Iranian Journal of Chemical Engineering
Vol. 9, No. 3 (Summer), 2012, IAChE

Research note

Investigation of Hydrogen Sulfide Oil Pollution Source: Asmari Oil Reservoir of Marun Oil Field in the Southwest of Iran

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Abstract

Marun oil field is located in the southwest of Iran and consists of two oil reservoirs named Asmari and Bangestan. Asmari oil reservoir has been producing sweet oil and gas since 1964, but for the first time a high amount of hydrogen sulfide gas was observed in one well of this reservoir in 1980. Moreover, the Bangestan oil reservoir is located deeper than the Asmari oil reservoir and has been producing sour oil and gas since 1972. This paper represents the conducted study on the determination of hydrogen sulfide oil pollution sources in the Asmari oil reservoir. There are two hypotheses for sources of hydrogen sulfide oil pollution in the Asmari oil reservoir; first, hydrogen sulfide gas migration from Bangestan oil reservoir and second, sour gas injection migration. Data of well souring history, hydrogen sulfide gas concentration of wells, volume of gas injection and RFT analysis were used to investigate these hypotheses. The results showed a similar trend of gas injection volume and hydrogen sulfide gas concentration of wells, which decreased over time. Also, the results demonstrated that the migration of gas injection is a source and cause of spreading of hydrogen sulfide gas in the Asmari oil reservoir.

Keywords: *Marun, Asmari, Hydrogen Sulfide, Reservoir souring, Sour gas injection*

1. Introduction

The presence of H_2S in reservoir fluid is a major problem in the petroleum industry and is associated with reservoir souring, poor sweep efficiently and corrosion. Its occurrence may cause the early abandonment of many oil and gas reservoirs by increasing costs, reducing revenue and environmental concerns. The transition of oils from sweet to sour is usually referred to a baseline of around 3 ppmv rather than zero [1]. In many cases reservoirs which did not initially contain hydrogen sulfide, have become sour as a result of some external sources such as H_2S migration and sour gas or water injection. To control the undesired results of reservoir souring, the pollution should be monitored and studied over time to have

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better management in hydrocarbon production and petroleum facilities.

The three main sources of H_2S in hydrocarbon reservoirs are: (1) bacterial or microbial sulfate reduction; (2) thermal decomposition of organic sulfur compounds in kerogen or oil; and (3) thermochemical sulfate reduction (TSR) [2, 3, 4, 5]. These mechanisms could not occur in the Asmari oil reservoir of the Marun oil field because of its low temperature, absence of anhydrite formation in the Asmari oil reservoir and no application of sea water injection for activity of sulfate reducing bacteria (SRB). Two possible sources of H_2S pollution in the Asmari oil reservoir are Bangestan reservoir and injection of sour gas into the Asmari oil reservoir which has been performing since 1990. Former study introduced Bangestan reservoir as a possible source of H_2S contamination in the Asmari oil reservoir [6] but the source of H_2S pollution in the Asmari oil reservoir has been a matter of debate up to now. Meanwhile, the effect of sour gas injection in Asmari oil pollution has not been studied yet. Previous study [7] on H_2S plume migration within the Asmari oil reservoir of Marun oil field showed that upper layers of this reservoir have good vertical and horizontal communication due to lithology type (mostly dolomite and limestone) and higher fracture. Results of Repeat Formation Test presented a good vertical pressure connection of layers 1, 2 and 3 in the central parts and the North East of the Asmari oil reservoir which showed good vertical communication of these layers in the mentioned parts. Also, it was proposed that by increasing depth from layer 1 to 5 this communication decreases. Meanwhile, in western parts of the Asmari oil reservoir, connections of layers were poor. Moreover, the trend of H_2S spreading was determined to be from the southeast to the northwest within the Asmari oil reservoir [7].

Knowing this, two hypotheses exist for hydrogen sulfide oil pollution sources in the Asmari oil reservoir; first, hydrogen sulfide gas migration from Bangestan oil reservoir and second, sour gas injection migration. In this paper, an attempt was made to determine the exact source of oil pollution in the Asmari oil reservoir by applying the data of well souring history, hydrogen sulfide gas concentration of wells, volume of gas injection and RFT analysis.

2. Area of study

One of the most important oil fields of Iran is Marun, which is located in the southwest of Iran in the south of North Dezful Embayment between Kupal, Aghajari, Ramin, Shadegan and Ramshir oil fields. This field consists of Asmari and Bangestan reservoirs producing oil and Khami reservoir comprising mainly gas. This field is an asymmetric anticline with NW-SE trend. The dimensions of Marun oil field at the Asmari oil reservoir horizon are 67 and 7 kilometers in length and width, respectively. Asmari oil reservoir is divided into 8 sectors. The Bangestan reservoir of this field is located at a higher depth than the Asmari oil reservoir and initially produced H_2S. In contrast, Asmari oil reservoir has been producing sweet oil and gas since 1964, but for the first time a considerable amount of H_2S gas was observed in 1980. It is worthy to note that tectonic activities caused severe fracturing, especially in the south limb of this field [8].

Asmari oil reservoir is an under saturated reservoir, and it was discovered in 1962 by seismic operation and drilling of the first well in this reservoir. The lithology of the Asmari oil reservoir is carbonate, shale and sandstone, where the lithology of Bangestan and Khami reservoirs are carbonate and shale. To date, about 370 wells have been drilled in the Marun oil field. Except for 6 wells of Khami and 20 wells of Bangestan reservoirs, all wells were completed in the Asmari oil reservoir of this field. Fig. 1 shows the schematic cross-view of formations in the Marun oil field, and also a 3D view of Asmari reservoir.

3. Procedure

To study the possible source(s) of H_2S pollution in Asmari reservoir, first, some contaminated wells and their H_2S concentrations and production layers were analyzed to discuss the possibility of different source(s) of oil pollution in Asmari reservoir. Then, RFT results of some polluted wells and their H_2S concentrations were studied to introduce the probable source of H_2S pollution and its extension in Asmari reservoir of Marun oil field. Furthermore, some other evidence such as production rate and reservoir pressure of Asmari reservoir were used to verify the source(s) and migration of this pollution. Finally, the trend of gas injection, its source(s) and all mentioned parameters were investigated to identify the probable source of H_2S plume spreading within the Asmari reservoir of the Marun oil field.

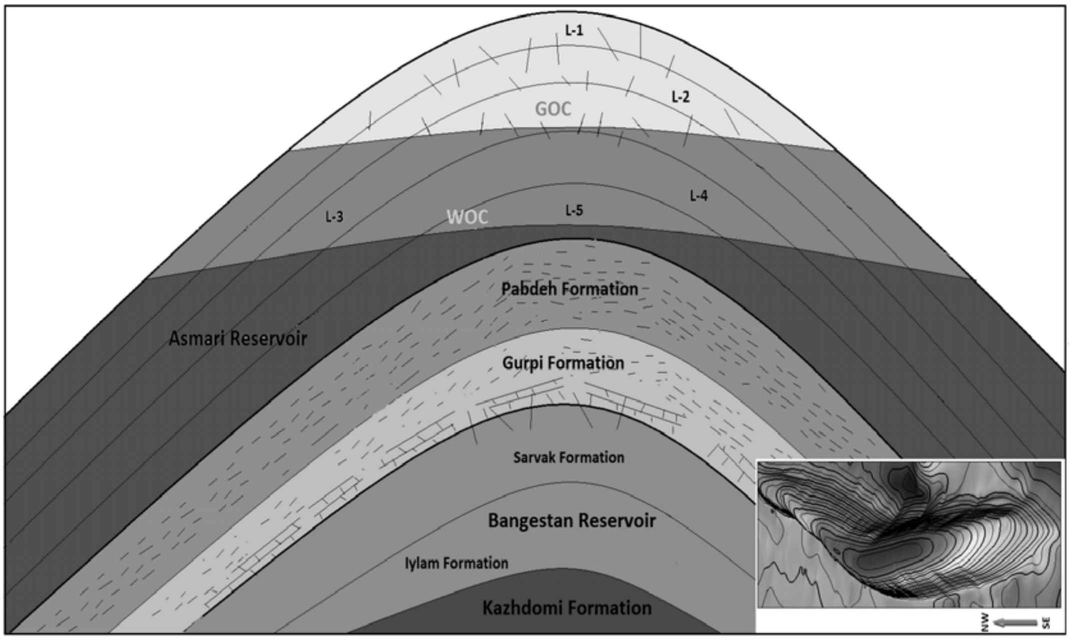

Figure 1. Schematic cross-view of Asmari and Bangestan reservoirs and also 3D view of Asmari oil reservoir in Marun oil field

4. Results and discussion

4-1. History of H_2S pollution in Asmari oil reservoir wells

After 15 years of hydrocarbon production in Asmari reservoir, pollution of well No.1 with a high amount of H_2S gas was reported. The sources of this pollution have been debated til now. To date, 60 wells have been reported to produce H_2S gas in Asmari reservoir. Except sector 2, all sectors have polluted wells and most of the polluted wells (38 % of all polluted wells) are located in sector 6. Fig. 2 shows the distribution of polluted wells in different sectors of Asmari reservoir. Sector 8 has one contaminated well, which was reported in 2004, but due to the lack of measurement no other polluted well has been reported in this sector. Moreover, H_2S concentrations in reported wells of sector 1 were less than 10 ppm, and this sector has been considered as a non-polluted sector up to now.

Initially, just eight wells had H_2S concentrations of more than 100 ppm but now just three wells have H_2S concentrations of more than 100 ppm, which shows that the amount of H_2S concentrations of wells is not remarkable, but pollution is spreading. In addition, about 28 sour wells produce from layer 4 and the other 32 wells produce from three upper layers. Fig. 3 shows the classification of sour well distribution based on H_2S concentration over the course of time. It shows that despite an increase in the number of polluted wells with the lower amount of H_2S, the number of wells containing the high amount of H_2S concentration is decreasing.

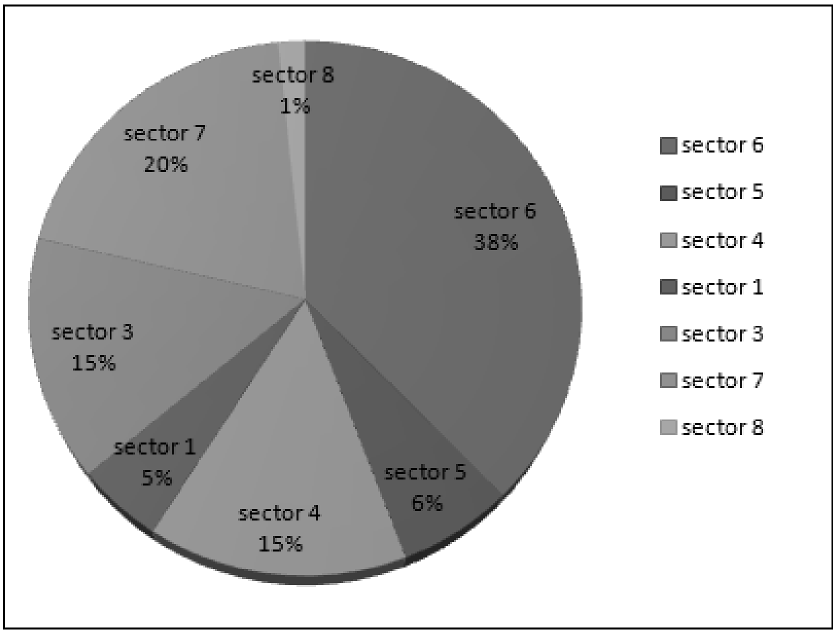

Figure 2. The distribution of polluted wells in different sectors of Asmari reservoir

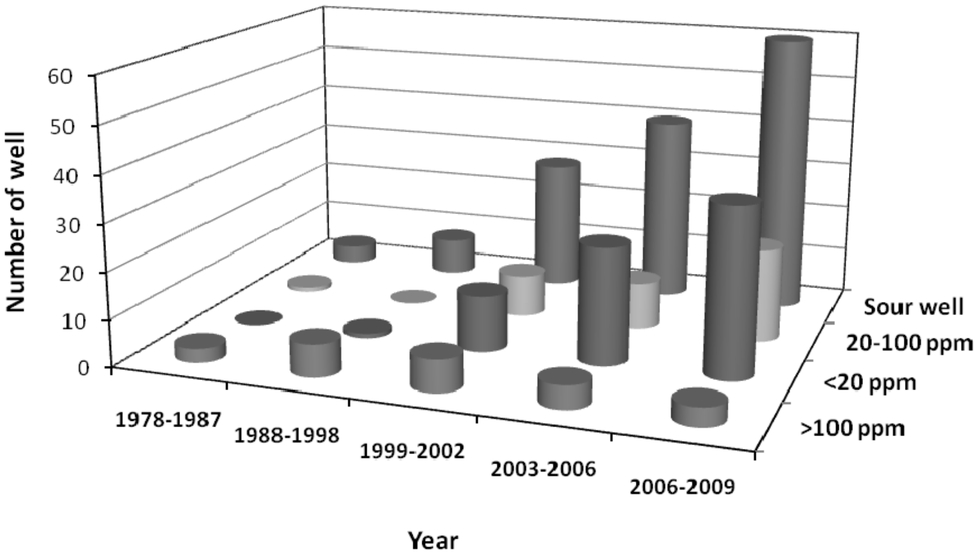

Figure 3. Classification of sour wells based on H_2S concentration during time

4-2. Challenging on source of H_2S pollution in Asmari oil reservoir

Hydrocarbon souring is an undesired phenomenon for any petroleum reservoir. Oil souring of the Asmari oil reservoir is one of the major problems of the Marun oil field. So, it is important to know how it happened. Two possible sources of H_2S pollution in the Asmari oil reservoir are migration from Bangestan reservoir and injection of sour gas into the Asmari oil reservoir which has been performing since 1990. Former study showed the possibility of oil migration from Bangestan reservoir [6] but sour gas injection has not been studied yet.

4-2-1. History of gas injection in Marun oil field

Producing hydrocarbons from the Asmari oil reservoir caused pressure depletion and decrease in productivity. Consequently, the necessity of gas injection was felt in the Asmari oil reservoir to increase pressure and productivity. The main part of the injected gas was sour with a high amount of H_2S, but recently, injection of sour gas has almost been replaced with sweet gas. Sixteen wells were used for gas injection into the Asmari reservoir. Almost all injection wells are located in the crest of the reservoir.

Gas injection has been performed since 1990. Two main sources of injected gas are Aghar/Dalan and Pazanan oil fields gas. Compared to the sour gas of Pazanan, the Aghar/Dalan source is considered to be sweet. Moreover, recently sweet gas of Khami reservoir has also been used for gas injection. Fig. 4 shows the total volumes of gas injected into the Asmari oil reservoir up to 2009. Gas injection can be divided to three periods: (a) from 1990 to 1997, where the total volume of injected gas was sour, (b) from 1997 to 2003, where the main volume of injected gas was sour, and (c) from 2003 to 2009, when almost the whole volume of injected gas was sweet.

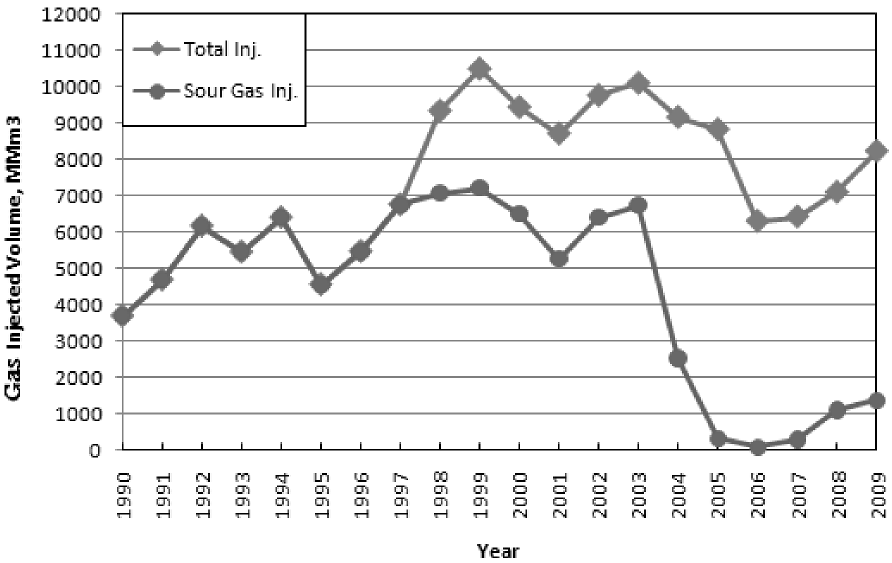

Figure 4. History of gas injection volume in Asmari reservoir

Based on this division, from 1990 to 2003, the volume of injected sour gas was high, but after 2003 a severe decrease in sour gas volume was seen. The influence of this severe decrease should be seen in the H_2S concentration of wells if gas injection affects the source of pollution in Asmari reservoir.

4-2-2. Possible mechanism of H_2S generation in Marun oil field

As previously mentioned, in various situations different mechanisms can cause a petroleum reservoir to be sour. Temperature range of the Asmari oil reservoir is too high for bacterial activity (higher than 80°C). Furthermore, seawater injection has not been performed in the Asmari oil reservoir which eliminates the existence of all bacterial activity for generation of hydrogen sulfide in Asmari reservoir. Moreover, a requirement of very high temperature for thermal decomposition of oil sulfate (usually more than 170°C) eliminates this mechanism in the Asmari oil reservoir which has a temperature of less than 120°C. Also, an absence of anhydrite formation and low temperature range in Asmari reservoir cancel TSR mechanism too. Meanwhile, it must be considered that Asmari reservoir did not initially produce sour oil. However, Bangestan reservoir of the Marun oil field has been producing sour oil. Former study introduced TSR as a mechanism of H_2S generation in Bangestan reservoir because of the existence of anhydrite formation (Gotina) in deeper parts and also the required temperature for TSR. Moreover, it was shown that the source rocks of Asmari and Bangestan reservoirs are the same [9], so H_2S could not come from the source rock. Therefore, all the evidence introduced an external source for hydrogen sulfide pollution in the Asmari oil reservoir of Iranian Marun oil field.

4-3. Where have H_2S of Asmari oil reservoir come from?

Former study suggested an interconnection between sour oil of Bangestan reservoir and Asmari oil, but there is some evidence which demonstrated the possibility of other sources for pollution of the Asmari oil reservoir with H_2S gas. Sour gas injection since 1990 has been one of the main possible sources of H_2S pollution and its spread to the Asmari reservoir. To show the effect of sour gas injection in H_2S pollution spreading within the Asmari reservoir, a history of H_2S concentration of wells can be useful. Here, two hypotheses for sources of the Asmari oil reservoir pollution with H_2S gas are discussed.

4-3-1. Migration of sour oil from Bangestan reservoir

The Bangestan reservoir has been producing sour hydrocarbons since 1972. This reservoir is located at a higher depth than Asmari oil reservoir and shaly formations of Pabdeh and Gurpi exist between these two reservoirs (see Fig. 1). The distance between these reservoirs is 400-500 meters, which is too long for oil migration, but it is perhaps possible. The hypothesis of pollution from Bangestan reservoir was suggested due to the fracturing and differential pressure between the two reservoirs that caused oil to migrate. This hypothesis indicates that, due to production from the Asmari oil reservoir, pressure depletion and also the existence of fracture sour oil may migrate from Bangestan reservoir but the former study showed less fracture distribution and connections of lower layers in the Asmari oil reservoir [9]. Moreover, reservoir pressure of the Asmari oil reservoir has been constant since 1986. Fig. 5 represents the Asmari oil reservoir pressure and production rate. Based on this Figure, differential pressure has not had any changes since 1986 (Bangestan reservoir oil pressure was constant during this time) which decreases the possibility of oil migration. Also, if migration happened, the migration rate would be constant and H_2S concentration of wells might be constant or increase. But conversely, an obvious decreasing trend in H_2S concentration of wells has been observed since 2005 which reduces the possibility of this theory. Meanwhile, it should be mentioned that before sour gas injection in 1990, four wells in sector 6 were reported to have a high amount of H_2S gas (wells No.1 in 1980, No.2 in 1982, No.4 in 1983 and No.3 in 1985). Furthermore, compared to Bangestan reservoir oil, these wells had no H_2S in oil phase before 1990 (see Table 1) which indicates strong misgiving about the hypothesis of oil mixing. The pollution of well No.1 was obviously due to the casing leakage and pollution from the lower sour reservoir. The other three wells produced from the same layer as well No.1 (Layer 4), which increases the possibility of pollution from this well because H_2S concentration decreases by increasing the distance between other three wells and well No.1. In spite of these four wells, no well souring had been reported till 1990 when the sour gas injection began. Fig. 6 shows the average H_2S concentration of the four wells, which were polluted before 1990. Except for well No.1 which was obviously polluted due to casing leakage and after repairing became sweet, other wells may be polluted just by well

No.1. In addition, before 1990, just two wells, (No.5 and No.6) were drilled between well No.1 and the other three polluted wells. Well No.6 was polluted after 2005 and well No.5 has not yet been polluted. This fact may be due to different producing layers and the drilling depths of these wells since the wells No.6 (produced from sub-layer 3) and No.5 (produced from sub-layer 3 to layer 4) are located at a deeper depth than the other four polluted wells. Now a question comes to mind; why, if the pollution has come from lower horizons, have these two deep wells not been polluted. These results are shown in Table 1. It should be mentioned that well No.3 is closer to well No.1 than well No.2 and No.4, which are very close together. Furthermore, there is a good relation between H_2S concentrations of these wells and their distances from well No.1. H_2S concentration of wells versus their distances from well No.1 is shown in Fig. 7.

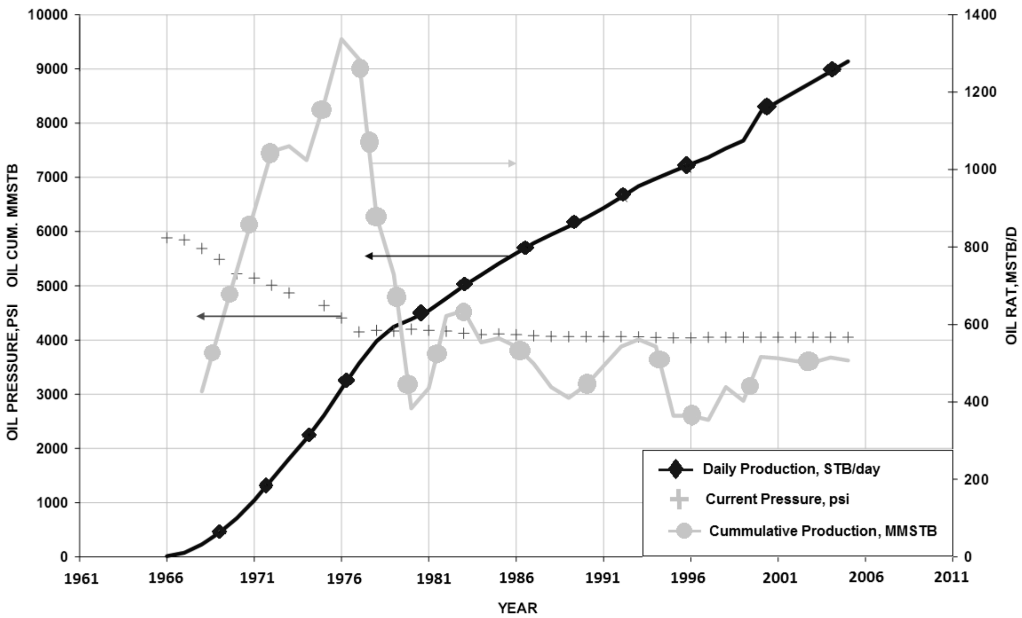

Figure 5. Pressure and production history of Asmari oil reservoir in Marun oil field

Table 1. Data of six wells in sector 6 before sour gas injection since 1990

Well No.	Average H_2S concentration before 1990 (ppm)		Produced layer	Production year	Drilled Depth (m)
	Oil	Gas			
#1	0	235	L-4 & L-5	1973	2562
#2	0	49	L-3 to L-4	1968	2519
#3	0	88	L-1 to L-4	1970	2950
#4	0	43	L-4	1977	2981
#5	0	0	L-3 to L-4	1988	3257
#6	0	0	SL-3	1977	3108

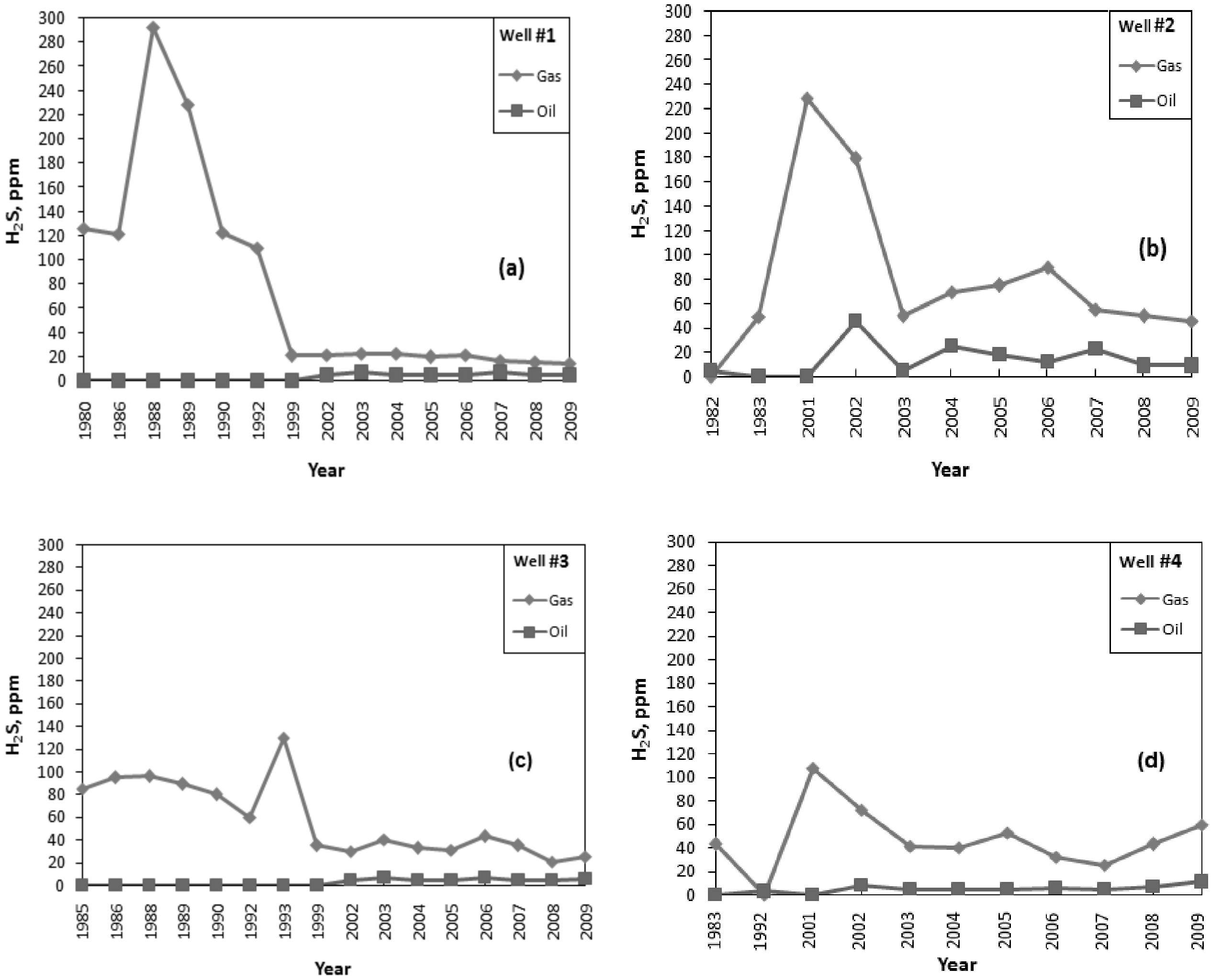

Figure 6. Parts (a), (b), (c) and (d) represent H_2S concentration of four wells which were reported to have high amount of H_2S before sour gas injection

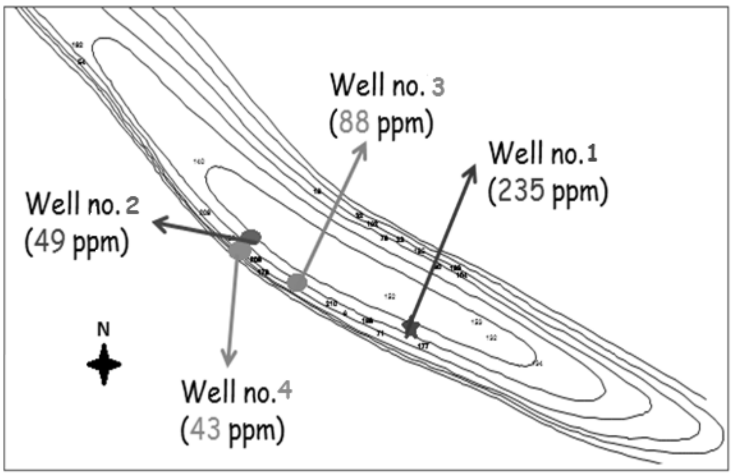

Figure 7. The H_2S concentration of wells versus their distances from well No.1 before sour gas injection

4-3-2. Effect of sour gas injection in pollution of Asmari oil reservoir

Most of the wells were polluted when sour gas injection began in 1990. The trend of H_2S concentrations in these wells is the same as the volume of injected sour gas. After 2005, H_2S concentrations of all wells decreased and some wells are producing sweet hydrocarbons now (e.g. well No.7, see Fig. 10). It should be mentioned that after 2003 almost all volumes of injected sour gas have been replaced with sweet gas.

Fig. 8 shows a decreasing trend in H_2S concentration of several wells which produce from three upper layers. As seen, this decreasing trend is the same as the volume of sour injected gas. This fact represents the strong effect of sour gas injection in the pollution of wells with hydrogen sulfide. In addition, RFT results of polluted wells showed that this contamination could not come from lower horizons. For instance, Figs. 9 and 10 demonstrate the H_2S concentration of two wells with their RFT results. All Figures demonstrate very poor connectivity of fluid in lower horizons which decrease the possibility of pollution from Bangestan reservoir, on the contrary, a good connectivity of reservoir fluid was seen in the upper layers, which shows if the Asmari oil reservoir had been polluted from the upper zone, the pollution would have extended easily. Then the spreading of pollution in the Asmari oil reservoir could be explained by sour gas cap extension. For example, in Fig. 9, well No.6 was producing from sub-layer 3 from 1976 till 1986 but no H_2S was seen during that period, which eliminates the pollution from lower horizons. But now, this well produces from Layers 1 and 2 and also was polluted after 2005. This pollution may be due to the gas cap extension. Also, as it is seen in Fig. 10, well No.7 has been producing sour oil from layer 4 due to the good connectivity of layer 1 to the upper part of layer 4 and existence of sour gas cap in the three upper layers. Moreover, lower horizons have poor connectivity, which eliminates the possibility of souring from lower horizons. In addition, a H_2S decreasing trend was seen the same as the volume of injected sour gas. Finally, the same observed decreasing trend in H_2S concentration and volume of injected sour gas and other results demonstrate the effect of sour gas injection in H_2S pollution and its spreading in the Asmari oil reservoir in addition to probable casing leakage of deep wells.

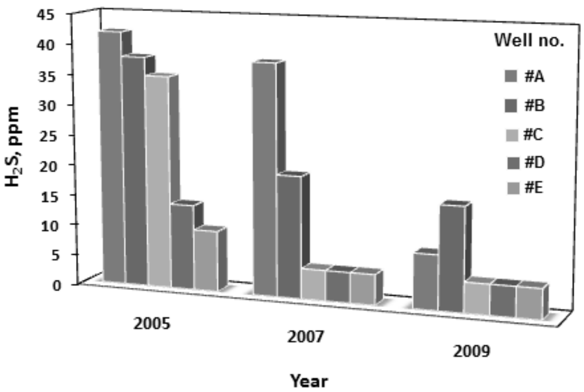

Figure 8. Decreasing trend in H_2S concentration of some wells which are producing from three upper layers. This trend is in agreement with sour gas injection trend

5. Conclusions

The purpose of this paper was to study the history of the Asmari oil reservoir pollution with H_2S gas in Iranian Marun oil field. Investigating the history of gas injection volume showed a decreasing trend in volume

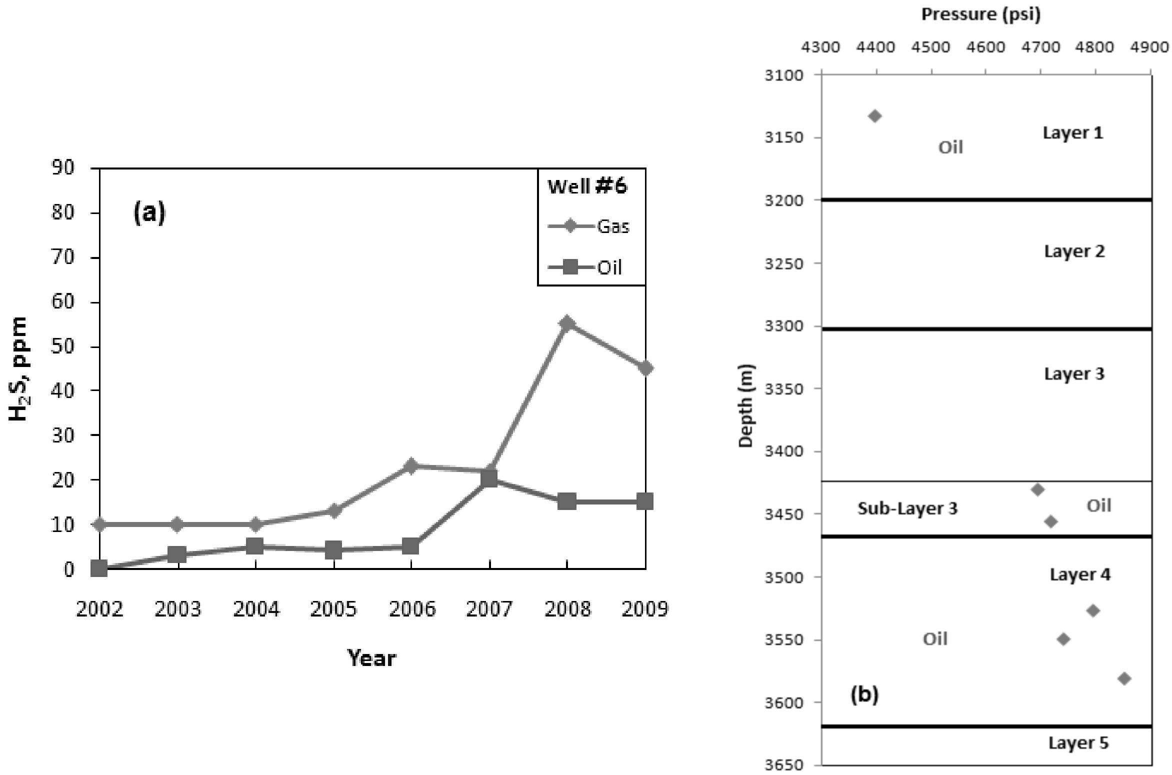

Figure 9. H2S concentration (a) and RFT results (b) of well No.6 in sector 6.

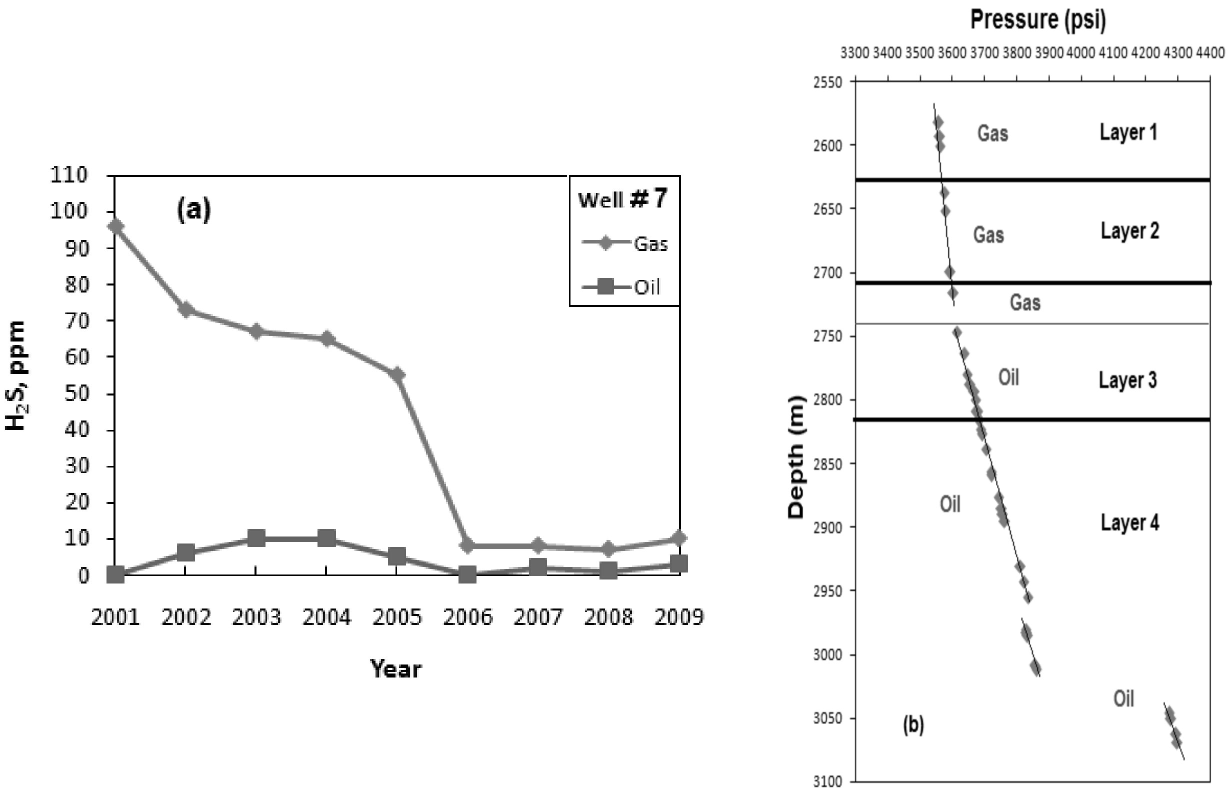

Figure 10. H_2S concentration (a) and RFT results (b) of well No.7 in sector 4

of sour injected gas. This fact was compatible with H_2S concentration of polluted wells, which confirmed the influence of sour gas injection in pollution of wells with H_2S gas. Based on the study of polluted wells, most sour wells were located in central parts of the Asmari oil reservoir, especially sector 6. Moreover, western parts of this reservoir were not polluted with hydrogen sulfide. This might be due to the fact that western parts are located deeper than other parts and sour gas cap has not affected these parts yet. Finally, the trend of sour gas injection volume, the H_2S concentration of wells, and also RFT results of some polluted wells, showed difficulty of pollution from lower horizons in contrast to upper parts of the Asmari reservoir. All these results suggested sour gas injection as a source of H_2S pollution spreading within the Asmari oil reservoir and ignored the hypothesis of oil pollution from the lower sour horizon.

Acknowledgment

The authors would like to thank the National Iranian Southern Oil Company (NISOC) for data preparation. In addition, we appreciate the Petroleum University of Technology (PUT) for supporting this study.

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