

Advanced Produced-Water Treatment & Reuse For Oilfields



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By Lloyd Vaz & George Di Falco

Trapped in underground formations, typically ancient sea or lake beds, produced water is brought to the surface along with oil during extraction. This by-product produced water of oil exploration may need proper treatment for disposal. In certain cases it represents new and promising opportunities for heavy oilfields needing to overcome their reliance on fresh water, especially where water is scarce or recycling/reuse needs to be considered (e.g. for stem injection into oil wells, etc.).

Produced water treatment also represents challenges for major oil-producing projects, particularly in India, that has special treatment requirements to meet the discharge norms for disposal or injection into spent oil wells. In such cases, oozing produced water from wells with high oils, suspended solids content, and Sulfate Reducing Bacteria (SRB) count, etc., must be minimized before disposal.

Whatever its purpose, produced water is higher in hardness and salinity, compared to fresh water, and therefore more prone to causing scaling and corrosion in equipment; thus, many are on the lookout for strong, stable treatment solutions that can help minimize maintenance and operational costs.

While produced-water treatment systems have been in use for some time now, conventional filtration for polishing the oil and suspended solid content and softening systems (for

hardness removal) have encountered various problems over the past several years –incurring serious costs and operational challenges for companies.

Canadian-based manufacturing and design company, Eco-Tec Inc., has been focused on reducing operational and maintenance costs for companies through advanced produced-water treatment systems, which overcome the challenges apparent in conventional systems. Eco-Tec has systems used for the recovery, purification, and recycling of industrial water, gases, and chemicals, primarily with its Spectrum Micro Media Filters (for oil and suspended solid removal) and RecoPur Ion Exchange Softeners (for hardness removal).

Two cases involving Eco-Tec produced-water treatment for oil production will be discussed. The first system deals with a heavy oilfield in Bakersfield, California (USA) which faced fresh-water shortages due to drought; and the second, an oilfield in Liaoning province, one of the largest heavy oil production facilities in China.

Heavy oilfields such as these rely on large amounts of water for boiler feed in various thermal techniques, better known as steam flooding, cyclic steam stimulation (CSS), or Steam Assisted Gravity Drainage (SAGD). Essentially, these enhanced oil recovery techniques involve the injection of steam into wells

which reduces the viscosity of the heavy crude oil or bitumen, allowing it to flow out of formations.

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Case Study 1: California Oilfield Takes Action

As California began enduring severe drought in 2008, it became even more challenging to extract heavy oil using steam generated from fresh water sources. Governor Arnold Schwarzenegger, in an effort to manage the crisis, proclaimed a state of emergency and put forth widespread water-conservation measures.

The drought, which officially ended in March 2011, significantly impacted heavy oil fields in the San Joaquin Valley, one of the most important oil-producing regions in the U.S. An example is Seneca Resources Corporation in Bakersfield, California, a company that found it could no longer practical to obtain

the 7,000 bpd of fresh water it needed because of the crisis. Seneca, the oil and gas exploration and production segment of National Fuel Gas Company develops natural gas and oil reserves in the California and the Marcellus Shale.

Because of shortages in 2008 and 2009, Seneca was denied fresh California-aqueduct water from the Lost Hills Water District and, instead, had to resort to purchasing its supply from farmers in the area. According to Seneca, "It made practical and economic sense to get off fresh water and move to produced water to produce steam."

Seneca Resources remained well aware of numerous issues as it began searching for a solution for its plant in Lost Hills, California, where its once-through steam generator (OTSG) was producing 70 per cent steam at 800 psig. First of all, it needed a pre-treatment system that could effectively remove the oil and suspended solids and then soften the high hardness (446.7 mg/L as CaCO³) or high total dissolved solids (7,100.3 mg/L) that make up the produced water (Table 1), at about 7,000 bpd.

There were also concerns regarding:

- Effective pre-treatment for oils and solids removal.
- Safety and costs related to handling acid and caustic often used for regeneration of the produced water ion exchange softeners.
- High chemical (salt, acid, caustic) consumption due to the limitations of conventional ion exchange softener designs especially when treating produced water with high hardness or high total dissolved solids (TDS).
- Large waste volumes regenerant waste and disposal problems.
- Large equipment which requires considerable floor area and site assembly jobs.

Interest Peaked

Seneca's interest was peaked by the Spectrum Plus Fine Media Filter and the compact RecoPur Ion Exchanger (IX) Softeners. Pretreatment with the Sprectum Filter would effectively polish out the free oils and solids, eliminating the many problems related to downstream softener fouling.

The softeners promise 40-80% reduction in regenerant salt consumption and waste volume (compared to conventional ion exchange softeners) and also eliminates the need of acid and caustic regenerants for weak acid cation (WAC) softeners—important features for Seneca to decide going ahead with the project. The fully automated, compact, skid mounted Eco-Tec equipment required a considerably smaller footprint compared to competing systems. And the ease of operation and adaptability to variations in feed water quality were additional features which pleased Seneca.

The system was designed through data supplied from a single fresh water analysis and several produced water analyses (listed in Table 1). For treatment of the produced water outlined, the system would purify water to a total hardness of $\leq 1.0 \text{ mg/L}$ as CaCO³, at a product flow rate of 7,000 bpd (200 USgpm / 45 m³/h). System installation took place in December 2009 and was successfully commissioned/ started up within 10 days.

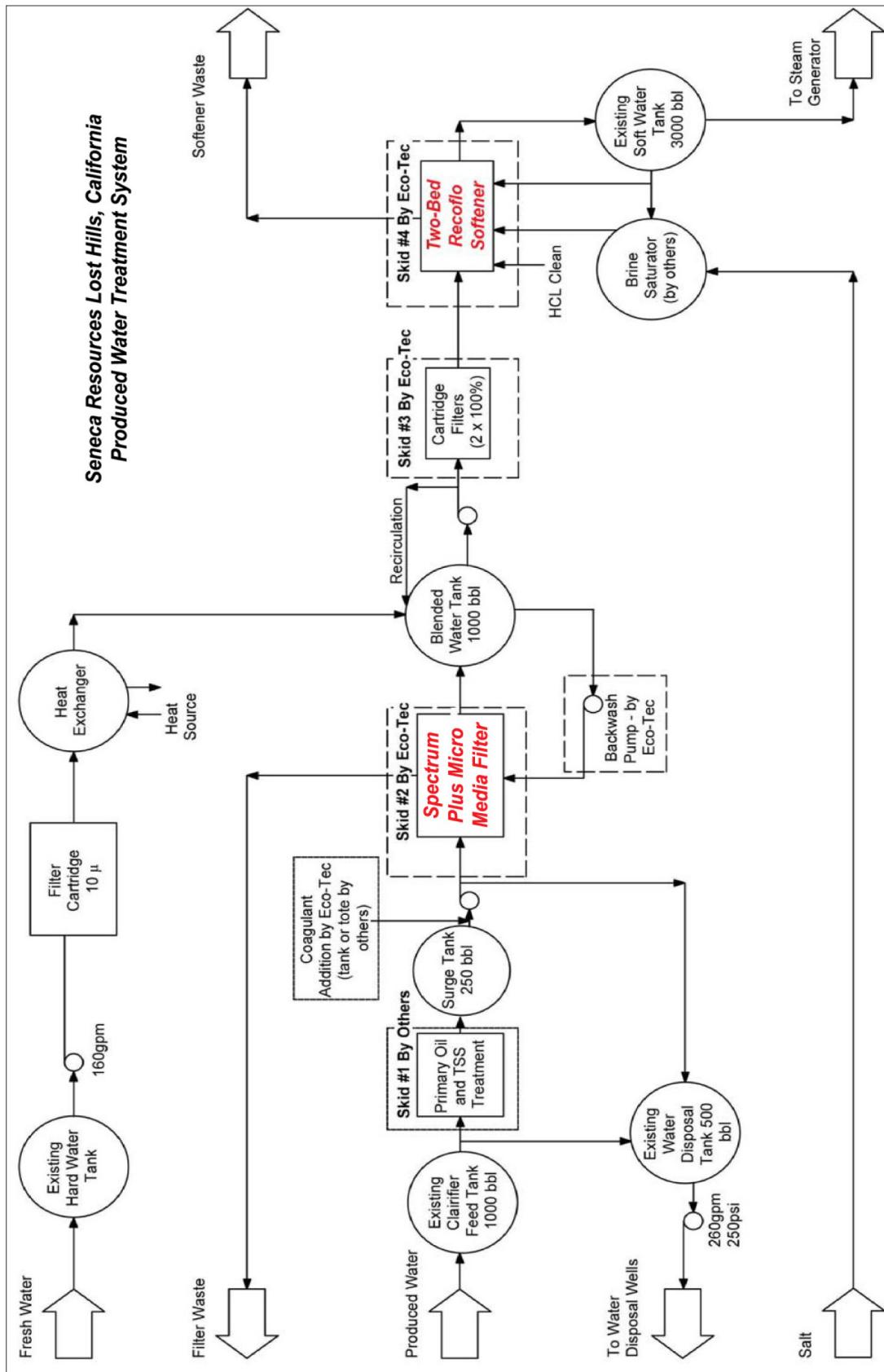


Figure 1: System Layout

The overall produced-water treatment process for steam generation (refer to Figure 2 System Layout) consists of primary oil and solids separation using the pre-existing gravity separators and a refurbished induced gas floatation cell followed by the Spectrum Plus micro-media filter (with an upper layer of walnut shell media for free oil removal and a lower layer of very fine micro media for fine solids removal) followed by the skid mounted, short bed ‘Recoflo’ Strong Acid Cation (SAC) and Weak Acid Cation (WAC) salt-regenerated ion-exchange softener.

Micro Media Pretreatment.

For Seneca, a specialty micro-media media filter known as ‘Spectrum’ is used to remove the residual oil and suspended solids remaining in the produced water after the induced gas floatation (IGF). It’s vital to have an effective, durable pretreatment system for produced water to ensure trouble-free operation of ion exchange resin. If allowed to accumulate, these solids can adversely impact water and regenerant chemical distribution will ultimately increase pressure drop and degrade water quality and quantity.

The oil and suspended solids levels in the feed were expected to be < 3mg/L (upsets to as high as 70 mg/L), and <10 mg/L (upsets to 70 mg/L), respectively. To avoid fouling of the downstream softener, oil and suspended solids must be reduced to <0.1 mg/L. To produce the required softened water product flow of 200 gallons per minute (gpm), a single 60-inch diameter filter was selected.

The Spectrum Micro Media Filter is basically a two-layer depth media filter with a number of features that depart from conventional designs; namely, an upper layer of coarse walnut-shell media, a lower layer of fine micro-media, and high service flow rates. The lower layer of very fine, dense micro-media is the key feature compared to conventional filter designs. While dual media filters typically employ silica sand with an effective size of about 0.35 mm as the ‘fine media,’ the Spectrum filter uses a lower layer of high density media with an effective size of less than 0.1 mm.

This very fine and dense media acts as a polishing layer to remove the residual oil and solids that leak through the upper nutshell layer. The small particle diameter greatly decreases the pores and channels through the media, improving oil and solids



Figure 2: ‘Spectrum’ Plus Micro Media Filter & a ‘Recoflo’ Two-Bed Ion-Exchange Softener Unit



Figure 3: Steam Distribution & Oil/Water Collection At Seneca’s Lost Hills, Heavy Oil Production Field



Figure 4: Spectrum Micro Media Filters on Site is a Key Factor in Produced Water Treatment at the Liahoe Heavy Oilfield in China

capture efficiency. This also increases pressure drop; however, the high operating temperature reduces viscosity, providing pressure-drop ranges from 10 to 25 psig. The top layer of media consists of black walnut nutshells (-20/+30 mesh) – similar to, but somewhat finer than that used in conventional dual media filters – and provides the bulk of the solids retention and therefore defines the run length.

To remove oil and solids, the media is agitated and washed through a simultaneous air scour and backwash. Air scour or backwash alone are inadequate since air alone does not lift and expand the media, but simply short circuits through a few rat holes leaving the majority of the media untouched. Backwash alone does not provide enough shear force to release the oil and solids from the media surface.

Mechanical agitation effectively cleans the media, but relative to this procedure is more costly and complex. In some cases, the use of natural gas or nitrogen instead of air is used to avoid adding oxygen to the backwash wastewater. These are of course more expensive options and may not be warranted since the impact on vessel internal corrosion would be minimal, and if the waste is recycled, the amount of oxygen relative to the full produced water stream is small. In the Seneca installation, the filter is backwashed using filtrate.

Overcoming Safety Concerns

One of the most important factors behind Seneca's selection of the Eco-Tec system was the need to avoid having to regenerate the WAC resins with hydrochloric acid (HCl) followed by sodium hydroxide/caustic soda (NaOH). According to Seneca, "Using produced water isn't something new, but what was new about this project was using a SAC/WAC system that didn't require hydrochloric acid and caustic in the regeneration process." The company didn't want the safety concerns for its people handling those two products.

Eco-Tec's system makes use of a novel ion exchange process called 'Recoflo' which makes it possible to utilize either strong or weak acid cation resin to soften produced waters at TDS levels up to 12,000 mg/L, to levels of residual hardness below 0.1 mg/L. By utilizing adequate dosages of high purity brine it is possible to eliminate the use of acid and caustic, even for regeneration of WAC resins.

The short-bed IX softener technology is significantly more compact than conventional units and characterized by use of the following:

- Short bed depths typically ranging from three in to 24 inches.
- Use of fine mesh resin typically $\frac{1}{4}$ the size of conventional beads.
- Fully packed resin bed.
- High hydraulic flowrates of 30 to 50 gpm/ft².
- Counter-current regeneration.

Seneca Produced-Water Treatment Results

The updated system at Seneca has performed consistently up to the time of publishing this article. A water hardness level of <1 ppm has been maintained, and additional field samples

Parameter	Unit	High Hardness Fresh Water	Produced Water
Suspended Solids • Normal • Excursions	mg/L	< 0.2	< 10 < 70
Oil and Grease • Normal • Excursions	mg/L	None	~ 3 < 70
Hardness	mg/L as CaCO ₃	96.5	446.7
Sodium	mg/L as Na	60.8	2186.0
Specific Conductivity	µS/cm	543.0	11300.0
Total Dissolved Solids	mg/L	339.3	7100.3
Temperature	oF	50 – 160	90 – 160

For treatment of the water outlined, the system produces the following:

System Product Flow: 7,000 bpd (200 USgpm / 45 m³/h)

Parameter	Unit	Value
Total Hardness	mg/L	< 0.2

Table 1: Water Analysis And System Performance For Produced Water Treatment For Seneca's Heavy Oil Production Field

reveal product hardness levels of 0.2, 0.33, and <0.13 ppm. And softener resin cleaning, as a result of resin fouling by oil and suspended solids, has not been needed in more than 20 months since the system has started up.

Before the Eco-Tec system went in, Seneca reports it experienced various operational challenges using fresh water to feed its boiler. The water coming out of the California aqueduct had a lot of algae and oxygen, so it was having problems with corrosion in the steam generator itself and also in the discharge piping away from the steam generator.

The corrosive dissolved oxygen in the fresh water, which is not present in produced water, frequently attacked the metal in the tubes of the generator and pipelines, forming iron oxide. As a result, Seneca had to regularly service the steam distribution system because of the oxygen, specifically the chokes that were clogging throughout its network of steam lines. Now, however, it no longer has to service the steam distribution system in this way, because the updated treatment system has significantly cut down on scale and erosion, Seneca says.

The consistent performance of the system prompted Seneca Resources to purchase another Eco-Tec produced-water purification system, at the end of 2010. The next project, a little bigger than the system at Lost Hills, is for its plant in Maricopa, California where hardness levels in the produced water are higher. Start up is expected in October of this year.

Case Study 2:

China Oilfield Finds Treatment Solution

The Liaohe Oilfield is the largest heavy oil production field in China with 10,000 oil wells and a production capacity of 250,000 BPD (12,500,000 T/year). Using a steam stimulation process, the oilfields produce 20,000 m³/day of produced water. It required a produced water purification system to provide water quality suitable for feed water to the high pressure, once-through steam generators.

The strict treatment target requirements, specified by the Chinese National Industrial Standards, required boiler feed quality that achieves: <2 mg/l oil, <2 mg/l TSS and <0.1 mg/l hardness (as CaCO₃). In addition to the standards required, other factors were taken into consideration for the design such as fluctuating flow rates in both TSS levels and oil levels.

After failed attempts with other produced water processes, a Liaohe delegation visited Canada to explore the latest technology for produced water. Eco-Tec designed and proposed a system to address the needs, and guidelines, specified by Liaohe officials. Through the minimization of risk, adherence to quality requirements, providing reliability and adaptability to fluctuations, and utilization of advanced technology and instrumentation, Eco-Tec has successfully implemented a large-scale produced water treatment system for heavy oil production.

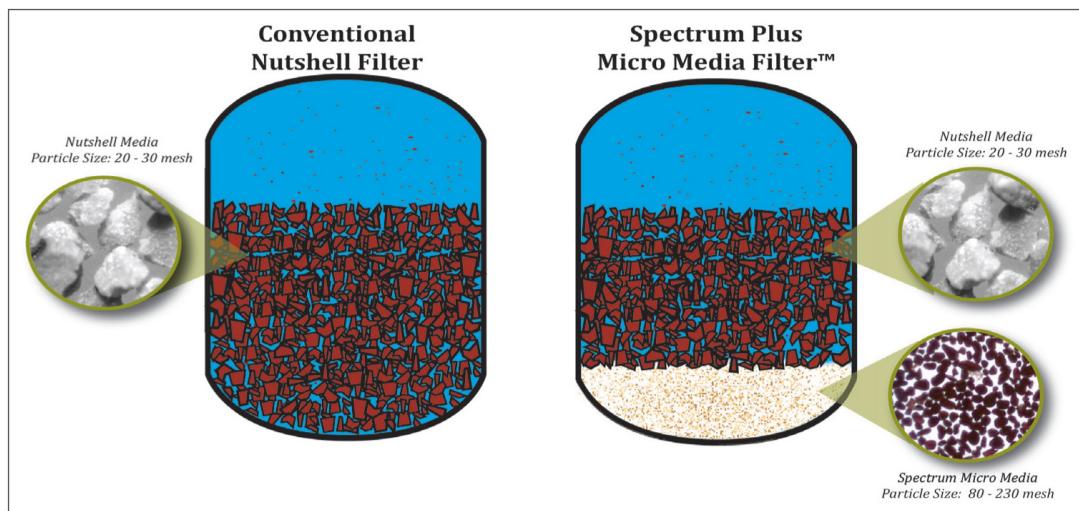


Figure 5: Compared To Conventional Media Filters, the Layer of Spectrum Micro Media Has a Very Small Particle Size and Acts as a Barrier to Small Suspended Solid Particles

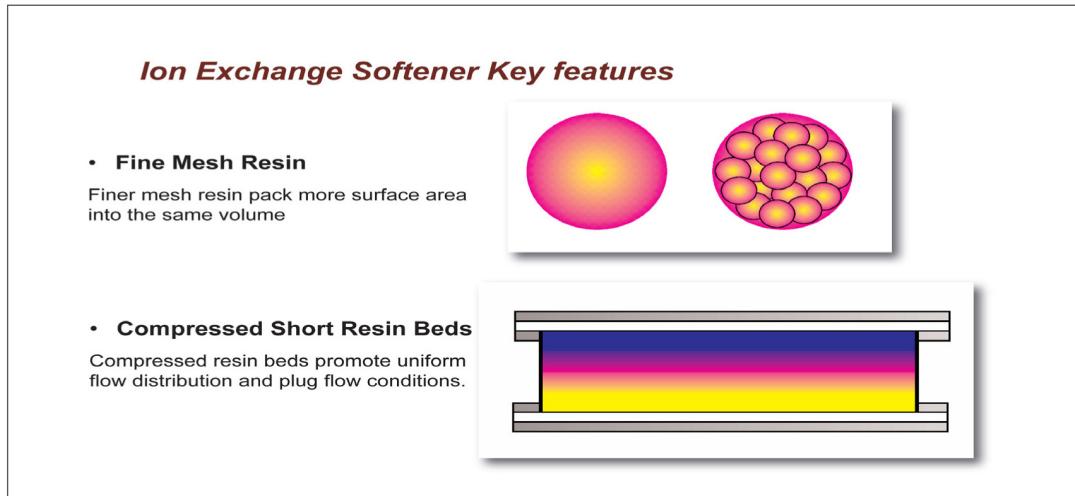


Figure 6: Some of the Key Benefits behind the Recoflo Ion-Exchange Softener About The

The produced water treatment system was designed to include components such as: a dissolved air flotation (DAF) process, a clarifier, walnut shell filters followed by Spectrum Micro Media Filters, and completing the process with Recoflo Softeners.

Liahe Produced-Water Treatment Results

The Eco-Tec process for treating and reusing produced wastewater has been in continuous operation at the Liahe Oil Field and is performing consistently. The aggressive project schedule, as well as the mandatory performance requirements for TSS, oil, and hardness removal have all been achieved. All of the sludge generated by the process has been effectively treated and re-used as supplemental fuel. Silica removal, which is not mandatory, was problematic and has not been implemented.

Overall, the system has proven reliable, simple to operate, and requiring minimal maintenance and operator attention. The DAF units remove the bulk of the TSS and oil and the micro-media filters achieve final effluent limits; both are key elements in the flow-sheet, ensuring the success of this project.

During the initial four-months of operation, the DAF units lowered the average oil concentration from 61.8 mg/L to 1.9 mg/L and the average TSS from 72 mg/L to 7 mg/L. The system has been shown to be very responsive to oil load fluctuations. Performance of all of the downstream equipment is undoubtedly enhanced as a result of the highly efficient oil and solids removal rate achieved by the DAF units.

Compared to conventional walnut shell filters, which alone do not reliably meet performance requirements, the Spectrum Micro Media Filters have fulfilled their role and consistently meet the final effluent requirements of 2 mg/L for TSS and oil. The average concentration of oil and TSS in the feed-water to steam generators is 0.8 mg/L and 0.3 mg/L, respectively.

Even when the concentration of TSS in the feed exceeded 300 mg/L, the allowable maximums of 2 mg/L were not exceeded. Largely because of the excellent pre-treatment, the WAC ion exchange softeners have consistently achieved hardness leakage levels below the limit of detection.

About The Authors

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