

Evaluation of a Rapid Solution for SRB Monitoring in Industrial Water System

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ABSTRACT

Sulfate-reducing bacteria (SRB) have been found to be the most troublesome group of microorganisms involved in microbial induced corrosion (MIC) of carbon steel and other metals used in the oil and gas industry. Uncontrolled growth of microorganisms in the oil field production systems has a major negative impact on the productivity and asset integrity. For monitoring microbial SRB populations, the conventional NACE-TM0194 method; based on the most probable number theory (MPN) and serial dilution technique, is still followed where it can take up to 28 days to be completed. Thus, there is an interest in having a rapid and inexpensive method to assess the presence of SRB in different environments for the control of MIC and also for taking mitigation measures like the biocide injection. In this study, a commercial rapid sulfate reducing bacteria monitoring solution was applied as a novel strategy on water samples produced by Ghawar Field under Southern Area Oil Operations (SAOO) in Saudi Arabia, where we have compared this modern technique with the conventional MPN method. The comparative analysis showed that rapid SRB detection pouch technology can be implemented in quantifying SRB bacteria in all clean water systems including sea water, ground water, fire tank water, and cooling water where H₂S is not present. The technology is showing a good correlation with the traditional MPN method with major advantages, such as reducing the time-to-result to three days, achieving cost saving, excellent tool to examine the effectiveness of biocide, the pouch formulation will work on all salinity (Total Dissolved Solids) levels, no interference from common oil field chemicals except H₂S, easy to handle and easy to train.

Key Words: Sulfate-reducing bacteria, SRB, microbiologically-influenced corrosion, MIC, bacterial growth detection and monitoring, serial dilution technique.

INTRODUCTION

Uncontrolled growth of microorganisms in the oil field production systems have a major negative impact on the productivity and asset integrity in oil and gas industry. Sulphate-reducing bacteria (SRB) have been found as the most troublesome group of microorganisms among all organisms involved in MIC of carbon steel and other metals used in the oil industry (Abdullah et al 2014). The formation of SRB biofilm on steel surface can affect the kinetics of anodic and cathodic reactions, leading to an acceleration of steel corrosion (Beech and Sunner, 2004; Zuo, 2007). In addition to that, SRB contributes to hydrogen sulfide-driven reservoir souring, increased suspended solids, reservoir plugging, etc., in oil field sites.

To effectively manage microbial induced corrosion, rapid and sensitive approaches for SRB detection are essential. Commonly, SRB in the oil field industry are detected and quantified by using NACE TM0194-2014 methodology; a culture dependent most probable number technique (MPN), which requires 28 days to obtain results. A variety of protocols and methods have been evaluated by Southern Area Laboratories Division (SALD) for the monitoring of SRB population, including the enzyme-linked immunosorbent assay, a rapid ATP bioluminescence-based test method, and fluorescence in situ hybridization (FISH). Although promising, these techniques are still in the development stage, and also several drawbacks were observed while they were used on the site in real time applications. Likewise, qPCR is a highly selective method of detecting SRB bacteria; however, it requires designing of primers, sophisticated equipment and specialized work force.

In this study, a rapid (a maximum of three days to obtain the result) and simple enumeration method represented by rapid SRB detection pouch was tested as a quantification method for SRB and applied on water samples produced by Saudi Aramco Southern Area Oil Operations (SAOO). The method was simultaneously compared with existing MPN technique both in the field and in-lab to evaluate its accuracy, interference, and detection thresholds.

EXPERIMENTAL PROCEDURES

Sample Description

It is well known fact that the actual damage observed in MIC is due to sessile bacteria in biofilm deposits. Although MIC is a biofilm phenomenon, it is often not possible to obtain representative biofilm samples from every location. Thus, planktonic samples are often used to make operational decisions.

For both methods (rapid SRB detection pouch and MPN technique), sampling and analysis were conducted simultaneously inside the lab and on-site. To capture seasonal changes in microbial community and its effect on the 3M pouches, sampling was conducted in all seasons from November, 2019, to January, 2021. In Category-1, we tested sour water samples (samples which contain approximately 25-200 ppm of H₂S) from different GOSPs (Gas Oil Separation Plants). In Category-2, samples from clean water sources (i.e.,

free of H₂S) such as sea water samples, which include suction headers, injection wells, cooling water, and ground water samples were tested. Category-3 included samples from sea water injection wells before and after the biocide slug dose.

For transportation to the laboratory, samples for in-lab analysis were preserved in amber-colored glass bottles. The bottles were filled completely, capped tightly to eliminate oxygen ingress, and incubated at different temperatures based on the original temperatures at which the samples were collected.

Eventually, a correlation test was performed to find the correlation coefficient between two data groups obtained by MPN technique and rapid SRB detection pouch method that the degree is a number between -1 and +1. A positive degree shows that the two data groups have positive relationship and a negative degree shows that the two groups have negative relationship.

MATERIALS AND METHODS

SRB Colonies Determination Using Classical MPN Method

MPN (Most Probable Number) was followed based on NACE TM0194-2014 methodology, which involves making replicate and consecutive dilutions of a sample in an appropriate liquid growth medium (ready-made bottles of anerobic modified Postgate B medium) and incubating it for growth of microorganisms. Interpretation assumes that if one replicate vial of media receives a dilution of the sample that contains a bacterial cell, the vial will in result turn turbid/black.

The inoculation was performed on-site and in-lab for resemblance single dilutions series of eight vials (1x8) and triplicate sets (3x8), where one mL of the sample was injected into the 9 ml ready-made vial followed by serial dilutions (a 10-fold dilution series where using successive 1:10 dilutions in each successive vial)). Positive SRB vials were then identified after 28 days of incubation at different temperatures by the formation of black iron sulfide deposition, as indicator of sulfidogenic activity. Interpretation of the results was determined using MPN table (NACE TM194-2014) for the single dilution and Bacteriological Analytical Manual (BAM) Appendix 2: Most Probable Number for the triplicate dilution.

It must be clear to the reader that the information obtained by the discussed MPN technique, which is based on dilution series might be affected by the bacteria's behavior. MPN assumes an even dispersal of the bacteria in the water sample and that bacteria are separate and do not affect each other; in other words, it assumes there is no attract or repel effect. In addition to that, MPN values for a variety of positive and negative vial combinations are not based on theoretical reasons. Serial dilution testing is an inherently inaccurate process to estimate bacterial count in large-volume oil field systems and it's a subject for statistical analysis, where the accuracy of the method increases dramatically when increasing the number

of replicate samples (NACE Standard TM0194-2004). The ideal procedure for estimating bacterial number is to use a triplicate dilution series then incorporate a statistically valid MPN technique to estimate the number.

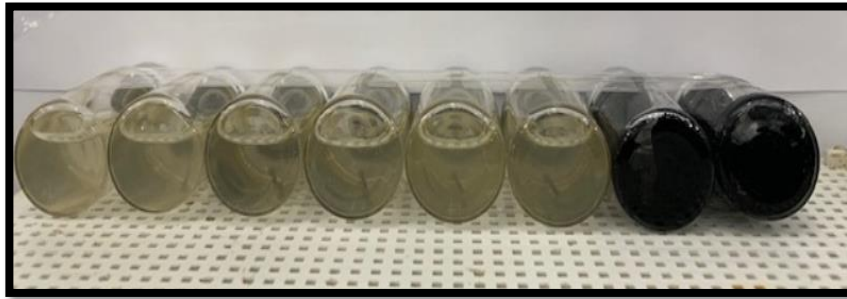


Image-1: Vials after incubation for 28 days for MPN screening and estimation. Occurrence probabilities for single dilution (1x8) setup.

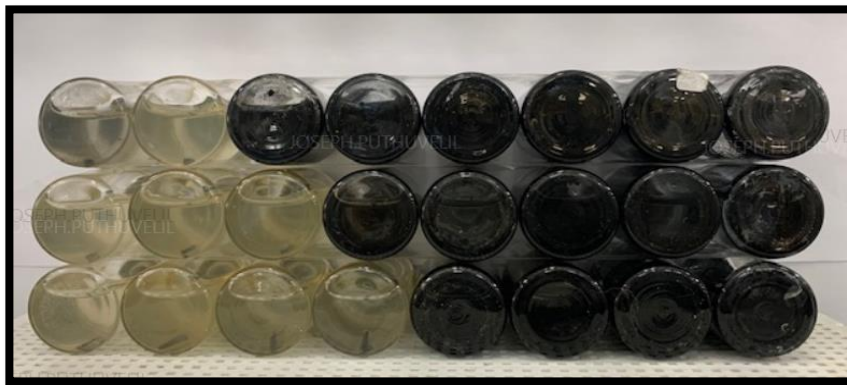


Image-2: Vials after incubation for 28 days for MPN screening and estimation. Occurrence probabilities for triplicate dilution (3 x8) setup.

SRB Colonies Determination Using Rapid Sulfate Reducing Bacteria Detection Pouch

The 3M-rapid SRB detection pouch technology is a special formulated growth medium, combined with oxygen scrubbing and reduction potential modifying chemistry. It's a standalone culturing method designed to make SRB growth estimation easier and faster, where it can provide results in significantly less time than the conventional serial dilution method. With the rapid SRB detection pouch, quantitative results can be obtained in five days only.

As per the vendor recommendation, no sample preparation is required and the sample can be added directly to the pouch without any dilution except for the sample, which contains high H_2S (>25 ppm). Incubation was done based on NACE TM0194-2014.