Journal of Petroleum Science and Engineering 171 (2018) 127–139

Contents lists available at ScienceDirect

Journal of Petroleum Science and Engineering

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

Oilfield scale formation and chemical removal: A review

Muhammad Shahzad Kamal[a], Ibnelwaleed Hussein[b], Mohamed Mahmoud[c,*], Abdullah S. Sultan[c], Mohammed A.S. Saad[d]

[a] Center of Integrative Petroleum Research, College of Petroleum Engineering & Geosciences, King Fahd University of Petroleum & Minerals, Dhahran, 31261, Saudi Arabia
[b] Gas Processing Center, College of Engineering, Qatar University, PO Box 2713, Doha, Qatar
[c] Petroleum Engineering Department, College of Petroleum Engineering & Geosciences, King Fahd University of Petroleum & Minerals, Dhahran, 31261, Saudi Arabia
[d] Chemical Engineering Department, College of Engineering, Qatar University, PO Box 2713, Doha, Qatar

ARTICLE INFO

Keywords:
Scale Removal
Chelating Agent
Carbonate
Sandstone
Organic Acid

ABSTRACT

In oil and gas industry operations, scale deposition on the surface and subsurface production equipment can cause different problems such as formation damage, loss in production, pressure reductions, and premature failure of down hole equipment. Due to geochemical processes between injection water, connate water and rock, the complex composition of reservoir fluids make it difficult to control the inorganic scale formation. Carbonate (calcium), sulfide (iron, zinc), and sulfate (calcium, barium, strontium) scales are more common in oilfield applications. The scale formation depends on several factors that include, but not limited to, temperature, pressures, solution saturation and hydrodynamic behaviour of the flow. This paper reviews different types of scales that are common in oil and gas production operations, their sources and formation mechanisms. The focus of this review is on the different chemicals that are used for the removal of different scales. Hydrochloric acid is one of the classical chemicals used since for most of the mineral scales are soluble in HCl. However, HCl is not environmentally-friendly and causes corrosion and could be very expensive particularly in high-temperature conditions due to the need of using many additives to reduce corrosion. This review discusses several alternatives to HCl that are more environment-friendly in removing oilfield scale deposits. These alternatives are mainly organic acids and chelating agents which have been successfully applied in different fields.

1. Introduction

In the last few decades, several solutions have been proposed to remove and mitigate formation damage to improve the productivity and injectivity of oil and gas wells. Scales are one of the most severe forms of formation damage; it can deposit scales in accessible and relatively less accessible areas. The scale is an accumulation of different materials that can lead to clogging and prevent fluid flow in the wellbore, production tubing, valve, casing, perforations and downhole equipment (Crabtree et al., 1999). The scale problem can arise anywhere along water paths from surface equipment to the reservoir itself. The scale deposit can take place in surface water injection facility, injection wells, formation, production well, topside production facilities, pipelines, and at disposal wells (Bader, 2007). Water is the major source of all scales and when water is produced along with oil and gas, different types of scale are expected to form in the reservoir or in the production tubing. The scale can deposit in the form of a thick layer in the wellbore tubing that reduces the production diameter of the tubing, which results in clogging and blocking of the flow (Fig. 1). This can cause a severe increase in the pressure drop and this result in a decrease in the productivity of the well. The production capacity can reach zero within a few hours and could cause a huge treatment cost (Olajire, 2015). The precipitation of scale can also cause formation damage in the reservoir, blockage of different pipelines, enhancing corrosion rate and can pose a threat to safe production operations (El-Said et al., 2009). In the case of water injection wells, the scale could deposit in the formation of pores that can reduce the injectivity with time (BinMerdhah et al., 2010). Scale deposited in the formation can reduce the permeability and porosity of the formation. The variation in rock permeability depends on injection rate and temperature (Haghtalab et al., 2015; Moghadasi et al., 2004). Several types of scale deposition in the well and surface facilities cause a decrease in production capacity and injectivity.

Scale inhibitors (SIs) are a class of specialty chemicals that is used to slow or prevent scale formation in water systems. There are different types of scales and they are usually prevented by using scale inhibitors (Bin Merdhah, 2010; Lu et al., 2010; Tung et al., 2004). In most of the cases, scale dissolver are required to remove the scale, even after

* Corresponding author.
E-mail address: mmahmoud@kfupm.edu.sa (M. Mahmoud).

https://doi.org/10.1016/j.petrol.2018.07.037
Received 24 January 2018; Received in revised form 5 July 2018; Accepted 12 July 2018
0920-4105/ © 2018 Elsevier B.V. All rights reserved.

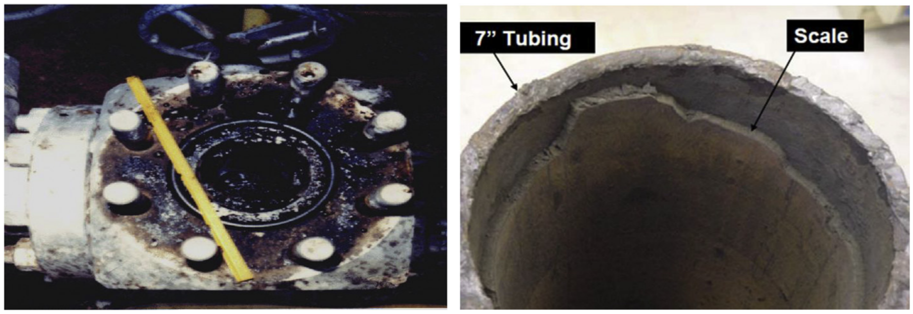

Fig. 1. Typical scale deposition in pipelines (Nasr-El-Din and Al-Humaidan, 2001).

utilizing scale inhibitors as a primary control method. There are different scenarios where scale inhibitors are not totally effective in scale prevention such as when scale formation is not predicted accurately in advance and when placement of inhibitor is non-optimal owing to reservoir heterogeneity (Jordan et al., 2014). Once the scale deposition takes place, it must be removed using scale dissolver.

Scale deposition in downhole surfaces is initiated due to formation of local brine in the environment and the low solubility of some of the inorganic salts that are produced. There are 3 mechanisms that led to the formation of scale deposits both in offshore and onshore. It can be due to; 1) mixing of two incompatible brines, 2) change in conditions (temperature and pressure), and 3) brine evaporation (BinMerdhah et al., 2010). In oilfield applications, water is of great importance since scale will only occur if water is produced. All types of natural waters are rich in ions due to the dissolution of different mineral components. The formation contains significant amounts of Ca^{2+}, Mg^{2+}, Sr^{2+}, and Ba^{2+} with total dissolved solids approaching 400,000 mg/L. The scale deposit usually starts when two or more incompatible water mix with each other (Olajire, 2015). The water systems are called incompatible when they interact with each other chemically and precipitate the minerals when mixed. Seawater (if it contains a high concentration of sulfate ions and low concentration of barium and calcium ions) and formation water (if it contains a low concentration of sulfate ions and high concentration of calcium and barium) are typical examples of incompatible brines (BinMerdhah et al., 2010). The mixing of two such water can lead to precipitation of barium sulfate and calcium sulfate. Other brine incompatibilities could result in depositing sulfide scales where hydrogen sulfide can react with iron, zinc, and lead. In water injection wells, the solubility of some salts in saturated injected water can reduce as it travels to high-temperature zone. This could also result in deposition of scale along the well stings. Similarly, a decrease in pressure can lower the solubility of various minerals in the water. For every 7000 psi decrease in pressure, the solubility of minerals can decrease by a factor of two (Crabtree et al., 1999). The solubility of some minerals such as carbonates changes with the presence of acid gases, such as CO_2 and H_2S.

The scale deposition depends on several factors such as temperature, pressure, chemical reaction equilibria, pH, contact time, evaporation, and ionic strength (Yap et al., 2010). The scale deposits can be as a single mineral phase, but usually, scales are composed of the combination of different elements. Several organic compounds such as naphthenic acids and their salts, aromatic compounds, sulfur-containing compounds, resins, paraffin and unsaturated hydrocarbons can also affect the formation of scale in downhole conditions (Lakshmi et al., 2013). The most common types of scales encountered in oil and gas production include sulfates (Ba, Sr, Ca), oxides/hydroxides (Fe, Mg), carbonates (Ca, Mg, Fe), and sulfides (Fe) (Li et al., 2009; Senthilmurugan et al., 2011). The typical scale compositions in sandstone and carbonate reservoirs are given in Table 1.

The selection of an appropriate chemical formulation to dissolve and remove scale is a challenging task due to the diversity of the scale minerals in a single well. The different types of scales have varying reactivity in acid media and chemical dissolvers. Additionally, the co-deposition of mixed scales in the well is also common, where an insoluble mineral covers a soluble mineral. Another issue in chemical scale removal is the precipitation of reaction byproducts following scale dissolution. This is more common at high pressure and high-temperature conditions where dissolution and precipitation kinetics are competitive.

Table 1
Typical scale in carbonate and sandstone reservoirs.

Carbonate		Sandstones	
Scale Type	wt%	Scale Type	wt%
Iron sulfide	29.2	Calcium Carbonate	33.5
Iron Oxide	28.1	Iron Oxide	30.3
Silicon Oxide	10.4	Silicon Oxide	28.5
Iron Hydroxide	9.0	Iron Sulfide	1.7
Iron Carbonate	5.5	Iron Carbonate	2.5
Dolomite	4.6	Barium Sulfate	1.1
Calcium Carbonate	3.8	Magnesium Oxide	0.6
Calcium Sulfate	3.6	Aluminum Oxide	0.6
Chlorite	2.2	Strontium Oxide	0.5
Sodium Chloride	1.4	Aluminum Silicate	0.4
Barium Sulfate	1.3	Chromium Oxide	0.2
Aluminum Silicate	0.9	Others	0.1
Molybdenum oxide	0.2		

Antony et al. reviewed the scale properties and mechanism of scale formation during reverse osmosis in water desalination and wastewater treatment (Antony et al., 2011). Li et al. (2017) reviewed the scale formation and control strategy using scale inhibitors (Li et al., 2017). Kelland (2014) also reviewed several scale inhibitors for oil and gas wells (Kelland, 2014). Scale inhibitors are applied to prevent scale formation, while scale remover (dissolver) is used to dissolve the scale. If the scale problems still arise even after utilizing scale inhibitors as a primary control method, scale dissolver (remover) is used to remove the scale. This review discusses the different types of scale dissolvers. Olajire (2015) reviewed the oilfield scale management technology (Olajire, 2015). The review mainly discusses the thermodynamic and kinetic prediction of mineral scale formation. Various chemicals that are applied as scale inhibitors in oil and gas industry are discussed in that review. Crabtree et al. (1999) reviewed the physical causes of scale formation during production operations (Crabtree et al., 1999). Some inhibitor systems that are used to prevent the formation of scale are also mentioned. Although the methods of scale removal by mechanical and chemical methods are compared, the chemicals used have not been discussed in detail. In addition, there are many recent advancements in oilfield scale removal. This review focuses on different chemicals that are used in oilfield applications for the removal of different types of scale. The current review has highlighted the conditions for the formation of the most common oilfield scales and identified several types of chemicals that are used for the scale removal. In addition, new green materials that are recently introduced are also reviewed. Future perspectives of oilfield scales are also discussed.

Download English Version:

https://daneshyari.com/en/article/8124378

Download Persian Version:

https://daneshyari.com/article/8124378

Daneshyari.com