Operating problems in secondary oil injection plants. Its impact on microbiological corrosion processes.

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Abstract

The first mention of corrosion involving microorganisms was made in the early twentieth century, however, only in the 80's it was worldwide recognized that the microbiologically induced corrosion (MIC) creates serious problems in the oil industry associated, mainly to the presence of sulfate-reducing bacteria (SRB). The presence of operational problems for poor performance of operators in charge in these facilities, may favor the development of MIC, which leads among other things, the replacement pipe failure, pressure loss in pipes, etc. In this paper we present several case studies of MIC found in three plants of extraction and secondary oil injection, due to operational problems. The plants are located in the provinces of Neuquén and Mendoza, Argentina. These sites have serious problems caused by high concentrations ranging from 10^4-10^8/mL SRB high H_2S concentrations of biological origin, plugging of wells (greater than 40% per year), high injection pressure and corrosion on valves, poor effectiveness of treatment biocides, etc. It presents a comprehensive analysis and interpretation of the problem of corrosion present in the deposits using information obtained from microbiological and physicochemical fields in order to propose strategies for diagnosis, evaluation of solutions in laboratory and field.

Key words: MIC, biofilms, microorganisms, oil plants, sulfate reducing bacteria.

Introduction

The first descriptions of corrosion by microorganisms were provided at the beginning of the twentieth century; however, only in the eighties it was worldwide recognized that the Microbiologically Induced Corrosion (MIC) causes serious problems in the oil industry (1), what means a 50 to 90% of the localized corrosion (2).

In many oil industries the production is obtained by water injection during secondary oil recovery processes. MIC is controlled mainly by studying the presence of sulfate reducing bacteria (SRB) (3, 4). Damages in these systems are mainly due to the H_2S reaction with the carbon steel, the most important component of these distribution systems, iron sulphide products are formed (FeS), which reduce the flow area of the lines and block the injector wells causing a production decrease (3-5).

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The H_2S content in these secondary recovery systems can be the result of abiotic reactions since the crude accompanies the formation water and/or bacterial activities (4-6), involving mainly the SRB as they are H_2S producers in their respiratory metabolism (1, 7, 8)]. Nevertheless, Magot (9) and Crolet (10) reported strains that are not of SRB H_2S producers, involved in the corrosion products from the water pipes of crude production in Africa, highlighting the capacity of these bacteria to produce significant amounts of H_2S and organic acids from thiosulphate and peptides, which can be the only source of carbon and energy of some bacterial species. These processes can be more corrosive than the sulphate reduction by the SRB because of the acidification gradient generated (10, 11).
Problems arising within these systems can be often avoided as in many cases there is biofouling and corrosion problems are due to a monitoring and a study of the system not careful enough along the time by the operators of the plant. Frequently, when the problem arises, the fact of applying the wrong measures to solve biofouling and biocorrosion comes on top of the lack of training of the plant operators.
The aim of this paper is to present several case studies of MIC found in three plants of extraction and secondary oil recovery by water injection, due to operating problems as well as to suggest able solutions for this question. These plants are located in the provinces of Neuquén (systems 1 and 2) and in Mendoza (system 3), Argentina, which will be described below.

System 1

The 93 to the 95% of the production is water. Wells of this system are mature; it means that their oil production average 7%, the rest is water. They presented sulphate reducing bacteria (SRB) with a concentration up to 100 times higher than the maximum value of 10^4, generating then H_2S.
The most important problem was connected with the use of a non oxidizing biocide (acrolein) because as soon as it was not injected in the plant, a blockage in the wells took place.
Hypochlorite and glutaraldehyde and later acrolein were used. It was started with two patching per week of 1100 ppm of acrolein, each of them during one hour. The basin where the water of the treatment plant passed through was modified and from that moment when passing through the basin the acrolein concentration decreases at the exit as it get mixed up with the whole water of the basin. Then, the biocide concentration was modified to one patching per week of 2200 ppm during four hours.
At the end of 2004 a dispersant plus biocide was used. The disincrustant caused the blockage of the wells and the consequent pipe bursting. Pressure increased so much that serious damages occurred in the system. Face to this situation the use of these chemical products was suspended and acrolein was used again. Probably an excessive dilution of the acrolein was used and this could have decreased its effectiveness. It is a system physically difficult to gain access to place a side stream with coupons. Some 15m^3/hr of fresh water from the Colorado river enter to the water treatment system into the washing tank. This could be a source of nutrients for the SRB.

Solutions

It is necessary to replace acrolein by a safer biocide. A previous dose of disincrustant must be used before starting with other biocide. Once the suitable biocide is determined and after starting to apply it, a long-term monitoring program must be carried out. The aim of the

treatment with biocides is to reduce as much as possible the H_2S in the wells. A decrease of the SRB counting must be reached. It is important that the test do not end abruptly, since once the results expected are obtained, the dose must fall up to a maintenance level.
Studies about the microbial charge of the Colorado River at the different seasons of the year were performed, incorporating a sampling protocol.
Bioremediation is applied to lower processes (for example, petroleum spills on soils or water). Here the system is very fast and there would not be enough time to do bioremediation. With wastes, it could be possible to carry out bioremediation of the petroleum by-products by activating nitrate reducing bacteria (NRB) and SRB in aerobic and anaerobic way.

System 2

There is a great environmental problem since there is no place to throw wastes removed from water. In the water treatment plant wastes are reinjected so the contamination reenters into the system generating a feedback system. Very high countings of SRB (10^{15} mo/ml) were obtained. In a liquid medium the maximum concentration expected is of 10^{10} mo/ml. (Figure 1). These high values observed in different systems are frequently due to staff dismissals caused by socioeconomic problems or to operators working without the suitable training.
When the Northern Plant is working and water is sent there to be processed, the concentration of microorganisms decreases but when it is not, the concentration increases.
Tetrakishydroxymethyl phosphonium sulphate (THPS) was applied.
There are high H_2S concentrations of genetic and microbiological origin. The treatment of water to be reinjected is not very effective. There are too much solids.

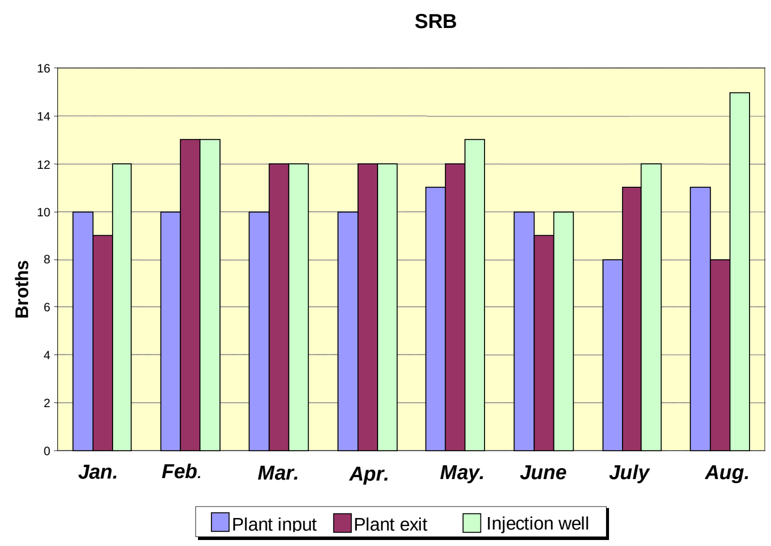

Figure 1- SRB countings

The well was closed. Sulphydric is generated by SRB. The system has a lot of genetic H_2S as water is not injected, only gas. There always was sulphydric in the wells.

There are three water treatment plants:

- Plant of water collection: it treats the river water.
- Center Plant: it treats the saltwater for injection

- Northern Plant: it treats the washing water (it does not work)

At the Center Plant quaternary salts and glutaraldehyde (GA) were injected together with alcohol. The GA is added at the both patchings per week, 200 ml/min during 4 hours. THSP was also used, 150 ppm-160 ppm, at two patchings per week.

Solutions

One of the solutions would be to carry out a pilot testing in the wells, a producer one and an injector one, in order to evaluate the biocompetence. The growth of nitrate reducing bacteria will be helped to stop the growth of the SRB and to reduce the sulphydric. Countings and microbiological studies must be performed. The concentration of H_2S diluted in water and gas, ions such as: nitrate, sulphate, phosphate, volatile fat acids, injection water salinity, etc., must be determined.
Another solution would be to run the Northern Plant and implement the waste recycling that provides a microbial charge to the system. This could decrease the SRB and H_2S concentrations. Lines cleaning and well interventions are also recommended.

System 3

The big problem is the blockage of the wells by solids (>40% per year), that started with the Secundary Recovery in 1967. The well blockage causes a significant injection pressure increase. It started with 160-180 kg and they are now of 210 kg.
The sulphide content at the entrance of the injector wells is very high. Lagged pipes are employed, where is paradoxally supposed not to have corrosion nor biofilms formation. The water treatment plant works discontinuously as there is a generalized problem of corrosion in the valves, (Figure 2).

Figure 2-Valves show corrosion problems

The oil field extension is of 100 x 30 km. It is a mature field. The 93% is water. There are different formations within the oil field and oil is extracted from different layers. The water possesses solids that pass through filters as they retain particles greater than 5 µ. When an

"Acid stimulation" of the well is carrying out the injection increases (the pressure decreases) but after a short time the pressure increases again.
During a period when fouling inhibitor was not used, lagged piping started to be used. But later a film of about 1.5-2 mm thickness was observed, slimy and lumpy, what indicated biofouling and biofilms.
The processes of the plant are not automatics. It is an operator who regulates the pumps and he did other operations manually, so the smallest lapse of concentrations is enough to cause problems.
Other problem connected to the discontinuous working is that data obtained can be no reliable if they have been taken before the stop of the plant, since after the stop, the conditions are not the same and neither does the water quality. There are high concentrations of sulphides. Sulphides would be deposited on the pipes. Biocides used were glutaraldehyde, acrolein and others.

Solutions

The replacement of the valves could allow the continuous working of the plant. There is not a microbiological study of the system, so it is necessary to analyze which of the bacteria are mesophilic, thermophilic, barophilic, SRB ones, etc. Besides, to do a mapping of sulphides, to discriminate how much is originated in the reservoir and how much in the piping system and in the water treatment plant. It is also recommended to do a sulphydric mapping. There is not sampling of sessiles, but countings must be performed.

Global solution proposal for problems of the systems 1, 2 and 3

It is expected to give a solution for the biofouling, biofilms and biocorrosion problems through the following global proposal: service of microbiological management of the systems and a set of consultancies and specific services. The general proposal is to collect, organize and display all the information related with microorganisms, as a tool for monitoring, controlling and preventing the bacteria presence in the oil systems.
The aim of the service**:** It will be to train the operators and responsible staff of the plants in order to decrease at the maximum mistakes when making decisions when unsuitable effects caused by the presence of microorganisms in the systems come out. It will be also possible to have a service and a methodological microbiological managemet of the systems.
Theoretical and practical courses on biofouling, biofilms and biocorrosion issues will be provided to the operators to acknowledge and train them on taking, preserving and transporting the samples.
A handbook of procedures for the operators will be creating on the management of the microbiological works to do in the field and at the laboratory.
Collecting qualitative-quantitative data of the reservoir, production installations and water injection will be carried out, as well as gathering and/or measuring of variables and parameters of interest necessary to characterize the system.
A daily monitoring of the microbiological state of the system (planktonic and sessile bacteria producing biofilms); identification and characterization for the microorganisms present potentially dangerous; use of kits for detecting and molecular techniques application are also expected.
As well, observing through Scanning Electron Microscopy (SEM) biofilms adhered to the metallic substrates (coupons) and XRD (X-ray diffraction energy). Monitoring through

sampling devices with coupons of the metal constituent of the system to study corrosion, biocorrosion and sessile bacteria (biofilms forming).
Among other possibilities, it is proposed here to solve the problem by the use of the suitable biocides in their suitable proportion according to studies performed by authorized staff.

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