Desalination and Water Treatment
www.deswater.com

51 (2013) 302–306
January

Taylor & Francis
Taylor & Francis Group

1944-3994/1944-3986
doi: 10.1080/19443994.2012.714524

Produced water characterization in Kuwait and its impact on environment

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Received 29 February 2012; Accepted 18 July 2012

ABSTRACT

Kuwait is a major oil producer in the Middle East with an oil production reaching three million barrels/day. The increased oil production will certainly result in more produced water that requires handling and treatment. The full picture of the produced water and its impact on the environment is yet to be fully realized due to the lack of data available on produced water characterization. In this paper a review of published work on the characterization of Kuwait oil-produced water is presented. From the review of published data there is clearly a big gap in the physical and chemical analysis of produced water. The choice of treatment methods considered and implemented was limited and driven primarily by economics, with little consideration to the environment. There was considerable research and data published on the environment mainly on the pollution of coastal regions from desalination plants and other causes, but hardly on the effect of produced water. Scarcity of water is a real issue acknowledged in the reviewed literature; however the consideration of recovering and treating produced water for domestic consumption and irrigation is yet to be realized. Finally, recommendations are proposed for handling and treatment of produced water taking into consideration future industrial development, environment and new treatment technologies available.

Keywords: Desalination; Produced water; Environment

1. Introduction

Produced water is water trapped in underground formation that is brought to the surface along with oil or gas. It is by far the largest volume by-product or waste stream associated with oil and gas production. Management of produced water and its environmental effects, present challenges to oil industry and environmental experts. It is well established that the composition of produced water is complex and varies widely. Produced water characteristics and physical properties vary considerably depending on the geographic location of the field, the geological formation with which the produced water has been in contact for thousands of years and the type of hydrocarbon product being produced and affect the physical and chemical properties of produced water.

Produced water properties and volume can even be varying throughout the life time of the reservoir [1,2]. While, its major constituents are inorganic salts which make it similar to seawater although salinity

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Presented at the International Conference on Desalination for the Environment, Clean Water and Energy, European Desalination Society, 23–26 April 2012, Barcelona, Spain

This version has been corrected. Please see Corrigendum (http://dx.doi.org/10.1080/19443994.2012.726325)

can range almost from fresh to fully saturated brine. Minor constituents, including trace elements and naturally-occurring radionuclides occur at very low concentrations. In addition produced water contains residual quantities of dispersed and dissolved hydrocarbons. The produced water contaminates the soil and causes the outright death of plants, and the consequent erosion of topsoil. Also, impacted soil serves to contaminate surface waters and shallow aquifers.

Produced water generated in Kuwait, as a result of increased oil production as well as the ageing of oil fields where the water cut percentage is very high, requires serious and urgent attention. Environmental considerations will help in determining how best to dispose of the produced water or subject it to treatment and supplement the already scare water resource as reported by [3]. Systematic characterization of Kuwait produced oil will help to determine the best course of action in handling and dealing with the ever increasing amount of produced water in Kuwait.

2. Kuwait oil fields and reservoirs

The following are the Kuwaiti oil fields and their most significant oil reservoirs per geographical regions and zones as illustrated in Fig. 1 below. Kuwait's oil production capacity in September 2011 reached 3.5 million barrels per day (bpd), vs. its quota which was at 2.2 million bpd. Kuwait Oil Company is targeting 4 million (bpd) by 2020 and trying to sustain it to 2030. Most of Kuwait's reserves are located in the 70 billion barrels Burgan area, which consists of Burgan, Magwa and Ahmadi. Greater Burgan generally produces lighter crudes with API's in the 28˚–36˚ range, and has a production capacity of 1.6 million bbl/d. The South Magwa field is estimated to hold at least 25 billion bbl of light crude. Other fields surrounding the Greater Burgan area include Umm Gudair, Minagish, and Abdaliya. Umm Gudair and Minagish produce heavier crude oil, with gravities in the 22˚–26˚ API range, and have a combined production capacity of 200,000 bbl per day. In January 2003, water injection

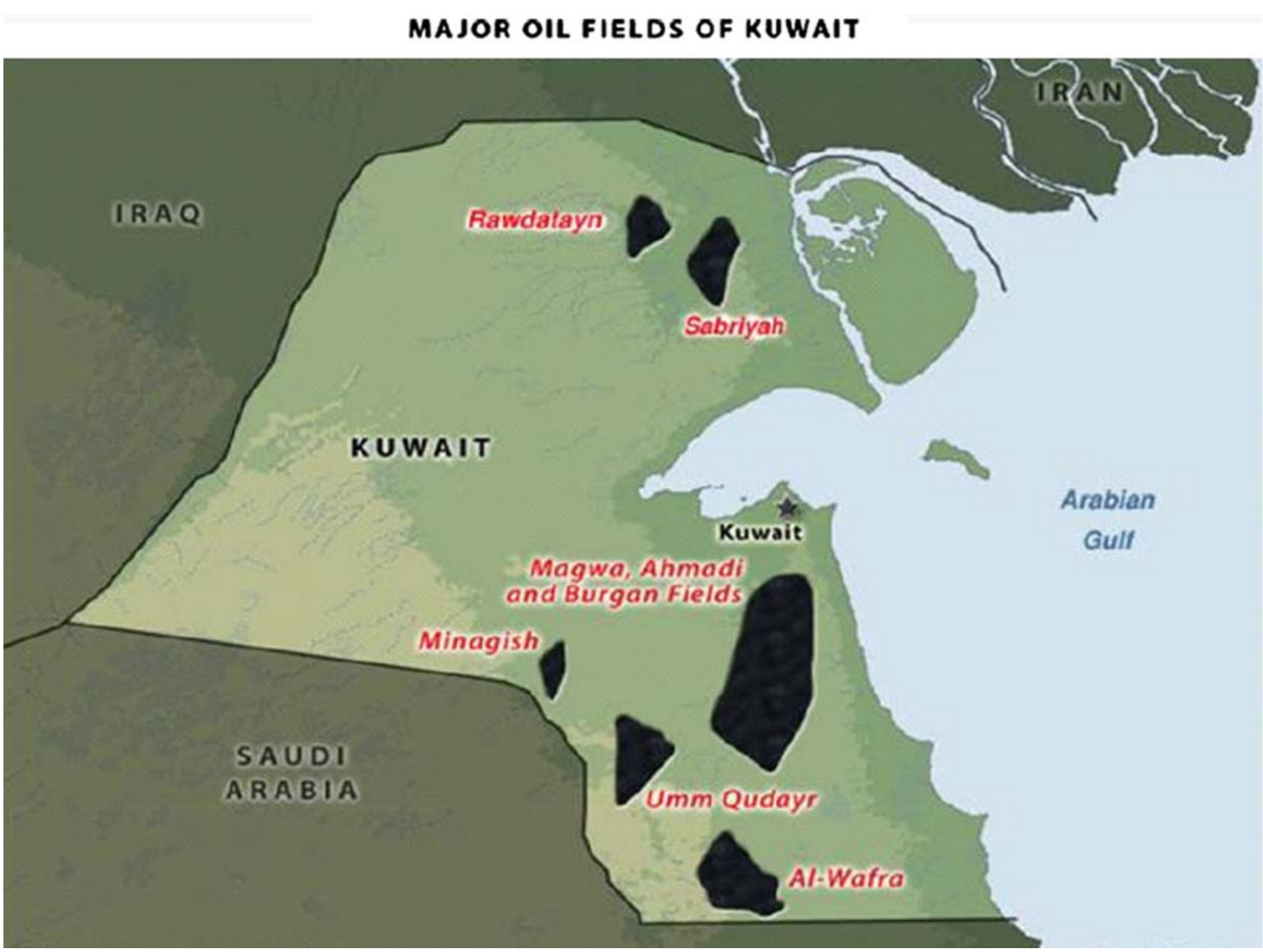

Fig. 1. The general view of the major oilfields in Kuwait.

began at Minagish to offset declines in production [4,5].

Northern Kuwait holds the majority of Kuwait's larger fields after Greater Burgan. Kuwait's second largest field, Raudhatain has 9.55 billion bbl of proven and probable recoverable oil. Raudhatain has the capacity to produce 450,000 bbl of oil per day.

3. Produced water composition

Produced water consists of formation water (the water present naturally in the reservoir), flood water and in the case of some gas production, condensed water. The increased volume of produced water handled in both onshore and offshore petroleum production operations is becoming a major concern, especially with the possibility of further reduction in the oil content allowed in the discharged water (offshore operations), as well as the fact that produced water contains a number of undesirable toxic components. Handling this volume of water is of prime concern to all oil companies wherever they operate. For example, Shell Oil is now producing two barrels of water for each barrel of oil and oil equivalent, worldwide [5].

The physical, chemical, and biological properties of oil-fields produced water depend on two factors: the geological formation and geographical location of the reservoir. These two factors dictate the type and concentration of inorganic species in formation water (silt, salts, scale salts, Naturally Occurring Radioactive Materials or NORM, and metals) as well as the type and specification of the co-existed hydrocarbons (heavy or light crude oils, and acid gases). Sulfate reducing bacteria (due to the existence of sulfate in formation water or via the introduction of sulfate through seawater injection) and/or general anaerobic bacteria can also be present in oil-fields produced water. Algae and fungi can additionally be present in oil fields produced water during processing at surface facilities.

Furthermore, residual production chemicals such as corrosion inhibitors, emulsion breakers, scale inhibitors and dissolvers, and biocides further complicate the properties of oil-fields produced water. Thus, oil-fields produced waters are very complex mixtures with significant variations in their volumes and the abundance of major and minor inorganic, hydrocarbon, chemical, and biological species over the life time of producing wells. The quality of produced water as strictly measured by its contents of total suspended solids and oil-in-water has been of significant concern since poor quality leads to injectivity reduction and wells plugging [6].

4. Characterization of Kuwait produced water

Qabazard et al. [7] investigated water qualities for re-injection purposes; four crude oil gathering centers (GC) in Kuwait were studied. Extensive field and laboratory measurements were made for several sampling points. Two modes of operations, namely "normal operation" and "recycled operation" were also studied. The results of this study could be used for core flooding evaluation and also for compatibility analysis of water injection. No conclusive observation was made on the quality of effluent water however; water quality was much lower at the wet tank sampling point for recycled mode. The lowest water quality was at the discharge of the desalters sampling points.

The ground water around pits used for the discharging of produced water was studied by M. Al-Rashed et al. [8] and they found it to be contaminated by the infiltration of the off specification seawater, used for injection in oil reservoirs, and brines produced with oil that were disposed in lined or unlined pits in the oil fields of north Kuwait. To observe any changes in groundwater salinity due to the discharges to the pits, four monitoring wells were drilled around one of the lined pits and one monitoring well was completed in the vicinity of an unlined one. The results showed that the peak values of total dissolved solids (TDS) in the monitoring wells to the north of the lined pit reached 57,000 mg/L and that for the well to the north of the unlined pit 45,000 mg/L. During the observation period of almost one year, the values came down to 3,000–5,000 mg/L and 37,600 mg/L, respectively. They recommended that all disposal pits within the perimeter or in close proximity to the freshwater basin (depression) be closed down and that new ones to be located outside and away from the depressions. Adoption of other environment-friendly means of disposal (e.g. injection in deep aquifers) should also be considered.

The authors in [9] studied the geochemical evolution of the water produced at the gathering centers (GC) (fresh brine) to stagnant pit water (evaporate) in the northern fields of Kuwait, and a presented model showing time-dependent variations. The objective of their study was to harmonize the database of brine waters in terms of regional identity by comparison with oilfield brines elsewhere, identify water–rock interaction, and statistically treat daily recordings from the pits in order to identify injection peaks and troughs. Laboratory analyses of major and minor cations and anions from the Rawdatayn samples and from the Sabriyah oilfield samples are shown in Table 1. The stable isotopic analysis of five samples

Table 1
A typical ion composition of oilfield brines from North America compared with the average ion concentration of Kuwait oilfield-produced brine water taken from Ref. [9]

Major ions (ppm)	Typical brine water from North America (Miller et al. [12])	Kuwait brine water (Bader [13])	Rawdatayn samples	Sabriyah oilfield samples
Na^+	12,000–15,000	68,959	11,698–203,977	9,807–274,947
Ca^{2+}	1,000–120,000	19,014	2,216–98,514	2,555–77,992
Mg^{2+}	500–25,000	3,198	1,602–28,885	1,415–28,183
K^+	30–4,000	2,851	1,528–16,573	764–19,201
Sr^{2+}	5–5,000	535	70–502	77.84–641
Ba^{2+}	0–1,000	2	0.01–18.04	0.15–6.76
Fe^{2+}			0.018.93	0.016–38.88
Li^+	1–50	2	0.09–6.48	0.05–6.83
Si^{2+}			0.00–13.18	0.0195–16.84
B^{3+}			0.05–37.45	7.17–55.33
$SO_4{}^{2+}$			330–3,100	44,812–135,264
Cl^-	20,000–250,000	150,948		

indicates normal trends in oxygen and hydrogen isotopes that classify the waters as "connate" which follow an evaporation trend. Carbon isotope average values for all brine samples from the GCs is equal to −56 which falls within normal hydrocarbon formation water category.

Al-Otaibi et al. [10] investigated experimentally the effect of five factors (gravity settling, chemical treatment, freshwater injection, heating, and mixing) on the efficiency of the dehydration/desalting process for a Kuwaiti crude oil and a commercial demulsifier (Servo CC 3408). These factors are systematically varied and efficiency is analyzed. Two efficiencies are defined: a Salt Removal (S/R) efficiency and a Water Cut (W/C) dehydration efficiency. Two main conclusions are drawn for the system studied. First, excessive amounts of a demulsifying agent had adverse effects on the desalting = dehydration process. Secondly, the most important factor that improved both efficiencies (S/R and W/C) was found to be the settling time. Efficiencies up to 75% were obtained at settling times of 5 min.

5. Disposal and treatment of produced water

Disposal of water produced with petroleum has been of great interest in Kuwait for the last 20 years. The current problem arose when the Burgan oil field, which is the second largest field in the world, experienced successive increases in the water content of the produced oil. Al-Hubail et al. [11] introduced a decision-making analysis of the considered alternatives for the disposal of the produced water. Four alternative solutions exist for the industry as practical solutions for the disposal of water produced in Kuwait. The first method utilizes a large number of pits to discharge water. The second alternative depends on discharging water into sealed pits. The third approach to dispose water is by injecting the water underground. The last method is similar to the previous one, but takes into consideration the recovery of reservoir pressure to maintain the rate of oil production. The analysis concluded that the optimal solution is to use the effluent injection method to discharge water produced with oil in Burgan and similar fields in Kuwait.

6. Conclusions

With the continued growth in Kuwait oil production and the ageing of some of its oil fields, the produced water associated with it will continue to grow. The growth in produced water has serious environmental consequences. The methods used in disposing of the produced so far are neither sufficient nor effective. From the above review of published work on the characterization of produced water in Kuwait, there is still a big gap in characterizing all produced water from the different oil fields.

A systematic characterization of all produced water coming from the different Kuwaiti oil fields which will help in deciding the best available course of action for the disposal or treatment methods of produced water that would minimize environmental hazards and supplement the water resources and would be a viable option in solving the scarcity in water resources in Kuwait remains a real problem.

References

[1] Fakhru'l-Razi Ahmaduna, Alireza Pendashteha, Luqman Chuah Abdullaha, Dayang, Radiah Awang Biaka, Sayed Siavash Madaenic and Zurina Zainal Abidin, [Review of technologies for oil and gas produced water treatment], J. Hazard. Mater. 170 (2009) 530–551.

[2] John A. Veil, Markus G. Puder, Deborah Elcock, Robert J. Redweik, Jr., A White Paper Describing Produced Water from Production of Crude Oil, Natural Gas, and Coal Bed Methane, 2004, Argonne National Laboratory. p. 87.

[3] M.A. Darwish, N. Al-Najem, The water problem in Kuwait, Desalination 177 (2005) 167–177.

[4] Kuwait State online document. Available from: http://www.moo.gov.kw/facts/en/index.asp?More=yes&NewsID=27&mode=0&day=2&page=3 (accessed 29 February 2012).

[5] World Energy Investment Outlook, 2003. Available from: http://www.worldenergyoutlook.org/ Publisher International Energy Agency, http://www.iea.org/.

[6] M.S.H. Bader, Seawater versus produced water in oil-fields water injection operations, Desalination 208 (2007) 159–168.

[7] H. Qabazard, M. Salman, M. Moshfegian, Field and Laboratory Analyses of Effluent Water, in SPE Annual Technical Conference and Exhibition, Society of Petroleum Engineers, Houston, TX, 2004.

[8] M. Al-Rashed, A. Mukhopadhyay, M. Al-Senafy, H. Ghoneim, A. Abbas, Contamination of groundwater from oilfield water disposal pits in Kuwait, Arabian J. Sci. Eng. 35 (1B) (2009) 105–123.

[9] A. Alfarhan, M. Duane, Geochemistry and modification of oilfield brines in surface pits in Northern Kuwait, Arabian J. Geosci. 5 (2012) 1055–1068.

[10] M. AL-Otaibi, A. Elkamel, T. AL-Sahhaf, A.S. Ahmed, Experimental investigation of crude oil desalting and dehydration, Chem. Eng. Commun. 190 (1) (2003) 65–82.

[11] J. Al-Hubail, K. El-dash, Managing disposal of water produced with petroleum in Kuwait, J. Environ. Manage. 79 (1) (2006) 43–50.

[12] A.R. Miller, C.D. Densmore, E.T. Degens, J.C. Hathaway, Hot brines and recent iron deposits in deeps of the Red Sea, Geochim. Cosmochim. Acta 30 (1977) 341–350.

[13] M.S.H. Bader, Sulfate removal technologies for oilfields seawater injection operations. Bader Engineering, Inc., College Station, USA. Petroleum Production Research in the Middle East. J. Petrol. Sci. Eng. 55(1–2) (2005) 93–110.