SCREEN EVERY DROP!

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Abstract

Microscreens also known as Rotating Belt Filters (RBF) are a keystone technology in wastewater treatment with multiple advantages improving the operation of wastewater facilities. These advantages are especially noteworthy in facilities utilising Biological Nutrient Removal (BNR) and include improved treatment efficiency compared to conventional primary clarification, smaller footprint, biological augmentation with improved nitrification rates, reduced odour, lower total CAPEX and lower overall OPEX. The prevalence of microscreen use is growing in the UK and throughout the world, with hundreds of plants taking advantage of the benefits of this technology. A detailed evaluation of this technology is useful to consultants considering facility upgrades and microscreen design options that will have a more positive lifecycle benefit compared to alternatives. This evaluation, how microscreens compare to conventional primary treatment, and the associated impacts on secondary treatment are presented in this paper.

Keywords

Eco MAT, Grit Removal, Headworks, Microscreen, Primary Filter, Primary Treatment, RBF, Screen.

Introduction

An effective equivalent to screening and primary clarification, microscreens also known as Rotating Belt Filters (RBF), enable a treatment design in a minimal form factor with significant capital and operating costs savings. Ancillary benefits effecting economics of sludge management, augmentation of secondary biological treatment, and reduction of carbon footprint at wastewater reclamation facilities have been observed and measured in several cases throughout the world (Rusten & Ødegaard 2006).

Screening is important with all biological treatment systems. To advanced media systems, such as an IFAS processes, biological contactors, or membrane plants, effective screening is critical. Grit, rags, and hair are extremely detrimental to the vessels and features of these treatment systems. Grit chambers and bar screens certainly help, but often come up short in preventing irreversible fouling and damage to media and membrane modules. A more effective solution is necessary, and microscreens certainly have the capability to further alleviate the conditions leading to failure in biological media systems (Rusten & Lundar 2006).

The prevailing drivers for rethinking conventional settling and clarification include the massive footprint of settling, the cost of excavation and concrete works, reliability and quality of treatment, and the power demands for operations. Upgrades, including the expansion of design flow to the facility or process redesign to incorporate biological nutrient removal (BNR) are examples of situations that would benefit from a more foot-print-friendly technology. Availability of land is a factor that if considered alone can often make or break the feasibility of wastewater system upgrades or expansions (Nussbaum 2006). Many plant expansions are halted, slowed, or come with astronomical costs due to lack of space. Conventional sedimentation is a simple design but is land hungry, inflexible, and costly to install.

Several studies have emphatically demonstrated that primary treatment is not merely an option for wastewater treatment sites, but comes with defined benefits to the downstream biological plant (Razafimanantsoa 2014a & b; Paulsrud 2014; Jimenez 2014). The positive environmental impact potential is shown in all models to date, and is usually accompanied by an economical benefit as well.

Keeping in mind the limitations of conventional the primary treatment clarifier there are many technical and commercial reasons that engineers consider before implementation of microscreens. The microscreen require 5 percent of the footprint of a conventional clarifier and offers higher and more customizable levels of primary treatment. Not only can microscreens meet the treatment capacity in a smaller footprint as is apparent in Figure1, but N+1 redundancy with conventional clarifiers can certainly balloon project cost whereas with the microscreens redundancy is more economically feasible. Figure1 illustrates the relative footprint savings of microscreen technology when compared to conventional primary clarification of the same performance capacity; the rendition illustrates a nominal 12,000 m^3/day treatment capacity footprint.

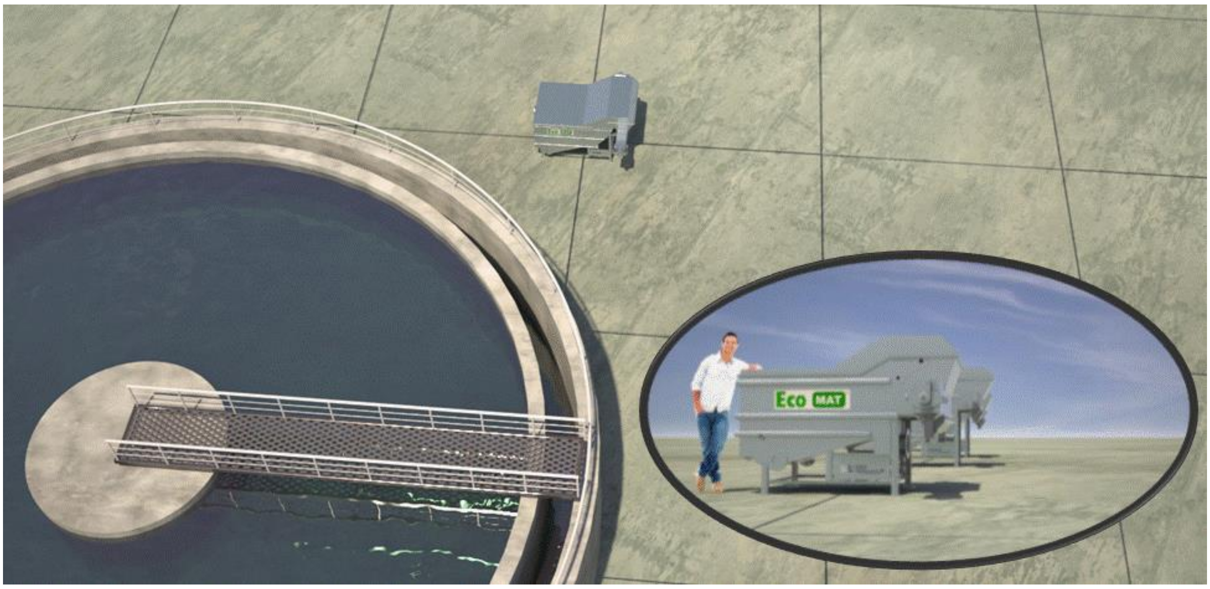

Figure 1: Microscreens are less than 5% of the footprint of conventional clarifiers.

Design Engineers often recommend microscreens as the site upgrade solution to screening and primary clarification at wastewater treatment facilities. The situations for implementation of microscreens are varied and include retrofitting treatment works that have no primary treatment works, storm water overflow, re-allocating primary sedimentation footprint to expand secondary treatment. On designing a new treatment works where space is a limited resource engineers have selected microscreens got primary treatment. The microscreen can be easily integrated on the treatment plant to gain treatment capacity by reducing the COD/BOD on the biological process. The microscreen strategy is being considered and applied throughout the Europe, the Americas, the South Pacific, and Asia.

Designing microscreens as primary treatment in new plants will save capital expenditure in equipment and civil works. The compact footprint of microscreens leads to potential savings in engineering, excavation, concrete, piping, scheduling, and many other aspects of the capital project. In many cases the capital studies shown microscreens to be between 25% of the conventional primary clarifier install cost. Where redundancy requirements are assessed there are significant commercial savings. Case histories also reveals that the operating cost is lower due to overall lower energy input. Even without consideration of the ancillary benefits, basic lifecycle cost analysis shows the microscreens beating conventional screening and clarification on direct costs alone.

Studies on ancillary economic impact are in progress to assess the total economic impact of microscreens. These studies include analysing the cost/benefit of the more effective COD removal, hair and grit capture inherent to the microscreens. An aspect of treatment with RBFs is that the technology provides a physical rather than hydraulic sequestration of particulate. The presences of hair in the secondary can create operational havoc in the secondary process. A range of activated sludge and fixed film secondary systems benefit from the mitigation of hair, as do membrane systems in particular. Reducing or eliminating the costly replacement of membrane modules or of media modules within the secondary and tertiary treatment systems appear having the potential of eliminating up to 50% of the annual OPEX for certain types of wastewater treatment subsystems, i.e. membranes. Multiple membrane manufacturers around the world are transitioning to RBFs for primary and pretreatment in membrane plants to extend membrane life.

Multiple engineering firms around the world have had an opportunity to study the umbrella of primary treatment technologies. Use of microscreens as an accepted solution for primary treatment is accelerating globally. There are several distinct challenges in screening and clarifying wastewater in municipal and industrial applications for which microscreens provide a ready answer, and their prevalence is particularly strong in Norway and Scandinavia countries. Over the past two decades microscreens have been erected on every major continent. With hundreds of plants around the world utilizing this technology, it is worthwhile to take a closer look at the design considerations.

Method of Treatment

Microscreens remove solids from wastewater through the use of a continuous-loop fine mesh belt screen. A side-view sketch of an RBF unit is shown in Figure 2. The belted screens move linearly, directed by filter headloss input to a programmable logic controller. As the screen moves, it acts as a conveyor and carries captured solids out of the incoming wastewater. A capable cleaning system is a critical aspect of the microscreen, as the integrated cleaning system is responsible for removing collected solids and providing a clean surface for treating incoming water.

Solids from the belt screen are discharged and deposited into a screenings hopper. Modern microscreens use a doctor blade as a minimal energy cleaning device for discharging the solids while an intermittent high-pressure water spray is use to dislodge the remaining solids off the belt and remove FOG. The doctor blade cleaning method has proven highly effective over older designs incorporating air backwash techniques, which tend to congeal the oil and greases right into the pores of the belt. Air cleaning also requires 400% of the energy input compared to systems using doctor blades due to the high volume of air needed. A modern microscreen design should use the latest technologies for minimizing energy input and overall carbon footprint.

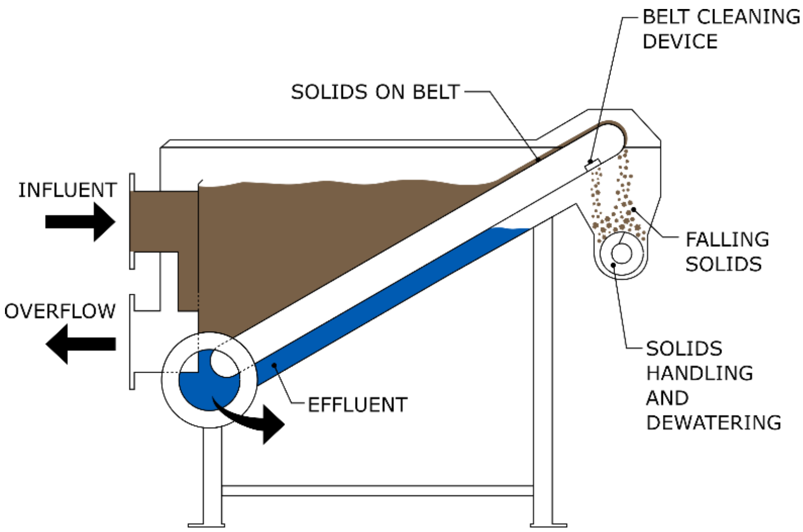

Figure 2: A generic steel-enclosed RBF configuration.

The RBFs remove between 30-80 percent total suspended solids (TSS) and 15-50 percent particulate Biochemical Oxygen Demand (BOD) from wastewater and the unique design allows for removal of organic and inorganic solids as fine as 15-50 micron. This economical filter mat of solids on the mesh is responsible for the high solids capture rate and efficiencies in removing particulate BOD. The thickness of the solids mat on the filter mesh and the removal efficiencies are affected in part by the ability to vary the belt speed. A slower belt speed results in higher capture rate of solids, creating a porous mat that not only results in a lower TSS effluent, but also shifts the particle size distribution for removal of smaller particulates. At higher belt speeds, the opposite effect seems to correlate; furthermore, the ability to control the belts' speed and porosity allows a relative customization of a particular unit efficiency to increase the beneficial effects to downstream biological digestion processes. The microscreen units are compact, completely enclosed, low-maintenance solutions for wastewater. The integral odour containment of the design allows for indoor installation in a clean environment, and some models are even designed for food-grade compatible maintenance. Manufacturers in the industry offer standard equipment, ranging in sizes suitable for small communities to large cities. The modular nature of the technology means that there is no limitation in flow capacity designs.

An integral dewatering screw press is a sludge management option on many smaller wastewater systems with total flow < 20,000 m3/day, whereas larger facilities can often utilize anaerobic digestion of captured solids in an effort to approach net-zero energy use on the facility. When integral dewatering is advantageous, the sludge discharged to the microscreen hopper is collected and conveyed through a compactor where the sludge is compressed to between 20-40 percent Total Dry Solids (TS), while screened wastewater continuously passes through the unit (Nussbaum 2008). Some larger facilities that incorporate anaerobic digesters in site works will omit dewatering and find it advantageous to convey the solids slurry discharged from the microscreens directly to Anaerobic digesters. This is a green, environmentally conscious arrangement where economically feasible.

In selecting microscreens special attention should be paid to the automation, design for safety, and ease of maintenance. There are many installations and pilot project assessments that have compiled design considerations for this purpose (Porter 2015). A microscreen should have the following noteworthy features:

1. Flow and overflow sensing for wastewater and sludge
2. A wall-flush sensor that will not be fouled or give false reasons due to rags or organic matter

3. A self-flushing screening system for wash water so as to keep debris from plugging spray bar nozzles
4. An effective, intuitive operator interface
5. Separation of primary sludge and inorganic screenings.
6. An effective, proven sludge management system
7. A safe efficient design for removing the microscreen cassette for maintenance of the belt.
8. Safety shrouds encompassing rotary features and safety interlocks on non-fixed access panels
9. Explosion proof motor and electrical design where appropriate
10. Redundancy considerations per the site requirements to maintain treatment goal

Discussion – An Illustrative Case Study

A plant-modelling study was conducted during the summer of 2014 in Largo, Florida, USA, to test the effects of replacing the existing primary clarifiers with microscreens. The objective of this evaluation was to provide recommendations for process improvements to the Largo Wastewater Reclamation Facility (WWRF) to increase system efficiency, reduce operating costs, and restore system reliability. The facility's long-term plan is to use the solids captured by a microscreen in a fermentation reactor to provide additional readily available substrate for the BNR process or send it to a sequencing facultative digestion process. The space currently occupied by the existing primaries will be re-allocated to secondary treatment. The results of the assessment and subsequent recommendations will be used as the basis for planning future capital improvement projects for the City of Largo.

The WWRF has a permitted daily capacity of 68,400 m^3/day annual average daily flow. The facility utilizes an Anaerobic/Anoxic/Oxic (A^2/O) BNR process followed by denitrification filters to achieve Advanced Wastewater Treatment (AWT) requirements for low nitrogen discharge. Treated effluent can be discharged to a surface water outfall and to a reclaimed water distribution system. Process modelling was conducted to evaluate options for improving nutrient removal within the A^2/O process with the primary goal of minimizing nitrate/nitrite (NOx-N) loading on the deep bed denitrification filters to reduce annual methanol usage. Reducing the nitrogen load to the deep bed filters will reduce operational costs and assist the City of Largo in meeting the strict effluent nitrogen limits economically.

The WWRF is a BNR facility that historically achieves very low TN concentrations. Historical data from January 2009 through December 2012 were evaluated to develop design influent flow, concentrations and loads. Historical effluent NOx-N and TN are shown in Figure 3. Effluent TN has consistently remained around 2.5 mg/L, and rarely peaked above 3.0 mg/L.

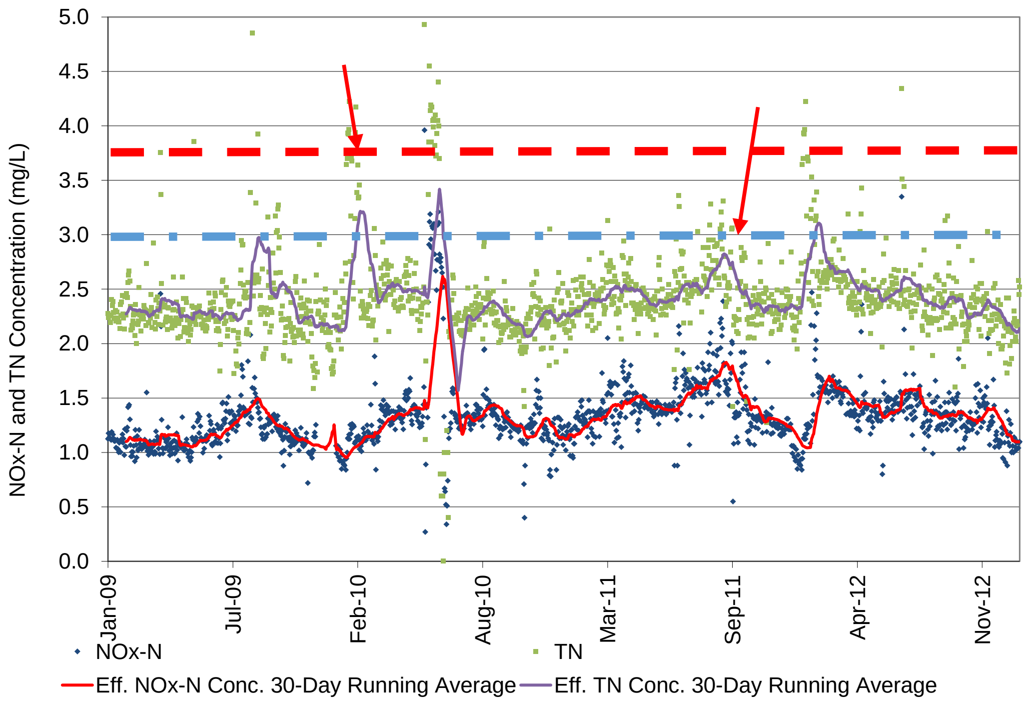

Figure 3: Historical Effluent NOx-N and TN Concentrations

A process model was previously developed for the WWRF using BioWin process simulation software. The model was calibrated and verified based on detailed wastewater sampling and plant operational data from March through to April 2008. Hazen and Sawyer and the City of Largo performed additional sampling on the 5th and 16th of April was used to update the BioWin model along with recent operational data. Dynamic simulations were performed for calendar year 2012 using daily influent and operational data. The process model accurately simulated MLSS and RAS solids concentrations from the middle of August 2012 through December 2012. The model underpredicted solids production prior to this period, mainly due to inaccurately reported wasting rates and solids concentrations. Once the City improved their wasting practices around August 2012, better correlation with the model was observed.

Nutrient Removal Improvements

The calibrated process model was used to assess potential alternatives for improving total nitrogen (specifically nitrate) removal in the secondary process. Decreasing nitrate in the secondary effluent will reduce the methanol feed required to the deep bed denitrifcation filters, resulting in significant operational savings.

The secondary process is currently configured as an A^2/O process, and a diagram of the current configuration is shown in Figure 4. The existing anoxic volume limits the potential for denitrification in the secondary process. Furthermore, the location of the nitrified recycle (NRCY) return discharge in the first anoxic zone is towards the end of the zone, resulting in limited denitrification capacity in the first anoxic zone. Backmixing from the aerobic zone was observed in the anoxic zone during site visits, further suppressing denitrification potential.

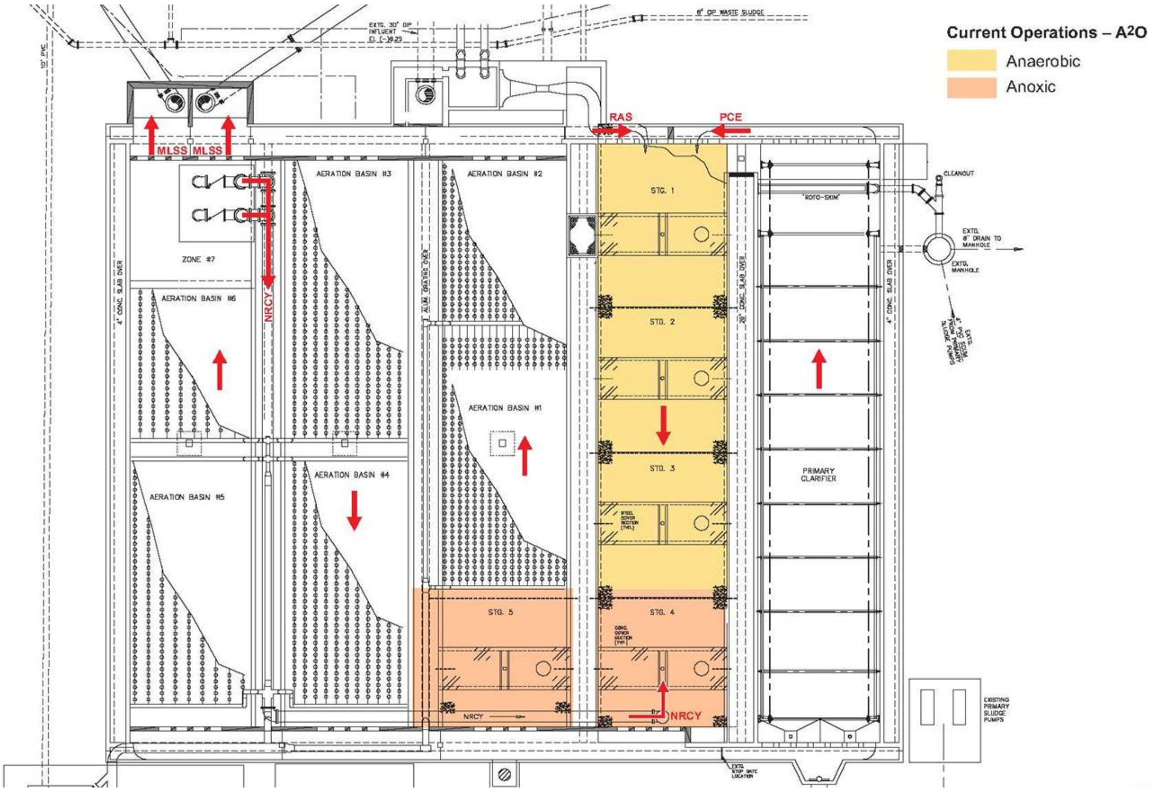

Figure 4: Current Process Configuration

Several alternatives were evaluated to increase denitrification through the aeration basins while maintaining full nitrification and biological phosphorus removal. One of these alternatives (**Error! Reference source not found.**5) includes increasing the treatment capacity by converting the integral primary clarifiers into A^2/O process volume. New primary clarifiers would be constructed. Mixers would be added to the converted primary clarifiers, and the volume would be turned into an anaerobic and anoxic zone. A baffle wall would be added in the middle of the converted clarifier to separate the anoxic and anaerobic zones, and the NRCY line would be extended to the head of the anoxic zone. This option could also include converting aeration basin 1 into a swing zone to increase process flexibility. Baffle walls would be added at the end of aeration basin 6 in order to reduce oxygen carry over to the NRCY pump inlet. RAS would be pumped from the secondary clarifiers to a point downstream of the new primaries (before entering the secondary process) in order to homogenize the primary clarified effluent and RAS before it enters the A^2/O basin.

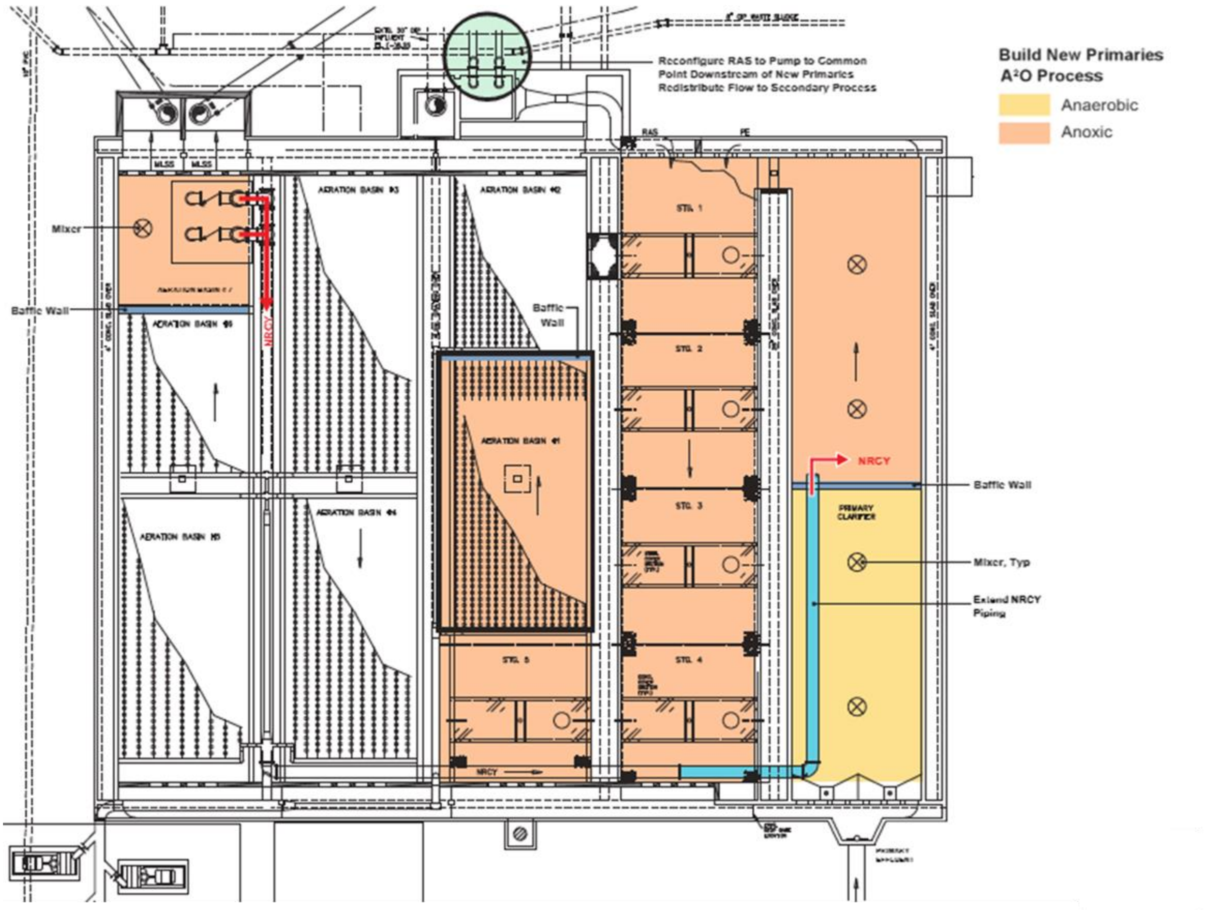

Figure 5: Proposed process configuration.

Of all the options considered, conversion of the existing primary clarifiers to A^2/O process volume provided for the lowest secondary effluent nitrate and total nitrogen concentrations. This will result in a reduction in methanol usage in the denitrification filters of at least 265 m^3/year. However, elimination of primary clarification resulted in excessive MLSS concentrations (near 7,000 mg/L as opposed to approximately 3,500 mg/L with primary clarification). A secondary clarifier evaluation performed as part of the Master Planning effort for the WWRF indicated that MLSS concentrations should be maintained below 4,000 mg/L.

For this alternative to be implemented, a low footprint, affordable alternate technology for primary clarification is needed. One option is to install microscreens to replace the primary clarifiers. It was recommended to pilot test this technology to determine the feasibility of using this process.

Pilot Testing

An Eco MAT microscreen was pilot tested from the 24th to the 27t June 2014.

Microscreens are manufacturered by Blue Water Technology in various sizes with the hydraulic capacity of the largest units being about 13,000 m^3/day depending on efficiency targets and inlet solids concentrations.

Process removal efficiency is driven by the microscreens ability to build a porous mat of primary solids on the screen (Figure 6), which can filter and sequester particles much smaller than the bare screen sieve. As filter mat is formed the screen speed is varied by a controller based on headloss. The screen acts like a conveyer carrying solids out of the incoming wastewater. A screen cleaning system discharges and deposits the filtered solids into the sludge hopper while minimizing any solids carry-over. Periodic degreasing cycles further clean the screen by removing oil and grease that may accumulate over time.

Figure 6: The solids mat discharging from a microscreen.

An Eco MAT model EM-3 was operated during the pilot with an influent pump capable of flows up to 1,360 m^3/day. At 1,360 m^3/day the EM-3 operated at 55% belt speed. Hourly grab samples were collected on process influent and effluent streams while composite solids samples were collected from the discharge of the conveyance screw. The samples were analysed for TSS and BOD by Southern Analytical Laboratories Inc. located in Oldsmar, Florida, and the results are summarized in the following tables and figures.

Table 1: TSS and BOD Date from the Eco MAT Pilot.

Date	Sample Time	TSS (mg/L)			BOD_5 (mg/L)		
		Influent	Effluent	Removal	Influent	Effluent	Removal
Average 350 µm Belt		472	84	76.8%	289	81	60.0%
Average 250 µm Belt		228	73	67.5%	319	130	54.0%

Table 1 demonstrates the effectiveness of the Eco MAT RBF in meeting the numeric performance criteria required for the project. The RBF operated by Blue Water met all process objectives. The following were demonstrated through equipment operation and data collection:

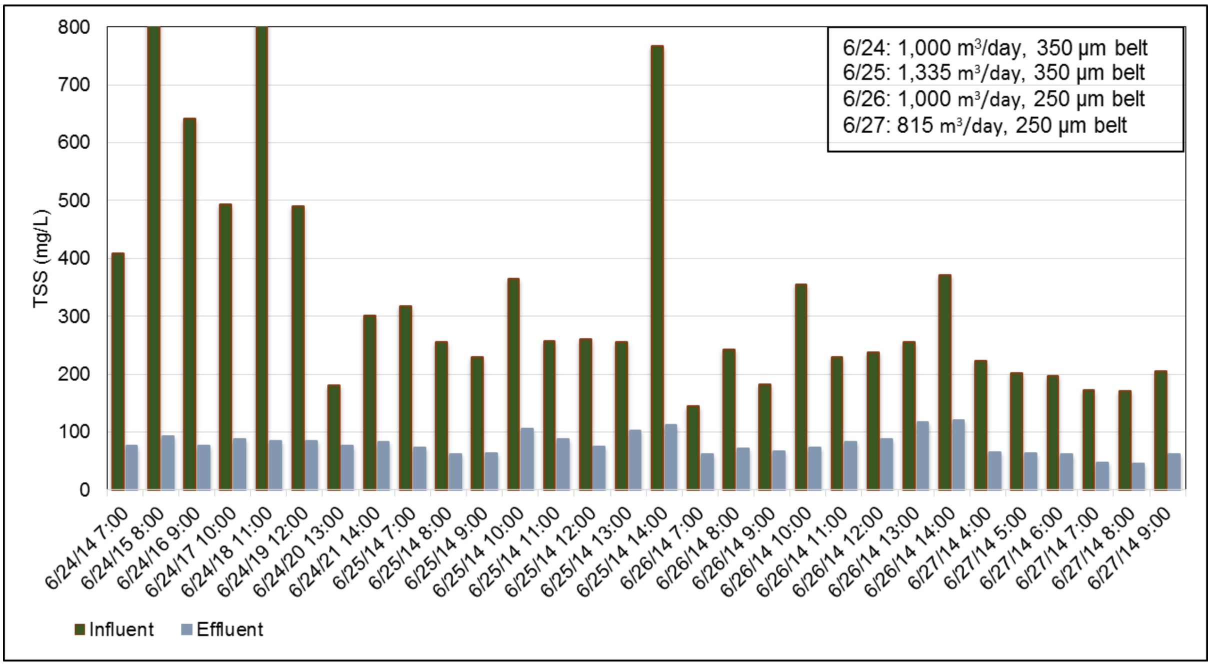

Figure 7: **TSS removal during the Largo pilot operations.**

The pilot data illustrates that the microscreen balances the TSS and BOD going to the activated sludge process by dampening peaks and valleys in the site inlet wastewater strength. When the wastewater strength and flows are lower, lower efficiency in TSS and BOD removal is observed. The screening and clarification occur consistently. Inversely, the TSS and BOD removal efficiency is higher when the wastewater strength is higher.

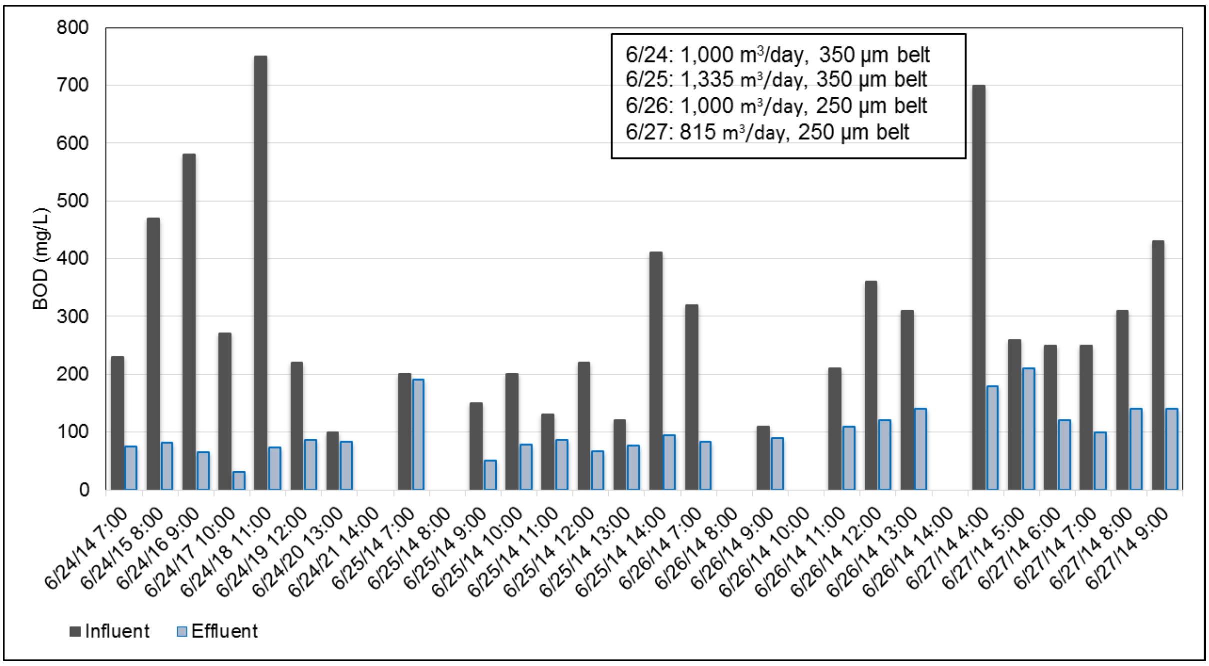

Figure 8: **Particulate BOD removal during the Largo pilot operations.**

It is noteworthy that only particulate BOD was removed. Soluble BOD fractions were sampled daily with no measurable removal. This is a critical observation for the BNR process as particulate (inaccessible) BOD does not lend itself to efficiency in the BNR process.

Microscreen design parameters can target removal efficiencies between 30-80% TSS and 20-50% BOD. There are several variables that affect microscreen operating efficiency including the belt sieve selection, hydraulic loading, and TSS size distribution and loading. It is difficult to isolate individual variables, especially the screen sieve impact on TSS capture efficiency without operating machines in parallel with different sieves. When this was done the following data was compile:

- TSS removal efficiency was strongly correlated to belt sieve size:
  - Average of 64.9% removal with a 250µm belt.
  - Average of 55.1% removal with a 350µm belt.
  - Average of 22.4 % removal with a 500µm belt
- Particulate BOD removal trended with the TSS removal:
  - Average of 38.1% removal with a 250µm belt.
  - Average of 17.5% removal with a 350µm belt.
  - Average of 7.69 % removal with a 500µm belt.

Following the pilot testing, additional process modelling was performed using the calibrated BioWIN model to evaluate the predicted plant performance with the process modifications as shown in Figure 5 and new microscreens. The primary goal is to reduce secondary effluent NOx concentrations while keeping the mixed liquor suspended solids concentration in the process basins near current levels. The data set revealed that the new configuration will significantly reduce the secondary effluent NOx concentrations as compared with the current system during annual average plant capacity flows (50% reduction) and wet weather peak equalized flows. As a result, these filters will accommodate the plant process design modifications to reduce annual supplemental carbon costs while not overloading the secondary clarifiers.

Additional Observations

An intuitive operator interface, access to critical control elements, access to cleaning devices, and an effective cartridge management system are all critical to a robust RBF system. The simplicity of the RBF primary clarifiers makes them amenable to operators for maintenance. All RBFs use a periodic hot water wash for degreasing. Onsite workshops during the Eco MAT pilot allowed operators and engineers to interface with the system controls and observe the basic maintenance and cartridge management protocols required for normal operation.

Microscreens using blowers for belt cleaning had lower throughput in general. One hypothesis was that the blower congealed the fats, oils, and greases on the belt, thereby blinding the openings. More frequent hot water washes were required to maintain capacity.

Table 2 includes an economic analysis that is largely representative of RBFs available to the industry. For RBFs using blower systems for cleaning, the blower power must be added to the tabulated power values for accurate assessment of those systems. RBFs also have potential as a retrofit solution to existing facilities, thus the installation costs can be lower in certain applications.

Table 2: Comparison of for RBFs vs Conventional Sedimentation.

	Plant Design Criteria	Conventional Primary Clarification	Mcroscreen/RBF
1,600 m³/day Plant Design	Area	49 m2	2.8 m2
	Required Total Concrete	84.1 m3	1.1 m3
	Cost for Concrete (€500/m^3)	€42,051	€573
	Installation (excludes excavation)	€235,000	€80,000
	Clarifier, 304SS with Half-bridge	€75,000	
	Microscreen, 304SS		€135,000
	Total Cost	*€352,051*	*€215,573*
	Total Power (Drive + Sludge Pump)	*7.1 kW*	*1.5 kW*
6,000 m³/day Plant Design	Area	263 m2	7.9 m2
	Required Total Concrete	267.6 m3	2.3 m3
	Cost for Concrete (€500/m^3)	€133,797	€1,147
	Installation (excludes excavation)	€350,000	€65,000
	Clarifier, 304SS with Half-bridge	€130,000	
	Microscreen, 304SS		€420,000
	Total Cost	*€613,797*	*€486,147*
	Total Power (Drive + Sludge Pump)	*11 kW*	*3.6 kW*
13,000 m³/day Plant Design	Area	591 m2	10.5 m2
	Required Total Concrete	458.7 m3	2.9 m3
	Cost for Concrete (€500/m^3)	€229,366	€1,434
	Installation (excludes excavation)	€475,000	€80,000
	Clarifier, 304SS with Half-bridge	€195,000	
	Microscreen, 304SS		€475,000
	Total Cost	*€899,366*	*€556,434*
	Total Power (Drive + Sludge Pump)	*13 kW*	*5.6 kW*
115,000 m³/day Plant Design	Area	4925 m2	60.4 m2
	Required Total Concrete	7755.6 m3	1966.4 m3
	Cost for Concrete (€500/m^3)	€3,877,822	€983,218
	Installation (excludes excavation)	€5,321,996	€1,400,500
	Clarifier, 304SS with Half-bridge	€750,000	
	Microscreen, 304SS		€2,200,000
	Total Cost	*€9,949,818*	*€4,583,718*
	Total Power (Drive + Sludge Pump)	*83 kW*	*30 kW*

1. For plant design < 35,000 m^3/day, the assumed RBF configuration is a totally enclosed steel unit with integral dewatering featured. Larger flows can take advantage of in-channel microscreen designs.

CONCLUSIONS

1. Microscreens/RBFs have a long track record as an efficient, space-friendly, and cost-conscious primary treatment solution with benefits over conventional sedimentation.
2. Studies demonstrate great potential for reduced footprint without sacrificing treatment efficacy in screening and primary treatment and stormwater treatment
3. The benefits preceding BNR include enhanced nitrification rates and enhanced plant energy efficiency.
4. Microscreens embody a keystone process for screening and primary treatment process for lower capital costs through design, construction, and full implementation.
5. Microscreens embody a keystone process for lower direct OPEX as well as significant indirect cost benefits through protecting and augmenting of downstream biological.
6. BioWIN modeling of BNR plants confirm earlier studies suggesting that microscreens can augment secondary BNR; observations include increased nitrification rates and 50% reduction in NOx modeling at the Largo facility.

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Acknowledgements

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