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Meeting refinery wastewater challenges through membrane-based biological treatment complemented by an integrated asset sustainability program

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ABSTRACT

The Middle East and North Africa region is blessed with many natural resources, but it is no secret that when it comes to freshwater, scarcity is abundant. Potable water supply to industries needs to be curtailed and industry needs to meet its regular needs through alternate reuse methodologies. Adequate quantities. Scaling, corrosion and microbial fouling can all be the concerns of intrepid operators, but the use of wastewater that is treated to an advanced level using proven technologies can offer all the benefits of pristine freshwater without the issues of supply constraints and cost overburden. In designing a water reuse system in industrial applications, a holistic approach requires looking at water balance calculations covering availability, makeup and blow down, water quality considerations, ease of system operation, power consumption, and capital and operating costs. With these considerations in mind, well-designed systems may incorporate any or a combination of reverse osmosis, ultrafiltration and membrane bioreactor solutions supported by the right chemistry, delivered in the right quantity at the right spot under a smart digital Internet of Things (IoT) approach. With the right engineered and chemical systems in fixed or packaged mobile configuration, there is no reason why the bar cannot be set higher today in attaining improved onsite water and wastewater operations. The Bahrain Petroleum Company Sitra Refinery in Bahrain is a good example of a holistic approach to addressing water and wastewater needs in industry. The refinery upgraded its existing wastewater treatment plant to improve the quality of its effluent and comply with stricter requirements using the best available technology in biological membrane-based treatment for its challenging operations. It further engaged packaged mobile water desalination to streamline its water supply challenges.

Keywords: Refinery; MBR; Mobile Water; IoT; Water balance

1. Introduction

The Middle East and North Africa region is blessed with many natural resources, but it is no secret that when it comes to freshwater, scarcity is abundant; whereas, potable use receives priority, it is only prudent that we create the infrastructure to maximize water reuse in industrial settings, without exception. Potable water remains limited and it is only sensible to retain as much of it for sustainable use today and for generations to come. The potable water supplies for industries need to be curtailed and the industries need to meet its regular needs through alternate reuse methodologies.

At any industrial plant, its water requirements are continuous and any shortcomings in water quantity and quality can affect plant asset integrity, overall production and ultimately the profitability. Along with the attention to chemistry and system monitoring and control, water reuse can go a long way in supporting water sustainability in today's industrial establishments. Adequate quantities. Scaling, corrosion and microbial fouling can all be the concerns of intrepid operators, but the use of wastewater treated to an advanced level using proven technologies can offer all the benefits of pristine freshwater without the issues of supply constraints and cost overburden.

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calculations covering availability, makeup and blow down, water quality considerations, ease of system operation, power consumption and capital and operating costs. With these considerations in mind, well-designed systems may incorporate any of or a combination of reverse osmosis, ultrafiltration and membrane bioreactor solutions supported by the right chemistry, delivered in the right quantity at the right spot under a smart digital IoT approach. With the right engineered and chemical systems in fixed or packaged mobile configuration, there is no reason why the bar cannot be set higher today in attaining improved onsite water and wastewater operations.

The Bahrain Petroleum Company (BAPCO) Sitra Refinery, located near Bahrain's capital Manama, is a perfect example of a holistic approach to addressing water and wastewater needs in industry. Following its commitment to environmental protection, BAPCO decided to upgrade its existing wastewater treatment plant to improve the quality of its effluent and comply with stricter requirements using the best available technology in biological membrane-based treatment for its operations. It further engaged packaged mobile water desalination to streamline its erratic and dated water supply arrangement.

2. Refinery water balance and wastewater

Wastewater systems are used to prepare process water streams for either re-use or discharge. In refineries, aqueous generated waste is the result of utility blowdown, wash waters, regenerant waste, stripper blowdown, knockout drums and run-off. Contaminants are high in TSS and COD and are typically treated with a primary separation followed by a secondary biological oxidation. A concentrated sludge is generated and then disposed. Discharge permits are dictated by the effluent receiving body. Regulatory compliance and environmental stewardship are the drivers of successful wastewater treatment operations.

Refineries and petrochemical plants have unique needs for water treatment and they use a large quantity of water, making it critical that the refiner has the quantity and quality of the water they need (Fig. 1). If the process water used is not properly treated, the soluble minerals, suspended solids and inorganic contaminants could affect the processing equipment by means of corrosion and deposition, leading to problems in heat transfer, water flow reduction, increased energy consumption and higher waste treatment cost. Further, regulations and water scarcity are making it more and more difficult for refineries and petrochemical plants to have access to conventional water.

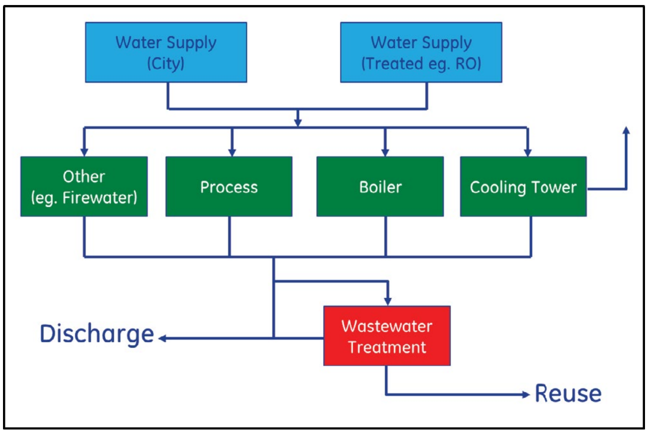

Fig. 1. Typical refinery water balance.

3. MBR and wastewater treatment

The membrane bio reactor (MBR) system consists of a biological treatment system followed by membrane ultrafiltration (UF) trains. Biological treatment has been a regularly adopted practice in oil refineries because of the high flow rates and the nature and concentration of the contaminants it can handle. Hollow fiber submerged membranes are employed with the membranes being the key to effective wastewater treatment (Alsalhy et al. 2016). The reinforced hollow-fiber membrane acts as a physical barrier, preventing suspended solids, and colloidal material from being released in the final effluent. Typically, raw water from the plant is pumped to a grit removal system for the removal of heavy solids, and then through an oil–water separator before entering the bioreactor. Mixed liquor overflows to the membrane tank. Filtration is achieved by drawing water to the inside of the membrane fiber using suction created by permeate pumps. Recirculation pumps take the remainder of the flow back to the bioreactor to ensure these tanks remain at the same relative MLSS concentration. Sludge is wasted from the recirculation line to a filter press, where it is thickened and then hauled off site.

4. Supplemental supplies and mobile water

Some plants in water-challenged areas need, in addition to water reuse, turn to desalination to mitigate their water challenges and sustain their production levels. Modular, pre-engineered mobile water and wastewater treatment systems deliver performance, reliability and economics. These make long distance networking infrastructures or trucking redundant, often saving significant capital and operating expenditure costs. Mobile water is an area in which industries can manage their water needs while minimizing their investment. Offered on rental or even build-own-operate basis utilizing fleets deployable from service centers at a short notice, industries such as power, chemical, refinery, metal, municipal and others can achieve quality, quantity and cost-effective water at their site (Fig. 2).

Taking up only a minimal footprint and on-site requirements, modular, containerized mobile water units help meet emergency outages or equipment failure, planned outages for equipment repair, seasonal demands, product expansion, start-ups and change in raw water quality or effluent specifications. Often industry is faced with immediate challenges to meet shortfalls in existing production capacities. While many have plans to increase installed capacity, this is often not easily achievable. Planning, funding, procuring, constructing and commissioning new plants can take several years. Even with plans in place, emergency situations can arise requiring a quick solution to overcome unplanned conditions. Mobile water offers a water availability solution literally on demand, for periods ranging from several days to months and longer.

Fig. 2. Mobile water.

5. Digital internet-of-things asset performance management

For all industries, the key to enhancing productivity, improving asset life, and operating more proactively lies in the internet-of-things (IoT), which brings together people, machines and data to work in a faster, more predictive way. IoT-based asset performance management (APM) tools are designed specifically to improve the reliability and longevity of equipment. The Industrial Internet is one of the critical services driving the future of water and energy management for all users.

InSight*, an APM solution, uses data and analytics to ensure assets – such as boilers, cooling towers, reverse osmosis and ultrafiltration membranes and other key components – operate at optimal levels of reliability, efficiency and output. InSight has been able to prevent unplanned downtime, increase asset reliability, and extend asset life, and deliver greater operational efficiency and transparency across a variety of industries. The remote monitoring and diagnostic solutions aggregate, capture and display data in meaningful ways, giving operators the insight they need to make informed decisions (Fig. 3). These solutions – and the physical assets they control – are infused with digital capabilities to drive better system outcomes through next-level predictive operations.

InSight provides analytics to help see at any point in time the historical and current performance against success criteria, and the trajectory of future performance; where it is on track; and the weaknesses that need improvement. Early detection is a key goal, detecting emerging problems, so that action can be taken now, before a failure is experienced in the future. Asset optimization helps identify opportunities to optimize the applications that lower the total cost of operations, without sacrificing production performance. Another measure is in the context of safety where acid leaks, chemical storage tank leaks or chemical overfeed are common occurrences that can be detected before a problem becomes serious. InSight also leads to improved productivity, helping people get more done with tools that enhance their personal productivity, enabling them to see and do more. It enables operators to choose the way they manage information with a wide range of functionality.

The output of the remote monitoring can be followed up at centralized service reliability centers (SRC; Fig. 4), which are an integral part of the InSight APM platform, providing the means to troubleshoot and resolve account issues. Utilizing highly trained experts, the SRC integrates data acquisition, software, analytics and domain expertise

Fig. 3. InSight asset performance management.

*Mark of SUEZ.

Fig. 4. Service reliability center.

to help site teams improve the reliability and efficiency of their production assets; as well as reduce the cost of their operations.

6. BAPCO refinery integrated water and wastewater case study

The BAPCO Sitra refinery, located near Bahrain's capital Manama, remains among the largest refineries in the Middle East processing more than 250,000 barrels a day. Over the last several years, it has undertaken several steps to achieve best-in-class facilities and practices in water and wastewater management that have included biological wastewater treatment, utility chemicals and mobile water.

Following its commitment to environmental protection, BAPCO decided to upgrade its existing wastewater treatment plant to improve the quality of its effluent and comply with stricter requirements using the best available technology; MBR was the technology chosen for this project (Daigger et al. 2009). The MBR system consists of a biological treatment system followed by membrane ultrafiltration (UF) trains. Biological treatment has been a regularly adopted practice in oil refineries because of the high flow rates and the nature and concentration of the contaminants it can handle. During the initial performance test carried out to ensure suitability of the biological treatment approach prior to full-scale implementation, each of the four UF trains with a maximum treatment capacity of 4,400 USgpm were operated at design instantaneous flow rates ranging from 1,470 to 1,820 USgpm to simulate the different design flow conditions expected during long-term operation (Ginzburg 2015). The rest of the operational parameters of the membrane trains such as membrane aeration flow rates and chemical cleaning frequency were kept according to operational guidelines and the performance of the UF system key performance indicators (e.g., transmembrane pressure, etc.) monitored. The obtained results showed that the UF system was not only able to consistently meet the required treatment capacities but also the required effluent parameters at all times (Fig. 5).

The measured transmembrane pressure during the performance test did not exceed 2.2 psig which is significantly lower than the maximum allowable value of 8 psig. Also, the membrane system did not require additional chemical cleanings outside those needed for the original design conditions. The effluent quality was also significantly lower than the guaranteed values. The measured average turbidity was

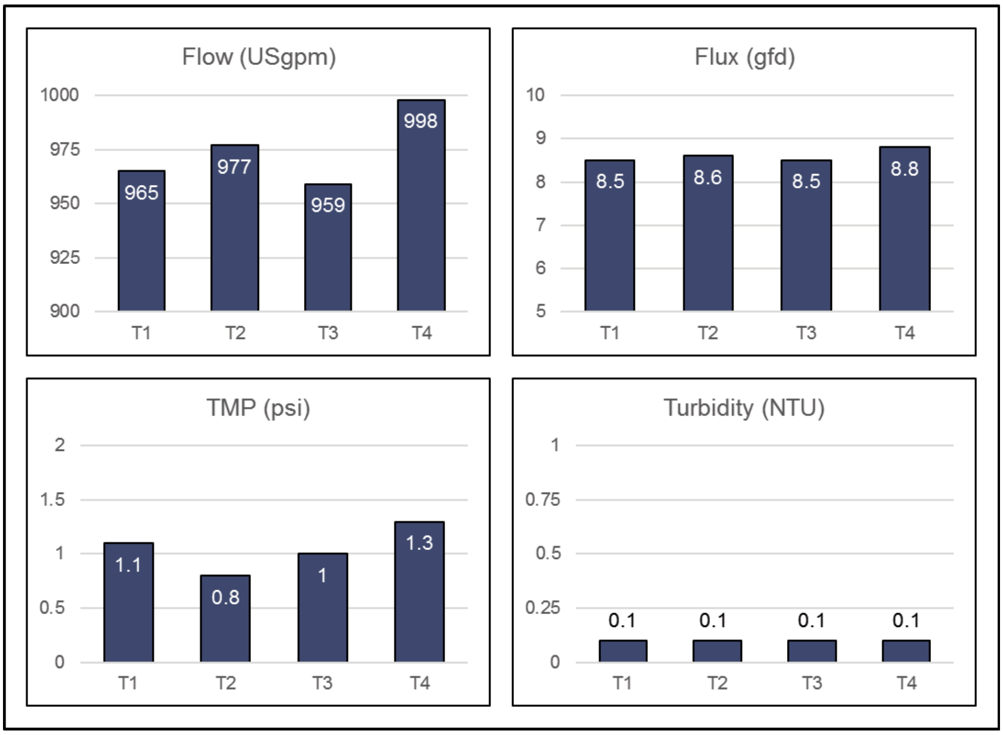

Fig. 5. Pilot test results.

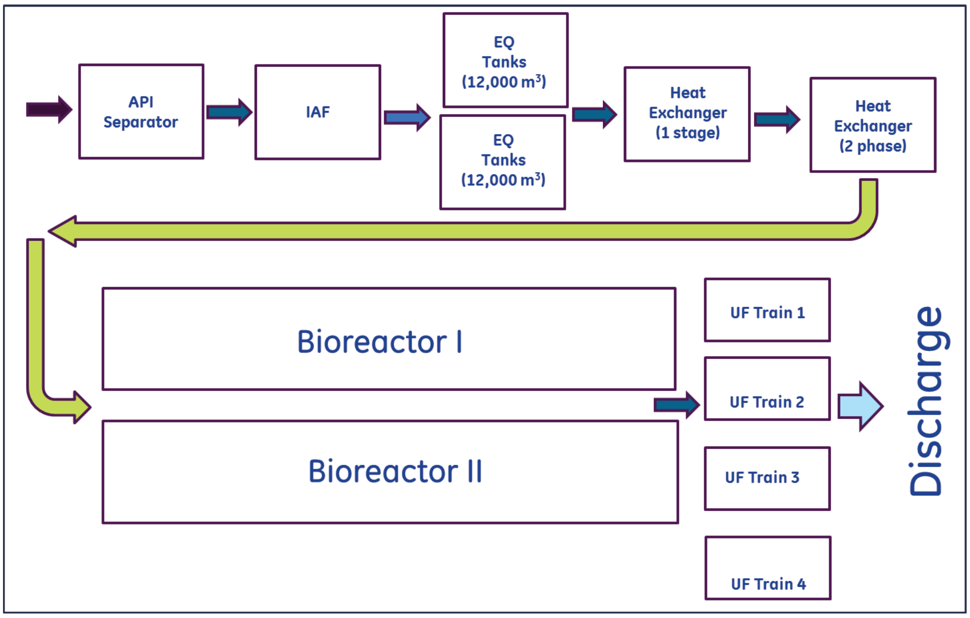

Fig. 6. BAPCO refinery wastewater treatment setup.

0.8 NTU which is lower than the maximum allowable value of 5 NTU. Similarly, the measured average total suspended solids were 1 mg/L, much lower than the maximum allowable value of 7 mg/L. Following the successful completion of the performance test, the UF system was put in operation. The performance of the first 3 months of operation confirmed the results obtained earlier during the performance test. The UF system consistently met the treatment capacity on a daily basis as well as all effluent quality parameters including total suspended solids and turbidity.

Following the extensive bench and pilot-scale testing to increase the level of confidence and to provide further insight into the selected solution, a 24,000 CM/D MBR was designed and installed as being the ideal technology for the refinery high salinity wastewater that exhibited poor biomass flocculation and low filterability. Today, the installed MBR consists of a four-stage biological treatment system followed by four membrane ultrafiltration (UF) trains (Fig. 6). Treatment challenges included stringent nutrient wastewater discharge limits and organic carbon and biological treatment complications from elevated temperatures. The latter was addressed through a double-stage cooling system to bring the wastewater temperature down from 48°C to 35°C. Spent caustic was used as a source of nutrients for the biomass. There was a concern on membrane fouling by oil but the pilot plant demonstrated the manageability of this risk and no problems with oil on the membrane or other issues concerning the membrane material have since been encountered.

Since its full operation commenced, the UF system has consistently met all effluent quality parameters, including total suspended solids and turbidity. With the success of the wastewater management program, BAPCO refinery has gone on to adopt mobile water to support its source water needs through seawater desalination, reducing its water bill and streamlining its water security operations.

In recognition of the treatment put in place by the BAPCO refinery and its commitment to water sustainability in industry, the project was awarded a Distinction Award at the GWI Global Water Awards event in Paris, France. Furthermore, the project won the 'Meed Quality Project of the Year 2014' and 'Meed Sustainable Project of the Year 2014 for the GCC'.

7. Conclusion and recommendations

Meeting refinery wastewater challenges through membrane-based biological treatment complemented by an integrated asset sustainability program offers excellent benefits in terms of environmental, operational and commercial gains. The prudent reuse of water can be accomplished through a creative combination of mechanical and chemical approaches, confidently addressing any corrosion, deposition and biological fouling issues that may be foreseen in reuse applications. Taking a holistic approach, the BAPCO Refinery in Bahrain, following intensive tests, has implemented a wastewater treatment system on best available technology basis to address its wastewater discharge concerns. Further, it has improved its water and wastewater footprint by engaging suitable chemical treatment and mobile water to meet its source water needs. A water reuse target in refineries can help with the economics of their water bill and with suitable polishing technologies, applications towards cooling and boiler water needs can be met. A review of the water balance at each industrial site is recommended to fully understand the economic and operational setting to achieve full results.

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