# A PARADIGM SHIFT FOR SHALE:
## THE ENVIRONMENTAL, FINANCIAL, AND LITIGATIVE IMPETUS FOR PRODUCED WATER RECYCLING

**The new heart of the American energy landscape, the Permian and Delaware Basins, is an exciting place to be right now. Production wells are expanding rapidly across western Texas and eastern New Mexico, which has brought forth the promise of economical prosperity for the region and greater energy security for our nation. However, with this growing opportunity also comes an immense set of responsibilities, particularly with respect to environmental stewardship and the implementation of sustainable practices.**

A lot has been made about the seemingly thirsty process of production well stimulation, hydraulic fracturing, whereby large amounts of water are utilized to extract sequestered hydrocarbons from relatively impermeable subsurface strata. In the case of production wells in the arid Permian region, where lateral fractures have increased in length from 5,700 to 6,800 lateral feet on average, the median amount of water used to stimulate each lateral has increased to 12 million gallons (Backstrom, 2018). Water use has increased by more that 400% in the past few years, which is attributable to the favorable subsurface geology and the fact that there are multiple petroliferous strata in west Texas that are 'stacked' underground and can be stimulated sequentially.

Further to this point, unconventional wells in the Permian region generate approximately 3 times more wastewater (produced water) than oil (Scanlon et al., 2017). When considering the water requirements for well stimulation, in conjunction with the fact that more than 2 million barrels of oil are being produced each day in the Permian (Khan et al., 2016), it is easy to see that the effective management of fresh and produced water streams is paramount to the oil and gas industry.

What is the most sustainable way to manage these waters? Are there treatment technologies out there that can recycle produced oilfield waste so that we don't have to use so much fresh water, and does this strategy makes sense on the balance sheet? Are there any legal liabilities? To address these questions, we discuss the mutually inclusive environmental, financial, and litigative impetus for produced water recycling in an effort to illustrate that this paradigm shift in the shale energy sector makes sense on multiple fronts.

## Environmental

What if we could treat the produced waste to the point that it could be reused for the stimulation of subsequent production wells? This would not only reduce the reliance on fresh water resources, but it will also reduce the occurrence of induced seismicity, which has been linked to the subsurface disposal of produced water (Hornbach et al., 2016). Unfortunately, waste streams from shale energy extraction can be incredibly complex matrices. They are comprised of multiple organic, inorganic, and biological constituents, which can preclude their direct reuse for practically any application.

The presence of certain volatile organic compounds and metal ions can affect downhole polymer chemistry, whereas various species of sulfate-reducing and iron-oxidizing bacteria can cause the souring of produced hydrocarbons, as well as compromise production infrastructure. Collectively, these contaminants have traditionally rendered the repurposing of these waste fluids a significant challenge, which, in turn, has made the subsurface disposal of oilfield waste a more functional and convenient option. Nonetheless, our research team has recently partnered up with several industry colleagues to evaluate a wide range of water treatment technologies (i.e., ozonation, particulate filtration, UV exposure, and the use of variable carbon medias), to ultimately assess the feasibility of oilfield waste recycling under field conditions.

Screening hundreds of samples for over 2,500 variables, we observed raw waste samples that exhibited total organic carbon levels as high as 1,500 mg/L, be treated to a clean state (<10 mg/L) resembling unperturbed brackish groundwater (Figure 1, left to right). Collectively, our experiments revealed that multiple treatment technologies were required in order to remove pertinent organic, inorganic, and biological contaminants below their respective reuse thresholds (Hildenbrand et al., 2018).

The next challenge for the environmental stewardship of produced water recycling will be to secure additional desalination technologies, which can convert any treated brine into a viable source for agricultural discharge and/or other beneficial uses. This is particularly germane to the Permian Basin region where the increased number of production wells and amplified scrutiny surrounding injection well permitting has created a perfect storm whereby quantum amounts of waste need to be

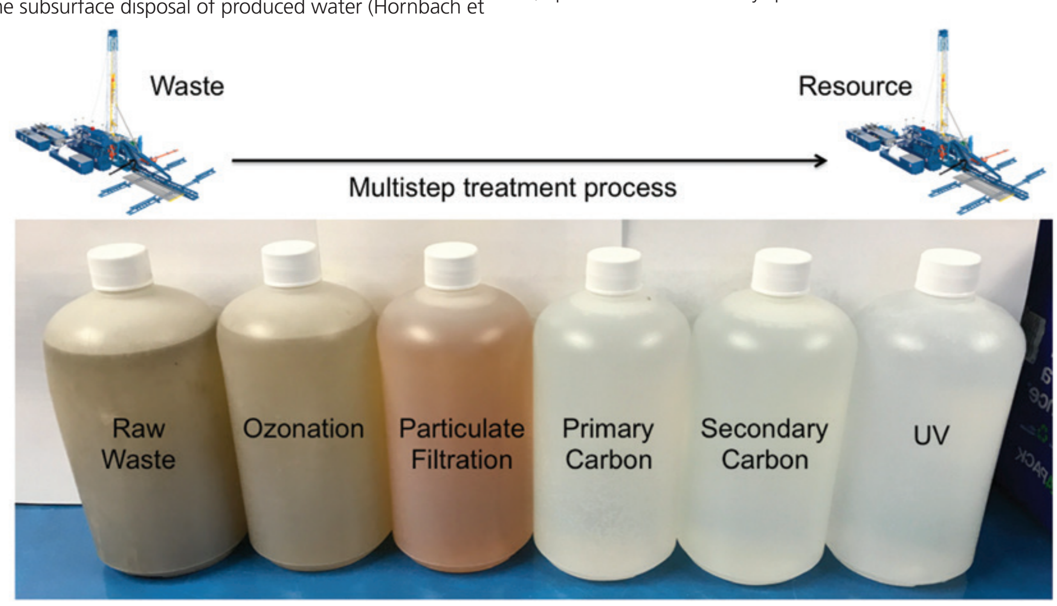


*Figure 1: The multistep treatment of produced water using complementary separation technologies (Challenger Water Solutions) (Hildenbrand et al., 2018).*

treated, desalinated, and then discarded responsibly. Generally, membrane-based modalities such as reverse osmosis are ideal for the removal of trace metals and salts. However, oilfield wastes can exhibit salt concentrations more than four times that of seawater, which can render traditional modalities ineffective and cost-prohibitive. This challenge, to desalinate brine solutions of notable ionic strength, coincides with significant financial implications, particularly with respect to the potential extraction of precious metals and the production of valuable chemicals.

## Financial

Irrespective of the environmental benefits of produced water recycling, the widespread adoption and utilization of this ostensibly novel paradigm hinges on economics. And while it is often difficult, at least as an academic research group, to quantify the exact costs of buying fresh water, paying for trucking to deliver said water to a production site, paying for trucking to transport the resulting waste to a nearby salt water disposal site, and then paying the disposal fees – the cumulative costs appear to range between $1.75 and $2.75 per barrel, depending on logistics. As such, if produced water could be treated to the point of reuse and/or where it could be repurposed for agricultural applications for less than $1.75/bbl, then this method of waste management would be economically favorable for operators. Fortunately, the excitement surrounding 'Permainia' has triggered significant competition in the water treatment industry, and this is being reflected in operational expenditures. We have seen start up companies like Challenger Water Solutions transform highly variable oilfield waste into a reusable resource for approximately $1.00/bbl. Again, as one considers the amount of produced water that is being generated by the large unconventional production wells in the Permian region, even a cost savings of $0.75/bbl is substantial and would make any O&G CFO smile.

As previously mentioned, the inherent geochemical richness of produced water offers opportunities to extract precious elements during the recycling process. For example, in many shale energy basins the representative produced water can exhibit extremely high levels of lithium, iron, and cobalt (Kang et al., 2017), which are of critical importance to the production of lithium-ion batteries. In other words, the recycling of produced water could not only save operators money by obviating the need to dispose of their waste through subsurface injection, it could also provide a source of revenue as the extracted metals are sold to battery manufacturers like Tesla. Further to this point, there are also now companies, such as Enviro Water Minerals, that can transform highly saline produced waters into hydrochloric acid, magnesium hydroxide, caustic agents, and other useful industrial chemicals. Collectively, the recycling of produced water can transform a waste source into a prized resource that can generate revenue from a number of different sectors.

## Litigative

Risk mitigation is another reason why the systematic recycling of produced water makes sense for all operators, especially for those operating in Texas. According to Chapters 122 and 123 of the Natural Resource Code of Texas (treatment and recycling for beneficial use of fluid oil and gas waste, and treatment and recycling for beneficial use of drill cuttings, respectively), when oilfield waste is transferred from an operator to a recycling/treatment company, that waste is now the property of the recycler and so too is the liability. In fact, section 122.003 specifically states that the transfer of oilfield waste relinquishes liability in tort for any consequences of the subsequent use of the transferred product. In other words, upon transferring produced water to a recycler, the operator is no longer liable for any surface spills and/or the mismanagement of the waste. This has positive financial implications as it greatly reduces operator risk during an era when the amount of waste water being produced continues to grow.

Collectively, the benefits of recycling produced water are growing, as are the incentives. This relatively new paradigm represents a significant opportunity within the oil and gas industry to champion environmental stewardship, all while reducing overhead costs associated with water management and potential liability. To learn more about produced water recycling and the various technologies that currently available, we invite you to join us in Arlington, TX on October 13th for the 2nd Annual Responsible Shale Energy Extraction Conference (www.shalescience.org). This year's event will feature panel presentations with experts covering waste management strategies, water infrastructure, and emerging technologies. Bringing scientists, engineers, regulators, operators, technology developers, service companies, and the investment community together, this event is poised to be a unique environment for new collaborations, partnerships, and opportunities.

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