Influent Screening: No Longer a Routine Process with MBRs

– Gary Hunter and Tom Cummings –

In recent years the use of membrane bioreactors (MBRs) in the wastewater industry has increased, and influent screening has become a critical and specialized part of a successful MBR treatment plant. Unfortunately, many lessons have been learned from inadequate prescreening, with problems ranging from a need for frequent cleaning to complete blinding of the membrane fibers and even premature membrane failure.

Depending on the type of membrane, the mesh size of fine screens upstream from MBRs may be as small as 1 millimeter (mm). Omni-directional punch plate openings are used to capture hair particles. Screen sizing, channel design, and even the degree of pretreatment ahead of the fine screens have become critical issues. Greater attention to the design of screenings washing and compacting equipment is also required.

Requirements for fine screening vary among MBR manufacturers, making them an important component of the overall system cost. Depending on the type of membrane recommended, the screen size may vary from 0.5 to 3 mm. Hollow-fiber membrane manufacturers require 0.5- to 2-mm screen opening, whereas the plate membrane manufacturers require only 2- to 3-mm openings. This range in sizes seems small, but the impacts on capital and O&M costs can be significant.

In addition to the O&M costs associated with the screening equipment, the membrane life and, consequently, the warranty period of the membranes must be considered. Some hollow-fiber membrane manufacturers suggest that they might tie their membrane warranty (membrane life and replacement requirements) to the screen opening size because of the potential for adverse impacts on the membranes, such as ragging and roping around the membranes. This means that a facility using a 1-mm screen has a longer warranty period or a lower price for an extended warranty than plants using a 2-mm screen.

One manufacturer advocates side stream screening in combination with a 2-mm influent screen. The concern is that a 1-mm screen could blind easily, especially if the wastewater contains significant amounts of influent grease.

With the rising interest in the use of MBRs, many new fine-screen manufacturers are entering the market offering a variety of screen configurations. While it is nice to have a wide selection of equipment available, it becomes even more challenging to understand the differences and the critical selection factors.

Available Screen Configurations & Sizes

Several options for fine screening of plant influent are currently available in the United States: fine bar screens, traveling band screens, step screens, front-entry perforated plate screens, center-flow perforated plate screens, and perforated plate drum screens.

One of the most recognized testing facilities is the National Screens Evaluation Facility (NSEF) in England, which evaluates real screen performance in municipal raw wastewater. This facility was constructed by UK Water Industry Research (UKWIR). Results of testing conducted by the UKWIR indicate that performance is a function of screen configuration, flow patterns, opening configuration, and opening size.

In order to rate screens, UKWIR has developed the screening capture ratio. This ratio is a measure of the quantity of screenings removed by the screen relative to the total amount in the raw wastewater. The calculation can be summarized as:

Gary Hunter is a senior wastewater process engineer in the Kansas City, Missouri, office of the engineering, consulting, and construction firm of Black & Veatch Corporation. Tom Cummings is a senior engineering manager in Black & Veatch's Orlando office.This article was presented as a technical paper at the 2007 Florida Water Resources Conference.

$$SCR = \frac{Y * 100}{Y + Z}$$

where SCR is the screenings capture ratio;
Y is the quantity of screenings removed by the screen; and
Z is the quantity of screenings remaining in the flow downstream of the screen.

Table 1 shows the screenings capture efficiencies for various types of screens tested by UKWIR.

As the screen opening decreases, its capture efficiency for the gross materials increases, resulting in significant accumulations of fecal matter and other organics. For this reason, the organics-laden screenings need further processing before disposal.

Several methods of screenings processing are available, including washer presses, maceration, dewatering, and mechanical washing and pressing. The preferred method is highly site-specific,

Continued on page 46

Fine Screening Technology	Screening Capture Ratio, %
Fine Bar Screens	30-40
Step Screens	30-40
Front Entry Perforated Plate Screens	65-75
Center Flow Perforated Plate Screens	75-85
Perforated Plate Drum Screens	75-85

Data courtesy of UKWIR

Table 1 – Fine Screening (6 mm) Screening Capture Ratio

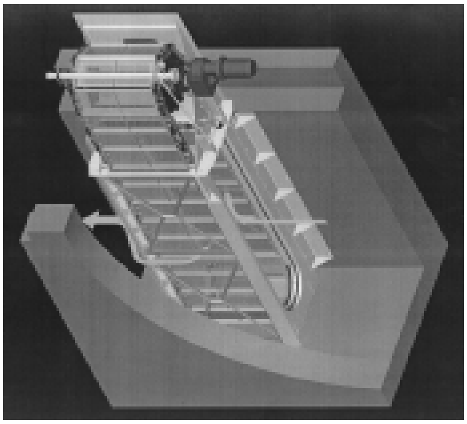

Figure 1: Band Screen Schematic

– PICTURES COURTESY OF EIMCO –

Figure 2. Typical Installation of a Band Screen

Continued from page 45

depending on the screening method and the disposal options available to the utility.

Traveling Band Screens

Traveling band screens are appropriate for fine-screening applications requiring 1- to 3-mm openings. Band screens operate with an inside-to-out flow pattern and are situated in open channels longitudinal to the channel, as shown in Figure 1. The screen is stationary during screening and rotates as required for cleaning. Band screens consist of a series of perforated plates. Cone-shaped perforations are preferred to prevent particles from wedging into the openings. A typical installation of a band screen is shown in Figure 2.

Drum Screens

Drum screens are most applicable for fine screening of large flows. They are available with a screen size from 2 mm down to 0.5 mm. The drum is situated either longitudinal to the flow channel in a double-entry, inside-to-out flow configuration or transverse to the channel in a single-entry configuration. The drum is partially submerged, with enough of its diameter out of the channel to accommodate the collection and discharge of debris, and with sufficient submergence to pass the required flow at low water levels.

Drum screens are configured so that the wastewater enters both sides of an open-ended drum. From the interior of the drum, wastewater passes through the screen panels of the drum and into the downstream channel, as shown on Figure 3. Typically the drums are much larger in both size and capacity than the band screens, and due to the flow pattern, the channel that houses the drum screen has a complex configuration.

The chief advantage of the drum screen is its mechanical simplicity. The drum rotates on a single axle mounted through the center of the drum. A small motor and gear arrangement drives a large gear on the centerline perimeter of the drum. A typical installation of a drum screen is shown in Figure 4 and an enclosed drum screen in Figure 5.

One manufacturer offers a configuration that integrates screening, washing, and compacting in one unit. The screen included with this system can be equipped with openings as small as 0.75 mm. Testing has shown that this unit can produce a screened material with up to 40 percent dry solids content.

Rotamat Screen

Forstner indicated that a micro-screening step is needed as the centerpiece to the mechanical pretreatment process, mainly for the elimination of fibrous materials and hair in the wastewater. Conventional, one-dimensional screens are not capable of providing adequate screenings reduction rates; consequently, micro-screening was introduced, thus adding two-dimensional screen geometry (wire mesh and perforated plate) with a well defined screen opening to the treatment process. This in turn ensures the reliable elimination of fibrous materials and hair.

Experience has shown that micro-screening is much more sensitive than conventional screening. The significantly larger screenings reduction rate and the increased sludge content in the total screenings amount necessitated the development of new technologies.

Huber Technologies manufactures the Rotamat® membrane screen RoMem®, which is installed at 35 degrees in a channel. It features a two-dimensional wire mesh with a well defined screen opening, thus eliminating fibrous materials and hair from the wastewater as shown in Figure 6.

Forstner indicates that the increased hydraulic throughput of the wire mesh surface as compared to the perforated plate surface is due to the much larger available effective screening surface.

Larger hollow-fiber membrane systems require between 0.75 to 1 mm^2 (750 to 1,000 microns) mesh wire opening. The cleaning system consists of a high-pressure pump and a moving mechanism which cleans the screening basket with 120 bar (about 1,700 pounds per square inch) from any residual fibrous material, hairs, and oil and grease. The cleaning takes place upstream of the screen, eliminating screenings carry-over.

The RoMem® has been in operation at numerous European sites in front of MBR systems for several years. Forstner indicates that measurements at these locations revealed that the wire mesh screens increased the absolute screenings amount by a factor of three to six, compared with conventional 1- to 3-mm (1/25" to 1/8") bar screens. In addition,

Continued on page 48

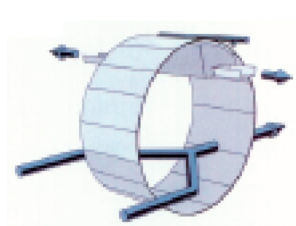

Figure 3. Drum Screen Schematic

PICTURES COURTESY OF EIMCO

Figure 4. Typical Installation for a Drum Screen

Figure 5. Enclosed Drum Screen PICTURE COURTESY OF PARKSON CORPORATION

Figure 6. RoMEM screen with 0.5 mm woven Mesh

Continued from page 46

experience gained at several sites showed that most of the oil and grease reduction does not occur in the grease trap/preliminary clarifier, but rather in the mesh wire screen.

Perforated Plate

Perforated plate-type screens with a circular opening of less than 1/4 inch in diameter have been used successfully for fine screening of plant influent flows, particularly in the United Kingdom, although a trend toward more fine screening appears to be developing in the U.S. as well. Perforated plate technology provides significantly greater capture of the longer materials, so that any materials that would pass through the small circular openings would no longer be discernible in the final biosolids.

Smaller perforations are available and are better suited for specific applications such as wastewater reuse. For applications in which fine screens are employed primarily to improve biosolids quality for beneficial reuse, 6-mm perforations are adequate. A number of manufacturers offer perforated plate units with 2- to 3-mm perforations.

Front Entry Perforated Plate Fine Screens

Front entry screens are configured so that wastewater flowing in a channel with a rectangular cross section passes through the screen panels installed perpendicular to the direction of flow. The screen panels periodically or continuously rotate out of the water by traveling along a track or channel so they can be cleaned of screenings.

The cleaning takes place at the top of the screen panel path using a rotary-brush, high-pressure water spray, or a combination of the two methods. The screenings are then discharged to either a trough or a conveyor that is mounted perpendicular to the channels at the back of the screen. Once cleaned, the screen panels travel back into the channel. With this configuration, wastewater must flow through the screen panels twice.

Design Considerations

Fine screening is necessarily going to require a significant amount of screen area to minimize head losses and reduce the flow velocities through the screen. Low flow velocities through the screen are important to reduce the chance of forcing particles into the screen openings which cannot be dislodged during backwashing process. The requirements for a large screen area will result in either multiple screening units, deep submergence of the screens, or screens with a large footprint.

Channel Design

The width and depth of the screen are key to the design of a fine screen system. Both of these factors have an impact on the design of the channel that will contain the fine screen.

WIDTH LIMITATIONS

The flow velocity in the influent

Figure 7. Washer Compactor

screening channel must be maintained at a higher rate to prevent solids from settling. Generally, the approach channels are designed for an approach velocity of 2 to 2.5 feet per second (fps) (Water Environment Federation and American Society of Civil Engineers, 1998). This velocity prevents solids from settling and the screenings from passing through the screen chamber at high velocities created by the decreased area of the screen, but it may not be possible to design a screen channel with the 2 fps velocity because of the minimum depth requirements of the fine screen. With a deep channel and the small screen openings, screen channels have to be modified to maintain the 2 to 2.5 fps velocity.

As the smaller openings are used, the effective opening sizes also decrease, impeding the flow through the fine screen and increasing the velocity through the actual opening. Velocities through the actual bar screen should be maintained between 2 and 4 fps (Water Environment Federation and American Society of Civil Engineers, 1998). The width of the screen impacts the total construction cost because the screen is constructed with stainless steel materials, so there must be a balance in the selection of the screen width, the screen depth, and the approach velocity.

DEPTH LIMITATIONS

Fine-screen installations for MBR applications are limited by the depth of the approach channel. Fine screens are generally limited to a channel depth of 25 feet or less to minimize the equipment cost. Drum screen depths are typically limited five to 10 feet, based on the mechanical limitation of the shaft. Depth will be a function of the type of screen selected. Individual manufacturers should be contacted to determine the exact depth limitation.

PRETREATMENT FOR FINE SCREENS

With 1- to 3-mm openings, fine screens require pretreatment to protect the screens and to remove material that would blind the screen. Grit removal ahead of the fine screens used at MBR plants is essential. Also, grease removal upstream from the fine screen is preferable.

It has also become common to provide pre-screening of 6 to 9 mm to remove larger debris ahead of grit removal. Channel grinders between the roughing screen and grit removal facilities can also be used to homogenize the flow. The type of pretreatment may vary, so exact requirements will need to be obtained from various manufacturers.

SCREENINGS WASHING/COMPACTING

Fine screens will tend to remove significant amounts of organic matter along with the inorganic debris. The amount of fine screening is dependent on the quality of the

Continued on page 50

Continued from page 49

pretreatment. Without additional treatment of the screenings, a serious odor problem is likely to develop. This additional treatment often consists of a washing step to separate the organic material from the inorganics and a compaction step to minimize the volume of the cleaned screenings.

Fine-screen manufacturers generally offer screenings washing and compacting equipment as a part of their overall screen package. Material removed may be combined with other material removed through pretreatment, or it may be combined with other material at the treatment plant for disposal.

Quantifying the amount of screen material for various spacing has yet to be completed because of the newness of the application. As a result, only limited data is available to quantify the amounts and characteristics of the screened material, especially for a 1- to 3-mm screen located downstream of a 6-mm screen.

The washer/compactor will wash and compact the material as shown in Figure 7.

The discharge chute should be short as possible to allow the disposal of the compacted material.

Conclusions

The selection of a fine screen for a new or existing facility impacts the following: facility layout, plant hydraulics, handling of solids and fecal matter, and grit deposition. These factors will need to be accounted for when designing a fine-screen facility and its associated solids-handling equipment to provide effective screening for an MBR facility.

References

1. Keller, John, Critical Factors in Designing Fine Screens, WEFTEC 2006, Washington DC, 2006.
2. Briggs T., Ross, D., Welp, J., Size Matters: An Overview of Screening Processes, WEFTEC 2006, Washington DC, 2006.
3. Cambridge, D., Fullingtion B.; Rom, P and Tattersall, Influent Fine Screening for Improved Biosolids Quality, WEFTEC 2003.
4. Water Environment Federation, D*esign of Municipal Wastewater Treatment Plants*, Manual of Practice 8; 1998.
5. Iowa Wastewater Facilities Design (1986) Fine Screens.
6. Forstner, Gerhard, Fine Screens, MBR Screens and Screenings Washing/Compacting (2002)
7. Lenntech, Screening Handling, *Water Treatment & Purification*, the Netherlands, 2001.
8. Oyler, Kenny, Headworks: Removing Inorganics and Preventing Wear, Water Engineering & Management, 148 (10), 2001.