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# MICROSCREENING FOR STORMWATER TREATMENT

## Mikrosilning för rening av bräddvatten

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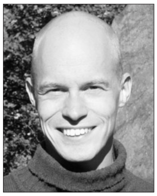



## Abstract

A competitive system for stormwater treatment should provide efficient particle removal, small footprint, rapid start-up, robustness, cost effectiveness and flexibility. Chemical pre-treatment followed by microscreening could fulfil these requirements. Thus the potential in such a system was investigated within the framework of a project involving Kemira Kemi AB, Hydrotech AB and the Department of Water and Environmental Engineering at Lund Institute of Technology. Results from treatment of raw wastewater indicated that suspended solids as well as total phosphorous could be reduced with more than 90 %. The article summarises the first phase of the project, whereas the next phase will focus in long-term effects and the response to the dynamics of real stormwater situations.

*Key words* – stormwater treatment, micro screening, chemical pre-treatment, disc filtration, drum filtration.

## Sammanfattning

Ett konkurrenskraftigt system för bräddvattenbehandling bör medge effektiv partikelavskiljning, litet platsutrymme, snabb uppstart, robust konstruktion, kostnadseffektivitet och flexibilitet. Kemisk förbehandling följt av mikrosilning kan uppfylla dessa krav, varför potentialen i ett sådant system undersökts inom ramen för ett samarbetsprojekt mellan Kemira Kemi AB, Hydrotech AB och avdelningen för VA-teknik vid Lunds Tekniska Högskola. Resultat från behandling av inkommande avloppsvatten visade att såväl totalfosfor som SS kunde reduceras med över 90 %. Artikeln sammanfattar projektets första fas. I nästa fas kommer långtidseffekter och systemets funktion vid verkliga bräddningar att studeras.

## Stormwater treatment

Successful management of stormwater is one of the key elements in reaching future effluent requirements. With large overflow quantities, effective stormwater treatment can result in considerable reductions of total discharge amounts of for example SS, BOD and $P_{tot}$. At some Swedish treatment plants as much as 10 % of incoming flow volumes has been reported as causing overflow due to stormwater events (Hernebring *et al* 2000).

An optimal system for stormwater treatment should fulfil a number of requirements and thus provide:

- Effective particle removal
- Small foot print
- Rapid start-up
- Robustness
- Cost effectiveness
- Flexibility

*Efficient particle removal* is fundamental in order to ensure sufficient removal of SS and thereby particulate fractions of BOD, phosphorous and nitrogen. Associated with efficient particle removal is the possibility to use coagulants and flocculants, i.e. compatibility with chemical pre-treatment, which is absolutely necessary in order to ensure comprehensive phosphorous removal. Low particle content is furthermore a prerequisite for efficient disinfection of wastewater besides the fact that effective particle removal as such reduces the discharge of pathogens. Space is often limited and a *small footprint* is therefore necessary when upgrading wastewater treatment plants. *Rapid start-up* could be crucial depending upon capabilities for storing of stormwater. *Robustness* is obviously important for a treatment system designed for relatively few, but intense, operating hours per year. Last but not least the system should provide c*ost effectiveness* and *flexibility*. Flexibility in terms of providing other treatment options, such as enhanced primary treatment during dry weather conditions, could be a considerable advantage.

## The project

The Hydrotech microscreens, i.e. the drumfilter and the discfilter, fulfil the listed requirements and the technology should consequently be suitable for stormwater applications. The critical question is how the filters can be successfully combined with chemical pre-treatment. This study was initiated in order to explore the potential of micro screening in combination with chemical pre-treatment of raw or primary treated wastewater. The first phase deals with dry weather wastewater for practical reasons but also on the assumption that important conclusions could be drawn for stormwater situations with or without overflow. Later phases of the project will also involve real stormwater situations. This general approach will provide flexibility in terms of treatment options.

The project is a cooperation between Kemira Kemi AB, Hydrotech AB and the Department of Water and Environmental Engineering at Lund Institute of Technology. Particle separation in a wastewater treatment is a well-established research interest at Lund Institute of Technology. Kemira Kemi AB provides products, expertise and know-how on issues related to chemical treatment of water and wastewater thus being an ideal partner in the development of a concept for stormwater treatment. The following article presents quantitative results and qualitative aspects from the first phase of the project, which was formed to create a framework for further development of the technology.

## Flocs and micro screening

The main separation mechanism in microscreening is straining, i.e. mechanical blocking of particles and flocs larger than the pore openings of the screen. In a granular media filtration process, for example rapid sand filtration, filter depth plays an important role. Adhesion mechanisms are crucial to the separation function, where attachment of particles to the media or to previously retained particles is strongly associated with surface-chemistry properties. The pore size in a micro screen, although well-defined for a clean filter cloth, is also variable, since retained particles will decrease the actual pore size during the filtration cycle. Depth filtration is however by definition not possible, thus resulting in somewhat different separation characteristics.

*Size* and *strength* are key floc properties, since flocs obviously should be larger than the applied pore size and strong enough to resist erosion or break-up during filtration. Flocs formed by the addition of metal salts are normally too weak to withstand the shear forces exerted in a discfilter or drumfilter (Särner 1976), a fact that was also noted in this study. Floc strength can however be significantly increased by the addition of polymers. A filter installation should consequently be designed in order to minimise inevitable shear stress in pumps, pipes and in the filter itself. Furthermore, flocs should easily be detached during back washing.

There are two main types of microscreens applicable for water and wastewater treatment; the discfilter and the drumfilter (Figure 1). The discfilter is successfully used worldwide for effluent polishing of water with relatively low solids concentration, for example after secondary settling preceded by activated sludge or after trickling filters (Bourgeous *et al* 2003, Grabbe *et al* 1998 and Persson *et al* 2005). The drumfilter is frequently used in different industrial applications and for water treatment. There are a few installations where the Hydrotech drum filter is used for primary treatment of wastewater, i.e. replacing a primary settler. Just recently a combination of drum filtration and disc filtration for stormwater treatment was installed in Copenhagen, Denmark. None of these installations utilise chemical pre-treatment. An extensive investigation of microscreening of raw wastewater was carried out by Särner (1976) concluding that disc filters could replace primary settling but that the technology suffered from certain limitations related to, for example, lack of effective back-washing. Technology has improved over the years and with the Hydrotech microscreens several construction details have been improved. Fig 1 shows the Hydrotech filters. Water flows by gravity into the drum (drumfilter) or into the filter segments from a center drum (discfilter). Particles are separated by the filter cloth. At a pre-set head loss back-washing is started and solids are back-washed into the collection trough. The filter construction is robust and provides easy maintenance. Fundamental to the stormwater concept is a small footprint. The largest disc filter with 20 dics provides 112 $m^2$ of filter area at 14 $m^2$, while the largest drumfilter provides 21.6 $m^2$ of filter area at 14.8 $m^2$.

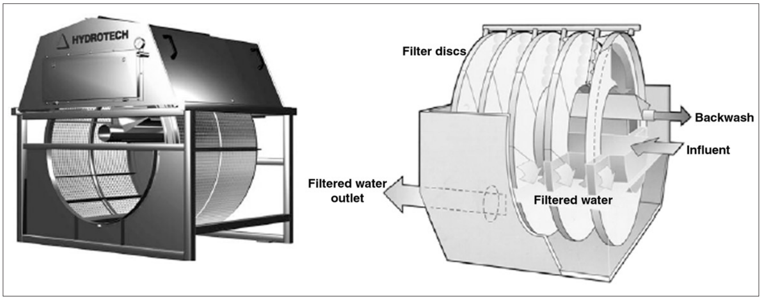


Figure 1. *The Hydrotech drumfilter (left) and the disc filter principle (right).*

## Methodology and the pilot plant set-up

The pilot plants (Disc filter HSF 1702 & Drum filter HDF 801), corresponding to the smallest available full-scale filters, were placed at Sjölunda wastewater treatment plant in Malmö, Sweden. Screens (3 mm), aerated grit chambers, pre-aeration and dosing of precipitation chemicals precede the primary settling unit. Following primary treatment is a high-rate activated sludge process, nitrifying trickling filters and post-denitrifying moving bed reactors with subsequent floc separation in a dissolved air flotation plant. Storm overflow is at present bypassed from the primary settlers or upstream in the system. The technology was tested both after primary settling as well as on raw wastewater (just after the grit chambers). Testing was normally conducted during dry-weather conditions. System performance in stormwater situations remains to be tested but it should be noted that sampling was performed with great variations in incoming suspended solids concentration.

A pilot plant was arranged according to Figure 2. The coagulant was added to the inlet pipe in order to ensure rapid and thorough mixing. Each mixing tank (0.8 $m^3$*2) was equipped with a mixer. Water was directed from the first tank to the second and into the filter by gravity. The polymer was added at the inlet to the second tank where an additional mixer was placed. The detention time was normally kept at four minutes in each tank in order to ensure good flocculation. However, preliminary tests indicated that the detention times could be lowered. Spot samples were taken from the inlet and the outlet pipe respectively. Samples were analysed immediately.

## Drum and disc filtration without chemical pre-treatment

Coagulants and/or flocculants are essential to accomplish extended particle removal as well as phosphorous removal. Filtration without addition of chemicals could however be of great interest (not only as reference), since the capacity and the removal efficiency of the existing primary treatment could be increased in dry weather situations, thus increasing flexibility at the plant. Figure 3 illustrates some examples of influent and effluent SS concentrations for drum and disc filtration with different pore sizes.

Clearly, both drum and disc filtration with pore openings between 20–60 microns provide high removal rates, in the range from 50–80 %, which is comparable to or higher than conventional primary settling units without pre-precipitation or addition of flocculation aids. The best results were achieved with the 20-micron disc filter.

Disc filtration of primary treated wastewater resulted in considerably lower reduction rates, which is perfectly

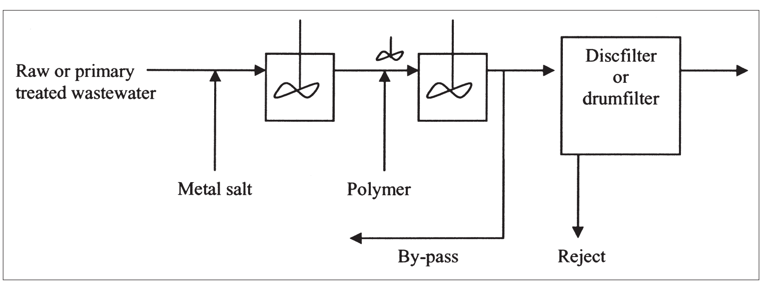


Figure 2. *The pilot plant set-up.* Influent samples were collected just before the metal salt addition and effluent samples at the very end of the plant, i.e. the outlet pipe.

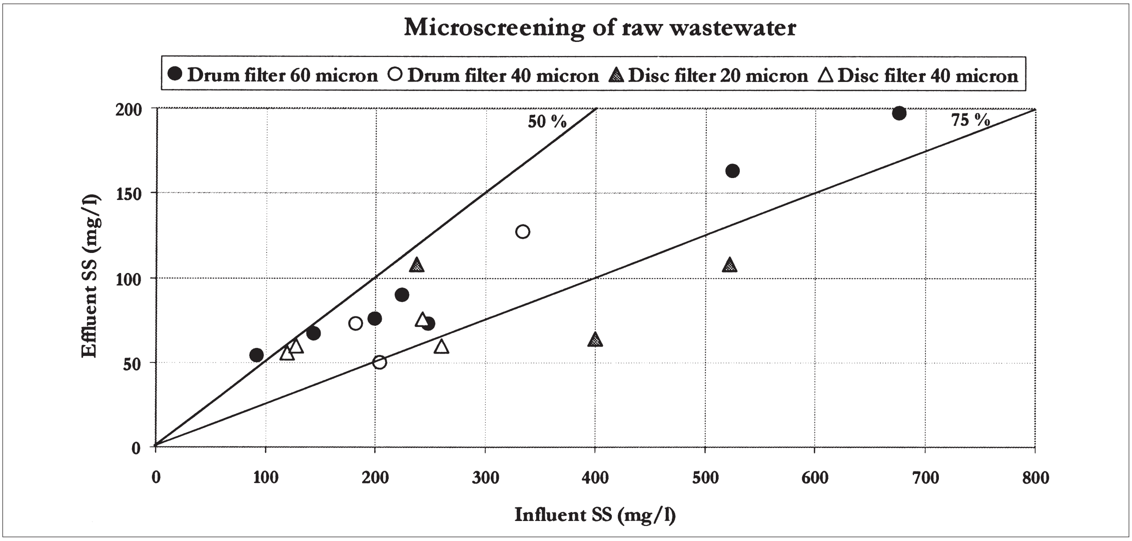


Figure 3. *Influent and effluent concentrations of SS for different filter types and pore openings.* The straight lines correspond to 50 and 75 % SS-reduction respectively.

logical since comparatively large particles are removed in the primary settlers. 20-micron filter opening resulted in 14–36 % SS-reduction ($SS_{in}$: 73–210 mg/l). Filtration with 40 and 60 micron resulted in none or very limited reduction.

Hydraulic capacity (flow divided by filter area) varies with incoming suspended solids content. Maximum hydraulic capacities were estimated (not measured) due to limitations in pumping capacity. Thus the following estimated maximum capacities should be considered as crude approximations. However, for raw wastewater, the capacity for the 20-micron disc filter was somewhat below 5 m/h (measured, not extrapolated), whereas the capacity for the 40-micron disc filter was up to 25 m/h. The drum filter capacity was noticeably higher; at $SS_{in}$ 200–300 mg/l approximately 30–50 m/h for the 40-micron filter and even higher for the 60-micron filter.

## Drum filtration with flocculant addition

Removal of suspended solids could be facilitated by the addition of cationic polymer. Fennopol K5060, characterised by high molecular weight and high charge density, was selected for this purpose. Figure 4 illustrates the effluent SS as well as the estimated hydraulic capacity at different polymer doses on raw wastewater.

Hydraulic capacity is clearly facilitated by increased polymer dosing. Relatively fewer and larger flocs, if strong enough, seem to favour flow through the filter panels. The effluent SS-concentration is approaching a concentration below 20 mg/l corresponding to a reduction of more than 90 %, whereas phosphorous removal obviously requires dosing of a coagulant. However, the optimum polymer dose is not only a function of required effluent SS-concentration and needed capacity. Flocs should not be too sticky, i.e. they should detach from the filter panel during back-washing.

## Drum and disc filtration with coagulant and flocculant addition

Initially jar tests were performed in order to select suitable chemicals. Various criteria, like rapid floc growth, resistance to shear stress and efficient floc formation in a broad pH-spectrum, were set up in the selection process for an appropriate metal salt. PAX XL-60 (and PAX XL-1) was chosen for the pilot tests. Furthermore the anionic polymer, Fennopol A 392, with a high molecular weight and a high charge density, was chosen to promote flocculation and form strong flocs. (Larsson 2004).

Initially disc filtration (20 micron) was tested on primary, treated wastewater. Difficulties were experienced in achieving good coagulation/flocculation and high quality filtration. Possible explanations could be the addition of ferrous sulphate in the pre-aeration basins, the return of reject from sludge dewatering or the primary settlers removing particles that otherwise could work as nuclei for floc growth. After adjustments of dosing points, doses, stirring devices and detention times separable flocs could be created at most occasions. However, in a stormwater situation, conditions like settling time etc. are obviously different.

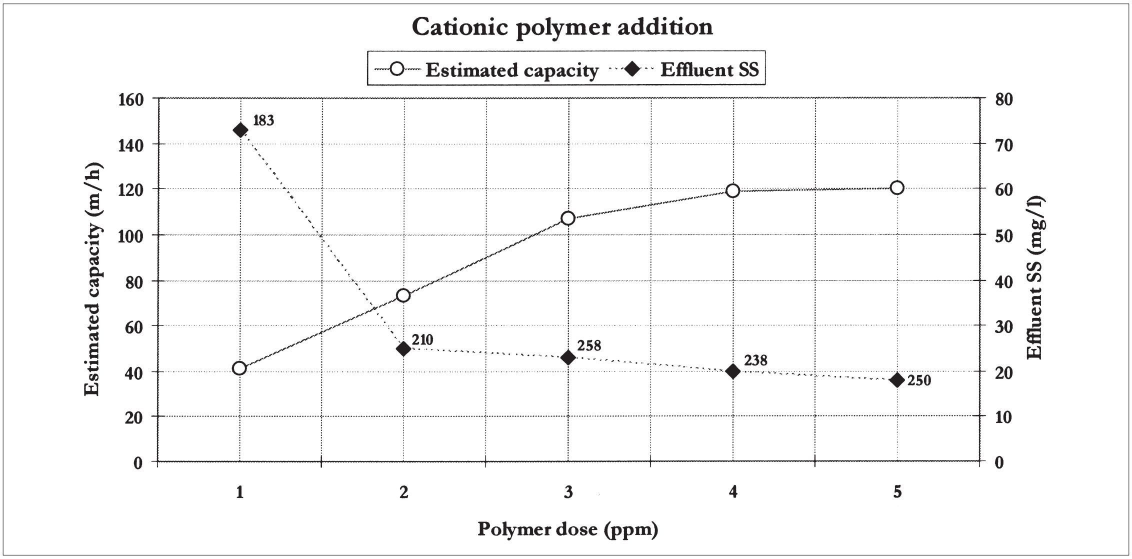


Figure 4. *Hydraulic capacity and effluent SS as a function of polymer dosing.* The numbers marked at each effluent value correspond to influent concentration.

Table 1 shows data from a test-day with relatively low SS-content in the incoming water.

From this and other data it was found that the filter is sensitive to overdosing of the coagulant as far as hydraulic capacity is concerned. Furthermore, increased polymer dosing provided both reduction of effluent SS and increased hydraulic capacity. Tests on COD and $P_{tot}$ resulted in removal rates of approximately 50 and 80 % respectively.

In order to increase the hydraulic capacity 40-micron filter panels were tested. With comparable doses acceptable filtration results could not be achieved. Flocs and re-formation of flocs could be observed in the effluent, which visually indicated system failure. At this stage background levels of alum were analysed. With the 20-micron filter the alum concentration was the same in the influent and the effluent. With corresponding doses and the 40-micron filter the level increased, possibly indicating floc break-up. In order to overcome the problem low alum doses in combination with very high polymer doses (2.5–3.75 ppm) were tested. Comparable reduction rates (SS ~ 75 %, P ~ 85 %) could now be achieved. Eventually PIX 111, based on ferric chloride, was tested. The results were comparable with PAX XL-60 but hydraulic capacity seemed to increase somewhat. This product was selected for the tests on raw wastewater.

Figure 5 illustrates results from microscreening of raw wastewater. The PIX doses were in the range of 0.07–0.13 ml PIX/l and the polymer doses between 1 and 3 ppm, where larger pore openings required higher doses.

Pre-treatment of raw wastewater turned out to be easier and more straightforward. Remarkably good results were achieved, possibly explained by the elimination of the preceding pre-precipitation and other possible sources of disturbance (addition of reject water, cleansing water etc.) SS-reduction of more than 90 % was possible even with filtration at 60 micron. Reduction of phosphorous was over 90 %.

Table 1. *Influent and effluent concentrations of SS as well as hydraulic capacity at different combinations of doses.*

| | 0.5 ppm | | 1.0 ppm | | 1.5 ppm | |
|---|---|---|---|---|---|---|
| | $SS_{in}/SS_{ut}$ (mg/l) | Q (m/h) | $SS_{in}/SS_{ut}$ (mg/l) | Q (m/h) | $SS_{in}/SS_{ut}$ (mg/l) | Q (m/h) |
| 0.10 ml PAX/l | 74/22 | 2.9 | 70/24 | 2.9 | 82/18 | 4.3 |
| 0.20 ml PAX/l | 78/30 | 1.1 | 78/22 | 1.8 | 70/16 | 3.6 |
| 0.30 ml PAX/l | 84/32 | 1.1 | 78/32 | 1.1 | 74/22 | 1.4 |

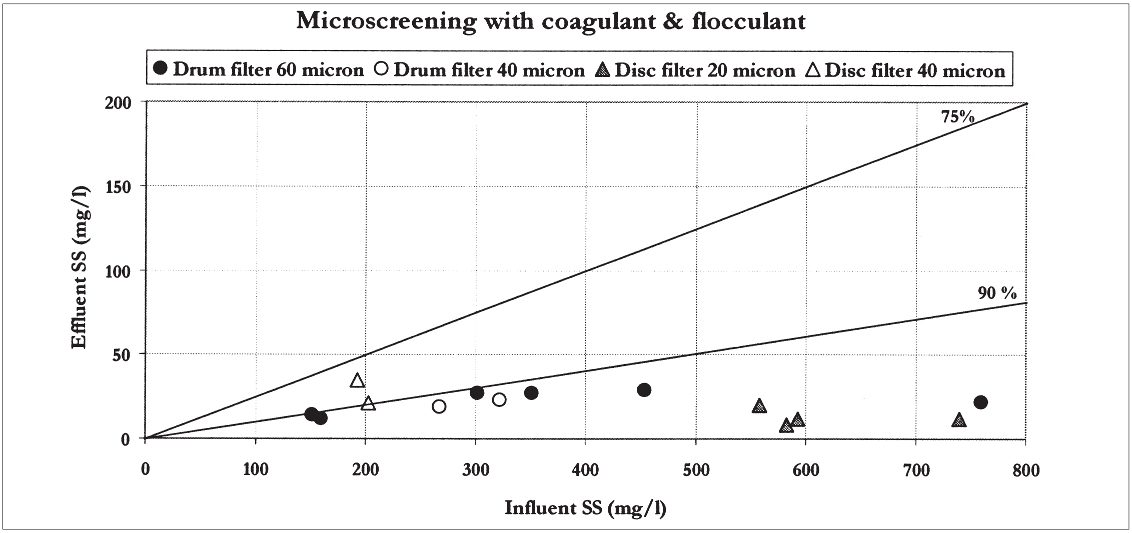


Figure 5. *Influent and effluent concentrations of SS for different filter types and pore openings.* The straight lines correspond to 75 and 90 % SS-reduction respectively.

In terms of hydraulic capacity disc filtration with 20 and 40 micron resulted in 4 and 10 m/h respectively (measured), whereas drum filtration at 40 and 60 micron resulted in capacities between approximately 20–40 m/h. Again, drum filtration resulted in relatively higher hydraulic capacities. The reason is probably that the patented Hydrotech low shear screen configuration facilitates the floc separation.

## Concluding remarks and the future

Disc and drum filtration with chemical pre-treatment show a great potential for treatment of raw (or primary treated) wastewater. One could also expect a great potential for stormwater treatment as such situations basically are characterized by diluted dry weather wastewater. Maintenance is easy, the units are compact and start-up is rapid (minutes). Long-term testing, both in continuous mode and with the system subjected to the dynamics in real stormwater situations, is important in order to further evaluate the technology. The effect on the filter panels will be further studied in order to investigate the effect of the polymer and the wastewater. Filtration capacity will thus be monitored in order to evaluate possible fouling of the filter plates. Such a long-term test is initiated and planned for start-up in the near future. Automatic on-line dosing will be applied in order to minimise chemical consumption and optimise coagulation and flocculation.

More info on the project partners can be found at www.hydrotech.se, www.kemira.com and www.vateknik.lth.se


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