Aligning Water's Value with Water Management Practices

Opportunities exist but much work remains before cross-sector water management planning achieves its objectives.

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Intuitively and objectively, we know water is a precious resource. We know water affects all facets of life and we are familiar with various platitudes often used to remind us of this point. But how well do our water management practices align with that understanding? When water is readily available, inexpensive and subordinate to the production of highly sought-after commodities, does it simply become a means to an end, a cost in the value chain to be minimized without consideration of broader implications? How do we improve our water management practices and transition from water simply being a cost of production to a vital resource tied to the health and economic future of the area? And how do we demonstrate that our understanding of the implications of our water use extends beyond those associated with its immediate use?

Much work remains before cross-sector water management planning achieves the objective of allocating the highest quality water to the highest value uses. Neverthless, progress is being made and some cross-sector cooperation is occurring. Here are some examples and technical developments to be considered that better value water as a special resource for which there is no substitute.

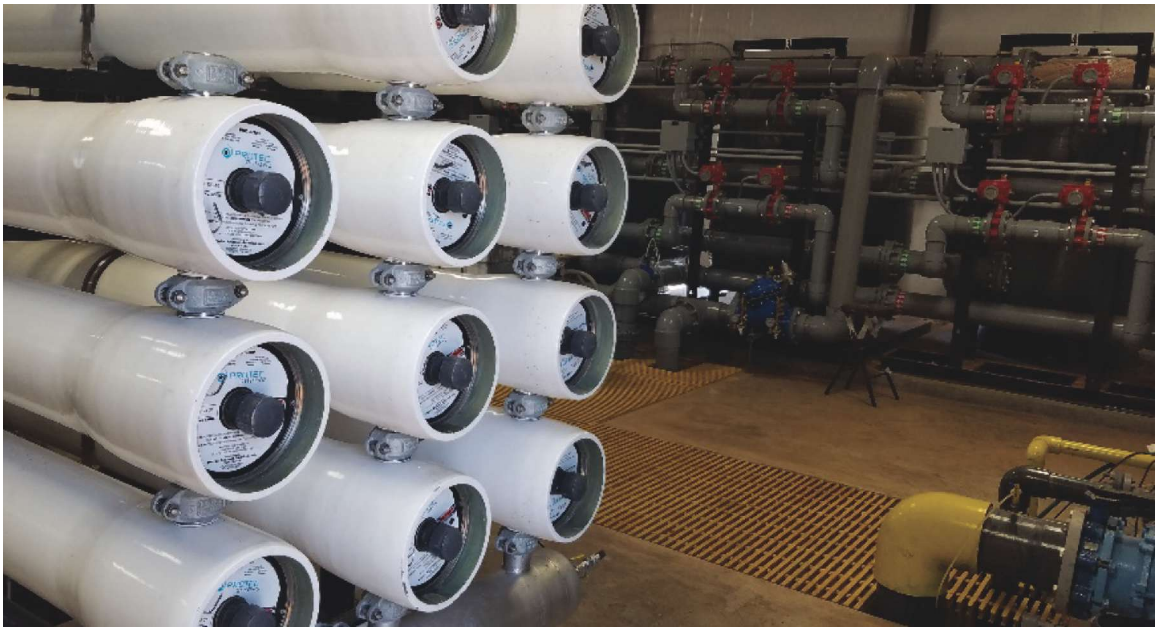
West Texas water resource integration

While still in the development stage, this concept originated as a result of changes in the Safe Drinking Water Act and EPA's new standard calling for lower levels of arsenic in drinking water. Since arsenic occurs naturally in much of the groundwater in West Texas and since groundwater is the primary source of drinking water in this area, additional treatment is required. After treatment, approximately 80% of the treated water is available for potable supply and the remaining 20% must be disposed of as wastewater.

As a result, a city not only needs to replace that 20% loss in supply, it also must find a suitable discharge alternative for the wastewater. This became an excellent opportunity for the municipal sector to cooperate with the oil and gas industry. Since the wastewater quality is acceptable for use by the industry, it can become a new source of supply. And since industry has a new source of supply, it can sell some of its freshwater to the city to help meet potable water demands.

Municipal wastewater as a reliable supply

Another opportunity for cooperation that is seeing increasing interest is the use of municipal wastewater treatment plant effluent. For example, in 2016 Pioneer Water Management (PWM) announced an agreement with the city of Odessa to provide Pioneer with millions of gallons of treated municipal wastewater for use in its op-



This drinking water treatment plant removes TDS, arsenic and fluoride. Wastewater generated is acceptable for industrial use. *(Photo courtesy of Primoris Services Corp.)*

erations. PWM constructed 20.3 miles of 24-in. polyethylene pipe from Odessa's Bob Derrington Water Reclamation Plant in Midland County to one of its water supply facilities. It is designed to flow 150,000 bbl/d of water. In December 2016, PWM announced a similar agreement with the city of Midland, except in this case, PWM would upgrade Midland's wastewater treatment plant to provide the requisite treatment so the effluent could be reused. These agreements significantly reduce PWM's need for freshwater and makes productive use of a non-potable resource that was previously unused.

Shared infrastructure

Another growing trend is the construction of shared pipelines and treatment systems that provide a regional supply of water to various entities in a geographic area. Such shared infrastructure is common in the municipal sector and companies like Primoris Services Corp. are extending that strategy to the industrial sector. Since the cost of the infrastructure is shared, a more robust system that delivers water over longer distances can be put in place while maintaining cost and service benefits. When coupled with site-specific water-treatment technologies (either mobile or semi-permanent) shared infrastructure preserves flexibility, opens new sources of supply and offers the benefits of economies of scale.

Water reclamation and reuse

Water reuse is a common practice in the municipal water sector and is becoming more common in the oil and gas sector. Several states are encouraging this practice by creating a regulatory framework that is friendly to reuse alternatives. As a result, recycling has reduced the use of freshwater in oil and gas production operations, the amount of produced water hauled by trucking and disposed underground has decreased, and produced water is now a resource and sold as a commodity for reuse in hydraulic fracturing operations.

New treatment options are aiding the transition to increased reclamation and recycling of produced water. One such technology that appears promising involves the introduction of nano-scale bubbles—estimated at 10 nm to 50 nm—in produced water, enabling operators to reduce residence time for settling solids, increase oil recovery and provide a cleaner water that can be repurposed for other applications. Full-scale use in the Permian has demonstrated that nano bubbles affect the fluid dynamics by changing the density, viscosity, electric potential, ionic potential and zeta potential enabling operators to handle produced water in a more efficient method.

The science of nano bubbles

The smaller the droplet size the more stable the system. Nano scale gas droplets are colloidal (less

Effluent from the Nano Gas process is shown. (*Photo courtesy of Nano Gas Technologies Inc.)*

than 10 μ in size); therefore, a more stable system of bubbles.

When a system incorporates nano-scale gas droplets, Stokes' Law for the frictional force exerted on spherical objects with very small Reynolds numbers in a viscous fluid does not occur. Instead, a modified Stokes Law applies due to the higher osmotic pressure at the gas liquid interface, thus preventing nano bubble dissolution. Zeta potential is then reduced in the presence of higher ionic strength.

Nano Gas Technologies Inc. has developed and patented equipment to infuse nano-scale bubbles of various gases into different waters. The effect on aqueous constituents of solids, FeS_2 (iron sulfide), sand and oils of varying API gravity (from extra heavy to light) without the use of heat is promising. The infusion of nano bubbles decreases the density by adding millions of bubbles per cubic meter in the solution which increases the buoyancy of oils and enables them to rise to the surface. The nano bubbles decrease viscosity and surface tension enabling solids to fall more rapidly due to the decrease in the drag coefficient. They have also observed solutions at levels exceeding six times that of Henry's Law or the Ideal Gas Law at standard temperature and pressure at scale sizes common at saltwater disposal sites. The saturated solution remains stable with a half-life expectancy of 15.2 days. This means virtually 100% of the infused nano bubbles are available to achieve the desired goals and objectives.

The velocity that bubbles rise freely through an uncluttered solution is directly related to the square of their radius such that 100-nm-diameter bubbles will take well over two weeks to rise 1 cu. m whereas 10 μ diameter bubbles only take 2 to 3 minutes to rise that far.

Finally, the infusion of nano bubbles increases the ionic potential which enables the bubbles to attract the polar oil droplets to attach to the bubbles and increase buoyancy and rise to the surface.

The Nano Gas process takes a slipstream of cleaned effluent water and a gas or blend of gases and injects it into a 30-gal pressure tank. The mixture of water and gas is then continuously released into a 240 bbl to 1,000 bbl treatment tank via proprietary delivery systems to cause the desired reactions. The equipment has the ability to infuse different individual gases as well as blends of gases to achieve the desired results. Since each gas has known properties, Nano Gas Technologies manipulates the gas or gas combinations in a nano bubble phase to enhance and exploit the characteristics of the gases. Depending on the gases used, the process can break emulsions, float oil (to include extra heavy low API oil), change the oil viscosity, drop the solids, oxidize iron sulfide, BOD and COD; reduce H_2S; and improve ORP.

Four different gases are currently used: nitrogen, carbon dioxide, oxygen and air. The different effects of each gas are described below.

Nitrogen: Nitrogen is an inert gas. Because it does not react it remains in a nano bubble state when infused into an oil/water emulsion.

Oil collects on the surface of a Nano Gas treatment tank. *(Photo courtesy of Nano Gas Technologies Inc.)*

When put into an emulsion of oil and water in high quantities and in a nano bubble state, it separates the oil and water droplets at the molecular level. Due to increased surface density change, as bubbles reduce in diameter there is a decrease in van der Waals attraction. Because the nitrogen is inert there is no chemical change to the solution (pH stays the same), and the gas bubbles stay in solution. Solids can be drawn and dewatered for disposal, the oil is skimmed, collected and sold, and the water can be recycled and reused. Field use has shown hydrocarbon removal using the Nano Gas treatment system down to as low as 2.78 ppm total petroleum hydrocarbons, with averages ranging in the 10 ppm to 20 ppm range with-out the use of chemical additives, surfactants, polymers, filters, membranes or other filtering methods.

Oxygen: The application using oxygen in produced water environments that have high ORP and high COD requirements have been shown to increase redox reactions to eliminate H_2S, oxidize FeS_2, and increase oxidation of other solution constituents such as iron to iron oxide. Reactions with oxygen nano bubbles reduce H_2S to elemental sulfur (innocuous off-gassing). The application of Nano Gas can saturate solutions with oxygen nano bubbles at levels exceeding six times that of Henry's Law or the Ideal Gas Law at standard temperature and pressure while maintaining stability of the solute in solution with a half-life of up to 15.2 days if no BOD or COD is present. The gas stays in solution to enable absolute use until the dissolved oxygen level reaches 0 ppm. The application of a nano bubble solution can achieve desired goals cost effectively and efficiently over that of traditional chemical applications.

Carbon Dioxide: It is well known that carbon dioxide in aqueous solutions produces a weak carbonic acid. It is miscible/soluble in oil, thus reducing oil viscosity. The solvent characteristics of carbon dioxide in oilfield applications has been utilized for more than 35 years, with over 13,000 carbon dioxide EO wells (injection and production) operating currently in the U.S. The corollary is increased production due to the ability to access constrained pore size influencing viscosity to break the geologic adhesion from oil. The decrease in surface tension enables the fluid to flow more freely due to decreased drag coefficient. Secondarily, by using carbon dioxide in alternating cycles (WAG process) increased carbonic acid production can be minimized or controlled even as productivity increases. Further, controlling the vertical stratification of carbon dioxide nano bubbles in solution by suppressing its tendency to buoyantly rise to the top of receiving formation can be enhanced, thereby increasing ultimate oil recovery while minimizing solids uptake. Due to the miscibility of carbon dioxide and the reduction of viscosity in oil, it can also be used as a blend gas in conjunction with nitrogen nano bubbles for breaking emulsions.

Air: Air is made up of approximately 78% nitrogen, 21% oxygen and less than 1% other gases. Air is considered a blend gas. When using it to clean

Sample Results Zone 5 - 4/7/2016				
Time (a.m.)	9:50	10:02	10:17	10:42
DO (% saturation)	8.6	14.1	153.4	289
DO (ppm)	0.7	1.11	13.14	24.89
Specific conductance (µS)	29759	29081	2612	27336
pH	7.27	7.33	7.4	7.44
pH mV	-37.1	-40.1	-44.1	-46.9
ORP	-207.1	-249.3	-165.8	-125.2

Table 1: Sample results from a 240 bbl continuous process tank with Nano Gas infusion of nano bubbles. *(Data and graphic courtesy of Nano Gas Technologies Inc.)*

produced water in a nano bubble state, the process can achieve multiple results simultaneously to recover oil, clean the water, reduce or eliminate H_2S hazards and iron sulfide.

Table 1 presents example operational data from a Nano Gas facility. The process flow was from the gun barrel into a 240 bbl continuous flow process tank. The ATI and YSI DO meters were cross-calibrated. Air temperature was 62.6 F. Total process time was 53 minutes at 3 bbl/min throughput. The saturation results show a significant ability to saturate high COD solutions to increase and maintain DO, decrease specific conductance, and have minimal to no impact on pH. ORP was reduced 39.6%. The tank turnover time is 80 minutes. Results in the table show complete saturation 65% of the time.

The Nano Gas process has been tested and/or applied to the following applications:

- *Water*: To clean produced water and tank bottom water; process removes solids to about 1 µ and oil to nearly non-detect.
- *Oil*: The process recovers virtually all the oil in produced water and tank bottom water to include extra heavy oil less than 10 API. Up to 66% of the solids and iron sulfide have also been separated from the oil.
- *Biocide*: The process can utilize oxygen as a biocide or can enhance the use of chemical biocides to prepare the water for reuse in an environment where microorganisms need to be eliminated.

Enhanced oil recovery

Nano Gas Technologies has patent-pending subterranean tool designs to apply nano bubble technology in formation to increase oil recovery. The use of carbon dioxide and nitrogen in formations is a known science. Applying these gases individually or as a blend in a nano bubble state should enhance oil extraction in a water flood or WAG environment while increasing the recovery from the water at the surface level separation. Nano Gas Technologies is currently writing protocols to conduct core sample testing.

Enhanced chemical reactions

Nano Gas processes decrease the zeta potential and increase the ionic activity, thus increasing the potential of chemical reactions within the water with oxidizers such as hydrogen peroxide and chlorine-based chemicals. The reduction of surface tension due to the nano bubbles increases the performance of surfactants.

Conclusions

Significant opportunities exist to better align how we manage water with our understanding of its value as an irreplaceable resource. In addition, these opportunities offer benefits beyond just the social or environmental aspects often associated with recycling and reuse. It is likely that these practices will be necessary to remain competitive in a resource-constrained setting. ■

References available upon request.

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