SHELL: PRODUCED WATER TREATMENT USING REED BEDS

Source/Organization: Petroleum Development Oman LLC (PDO): joint venture with The Shell Petroleum Company Ltd and the Government of Oman (majority)

Scale: Large – world's largest commercial wetland covering more than 360 ha and treats more than 95,000 m^3 of produced water per day

Key stakeholder(s): Government of Oman , BAUER Nimr LLC, Oman (a subsidiary of BAUER Resources GmbH in Germany).

Project Phase: The plant came online in late 2010.

Geographical Location: Nimr, Oman (Nimr is located inland in South West Oman)

PROJECT OVERVIEW

At the PDO Nimr oil fields, a tenth of the total production is crude oil. The remaining production, around 330,000 m³ 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 re-injecting the produced water, PDO together with BAUER, developed a project proposal that would reduce or eliminate the power consumption and CO_2 emissions associated with the operation of equipment for deep well disposal. The solution was a four-tier gravity-based wetland design.

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 the purification of produced water. The composition of the produced water from the Nimr oilfield is brackish; with total dissolved solids (TDS) ranging between 7,000 mg/l and 8,000 mg/l, and the oil in water content varies between 100 to 500 mg/l. The plant layout includes a pipeline, which enters the NWTP 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 feed. Finally, evaporation ponds are used to recover the salt while the biomass is land filled. Alternative uses of the water and biomass that could offer a variety of environmental and socio-political benefits are being explored.

The constructed wetland is designed to treat 95,000 m³ per day (30% of the daily volume of water produced by the oilfield). 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.

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.

A pilot study was used to evaluate and optimize reed bed efficiency. The reed beds have proven to be capable of efficiently, and cost effectively, handling the treatment of the produced water from the Nimr oilfields.

Technology Maturity

Proven; fully operational since late 2010.

Investment/Costs/Time

- The project required a pilot study of more than 2 years.
- The wetland was fully operational 2 years after the contract was awarded.

Project Management Considerations

- Project selection criteria: capital and operational cost reductions, lowering the carbon footprint.
- Construction time of the wetland was roughly half of the traditional, gray infrastructure.
- Pilot studies involved recording and determining temperature, evaporation and evapo-transpiration rates as these can highly influence the performance of the constructed wetland.
- Pilot studies also investigated throughput parameters like retention time and hydraulic load for winter and summer seasons.

Benefits

- Significant capital cost savings compared to the man-made produced water treatment and injection facility.
- The gravity-based wetland design requires close to zero energy for water treatment, thus reducing power consumption by approximately 98% (for the 30vol% of water treatment) due to the elimination of electric powered water treatment and injection equipment. Also, the new facility enables an additional crude oil recovery of 200 barrels per day.
- Satisfactory water treatment performance ever since the start of the wetland operation (December 2010). The oil content in the produced water is consistently reduced from 400 mg/l to less than 0.5 mg/l when leaving the wetland system.
- CO_2 emissions reduced by approximately 98% (for the 30vol% of water treatment) due to the elimination of electric powered water treatment and injection equipment.
- The wetlands provide habitat for fish and hundreds of species of migratory birds. Also, the wetlands offer potential for innovative customer value propositions that could provide a variety of socio-political benefits e.g. through by-product optimization (fresh water, biomass etc.).

Risks/Challenges

- Large required land footprint: more than 360 ha to treat 95,000 m^3/d of produced water
- Long pilot period (>2 years) required to de-risk the constructed wetland technology and find the optimum wetland design.
- Operational risk of the wetland: potential risk of not meeting the performance requirements due to external factors (e.g. seasonal temperature swings, biotic stresses).

Resiliency Aspects

- This system is modular and the capacity can be increased stepwise.
- Potential for achieving improved system resiliency by increasing biodiversity (using various types of reeds).
- The facility makes use of feedback loops for monitoring the health and efficacy of the wetland system.

Key Learning

- Climate data and local soil conditions are essential design parameters.
- A champion was required to push this project even with positive results from the pilot study.
- It's important to involve other key stakeholders in the project (e.g. universities).
- It's recommended to use a non-biased project evaluation process to select the best available solution.