HOW TO ASSESS, SELECT, AND DEVELOP YOUR OPTIMAL WATER MANAGEMENT SYSTEM

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ABSTRACT

Water management is one of the largest expenses associated with the production of oil and gas (O&G) resources. Water recycling and reuse can save time, costs, and resources for exploration and production (E&P) companies resulting in enhanced operating efficiencies and improved bottom line results.

To optimize results from water management efforts, it is important to accurately identify the contaminants to be treated in source water and determine the minimum required parameters for the intended reuse of the water. This information is used to select and implement the most cost-effective and efficient system to produce the desired results.

INTRODUCTION

Water is a major issue challenging E&Ps. As water required for energy production increases with demand, water needs for domestic, agricultural, industrial, and municipal uses also continues to increase. E&Ps are adapting by investing in new water management processes and recycling technologies to meet regulatory and public demands for improved water use efficiencies. E&Ps must cope with water scarcity issues, competition for water sources, increasing industry regulations on water consumption and disposal, and productive fields in urban areas.

In order for water reuse activities to be sustainable in the industry, the benefits of such activities must be economical. This is best achieved through the proper selection of water treatment technologies and processes. Therefore, a broad range of technologies and services must be evaluated prior to field operations. There is not a one-trick-pony technology in the market that will be the best solution for each job. Instead, optimal benefits will result from utilizing a combination of innovative water treatment technologies capable of treating a wide range of water qualities that will enable reuse of water in oil and gas activities.

PRODUCED AND FLOWBACK WATER

Hydraulic fracturing, or fracing for short, is a procedure where fluid is pumped down a well into subsurface rock formations under high pressure to fracture the rock. This creates an interconnected set of fissures that allow the oil and natural gas trapped in the rock to move across the formation to the well bore where it can be recovered.

Most fracs use a mixture of water and sand to fracture the rock. The high pressure slurry cracks open the rock leaving the sand to prop open the fissures and keep the rock from collapsing back on itself once the pressure is removed. Small amounts of chemicals, mainly friction reducers and gelling agents, are added to the water sand mixture to improve performance. The gelling agents helps the sand form into an 'open' network that allows easy flow of the oil and natural gas while the friction reducers, as the name implies, reduce the pumping pressure required to move the water/sand mixture down the wellbore. Once the frac is completed oil bearing water flows back up the well bore where the oil and natural gas are recovered. Flow back and produced waters in the oil field are heavily laden with contaminates including insoluble iron sulfides, poisonous hydrogen sulfide, residual gels, friction reducers and other chemicals. The water coming back out of the well has been pushed through the formation picking up all sorts of undesirable contaminates in the process. These contaminates include:

Mineral Deposits – As the water passes through the formation to the well bore it will pick-up minerals along the way. Calcium, iron, chlorides, potassium, sulfur along with trace elements such as barium are absorbed out of the rock and carried along with the water. Of these components the most troublesome to the recycling of oil field water are iron, sulfur compounds and chlorides.

Friction Reducer & Gels – Both the friction reducer and the gel are water soluble. Any residual material that was not actively used in the fracing process is picked up by the water and transported back to the well bore where they can plug the perforations restricting oil and gas flow. In many cases the residual friction reducer and gel will combine with the dissolved minerals and form stable emulsions. These emulsions capture fine solid particles (such as sand and silt) and carry them along to the well bore.

Bacteria and Biomass – There are significant amounts of dormant bacteria trapped in the oil formation. As the water and oil flow through the formation the bacteria is carried along. The most troublesome of these bacteria are the class referred to as Sulfate Reducing Bacteria (SRB). These bacteria take the soluble sulfur compounds and convert them into insoluble iron sulfides (FeS) and highly poisonous hydrogen sulfides (H2S). The iron sulfides settle out and plug the well bore restricting the flow of oil and natural gas. The hydrogen sulfide is carried along with the water and oil to the surface where it presents a significant safety hazard to everyone present at the site.

Recycling oilfield water can be complex, involving both organic and inorganic chemistry as well as challenges getting treatment chemicals in contact with the treatment factors.

Selecting proper water recycling and treatment technologies results from thoroughly understanding water quality parameters, targeted contaminants, and reuse for each specific project.

DETERMINE PARAMETERS

It is vital to understand the unique characteristics of the waste water to be treated. Testing samples of dirty water allow for better understanding of the contaminants present in the water. Equally as important is knowing the required water quality parameters for recycled water intended for reuse.

Depending on what type of frac is being employed will often dictate required water quality parameters for water recycling, and hence, what type of treatment technology to utilize. The most commonly used types of frac jobs currently consist of slick water, gel, or cross link (hybrid). Levels of treatment and water quality for reuse in subsequent frac jobs will differ for each type of frac being employed. In addition, targeted priority contaminants in source water will also differ for each type of frac. These differences are due to how additives in completion fluids respond to elements in the water.

While this paper does not venture into completion techniques or frac fluid formulas, it is important to note the significant progress that has taken place over the past few years regarding the industry's ability to successfully frac wells with higher and higher salinity water. This advancement has enabled water treatment solutions to become much more economical as costly desalination treatment is no longer necessary in many circumstances.

TECHNOLOGIES

The conditions and needs of the O&G industry are constantly changing and many types of unexpected issues emerge. A broad range of treatment capabilities that range from distillation to filtration can be strategically implemented in order to tackle unique water issues that arise in the field. Drawing from a breadth of technologies provides different levels of treatment options to tackle many sorts of water issues. Water quality requirements are determined first, and then appropriate technologies are implemented to achieve the determined level of treatment. Combinations of different technologies are often used together to enhance the product water results and efficiencies.

CHLORINE DIOXIDE

Treatment factors include:

- Hydrogen Sulfide
- Iron Sulfide
- Bacteria
- Gel Breaker
- Friction Reducer Breaker
- Emulsions
- Biomass

Chlorine dioxide is a powerful, yet selective oxidizer. ClO2 has the ability to break up residual gels and friction reducers while removing insoluble iron sulfide and killing hydrogen sulfide. Additionally, ClO2 is an EPA approved biocide that kills bacteria which are the root cause of the many of the problems with water reuse.

Chlorine dioxide is present as a gas dispersed in solution. ClO2 does not react at any significant amount with the water; it is not hydrolyzed like chlorine, or chemically bound to the water like sodium hypochlorite (bleach). Since there is no strong bond with the water, the ClO2 remains extremely mobile. This mobility, combined with the fact that the ClO2 is equally soluble in both oil and water, allows the ClO2 to disperse through both the oil and water phases to attack contamination regardless of where it is located.

Most chemicals only react with the exposed surface of the scale or emulsion when considering scales such as insoluble iron sulfides or iron carbonates or emulsions formed around an inorganic nucleus. The small size and high mobility of the ClO2 molecule allows the ClO2 to penetrate into the solid matrix and attack the problem from inside as well as the surface. This penetration into the scale or emulsion enables the treatment to be much more effective, especially when the ClO2 penetrates to the back side of the scale where it is attached to the surface. Once the scale breaks free the remaining pieces can be fully dissolved by the chemicals or flushed out of the system.

Oxidizing power of ClO2 is important when considering hydrogen sulfide (H2S) and iron sulfide (FeS).

The best place to handle H2S is down in the well before it ever comes to the surface. This is done by applying ClO2 to a well immediately prior to the frac. The ClO2 will take care of any H2S present in the wellbore and then be pushed out into the formation by the frac. Wells treated in this manner have much lower H2S concentrations then surrounding wells. The effect is both noticeable and long lasting. The advantage is the H2S never makes it to the surface where it poses a safety hazard.

Iron sulfide is an insoluble scale that forms in the formation and near the well bore. If the situation is not corrected the FeS scale accumulates to the point where it restricts flow (production) from the well. ClO2 is able to react with the contamination and remove the problem. Under acidic conditions the ClO2 converts the insoluble FeS into very soluble iron chloride (Fe2Cl3) and equally soluble iron sulfate (Fe2(SO4)3). The result is that the iron sulfide is converted from an insoluble scale into a soluble form that can pass freely through the formation.

The reactions of ClO2 with organics are more complex and slower than the reactions with inorganic compounds such as FeS and H2S. Contact time and the relative concentrations of ClO2 to the organic compound play a much larger role in determining the extent of the reaction. For example, mixing concentrated (3000-ppm) ClO2 directly into water containing 1 gal per thousand of friction reducer (FR) will almost completely destroy the friction reducer. On the other hand, there is no measurable effect when mixing water that has been treated with ClO2 to a residual between 2 and 5-ppm with the same friction reducer solution.

ELECTROCOAGULATION

Treatment factors include:

- pH Control
- Total Suspended Solids (TSS)
- Iron
- Oil and Grease
- Hardness (Magnesium and Calcium)
- Bacteria
- Turbidity
- Alkalinity
- Bicarbonates

Electrocoagulation (EC) is a technology based on proven scientific principles of electro-chemistry and successfully used in the water treatment industry for many years. Recently, EC has grown rapidly as an effective and economical method for treating water in the O&G industry. The use of EC is a proven method for treating produced and flowback water for reuse in production activities or subsequent frac jobs. Savings are generated from reducing costs associated with fresh water sales, water transport, and disposal. Compared to traditional treatments utilized to remove residual oil and suspended solids, EC delivers lower operating costs using less labor and smaller footprint.

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Wastewater enters the EC system where positive and negative charges are introduced causing suspended molecules to join forming larger molecules. Iron and aluminum are used as primary coagulates.

Reaction time occurs in only a few seconds, and coagulation takes just minutes. The charged wastewater enters the weir tanks where the solid particles suspended in the water separate. Solids settle to the bottom of the tanks and are subsequently removed for disposal.

The water is pumped from to the media filter system where it is further polished resulting in clean brine water that can be reused for fracturing a subsequent well. The brine water can be blended with other clean brine water or fresh water if needed.

EC treatment processes may combine EC technology with any combination of filtration, solids settling, and polishers to complete a system. EC systems are scalable in size, footprint, and treatment volume. Additionally, EC systems are easily constructed as mobile units allowing for easy deployment to site-specific locations.

MEDIA FILTRATION

Treatment factors include:

- Pre-treatment
- Total Suspended Solids (TSS)
- <20 Micron
- Iron Reduction
- Polishing

Quality filtration systems are necessary for use in the O&G industry where environments and conditions can be extreme. Media filters operate when the source water is pressurized and introduced into the top of the media tanks. A diffusion plate in the top throat of the tank serves to reduce water velocity and distribute the water evenly across the top of the media bed. The typical media bed is a layer of size-graded crushed silica sand or crushed glass. The particles in the water are captured in the media bed and filtered water passes into the discharge manifold at the bottom of the tanks.

More advanced filters are designed to perform at high flow rates in the harshest conditions and are capable of using various media sizes to fit different levels of treatment. The systems are designed to perform automatic backwash functions while continuing operations. Filtration systems can be used as standalone units or can be used in combination with other technologies as a pre-treatment or polisher.

The versatility of media sources that can be interchanged in multi-media filter units allows for a broad array of possible treatments. For example, contaminated laden produced/flowback water is processed through a pressure vessel bed of ion exchange resin causing a chemical reaction to remove the contaminant ions from the process stream. The chemical reaction can be reversed after exhaustion of the media bed by use of regenerate chemicals so that the bed can be reused. The exhaustion of the bed is determined by the volume of water and contaminants in the process stream.

SUMMARY

Oil field waters are a heterogeneous mixture of oil and water that is contaminated with a wide variety of materials ranging from insoluble iron sulfides, poisonous hydrogen sulfides, residual gels, friction reducers, emulsions, inorganic salts and bacteria. In order to reuse this water it must be cleaned in such a way that it can be re-introduced into a well without causing problems or reused as part of a larger frac solution. In order to do this the bacteria must be killed, the H2S destroyed , the iron returned to solution, the gels and friction reducers broken down to the point where they will not plug the formation and accumulate and cause plugging issues.

Various technologies and processes exist to deal with the many levels of complexities that are associated with water treatment in the O&G industry.
The three technologies presented:

- Chlorine Dioxide
- Electrocoagulation
- Media Filtration

These three technologies are effective and economical treatment options for various levels of water qualities commonly found in the O&G industry.