The PDO Nimr Reed Beds, Oman

Project Details

COMPANY

Petroleum Development Oman LLC

COUNTRY

Oman

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Produced Water Treatment Using Reed Beds

CONTEXT

Petroleum Development Oman (PDO) LLC is the foremost exploration and production company in the Sultanate. They account for more than 70 percent of the country's crude oil production and nearly all of its natural gas supply. PDO – a joint venture with The Shell Petroleum Company Ltc and the Government of Oman – is owned by the Government of Oman (with a 60 percent interest), Royal Dutch Shell (34 percent), Total (4 percent), and Partex (2 percent). The first economic oil find was made in 1962, and the first oil consignment was exported in 1967.

PDO operates in a concession area of approximately 100,000 square kilometers (one-third of Oman's geographical area), has approximately 130 producing fields, close to 6,000 producing wells, a diverse workforce of about 8,000 employees, comprised of 64 different nationalities, and more than 45,000 contractors.

At the PDO Nimr oil fields in Nimr, Oman, a tenth of the total production is crude oil. The remaining production, around 330,000 cubic meters per day, is water that is brought to the surface together with the oil. This water used to be disposed of by injection into a deep disposal well. To reduce the high costs of treating and reinjecting produced water, PDO together with BAUER, developed a project proposal that would reduce or eliminate the power consumption and carbon dioxide (CO_2) emissions associated with the operation of equipment for deep well disposal.

Stakeholders included PDO, a joint venture with The Shell Petroleum Company Ltd and the Government of Oman; and BAUER Nimr LLC, Oman, a subsidiary of BAUER Resources GmbH in Germany.

OBJECTIVE AND PROJECT OVERVIEW

PDO and BAUER developed a four-tier gravity-based wetland to remove oil from the water via microbes in reeds that naturally feed on hydrocarbons underground. This in turn reduces the high costs of treating and reinjecting produced water.

The facility was constructed under a build-own-operate contract, and as such, BAUER designed and built the facility and is now operating it for a 20-year period. The project, which became operational in late 2010, represents the world's largest commercial wetland currently covering more than 360 hectares and treating more than 95,000 cubic meters of produced water per day. Its capacity can be increased stepwise since the system is modular.

THE BUSINESS CASE

The reed beds provide significant energy savings compared to a manmade produced water treatment and injection facility. The gravity-based wetland design requires close to zero energy for water treatment, thus reducing power consumption – and CO_2 emissions – by approximately 98 percent (for the 30vol% of water treatment), because of the elimination of electric-powered water treatment and injection equipment.

DECISION MAKING PROCESS

Internal decision making was managed by the asset manager of the PDO Nimr operating asset (i.e., someone from the core business). Since there was a clear business case, no high-level CEO support was needed. However, a local project champion was required to push this project forward even with positive results from the pilot study. PDO also engaged the Government of Oman (shareholder of PDO) and a local university.

A 2-year pilot study was conducted to evaluate and optimize reed bed efficiency. This included recording and determining temperature, evaporation, and evapotranspiration rates, as these can highly influence the performance of a constructed wetland; as well as water throughput – total water going through the wetlands per unit time – parameters like retention time and hydraulic load for winter and summer seasons.

In addition to the performance evaluation, project selection criteria included capital and operational cost reductions and lowering the carbon footprint. Construction time of the wetland was found to be roughly half of the setup time for traditional gray infrastructure, in addition to the reduction in CO_2 emissions detailed above.

PROJECT DETAILS

As described above, PDO and BAUER developed a four-tier gravity-based wetland to remove oil from water via microbes in reeds that naturally feed on hydrocarbons underground.

The composition of the produced water from the Nimr oilfield is brackish, with total dissolved solids (TDS) ranging between 7,000 and 8,000 milligrams per liter (mg/L), and the oil in water content varies between 100 and 500 mg/L. As gravity pulls the water downhill, the reeds act as filters, removing oil from the water. The oil is eaten by microbes that naturally feed on hydrocarbons underground. Locally grown *Phragmites australis* plants are used for purifying produced water.

The plant layout includes a pipeline, which enters the Nimr Water Treatment Plant system and leads to an oil/water separator. The water is then distributed into a wetland facility where it is channeled through four wetland terraces by gravity. Finally, evaporation ponds are used to recover the salt while the biomass was initially planned to be landfilled. Alternative uses of the effluent water and biomass that could offer a variety of environmental and socio-political benefits are being explored.

As with every effluent treatment plant, the subsoil must be properly sealed. In selecting suitable sealants, synthetic materials were rejected in favor of a natural product. The surrounding desert areas were searched for suitable clay until an appropriate sealant mixture was found.

The site has been fully operational since December 2010, two years after the contract was awarded. The reed beds have proven to be capable of efficiently and cost effectively handling treatment of the produced water from the Nimr oilfields. The facility makes use of feedback loops for monitoring the health and efficacy of the wetland system. The oil content in the produced water is consistently reduced from about 300 mg/L to less than 0.5 mg/L in effluent. Furthermore, the wetland facility enables a crude oil recovery of 200 extra barrels per day.

In addition, the wetlands provide habitat for fish and hundreds of species of migratory birds, and provide potential for achieving improved system resiliency by increasing biodiversity, by using various types of reeds.

LESSONS LEARNED

Key lessons were learned through implementing the project:

- The project required a large land footprint; more than 360 hectares to treat 95,000 cubic meters per day of produced water.
- A long pilot period (more than 2 years) was required to de-risk the constructed wetland technology and find the optimum wetland design.
- There were operational risks of the wetland pilot test – including the potential risk of not meeting the performance requirements because of external factors (e.g., seasonal temperature swings, biotic stresses).
- It is recommended to use a non-biased project evaluation process to select the best available solution.
- Climate data and local soil conditions are essential design parameters.
- A champion was required to propel this project forward even with positive results from the pilot study.
- It is important to involve a variety of key stakeholders in the project (e.g., universities).

FUTURE IMPLEMENTATION AND NEXT STEPS

Although green infrastructure solutions often present a strong business case and typically provide more categories of benefits than gray solutions, they have not yet been widely adopted into core business practices and capital project evaluations. Critical success factors for implementing green infrastructure solutions are summarized below:

- Employ a more comprehensive economic and environmental footprint analysis to more accurately compare green versus gray infrastructure.
- Engage with the engineering community (utilities/process technology/waste stream management, etc.) to build organizational capacity and expertise in green or hybrid infrastructure engineering.
- Develop learning modules that focus on identifying green infrastructure opportunities and evaluating typical failure modes of green infrastructure solutions to develop internal skill sets.
- Establish an external network from academia, research and development institutes, and contractors to facilitate knowledge sharing and skill transfer activities.
- Engage with the project community early on in the project development process to ensure green infrastructure solutions are being considered as part of the early field planning process.
- Engage with the new business development community to develop innovative value propositions that emphasize the potential of green infrastructure solutions to boost the local economy (e.g., through innovative byproduct optimization).

Build a fit-for-purpose set of capabilities integrating the areas of strategy, innovation, new business development, project economics, engineering, and environmental sustainability.

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