatment, unless they are converted to direct precipitation plants by adding chemicals.

Rotating belt sieves will achieve the required EU removal efficiencies for primary treatment if they are properly built and equipped, properly designed, and operated with a filter mat.

Design sieve rates should be established by screening tests as described in this paper and will range from 20 m³/m²/h to about 300 m³/m²/h, depending on wastewater characteristics and required removal efficiencies. To meet the EU primary treatment requirements sieve rates will normally be below 200 m³/m²/h.

A sieve opening in the range of 250–500 microns will normally be the proper choice for typical municipal wastewater, but this should be determined after screening tests. Once a filter mat is formed on the sieve, there is practically no difference in the performance of sieve cloths within this size range, with regard to both % SS removal and filtration rate.

To be considered suitable for primary treatment with fine mesh sieves the screening tests indicated that at least 20% of the SS in the wastewater should consist of particles larger than 350 microns. However, cationic polymer in combination with rotating belt sieves has successfully treated wastewater that was originally classified as unfavourable for fine mesh sieves.

Fine mesh sieves with screw presses can typically dewater primary sludge to about 25–30% total solids.

For successful design, installation and operation of primary treatment plants the R&D program confirmed that it is crucial that consultants, vendors and operators have a good knowledge base and a complete understanding of the processes involved.

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References


