VATTEN 62:171–177. Lund 2006

MICRO SCREENING IN WASTEWATER TREATMENT – AN OVERVIEW

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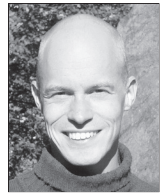

Abstract

Microscreens, or microstrainers, are widely used within wastewater treatment, and applications include primary and tertiary treatment as well as treatment of stormwater. The following paper is an attempt to present an overview of literature in order to identify possibilities and key questions associated with two types of microscreens based on gravity flow – disc- and drumfilters. Generally there is a good foundation based on practical experience, especially for tertiary treatment. The particle size distribution and floc strength are identified as crucial parameters in understanding and design of microscreens. Difficulties in applying chemical pre-treatment and clogging of filter media are described as drawbacks but also as key questions for further development of the technology.

Key words – micro screening, disc filtration, drum filtration, particle separation, wastewater treatment

Introduction

Microscreens, or microstrainers, can be found in various applications within water and wastewater treatment. The following paper is an attempt to present an overview of literature in order to identify possibilities and key questions associated with two types of microscreens based on gravity flow – disc- and drumfilters. The literature presented is limited to applications within wastewater treatment and is by no means complete. During the 1960's and 1970's quite many papers and reports were published but more recent publications seem to be few. The older material is undoubtedly of high quality, but the lack of recent scientific papers is noteworthy, since there is a commercial interest for the technology in many parts of the world. In this study commercial material, available on the internet etc., has been disregarded although often quite informative.

Principle

The main principle of operation is relatively simple and straightforward. Water flows by gravity into a central drum. This drum either supports vertically mounted discs with filter media on each side (Figure 1) or the drum itself is covered with filter media (Figure 2). During filtration solids are caught on the filter panels and the flow of water through the filter is impeded. Consequently, the water level inside the filter rises and eventually backwashing is initiated. It should be noted that filtration is continuous and not stopped due to backwashing. Nozzles spray the screen and solids are thereby rinsed off and discharged via a solids collection trough. Typically the backwash requires a few percent of the total flow. A downstream retaining weir and an upstream by-pass arrangement are normally used to limit the differential head across the micro-fabric, while the

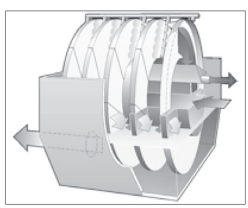

Figure 1. *Example of discfilter principle.*

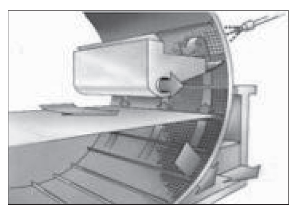

Figure 2. *Example of drumfilter principle.*

operational pressure can be controlled via a level sensor. Microscreens operate at comparatively small head loss, which is normally described as an advantage compared to other filtration processes. When comparing disc and drum filtration one important difference is the filtration area available, which is considerably higher (per ground surface area required) for the discfilter.

Separation mechanism

Micro screening or micro straining should not be confused with the membrane process referred to as micro filtration. There is some overlap in terms of pore size but while microscreens are commercially available with filter openings from about 10 μm, membranes for micro filtration are available with much smaller pores. Filter construction, operation and expected removal are also completely different, although the separation mechanism is similar.

Micro straining is based on physical blocking of particles in well defined apertures. Thus there is a fundamental difference with respect to granular media filtration or depth filtration where other mechanisms ideally are more important for particle separation. This interpretation is supported by the fact that the last liquid passing the screen, just before backwashing, nearly has the same concentration of suspended solids (SS) as the first (Ewing 1976). There is however agreement that previously deposited particles and flocs forming a mat or cake of solids, sometimes referred to as *Schmutzdecke* (Kirkup 1971), can aid the filtration process. The efficiency of filtration is thus at maximum just before cleaning. Analogously there is a risk for break-through, which depends on aperture size, strength of intercepted material and the hydraulic force applied to the solids spanning the apertures (Lowndes 1970). It is however reasonable to assume that deep-bed filters could produce an effluent with somewhat lower particle content and several comparisons confirm this statement (Kobler & Boller 1997, Hultman 1979, Tholander 1979).

Figure 3 shows a principal illustration of particle separation in a discfilter applied on effluent polishing. Separation is interpreted as relative difference between influent and effluent particle counts in different size intervals, and each size interval is replaced with the average size on the x-axis. (Original data and methodology is described in Persson *et al* 2005). First and foremost, particles larger than the pore openings are effectively separated. The separation of particles smaller than the pore opening is explained by the filter cake of retained particles reducing the pore opening during the filtration cycle. These particles are however not necessarily contributing significantly to mass (SS) if the applied pore size opening is small. The presence of particles larger than the filter opening could be explained by reflocculation in the effluent tank or by the interpretation of particle size and the analysis method applied – that is if imperfections and leakage from the influent side can be excluded.

In some samples negative separation, i.e. increase of particle counts, for the smallest particles, was noticed. Kobler & Boller (1997) noticed the same phenomenon, which probably is explained by breakage of flocs. Boller & Blaser (1998) point out several interesting aspects, for example the possibility of flocs being deformable and estimations of strain forces in the entrance to a porous media filter. Furthermore, interactions related to surface chemistry rather than geometry of pores and particles are naturally possible. However, Shea & Males (1971) conclude that the particle size distribution is the key characterizing parameter in determination of treatment effectiveness and an assumption of sieving/screening/ straining of particles as the main separation mechanism seems reasonable.

Applications

Microscreens were originally used for pre-treatment to slow and rapid sand filters at potable water treatment works. Coagulant dose could be reduced as well as washwater consumption and solids loading and thus filter run times could be increased. There are also related applications entirely based on micro straining (and disinfection) as well as applications with screening after sand filtration for control of organisms breeding in filter sand beds. (Boucher 1967, Kirkup 1971, Lowndes 1970)

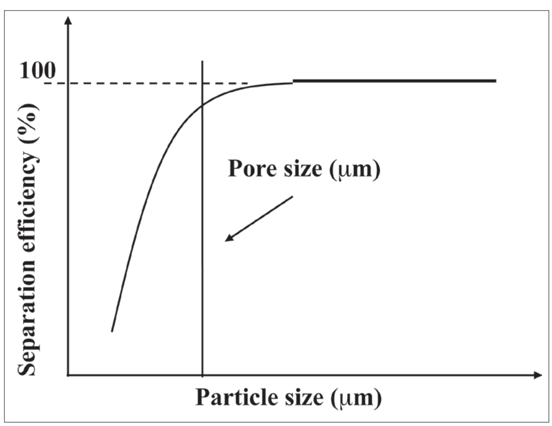

Figure 3. *Particle separation as a function of size in micro screening (applied on effluent polishing).*

In municipal wastewater treatment disc- and drumfilters are used for particle separation both in primary and tertiary treatment as well as in related applications like stormwater treatment. The first rotating drumfilter was constructed in the 1940's by Glenfield & Kennedy Ltd and soon after used for effluent polishing of biologically treated wastewater. The first installation was established in Luton, England 1950 and soon installations could be found in Australia, South Africa and North America (Diaper 1969). Kummer and Geiger (1994) present an innovative wastewater application where micro screening is introduced between the aeration tank and the final clarifier in an activated sludge process with the intention to reduce drifting of sludge during wet weather flow. A more recent parallel to the original applications described above is pre-treatment to different membrane processes. Furthermore there are several industrial applications for the process with fibre recovery and use on fish-farms being two important examples.

Primary treatment

Primary treatment often refers to primary clarification. Sometimes preliminary steps, like screens and gritchambers are included. Ødegaard (1975) discusses the role of micro screening for primary treatment and makes the important distinction between screening for protection of downstream units and screening for removal of for example suspended solids and related fractions of organics and nutrients. The overall conclusion is that primary settlers could be replaced by microstrainers. Särner (1976, 1978) reaches the same conclusion. With filter apertures of 200 microns an SS-reduction of 20–35 % was possible in filtration of raw wastewater. Smaller filter openings (40 and 120) were tested but the problem of clogging from oil and grease was considered as too frequent. It is interesting to note that the selection of pore opening was based on operational considerations rather than removal efficiency. It was furthermore noted that small particles, for example as a result of reject water addition, heavily reduced filter capacity. In comparison to settling more maintenance was required although operation was considered as easy with special cleaning of the screens every second or third week. Another interesting and important reflection considered the fact that the effluent was close to saturated with oxygen meaning that for example a downstream pre-denitrification or bio-P process could be negatively affected. Garman (1975) presents a comparison of different microscreens used for primary treatment including one disc- and one drumfilter indicating that screening should be a competitive alternative. Eriksson & Nielsen (1974) present an extensive study on primary and stormwater treatment by drum filtration. With 20 micron filter opening SS was on average reduced with close to 50 % at hydraulic loadings up to 50 m/h (influent SS 100–150 mg/l). A recent study by Petterson (2004) on drum filtration of municipal (strictly from households) wastewater showed that SS could be reduced with approximately 50 % (influent SS 200 mg/l) and COD with 30 % with 30 or 60 micron filter opening. Tests by Ljunggren *et al* (2005) showed that it is possible to reduce SS with 50–75 % in municipal wastewater after grit removal. Both disc- and drumfilters were tested with pore openings in the size range of 20–60 micron.

Tertiary treatment

Microscreens are used worldwide for tertiary treatment of biologically treated water. The definition of tertiary treatment is not entirely clear and different authors use the term in somewhat different contexts, but additional treatment after biological treatment incorporating particle removal, i.e. effluent polishing, could be a working definition. Chemical treatment could be integrated with the tertiary treatment step (post-precipitation). The first installation was designed for treatment of trickling filter effluent, but treatment of effluents from final clarification after activated sludge treatment was also soon to come. During the first decades drumfilters with filter openings of 23 or 35 microns were almost exclusively used. Removal rates are heavily dependent upon the influent solids concentration and thus on the functioning of the upstream process, but effluent values well below 10 mg/l and removal rates ranging from 45–85 % are reported in a compilation of microscreen installations published by the U.S. Environmental Protection Agency (EPA 1975). Low Sludge Retention Time and high clarifier loadings result in higher screen effluents but not necessarily lower percentage removal (Ewing 1976). In a more recent German investigation (Grau *et al* 1994) drum filtration (20 micron) resulted in 75–85 % solids reduction and a consistent effluent concentration < 5 mg/l. Hultman (1979) described a trend from 35 to 23 micron made possible with improved machine design. One could perhaps say that this is an ongoing trend since many installations today are equipped with 10 micron, or similar, filter cloths. Furthermore discfilters are now frequently used instead of drumfilters. Persson *et al* (2005) present successful disc filtration of an effluent from a post denitrifying biofilm process utilising suspended carrier material (The Kaldnes Moving Bed™ Process). Filter cloth with 10 and 18 micron filter openings produced effluents in the range of 2–5 and 2–8 mg/l respectively and influent SS of 10–50 mg/l. Bourgeous *et al* (2003) present the cloth-media disk filter as an alternative to granular-medium filtration for wastewater recycling producing effluent turbidity values less than 2 NTU with an influent of 25 NTU. It should be noted that this filter type is somewhat different from a microscreen in the sense that is described as random-weave filter cloth offering some degree of depth filtration. Grabbe *et al* (1998) present low effluent values with a modified filter cloth mounted on a discfilter.

Stormwater treatment

Microscreens have been tested in different stormwater applications. Diaper & Glover (1971) present a system with micro straining of combined sewer overflow (CSO) followed by ozonation and chlorination. Filter openings of 23 and 35 micron were tested and pre-treatment with solids trap and bar screen was recommended. With 23 micron average solids removal of 80 % with an average influent SS of 174 mg/l could be achieved. Mason & Gupta (1972) present a process alternative with drum filtration and flotation. The screening unit had relatively wide filter apertures, 297 micron, resulting in SS-removal of 20–30 % and BOD-removal of 20 %. Keilbaugh *et al* (1969) made some interesting remarks on analyses of samples from a similar application. BOD-removal turned out to be a very difficult parameter to measure, since BOD in several cases increased significantly over the screen despite considerable solids reduction. Several explanations are discussed but the one considered most likely is that bacterial food supply is made more available since more surface area is produced on the escaping solids and thus growth kinetics are enhanced. In Eriksson & Nielsen (1974) drum filtration was occasionally and successfully tested on stormwater.

Design

Design of micro screening plants could be performed according to (Ewing 1976):

- Bench tests
- Pilot tests
- Rule of thumb
- Data from similar installations

30 years later these alternatives are still practical. Rule of thumb and data from similar installations are obviously closely related and the cheapest alternatives if reliable data is available. Pilot tests are perhaps the best alternative but on the other hand costly. Bench tests could serve as indications of filterability. With wastewater being very variable site specific tests are always valuable. Models for removal efficiency and capacity are normally empirical. However, Boucher (1947) originally developed a mathematical model describing drumfilter capacity on the basis of the expression:

$$H = H_0 \cdot e^{IV}$$

where H refers to the pressure gradient and V to filtered volume. I is denoted the filterability index. Assuming that the pressure over the filter is changed according to the equation an expression for drumfilter capacity was developed on the basis of the pressure gradient, filter area, rotational speed and filterability index. It should be noted that the filterability index is a measure for the cloth *and* the filterability of the water and must be estimated from practical tests. The expression was later modified by Mixon (1970).

Design parameters

Design of microsreens is dependent upon a number of factors: clogging rate, rotational speed of drum or disc, area of submergence, backwash efficiency, applied head and not least water characteristics. A compilation of key parameters and applicable values from a number of full-scale installations for tertiary treatment can be found in EPA (1975):

- 20–25 micron filter opening with variations from 15–60 micron
- Hydraulic loadings of 12–25 m/h based on submerged drum filter area
- Head loss < 0.15 m

Higher values of head loss are also reported. Drum diameter is normally set to maximum 3 m and peripheral speed limited. Backwash pressure is in general set to 3.5 bars. It is furthermore noted that screen performance tends to be better at lower hydraulic loadings, which is confirmed in several other studies. In the German investigation previously mentioned (Grau *et al* 1994) drum filtration with filter openings of 10, 20 and 40 micron was operated at similar hydraulic loadings (10–35 m/h). Saffran & Kormanik (1976) are pointing out each application as unique but give some rules of thumb; 15–30 m/h for tertiary treatment and 60–120 m/h for CSO but there is no note on pore openings. In tertiary treatment SS-removal of 50–80 % can be expected and for treatment of combined sewer overflows 30–70 %. The maximum head loss is set to 0.30 (m) for tertiary treatment. Regarding primary and stormwater treatment the applied surface loadings are obviously much higher due to the use of larger filter apertures.

There are other aspects to design of microscreen units that are of crucial importance in order to accomplish maximum capacity and high removal efficiency. Several authors conclude that pumping should be avoided in order to minimize shearing action (Diaper 1969). It is furthermore important to recognise that different processes result in markedly different characteristics affecting screen capacity (Ewing 1976). Control of peripheral speed and head loss are other aspects of great importance to the filtration result (Kirkup 1971, Ewing 1976) and fine tuning of these parameters can result in great improvements in both SS-removal and capacity (Diaper & Glover 1971). Lynam *et al* (1971) suggest micro screening at lower drum speeds for better effluent quality, since a better straining action through a thicker mat of solids building up at low speeds is possible. This is also noted by Ewing (1976) arguing that there is a critical drum speed for deflocculation. Hydraulic head across screen media should also be limited in order not to drive particles through. It is furthermore stressed that the effectiveness of the solids collection system is important in order to get all particles in the collection through and not back into the drum pool thus reducing capacity.

Operational experiences

Two key issues can be identified with respect to operation of disc- and drumfilters; clogging of filter media and the possibility to practise chemical pre-treatment.

Media, clogging and cleaning

Filter media can be made of several different materials for example stainless steel, nylon or polyester. Stainless steel has a long history and demonstrated service life but the material is susceptible to attack from certain chemicals. Also polyester (Figure 4 and 5) also has a demonstrated service life and good flow characteristics. The material could be adversely affected by strong alkalis and some organic solvents but is resistant to for example chlorine (Ewing 1976). Cleaning and prevention of clogging can be performed in many ways. By applying high pressure systems using 4–8 bar, and perhaps even higher, the need for chemical cleaning can in many cases be reduced presupposed that spray patterns are uniform and nozzles well functioning. Increase of pressure has proven to be effective (Truesdale & Birkbeck 1967).

Truesdale & Birkbeck (1968) and Vandyke (1971) describe clogging as a result of biological growth and solution of the problem by chlorination. UV-light was tested but not sufficient. Acid cleaning is suggested in case of precipitation of manganese and iron oxides (Diaper 1969) and for removal or organic impurities (Ives 1971 cited by Hultman 1979). Some installations for tertiary treatment were equipped with UV-irradiation (Anonymous 1971) in order to inhibit biological and algal growth. Application of chemicals can be performed manually or via the backwash system. With respect to applications for primary treatment oil, fat and grease seem to be the major problems. Hot water and/or steam are sometimes practised. Särner (1976) also reports on the successful use of a degreasing aid.

Chemical pre-treatment

If micro screening could be combined with chemical pre-treatment the possible applications for the technology would increase. Several authors note difficulties when adding a coagulant to improve tertiary treatment (Truesdale & Birkbeck 1968, Lynam *et al* 1971), simply because the flocs are not strong enough to withstand shear forces in the strainer. Hultman (1979) concludes that chemical flocs must be strengthened by a polyelectrolyte. Ewing demonstrates very good results (SS re-

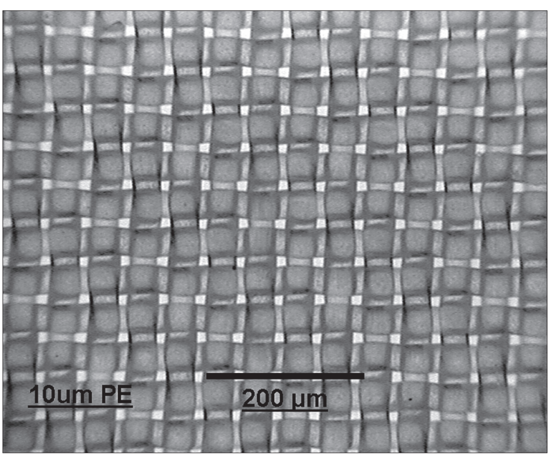

Figure 4. *Polyester filter cloth with 10 micron filter opening.*

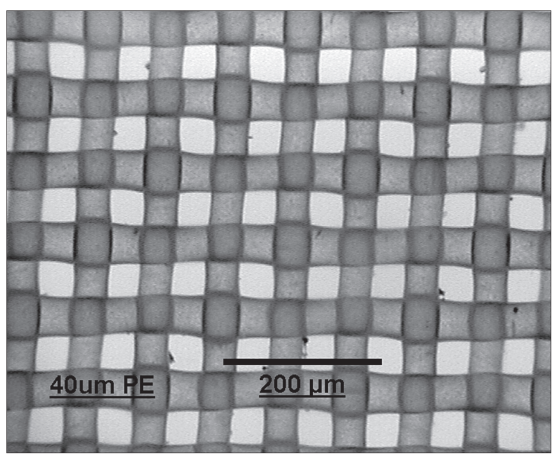

Figure 5. *Polyester filter cloth with 40 micron filter opening.*

duction of 85 % and SS < 4 mg/l for tertiary treatment) and states that polymers or combinations of trivalent metal salts and anionic polymers can be effectively used. Detention times of 2–4 minutes for the metal salt and 1–2 minutes for the polymers together with slightly reduced drum speeds are suggested. Rimer (1971) presents results with drum filtration (60 and 25 micron) of paper mill wastewater pre-treated with a number of different combinations of chemicals. The study showed that chemical addition resulted in better quality effluent than with the strainer only and that very high removal efficiencies were possible (> 90 %). With respect to chemical pre-treatment of raw wastewater followed by micro screening very few results seem to be published. Aspects on chemical pre-treatment, including clogging problems, is reported by Karlsson (2005). Garman (1975) concluded that although apparently good floc formation was achieved it was difficult to form strong enough flocs. In tests performed by Ljunggren *et al* (2005) the same problem was noticed but for some combinations successful screening was achieved indicating a potential for this type of treatment.

Final reflections

Micro screening is obviously a competitive alternative for primary, tertiary and stormwater treatment, especially when compact units are needed. There is a need for more documentation on the technology, especially with respect to disc filtration. Generally there is a good foundation based on practical experience, especially for tertiary treatment with drumfilters.

With the particle size distribution identified as a key parameter it should be possible to use particle size analysis in modelling and design of microscreens and thereby create a stronger theoretical basis. Already 1973 Carlstedt & Stahre suggested that such a methodology possibly could be established for selection of appropriate pore size opening. A successful attempt has been made by Brinker *et al* (2005) in predicting filtration efficiency on basis of PSD for a fish farm.

In many studies floc strength is considered as an important parameter, both with respect to upstream units (like pumps, weirs etc) but also to chemical pre-treatment which must be designed in order to form very strong flocs. With the possibility to practise chemical pre-treatment the number of possible applications would increase.

A problem reported in almost every single publication, is irreversible clogging of the filter media. With careful operation, supervision and proper cleaning methods the problem can normally be solved, but clogging still remains the major drawback related to micro screening.

Acknowledgements

Hydrotech AB is gratefully acknowledged for providing the pictures. Thanks also to Erik Särner for providing several papers and to Åsa Lindblad at the Library of Chemistry and Chemical Engineering for great assistance in finding some of the older papers and reports.

References

Anonymous (1971). Microstraining plant for effluent polishing. Effluent Water Treatment Journal, vol. 11, 1971.

Boller, M., Blaser, S. (1998). Particles under Stress. Water, Science & Technology, vol. 37, No. 10, 1998.

Boucher, P. L. (1947). A new measure of the Filtrability of Fluids with Applications to Water Engineering. Journal of the Institution of Civil Engineers, No. 4, 1946–1947.

Boucher, P. L. (1967). Micro-Straining and Ozonation of Water and Waste Water. Proceedings of the 22nd Industrial Waste Conference, Purdue University, May, 1967.

Bourgeous, K. N., Riess, J., Tchobanoglous, G., Darby, J. L. (2003). Performance Evaluation of a Cloth-Media Disk Filter for Wastewater Reclamation. Water Environment Research, vol. 75, No. 6, 2003.

Brinker, A. Schröder, H. G., Rösch, R. (2005). A high-resolution technique to size suspended solids in flow-through fish farms. Aquacultural Engineering, 32, 2005.

Carlstedt, C., Stahre, P. (1973). Mikrosilning av obehandlat avloppsvatten vid Åkeshovs reningsverk. Kungl. Tekniska Högskolan, Institutionerna för Vattenförsörjnings- och Avloppsteknik samt Vattenkemi. Publikation 73:1, 1973.

Diaper, E. W. J. (1969). Tertiary treatment by microstraining. Water & Sewage Works, vol. 116, No. 6, 1969.

Diaper, E. W. J., Glover, G. E. (1971). Microstraining of combined sewer overflows. Journal Water Pollution Control Federation, vol. 43, No. 10, 1971.

EPA 625/1-75-003a. Process design manual for suspended solids removal. U.S. Environmental Protection Agency, Technology Transfer, 1975.

Eriksson, Ö., Nielsen, P. (1974). Mikrosilning av obehandlat avloppsvatten samt dag- och bräddvatten. Kungl. Tekniska Högskolan, Institutionerna för Vattenförsörjnings- och Avloppsteknik samt Vattenkemi. Publikation 74:2, 1974.

Ewing, L. (1976). Design Criteria for Microscreening Biological Wastewater Plant Effluents. Water & Sewage Works, April 1976.

Garman, J. J. (1975). Silning av kommunalt avlöpsvann. Vann, nr. 4, 1975.

Grabbe, U., Seyfried, C. F., Rosenwinkel, K. H. (1998). Upgrading of wastewater treatment plants by cloth-filtration using an improved type of filter cloth. Water, Science & Technology, vol. 37, No. 9, 1998.

Grau, A., Haeusler, M., Schmitt, W. (1994). Micro-straining as advanced treatment of wastewater applied to the main wastewater treatment plant in Wiesbaden. Water, Science & Technology, vol. 29, No. 12, 1994.

Hultman, B. (1979). A comparison between deep-bed filters and microstrainers. Nordforsk rapport 2, Filtrering av avlopsvann, Stockholm 1979.

Ives, K. J. (1971). Filtration of water and wastewater. CRC

Critical Reviews in Environmental Control, August, 1971.
Karlsson, J. (2005). Optimering av trumfilter för behandling av avloppsvatten. Projektpublikation nr 16, Stockholm Vatten, 2005.
Keilbaugh, W. A., Glover, G. E., Yatsuk, P. M. (1969). Microstraining – with ozonation or chlorination – of combined sewer overflows. Water Pollution Control Research Series 03/70, 1969.
Kirkup, P. (1971). The techniques of microstraining. Effluent Water Treatment Journal, vol. 11, 1976.
Kobler, D., Boller, M. (1997). Particle removal in different filtration systems for tertiary wastewater treatment – a comparison. Water, Science & Technology, vol. 36, No. 4, 1997.
Kummer, K. D., Geiger, W. F. (1994). Stabilization of activated sludge processes during wet weather flow through microscreening. Water, Science & Technology, vol. 29, No. 1–2, 1994.
Ljunggren, M., Nilsson, B., Strube, R., Jönsson, L., Jansen, J. la Cour. (2005). Microscreening for stormwater treatment. VATTEN 61, 2005.
Lowndes, M. R. (1970). Microstraining and its Applications. Filtration & Separation, November/December, 1970.
Lynam, B. Ettelt, G., McAloon, T. (1969). Tertiary treatment at metro Chicago by means of rapid sand filtration and microstrainers. Journal Water Pollution Control Federation, vol. 41, No. 2, 1969.
Mason, D. G. (1970). Combined Sewer overflow abatement technology. Water Pollution Control Research Series, 06/70, 1970.
Mason, D. G., Gupta, M. K. (1972). Screening/Flotation treatment of combined sewer overflows. Water Pollution Control Research Series, 01/72, 1972.
Mixon, F. O. (1970). Filtrability Index and microscreener design. Journal Water Pollution Control Federation, vol. 42, No. 11, 1970.
Persson, E., Ljunggren, M., Jansen, J. la Cour, Strube, R., Jönsson, L. (2005). Disc Filtration for Separation of Flocs from a Moving Bed Biofilm Reactor. Conference proceedings "Nutrient Management in Wastewater Treatment Processes and Recycle Streams", 19–21 September, Krakow, Poland, 2005.
Petterson, F. (2004). Mikrosilning som förbehandlingsmetod av hushållsavloppsvatten. Projektpublikation nr. 10, Stockholm Vatten, 2004.
Rimer, A. E. Microstraining Paper Mill wastewater. Journal Water Pollution Control Federation, vol. 43, No. 7, 1971.
Saffran, E. P., Kormanik, R. A. (1976). Designing microscreens? Here's some help. Water & Wastes Engineering, April, 1976.
Shea, T. G., Males, R. M. (1971). Investigation of Response Surfaces of the Microscreen Process. Water Pollution Control Research Series, 12/71, 1971.
Särner, E. (1978). Silning som förbehandlingsprocess. Bulletin, Serie VA, nr. 12, Lund, 1976.
Särner, E. (1978). Silning av obehandlat avloppsvatten. VATTEN, nr. 1, 1978.
Tholander, B. (1979). Research with a microstrainer for filtration of effluent from Ejby Molle sewage treatment plant, Odense. Nordforsk rapport 2, Filtrering av avlopsvann, Stockholm 1979.
Truesdale, G. A., Birkbeck, A. E. (1967). Tertiary Treatment Processes for Sewage Works Effluents. Journal of the Institute of Water pollution Control, vol. 66, No. 4, 1967.
Truesdale, G. A., Birkbeck, A. E. (1968). Tertiary Treatment of Activated-Sludge Effluent. Journal of the Institute of Water pollution Control, vol. 67, No. 5, 1968.
Vandyke, K. G. (1971). Microstraining in water pollution control. Effluent Water Treatment Journal, vol. 7, 1971.
Ødegaard, H. (1975). Bruk av siler i kloakkrenseteknikken. Vann, nr. 4, 1975.