ENVIRONMENTAL IMPLICATIONS OF WATER RECLAMATION FOR PETROLEUM OPERATIONS

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ABSTRACT

High costs of obtaining fresh water and produced water disposal, as well as low commodity prices have made water reclamation an attractive option for companies looking to increase their profit margins. Special environmental considerations arise when dealing with the handling and treatment of produced and reclaimed fluids for use in oilfield operations. These include the handling of wastes generated from treating large volumes of produced water, storing and transporting the water via properly designed tanks, ponds, pipes, and other equipment, and complying with existing environmental regulations while adequately assessing additional risks associated with water recycling. The paper will discuss the current technologies utilized to treat reclaimed water and the environmental risks associated with each of them, special facilities design considerations for handling reclaimed water, relevant environmental policies, and the general pros and cons of water recycling including economic factors, infrastructure requirements, and public perceptions.

INTRODUCTION

The oil and gas industry uses millions of gallons of water to drill, complete, and stimulate wells in unconventional plays; the USGS reports, on average, each well will require approximately 2-6 million gallons during the development process with some wells requiring up to 16 million gallons. With increased water shortages and environmental awareness, as well as the desire for industries to become more efficient and sustainable, a shift toward closed loop or semi-closed loop systems for water utilization and environmental preservation is imminent. Even the much relied upon method of deep well injection disposal of produced water can result in contamination of unintended zones and via casing leaks, and has been cited as the source of increased seismic activity in the Mid-Continent area- particularly Oklahoma (USGS). Other disposal methods such as evaporation ponds and land farming have proved environmentally risky, and even illegal in some areas (Pierce et al, 2010). These factors increase the attractiveness of active and sustainable water management programs for the oil and gas industry. Potential sources of water include the large quantities of produced and flowback water, wastewater effluents from drilling operations including grey and black water, wastewater from other industries, and brackish groundwater not considered useful for potable or agricultural applications. Successful water recycling operations in the Marcellus Shale can provide a model for applying these techniques elsewhere (Paugh et al, 2010).

Chemical Analyses

Typical constituents found in produced water include large amounts of dissolved solids, particulates of organic (primarily hydrocarbons) and inorganic origin, heavy metals, biota, and a wide variety of other region dependent materials too numerous to list systematically (Neff et al, 2011); flowback water will often contain the produced water constituents, plus any chemicals previously added to the water prior to the operation. Recycled wastewater from other industries, such as cooling water from refinery operations, will have entirely different characteristics as will any brackish groundwater. Indeed, each source of water will have a different chemical composition, and there is no general treatment method appropriate for every water. Regardless of the treatment or disposal method selected, care must be taken to prevent the discharge of harmful materials to the environment, as many of the constituents found in these waters are toxic- even in small quantities.

TREATMENT TECHNOLOGIES

There are many treatment options available to operators based upon the source water characteristics, location constraints, and economic considerations. The following list is a brief overview of some of these options.

Blending

Although not explicitly a treatment technique, perhaps the simplest method for recycling water is to blend the raw water with clean fresh water to dilute constituents present and achieve desired quality. The recycled water may be treated before blending, or may be directly mixed with clean water before use.

Gravimetric Separation

Gravimetric separation techniques seek to remove particles according to their specific gravities. Dense particles tend to settle over time, and centrifugation can accelerate this process. Less dense constituents such as hydrocarbons will typically rise to the surface and may be skimmed or decanted (Pierce et al, 2010). These may be energy passive processes or may require input energy depending on the specific technique selected.

Coagulation and Flocculation

Coagulation and flocculation refer to the process of destabilizing colloid suspensions thereby removing suspended particles in water. Many of the small colloid particles suspended in water carry a negative surface charge, and therefore repel each other to remain in suspension. Coagulation, either by the addition of a chemical coagulant, or direct application of ions (known as electrocoagulation), neutralizes the surface charges of these particles so that they may stick together to form settleable or filterable flocs. Common chemical coagulants are multivalent cations such as aluminum and iron salts. Floc formation is facilitated by slow mixing of the water known as flocculation (Edzwald and AWWA, 2011). Often coagulation is used in conjunction with dissolved air floatation which seeks to remove dissolved hydrocarbons (Younker et al, 2011).

Adsorption

Adsorption is defined as the process in which molecules attach themselves to a solid surface through universal attractive forces known as Van der Waals interactions (Eckenfelder, 1980). It is an effective method for removing organic and inorganic material from water. The most common medium for adsorption is activated carbon, which comes in powdered and granular varieties; carbon is activated by treating organic material (coconut shells, wood, lignin, etc.) with heat to create a large number of tunnel like pores and channels and available adsorption surface area (Edzwald and AWWA, 2011). Other adsorption mediums include activated alumina, certain resins, and zeolite materials.

Ion Exchange

Due to the nature of brackish waters, they can often be treated with desalination techniques such as ion exchange processes. Typically, the water will be forced through alternating columns of cation and anion exchange resins to remove the dissolved ions in the water (Epstein and Yeligar, 1971). Also effective are electrodialysis cells which transport salts through alternating anion and cation exchange membranes (Pierce et al, 2010). Energy costs for these processes can preclude their practicality, but with the right economic scenario very clean water can be obtained. Seawater desalination has been practiced successfully for a number of years, however unlike seawater desalination in which most of the seawater is wasted in the process (Edzwald and AWWA, 2011), oil field operations do not have the luxury of wasting any of the source water.

Filtration

Often simple filtration techniques are the most economic for water treatment (Pierce et al, 2010). Filtration involves passing a fluid-particle mixture through a medium that will retain the particles and produce a cleaner fluid (Tien, 2012). There are many mathematical and empirical correlations which govern the selection of filtration medium, but ultimately the costs vary with the size of particle to be removed. Microfiltration and nanofiltration processes will remove particles on the nm-μm scales respectively, and reverse osmosis can separate water molecules from practically any constituents. All membranes are subject to fouling, and pretreatment is often required before membrane processes can be used effectively (Tien, 2012).

Evaporation Processes

These Evaporative processes include distillation and other phase change processes such as sublimation, freeze thaw, and crystallization (Pierce et al, 2010). There exist proprietary methods for treating water with these methods for either direct re-use or discharge; although effective at achieving a water free of contaminants, 90% of the costs of distillation processes are energy requirements (Becker, 2000). For many oilfield applications, the energy requirements of treating water via evaporation and other phase change processes are too high and these processes are not deemed economic. However, where the suppliers of treatment exist, as is the case in the Marcellus shale, distillation processes have been used successfully (Rassenfoss, 2011).

Disinfection/Biocides

Some water sources will contain ammonia, phosphates, nitrates and other nutrients that, under certain conditions, can stimulate the growth of microorganisms and cause eutrophication of the water from excessive algae growth (Neff, et al 2011). Control of biota via the application of disinfecting chemicals, UV radiation, oxidizing agents such as ozone, or a combination of these is therefore critical to control water quality.

All of the aforementioned treatment techniques will include associated waste disposal and important precautionary measures. Removal of constituents from water prior to treatment has the disadvantage of concentrating the potentially harmful materials that need to be properly disposed.

DESIGN AND INFRASTRUCTURE CONSIDERATIONS

Certainly, due to the nature of alternative water sources care must be taken to ensure facilities are fit to handle the often toxic and corrosive properties of recycled water. Successful water recycling programs also rely on the presence of proper infrastructure; often the infrastructure follows a catalyst that makes water recycling either mandatory or economically necessary- as was the case in the Marcellus shale for many operators (Rassenfoss, 2011).

Corrosion Control

One of the most important aspects of designing facilities for recycled water is corrosion control. Corrosion resistant materials with proper pressure ratings must always be selected, which can include coated pipes and polyethylene materials among other proprietary types. Corrosion inhibitors can also be added to the water itself during treatment to slow any reactions the water may have with steel it may come in contact with (Lake and Clegg, 2007).

Facilities

Typical facilities for water recycling will include safe methods for the transportation and storage of the water. Where permitted, double lined ponds equipped with leak detection and alarms will suffice for storage, and these are common in the places where water recycling is practiced. Some states prohibit storage of produced water in ponds, and in this case tanks may need to be used. Risk is minimized when the distance water must travel to reach its intended destination is as short as possible, so water storage and access points must be optimized whenever possible (Paugh et al, 2008).

Waste Disposal and Environmental Policies

As previously mentioned, most treatment techniques will result in waste that will need to be disposed of; for example, a million gallon per day distillation plant for produced water can generate 400 tons of waste (Rassenfoss, 2011). Local authorities and environmental agencies must be consulted to ensure responsible handling of wastes. This may include making sure that all waste transportation and disposal companies employed are licensed and registered with the appropriate authorities, and even conducting grassroots research studies to ensure that any waste disposal methods are not going to adversely affect the environment. Many of the constituents found in reclaimed water are either acutely toxic to receiving waters or tend to bioaccumulate, and should not be discharged (Phillips and Rainbow, 1993).

ADDITIONAL CONSIDERATIONS

Economics and Industry Standards

Ultimately, the decision to recycle water in lieu of disposal and which treatment method is most appropriate if water recycling is selected will almost always be dependent upon economics. The oil and gas industry historically adapts quickly to increasingly strict environmental policies and ever fluctuating commodity prices; poor public perception of freshwater usage for industrial applications is likely to cause policy changes and consequently an industry shift toward streamlining water use.

Ethics

It cannot be overemphasized that as per the NSPE Code of Ethics for Engineers, an engineer's duty is to first protect the health and welfare of the public. This includes making decisions based upon what is best for people and the environment, even if perceived as uneconomic or if policies have not rendered a particular practice illegal.

CONCLUSION

Companies looking to increase their profit margins may consider water recycling to lower the costs of disposal of produced water and fresh water acquisition. Many treatment techniques exist to make chosen sources of reclaimed water appropriate for oilfield operations. Proper facilities and infrastructure for storage, transportation, treatment, and waste disposal are necessary for successful recycling operations, and certainly industry trends are moving toward a higher degree of sustainability and environmental consciousness with regard to water use.

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