Oil and Gas Wastewater Treatment Simplified – PACT® MBR System

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Streamlined oil and gas wastewater treatment via the unique, all-in-one PACT® MBR system by Siemens — proven, available and supported worldwide — uses half the space of conventional methods and offers substantial cost savings.
Protecting the world’s fresh water via responsible reuse

Fresh water. Some call it “blue gold” — so precious to life, yet so relatively scarce. In fact, only 0.007 percent of Earth’s water is considered readily accessible for more than 7 billion people, a number expected to approach 10 billion by 2050.

Meanwhile, thirsty populations are drawing down aquifers around the world, while climate change-derived regulatory policies, thoughtful in their intent, may be inadequate to alter frequency of drought conditions and affect aquifer replenishment. Small wonder that intelligence agencies think water could reorder the world’s geopolitics in this century much as oil did in the 20th century.

That’s ironic, given the crucial role water plays in the world’s oil and gas industry, both as an input and by-product output. Water’s growing scarcity and ever tightening environmental regulations are also why the industry has increasingly taken steps to responsibly reuse this resource by deploying sophisticated water treatment technologies. The Middle East and China have especially strict mandates in this regard.

But treating the water generated by oil and gas production and refining or as by-products for reuse can be a tall order. It’s full of dissolved solids, hydrocarbons and other forms of toxic compounds. Technologies used in municipal wastewater treatment fall short of what’s needed by the oil and gas industry, as this paper will soon explain in detail.

Across the oil and gas industry, treated water quality and reuse potential is just as important as other production inputs, while water’s cost and availability continue to become more of an everyday concern. These factors, along with increasingly tighter regulatory restrictions on wastewater discharge, mean that a facility’s strategy for managing its process water must consider that at some point in its multi-decade lifecycle, the treated water is to be considered a resource to be reused in the process.

Of course, with the global downturn in crude oil prices in recent years and resulting pressures on operating margins and net profits, water reuse projects must be economical, too. The good news is that advancements in the way activated carbon is used in biological processes to remove most of the organic contaminants, coupled with membrane filtration technology, have helped drive down the costs of treating refinery and petrochemical wastewater for beneficial reuse such as cooling applications and boiler feedwater.
Since the 1970s, Siemens has driven key innovations in these water treatment technologies. The PACT® system for example, combines biological and carbon treatment in a single treatment step, consolidating the biological reaction steps of conventional activated sludge with the mass transfer kinetics of carbon adsorption into a single process, reducing footprint and capital requirements compared to the conventional, separate biological treatment and granular activated carbon (GAC) filtration steps.

The PACT® system has proven its effectiveness in more than 100 installations worldwide, with early deployments having operated continuously for decades. Among those are several U.S. and international refineries, which use the PACT® system to achieve treated water quality that meets some of the strictest discharge standards anywhere in the world, as well as rigorous bioassay testing standards.

Unique in the wastewater treatment industry, the PACT® system by Siemens is an enhancement of activated sludge technology to address extremely complex water treatment requirements—oil and gas among them. For example, it can help refineries achieve low chemical oxygen demand (COD) mandates, such as China's strict COD limit 50 mg/L on treated wastewater, one of the world's most stringent.

These capabilities led Sinopec Corporation, China's top oil refiner, to install PACT® systems at its giant petrochemical plant in Jiujiang. This is a large industrial city on the shores of the Yangtze River and adjacent to Poyang Lake, China's largest freshwater lake. It also installed PACT® systems at other refinery locations along the Yangtze River, including those in Anqing and Wuhan, and a Sinopec joint venture in Fujian province.

The PACT® system's biological capabilities remove biodegradable organics, at rates typically better than conventional activated sludge. That's because the presence of carbon buffers the biosystem against toxic shocks. In addition, its activated carbon features effectively adsorbs refractory organic pollutants, volatile organic compounds and odors from refining processes.

To reduce the total cost of ownership (TCO) during the multi-decade lifecycle of the PACT® system, Sinopec’s PACT® solution uses an exclusive wet air regeneration (WAR) technology from Siemens to regenerate the activated carbon on-site and in the process of doing that, destroy the excess biomass that would otherwise have to be dewatered and hauled for landfill disposal. Up to 95 percent of the spent activated carbon is regenerated, reducing replenishment costs by that same amount.

Another technology development that Siemens brought to refinery and petrochemical wastewater treatment is the Petro™ MBR system. This membrane bioreactor (MBR) technology addresses the needs of refineries for treating oily wastewater for reuse as a cooling water make-up supply or for discharge quality that is virtually free of suspended matter. It combines biological treatment with an integrated, immersed ultrafiltration membrane system.
Several benefits emerge by using membrane separation instead of conventional clarification processes. Among them are a much smaller system footprint with lower construction costs, and improved operational stability—in addition to exceptionally high-quality effluent production.

To drive further innovation in oil and gas water treatment, Siemens launched an investigation in 2006 to learn how its field-proven PACT® and MBR process technologies could combine for a better and even more cost-effective approach to oil and gas water treatment.

Ten years of intensive development, pilot projects and early deployments, plus significant investments in that research, have resulted in the Siemens PACT® MBR wastewater treatment solution. It’s available worldwide, backed by Siemens’ global service and support.

**PACT® MBR — combining the best water treatment technologies for the toughest oil and gas requirements**

In order to reuse oily wastewater from refinery and petrochemical operations, the concentration of organic contaminants and inorganic dissolved solids in the wastewater must be reduced to levels that avoid bio-fouling, corrosion and other detrimental effects to the downstream water plant process units.

Toward these ends, wastewater undergoes a series of specific treatment steps leading to a final treatment step of reverse osmosis (RO) membrane filtration. These steps are designed to remove free hydrocarbons (de-oiling) and dissolved organic compounds to produce the RO feed quality shown in Table 1 below.

<table>
<thead>
<tr>
<th>Typical Oil and Gas Wastewater Characteristics</th>
<th>Refinery Wastewater Post De-Oiling</th>
<th>Reverse Osmosis (RO) Feedwater Quality Minimums</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biochemical Oxygen Demand (BOD)</td>
<td>125-350 mg/L</td>
<td>&lt; 5 mg/L</td>
</tr>
<tr>
<td>Chemical oxygen demand (COD)</td>
<td>300-1000 mg/L</td>
<td>&lt; 40.0 mg/L</td>
</tr>
<tr>
<td>Oil and grease</td>
<td>20-50 mg/L</td>
<td>&lt; 0.1 mg/L</td>
</tr>
<tr>
<td>Phenols</td>
<td>5-30 mg/L</td>
<td>&lt; 0.02 mg/L</td>
</tr>
<tr>
<td>Silt density index (SDI)</td>
<td>varies</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>Total organic carbon (TOC)</td>
<td>80 – 300 mg/L</td>
<td>&lt; 15.0 mg/L</td>
</tr>
<tr>
<td>Total Suspended Solids (TSS)</td>
<td>30-75 mg/L</td>
<td>&lt; 2 mg/L</td>
</tr>
<tr>
<td>Turbidity</td>
<td>varies</td>
<td>&lt; 1 NTU</td>
</tr>
</tbody>
</table>

*Table 1. Refinery wastewater characteristics, post de-oiling versus reverse osmosis (RO) feedwater quality minimums.*
Conventional biological wastewater treatment processes can significantly reduce the amount of unwanted chemical compounds in RO feedwater. Recalcitrant constituents, such as non-biodegradable organics, remain in the treated wastewater and can cause severe fouling issues to RO membranes and frequent cleaning if not removed prior to RO treatment. That's where the PACT® MBR comes in.

The **PACT® MBR water treatment system** combines two of industrial water treatment’s most efficient total organic carbon and solids removal technologies, yielding an extremely compact footprint and reduced construction costs. As shown in **Figure 1** below, the PACT® MBR system requires just 50% of the footprint of a conventional treatment technology consisting of activated sludge, ultrafiltration (UF) and GAC adsorption. It also greatly simplifies operations.

**Figure 2** illustrates another way to visualize the relative operational simplicity of the PACT® MBR ultrafiltration water treatment system compared to conventional activated sludge and GAC columns. Again, fewer treatment stages mean lower operating costs and less space is needed.

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**Figure 1.** The Siemens PACT® MBR ultrafiltration water treatment system uses a membrane for solids removal instead of gravity-fed settling tanks and standalone carbon columns. This cuts space requirements in half, as shown, helping to dramatically reduce capital construction costs and simplifying operations.
Of course, an obvious question is, "How does RO feedwater quality compare to other forms of treatment?" To answer that, Figure 3 shows the side-by-side clarity of MBR filtrate and PACT® MBR filtrate, while filtrate removal test results are listed in Table 2.
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## Test Results

<table>
<thead>
<tr>
<th>Refinery Wastewater Compounds</th>
<th>MBR-only Filtrate Removal % (Remaining mg/L)</th>
<th>PACT® MBR Filtrate Removal % (Remaining mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biochemical Oxygen Demand (BOD) ~400 mg/L</td>
<td>99% (&lt;5 mg/L)</td>
<td>99% (&lt;5 mg/L)</td>
</tr>
<tr>
<td>Chemical oxygen demand (COD) ~750 mg/L</td>
<td>81% (151 mg/L)</td>
<td>92% (46 mg/L)</td>
</tr>
<tr>
<td>Total organic carbon (TOC) ~200 mg/L</td>
<td>86% (27 mg/L)</td>
<td>94% (11 mg/L)</td>
</tr>
</tbody>
</table>

*Table 2. Comparison of test results between MBR-only filtrate and Siemens PACT MBR filtrate percentages and remaining compounds.*

At refineries and petrochemical plants, improperly treated boiler feedwater can lead to higher maintenance, power and chemical costs. It can also cause premature equipment replacement because of excessive corrosion and scaling and the subsequent loss of production. Treatment of process water can have a substantial and serious impact on a facility’s bottom-line results in the short term as well as over the life of the equipment. Siemens PACT MBR produces best-in-class wastewater quality, allowing refineries and petrochemical plants to implement sustainable wastewater reuse programs, including for high end uses such as boiler feed water.

## Benefits of Siemens’ PACT® MBR Solution

The PACT® MBR system combines the process performance of activated sludge biological treatment, activated carbon adsorption and membrane filtration into a simplified and compact waste treatment model. This enables it to occupy 50 percent less space compared with the area required by conventional treatment systems using separate activated sludge, ultrafiltration, and GAC column methods alone.

Operating costs over the system’s lifecycle can be further reduced with the patented Wet Air Regeneration (WAR) technology for regenerating activated carbon, which can lower carbon replenishment costs by up to 95 percent.

*The Siemens PACT MBR ultrafiltration system combines the process performance of activated sludge biological treatment, activated carbon adsorption and membrane filtration into a simplified and compact waste treatment model.*
It also can significantly cut sludge disposal costs.

The PACT® MBR system provides these water-treatment performance advantages:

- **Improved organics removal**, including removal of recalcitrant COD, especially COD adsorbed onto the surface of the activated carbon;
- **Reduced bio-fouling of the UF membrane**, resulting in less frequent clean-in-place (CIP) cleaning cycles and greater membrane flux;
- **Reduced RO membrane fouling** in reuse applications, saving membrane cleaning and replacement costs;
- **Increased biological process stability** that is much less prone to upsets and their consequent process disruptions versus conventional biological processes;
- **Improved nitrification kinetics** by reducing nitrification inhibition caused by toxic compounds;
- **Maximum activated carbon utilization** by keeping the carbon in the reactor at retention times equal to the age of the biomass;
- **Reduced effluent toxicity** caused by residual, non-biodegradable organics and heavy metals.

In all, the PACT® MBR system can provide the water treatment efforts of oil and gas industry operators with increased membrane availability and uptime, while reducing chemical and operator labor costs. Over a lifecycle measured in decades, the total cost of ownership can be significantly lower than conventional water treatment methods and produce a better effluent.

**PACT® MBR: A next-generation solution for wastewater treatment facilities in oil and gas operations**

For oil and gas industry end-users as well as the EPC firms that support them, the PACT® MBR system’s value is straightforward: it offers a simplified and highly cost-effective, next-generation alternative to conventional wastewater treatment systems that use separate activated sludge, ultrafiltration, and GAC column technology to achieve water reuse quality.

In greenfield wastewater treatment projects, the potential construction cost savings of eliminating settling tanks and GAC columns can be substantial and offset the investment cost of the PACT® MBR system. Additionally, its all-in-one configuration can make for easier installation and commissioning, which can reduce project time and schedule risks.
Further, the operating expense savings, as detailed in the previous section, can contribute to immediate savings in chemicals, maintenance and labor, while providing a lower TCO over a system lifecycle spanning decades. This can boost the overall business case and help raise the projected return on investment even more.

For existing wastewater treatment systems, a PACT® MBR system can be deployed by retrofitting existing infrastructure, conserving a significant portion of an oil and gas operation’s legacy capital investment. At the same time, it is possible to increase organic and hydraulic capacity without increasing the facility’s footprint.

As with greenfield deployments, the system’s relative simplicity versus traditional systems can help to minimize installation and commissioning costs and time. Similarly, its lower operating expenses can provide near-term savings over conventional approaches, while contributing to a lower TCO over a decades-long lifecycle to help make the business case.

Siemens Water Solutions: Not just global service and support...global lifecycle management

Few companies have the global reach and presence to organize themselves and deliver their services and support using a Life Cycle Management approach like Siemens Water Solutions does. With a direct operations footprint in nearly every country in the world, and the financial strength and solutions diversity to ensure its vitality as a global solutions supplier, it’s easy to see why Siemens is the preferred solutions provider for many of the leading global oil and gas enterprises. Backed by sound research and development, Siemens Water Solutions continues to innovate, delivering new technologies and solution platforms to oil and gas enterprises, achieving exceptional performance in wastewater treatment quality and sustainable reuse projects.