Journal of Petroleum Science and Engineering 144 (2016) 91–98

Contents lists available at ScienceDirect

Journal of Petroleum Science and Engineering

journal homepage: www.elsevier.com/locate/petrol

Characterization of solids in produced water from wells fractured with recycled and fresh water

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ARTICLE INFO

Article history:
Received 13 October 2015
Received in revised form
14 March 2016
Accepted 15 March 2016
Available online 15 March 2016

Keywords:
Produced water
Wattenberg field
Solid characterization
Particle size
XPS

ABSTRACT

Wastewater from shale oil and gas wells contains high levels of organic and inorganic compounds, and the beneficial reuse of produced water requires some level of treatment to remove emulsified oil and grease, suspended solids, and multivalent ions. It is important to identify the quantity and makeup of solids in produced water, so that an optimized reuse or treatment approach can be achieved. This study provides a qualitative and quantitative characterization of solids in frac flowback and produced water from five horizontal wells at two separate sites in the Wattenberg field of Northern Colorado. Difference in solids from wells fractured with fresh water and recycled water is compared in this study, and their distribution and characterization are identified by particle size distribution measurement and X-ray photoelectron spectroscopy (XPS). Results show that particle sizes were smaller and more uniform in produced water samples collected during the first week of production from the wells fractured with recycled water, suggesting that the recycled water was more compatible with the shale formation and wells fractured with recycled water tend to clean out faster.

1. Introduction

The Wattenberg field, lying in the northeast of the Denver-Julesburg Basin, is an unconventional shale play with an estimated 195.3 billion cubic feet (5.5 billion cubic meters) of wet natural gas reserve in 2009 (U.S. Energy Information Administration, 2012). Raabe (2011) also predicted that as much as 1 to 2 billion barrels of oil equivalent is reserved in the Wattenberg field, with 70% oil and 30% natural gas. There are five major formation layers in the Wattenberg field: J Sandstone, Codell Sandstone, Niobrara Formation, Hygiene Sandstone and Terry Sandstone (Weimer et al., 1986). By the end of February 2013, there are more than 22,000 active wells in the Wattenberg field, producing about 740 million cubic feet of natural gas and 100,000 barrels of oil per day (Colorado Oil and Gas Conservation Commission, 2013).

To extract oil and gas from the deep shale formation, hydraulic fracturing has been widely performed all over the world, and large amount of water is used during the hydraulic fracturing process to open up the target formation. Goodwin et al. (2013) estimated that each vertical and horizontal well in the Wattenberg field of Northern Colorado uses an average of 0.4 and 2.9 million gallons (1500 and 11,000 m^3) of water, respectively. With oil-rich fields often located in water-scarce areas, the water demand of oil and gas production could add to the already-intense demand for water for municipal and agricultural purposes or even contribute to water shortages during severe drought conditions.

With the large amount of water being put into the wells for hydraulic fracturing, significant volume of wastewater (as known as produced water) is generated with the production of hydrocarbon, and it has become crucial waste management and environment issues. The most common means of disposing wastewater from oil and gas production in the United States is through deep well injection—a practice that costs an average of 1 to 4 U.S. dollars per barrel (Clark and Veil, 2011). However, an increasing number of oil and gas companies are taking advantage of reusing treated produced water as fracturing fluid for new wells (Huang et al., 2005); this practice could help cutting down the demand for fresh water and, furthermore, the transportation and handling costs of the wastewater for deep well injection. Typically treated produced water (or recycled water in this study) is used to form fracturing fluids under different blend ratio with fresh water. Softening and coagulation are the most common treatment processes for operators to recycle the produced water. As a result, the reused produced water always has high total dissolved solid (TDS) concentration, and it is important to understand its potential impacts on the performance of wells that are fractured with recycled water.

The major compounds of produced water include dissolved salt and organic compounds, emulsified oil, fracturing chemical compounds, and suspended solid particles. Solids in produced water

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http://dx.doi.org/10.1016/j.petrol.2016.03.011
0920-4105/

represent a wide range of materials, including formation solids, corrosion and scale products, bacteria, waxes, and asphaltenes (Fakhru'l-Razi et al., 2009). Deng et al. (2009) characterized suspended solid in produced water after water flooding at Daqing oilfield, China. The result showed presence of inorganic substances such as SiO_2, Fe_2O_3, Fe_3O_4, and $BaSO_4$ in insolated solid samples, and authors recommend implementing fine filtration methods (fiber ball and membrane) for a successful suspended solid removal. With multiple studies focused on produced water qualities from shale wells fractured with fresh water (Benko and Drewes, 2008; Alley et al., 2011; Barbot et al., 2013), very few work has been done on recycled water fractured wells. In this study, produced water quality is compared between wells fractured with fresh and recycled water. Additionally, the suspended solids in produced water from these wells are characterized with gravimetric and particle sizing analyses, and their surface chemistry was tested through X-ray photoelectron spectroscopy (XPS). The understanding of solids properties and chemical composition will help guide the selection of the treatment technique that will improve wastewater treatment effectiveness and allow beneficial wastewater reuse.

2. Methods

2.1. Well location and sampling methods

In this paper, two Noble Energy Inc. well pads in the Wattenberg field were studied: Crow Creek and Chandler State as shown in Fig. 1. Five horizontal wells in the Niobrara formation, described

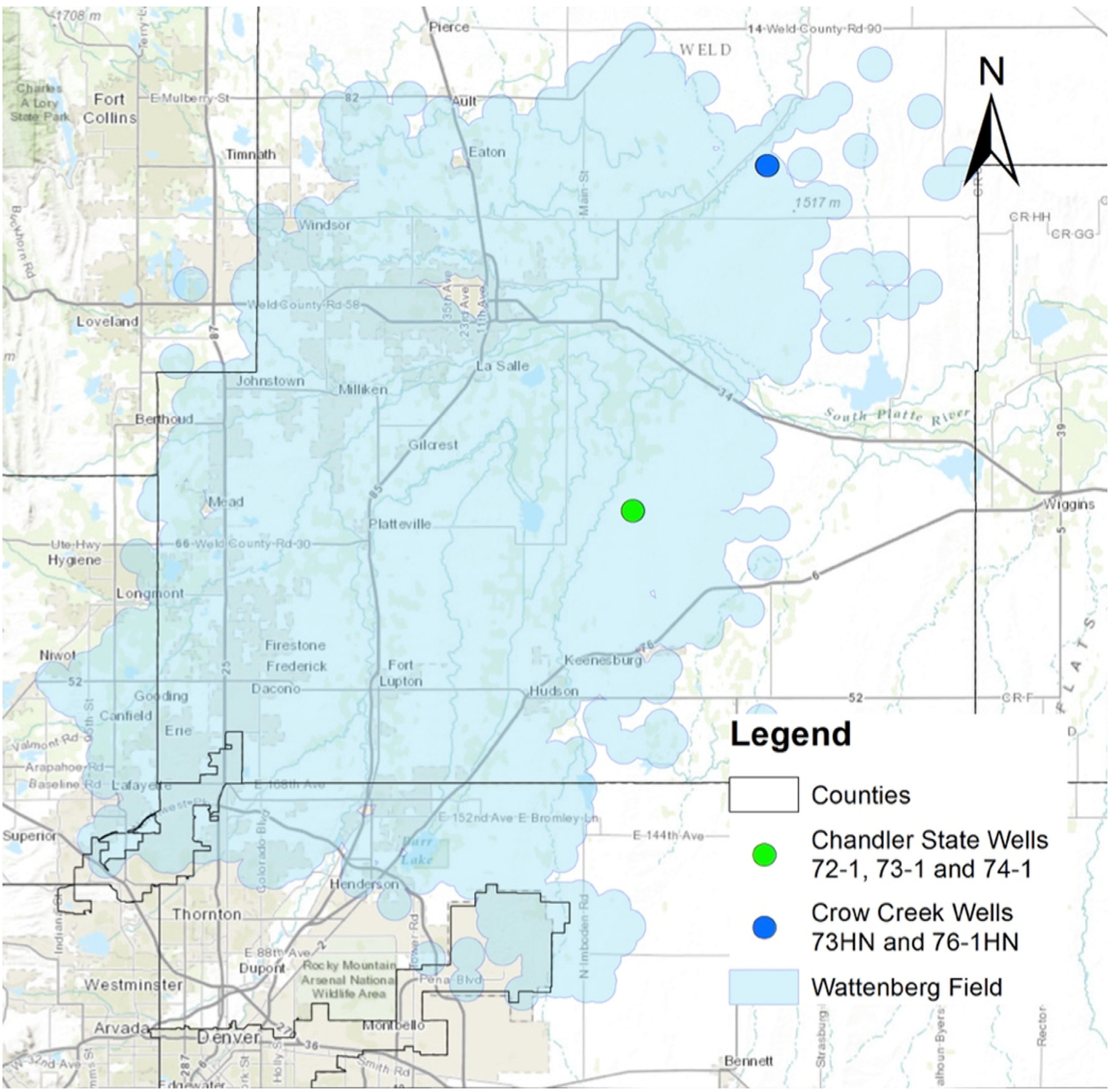

Fig. 1. Location of studied wells within the Chandler State and Crow Creek pads.