

Mechanical treatment of wastewater prior to Marine Outfall

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Abstract

In contrast to biological treatment systems, the mechanical treatment of wastewater represents a fast to implement and cost-effective solution for the removal of undissolved matter from wastewater flows. New developments in the field of mechanical wastewater treatment can be tailored to meet specific cleaning targets and requirements situations. Especially the combination of very fine apertures (ultra-fine and micro screens) and precipitation/flocculation is able to significantly improve wastewater quality. A virtually solids-free effluent can for example be achieved with the use of micro screens (e.g. a disc filter) with apertures from 20 to 100 micron.

Keywords

Marine outfall; mechanical/chemical treatment; disc filter; drum screen;

1. GENERAL

The aim of a marine outfall must be the eco-friendly, economical and especially safe disposal of wastewater with an as minimal as possible impact on the sea. Marine outfalls should be regarded as a system comprising of three components: wastewater treatment, discharge and distribution. Wastewater treatment is always the first step of a marine outfall and sets the course for successful wastewater disposal. The importance of wastewater treatment is reflected in the fact that nowadays more plastic articles are discharged to the sea than fish is harvested.

Biological wastewater treatment projects are frequently put on hold due to their enormous investment costs, increased energy demand (high operating costs) and a high level of plant attendance required from operating staff. Mechanical treatment systems, in contrast, represent a fast to implement, cost-effective and safe solution for the removal of undissolved matter from wastewater flows. At present, mechanical treatment systems therefore are most commonly used as first step treatment with the aim to eliminate to the greatest possible extent the particulate material contained within raw sewage. Especially new developments in the field of ultra-fine and micro screening with very fine apertures of below 1.0 mm further improve the quality of discharged wastewater and can be tailored to meet various specific requirements.

2. AN OVERVIEW OF MECHANICAL WASTEWATER TREATMENT STEPS

The individual stages of mechanical solids/liquid separation are in most cases

- pre-screening (coarser and finer screens),
- fine screening (coarser fine screens, ultra-fine screens, micro screens),
- sedimentation.

The category of pre-screening units comprises of rack screens installed in the free flow cross section. Coarser or finer screens are available with different clear bar widths. Coarse screens have a clear bar width of 60 to 100 mm, finer screens of 20 to 7 mm. As the usually first step

of mechanical wastewater treatment, these screens remove coarse sanitary and plastic products and thus protect downstream treatment equipment.

Also fine screening systems are classified by their aperture according to DIN 19569, part 2:

- Coarser fine screens: $e \geq 1\text{mm}$
- Ultra-fine screens: $e < 1\text{mm}$
- Micro screens $e \leq 0.05\text{mm}$

In view of the new developments in the field of mechanical wastewater treatment, however, these screens should not only be classified by their aperture alone. Also screen geometry is a factor with significant influence on separation efficiency and throughput capacity. Two-dimensional screen designs, such as perforated plate or filter mesh, show considerable advantages over one-dimensional wedge wire screens. Due to the increased solids retention of perforated plate or filter mesh screens, their hydraulic capacity is lower than that of one-dimensional screens.

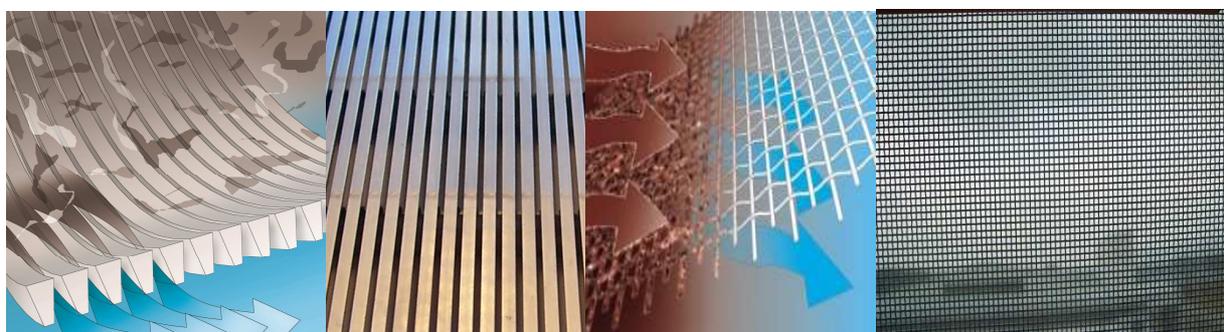


Fig. 1: Compared to one-dimensional wedge wire screens, two-dimensional perforated plate or mesh screens achieve a significantly higher separation efficiency.

Sedimentation processes are used in several stages of conventional wastewater treatment plants. The precondition for the applicability of sedimentation is a difference in density between solids (disperse phase) and carrier liquid (dispersion phase). Sedimentation is used in the grit traps, preliminary clarifiers and secondary clarification tanks of conventional sewage treatment plants.

3. MECHANICAL WASTEWATER TREATMENT ADAPTED TO SPECIFIC REQUIREMENT SITUATIONS

3.1 Removal of sanitary and plastic products

If the receiving water body is able to cope with high organic loads and ensure the distribution and quick dilution of the discharged wastewater, the wastewater treatment systems for marine outfalls are in most cases only required to remove coarse material, such as sanitary and plastic products.

The process technology of such treatment plants consists in most cases of:

- coarse screening
- grit trap
- and fine screening

Examples of plant installations can be seen at Cartagena (Colombia), La Taboada (Lima), or Coquimbo (Chile).

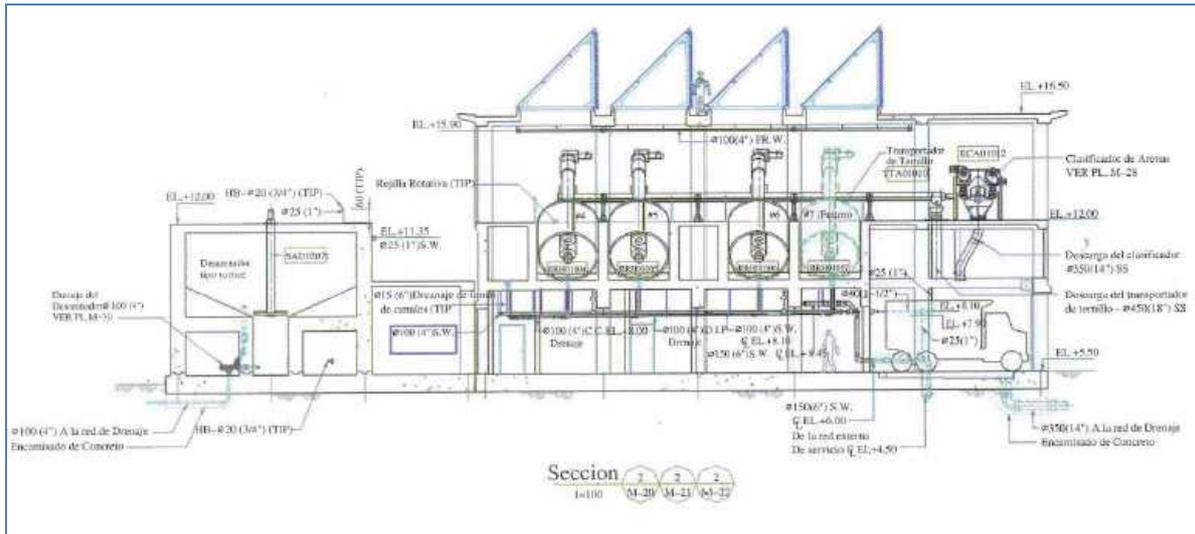


Fig. 2: Detail view of the Cartagena plant in Colombia with grit trap and 6 fine screens with 2600 mm diameter and 1.5 mm aperture

Coarse Screen

In most cases step screens or multi-rake bar screens are used for coarse screening. Due to its screen rack cleaning design the multi-rake bar screen can easily be adapted to meet different transport requirements. There is a positive effect especially with high pollution loads due to the possibility to variably adapt the cleaning elements and achieve optimised screenings discharge capacities individually for each application. In the majority of cases the aperture of coarse screens ranges between 12 and 6 mm. Screenings treatment is achieved by means of separate downstream wash presses. The recommended solution is to discharge the generated screenings to a launder channel and transport them along with screened wastewater to the screenings treatment units. Screenings transport via launder channels is significantly cheaper with lower maintenance requirements than screw conveyor solutions. The launder channel flushes the screenings into the wash tank of the screenings wash press. To minimise disposal costs, the wash press should offer integrated, specific organics washing. The dewatered screenings with a dry residue of up to 50% are preferably landfilled.

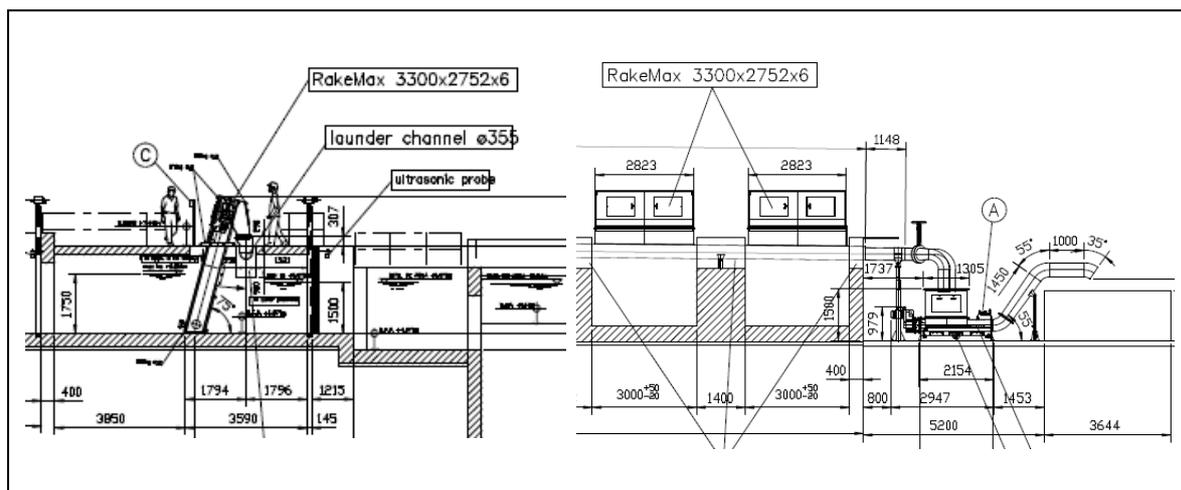


Fig. 3: Multi-rake bar screen, launder channel and screenings treatment system of the La Taboada marine outfall

Grit Trap

A grit trap is installed downstream of the coarse screen. Grit trap types are basically divided into circular and longitudinal grit traps. Grit removal is applied to eliminate wear of pumps and pipelines and prevent clogging and silting of the plant. In circular grit traps, as used for the Cartagena marine outfall, the screened wastewater enters the grit trap as a tangential flow at the grit trap bottom. Due to the rotational movement generated inside the grit trap the grit is separated from the wastewater. Centrifugal or airlift pumps are used to deliver the collected solids from the grit collection tank into grit classifying or washing plants.

Fine Screen

The basic element of the mechanical treatment system of a marine outfall is fine screening. Fine screens used for this purpose normally have a bar spacing between 1.5 and 0.75 mm. The average reduction of COD load and filterable solids achieved by a 1.0 mm screen is 5 to 10% or 10 to 30%. The screen type most frequently installed for this purpose is the ROTAMAT[®] Rotary Drum Fine Screen Ro2. The special design feature of this screen is the arrangement of its bars as a screening basket installed in the liquid flow at an angle. This basket design permits to combine the screen with other process technologies, such as screenings washing and dewatering in one machine, whereas conventional systems require the installation of additional components.



Fig. 4: The rotary drum fine screen with 1.0 mm wedge wire combines in one unit the process steps of screening, screenings transport and dewatering. The picture on the left side shows some of the ROTAMAT[®] Rotary Drum Fine Screens Ro2 with 2600 mm diameter and 1.5 mm screen aperture installed at the waste water treatment plant in Cartagena (Colombia).

Furthermore, due to the inclined installation of the screen basket, an overproportionally larger screening surface can be submerged and utilised with rising water levels. Compared with the submerged screen area of conventional rack / wedge wire screens where the screen has a linear shape the moistened mantle area of the inclined screen basket is much higher. Based on this greater flow velocities will occur in between the racks / wedge wires of conventional systems resulting in the acceleration especially of fibres and bristly substances that will then be pulled through the screen. With the ROTAMAT[®] fine screen this effect is not given due to the increased screening area and the diversion of the flow between the wedge wires. Due to the fact that the screening surface is overproportionally growing with the rising water level the flow velocity through the screen basket gaps is low with the result of improved separation efficiency and lower hydraulic losses compared to other systems. Another big benefit of the ROTAMAT[®] fine screen is the construction of the wedge wire. The vertical sectional view through the wedge wire of the ROTAMAT[®] fine screen illustrates the V-shaped widening in the direction of the flow. The V-shape enhances a very good liquid throughput leading to lower losses due to pressure even with high throughputs. In addition wedging in of grains with critical sizes can be nearly ignored due to the V-shapes. Consequently, the V-shaped

wedge wire can be cleaned without problem. Conventional screen systems doesn't use this V-shaped wedge wires and therefore often have problems that grains or screenings with a critical size gets wedged into the screen and block the screen area. The stainless steel wedge wire and the wire-welding construction of the ROTAMAT® fine screen guarantees high mechanical strength, operating safety and a long life time which plastic wedge wires can't achieve.

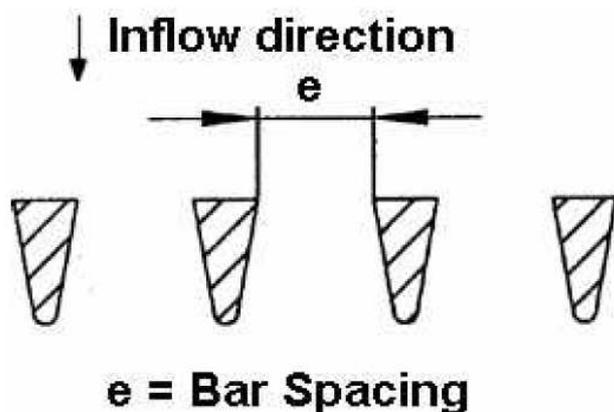


Fig. 5: Vertical sectional view through a wedge wire of the ROTAMAT® fine screen

As an option, especially for smaller marine outfalls, fine screening and grit removal can be combined in one single unit. Such compact units can additionally be equipped with integrated screenings washing as for example in the Coquimbo marine outfall project in Chile.

The installation of some examples of the above described technology has recently been completed or is going on at present:

- La Taboada (Lima): coarse screening system consisting of 8 RakeMax® Multi-Rake Bar Screens, 3300 mm length, 2752 mm width, 6 mm screen aperture; screenings treatment system with launder channel and connected HUBER Wash Press WAP-SL; fine screening system with 22 ROTAMAT® Rotary Drum Fine Screens Ro2 units with 3000 mm diameter and 1.0 mm aperture
- Split (Croatia): coarse screening system consisting of 2 ROTAMAT® Ro1 Rake Screen with diameter 2000 and 10mm aperture; fine screening system with 2 ROTAMAT® Rotary Drum Fine Screens Ro2 units with 2400 mm diameter and 2.0 mm aperture
- Gisborne (New Zealand): fine screening system with 3 ROTAMAT® Rotary Drum Fine Screens Ro2 units with 1600 mm diameter and 1.0 mm aperture
- Cartagena (Colombia): fine screening system consisting of 6 ROTAMAT® Rotary Drum Fine Screen Ro2 units with 2600 mm diameter and 1.5 mm screen aperture
- Coquimbo: 6 ROTAMAT® Complete Plant Ro5 units equipped with a ROTAMAT® Rotary Drum Fine Screen Ro2 each, 1200 mm diameter, 3 mm aperture
- Santos Lote 2 and Lote 3 (Brazil): coarse screening system consisting of 8 HUBER STEP Screens Flexible SSF-HF, length 3500mm, 826mm width, 6mm screen aperture; fine screening system consisting of 4 ROTAMAT® Rotary Drum Fine Screen Ro2 units with 2600 mm diameter and 1.5 mm screen aperture and 2 ROTAMAT® Rotary Drum Fine Screen Ro2 units with 2400 mm diameter and 1.5 mm screen aperture

3.2 Finer screens for higher effluent quality requirements

Where effluent quality requirements are higher due to sensitive or already heavily loaded waters and fine screens are insufficient, ultra-fine screens are used to clarify the water. These screens are equipped with a two-dimensional screening surface, i.e. a mesh or perforated plate. Contrary to one-dimensional screening elements, such as a wedge wire, the apertures of a mesh or perforated plate are defined in two directions. This gives a defined separation size and ensures extensive removal of solids. Very fine screen openings from 0.2 mm to 1.0 mm are necessary to separate high oxygen-consuming loads. Despite their fine apertures, especially machines with a filter mesh are able to cope with high throughputs due to the large free surface offered by the mesh. Screens with mesh sizes from 0.2 mm to 1.0 mm achieve a COD reduction of up to 30% and AFS reduction of up to 60%. The higher the ratio of undissolved / dissolved COD, the higher is COD separation efficiency as only undissolved substances can be removed if no chemicals are added.

Well-proven screens have an installation angle of 30°, or are horizontally installed drum screens. They are often used as preliminary screens for membrane wastewater treatment plants, primarily for the removal of hairs and fibres which otherwise could cause severe problems in the downstream membrane plant. The screenings separated by such very fine screens consist of significantly smaller particles than screenings from coarser screens and can even be composted if sanitary and plastic products have been removed by an upstream preliminary screen.



Fig. 6: ROTAMAT[®] Membrane Screen RoMem and ROTAMAT[®] Rotary Drum Screen RoMesh with 0.2 – 1.0 mm mesh size. The picture on the right side shows 16 ROTAMAT[®] Rotary Drum Screen RoMesh units with 1600 mm diameter, 3000 mm length and mesh opening size 0,2mm which were installed and operated during the Olympic Games in Beijing.

The performance of the screens can be increased if chemicals are added. Especially if there is the danger of eutrophication of the receiving water body due to the high amount of discharged nutrients, COD and phosphorus in the effluent can further be reduced by adding precipitants and flocculants. Precipitation is the conversion of dissolved components (mostly ionic) contained in wastewater into a particulate form in a chemical reaction. The dissolved matter is converted into hardly soluble substances that can be converted into mechanically separable particles (macro flocs) through addition of flocculants. Controlled coagulant agent addition is achieved by means of a dosing station which adjusts the amount of coagulant agent to the required coagulation result. By addition of flocculants, filterable solids can be reduced by up to 95%, COD/BOD by 65 % and phosphorus by 60 %. Of course, operating costs rise in turn as chemicals are required and the screenings volume increases. On average, about 10-50 mg/l precipitants and about 10-15 mg effective substance of flocculants are required per litre of

wastewater. The wider the selected mesh size, the more flocculants are needed. The reason for this is that with a smaller mesh size the requirements of the floc in terms of stability and shearing strength are lower so that lower flocculant doses are sufficient.

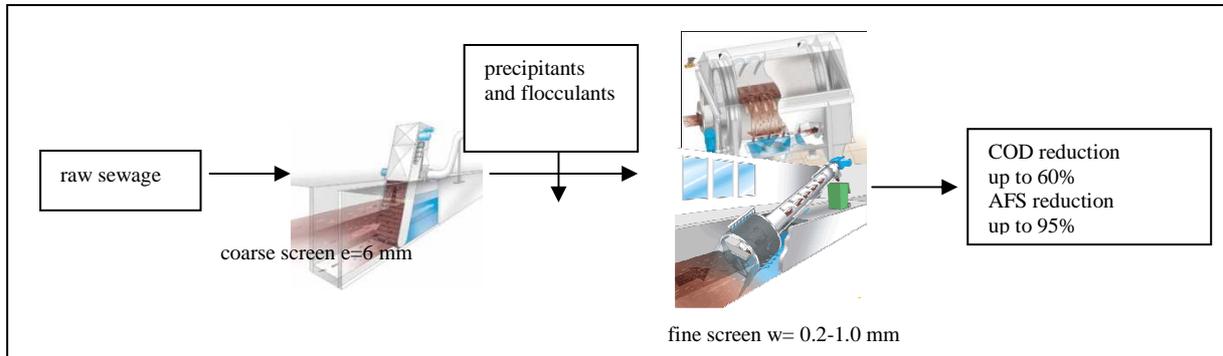


Fig. 7: Flow diagram of fine screening with addition of chemicals to increase separation efficiency

Such a system was for example used during the Summer Olympics 2008 in Beijing. It had soon become obvious that the existing sewage treatment plants would not be able to treat also the additional wastewater volumes expected to be generated during the Olympics. There were two options – either expand the existing sewage treatment plants or temporarily install systems for fine screening with flocculants. When the two options were compared, the installation of fine screening systems turned out to be the considerably cheaper solution in terms of purchase and operating costs. So, 16 ROTAMAT[®] Rotary Drum Screen RoMesh units with 1600 mm diameter, 3000 mm length and an opening size of 0,2mm mesh were installed and operated during the Olympic Games.

3.3 Micro screening

If a virtually solids-free effluent and as extensive as possible COD reduction is required, this can cost-effectively be achieved with the installation of a downstream micro screening plant. New technical developments allow for the use of filtration technologies known from tertiary wastewater treatment also for the purely mechanical treatment of wastewater. Filter disc technology is especially suitable for this purpose due to its simplicity, small space requirements, reliable separation performance and the large filter surface that allows for high throughputs. A solids reduction of up to 60-80% can be achieved with filter sizes as small as 20 micron.

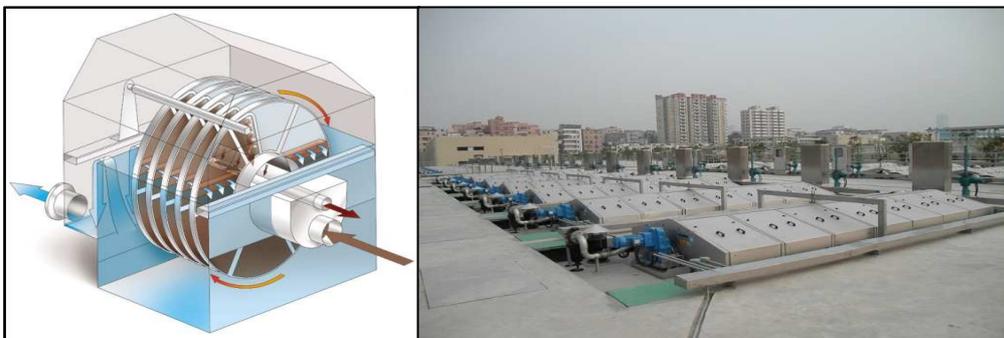


Fig. 8: Schematic drawing of a disc filter with the wastewater flow streaming through the screen surface from inside to outside. The picture on the right side shows one of the greatest disc filter installations worldwide. In summary 28 HUBER RoDisc[®] micro screen units were installed each equipped with 24 discs.

Combined chemical and mechanical treatment, i.e. with the addition of flocculants and use of micro screens, is able to reliably and cost-effectively achieve outlet concentrations of below 50 mg/l (and possible AFS reduction of 95%) even with screen apertures not smaller than 50 micron. Compared to the combined system of fine screening with the addition of precipitants and flocculants, the chemicals consumption of micro screens is significantly lower due to the much smaller filter size and therefore much lower requirements in terms of floc stability and shearing strength. The reduced chemicals demand in turn reduces operating costs compared to the combination of fine screening plus precipitation / flocculation. The chemical consumption of micro screening combined with flocculation varies between 1 and 8 mg/l depending on inlet concentration and filter mesh size. The general rule is that the higher the inlet concentration and the bigger the filter mesh size, the more chemicals are needed. Although the investment costs for micro screens are higher than for fine or ultra-fine screens, they are still lower than for biological treatment solutions.

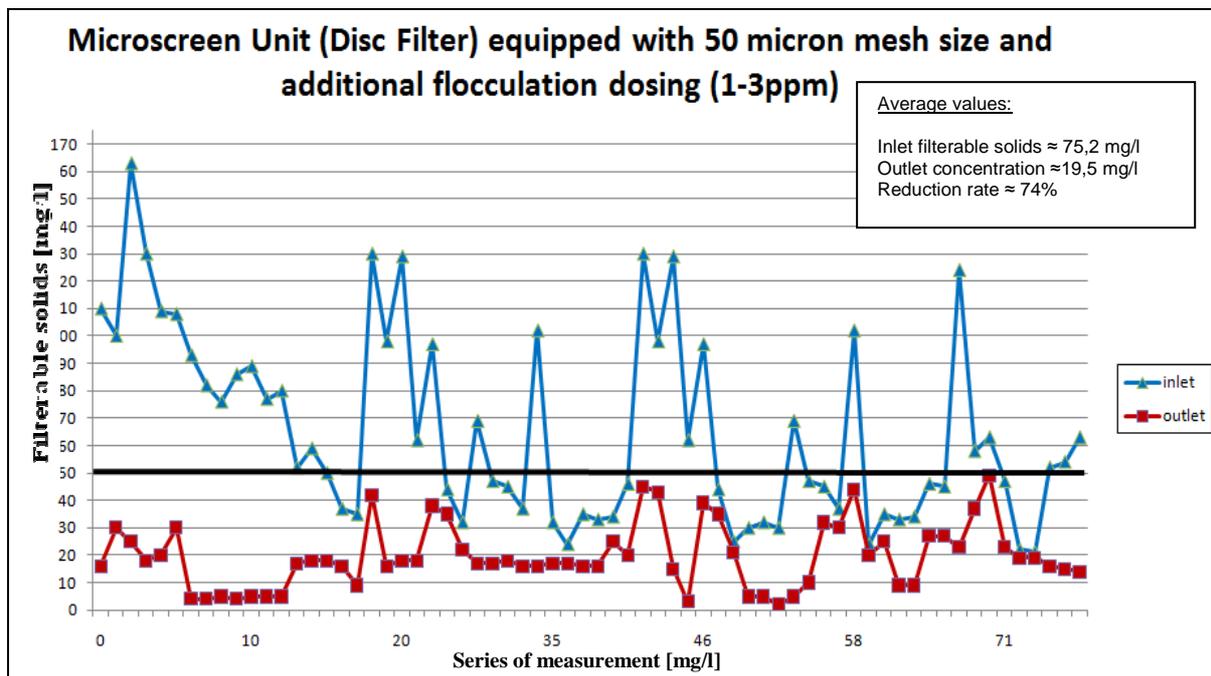


Fig. 9: Inlet and effluent values of a disc filter

This machine is installed downstream of a preliminary clarification tank and achieves a solids reduction of 74% with the addition of 1-3 mg/l flocculants. The average effluent concentration is 19.5 mg/l! The best effluent qualities have been achieved with the use of cationic polymer. In most cases, screenings separated by micro screens are removed as liquids with about 0.2% to 0.5% dry substance so that downstream sludge thickening is necessary. Other sludge treatment options are drying beds, anaerobic digestion or composting.

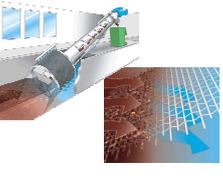
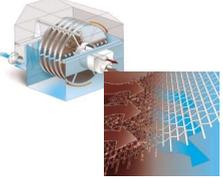
If especially high effluent hygiene requirements have to be met, downstream UV disinfection or chlorination can for example be added. Micro screening and disinfection provide for a sustainable, economical and feasible solution to environmental problems allowing for the optional reuse of the treated wastewater. The filtrate for example can be reused for irrigation purposes.

4. Conclusion

New concepts need to be developed in view of the fact that the biological wastewater treatment systems we know from industrialised countries are sometimes not suitable to solve the problems in coastal areas of developing and emerging countries. Biological treatment

systems are highly efficient in removing COD, BOD and nutrients, where required. But this efficiency comes at a high price and poor cost-effectiveness (e.g. expressed as COD removal capacity per investment sum). Simple and more cost-effective treatment technologies should be preferred as a first step. New mechanical wastewater treatment concepts are able to meet the requirements of adapted wastewater treatment solutions. A variety of mechanical wastewater treatment systems is available for different clarification requirements and intended purposes of use. Aside from that if later a biological wastewater treatment step should be added the mechanical treatment system is further on necessary as a pre-treatment step and is therefore anyway amortisable.

The range of available solutions includes systems for the separation of sanitary and plastic products but also for finer screening up to micro screening plants for the extensive removal of solids. A virtually solids-free effluent can be achieved if flocculants are added. Chemical consumption strongly depends on inlet concentration and screen apertures. The smaller the openings of the screening elements are selected, the lower is chemical consumption. Mechanical wastewater treatment plants offer the additional advantages of low investment and operating costs and low maintenance requirements compared to biological treatment systems.

Treatment technology	Screen aperture [mm]	COD reduction* [%]		AFS reduction** [%]		Screenings volume [l screenings per 1000 m ³ ww]	Chemical consumption [mg effective substance per litre ww]
		Without chemicals	With chemicals	Without chemicals	With chemicals		
 <p>Wedge wire</p>	1.5-1.0	5-10	-	10-30	-	150-250***	-
 <p>Fine screening (Mesh or perforated plate)</p>	1.0-0.2	10-30	30-55	30-60	60-90	300-500***	8-35
 <p>Micro screening (Filter mesh)</p>	0.1-0.02	20-40	40-60	60-80	70-95	300-550***	1-8

* Percentage COD reduction strongly depends on the dissolved/undissolved COD ratio of the wastewater to be treated.

** AFS reduction depends on particle size distribution. All specifications refer to common European wastewater.

*** The screenings volume refers to 25% DR and is proportionately spread on the individual treatment stages if a pre-screening system is installed, with a significantly higher solids removal of fine / ultra-fine screens compared to coarse screens (approximate screenings volume ratio 4:1). Screenings separated by micro screens require additional treatment with thickening and dewatering machines to achieve 25% DR.

Fig. 10: Overview of treatment systems for different treatment stages and their approximate separation efficiencies

5. Literature

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