

Water scaling case studies in a Kuwaiti oil field

M. Salman, H. Qabazard, M. Moshfeghian *

Petroleum Research and Studies Center, Kuwait Institute for Scientific Research, Ahmadi, Kuwait

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Abstract

This paper presents a computer scaling study on the effluent waters from four Gathering Centers (GC) of an oil field in the State of Kuwait. The experimentally measured chemical analyses of effluent waters and that of formation water were used by computer software to determine the tendency of scale formation. The scaling results for the commingling of individual effluent waters with formation water at reservoir temperatures and pressures are presented. In order to determine scaling tendency, four case studies were investigated. Attention was made on the scaling tendency of CaCO_3 and BaSO_4 for various mixing proportions of effluent water with formation water.

It was found that commingling of the effluent water and formation water may lead to calcium carbonate and barium sulphate scaling above 50% effluent water.

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1. Introduction

One of the main oil recovery processes is waterflooding. This process has been applied in many reservoirs around the world. Sea water is used mainly for waterflooding; however, production water may also be used. Waterflooding may cause corrosion and scaling. Scale is deposition of inorganic minerals from brine (Cowan and Weintritt). Scale deposition occurs in reservoir and in production facilities (Sorbie and Macky, 2000). Scale deposition has been a major problem and has been investigated by many researchers (Jordan et al., 2001; Graham et al., 2003; Collins and Jordan, 2003). Scale causes corrosion, equipment damage, and flow restriction and therefore lowering the production rate. The mechanism of mineral scale formation and inhibition has

been studied by Jordan et al. (2001), Tomson et al. (2003) and Mackay et al. (2003).

Compatibility or scaling tendency of effluent waters with formation waters in the Burgan field (in the state of Kuwait) will be a major factor in determining the feasibility of produced water re-injection and defining engineering solutions for the injection system.

A computer scaling study was performed on the effluent waters from Gathering Centers (GC's) A, B, C and D. Four cases were considered:

1. Scaling tendency of individual effluent waters at surface conditions.
2. Commingling of effluent waters with each other prior to injection.
3. Scaling tendency of effluent waters at reservoir conditions.
4. Commingling of effluent waters with formation water at reservoir conditions.

* Corresponding author.

E-mail address: mahmoodm@jmcampbell.com (M. Moshfeghian).

This paper presents the results and conclusions arising from this scaling study. It also includes a short theoretical discussion on scale formation encountered in oilfield operations involving water injection. It should be noted that this is a general discussion and is not specific to any particular operation.

2. Scaling background

Scaling is usually associated with precipitation. It is recognised that precipitation does not necessarily lead to scaling, but scaling is often thought to result from precipitation followed by adhering of the precipitates to surrounding surfaces. Scaling which occurs at ambient pressures and static conditions may not necessarily occur at elevated pressure and dynamic flows, and vice versa.

After displacing and commingling with the formation water in the immediate area of the injection well bore, the flood front moves radially away from the injection well, pushing the oil and formation water before it (Sorbie and Macky, 2000). Most injection systems do not perform ideally and the injection flood front starts to break up and finger towards the producing well. Eventually, these fingers break through and the injected water is co-produced with the formation water and oil. Formation water and injection water are also able to mix intimately in the vicinity of the production well and the production system. Any water incompatibility will manifest itself in this area.

Within the reservoir, away from the well bore, there is little turbulence and commingling of the two waters; therefore water incompatibility should not be the overriding scaling mechanism. Self scaling of the injection water under production reservoir conditions can become a problem when the system undergoes temperature and pressure changes. The location of scale formation in an oilfield is crucial.

The two parameters of temperature and pressure do not occur in isolation to each other in a producing system. The combined effect of temperature and pressure generates extremely complex scaling tendencies. Further detail is given in references (Dyes et al., 1958; Shen and Cosby, 1983; Fulford, 1986).

It is important to note the following:

1. The most damaging scale will be on the “wrong” side of the sand face, namely, inside the formation. Therefore, attempts to prevent permanent formation damage by placing scale preventers inside the fracture (solid solubility controlled phosphates) will fail.
2. The scale problem is shifted away from the wellbore into the formation where it becomes more difficult or even uneconomical to fight or to remove.

The physical parameters of pressure and temperatures are constantly changing and there will be localised situations where pressure drops across a valve or choke or producing zone can favour one scaling mechanism. This also applies to temperature increases at the fire tubes of a heater-treater or heat exchanger or across a reservoir.

With so many variable parameters it is difficult to absolutely quantify a scaling prediction in relation to an actual system. Many laboratory tests are designed to duplicate the system and variables as closely as is practically possible.

Scale preventative chemicals can be added to prevent the formation of scale, retard the growth of scale crystals or keep scale mobile. In the injection side of the system it is preferential to totally prevent formation of scale as mobile crystals can still block the formation and cause plugging with loss of injectivity. On the production side, totally preventing formation is not so critical so a chemical which keeps the crystals mobile could be suitable.

3. Scale types studied

Many and varied are the chemical compounds existing in any naturally-occurring aqueous system. Of these, the precipitation of the sulphates of calcium, barium and strontium, together with calcium carbonate, are responsible for the majority of problems encountered with respect to scale formation. For a detail chemistry of scale prediction of these compounds, see references (Atkinson and Mecik, 1997; Mackay et al., 2000).

4. Techniques

To gain an insight into the chemical equilibria characterising aqueous systems and, in this case, to predict the scaling tendency of these systems, numerous computer models have been developed (Downhole Sat, 1992; OKSCALE, 1993; Geochemist's WorkBench, 1995). The complete thermodynamics of scale forming materials is discussed in detail by Atkinson and Mecik (1997). In their thermodynamic model, the effects of temperature, pressure, and non-ideal solutions are analyzed and the special case of CaCO₃ scale formation was considered in detail (Atkinson and Mecik, 1997). In order to obtain ‘sensible’ results from such programs, however, it is essential that:

1. The results of the water analyses are accurate.
2. A suitable computer program is used and the capabilities and limitations of the program are understood.
3. The user understands the system they are attempting to model.

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