Utilizing Unconventional Water Sources for Industrial Reuse

Reclamation and reuse of unconventional wastewater sources for plant raw water, cooling water and process pre-treatment has increased substantially due to increases in the cost of drinking water, recurring water shortages that can impact business operations, and tightening government regulation.

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Water is required in almost every industrial sector for the processing and manufacture of products. In 2015, it is estimated that industrial raw water consumption within the United States will exceed two million mega-liters per day (500 billion gallons). Sources of high quality raw water for commercial plants are becoming progressively scarce. The availability of water from rivers and lakes is not only diminishing, but what is available is increasingly regulated by Federal, State and local mandates. This scenario has pushed industrial water recycling in the United States into the forefront as a high-profile concern.

Industrial water reuse refers to the recycling of water for purposes other than irrigation or groundwater recharge. Use of recycled water by industry has increased substantially due to increases in the cost of drinking water, recurring water shortages that can impact business operations, and increased regulation. Cooling water systems, particularly at power plants and oil refineries, are the largest industrial consumers for recycled water, due to the high-volume water demand in their cooling towers and boilers. Other industrial applications include oil and gas drilling, petroleum refining, chemical plants, metal finishers, textile and carpet dying, paper manufacturing, cement manufacturers, and other cooling and process applications.

Many companies have spotted the risk that growing water constraints could place on their operations, and recognize the need to consider unconventional sources of water. Water from sewage treatment effluents, mine pool water and acid mine drainage, and recycling hydraulic fracturing flowback and produced water, is increasingly capturing the attention of engineers and other decision makers. The technology, chemistry and processes exist today to feasibly and economically integrate water reuse from unconventional sources into almost any industrial process application.

Unconventional Water Sources

As different from conventional water sources like potable supplies, rivers, lakes, surface ponds and fresh water wells, unconventional water sources can originate from wastewater treatments, mining operations, and industrial activities.
treatment plant (WWTP) sewage effluents, brackish surface and well water, mine pool water and acid mine drainage, and hydraulic fracturing flowback and produced water. These water sources may contain varying levels of suspended solids, oils and greases, colloidal silica and metals, and dissolved minerals and organics. Contaminates can include dirt and sediments, hardness (such as dissolved calcium and magnesium), heavy metals (like lead, zinc, cadmium, mercury and arsenic), salts, organics and color. Since every industrial application requires a different level of finished water quality, understanding the condition of the source water and the finished water quality requirements determines the processes and equipment needed. For most industrial uses of reclaimed water, conventional processes involve secondary treatment, filtration and disinfection steps to achieve a desired level of water quality. Most applications will require multiple processes to achieve the desired finished water quality.

**Municipal Wastewater Reuse**

Recycled municipal wastewater can be used for a broad range of reuse applications, short of direct drinking water and the manufacturing of food and beverages. Besides traditional uses such as for industrial processes, agricultural irrigation, and the irrigation of lawns, landscapes, cemeteries and golf courses, states like California, Arizona and Texas add recycled water to underground storage basins that are used as drinking water supplies.

Water recycling is very important in arid climates, like in Southern California, where water must be imported from other parts of the state. The Sanitation Districts of Los Angeles County operate the largest engineered wastewater recycling program in the world. The goal of the Sanitation Districts is to recycle as much water as possible from its ten water reclamation plants (WRPs). The WRPs play a major role in meeting Southern California’s water needs, providing primary, secondary, and tertiary treatment for approximately 510 million gallons per day (mgd), 165 mgd of which are available for reuse. The recycled water is used at more than 720 sites for a variety of industrial and commercial purposes. This recycling significantly reduces the Los Angeles basin’s dependence on costly imported water and helps to replenish a large percentage of the groundwater used by the region.

An example of using recycled municipal wastewater for power generation is the Fox Energy Center, located in Wrightstown, Wisconsin, a natural gas fueled electric generating unit that produces electricity for Wisconsin Public Service customers. The plant is a combined-cycle generating facility that is capable of producing 620 megawatts. The power plant features two General Electric combustion turbine generators fueled by natural gas, that are cooled by a cooling tower which uses recycled water from a nearby sewage treatment facility. The plant uses 4,600 gallons per minute (gpm) of sewage effluent as make-up water.

**Utilizing Mine Pool/AMD Water**

Nearly 90 percent of the country’s electricity is generated at power plants using steam-based systems, which use water for cooling. Electricity generation at steam electric plants requires a cooling system to condense the steam. Water usage occurs through once-through cooling, or as make-up water in a closed-cycle system, generally involving one or more cooling towers. According to a U.S. Geological Survey, the steam electric power industry withdraws about 136 billion gallons per day of fresh water. This is a comparable volume withdrawn for agricultural irrigation purposes in the U.S. In addition to fresh water withdrawals, the steam electric power industry withdraws about 60 billion gallons per day of saline water. Many parts of the United States are facing fresh water shortages, even areas that traditionally have had adequate water supplies are reaching capacity limits. New or expanded steam electric power plants frequently need to turn to non-traditional alternate sources of water for cooling. One type of alternate water source is ground-water collected in underground pools associated with coal mines, known as mine pool water. When this water flows from the mine to the surface it is called acid mine drainage (AMD), which contains multiple combinations of acidity, and metals such as arsenic, cadmium, copper, mercury, silver and zinc. With water sources becoming harder to obtain for industrial applications, these marginal-quality mine pool waters and AMD streams are becoming more attractive for reclamation and reuse. From a cooling perspective, mine pool/AMD water is desirable because it has a relatively consistent and low temperature year round.

Implementing sustainable and financially viable methods to reuse vast quantities of mine pool/AMD water is an area of relatively new, but growing, interest for mining operations. The technologies exist to...
economically treat any strength of acid mine drainage for industrial reuse. Recent technological refinements in such processes as CO$_2$ stripping, aeration, thickening, clarification, sludge disposal, ultrafiltration and reverse osmosis are making these systems more streamlined and efficient, enabling full-scale mine pool water/AMD reuse projects to not only control, manage and reuse these contaminated waters, but also make these projects financially viable.

More than 1.3 trillion gallons of acid mine pool water is estimated to be flowing in abandoned mines in Pennsylvania and parts of West Virginia, according to the Department of Energy. In Pennsylvania alone, more than 300 million gallons of polluted water discharge daily from abandoned coal mines into that state’s waterways. In the U.S., seven power plants are drawing water from mine pool water/AMD. Six of these power plants are located in Pennsylvania, and one is located in West Virginia.

The coal-fired power plant in West Virginia contracted to access wastewater from a large mine pool water/AMD reservoir at an abandoned coal mine. In addition to other processes, the plant utilized the latest advancements in surface aeration, to treat the water prior to decanting to the power plant. Consuming 3,000 gallons per minute, the entire reservoir was eventually depleted, at which point the coal mine went back into operation, and now produces coal for the power plant. An advanced surface aeration process was critical in facilitating an economically feasible solution for treatment of the mine pool/AMD wastewater.

With this surface aerator technology new impeller designs increase oxygen transfer efficiency, and reduce axial and radial loads. Such a system can produce a minimum efficiency of 3.8 pounds of oxygen per horsepower-hour. This improved transfer efficiency saves significant operational costs over the life of the equipment. The reduced axial and radial loads increase the life of the drive unit and reduce the size of support structures and beams for the surface aerators. Systems like these are making acid mine drainage reuse more accessible for mining operations, which require systems to be financially feasible, as well as capable of efficiently handling wastewater streams at remote locations, within usually a confined footprint.

The latest developments in high-rate thickeners, used to separate liquids and solids at very high rates, are highly effective in coal refuse thickening, gold recovery, copper leaching, molybdenum processing, and other mining and chemical applications where mine pool water/AMD is sourced. Separation is effected rapidly because of this system’s hydraulics, which can be in excess of twenty times the hydraulics of conventional thickeners. As a result, the plant area required for this new generation of thickeners is greatly reduced, important for typically remote mine pool water/AMD locations. The smaller equipment size substantially reduces capital, installation costs, and plant space when compared with conventional thickening units sized for the same production rates.

**Hydraulic Fracturing Water Sources**

The U.S. has vast reserves of oil and natural gas that are commercially reachable as a result of advances in horizontal drilling and hydraulic fracturing technologies, which have enabled improved access to oil and gas in shale formations. But as more hydraulic fracturing wells come into operation, so does the stress on surface water and ground water supplies from the withdrawal of large volumes of water used in the process – needing up to one million gallons of fresh water per wellhead to complete the fracturing process alone. Equally important is the growing volume of wastewater generated from fracturing wells, requiring disposal or recycling. Up to 60 percent of the water injected into a wellhead (potentially 600,000 gallons) during the fracturing process will discharge back out of the well shortly thereafter, as flowback wastewater. Thereafter, and for the life of the wellhead, it will discharge up to 100,000 gallons per day of produced wastewater.

Because water is the base fluid and biggest component used in hydraulic fracturing, its importance remains a critical factor in the operation and economics of shale oil and gas production. But significant and growing water management challenges are impacting hydraulic fracturing. Fresh water and wastewater operating procedures which have been in place since the late 1990s are experiencing increasingly stiffer governmental regulations on water availability and disposal limitations. These factors are prompting oil and gas executives to reassess their current water utilization activities regarding fracturing, and adopt a more unified, and longer-range perspective on their water life-cycle management.

Fresh water supplies for use in hydraulic fracturing are becoming more expensive and more unobtainable. Relatively recently, the Army Corps of Engineers mandated against the long-standing policy of acquisition
of water from the Missouri River watershed for use in shale oil and gas fracturing. This diverted fracturing operators to purchase pond and well water at higher rates from local landowners. Now these landowners are running out of water. In Texas, where hydraulic fracturing wells deal with the constant threat of drought, fracking operators compete with farmers and ranchers for their share of fresh water. As with the Missouri River watershed, water sourcing is the main fracturing challenge in Texas, where there does not exist an indefinite supply of water for expansion of hydraulic fracturing operations. And in Pennsylvania, where 4 to 8 million gallons of water is typically sourced within about a week period for hydraulic fracturing, these large water withdrawals may come from streams, rivers, privately-owned lakes and ponds, or groundwater, and could affect availability of nearby drinking water sources.

Wastewater associated with shale oil and gas extraction can contain high levels of total dissolved solids (TDS), fracturing fluid additives, total suspended solids (TSS), hardness compounds, metals, oil and gas, bacteria and bacteria disinfection agents, and naturally occurring radioactive materials (NORMs). These contaminants are partially a combination of chemicals and agents inserted deep into the well (9,000 feet and deeper) which facilitate fracturing by modifying the water chemistry to increase viscosity, carry more sand and improve conductivity. Effectively, the fracturing process is pushing the water down into the rock formation, trying to wedge the rock cracks open. The sand fills in between the cracks that the hydraulic fluid has propped open. Once the fracturing is done, much of the water comes back up the well as flowback wastewater. Along with it comes bacteria and characteristics of the geologic formation, including minerals, radioactive materials and oil and gas.

Wellhead Recycling. Some drilling operators elect to reuse a portion of the wastewater to replace and/or supplement fresh water in formulating fracturing fluid for a future well or re-fracturing the same well. Reuse of shale oil and gas wastewater is, in part, dependent on the levels of pollutants in the wastewater and the proximity of other fracturing sites that might reuse the wastewater. This practice has the potential to conserve and reuse water resources.

Mobile solutions to treat wastewater at the wellhead enable recycling and reuse of flowback without the need for storing wastewater in surface ponds on-site, or for trucking flowback wastewater for disposal at off-site deep-well injection locations. The drawback of wellhead mobile solutions is that they do not provide continuous processing to handle produced wastewaters, which would need to be processed for potentially 20 years following fracturing. Since produced wastewater represents 95 percent, or more, of the wastewater generated during the lifecycle of a well, mobile processing systems do not provide a solution adequate to solving the long-term problems of diminished water sourcing.

Brackish Surface and Well Water. Brackish water refers to water supplies that are more saline than freshwater, but much less salty than seawater. This level of salinity in water is measured in total dissolved solids (TDS). In hydraulic fracturing, saline water is introduced into the process by contacting brackish aquifers.

The two most common desalination technologies are membrane and thermal processes. Membrane processes rely on permeable membranes to separate salts from water. Membrane processes can be pressure-driven (reverse osmosis) or voltage-driven (electrodialysis). Reverse osmosis is currently the most common desalination treatment method. The thermal process involves heating saline water to produce water vapor, which is then condensed and collected as fresh water.
a reverse-osmosis system, the greater the TDS concentration of the water, the higher the pressure needed for the pumps to push water through the membranes, and consequently, the higher the energy costs.

As desalination processes are becoming more streamlined, the costs are reducing. In Texas, for example, the cost of desalination in fracturing is less than wellhead water recycling. More than 21 percent of the wells in the state are using desalination, compared to single-digit use of wellhead recycling.

Mine Pool Water/AMD. The reuse of mine pool water/AMD in hydraulic fracturing for shale oil and gas production is quickly becoming a hot topic of interest. In 2013, the Pennsylvania state Department of Environmental Protection issued new policies that support natural gas drilling companies in using mine pool water/abandoned mine drainage as a source of water for hydraulic fracturing. Hydraulic fracturing uses millions of gallons of water to create microscopic fissures in dense shale formations, allowing the hydrocarbons to flow freely from the formation and into the well bore. Until recently, in Pennsylvania, the use of mine pool water/AMD from abandoned coal mines had not been a viable option.

Many current Marcellus shale oil and gas hydraulic fracturing wells are in close proximity to mine pool water/AMD areas, creating a unique opportunity to beneficially use these wastewater sites for hydraulic fracturing. According to a 2013 Duke University-led study, much of the naturally occurring radioactivity (radium and barium) in fracturing wastewater might be removed by blending it with wastewater from mine pool water/acid mine drainage. Blending them can bind some fracturing contaminants into solids that can then be removed before the water is discharged back into waterways. Blending mine pool water/AMD with fracturing wastewater would also help reduce the depletion of local freshwater resources by giving oil and gas drillers a source of usable recycled water for the hydraulic fracturing process.

Centralized Handling of Flowback and Produced Wastewater. Centralized treatment of wastewater has emerged as a viable solution for long-term efficiency in managing water sourcing and wastewater treatment in hydraulic fracturing. Centralized treatment facilities handle both the flowback wastewater and produced wastewater from oil and gas wells within a region, at a radius of 40 to 50 miles. Pipelines connect all wellheads directly with the central treatment plant.

Such centralized plants can be integrated with alternative sources of water to supplement fresh water needs for fracturing, such as from abandoned mines, storm water control basins, municipal treatment plant effluent, and power plant cooling water. Centralized water management allows wastewater sourcing to be implemented on an economy of scale that has not before been realized in the shale oil and gas production industry.

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About WesTech Engineering, Inc.

WesTech Engineering Inc., engineers and manufactures water and wastewater treatment process equipment for power generation, mineral, and industrial applications worldwide. With broad experience in providing process equipment for diverse liquid-solids separation settings, WesTech’s process approach provides solutions for any water treatment challenge.

Since 1972, industries served include municipal water and wastewater treatment, food processing, petrochemical, industrial pre-treatment, water reuse, mining and minerals processing, power generation, and all manner of municipal and industrial process flow. WesTech is employee owned and ISO 9001 certified.

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