# Spectrum™ Filters

## The Next Generation in Water Filtration for the Oil and Gas Industry

*Eco-Tec White Paper*
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### Introduction

There is a need in many segments of the oil and gas production industry for an improvement in water filtration over traditional methods. This is especially true since the trend in oil and gas production is toward tighter, less permeable reservoirs and greater use of Enhanced Oil Recovery (EOR) techniques, many of which involve injecting water into oil reservoirs.

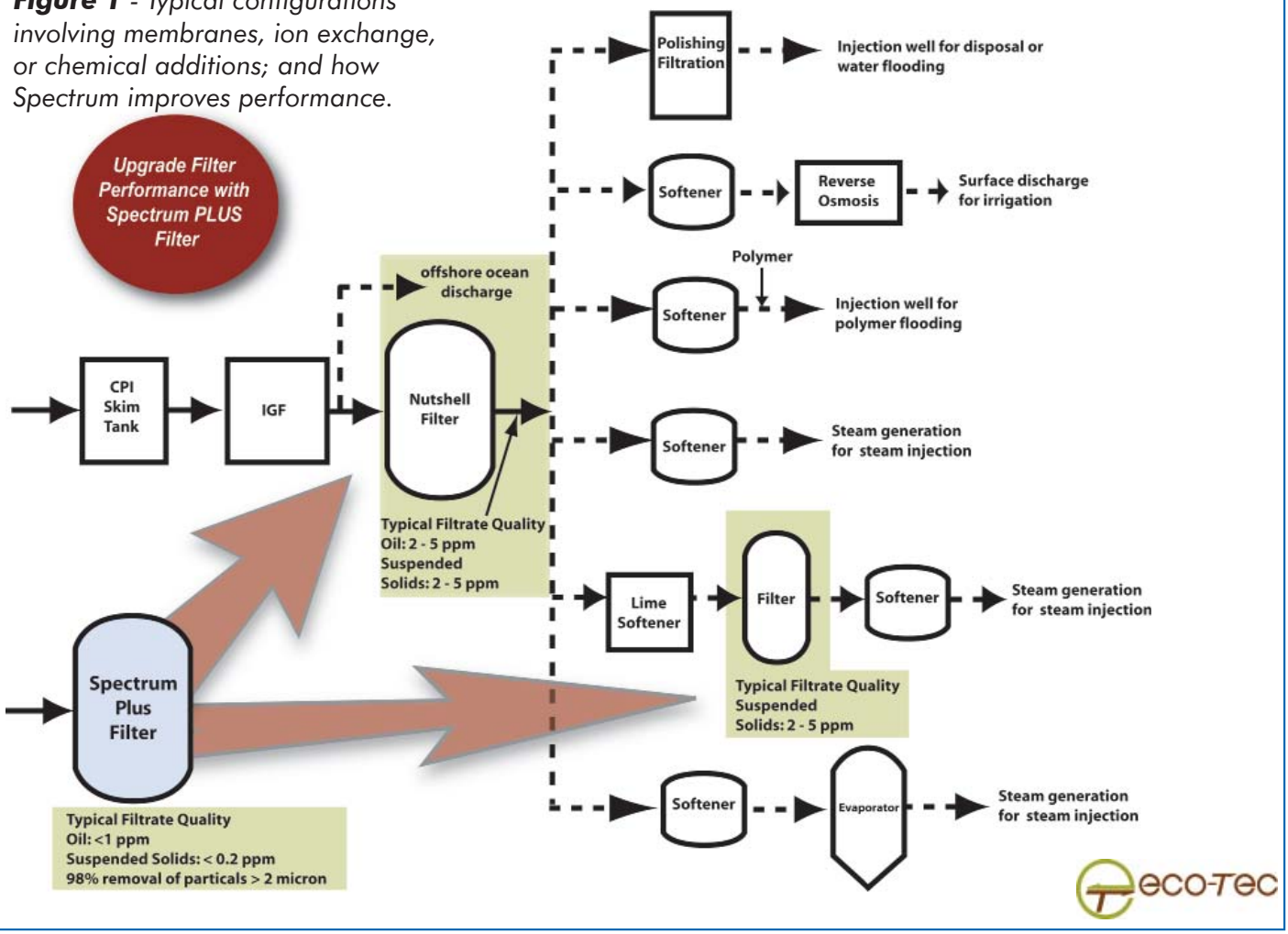
In order to protect the integrity of such reservoirs, the amount of solids introduced into the reservoir through water injection, even solid particles down to one micron in size, must be minimized. Conventional filtration methods generally do not meet this requirement.

An enhanced filtration technology known as Spectrum™ Plus Filtration, which incorporates the use of fine polishing media, has been proven in various industrial applications and introduced successfully for the treatment of produced water. This technology holds the promise of meeting new requirements while being economical and robust. This White Paper reviews the needs for improved water filtration, describes the enhanced Spectrum filtration technology, and provides operational data and experience.

### The Need for Improved Water Filtration

*Table 1* summarizes some of the characteristics of oil production in the past in comparison with characteristics of new production. Note how the new production practices often involve more water treating and more water injected into wells and reservoirs that are tighter and more costly to develop. This means that there is an ever greater concern over injecting excessive amounts of solids into these wells and reservoirs. The consequences of this can be:

***Figure 1*** *- Typical configurations involving membranes, ion exchange, or chemical additions; and how Spectrum improves performance.*



- Reservoir plugging which can cause production declines or inadvertent fractures
- Greater frequency of well and reservoir plugging requiring work-overs, acid treatments, and new wells with the associated production loss

***Table 1***

| Characteristic | Old Conventional Oil | New Unconventional Oil | New practices |
|---|---|---|---|
| Oil type | Light, sweet | Heavy, sour | Thermal processes - Most commonly steam injection (CSS, SAGD, steam flood) |
| Water cut | Low | High | - Reinjection of water to reservoir or to disposal wells.<br>- ASP polymer floods to increase oil cut and recovery.<br>- Gas or WAG (Water-Alternating-Gas) flooding |
| Reservoir porosity | High porosity | Low porosity | Hydraulic fracturing to create porosity through multiple fissures in low porosity formation |
| Reservoir pressure | High pressure – low lift costs | Lower pressure – higher lift cost | Water injection for reservoir pressure maintenance. |
| Location | Onshore | Offshore | Produced water treatment for discharge or reinjection.<br>- Seawater injection, increasingly with membrane processes for sulfate removal<br>- More costly wells and reservoirs to be protected from plugging. |
| Well types | Simple, vertical, high, long term production | Complex, horizontal, multiple fracs, shorter production life | Water used for initial fraccing. May be used for flooding as well.<br>Flowback and produced water reused for fracccing or to disposal wells. |

- Reduction in production or in the total recoverable potential of the reservoir
- Souring of wells through introduction of sulfur reducing bacteria (SRBs) via the water injection

In response to the concerns that solids injected into wells can have, specifications for the water quality being injected into such wells are increasingly being defined by a particle-size cutoff at about 2 micron, with many specifications requiring that 95-98% of the particles greater than 2 micron are removed.

Some other new production practices involve other water conditioning process equipment, which in turn requires excellent filtration for it to perform properly. *Figure 1* illustrates a number of these processes which involve the use of membranes, ion exchange resins, or chemical additions, all of which will be affected if the water fed to it is not well filtered of solids and oil.

**Traditional Water Filtration Methods**

*Table 2* lists some of the traditional water filtration technologies and their limitations in meeting the new requirements.

**Alternative Water Filtration Technology**

***Membrane Filters***

When alternative filtration technologies are considered, the discussion may turn to membrane filtration using polymeric, or more recently ceramic or metallic membranes which are rated as microfilters or ultrafilters depending on the pore size of the membrane. While such filters have had some measure of success in some industrial applications, they have not been widely deployed in the filtration of produced water. This is apparently the case for a

number of reasons, such as:

- CAPEX – the initial cost of such filters is considerably more than the traditional water filtration systems.
- OPEX – membranes are manufactured to have very small pores to allow water to pass but not suspended solids or oil droplets. In order to keep the pores open, the flow through such filters is tangential to the flux across the membrane (i.e. cross-flow). This often requires pumping much more fluid in a recirculation loop than is actually filtered. Further, regular backpulsing of the flow is required to keep the pores clean. This requires valves, controls, and auxiliary equipment. Periodically, the membranes require chemical cleaning to dissolve material which has been imbedded in the pores. This requires chemicals and more auxiliary equipment. Ultimately, the membranes have a limited life and must be replaced at considerable cost.

- Incompatibility – Some polymeric membranes are incompatible with hydrocarbons while some are also temperature sensitive and cannot be used when the produced water is warm (typically limited to < 40 °C).

- Prone to fouling – Many pilot tests have been conducted using membranes for filtering produced water but with limited success due to their propensity to foul irreversibly with oil and dirt. If the operating conditions and cleaning regimes are not properly maintained, the life of the membranes may be significantly comprised and require premature replacement. In some cases, membrane filters are proposed downstream of conventional filters with the intention that this will protect the membranes and reduce the dirt load and fouling rate However this increases the cost of the overall filtration process.

**Alternative Water Filtration Technology**
***Spectrum™ Plus Filtration***

An alternative filtration technology has also been introduced by Eco-Tec Inc. that fulfills the promise of meeting new filtration requirements but without many of the drawbacks of membrane filtration. This new process is known as Spectrum™ Plus Filtration.

*Figure 2* illustrates the key difference between a Spectrum Media Filter and a conventional nutshell or sand filter.

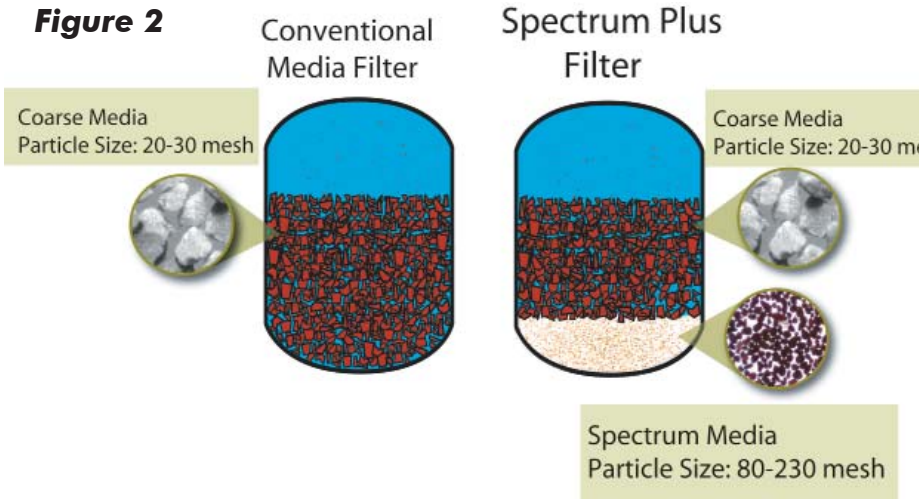
Spectrum has an upper layer of media which may be nutshells or anthracite to remove larger particles and oil droplets. However it also has a lower layer

***Table 2***

| Filtration Technology | Comments |
|---|---|
| Cartridge Filters | Low CAPEX. But OPEX depends on flow and solids content in feed. Practical for low flows and low solids content water. Higher flows and higher solids require frequent cartridge replacement.<br>In order to achieve fine filtration to less than 2 micron requires more expensive cartridge elements that clog quickly and require even more frequent replacement. |
| Bag Filters | Less expensive to replace than cartridge filters but since they are depth filters, they clog more quickly. Generally more practical for larger solids that are non-compressible and can form a cake. |
| Backwashable Strainers | Generally more practical for larger solids (> 10 micron). Cleaning may not be effective with oil present. |
| Hydrocyclones | Generally more effective for larger solids (>10 micron) |
| Backwashable Sand Filters | Generally can remove particles to the 5-10 micron range, depending on factors like media particle size, bed depth, flow rate, and feed water characteristics |
| Backwashable Nutshell Filters | Similar to sand filters but with the ability to “release” free oil accumulated on the nutshell media. |
| Backwashable Multimedia Filters | Similar to sand or nutshell filters but with somewhat improved removal of small particles depending on the media size. Generally limited effectiveness below 5 micron particle size. |

of fine polishing media. A key feature of the fine Spectrum media is its greater density compared to the upper media. This ensures that after backwashing, during which both media are fluidized simultaneously, the dense micro media quickly settles to form a distinct layer below the coarse upper media layer. This allows it to act as an integral polishing filter capable of removal of much smaller solid particles and oil droplets, which normally pass through a conventional media filter.

***Figure 2***




**Development and Industrial Experience of Spectrum Technology**

Spectrum Filter was developed initially as a prefilter for Eco-Tec's Recoflo® packed ion exchange systems using fine mesh resin. Recoflo systems have significant advantages over conventional ion exchange for applications such as water demineralization or softening and chemical process separations 1. However, since the resin beds are packed and do not get backwashed, they require removal of all solids that may cause plugging. It has been determined that this corresponds to a feed suspended solids specification of <0.2 ppm TSS, with nominal particle removal < 1 micron.

Spectrum filters have been in operation for more than 20 years in a variety of process applications including pre-filtration of surface and well waters for demineralization processes [2].

For the past 15 years Spectrum has been used as pretreatment for reverse osmosis membranes which also require very fine filtration in order to prevent membrane fouling. *Figure 3* is a photograph of a 330 m3/hr (50,000 BPD) Spectrum Filtration system in operation for 12 years in which raw lake water is filtered before reverse osmosis and further downstream polishing to produce ultrapure water for a nuclear power station.

In 2000, two Spectrum systems were supplied for filtration of produced water in heavy oil production in northern China [3].

Since 2009, 10 Spectrum Filtration systems have been put into operation at six different sites to filter produced water from heavy oil production in the Bakersfield, California area. These filters have all been installed as pre-filters before advanced ion exchange water softeners which condition the produced water to be fed to once-through steam generators.
Users' experience indicates that the filters have been

**Figure 3** - *A 330 m³/hr (50,000 BPD) Spectrum Filtration system*

**Figure 4** - *An 18,000BPD (2860M3/day) Spectrum Filter*

***Table 3***

| Parameter | Method |
|---|---|
| Turbidity | HF Scientific Micro TOL Series Turbidimeter 0.02 – 10.0 NTU |
| Total Suspended Solids | Standard Methods for the Examination of Water and Wastewater 2540 D with 1.2 $\mu$m Millipore RAWG filter |
| Oil in Water Total and Dispersed ("free") Oil | Turner Designs TD-500D Handheld Oil-in-Water Meter "No-Solvent Method" for Oil-in-Water Analysis |
| Oil Droplet Size and Particle Size Distribution | Canty Process Technology In-flow Oil in Water Analyser with CantyVision software |

performing very well on a qualitative basis since there has been virtually no fouling of the packed bed ion exchangers due to solids or oil passing through the filters.

Along with qualitative results, it was also recently decided to measure the performance of the Spectrum filters quantitatively and compare their performance with conventional filters (i.e. nutshell and/or sand filters) operating at other sites in the area.

**Field Performance Testing of Spectrum Filters**

In late 2012, field testing was carried out on commercially operating filters at eight sites in the Bakersfield, California area. Four sites were operating Spectrum Filters and four sites were operating either nutshell filters or sand filters. *Figure 4* is a photo of one of the Spectrum sites. This was not a pilot testing program but performance testing of the operating filters on a given day at each site. *Table 3* lists the testing methods that were used. Data from all eight sites was collected and it is summarized in *Figure 5* which averages the results from the sites.

Note the significantly better performance of the Spectrum Filter sites over the conventional sites. Conventional filters removed 74.9% of total suspended solids fed to them while the Spectrum filters removed 99.8% of solids (as measured by the Standard Method, using 1.2 micron Millipore discs). Free or dispersed oil removal was 26.1% by conventional filters but 91.8% with Spectrum Filters.

*Figures 6* and *7* show the solid particle and oil droplet size distributions for feed water and filtered water at one of the Spectrum Filter sites. This data shows that virtually all oil droplets and solids particles were removed down to the limit of detection of the analyzed device (in the 0.5 – 1.0 micron range).

In addition to the data which overwhelmingly showed the superior performance of the Spectrum filters, photos of the Millipore discs used for determining total suspended solids are shown in *Figures 8* and *9*. The markedly lighter appearance of the discs after the Spectrum, despite the fact that considerably greater water volumes had to be passed through these discs to develop enough material to be weighed for the analysis, is further evidence of the significant performance advantage of Spectrum.

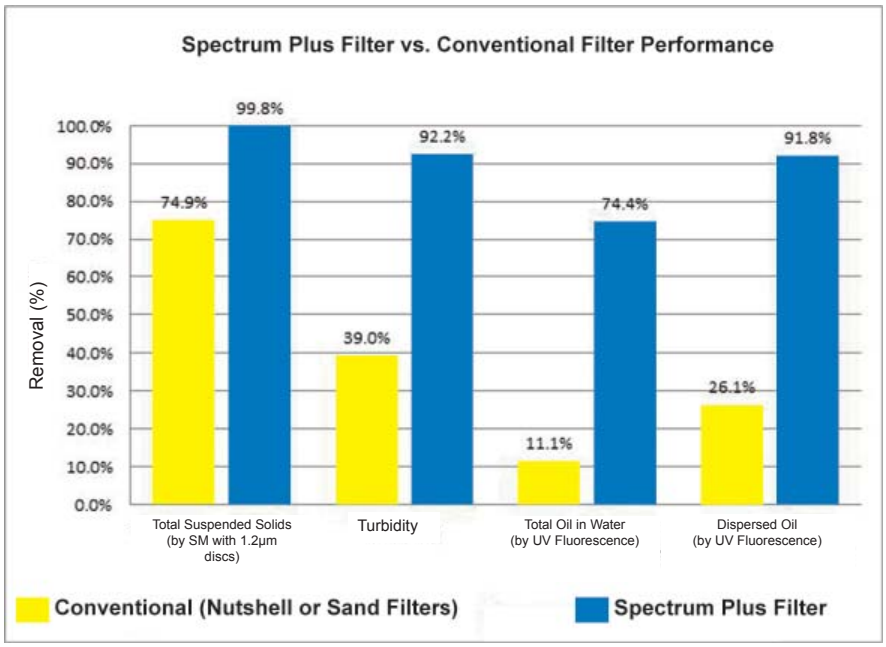



**Figure 5** – *Averaged site results collected from field study*

One other interesting note is that while seven of the sites had filters operating downstream of IGF (Induced Gas Flotation) units, which reduce oil and solids prior to the filters, one of the Spectrum sites operated directly downstream of a skim tank with no IGF (site C as identified in Figure 4). Oil levels in the feed to the filter are reported to be typically in the 20-50 ppm range. On the day of testing, the feed was measured to contain 78 ppm of

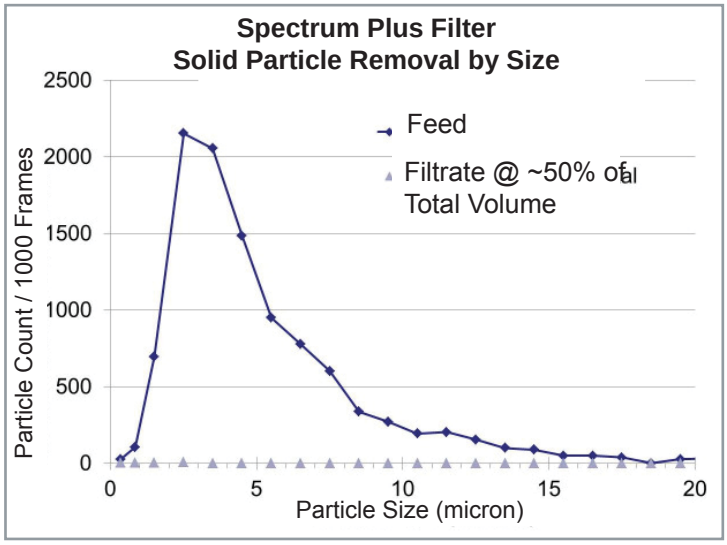



**Figure 6**

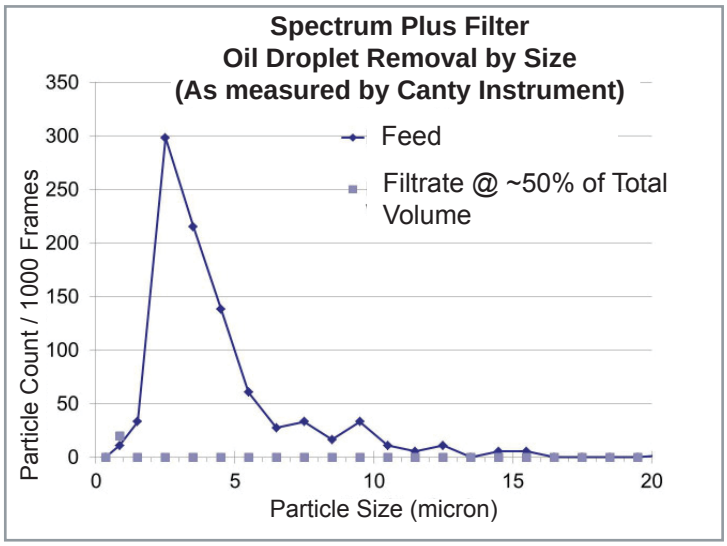



**Figure 7**

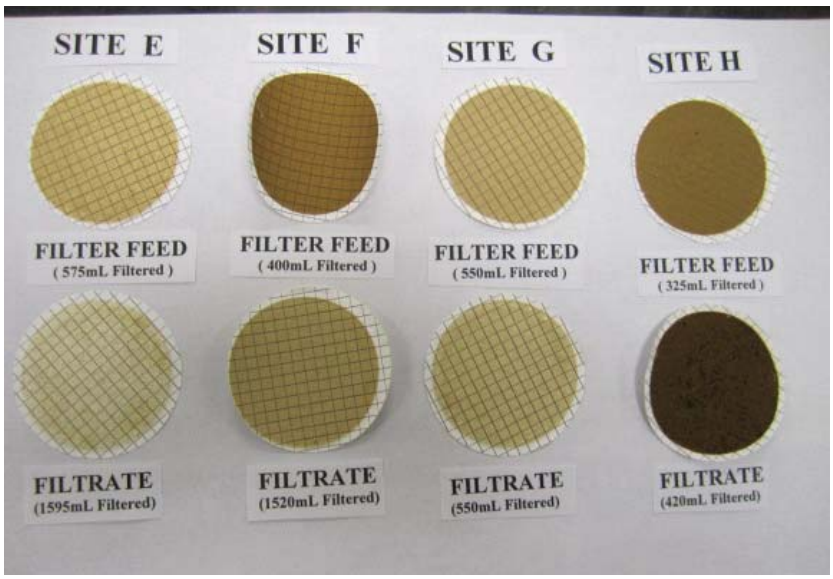



**Figure 8 -** *Millipore Filter Discs from Conventional Filter Sites*

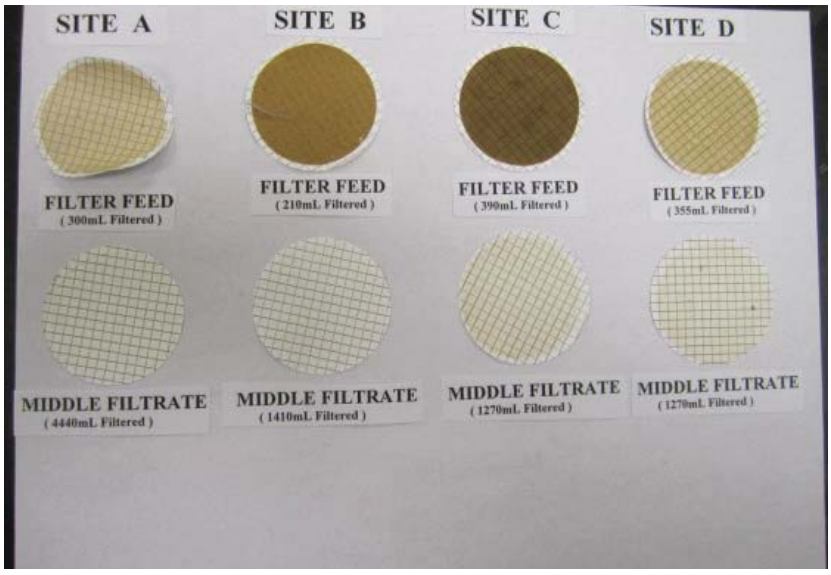



**Figure 9 -** *Millipore Filter Discs from Spectrum Filter Sites (Note filtrate volumes)*

free oil. In addition to the good performance numbers gathered at this site, it is also significant that a downstream packed ion exchange softener has been operating for the past year with no fouling or need for any cleaning. This further supports the strength of Spectrum over conventional filters.

**Summary and Conclusions**

The oil and gas industry is evolving in the direction of greater reliance on EOR techniques to recover greater quantities of oil from mature reservoirs and to recover oil from tight, lower porosity reservoirs. The success of many of these processes could be improved if the water injected into these reservoirs contains fewer solids. This is being recognized by the industry through new specifications for injection water quality that increasingly require significant removal of solids down to 2 microns in size. Filtration to this level would also result in a significant removal of sulfate reducing bacteria (SRB) being injected downhole.

Conventional filters (nutshell, sand, cartridge, etc.) are generally not capable of meeting such limits. Membrane filters, which may be capable of meeting this performance, in addition to being very costly, face challenges in treating produced water without fouling.

The performance and operability of Spectrum filters as demonstrated to-date, with the ability to remove solid particles and oil droplets to 1 micron in size, making them an attractive consideration for a variety of water treatment applications in the oil and gas industry in the future.

*For more information on Spectrum Filters, visit www.eco-tec.com or contact:*
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## References


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