Task 5-D. Desktop Version of:

Treatment Train for Reusing and Recycling Produced Water

This desktop study is identical to the full version of Task 3, but omits all aspects related to building or testing the bench-scale apparatus. The key technical element in this desktop study is the process flow diagram and may benefit from computer simulations. The virtual competition will include an oral Zoom presentation and a follow-up Zoom Brochure Discussion.

Task proposed by The Produced Water Society

The Produced Water Society (PWS) is taking the lead to standardize water-quality specifications for treated produced water and your team is invited to become part of this ground-breaking effort. The PWS seeks to establish a standard for "clean brine" (CB), that has a dependable chemistry and is suitable for reuse in fracturing fluids[1]. By standardizing CB chemistry, production costs of treating produced water (PW) can be greatly reduced, leading to increased reuse of PW[2].

Two significant environmental results will be 1) conserving fresh and brackish groundwater and 2) reducing the volume of saltwater being disposed in deep-injection wells that may contribute to induced seismicity[1].

Background

In conventional oil production, oil is pumped from permeable rock formations, such as sandstone. The permeable layers allow the oil to flow through the formation to the well bore to be recovered. The sands are termed a 'conventional play.' (A 'play' is a geologic formation that is producing hydrocarbons oil and gas.) In recent years, oil companies have expanded their efforts to recovering hydrocarbons in geologic formations that have low permeability, such as shale. Known as unconventional plays, these require horizontal drilling and hydraulic fracturing of the shale to create high-surface-area flow paths that will allow the hydrocarbons to flow to the well bore.

Hydraulic fracturing technology requires large quantities of water for the fracturing fluids and also generates huge quantities of byproduct water. These waters are from flowback of the fracturing fluids as well as from connate water (water that was trapped in the rock prior to drilling). Since flowback and connate waters are often combined in the field, we group them together in the term 'produced water.'

Companies known as water midstream companies have installed pipelines to gather PW from producing plays. Depending on the situation, they either deliver the water to disposal wells, or they treat the water and sell it back to the oil companies to reuse in hydrofracturing operations. Currently, with no standardization for CB, each oil company that purchases PW from the water midstream companies sets unique water-quality specifications. This requires the midstream companies to specialize their treatment processes to meet a myriad of specifications. Each new set of specifications limits the scale of operations for treatment, driving up costs and therefore limiting reuse of the waters, since it is often cheaper in the short run to use fresh groundwater.

Standardizing CB specifications will allow water midstream companies to treat PW at greater scale and, more significantly, they will be able to share CB across their pipeline systems. This reduces the need for costly storage ponds that not only have a large footprint, but often require a greater level of treatment to adjust for natural water quality degradation in the ponds. Hence, establishing a standard for CB will reduce capital costs, production costs, storage costs, and environmental footprint for PW. The PWS has drawn up specification guidelines as a first step toward standardization. The guidelines will be used in this task.

See Appendix I for more information about PW.

Treatment Train

This task calls for a treatment train to produce CB of a specific chemistry. A "train" refers to a process in series (that may involve multiple unit operations) that can be replicated. Thus, if one treatment train treats 20,000 bbls per day of produced water, then five trains combined can treat 100,000 bbls per day.

The task targets a 20,000 bbl/day treatment rate that can be duplicated to achieve a 100K bbl/day treatment rate because there is much potential for innovation at the 20K bbl/day rate. However, if a team identifies innovative ways to directly treat the PW at a rate of 100K bbl/day, they may do so. Your team is given the choice of approaches and is encouraged to think out of the box to explore new ways of treating 100,000 bbl/day.

Problem statement

Your team will research, evaluate, and design a process for producing clean brine from produced water to the specification guidelines listed by the Produced Water Society (see Table 1) starting from a PW chemistry shown in Table 2. Teams are encouraged to explore innovative treatment methods.

The goal is to develop a treatment process that meets the proposed standards with a practical, low cost, small footprint solution that can treat 20,000 bbl/day (times 5) or 100,000 bbls per day, when utilized for larger-scale treatment.

Teams may include a computer simulation to assist in the presentation.

Table 1. Common Clean Brine Minimum Specification for Reusing Recycled Produced Water[1,3].

Parameter	**Minimum Specification**
Salinity	Reported after treatment
pH	6.0-8.0
Oxidation reduction potential (ORP)	>350 mV
Turbidity	<5 mg/L (approx. 25 NTU)
Oil	<30 ppm – no sheen
Hydrogen sulfide (H_2S)	Non-detectable
Particle size	Filter <25 micron

Table 2. Starting chemistry. Assume you are treating produced water with chemistry shown below[4].

Water phase	**Amount per liter of synthetic solution**
DI water	750 mL
Sea Salt	120 g
Oil phase	**Amount per liter of synthetic solution**
TrueSyn 200 I	92 mg
Xylene	4 mg
Hexadecane	4 mg
Solid phase	**Amount per liter of synthetic solution**
Fine-grade Arizona Test Dust	50 mg
Bentonite Clay	50 mg

Design Requirements

Your proposed design should provide specific details and outcomes as follows:

- Design a treatment train or a treatment process for producing clean brine from produced water (specification guidelines in Table 1; starting PW chemistry in Table 2).
- The key feature of your analysis is an accurate and detailed Process Flow Diagram (PFD) that addresses the total 100,000 bbl/day treatment rate, either treated directly or made of 20,000 bbl/day trains. The PFD should include all selected treatment processes and must include mass and energy balances (input and output rates, reactants, and reaction rates, etc., as applicable). See the 2021 Team manual for an example of an acceptable PFD.
- Your analysis may include a computer simulation, but it must be based on the PFD.
- List all vendor sources, and report and reference all performance data for each piece of equipment or materials.
- List all equipment, materials, and chemicals needed, and indicate all efforts to reduce costs.
- Minimize and report on the footprint required for the full-scale treatment operation.
- Estimate the capital expenses (CAPEX) to construct a full-scale water treatment process to treat 100,000 bbl/day of PW using your selected water-treatment technology.
    - If your team has chosen to design a 20,000 bbl/day treatment train, show all expenses for one train and any cost reduction per train when duplicating the train to process the full 100,000 bbls/day.
    - If your team has chosen to design a 100,000 bbl/day treatment process directly, without the use of multiple treatment systems, show all expenses needed for this large-scale process.
    - Capital Expenses include, but are not limited to, equipment, pipes, pumps, etc.
    - Do not include costs of buildings and appurtenances to the treatment train.
- Estimate the operating expenses (OPEX) (calculated as cost/bbl of clean brine produced) to treat this water on an annual basis, including, but not limited to,
    - materials needed, including consumables (chemicals, sacrificial components, etc.)
    - solids disposal costs ($50/ton)
    - energy requirements (Cost/bbl and Kwh/bbl) assuming an industrial electricity rate of $0.09/kWh
    - staff required and labor rate of $70/hr.
- Identify and address the fate of any waste products generated by the PW treatment technology.
- Address any intangible benefits of the selected treatment process.
- Discuss your plan's adherence to appropriate federal (USA), state and local laws and regulations. Be sure to attend WERC's webinar for helpful tips for addressing regulatory issues.
- Include a Public Involvement Plan, as applicable (See Team Manual).
- Address safety aspects of handling the raw produced water and any final products. Be sure to attend WERC's webinar for helpful tips for addressing health and safety issues.
- To qualify for the P2E2 award, in a separate section of the report, document success in improving energy efficiency, pollution prevention, and/or waste minimization, as it applies to your project.

Technical Report Requirements
The report should demonstrate your team's insight into the full scope of the issue and include all aspects of the problem and your proposed solution. The report will be evaluated for writing quality, organization, clarity, reasoning, and coherence. Standards for publication in technical journals apply.

The report must address in detail the items highlighted in the Problem Statement, Task Requirements, Evaluation Criteria, and the 2021 Team Manual.

This desktop-study technical report should total no more than 16 pages, including title page, executive summary, and references. Note that this is shorter than the full-contest entry, because virtual contest entries do not include discussion of bench-scale results. The required page formatting has changed this year—check the 2021 Team Manual for more information.

Technical Report Checklist:

- Title Page
- Executive Summary
- Body
  - Background Research
  - Detailed Process Flow Diagram quantifying all mass/energy balances
  - Materials List
  - CAPEX
  - OPEX
  - Public Involvement Plan (no more than 1.5 pages)
  - Regulatory Discussion (no more than 1.5 pages)
  - Health and Safety issues associated with full-scale treatment (no more than 1.5 pages)
- References
- Audits (not included in page count)

Evaluation Criteria
Refer to the 2021 Team Manual for a comprehensive explanation of the evaluation criteria. For a copy of the Team Manual, Public Involvement Plan, and other important resources, visit the WERC website:
https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/

Evaluation of your solution will be based on the items highlighted in the Problem Statement, Design Requirements, and the following:

- Technical fundamentals, performance, safety and other issues stated in the problem statement
- Potential for real-life implementation
- Thoroughness and quality of the economic analysis
- Originality, innovation, functionality, ease of use, maintainability, reliability, and affordability of the proposed technology
- Estimated treatment rate and efficiency
- Other specific evaluation criteria may be provided at a later date (watch the FAQs).

FAQs/Deadlines

- Teams are responsible for all task updates posted in the FAQs online (wercdesigncontest.nmsu.edu)
- Due 29 March 2021: Technical Report.

References

[1] A Common Clean Brine Specification for Reusing Recycled Produced Water – Draft Guidelines, June 2020. Accessed 8/26/2020: https://www.producedwatersociety.com/

[2] Will Water Issues Constrain Oil and Gas Production in the U.S.? Bridget R. Scanlon*, Svetlana Ikonnikova, Qian Yang, and Robert C. Reedy *Environ. Sci. Technol.* 2020, 54, 6, 3510–3519

[3] Trading Water at Terminals, Aaron D. Horn, Shale Play Water Management, Nov-Dec 2019. (Accessed 8/6/2020: https://www.shaleplaywatermanagement.com/trading-at-water-terminals)

[4] Produced Water, Volumes I and 2, John M. Walsh, Petro Water Technology, 2019.

Awards

Each year, the WERC Environmental Design Contest and its sponsors award more than $25,000 in cash prizes. Successful completion of every stage of the design project qualifies each team for the following awards.

1. Full task awards (First, Second, Third Place; minimum amounts: $2500-$1000-$500, respectively).
2. Virtual (Desktop Study) Awards (awarded independently of the full bench-scale designs). Amounts TBA.
3. WERC Resources Center Pollution Prevention/Energy Efficiency Award (P2E2) ($500)
4. Judges' Choice Award ($500)
5. Peer Award ($250)
6. Terry McManus Outstanding Student Award. ($500-$1000, according to funding).
7. Additional awards may be announced later.

Award amounts listed are minimum amounts and may increase with available funding.

Detailed criteria for each award: https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/

Appendices

Appendix I–Produced Water in Oilfield Applications.

Hydrocarbon production from unconventional formations (those that require horizontal drilling and hydraulic fracturing technology) uses large quantities of water and generates huge quantities of byproduct water. The byproduct waters are from two distinct sources: 1) Flowback waters are the initial waters that come back to the surface within 3-4 weeks after a well is producing. These largely consist of the water used for hydrofracturing. They have a complex fracking chemistry and are loaded with shale fines. 2) Connate waters. After 3-4 weeks, most of the water coming up is connate water (water trapped in the rock formation before drilling). Connate waters contain hydrocarbons and fines, but they are less complex and simpler to treat than flowback waters.

When shale plays were first under development, most of these waters were disposed of in UIC Class II saltwater disposal (SWD) wells[1], but early in the shale boom, PW recycling was widely adopted in the Marcellus and Utica plays due to the high cost of transporting PW to disposal wells in Ohio and West Virginia. The practice of PW recycling has been gradually adopted in the largest shale plays: The Midland and Delaware portions of the Permian Basin. There has been very limited PW recycling in other shale plays.

As treatment technologies have improved and scales of operation have grown, it is now often more cost effective to recycle PW than to dispose of it in SWD wells. Improvements such as the development of salt-tolerant fracking chemistry packages has facilitated this change, allowing for the recycling of PW as make-up water for fracturing fluids. Presently, produced water volumes are 200-400% in excess of the annual completion source-water demand in the Delaware portion of the Permian Basin, offering significant opportunity for reuse.

Appendix II—Discussion of Parameters

a) ***Salinity*** —The salinity of CB may vary throughout the unconventional play and can fluctuate in individual wells over the course of their productive lives. In industry, companies are expected to report salinity, but not alter it. For the contest, teams are expected to measure and report salinity values, but treatment processes should not significantly alter initial salinity.

b) ***pH***—The pH parameter can be measured with pH probes.

c) ***ORP***—ORP is a valuable parameter that can be measured with probes. Water with ORP >350 mV should be relatively free of bacteria. This level of ORP should oxidize any dissolved iron to the ferric state, which will precipitate.

d) ***Turbidity***—Measurement of turbidity can be performed with a line light transmittance probe measuring NTU (nephelometric turbidity units). Turbidity is a measure used to determine the level of total suspended solids (TSS). Turbidity does not give any indication of particle size. Large particles would need to be captured in 25-micron solids filters at the point where the CB is transferred to the sales line.

e) ***Oil***—It is in the water treater's interest to capture as much of the oil as possible that comes into their treatment facility, as recovered oil is a revenue stream. Oil can be measured on-line with fluorescence technology, but this is an expensive instrument and must be calibrated when there is any change in source water.

The Static Sheen Test (EPA Method 1617) is adequate for this contest. The 30-ppm oil limit intends to avoid oil sheens on CB storage ponds receiving this water because free-phase oil sheens would require expensive bird protection measures around ponds.

f) ***H_2S***—Operators will not accept CB waters with detectable H_2S. This parameter poses significant risk to personnel, as well as a corrosion risk for facilities. Any hydrogen sulfide in excess of 1 ppm above the water phase will easily be detected by the treatment team. Since this is a bench-top competition, hydrogen sulfide is not expected, but can develop in actual produced waters that are not treated with a biocide. WERC will not test for H_2S at the contest.

g) ***Particle size***—Particle size can be measured with on-line laser spectroscopy, which are expensive instruments. A low-cost and practical approach is to use a Millipore test. For the contest, it is unacceptable to have particles large enough to sink to the bottom of the treated CB. Each team's CB will be allowed to sit overnight to ensure that no large particles precipitate.