

PRETREATMENT USING MICRO-MEDIA FILTRATION

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ABSTRACT

Pretreatment is crucial to the operation of all water treatment equipment. This is particularly true for reverse osmosis units and most ion exchange columns. These technologies require TSS of 0.1-0.5 mg/L, turbidities of 0.1-1NTU, and SDIs values <5 and ideally <3. Media filtration is the lowest cost pretreatment option, however high levels of filtration efficiency can be difficult to achieve when using conventional media. This paper describes a filtration system that uses a unique micro-media. The small particle size of this media ensures a high level of filtration efficiency, while still maintaining the benefit of a relatively lower capital cost and high solids loading. Case studies are presented for the treatment of various waters.

SPECTRUM FILTER

Due to its low cost, simple and reliable operation granular media filtration has historically been amongst the most common of pretreatment methods. However, there is a growing requirement for improved total suspended solids (TSS) removal. The result has been a move towards membrane based pretreatment processes such as microfiltration and ultrafiltration. Without question, the absolute filtration barriers that these technologies utilize have resulted in an increase in removal efficiencies. However, this improvement is counter balanced by relatively higher capital and operating costs.

Spectrum Filter Features – “The Micro-media Makes the Difference”

By utilizing a very fine polishing, or “micro” media layer, the Spectrum filter improves filtration efficiency while maintaining the low capital and operating cost of conventional dual media filters. The principal features of this filter are the following: an anthracite upper layer, a fine micro-media lower layer, and high service flowrates.

The upper layer consists of anthracite. When loaded with dirt, this layer contributes less than 5 psi pressure drop. As with conventional dual media filters, the bulk of the solids are accumulated in this layer.

The lower layer of the Spectrum filter is a significant departure from the conventional design. Normally, silica sand with an effective size ranging from 0.35 – 0.55 mm is used. The Spectrum filter incorporates a layer of higher density micro-media with an effective size less than 0.1 mm. The resulting higher surface area density improves filtration efficiency.

While the smaller particle size improves filtration efficiency, it also increases pressure drop. Under typical flow conditions, the drop through this layer is approximately 40 - 50 psig vs. a range of 5 – 10 psig that would be typical for a conventional dual media filter. Recent tests have identified an alternate micro-media that has a similar effective size and density but operates with a pressure drop of only 22 psi.

Because of the improved filtration efficiency associated with the micro-media, it is possible to operate the Spectrum filter at higher loading flowrates. A conventional filter may operate at 4 – 8 gpm/ft² while the Spectrum filter is run at 12 – 18 gpm/ft². As a result of this higher flowrate the vessel diameter to treat a given flowrate is reduced.

Spectrum Filter Performance vs. a Conventional Dual Media Filter

In order to make a direct comparison of removal efficiency for the Spectrum and conventional filters just described, pilot plant tests were conducted with a common feed source containing 10 mg/L fine test dust dosed with 3 mg/L of PAC coagulant. Figure 1 clearly shows the improved particle removal efficiency for the Spectrum filter. 99+% of the particles greater than 1.8 microns were removed by the Spectrum filter. At this particle size the conventional filter removal efficiency was only about 91% and did not reach 99% until 7 microns.

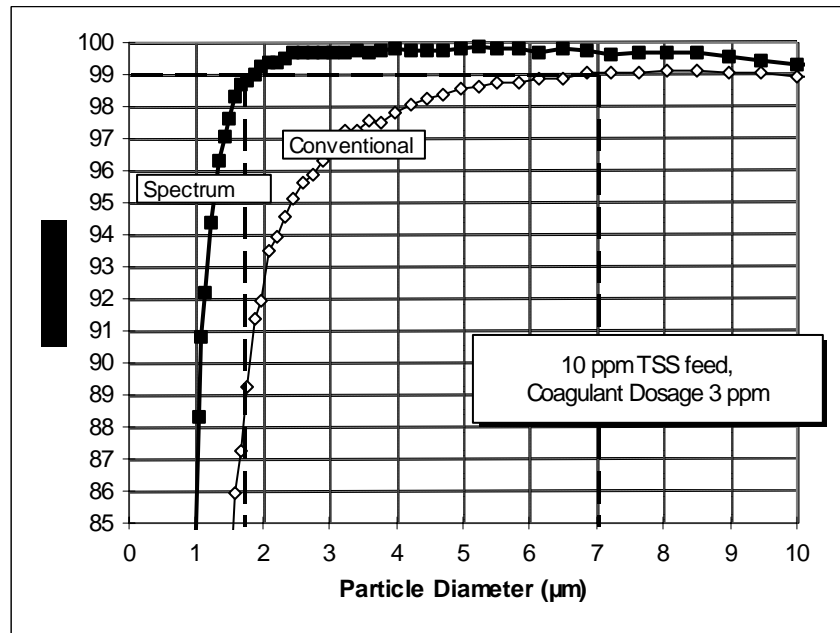


FIGURE 1

DESCRIPTION OF SPECTRUM FILTER

The filter operation is similar to other multi-media filters. Feed water is delivered, under pressure, to the top of the filter. The water passes downward through two separate layers of media. The upper media is coarser than the lower media. This upper layer provides depth filtration. This means that the majority of the filtration is achieved by coarse particles, which are first retained within the media, and then become a barrier to further passage of solids. The bulk of the filtered solids are collected here.

The lower media layer is a much finer media, referred to as micro media. The micro media filters out the finer particulates, the majority of which are retained in the interface between the coarse and micro media. The feed water is then collected at the bottom of the filter through media retaining laterals. These laterals are constructed using wedge wire meshes that have very fine pores.

Eventually all filters become fully loaded with solids. This is generally determined by volume throughput or pressure drop across the vessel. Once the setpoint is reached, typically the filter is backwashed to return the media to a regenerated state.

It has been found with the multi-media filters that the interface between the two medias is where the pressure drop first begins to build. This leads to a backwash being triggered when only the media interface has become fully loaded whereas the bulk of the media is only partially loaded with solids.

A unique operational sequence has been incorporated into the Spectrum Micro Media Filter to ensure that all of the media is fully loaded before the media is backwashed to return it to the regenerated state. This is achieved by multiple short backwash sequences, called backslips. During a backslip filtered water is sent, under pressure, up through the filter laterals. The volume and flow is enough to disturb the entrained solids that have built up at the media interface but not enough to flush out the solids from the vessel. The upward flow of water lifts the media and causes it to expand. The entrained solids then redistribute themselves more equally throughout the media. The filter can then return to service until pressure drop or volume throughput dictates that another backslip operation is required.

Once a certain amount of water has been processed the media in the filter is completely loaded and a full backwash and regeneration of the media is required. The full backwash sequence uses a larger volume of filtered water for a longer period of time. Depending on the nature of the feed, air is sometimes introduced to ensure a more vigorous backwash. The combination of air agitation with water scours tightly bound solids from the media. The backwash expands the media, which frees the filtered solids. As the backwash continues the solids are carried out of the top of the filter to waste. The coarse and micro media remain in the filter as they have a higher density than the suspended solids. When the backwash is completed, the micro media sinks to the bottom first followed by the coarse media. This is due to the differences in density between the two media. In this way the media are stratified into two distinct layers.

BENEFITS

The operational features outlined above result in a filter with some unique benefits in water treatment applications. The dual layers of media allows for high solids loading capacity, due to the coarse media, and high quality filtrate from the micro media. By passing feed through two layers of media with different properties the filter is also better suited to feeds with variable solid content. When treating a source with very few fine solids the majority of the filtration will occur in the coarse layer. This keeps the micro media from becoming loaded and causing excessive pressure losses. When treating a source with a higher content of fine solids, the coarse media will be unloaded and most of the filtration will occur in the interface between the two media.

Conventional filters may have breakthrough of solids if during their operation they become overloaded with solids. Results have shown that due to the micro-media layer when a Spectrum Micro Media Filter becomes overloaded with solids the result is normally a steady increase in pressure drop until flow is completely throttled but there is no solids breakthrough.

The backslip operation allows the filter to be more fully loaded between each full backwash. This has two advantages. The first is that water is conserved by reducing the amount of backwash water used per volume of water treated. The second advantage is that the filter capacity is increased leading to a lower capital expenditure.

CASE STUDIES

WE ENERGIES' PLEASANT PRAIRIE POWER PLANT

In the fall of 2002 WE Energies' Pleasant Prairie Power Plant, PPPP, near Kenosha, Wisconsin commissioned a new water treatment system that utilizes a Spectrum Micro Media Filter followed by a packed bed ion exchange process. This system produces 500 gpm of high purity water. The primary water source is Lake Michigan but the system is also capable of running off of a city water source. This new system has now been in service for more than 4 years and has consistently met the system requirements. PPPP is a two-unit coal fired facility with a net generation of approximately 1230 MW. Normal plant operation requires approximately 200 gpm of demineralized makeup water. This makeup water replaces the water lost during boiler blowdown, sootblower operation, demineralizer regenerations, condensate polisher regenerations, process sampling, and system leaks. The supply to the makeup water system is either raw Lake Michigan water or municipal water.

WATER TREATMENT PLANT DESCRIPTION

Figure 2 shows the process schematic for the new water treatment plant. WE Energies specified a water treatment system with a total capacity of 500 gpm. Water from Lake Michigan passes through rough screening and is delivered into two 6 million gallon sedimentation basins. A detailed water analysis was provided. However, only the parameters used for the design of the filter are summarized below.

Turbidity	up to 100 NTU	pH	7.5 – 8.5
TSS	up to 100 mg/L	Temperature	35 – 80F
TOC	normally <2 mg/L, spikes to 7 mg/L		

Process Flow Diagram

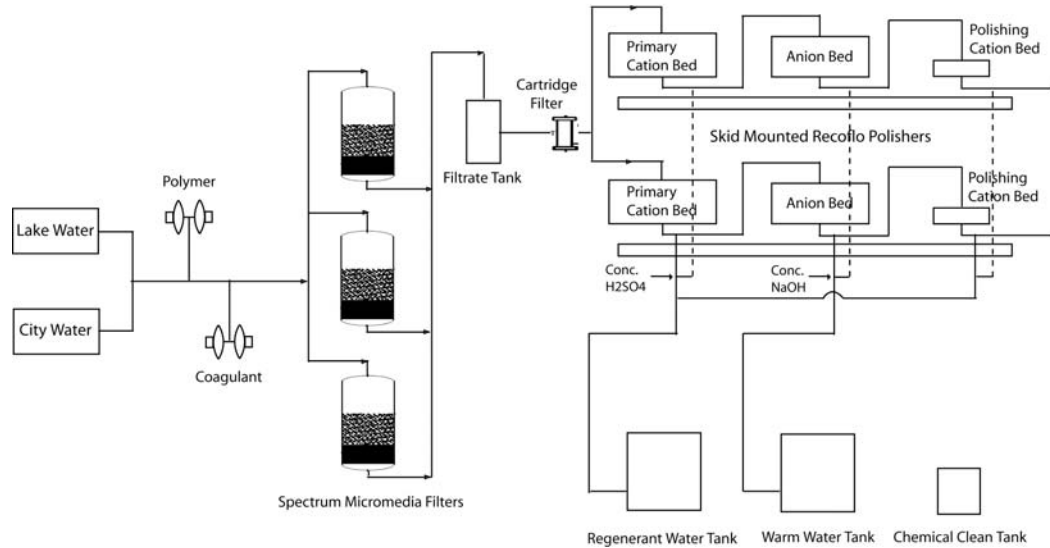


FIGURE 2

Separate metering pumps are used for the direct inline injection of an inorganic coagulant and polymer. Both metering pumps are duplexed and add chemicals on a flow-paced basis to provide a consistent dosage. The dosed water then passes through a static mixer to ensure that the coagulants are well dispersed. The piping run from the injection point to the top of the dual media Spectrum Filters allows only a short residence time of approximately one minute.

Three Eco-Tec Spectrum Filters were provided with each capable of delivering 50% of the required net product flow. A photograph of one of the filters is shown in figure 3. Each filter is 66 inches in diameter and is operated at a maximum hydraulic flowrate of 428 gpm (18 gpm/ft²). The bulk of the suspended solids are removed in the upper filtration layer. This top layer consists of coarse anthracite with an effective size of 0.6 – 0.8mm. The lower layer acts as a polishing filter to remove the residual solids not retained by the anthracite. A unique high density micro-media is used with an effective size less than 0.1mm.

As suspended solids accumulate in the filter media during the onstream step, the resulting increase in pressure drop is monitored by pressure transmitters and once a preset value has been exceeded backwash is automatically initiated. To ensure thorough removal of the dirt and to avoid mud ball formation, the backwash sequence includes an initial simultaneous air scour and water backwash followed by an extended backwash.

The complete, fully automated backwash cycle takes approximately 30 minutes. A lateral system is used for both filtrate collection and introduction of the backwash water. To avoid plugging the laterals, filtrate from an existing 60,000 US gallon filtered water storage tank is used to supply the backwash water. To prevent microbiological growth in the media filter, sodium hypochlorite is dosed directly into the backwash water.



FIGURE 3

The size of the filtered water storage tank allows enough surge capacity to permit the continuous operation of the ion exchange trains during the relatively short filter backwash. To provide for continuous filtrate to maintain tank level, two filters are normally selected for operation so that one remains in service while the other is in a backwash cycle.

Operating History at PPPP

Since commissioning, the filters have been in continuous service. A log sheet program has been implemented to monitor system performance. Incoming feed water turbidity over most of 2003 is summarized in figure 4, note the high turbidities at the start of the year with values peaking in excess of 70 NTU. Over the same time period Spectrum filtrate data are shown in figure 5. Filtrate turbidities were consistently below 0.1 NTU. SDI values are not normally monitored, however filtrate was checked in the middle and end of July 2003 and gave SDI values of 3.1 and 4.5. During these tests the filtrate turbidity was measured as 0.05 NTU.

WE Energies' experience has been that the Spectrum filters consistently produce water at 0.07 – 0.08 NTU from raw waters with up to 90 NTU. They have found that when lake water turbidity drops below 10 NTU, it was necessary to increase the coagulant dosage to 9 ppm PAC in order to maintain the filter effluent quality below 0.1 NTU. After 6 months operation at this higher dosage, an increase in cation bed pressure drop was noted on the demineralizer units. Analysis of the resin indicated high levels of Al and organics consistent with coagulant fouling from the PAC/DADMAC mixture being used.

Cation resin fouling by DADMAC carry-over from clarifiers is well known¹. The recommended cleaning procedure is the use of 7% HCl followed by warm 8% NaOH. This was found to be completely effective in removing all the fouling from the resin in one of the demineralizer units.

This resin cleaning period coincided with a switch to the city water source in December 2003. As a result, coagulant dosage was dropped to 1 ppm and use of the DADMAC was discontinued. The cation resin bed on the other demineralizer unit was left in service without any cleaning. It was noted that over a period of 2 months performance of this uncleaned bed was restored to its normal value. It appears that regular cation regeneration was able to clean the resin. This also suggests that a periodic additional regeneration every few days may have prevented the problem in the first place.

ONTARIO POWER GENERATION PICKERING NUCLEAR GENERATING STATION

Ontario Power Generation's Pickering Nuclear Generating Station (PNGS) is an eight-unit nuclear station located near the shore of Lake Ontario, in the City of Pickering, Ontario, Canada. The original set of four (A-side) units were placed in commercial service in the early 1970's, the second set of four units (B-side) were placed in commercial service in the mid-1980's. The generating units are rated at a Net Electrical Output of 515 MW each.

OPG awarded a 10-year build, own, operate, and maintain WTP contract to a team consisting of a Prime Contractor and Eco-Tec Inc (hereafter referred to as the O&M Company/Team). OPG supplied the building; the Prime Contractor owns the WTP equipment, and Eco-Tec Inc., a local, Pickering-based company, supplied the equipment and is operating the WTP under contract to the Prime Contractor.

WATER TREATMENT PLANT DESCRIPTION

OPG provided the following Raw Water Analysis as a basis for design of the water treatment plant².

A detailed water analysis was provided. However, only the parameters used for the design of the filter are summarized below.

Turbidity (NTU)	0.08 – 120	TOC (mg/l)	1.9 – 2.2
TIC (ppm)	16.9 – 17.5	Silt	Not quantified

The basic process involves treating feed water by direct filtration for suspended solids removal using a set of micro media backwashable filters. Reverse osmosis for bulk ion removal and the separation of organic compounds. Ion exchange polishing using short, compressed bed ion exchangers for final polishing of the water to the specified product water quality.

Feed water from the PNGS's condenser cooling return ducts is pumped to a set of three Micro Media Filters (see Figure 6 on the following page). Prior to the filters, coagulant (poly-aluminum chloride) is injected and mixed in-line. The coagulant dosage is automatically controlled based on flow and feed turbidity, and is typically in the range of 1 – 5 ppm.

Filtrate quality from the filters is continuously monitored on-line for turbidity and typically falls in the range of 0.05 – 0.12 NTU (see Figures 8 and 9 on the following page). Periodic manual sampling for silt density index (SDI) has been conducted and SDI values in the range of 2 – 5 have been obtained. The filtrate quality is maintained despite significant fluctuations in the feed water turbidity (3 – 100 NTU) caused by varying weather conditions over the lake. Using a patented operating feature known as "backslip", the filters are able to maintain extended runs between backwashes even at relatively high turbidity conditions (50 – 100 NTU).

The filter backwash sequence is automatically initiated based on flow and pressure drop across a filter. Backwash is accomplished using filtered water directly from the remaining, in service, filters. During infrequent occasions when the demineralized water demand is high and the feed water turbidity is also very high, City Water is used to augment the filter-backwash. A cartridge filter is installed down-stream of the Micro Media filters as a trap in the event of a filter lateral failure. The cartridge filters are rated at 10 microns and run for 4 – 6 months before replacement.

Since the WTP was commissioned in October 2001, it has continuously supplied the normal water requirements of the nuclear power plant without the need for supplemental demineralized water from other sources. During the first few months of operation, the WTP experienced some teething pains. It was found that the feed water turbidity excursions, along with the presence of silt and sand were considerably higher, more frequent, and prolonged than was originally anticipated. For the most part, the Micro Media filters responded well in terms of their ability to produce a high quality filtrate despite turbidities exceeding 100 NTU on a number of occasions. However, this resulted in more frequent backwashing of the Micro Media filters, with a resultant decline in net flow capacity. This situation was corrected by modifying the filter operating sequence to introduce a very short flow reversal, rather than a complete backwash. This increased the run length between backwashes by more than 500% with the improved net capacity despite turbidity upsets. Subsequent investigation into the mechanism of this flow reversal (subsequently named "backslip"), and its refinement has led to a patent application for the process by the Equipment supplier.

Both the O&M Company and OPG’s personnel have monitored the performance of the reverse osmosis system closely. At the time of writing this paper, nearly four years since the plant start-up, two of the three RO membrane skids are still operating with the original membrane elements in place.

Summary

As expected, some teething pains were experienced during the first year of WTP operation. OPG and the O&M Team’s staff worked closely together during this period to identify and overcome these problems. Operation and maintenance of the WTP has now become routine and requires less involvement from OPG’s personnel on a day-to-day basis.

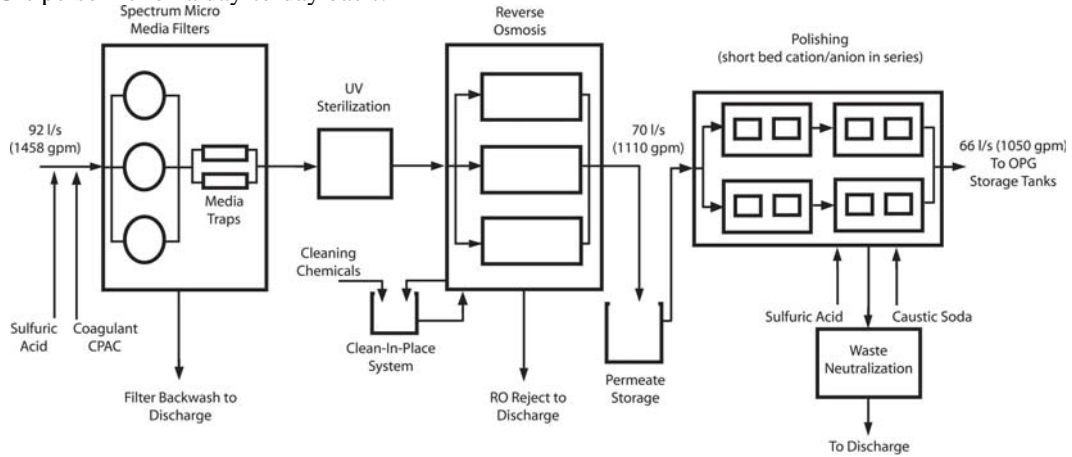


FIGURE 6

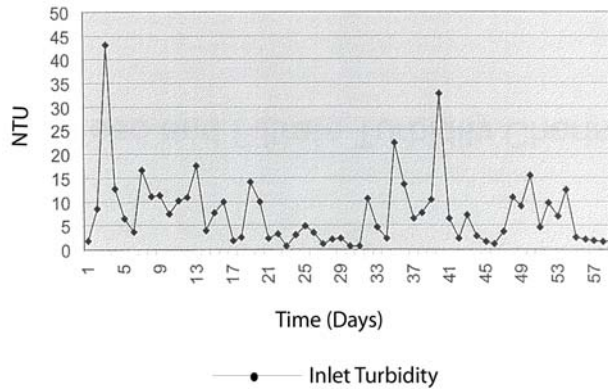


FIGURE 7

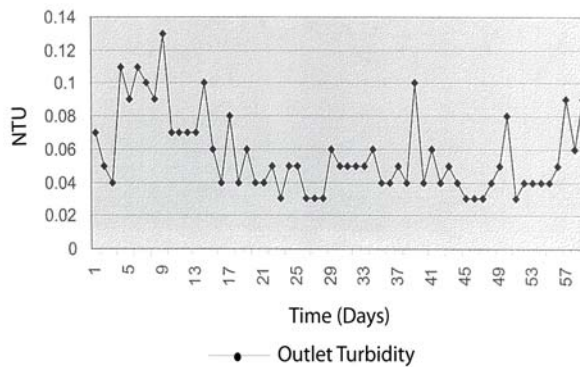


FIGURE 8

A POWER PLANT IN MEXICO

The Power Plant is a 600MW power plant and is fueled using natural gas. The plant is a combined-cycle gas turbine (CCGT) power station. It has two gas turbines, a steam turbine and a heat recovery steam generator (HRSG). The plant is connected to the US electric grid via a new, 230kV transmission line. The power plant was completed in July 2003. The plant treats raw wastewater and uses it in the cooling process. The discharged plant water is cleaner than it was to begin with.

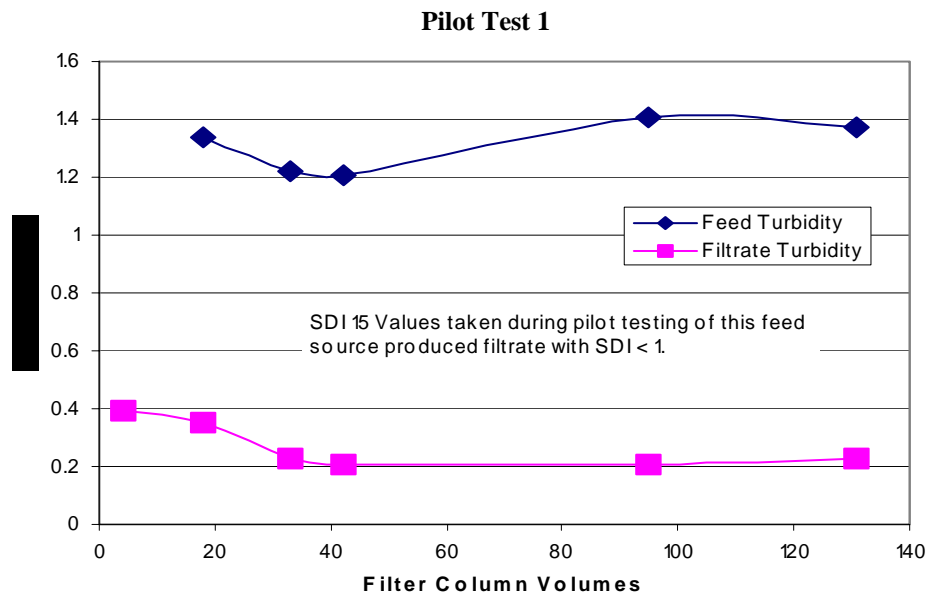
In addition to treating wastewater for the plant’s cooling process part of this water supply is used as a source of raw water for boiler makeup water. After passing through the wastewater treatment plant, which includes clarification and sedimentation, the water is supplied to a Spectrum Micro Media Filter™ for filtration ahead of a downstream Reverse Osmosis unit. The filtration system is designed to process feed water with a TSS of approximately 10 mg/L and produce a filtrate quality of ≤ 0.35 NTU with a capacity of 70 m³/hour of filtered water. The raw water is preconditioned with coagulant and passed through the Spectrum Micro Media Filter™ (SMMF).

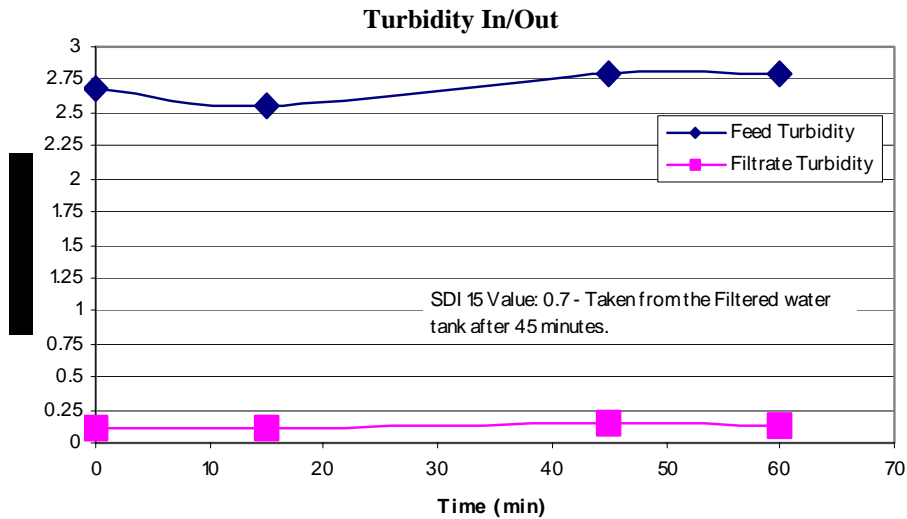
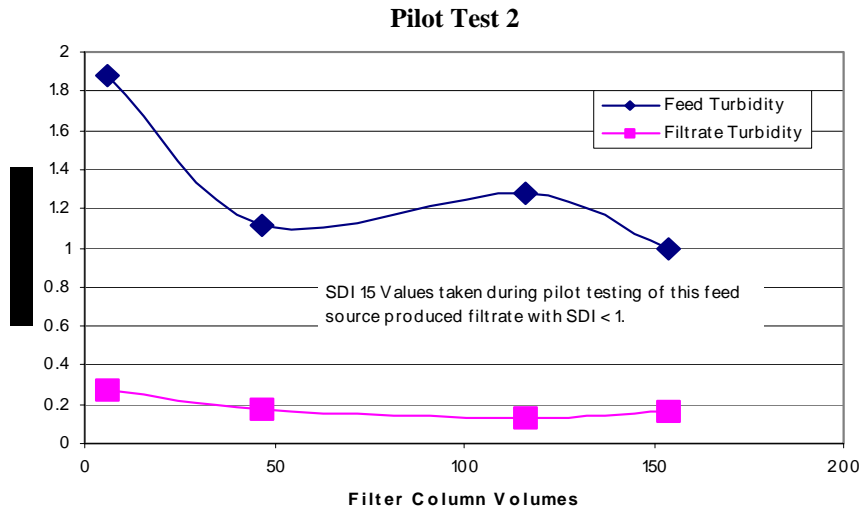
A detailed water analysis was provided. However, only the parameters used for the design of the filter are summarized below.

Turbidity (NTU)	5 –12	pH	6.5 – 8.5
Total Suspended Solids (mg/L)	5 - 10	Temperature °C	15 - 30
BOD (mg/L)	5 - 15	TOC (estimated) mg/L as C	< 2

There are relatively few applications that use tertiary water as a source of feed to a boiler makeup water system. As such, to confirm the Spectrum Filter performance an onsite pilot study was completed prior to the installation of a full size filter. The pilot study looked at the solids loading capacity, proper coagulant dosage and filtrate quality for treating the tertiary water source.

Figures 9 and 10 show results of the pilot testing over two runs. Figure 11 shows initial field results after completion of installation of the full-scale filtration unit.





The results from the testing show that the filtrate silt density index is quite low (less than 1 in all cases). However the filtrate turbidity was higher than was achieved when treating other water sources for which we have data.

There are a number of possible reasons for this performance. It has been observed from other case studies that low levels of turbidity are often more difficult to coagulate and filter. This is because suspended solids themselves act as a filtration media by impacting with each other to form larger, more easily filterable material. Also, the nature of the solids may be quite different from raw surface, well or municipal water sources. Polysaccharides, colloids and other organic material may all play a greater role in tertiary water sources.

REFERENCES

1. L.M. May, W.M. Carlson, "Effect of Coagulant Overdose in Clarifiers on Downstream Ion Exchange Processes" Proceedings of the International Water Conference 46th Annual Meeting, November 1985, IWC-85-24, p235 – 239.
2. OPG Specification No.: P-TS-71600-10002, "Technical Specification"