Produced Water

Natural gas and oil production from stripper wells also produces water contaminated with hydrocarbons, and in most locations, salts and trace elements. The hydrocarbons are not generally present in concentrations that allow the operator to economically recover these liquids. Produced liquids, (Stripper Gas Water) which are predominately water, present the operator with two options; purify the water to acceptable levels of contaminates, or pay for the disposal of the water. The project scope involves testing SynCoal as a sorbent to reduce the levels of contamination in stripper gas well produced water to a level that the water can be put to a productive use. Produced water is to be filtered with SynCoal, a processed sub-bituminous coal. It is expected that the surface area of and in the SynCoal would sorb the hydrocarbons and other contaminates and the effluent would be usable for agricultural purposes. Test plan anticipates using two well locations described as being disparate in the level and type of contaminates present. The loading capacity and the rate of loading for the sorbent should be quantified in field testing situations which include unregulated and widely varying liquid flow rates. This will require significant flexibility in the initial stages of the investigation. The scope of work outlined below serves as the guidelines for the testing of SynCoal carbon product as a sorbent to remove hydrocarbons and other contaminants from the produced waters of natural gas wells. A maximum ratio of 1 lb carbon to 100 lbs water treated is the initial basis for economic design. While the levels of contaminants directly impact this ratio, the ultimate economics will be dictated by the filter servicing requirements. This experimental program is intended to identify those treatment parameters that yield the best technological practice for a given set of operating conditions. The goal of this research is to determine appropriate guidelines for field trials by accurately characterizing the performance of SynCoal over a full range of operating conditions.

This volume constitutes the proceedings of the Produced Water Seminar held in Trondheim, Norway, in September 1995. Hosted by Statoil Research and Development and IKU Petroleum Research, the seminar was an update of the 1992 seminar of the same title held in San Diego, California (Ray and Engelhardt, 1992). Produced water remains the largest volume waste stream from oil and gas production offshore. In the North and Norwegian Seas, produced water volumes are projected to increase significantly over the coming decades, as oil reservoirs near depletion. These releases are therefore the focus of continuing environmental concern. The purpose of this seminar was to provide a forum for scientists, legislators, and industrial and environmental representatives to share recent information and research results, and to encourage cooperative pursuit of solutions in the future. The success of the seminar, and the quality of this volume, are due in large part to the many authors from around the world who presented almost 50 posters and papers focused on environmental issues and mitigation technologies. In addition, we wish to acknowledge the contributions of the local and international organizing committees. Local Committee Asbj0fg 0verli and Heidi Torp, Statoil Egil Wanvik and Laila S. Olden, IKU Petroleum Research International Committee James P. Ray, Shell Chemical and Petroleum Products Companies Alexis E. Steen, American Petroleum Institute Theodor C. Sauer, Battelle Ocean Sciences Steven A. Flynn, British Petroleum Martin C. Th. Scholten, TNO Kjell Lohne, Statoil Ingvild Martinsen, Norwegian Pollution Control Authority.

Produced water volume generation and management in the United States are not well characterized at a national level. The U.S. Department of Energy (DOE) asked Argonne National Laboratory to compile data on produced water associated with oil and gas production to better understand the production volumes and management of this water. The purpose of this report is to improve understanding of produced water by providing detailed information on the volume of produced water generated in the United States and the ways in which produced water is disposed or reused. As the demand for fresh water resources increases, with no concomitant increase in surface or ground water supplies, alternate water sources, like produced water, may play an important role. Produced water is water from underground formations that is brought to the surface during oil or gas production. Because the water has been in contact with hydrocarbon-bearing formations, it contains some of the chemical characteristics of the formations and the hydrocarbons. It may include water from the reservoir, water previously injected into the formation, and any chemicals added during the production processes. The physical and chemical properties of produced water vary considerably depending on the geographic location of the field, the geologic formation, and the type of hydrocarbon product being produced. Produced water properties and volume also vary throughout the lifetime of a reservoir. Produced water is the largest volume by-product or waste stream associated with oil and gas exploration and production. Previous national produced water volume estimates are in the range of 15 to 20 billion barrels (bbl; 1 bbl = 42 U.S. gallons) generated each year in the United States (API 1988, 2000; Veil et al. 2004). However, the details on generation and management of produced water are not well understood on a national scale. Argonne National Laboratory developed detailed national-level information on the volume of produced water generated in the United States and the manner in which produced water is managed. This report presents an overview of produced water, summarizes the study, and presents results from the study at both the national level and the state level. Chapter 2 presents background information on produced water, describing its chemical and physical characteristics, where it is produced, and the potential impacts of produced water to the environment and to oil and gas operations. A review of relevant literature is also included. Chapter 3 describes the methods used to collect information, including outreach efforts to state oil and gas agencies and related federal programs. Because of the inconsistency in the level of detail provided by various state agencies, the approaches and assumptions used to extrapolate data values are also discussed. In Chapter 4, the data are presented, and national trends and observations are discussed. Chapter 5 presents detailed results for each state, while Chapter 6 presents results from federal sources for oil and gas production (i.e., offshore, onshore, and tribal lands). Chapter 7 summarizes the study and presents conclusions.

Tranquillon Ridge Oil and Gas Development Project, LOGP Produced Water Treatment Upgrade and Expansion, Sisquoc Pipeline Bi-directional Flow

ADVANCED STRIPPER GAS PRODUCED WATER REMEDIATION.

Coalbed Natural Gas (CBNG) Produced Water Qualtiy [sic] Trends in the Powder River Basin, Wyoming

Characterization of Organic Constituent Patterns at a Produced Water Discharge Site/barium Relations to Bioeffects of Produced Water

Produced Water Management at Oil & Gas Production Facilities

Hydraulic fracturing is a process adopted by the oil and gas industry to extract natural gas out of shale rock formations from depth ranging from 2,440 to 3,048 meters below the surface. Produced water is the largest by product of hydraulic fracturing. The composition of produced water can be toxic due to the presence of oil, grease, suspended and dissolved solids, heavy metals, chemicals that are part of fracturing fluid mixture which is injected to enhance gas production. The composition may vary significantly based on the geological formation. Safe disposal or treatment of produced water has been a challenge to the oil and gas industry both from an economic and environmental perspective. Over the last several years, many companies in the water treatment industry have developed technologies to treat produced water for safe disposal or for reuse in drilling new wells. The objective of this research is to characterize produced water samples collected from the Eagle Ford shale play region in Texas, and to assess the efficiency of treatment processes using the reactor developed by Elequa LLC, San Antonio, Texas which works on the principle of electro-coagulation. The reactor performance is then assessed based on the removal efficiency of various constituents. This method of treatment has been around since early 21 st century but has not been implemented to its full potential. A review of various other technologies developed and implemented for treatment of produced water is included in this report. The electro-coagulation reactor is tested for its efficiency in reducing the turbidity, total dissolved solids, total suspended solids and inorganic chemicals (i.e., cations) of major concern present in water produced from hydraulic fracturing. Based on test results, it is observed that there were significant levels of total suspended solids, total dissolved solids and inorganic cations present in produced water and that treatment with the electro-coagulation reactor decreased the values. There was a 75% to 97% reduction in these levels after the treatment. There were no additional pre-treatment methods used. Based on the research outcomes recommendations for modifying Elequa's Electro-coagulation reactor/technology to improve performance and an assessment of the efficiency of cathodes and anodes are provided.

The US Environmental Protection Agency (EPA) establishes controls on produced water discharges into US waters through effluent limitations guidelines (ELGs), and general and individual discharge permits. Over the past 20 years, produced water controls have become much stricter, and in some areas, no discharge of produced water is allowed. In setting discharge standards, EPA considers vast amounts of data, makes assumptions regarding which data and what approaches are representative, selects the most appropriate analytical methods, and interprets the analytical results. Despite EPA's considerable efforts to accurately understand and characterize the economic and environmental impacts of produced water discharges before proposing and adopting ELGs and issuing permits, current US produced water controls may be overly restrictive and not cost-effective. This paper summarizes several studies that have reviewed in detail EPA's data, assumptions, and analytical methods for earlier proposed regulations and general permits. These include the offshore oil and gas ELGs, EPA's Region 6 general permit for coastal waters, and most recently, the proposed ELGs for the coastal oil and gas industry. By substituting different data, using revised assumptions, and reanalyzing data that are equally or more valid, the studies reach alternate conclusions on the cost-effectiveness of current produced water controls.

This book outlines the technologies and techniques used in the oil & gas industry's shift from treating produced water as a "waste stream" to an integrated water management approach. Produced water is formed underground and brought to the surface during oil & gas (O&G) production and exploration and production (E&P) operations. It is usually a complex mixture of inorganics and organics and contributes to the largest volume waste stream of O&G and E&P operations. Traditionally, produced water has been considered a waste and conventional management strategies include disposal (typically by injection into depleted wells or permitted disposal wells), recycling (direct reuse within the E&P operation) and reuse (treatment and reuse offsite for food crop irrigation, livestock watering or industrial use). The O&G industry is going through a paradigm shift where scarcity of water, economics of water management, declining oil costs, and increasing focus on environmental and ecological stewardship are shifting the focus toward integrated water management in E&P operations. Water is no longer a problem to be delegated to a third-party disposal or treatment vendor, but is becoming a cornerstone of O&G production. This is a summary of produced water characteristics, regulations and management options, produced water treatment fundamentals, and a detailed discussion of process equipment and advantages/disadvantages of currently available treatment processes. It provides a guide for selecting appropriate technologies for the desired application and points toward the optimization of current technologies and the use of combined treatment processes to meet reuse and discharge limits and critically, more stringent environmental regulations.

Produced Water Volumes and Management Practices in the United States

A Comprehensive Analysis of Its Impact on the Formations of the Appalachian Basin

RI-64: Implications for Future Developm

Bioaccumulation in Marine Organisms

Further Explorations in the Energy-Water Nexus

This report summarizes the work performed from 1 April 2003 to 30 September 2003 and recommends the tasks to be performed during Phase II (Pilot Evaluation). During this period discussions were held with various water agencies regarding use of the treated produced water either directly or indirectly through a water trading arrangement. In particular, several discussions were held with Monterey County Water Resources Agency, that has been charged with the long-term management and preservation of water resources in Monterey County. The Agency is very supportive of the program. However, they would like to see water quality/cost estimate data for the treated produced water from the pilot study prior to evaluating water use/water trade options. The agency sent a letter encouraging the project team to perform the pilot study to evaluate feasibility of the project. In addition, the regulations related to use of the treated water for various applications were updated during this period. Finally, the work plan, health and safety plan and sample analyses plan for performing pilot study to treat the oilfield produced water were developed during this period.

Produced water handling has been an issue of concern for oil and gas producers as it is one of the major factors that cause abandonment of the producing well. The development of effective produced water management strategies poses a big challenge to the oil and gas industry today. Conversion of produced water into irrigation or fresh water provides a cost effective tool to handle excessive amounts of the produced water. In this research we proposed on-site produced water treatment units configured to achieve maximum processing throughput. We studied various advanced separation techniques to remove oil and dissolved solids from the produced water. We selected adsorption as the oil removing technique and Reverse Osmosis (RO) as the dissolved solids removing technique as being the best for our purpose. We performed experiments to evaluate operating parameters for both adsorption and RO units to accomplish maximum removal of oil and dissolved solids from the produced water. We compared the best models fitting the experimental data for both the processes, then analyzed and simulated the performance of integrated produced water treatment which involves adsorption columns and RO units. The experimental results show that the adsorption columns remove more than 90% of the oil and RO units remove more than 95% of total dissolved solids from the produced water. The simulation results show that the proper integration and configuration of adsorption and RO units can provide up to 80% efficiency for a processing throughput of 6-8 gallons per minute of produced water. From an oil and gas producer's viewpoint output from the produced water treatment system is a revenue generating source. The system is flexible and can be modified for the applications such as rangeland restoration, reservoir recharge and agricultural use.

Fundamentals, Water Chemistry, Emulsions, Chemical Treatment

Final Technical Summary, Final Technical Report

Produced Water 2

Engineering the Use of Green Plants to Reduce Produced Water Disposal Volume

Prevention of Water Contamination Through Effective Disposal of Produced Water Generated by Onshore Oil and Gas Production

Plasma Discharges in Produced Water and Its Applications to Large Scale Flow

In some coalbeds, naturally occurring water pressure holds methane--the main component of natural gas--fixed to coal surfaces and within the coal. In a coalbed methane (CBM) well, pumping water from the coalbeds lowers this pressure, facilitating the release of methane from the coal for extraction and use as an energy source. Water pumped from coalbeds during this process--CBM 'produced water'--is managed through some combination of treatment, disposal, storage, or use, subject to compliance with federal and state regulations. CBM produced water management can be challenging for regulatory agencies, CBM well operators, water treatment companies, policy makers, landowners, and the public because of differences in the quality and quantity of produced water; available infrastructure; costs to treat, store, and transport produced water; and states' legal consideration of water and produced water. Some states consider produced water as waste, whereas others consider it a beneficial byproduct of methane production. Thus, although current technologies allow CBM produced water to be treated to any desired water quality, the majority of CBM produced water is presently being disposed of at least cost rather than put to beneficial use. This book specifically examines the Powder River, San Juan, Raton, Piceance, and Uinta CBM basins in the states of Montana, Wyoming, Colorado, New Mexico, and Utah. The conclusions and recommendations identify gaps in data and information, potential beneficial uses of CBM produced water and associated costs, and challenges in the existing regulatory framework.

The objective of this project was to create an internet-based Water Treatment Technology Catalog and Decision Tool that will increase production, decrease costs and enhance environmental protection. This is to be accomplished by pairing an operator's water treatment cost and capacity needs to specific water treatments. This project cataloged existing and emerging produced water treatment technologies and allows operators to identify the most cost-effective approaches for managing their produced water. The tool captures the cost and capabilities of each technology and the disposal and beneficial use options for each region. The tool then takes location, chemical composition, and volumetric data for the operator's water and identifies the most cost effective treatment options for that water. Regulatory requirements or limitations for each location are also addressed. The Produced Water Treatment Catalog and Decision Tool efficiently matches industry decision makers in unconventional natural gas basins with: 1) appropriate and applicable water treatment technologies for their project, 2) relevant information on regulatory and legal issues that may impact the success of their project, and 3) potential beneficial use demands specific to their project area. To ensure the success of this project, it was segmented into seven tasks conducted in three phases over a three year period. The tasks were overseen by a Project Advisory Council (PAC) made up of stakeholders including state and federal agency representatives and industry representatives. ALL Consulting has made the catalog and decision tool available on the Internet for the final year of the project. The second quarter of the second budget period, work was halted based on the February 18, 2011 budget availability; however previous project deliverables were submitted on time and the deliverables for Task 6 and 7 were completed ahead of schedule. Thus the application and catalog were deployed to the public Internet. NETL did not provide additional funds and work on the project stopped on February 18, 2011. NETL ended the project on March 31, 2012.

The exploration for and production of oil and gas to meet our nation's energy needs also results in the production of large quantities of water as a by-product. This water, which is produced from wells during exploration and production, is known as "produced water." Because produced water may contain a variety of contaminants, such as salts and minerals, it is often considered to be a waste stream that oil and gas producers must appropriately manage and treat before this water can be disposed of. If it is not appropriately managed or treated, the contaminants present in produced water discharged from oil and gas operations may threaten human health and the environment. This book explores the inextricable link between energy production and water with a focus on what is known about the volume and quality of produced water from oil and gas production; what practices are generally used to manage and treat produced water; and how the management of produced water is regulated at the federal level and in selected states.

Produced Water

Recycling Produced Water in Hydraulic Fracturing

System for Treating Produced Water

Beneficial Reuse of San Ardo Produced Water

Assessing Oil and Gas Produced Water Disposal to Western U.S. Surface Water

The purpose of this study is to evaluate produced water as a supplemental source of water for the San Juan Generating Station (SJGS). This study incorporates elements that identify produced water volume and quality, infrastructure to deliver it to SJGS, treatment requirements to use it at the plant, delivery and treatment economics, etc. SJGS, which is operated by Public Service of New Mexico (PNM) is located about 15 miles northwest of Farmington, New Mexico. It has four units with a total generating capacity of about 1,800 MW. The plant uses 22,400 acre-feet of water per year from the San Juan River with most of its demand resulting from cooling tower make-up. The plant is a zero liquid discharge facility and, as such, is well practiced in efficient water use and reuse. For the past few years, New Mexico has been suffering from a severe drought. Climate researchers are predicting the return of very dry weather over the next 30 to 40 years. Concern over the drought has spurred interest in evaluating the use of otherwise unusable saline waters. Produced water is generated nationally as a byproduct of oil and gas production. Seven states generate 90 percent of the produced water in the continental US. About 37 percent of the sources documented in the US Geological Survey's (USGS) Produced Waters Database have a TDS of less than 30,000 mg/l. This is significant because produced water treatment for reuse in power plants was found to be very costly above 30,000 mg/l TDS. For the purposes of this report, produced water treatment was assessed using the technologies evaluated for the San Juan Generating Station (SJGS) in Deliverable 3, Treatment and Disposal Analysis. Also, a methodology was developed to readily estimate capital and operating costs for produced water treatment. Two examples are presented to show how the cost estimating methodology can be used to evaluate the cost of treatment of produced water at power plants close to oil and gas production.

U.S. Environmental Protection Agency (EPA) Region VI has issued a general permit for offshore oil and gas discharges to the Gulf of Mexico that places numerical limits on whole effluent toxicity (WEI) for produced water. Recently proposed EPA general permits for other produced water discharges in Regions VI and X also include enforceable numerical limits on WET. Clearly, the industry will be conducting extensive produced water WET testing. Unfortunately, the WET test may not accurately measure the toxicity of the chemical constituents of produced water. Rather the mortality of test organisms may be attributable to (1) the high salinity of produced water, which causes salinity shock to the organisms, or (2) an ionic imbalance caused by excesses or deficiencies of one or more of seawater's essential ions in the test chambers. Both of these effects are likely to be mitigated in actual offshore discharge settings, where the receiving water will be seawater and substantial dilution will be probable. Thus, the additional salinity of produced water will be rapidly assimilated, and the proper marine ionic balance will be quickly restored. Regulatory authorities should be aware of these factors when interpreting WET test results.

A state-of-the-art review of scientific knowledge on the environmental risk of ocean discharge of produced water and advances in mitigation technologies. In offshore oil and gas operations, produced water (the water produced with oil or gas from a well) accounts for the largest waste stream (in terms of volume discharged). Its discharge is continuous during oil and gas production and typically increases in volume over the lifetime of an offshore production platform. Produced water discharge as waste into the ocean has become an environmental concern because of its potential contaminant content. Environmental risk assessments of ocean discharge of produced water have yielded different results. For example, several laboratory and field studies have shown that significant acute toxic effects cannot be detected beyond the "point of discharge" due to rapid dilution in the receiving waters. However, there is some preliminary evidence of chronic sub-lethal impacts in biota associated with the discharge of produced water from oil and gas fields within the North Sea. As the composition and concentration of potential produced water contaminants may vary from one geologic formation to another, this conference also highlights the results of recent studies in Atlantic Canada.

Management of Produced Water in Oil and Gas Operations

Technological/Environmental Issues and Solutions

Environmental Issues and Mitigation Technologies

Tranquillon Ridge Oil and Gas Development Project, LOGP Produced Water Treatment Upgrade and Expansion, Sisquoc Pipeline Bi-directional Flow: Appeal of the Lompoc oil and gas produced water treatment upgrade and expansion

Liber Psalmorum, Hebraicè, cum versione latinâ Santis Pagnini

The project goal is to convert a currently usable by-product of oil production, produced water, into a valuable drinking water resource. The project was located at the Placate Oil Field in Santa Clarita, California, approximately 25 miles north of Los Angeles. The project included a literature review of treatment technologies; preliminary bench-scale studies to refine a planning level cost estimate; and a 10-100 gpm pilot study to develop the conceptual design and cost estimate for a 44,000 bpd treatment facility. A reverse osmosis system was constructed, pilot tested, and the data used to develop a conceptual design and operation of four operational scenarios, two industrial waters levels and two irrigation/potable water.

A system and method were used to treat produced water. Field-testing demonstrated the removal of contaminants from produced water from oil and gas wells.

Produced Water (PW) is the largest volume of waste that is normally generated during oil and gas production. It has large amounts of contaminants that can cause negative environmental and economic impacts. The management method for PW relies highly on types and concentrations of these contaminants, which are field dependent and can vary from one oil field to another. Produced water can be converted to fresh water if these contaminants are removed or reduced to the acceptable drinking water quality level. In addition, increasing oil production rate and reducing amounts of discharged harmful contaminants can be achieved by removing dissolved hydrocarbons from PW. In order to identify the types of these contaminants, effective tools and methods should be used. Six Sigma, which uses the DMAIC (Define- Measure- Analyze- Improve- Control) problem-solving approach is one of the most effective tools to identify the root causes of having high percentages of contaminants in produced water. The methodology also helped develop a new policy change for implementing a way by which this treated water may be used. Six Sigma has not been widely implemented in oil and gas industries. This research adopted the Six Sigma methodology through a case study, related to the southern Iraqi oil fields, to investigate different ways by which produced water can be treated. Research results showed that the enormous amount of

contaminated PW could be treated by using membrane filtration technology. In addition, a Multi Criteria Decision Making (MCDM) framework is developed and that could be used as an effective tool for decision makers. The developed framework could be used within manufacturing industries, services, educational systems, governmental organizations, and others.

Treatment and Management of Produced Water from Hydraulic Fracturing Using Electro-coagulation Technology

Managing, Controlling and Improving the Treatment of Produced Water Using the Six Sigma Methodology for the Iraqi Oil Fields

Analysis of U.S. Produced Water Controls -- Are They Cost-effective?.

Overview of Produced Water Treatment Technologies

Effect of Contaminants from Oil Well Produced Water

In 1990, the Laboratory began an investigation into biological approaches for the reduction of water produced from oil and gas wells. In the spring of 1995, the Company began an on-site experiment at an oil/gas lease in Oklahoma using one of these approaches. The process, known as phytoremediation, utilizes the ability of certain salt tolerant plants to draw the produced water through their roots, transpire the water from their leaves, and thereby reduce overall water disposal volumes and costs. At the Company experimental site, produced water flows through a trough where green plants (primarily cordgrass) have been planted in pea gravel. The produced water is drawn into the plant through its roots, evapotranspirates and deposits a salt residue on the plant leaves. The plant leaves are then harvested and used by a local rancher as cattle feed. The produced water is tested to assure it contains nothing harmful to cattle. In 1996, the Company set up another trough to compare evaporation rates using plants versus using an open container without plants. Data taken during all four seasons (water flow rate, temperature, pH, and conductivity) have shown that using plants to evapotranspirate produced water is safe, more cost effective than traditional methods and is environmentally sound.

Produced water is typically the largest bi-product or waste stream volume accompanied with the oil and gas production. It is basically the waste product full of chemical contaminants; which cannot be utilized for any useful purpose. Produced water quality fluctuates considerably based on type of hydrocarbons produced, geographical location and the geochemistry of the generating reservoir. This book is helpful in selecting the most appropriate method for produced water in oil & gas sector across the globe. Each of the produced water handling techniques has pros & cons with respect to their implementation at site depending upon the volumes of it generated each day, it's chemical and physical characteristics etc. This book also contains produced water data from oil & gas companies which is evaluated and analyzed in detail to reach at a conclusion that Forced Evaporation system is the most feasible and viable handling technique for controlled produced water productions. As for the higher produced water generation, definitely other handling techniques such as well injection, water treatment, down-hole injection for oil recovery are the alternate solutions to the problem.

This book represents the proceedings of the first major international meeting dedi cated to discuss environmental aspects of produced water. The 1992 International Pro duced Water Symposium was held at the Catamaran Hotel, San Diego, California, USA, on February 4-7, 1992. The objectives of the conference were to provide a forum where scientists, regulators, industry, academia, and the enviromental community could gather to hear and discuss the latest information related to the environmental considerations of produced water discharges. It was also an objective to provide a forum for the peer review and international publication of the symposium papers so that they would have wide availability to all parties interested in produced water environmental issues. Produced water is the largest volume waste stream from oil and gas production activities. Onshore, well over 90% is reinjected to subsurface formations. Offshore, and in the coastal zone, most produced water is discharged to the ocean. Over the past several years there has been increasing concern from regulators and the environmental commu nity. There has been a quest for more information on the composition, treatment systems and chemicals, discharge characteristics, disposal options, and fate and effects of the produced water. As so often happens, much of this information exists in the forms of reports and internal research papers. This symposium and publication was intended to make this information available, both for open discussion at the conference, and for peer review before publication.

Spatial Variability of Coalbed Natural Gas Produced Water Quality, Powder River Basin, Wyoming

Implications for Beneficial Use as Disposal Management

Tranquillon Ridge Oil and Gas Development Project, LOGP Produced Water Treatment System Project, Sisquoc Pipeline Bi-directional Flow Project: Appendices

Developing a Cost Effective Environmental Solution for Produced Water and Creating a ''new'' Water Resource

Identification of Bioactive Compounds from Produced Water Discharge/characterization of Organic Constituent Patterns at a Produced Water Discharge Site

Management and disposal of produced water is one of the most important problems associated with oil and gas (O & G) production. O & G production operations generate large volumes of brine water along with the petroleum resource. Currently, produced water is treated as a waste and is not available for any beneficial purposes for the communities where oil and gas is produced. Produced water contains different contaminants that must be removed before it can be used for any beneficial surface applications. Arid areas like west Texas produce large amount of oil, but, at the same time, have a shortage of potable water. A multidisciplinary team headed by researchers from Texas A & M University has spent more than six years is developing advanced membrane filtration processes for treating oil field produced brines The government-industry cooperative joint venture has been managed by the Global Petroleum Research Institute (GPRI). The goal of the project has been to demonstrate that treatment of oil field waste water for re-use will reduce water handling costs by 50% or greater. Our work has included (1) integrating advanced materials into existing prototype units and (2) operating short and long-term field testing with full size process trains. Testing at A & M has allowed us to upgrade our existing units with improved pre-treatment oil removal techniques and new oil tolerant RO membranes. We have also been able to perform extended testing in 'field laboratories' to gather much needed extended run time data on filter salt rejection efficiency and plugging characteristics of the process train. The Program Report describes work to evaluate the technical and economical feasibility of treating produced water with a combination of different separation processes to obtain water of agricultural water quality standards. Experiments were done for the pretreatment of produced water using a new liquid-liquid centrifuge, organoclay and microfiltration and ultrafiltration membranes for the removal of hydrocarbons from produced water. The results of these experiments show that hydrocarbons from produced water can be reduced from 200 ppm to below 29 ppm level. Experiments were also done to remove the dissolved solids (salts) from the pretreated produced water using desalination membranes. Produced water with up to 45,000 ppm total dissolved solids (TDS) can be treated to agricultural water quality water standards having less than 500 ppm TDS. The Report also discusses the results of field testing of various process trains to measure performance of the desalination process. Economic analysis based on field testing, including capital and operational costs, was done to predict the water treatment costs. Cost of treating produced water containing 15,000 ppm total dissolved solids and 200 ppm hydrocarbons to obtain agricultural water quality with less than 200 ppm TDS and 2 ppm hydrocarbons range between $0.5-1.5 /bbl. The contribution of fresh water resource from produced water will contribute enormously to the sustainable development of the communities where oil and gas is produced and fresh water is a scarce resource. This water can be used for many beneficial purposes such as agriculture, horticulture, rangeland and ecological restorations, and other environmental and industrial application.

Produced Water Treatment Field Manual presents different methods used in produced water treatment systems in the oil and gas industry. Produced water is salty water that is produced as a byproduct along with oil or gas during the treatment. Water is brought along with the oil and gas when these are lifted from the surface. The water is then treated before the discharge or re-injection process. In the introduction, the book discusses the basic terms and concepts that describe produced water treatment. It also presents the different methods involved in the treatment. It further discusses the design, operation, maintenance, and sizing of the produced water treatment systems. In the latter part of the book, the ways to remove impurities in water are discussed, including choosing the proper filter, filtering equipment, filtering methods, and filtering types. The main objective of this book is to provide information about proper water management. Readers who are involved in this field will find this book relevant. Present a description of the various water treating equipment that are currently in use Provide performance data for each unit Develop a "feel" for the parameters needed for design and their relative importance Develop and understanding of the uncertainties and assumptions inherent in the design of the various items of equipment Outline sizing procedures and equipment selection

Although the production of Coalbed Natural Gas (CBNG) is variable, a large amount of produced water continues to be brought to the surface. The produced water can be very useful in the water-limited regions of Wyoming, but beneficial uses may be hindered by potential water quality problems. To assess these problems a water quality monitoring study began in 1999. Nine years of water data from CBNG outfalls and discharge ponds was measured over the last eleven years and used for trend analyses. The CBNG produced water was measured on-site for pH, electrical conductivity (EC), oxidation-reduction potential, dissolved oxygen, and temperature. The water samples were later analyzed for alkalinity, Ca, Na, Mg, K, Fe, Al, Cr, Mn, Pb, Cu, Zn, As, Se, Mo, Cd, Ba, B, Cl, SO4, NO3, and PO4. In addition to the trend analyses of CBNG produced water, pond sediment samples were collected over the last four years. Sediment samples were analyzed with TCLP (Toxicity Characteristic Leaching Procedure) for As, Ba, B, Cr, Cu, Mn, Mo, and Se. Trends in CBNG outfalls are not always the same in CBNG discharge ponds: environmental factors play an important role in the water quality of these produced waters. pH is not significantly changing in outfalls of the Belle Fourche River, Cheyenne River, Little Powder River, or Powder River watersheds, but the pH in the Tongue River watershed outfalls is increasing by 0.18 per year. pH in the discharge ponds is increasing by 0.13 per year in all watersheds. Sodium adsorption ratio (SAR) showed no significant increasing or decreasing trends in outfalls or discharge ponds. Alkalinity is significantly decreasing in the outfalls and discharge ponds of the Belle Fourche River, Cheyenne River, and Little Powder River watersheds, and is increasing significantly in the Powder River and Tongue River watersheds. Iron, copper, and chromium concentrations are decreasing in all outfalls of all watersheds. Iron concentrations in the discharge ponds are increasing in the Belle Fourche River, Cheyenne River and Tongue River watersheds, and are decreasing in the Little Powder and Powder River watersheds. Copper and chromium concentrations are decreasing in all watersheds. Overall trend analyses suggest that CBNG outfall produced water in all watersheds of the Powder River Basin meet beneficial use criteria for aquatic life, livestock and wildlife watering, and irrigation except for SAR and to some extent EC. The discharge ponds across all watersheds meet all criteria for all uses except for pH, SAR, and to some extent EC for irrigation, aquatic life, and livestock and wildlife watering. Arsenic concentrations in discharge ponds also exceed aquatic life standard of 7 mcg/L in the Little Powder River and Powder River watersheds. All other water quality components (e.g. Ca, Mg, Na, K, NO3, PO4, SO4, Cl) and trace metals (e.g. Fe, Al, Cr, Mn, Pb, Cu, Zn, Se, Mo, Cd, Ba, B) meet criteria for all common beneficial uses such as, livestock and wildlife watering, aquatic life and irrigation. The results of trend analysis and sediment TCLP analysis discussed in this study could help the CBNG industry, ranchers and landowners, and the state and federal agencies manage CBNG produced water.

USE OF PRODUCED WATER IN RECIRCULATING COOLING SYSTEMS AT POWER GENERATING FACILITIES.

Management and Effects of Coalbed Methane Produced Water in the Western United States

Produced Water Toxicity Tests Accurately Measure the Produced Water Toxicity in Marine Environments?.

Oil & Gas Produced Water Management

Online Produced Water Treatment Catalog and Decision Tool

Environmental interest, regulation changes, and costs have motivated the oil and gas industry to begin recycling produced water in high concentrations during new well stimulation. Accordingly, the potential impact of this practice on production should be investigated. In this thesis paper, tests were conducted to determine whether Marcellus produced water would cause incompatibilities in the Utica and Point Pleasant formations. A multivariate statistical analysis was then completed using a historical dataset of over 300 Marcellus wells to measure the effect of produced water used in stimulation had on well production. The results indicate that recycling produced water in high proportions, even from the Marcellus, should have no measurable impact on the productivity of Utica and Point Pleasant wells. This conclusion supports the use of recycled water not only to comply with regulations and address environmental concerns, but also as a method to reduce water management costs by at least 40 percent.

Natural gas from shale is a relatively clean energy source and is widely viewed as a key asset for economic growth in the U.S. Extraction of shale gas and oil through horizontal drilling and hydraulic fracturing is expected to continue to grow. Likewise, volumes of produced water, which is wastewater from oil and gas production, are also expected increase in the future. Currently, a number of different methods are used to treat produced water for surface discharge, reuse in the shale formation, and other beneficial use. The objective of the present study was to utilize plasma discharges to treat a large volume of produced water for the purpose of recycling it for subsequent fracking. To recycle produced water, both bacterial inactivation and water softening are required, which are the two main objectives of the present plasma water treatment study. The present study consists of two parts: (1) a bacterial inactivation study using both gliding arc discharge (GAD) and high frequency spark discharge and (2) the study of a spark-assisted self-cleaning (SASC) filtration technology in produced water. Note that the SASC filtration technology is a key component for plasma-assisted water softening. Microorganisms, particularly acid-producing bacteria (APB) and sulfate-reducing bacteria (SRB) in produced water, cause microbiologically influenced corrosion such as pipeline corrosion, reservoir souring, and biofouling, which are persistent problems in oil and gas production. E-coli contaminated water was used for the bacterial inactivation study, and the effects of H2O2 and low pH generated by GAD on the inactivation of E-coli bacteria were investigated at a range of water injection rates and air flow rates within GAD system. Furthermore, it was shown that the magnitude of bacterial inactivation and its energy efficiency in a large volume of water could be increased by the use of a microbubble generator to re-inject plasma byproducts in gas form to plasma-treated water enabling the residual effects of plasma water treatment to be captured and used. A new co-axial electrode system was developed for the generation of spark discharges in high-conductivity produced water. This new technology was used in both the biodecontamination and water softening parts of the present research. In static batch tests (no flow), 10-min treatment of semi-transparent produced water by spark plasma showed a 3-log reduction of APB and 2-log reduction of SRB based on the most probable number method in cfu/mL units. In once-through flow tests at water flow rate between 1 and 5 gpm, 2-log reduction of APB was observed in the case of semi-transparent produced water, whereas 1-log to 1.5-log reductions were observed in dark produced water. The energy efficiency (D-value) for APB inactivation in once-through flow tests of dark produced water was 1.7 kJ/L per 1-log reduction. The validation study for the SASC filtration technology was conducted using 10-in cartridge filters having 3- and 5-micron pores in synthetic (high conductivity) produced water and actual produced water. Tests of SASC filtration were performed at different levels of total dissolved solids (TDS) and total suspended solids (TSS) and at a range of flow rates. The present study demonstrated the validity of the SASC filtration concept with water samples having TDS levels 9?Þ 50,000 mg/L and TSS levels 9?Þ 2,500 mg/L. Pressure drops across the filter cartridges obtained with spark discharges were significantly less than baseline pressure drops (i.e., without spark discharges). Pressure drops increased consistently over time in baseline tests resulting in pump failure due to excessive pressure buildup. In summary, the present study demonstrated the feasibility of plasma treatment of wastewater from shale-oil and shale-gas exploration. In particular, the present study validated that the plasma water treatment could be done in an energy-efficient manner in a large enough scale that can be utilized by the wastewater treatment industry.

Oil and gas (O&G) produced waters, wastewater brought to the surface during extraction processes, are often highly saline solutions (10-300 g/L Total Dissolved Solids (TDS)) with increased concentrations of radium, trace and heavy metals, and organic contaminants. Eighty percent of the United States' produced water (3.3 trillion L/year) is generated in states west of the 98th meridian. In western states produced waters are frequently discharged to surface waters in the O&G fields through the National Pollutant Discharge Elimination System (NPDES) and permitted for beneficial reuse downstream for irrigation, livestock watering, and wildlife propagation after minimal treatment. In arid regions, local NPDES discharges may offer substantial water resources to boost agricultural economies and drinking water supplies. The overall dissertation objective is to assess management of O&G produced water as beneficial use in terms of human and environmental health and to provide quantitatively-based recommendations regarding the current regulations. Chapter 1 provides a background on the issues regarding large volumes of O&G produced water, contaminants of concern for beneficial reuse of produced water, and opportunities for recycling and reusing produced water. Chapter 2 contains a geochemical and hydrological salinization assessment of the produced water discharge impacts to stream health downstream of NPDES facilities. Chapter 3 represents a study that sought to understand radium accumulation and sequestration mechanisms in grab and shallow core sediments near O&G discharges where radium was significantly associated with calcium carbonate minerals. Chapter 4 contains a study to determine if radium is bioaccumulating in vegetation growing near O&G NPDES facilities and created produced water retention ponds downstream. Chapter 5 represents a freshwater mussel tank study in which mussels were dosed with O&G produced water derived from the Marcellus Shale. Mussels were then analyzed for bioaccumulation of O&G produced water contaminants to establish environmental tracers (226Ra/228Ra, 87Sr/86Sr) for future forensic studies related to O&G produced water impacts to local water quality. Chapters 2 and 3 are currently published in Science of the Total Environment and Environmental Science: Processes & Impacts; Chapters 1, 4, and 5 are currently in preparation for publication.

Environmental Risks and Advances in Mitigation Technologies

Long-term Biomonitoring of a Produced Water Discharge from the Cedar Cove Degasification Field, Alabama

Recovery of Fresh Water Resources from Desalination of Brine Produced During Oil and Gas Production Operations

Prepared on Behalf of U.S. Department of Energy, Metairie Site Office

Produced Water Treatment Field Manual

Large volumes of produced water are generated and discharged to the coastal and ocean waters worldwide from offshore oil and gas production facilities. There is concern that the chemicals in the produced water may harm marine ecosystems. This book summarizes the bioavailability and marine ecotoxicology of metal and organic contaminants that may occur in oil well produced water at concentrations significantly higher than those in ambient seawater. The contaminants of concern include arsenic, barium, cadmium, chromium, copper, lead, mercury, radium isotopes, zinc, monocyclic aromatic hydrocarbons, polycyclic aromatic hydrocarbons, phenols, and bis(2-ethylhexyl)phthalate. The first part of the book is a detailed discussion of the chemical composition of produced water from offshore oil wells worldwide and its fates following discharge to the ocean. The remaining chapters of the book summarize the current scientific literature on the sources and distributions in the ocean of each of the contaminants of concern and their bioaccumulation and toxicity to marine organisms. This book will be of value to: environmental scientists in the oil and gas industry; marine toxicologists and ecological risk assessors in academia, government, and industry; government regulatory agencies concerned with marine environmental protection. The book advances the concept that bioavailability evaluation must be included in all ecological risk assessments and other environmental assessments of chemical contaminants in marine and freshwater ecosystems.

Produced water contributes to the largest volume waste stream associated with oil and gas (O&G) exploration and production (E&P) operations. It is usually a complex mixture of inorganics and organics that is formed underground and brought to the surface during O&G production. Traditionally, produced water has been considered as a waste to the O&G industry. The conventional management strategies include disposal (typically by injection into depleted wells or permitted disposal wells), recycle (direct reuse within the E&P operation), and reuse (treatment and reuse offsite for food crop irrigation, livestock watering or industrial use). The O&G industry is going through a paradigm shift, where scarcity of water, economics of water management, declining oil costs, and increasing focus on environmental and ecological stewardship are shifting the focus toward integrated water management in E&P operations. Water is no longer a problem to be delegated to a third-party disposal or treatment vendor, but is becoming a cornerstone of O&G production. In this review, we summarize produced water characteristics, regulations and management options, produced water treatment fundamentals, and a detailed discussion of process equipment and advantages/disadvantages of currently available treatment processes. These results in peer-reviewed publications could provide a guide for the selection of appropriate technologies based on the desired application. Major research efforts in the future could focus on the optimization of current technologies and use of combined treatment processes of produced water in order to comply with reuse and discharge limits, under more stringent environmental regulations.