MBR Screening Selection Criteria

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INTRODUCTION

The number of Membrane Bioreactor (MBR) treatment plants in design, construction and operation has increased considerably over the past decade. MBR operators as well as manufacturers of flat sheet and hollow fiber membranes technologies have realized through past experiences the importance of proper and reliable pretreatment, in particular fine screening, as it relates to the operation of their MBR process and the lifetime of their membranes. Most membrane suppliers nowadays even limit their product guarantee with regard to the installed pretreatment equipment. Huber Technology was one of the first screen suppliers to modify their existing fine screen products to meet the needs of MBR plants for reliably removing fine solids. Hair and fiber removal is a critical requirement. The first fine screens at MBR plants in Europe were installed in 2002/2003 (WWTP Schilde, Belgium - GE Zenon membrane; WWTP Hilversum, Netherlands – Kubota test plant). Today Huber Technology's fine screens reliably protect over 85 small, medium and large MBR plants (over 35 WWTPs in North America).

MBR SCREENING SELECTION

Important Design Features

Key design points to consider for an MBR screen are opening type and size, screen surface area cleaning system, seals, and bypass possibilities. Lessons learned from the first generation of

MBR installations were that a 1-dimentional screen (slot openings) is not suitable. The opening size would need to be at least 5 times smaller to capture the same amount of solids compared to a 2-dimensional screen (hole or square mesh). In addition many investigations since then have shown that the cleaning system of the screen plays an important role not only in keeping the screen surface area clean but also with regard to screenings bypass. Cleaning systems which are located behind the screen (e.g. brush on a double flow perforated plate band screen) or designs which clean the surface from the inflow side (e.g. brush on the helical auger for a basket screen such as a Microstrainer) will allow screenings to bypass. An important feature is also the type seal between individual screen elements (or if no seals are used the gap size between the plates need to be carefully considered), seal between rotating screen parts and a stationary frame, as well as between the screen and the channel walls and channel floor. Leaking seals or gaps between screening elements due to inefficient design, poor manufacturing quality, or high wear are the number one reason for screenings bypass and the resulting performance and maintenance issues with the membranes themselves.

ROTAMAT® Rotary Drum Fine Screen

One of the most versatile and well proven fine screen used worldwide, the ROTAMAT® center feed rotary drum fine screen is available with wedge wire (Ro2), perforated plate (RPPS), folded perforated plate (RPPS STAR) or woven mesh wire media (RoMem).

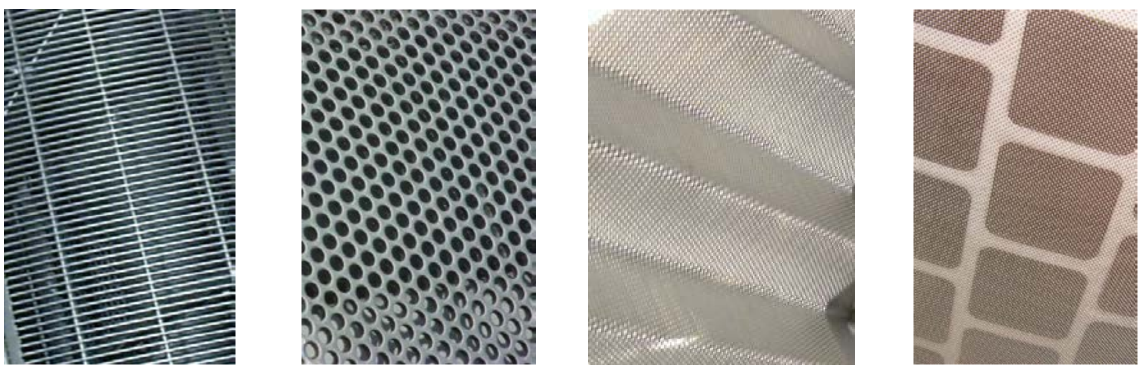
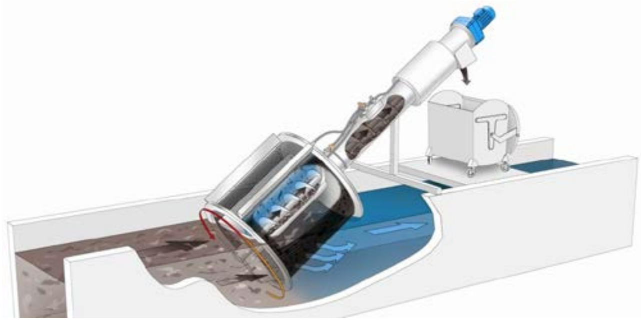


Figure 1. Screening media: wedge wire (left), perforated/folded perforated plate (middle), woven mesh (right)

The ROTAMAT® principle (see Figure 2) is by far the least complex and easiest to maintain and service as compared to other screen and compactor designs. This design has an integrated screenings washer, compacter, and conveyance where other approaches require a separate piece of equipment for each treatment step. The ROTAMAT® Rotary Drum Fine Screen is installed into the channel with an inclination of 35° (30° for extended drum size - XL basket). The wastewater gets to the drum via the open front side and flows through the openings. The machine operates intermittently based on a programmed differential or upstream water level. By means of the rotating drum the screenings are removed. With the help of a scraper brush and a spray bar the screenings are gathered into a storage hopper which is centrally arranged within the drum. The cleaning of the basket from the outside to the inside makes sure that no screenings are pushed through the openings to the screened wastewater side (see Figure 3).



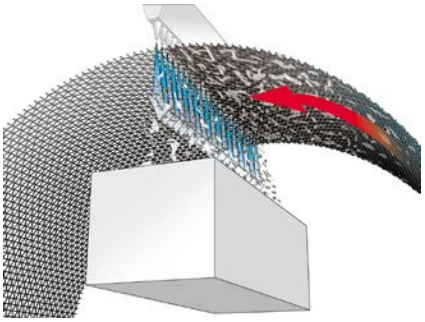


Figure 2. Rotary Drum Fine Screen Principle **Figure 3. Cleaning System**

The screw conveyor in the hopper, which is fixedly linked to the drum, transports the screenings through the closed rising pipe. By means of the integrated screenings washing in this step the soluble components are washed out of the screen and returned to the waste water stream. The conveying screw transports, dehydrates and compacts the screening without any odor annoyance and deposits it into the provided container.

- Max. drum diameter is 10 ft (3 m) which is good for about 20-24 MGD (2mm opening)
- Perforated plate openings available down to 1.5 mm
- Folded perforated plate available with 1 mm, 1.5mm and 2mm openings
- Mesh available as 0.75 mm and 0.5 mm
- Can be installed in tanks up to drum diameter of 7 ft (2.2 m)

Figure 4. 4xRPPS2600, North Las Vegas, NV **Figure 5. 2xRPPS1000 in tanks, Moroni, UT**

Figure 4 and 5 show installation examples for channel mounted and tank mounted RPPS screens.

The folded perforated plate of the recently introduced RPPS STAR allows for the use of 1mm perforated plate material. Standard flat 1mm perforated plate is not strong enough to sustain the high forces from the wastewater in the drum and can only be operated with low differential pressure and are prone to rupture when headloss increases due to brief solids spikes. In addition to providing the needed structural integrity, the folded basket of the RPPS STAR increases the screening surface area by 25% thereby increasing the flow capacity by 25% within the same channel dimensions. This can save considerable footprint in particular on large installations

(>40MGD) where several large diameter drum screens are required. The STAR basket also is suitable for retrofit applications for smaller plants with minimal changes to existing channels or plant upgrades with limited space availability.

Figure 6. RPPS STAR Installation in France

MBR SCREEN HYDRAULIC DESIGN

Selecting and sizing the best fine screen to protect an MBR plant requires considerably more information than just selecting and sizing a conventional headworks screen. Several factors affect the selection and sizing such as sewer system, plant size, wastewater influent quality, existing or planned coarse screen(s), other existing pretreatment processes such as grinders, equalization, primary clarifiers, RAS (return activated sludge) rescreening, avg. vs. peak flow, type of MBR plant (e.g. scalping plant, sidestream plant), hollow fiber vs. flat sheet membrane needs, plant hydraulics, and the need for redundancy. In particular the plant hydraulics need to be evaluated very carefully. Fine screens for MBR plants (< 3mm openings) are much more sensitive to flow and solids loading and variations and can blind very fast. Therefore MBR screens need to be designed with a much higher safety factor, which translates to more separation surface area and thereby larger screens, to handle comparable flows. Appropriate safety factors for 1.5 to 3mm MBR screens depend on the peak TSS concentration in the wastewater in front of the screen but are in the range of 1.3 to 2.5 (see also Table 1). This factor accounts for the blinding of the screen but cannot be compared with the % blinded area typically used for inclined screen applications. Rotary drum screens have a screen surface area which is not linear to the water level and cannot be sized based on standard equations used for inclined screens. Rather they are sized based on the manufacturers experience using the maximum clear water flow and down-rating it by a safety factor.

Table 1. Suggested Safety Factors (SF) for MBR screens based on TSS concentration

	Screen Design Maximum TSS			
Perforations	**750 mg/L**	**500 mg/L**	**350 mg/L**	**250 mg/L**
1 mm*	TBD based on application			
1.5 mm*	2.5	2.0	1.9	1.8
2 mm*	2.1	1.6	1.5	1.4
3 mm	1.8	1.5	1.4	1.3
*Preceding 6 or 8 mm screen and grit removal is strongly recommended; SF might change based on pretreatment				

Other important considerations for rotary drum screen design are the maximum upstream and downstream water levels and the available hydraulic headloss. The maximum upstream water level of the ROTAMAT® screen is fixed by the screenings collection hopper (see Figure 7).

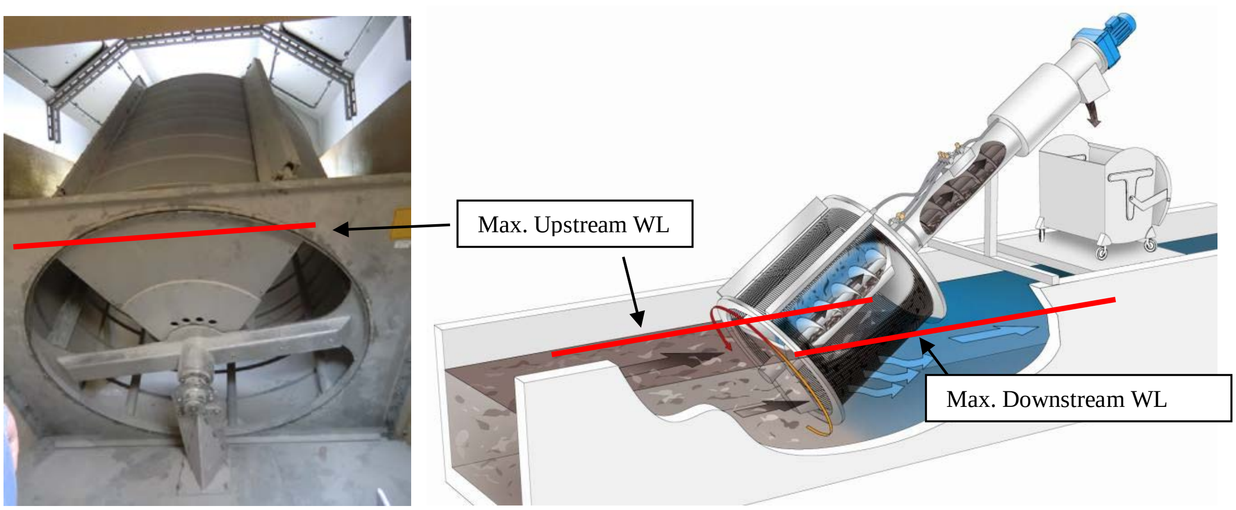


Figure 7. Max. upstream WL (top of hopper); max. DS WL (bottom of auger trough)

Consideration should be given to rotary drum screens from manufacturers which use a high screenings trough to allow for higher upstream water levels, increased capacity, and lower runtime. If the maximum water level is exceeded the screen can no longer function correctly. Also the maximum downstream water level is fixed by the bottom level of the screenings collection hopper (see Figure 7). This is due to the collection trough using a perforated opening at the screenings collection point for proper drain off of water. If this level is exceeded water will back flow into the trough and float the screenings in the collection hopper. The screenings cannot be conveyed out of the screen any longer and will float back into the screen drum clogging the screen surface and reducing the screen capacity.

Huber has developed a special ROTAMAT® version with a double trough design closing the lower bottom of the trough to allow for higher downstream water levels if required by the existing hydraulic profile. This ROTAMAT® version, which is called the RPPS PRO, uses a small centrifugal pump to pump the liquid from the screenings collection hopper to the front of the screen allowing the “dry” screenings to be conveyed out of the hopper by the standard ROTAMAT® auger.

Another ROTAMAT® option available is the RPPS LIQUID. This screen version does not use an auger to convey the screenings out of the screen drum but rather sluices the screenings-water-mixture from the collection hopper to a specially designed washer compactor (WAP LIQUID) or to a common pump sump. The RPPS LIQUID is installed at a 5° installation angle providing more submerged screen area. It is also the recommended screen after a primary clarifier or before tertiary membrane filtration as the screenings from these process steps cannot be conveyed by an inclined auger any longer due to their sludge consistency and missing structural material within the sludge.

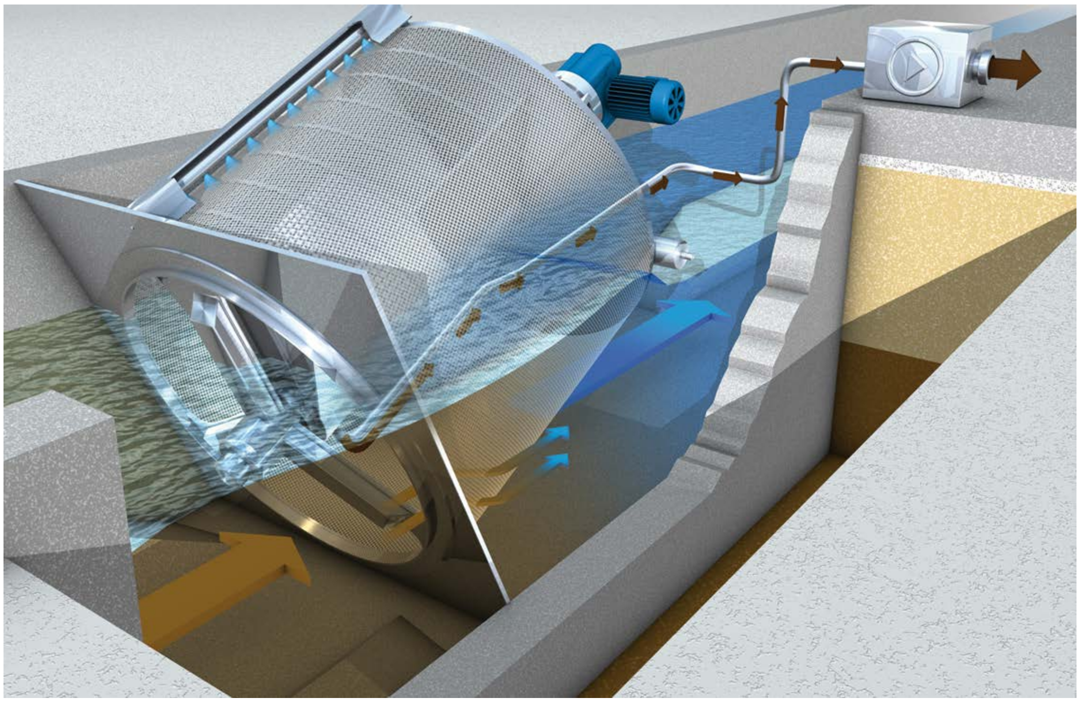


Figure 8. RPPS Liquid – Screening conveyance by sluiceway or suction pump

While rotary drum screens by design have a lower peak headloss than inclined flat screens (more submerged screen surface at higher flows and water levels) they should be operated closed to the maximum upstream water level to maximize the screen surface area for screenings and limit runtime of the screen.

PARAMETERS AFFECTING THE DESIGN OF THE MBR SCREEN

There are many parameters affecting the design and sizing of an MBR screen such as:

- Sewer system (combined or sanitary, gravity or pumped, length and age of sewer network, I&I)
- Number of pump stations
- Grinders or chopper pumps in Pump Station or WWTP inlet
- Wastewater sources and characteristics in particular if special indutrial dischargers
- EQ tanks in front of fine screens and management strategy for these tanks
- Any additional pretreatment in front of MBR screens

- Hydraulic head available for MBR screening
- Footprint available for MBR screening
- Wastewater average and peak design flows and current flow conditions
- Design and operation of grit traps in front of MBR screens
- Any wastewater return flows in front of screens (e.g. from grit or sludge treatment, membrane bioreactor)

Therefore there is no “one system fits all” mentality and each application should be considered independently.

Sewer system

Details of the sewer system are very important for the sizing of the fine screen. Combined sewer systems, in particular if the sewer network is long, by gravity, and shallow can lead to sudden solids peaks. These sudden peaks can lead to increased blinding of the fine screen. Larger sized screens will be required to handle these loads. Screens will run longer and wash water demand will increase. It is recommended that for such applications a 6 or 8 mm screen precedes the fine screen to lower the peak loading and reliably remove the coarse screenings from the wastewater. Sewer systems with many pump stations often lead to maceration of coarse screenings. This results in a different challenge to the fine screens as any preceding coarse screens, in particular if they use a 1-dimensional media, might not be able to remove the macerated screenings sufficiently. The fine screen then will still see the bulk of the screenings load. The same effect can happen if grinders or comminuters are used upstream of the fine screen.

Pretreatment

Installing coarse screens (or even additional fine screens when very fine openings are used for MBR protection) in front of the MBR screen is very important in particular for CSO applications, larger plants with high TSS load applications, and when fine screens with 2mm and smaller openings are used for MBR protection.

Grit traps should be installed in front of the fine screens utilizing a two stage screening approach. Consideration should be given not to oversize the grit trap as internal studies by Huber have shown that high amounts of very fine grit and silt can be flushed out of grit traps if there are large differences between peak flows and low flows for an individual grit chamber.

A grease management strategy or grease removal upstream of the fine screen needs to be implemented to avoid blinding of the screen surface with grease. Fine screening elements that are blinded with grease reduce the free cross-sectional surface, increase hydraulic losses and affect the hydraulic capacity of the screen. If grease is a known issue, wash water pressure to the screen should be increased to 100-140 psi and if possible a separate hot water wash connection should be added.

Primary clarifiers can decrease the solids loading to the fine screens considerably and in particular even-out solids peaks. However they also change the nature of the screenings removed by the fine screens. Screenings will be mostly fine grit or fine silty material along with very fine fibers and some floatables. This material behaves more like sludge than normal screenings. Conveying the material with an inclined auger and using the traditional screenings wash and compaction prove to be challenging. It is therefore recommended to use a rotary drum screen version which either pumps the screenings-sludge mixture out of the screen or alternately uses a sluice to transport the screenings out of the drum screen. The screenings-sludge mixture can then be either combined with the primary sludge from the clarifier or directly pumped to a digester or sludge dewatering device. The high fiber content of the screenings-sludge mixture typically has a beneficial effect on the dewaterability of the plant sludge.

Grinders or comminuters are not recommended in front of MBR plants. Fine particles created by these devices can pass the fine screen. They also create sharp debris which can damage the membrane plates or hollow fibers. Also, string/rag reformation has been observed downstream of some grinder applications.

RAS Re-Screening and Supernatant from Sludge Treatment

Some membrane manufacturers require or recommend that the return activated sludge (RAS) is at least partially re-screened. This recommendation is either based on previous bad experiences with MBR screens (bypassing and accumulation of trash in mixed liquor) or if there are issues with material (e.g. leaves, seeds) being blown into the process tanks when the tanks are open and not housed in a building. Mixed liquor screening with the headworks fine screens is not recommended as the high solids loading of the sludge (>10,000 mg/L) will instantly blind the fine screens. Accounting for such high solids loading during design requires very high safety factor and leads to extremely large screens. This is not an economical solution. Huber recommends that either the existing inefficient headworks fine screen is replaced or an additional properly working fine screen is placed after the existing headworks screen. Studies by LOTT and HDR (Koch, J., Hielema, E., McConkey, B. *Saga of Two Screens*, WEFTEC 2010) have shown that such a solution replaces the need for RAS rescreening, restores membrane capacity and reduces maintenance needs on the membranes. If the issue is material such as leaves or trash blown into open tanks and covering the tanks is not an option it is recommended that separate fine screens are installed in the RAS channels. These screens typically do not need to be two dimensional and very fine. A good solution to handle the large flow at the high solids loading of the mixed liquor is a 3mm STEP SCREEN®. These screens can directly be installed in deeper RAS channels. For partial screening of pumped RAS or small plants one or several STRAINPRESS® units are the recommended screening technology. The STRAINPRESS® can be supplied with different perforated hole opening sizes.

Ideally supernatant from the sludge treatment process should be fed back to the headworks and not directly in front of the fine screen. Supernatant might be only a small flow portion compared to regular wastewater flow however its solids content is high and more problematic due to potential unused polymer still being present (typically identified by a milky stream in the wastewater). Polymer has a high viscosity and can easily blind the perforations of the fine screen. During low and average flow times this might not be an issue hydraulically but it will increase the runtime of the screen and the wash water consumption unnecessarily.

Redundancy

For a membrane plant having at least one redundant fine screen is extremely important to ensure maximum operating reliability and to avoid any damage to the membranes. A simple emergency bypass with manual bar screen acceptable for conventional plants should be avoided for MBR plants. In the event of a screen failure a standby screen must be available to ensure 100% hydraulic screening of the wastewater flow prior to the membrane tanks. Having a redundant screen is also very important for smaller plants to allow for downtime of the duty screen during maintenance. Considerations should be given to the design of an emergency overflow in front of the fine screen (either to a standby screen or to an EQ tank or sidestream treatment process). Fine screens can easily get overloaded when TSS concentrations exceed the design concentrations due to short time solids peaks.

Average and Peak Flows and their Duration

Traditionally screens have been designed mainly for peak flow conditions. For fine screens for MBR plants it is also important to know how long the screen will see the peak flow. This can greatly affect the runtime and thereby the wear and wash water consumption of the screen. Typically peak flow to an MBR plant is limited to 2-3 times average flow equalizing higher flows before the fine screen. Some MBR plants are designed as side stream plants using the high quality membrane treatment for their main flow and some lower quality or existing treatment process for any excess flow. Scalping plants are designed to provide a constant treatment for water reuse close to a major water consumer. The amount of water the scalping plant needs to produce is often constant or seasonal and regulated by fixed water contracts. Having little or no variations in flow will require the fine screen to operate close to peak flow much longer. Also peak flow in this case most certainly will have higher solids loading than peak flows which are diluted by storm water inflow or groundwater infiltration (I/I). Fine screens for such applications need to be sized larger to avoid the machines from running continuously.

Screenings Treatment and Handling from Fine Screens

Fine screens can significantly increase the amount of screenings a plant needs to handle. Experience has shown that average screenings load going from a 6 mm fine screen to a 2 or 3mm fine screen can increase by a factor of 2-4 with some installations seeing an even higher increase.

DESIGN GUIDELINES - SINGLE STAGE VS DUAL STAGE SCREENING

Single Stage Fine Screening

Single stage screening is defined as using the fine screen as the primary headworks screen. This approach has been successfully implemented using a 3 mm, or in some cases, a 2 mm perforated plate fine screen. It is mostly used for sanitary sewers only and plants < 2-5 MGD. Single stage screening will require a preceding coarse screen (1” or ½”) or at least a manual bar rack to protect the fine screen from very large debris in particular in combined sewer systems and gravity systems. It is also recommended that a grit trap be in place prior to the fine screen.

Grinders are not recommend placed in front of MBR screens as they tend to produce more problems downstream by allowing finely ground and sometimes sharp screenings to bypass, are very maintenance intensive, and have high O&M costs associated with the grinder operation.

Single stage screening is also used if a primary clarifier is in front of the fine screens. However these application typically have a ½” to 1” coarse screen in place to avoid trash accumulation in the primary clarifier.

Huber has several installations utilizing a 2 mm ROTAMAT RPPS fine screen with no additional coarse screen installed in front of the screen. These installations work very well and the screen is commonly protected by a coarse trash rack that prevents very large debris. These screens are typically for smaller installations up to 5 MGD, sanitary sewer only, and are sized for higher solids loading to the MBR screen. Fine screens with smaller than 2mm openings always need a 6 or 8mm preceding coarse screen.

Advantages:	Disadvantages:
- Single fine screen - Lower capital costs - Lower O&M costs - Lower footprint	- Larger Screen (higher solids loading) - Longer running times (higher solids loading) - Higher wear (longer run times)

Dual Stage MBR Screening

Dual Stage MBR screening is strongly recommended for <1mm mesh, 1mm folded perforated plate, 1.5 mm or 2mm perforated plate screens. Most dual stage screening treatment trains do not have an additional coarse screen installed at the wastewater treatment plant. The first screen is typically a 6mm or 8mm bar or perforated plate screen. Perforated plate screens are typically recommended when the wastewater has already been through several pump stations, grinders, chopper pumps etc. or wastewater is known to contain smaller solids. Additional coarse screens > 8mm are typically recommended for combined sewer application and very large WWTPs. They might be located not at the treatment plant but rather at pump stations within the sewer network. Dual stage screening is mostly employed for > 2-3 MGD plants. For small MBR plants the cost of the membrane elements is comparatively small to the overall MBR cost, so that a dual stage screening process to protect the membranes is less critical. In addition for small plants, 2 or 3 mm screens typically have some hydraulic reserves build into their design.

Advantages:	Disadvantages:
- Smaller size fine screens - More consistent operation during peak loading events - Less run time - Lower wear	- Second set of screens - Higher capital costs - Increased footprint - Higher O&M costs - Typically higher (total) headloss - Two separate screenings treatment systems (if not integral to screen)

Installation and Start-up Considerations

Making sure that the fine screen is installed properly in the channel is very important to avoid any bypassing of fine solids. Special considerations should be given to the inspection of the seal(s) between the screen and the channel in particular if the required channel tolerances are exceeded. It is recommended that the screen manufacturer supervises the screen installation, checks the proper alignment and sealing, and inspects for proper installation of the screens. This becomes increasingly important on larger installations. It is also recommended that the channel seals are inspected on a regular basis during maintenance cycles. Missing channel seals have been found to be the number one reason for screenings bypass. Possible causes might be seals were never installed, not installed properly, or large gaps between the baffle plate and channel wall/floor.

Retrofitting ROTAMAT® Fine Screens at Existing MBR Plants
Many of the first and second generation MBR plants have been designed with fine screens which do not protect the membranes properly. Operational issues and increased maintenance time and costs are often the result of membrane fouling caused by poor screening performance. MBR plants are operated with a higher SRT than conventional plants and this leads to increased accumulation of fine screenings in the membrane tanks. RAS screening with very fine openings is often discussed to fix the problem with the non-performing MBR screens. Also, often operators and engineers look at reducing the headworks screen opening size even further e.g. 1mm screening instead of 2 or 3 mm screening. Often existing hydraulics and channel construction prohibits going to a 1mm screen as capacity of the screen will be reduced considerably. However experience has shown that a properly working 2mm ROTAMAT® RPPS rotary drum screen can solve this issue and greatly reduce the amount of fine screenings accumulation in the membrane tanks. RAS rescreening will become obsolete with the right MBR screen.

One example of such a retrofit application is the LOTT Alliance Martin Way Water Reclamation Plant in Washington State. Huber was contacted to provide a proposal for either a replacement screen for the existing 3mm perforated band screen or a second fine screen keeping the 3 mm screen as pretreatment. The site originally was adamant to have 1mm screen openings and the screen to be able to partially rescreen RAS. Hydraulically this would have meant completely oversizing the fine screen resulting in several large diameter screens. Based on Huber's existing MBR installation experience and positive feedback from those installed sites, we convinced the site that 2 mm screening would be sufficient to protect the hollow fiber membranes. Some allowances for partial RAS screening were made during design, but Huber was convinced that RAS re-screening would not be required after the new screen was installed. The screen was installed as a tank mounted configuration in a small space in the grit treatment room. After it was installed chemical cleaning of the membranes decreased from once a week to once every three months. The site also increased average permeability by almost 40% (Koch, J., Hielema, E., McConkey, B. Saga of Two Screens, WEFTEC 2010).

MAINTENANCE

Regular maintenance of the MBR screen will assure that wear on the screen is reduced and reliable removal of hair and fibers from the influent before the membrane bioreactors is guaranteed.

Making sure that channel seals are not compromised over time is important to avoid any fine material bypassing into the MBR tanks. This should be checked by draining the channel and by inspecting the seals e.g. on an annual or semi-annual basis. Good indications of failing seals are also increased trash content in the mixed liquor over time. Some membrane manufacturers recommend or even require this mixed liquor testing on a regular basis (e.g. monthly) and tie their membrane warranty to certain trash content limits. Other simple tests which can indicate issues with screenings bypass and failing seals are the insertion of a fine mesh or perforated plate basket or pool strainer in the wastewater after the fine screens for a few minutes. Material collected in the basket or strainer should be visually inspected for its size. Fine fibers have the tendency to re-rope or get entangled to larger particles if the flow conditions are right. Also flexible material can be pushed through openings smaller than their size. However issues with seals will lead to visual detection of screenings bypass (particles larger than the screen opening).

Another important maintenance item is the weekly inspection of the screen drum surface and the spray bar pressure and pattern. Dirty wash water can lead to clogging of the spray nozzles or preceding water strainer. If the wash water pressure is too low the screen surface will not be cleaned properly which results in reducing the available hydraulic capacity and increasing the run-time of the screens. Typical run-times of the rotary drum screens depend on the drum size, the start level set-point and the design of the screen (flow and solids loading). They should be in the range of 4-8 hours per day on average. Long runtimes over several days in particular if the plant does not see a peak flow should be an indication that something is not correct and a visual inspection of the screen, channel in front of the screen, and level sensor(s) by an operator should take place.

CONCLUSION

The pretreatment system, in particular the fine screens, play an important role in protecting membranes, ensuring stable operation of the MBR stage, and reducing physical maintenance as well as chemical cleaning needs of the membrane units. Besides the opening size of the screen the screen cleaning system and seals are important features to consider during MBR screen selection. Proper sizing and design of the fine screens are key to a successful MBR screen application as fine screens are very sensitive to flow and solids variations and can be overloaded very easily. Screen manufacturers such as Huber have a long history in successfully protecting MBR plants worldwide for all large membrane suppliers and are continuously innovating their fine screen design to offer adapted solutions for different applications and hydraulic conditions.

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