

Development of an Efficient Microbiologically Influenced Corrosion (MIC) Mitigation and Control Strategy in Pipeline Pigging Operations

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ABSTRACT

Eleven fluid samples, taken in two groups from pipeline pigging operations in the Texas Gulf Coast region were used in this study. All of the samples contained high amounts of Iron Sulfide (FeS), Sulfate Reducing Bacteria (SRB), and Acid Producing Bacteria (APB) and were producing varying amounts of hydrogen sulfide (H₂S). These pipelines had historically been treated with increasing amounts of glutaraldehyde and glut/quat blends, to no avail. Increasing problems associated with microbiological activity (biofilm, corrosion, FeS, H₂S) required a revised treatment regime.

The first part of this study was undertaken in order to determine a successful biocidal treatment program that would address both the planktonic and, if necessary, the sessile bacterial populations in the pipelines. Due to the perceived induced resistance to glutaraldehyde and the dirty water conditions in the pipelines, alternative dosing regimens and additional biocides were considered including tetrakis (hydroxymethyl) phosphonium sulfate (THPS), tributyl tetradecyl phosphonium chloride (TTPC), aldehydes, and cocodiamines.

The second part of the study sought to determine how to link these findings to the general and localized corrosion caused by biological activity. A corrosion inhibitor package was developed that was compatible with the customer's formulations and the recommended biocidal treatment program.

Finally, the third part of this study combined these treatments and evaluated their biocidal and corrosion inhibition efficacies on carbon steel coupons in the presence of fluids and solids.

A biocidal treatment and corrosion inhibition program are inherently intertwined and a successful treatment program must combine elements of both fields of study.

Key words: Corrosion inhibitor, biocide, ATP, glutaraldehyde, general corrosion, localized corrosion.

INTRODUCTION

An operating company was concerned that its biocide and corrosion mitigation strategy was not sufficient to control corrosion in their pigging operations across the Gulf Coast of Texas. They provided water samples from several pigging access points that were heavily contaminated with SRBs, APBs, black deposits and oil. H₂S was present in most of the samples suggesting a heavy presence of SRBs. They suspected that the black deposits were most likely FeS caused by the presence of microorganisms interacting with their pipelines. Indeed, culture vial tests (sometimes referred to as “bug bottles”) proved that the samples were heavily contaminated with microorganisms.

They claimed to have been using glutaraldehyde as a biocide for years but had noticed that it was losing its efficacy as more and more glutaraldehyde had to be dosed for them to achieve the same microbial control. In recent years, an increasing number of reports of glutaraldehyde-resistant microorganisms have surfaced and operators have been moving to glutaraldehyde blends containing other biocides other biocides entirely.¹⁻³ In addition to the increased resistance, glutaraldehyde as a biocide has been shown to induce localized corrosion pitting.⁴ For these reasons, the customer wanted to explore other microbiocidal mitigation programs and offered to supply fluid samples from their pigging operations.

A three part laboratory study was carried out. The first part would be to perform a biocide efficacy study on customer supplied fluid samples. The second part would be to perform a corrosion study to determine how the fluid samples contributed to localized corrosion. Finally, a treatment corrosion efficiency study would be performed that would include a combination of biocide and batch corrosion inhibitors.

It is well known that SRB, APB, and Nitrate Reducing Bacteria (NRB) can be corrosive to carbon steel in the oil and gas industry.⁶⁻⁸ The widely accepted mechanism of Microbiologically Influenced Corrosion (MIC) is that microorganisms attached to the metal surface forms biofilm. The biofilm deposited on the surface creating an environment conducive to the formation pitting corrosion. There will be significant value in determining the corrosivity of a fluid relating to the bacterial level in the fluid.

In this paper, we aim to link biocidal efficacy testing with corrosion testing and treatment to provide a successful combination treatment strategy.

EXPERIMENTAL PROCEDURE

Quantitative Suspension Test

3% Modified Postgate’s BM bottles (SRB bottles) and 3% Phenol Red Dextrose (APB bottles) were used according to the manufacturer’s recommended directions. After dosing with biocides, bottles were placed in the incubator at 30 °C and left undisturbed before recording results. APB bottle results were recorded after 7 days and SRB bottles were recorded after 28 days.

ATP Testing

ATP testing was performed according to manufacturer’s directions with one modification: Samples were either treated as is and then filtered through a 5 µm filter prior to ATP analysis or filtered through a 5 µm filter prior to biocide dosing (Figure 1). This step was performed because of the high concentration of particulates and other substances present in the samples that made detection by ATP analysis difficult.

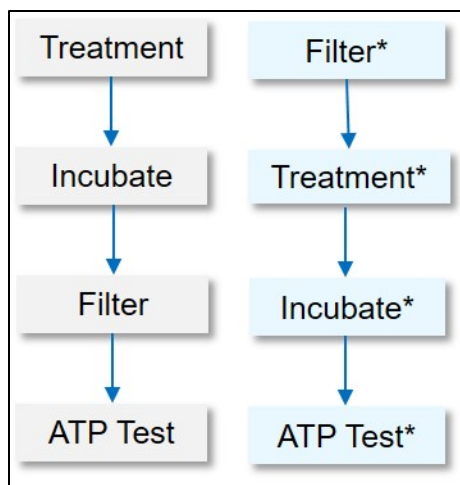


Figure 1. Method used to prepare the samples for testing.

Crystal Violet Biofilm Testing

Water samples taken from oil transmission pipelines in the Texas Gulf Coast region were diluted 1/100 with distilled water and then supplemented with a 1/10 dilution of Tryptic Soy Broth made according to the directions on the label. 100 uL of sample was added to each well on a 96-well Falcon untreated plastic plate. Row “A” was dosed with 200 uL initial sample and treated with biocide. Rows were then diluted 1:1 with the previous row resulting in a 50% dilution of the biocide on each successive row. 100 uL from the last row were discarded so that every row contained a final volume of 100 uL. Plates were then covered and placed in the incubator overnight at 30 °C. The plates were then washed, stained, and examined for biofilm using the method of O’Toole.⁵

Corrosion Study of the Fluid Samples

The fluid samples from Operations were the mixture of crude oil and brine. For the corrosion tests and chemical performance tests, the brine was separated from the mixture and used. The first group of seven samples were labelled as FL-1, FL-2, FL-3, FL-4, FL-5, FL-6, FL-7. The second group of 4 samples were labelled FL-8, FL-2a, FL-3a, FL-9. FL-2a and FL-3a came from the same location as FL-2 and FL-3. The biocides are labelled A-cide, B-cide etc. The corrosion inhibitor was named as CI Batch. Finally, the combination product of batch corrosion inhibitor and biocidal chemical was called CI BPlus.

The testing brine was deoxygenated with nitrogen gas before the tests.

The rectangle corrosion coupons made of 1018 Carbon steel were degreased and weighed before and after the experiments. The testing duration was around 30 days. Mass loss was used to calculate the general corrosion rate. The coupons after the experiment were analyzed for localized corrosion with a surface profilometer, as shown in Figure 2.

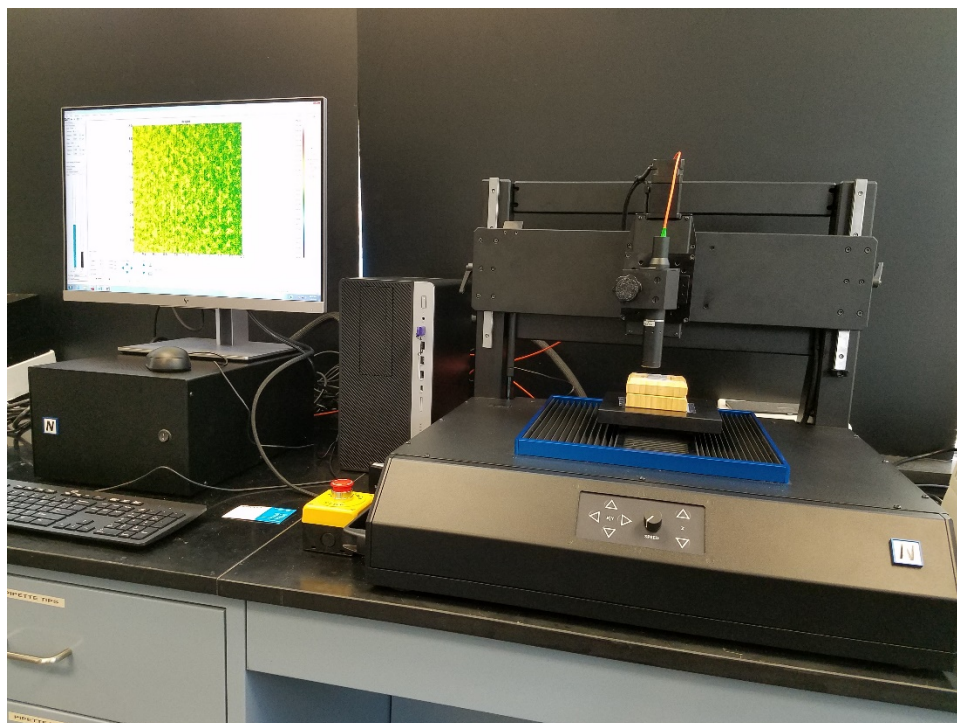


Figure 2. The Surface Profilometer and Analysis Software

Evaluation of Chemical Performance to Control MIC

Five commercialized biocides, one batch corrosion inhibitor and one combination product of batch corrosion inhibitor with biocidal effect were investigated in this project. Based on the feedback from operations regarding the importance of the pipelines, bacterial level, and corrosion data, the chemical performance tests were carried out in field fluids from two samples selected by the operator among those from nine different locations. Two samples were taken from the same location, but at a different time. The performance of the chemicals were determined by both the general corrosion with mass loss and localized corrosion by the above mentioned surface profilometer.

RESULTS AND DISCUSSION

Several different water samples (Table 1) were obtained from the samples previously supplied by the operator. Most of the water samples were heavily contaminated with oil, black solids, various chemicals, and other debris. The use of culture vials in this study was helpful due to the nature of the water supplied by the customer since the samples could be applied 'as is' to the culture vials without extensive solids and oil removal which would also possibly remove microorganisms. As shown in Table 1, all the supplied water samples with the exception of FL-2a strongly tested positive for both SRBs and APBs. When the water sample FL-7 was tested with 100 ppm of biocides (product loading), no significant reduction in microorganism counts, as shown by culture vial testing, was observed.

Fluid Sample	Positive Bottles	
	APB	SRB
FL-1	0	2
FL-2	6	6
FL-3	6	6
FL-4	6	6
FL-5	6	6
FL-6	4	4
FL-7	6	4

Table 1. Results of Untreated Culture Vials

FL-7 was treated with the full spread of biocides (100 ppm product loading) as shown in Figure 3 and none of the biocides provided a significant reduction in the number of positive culture vials at this loading.

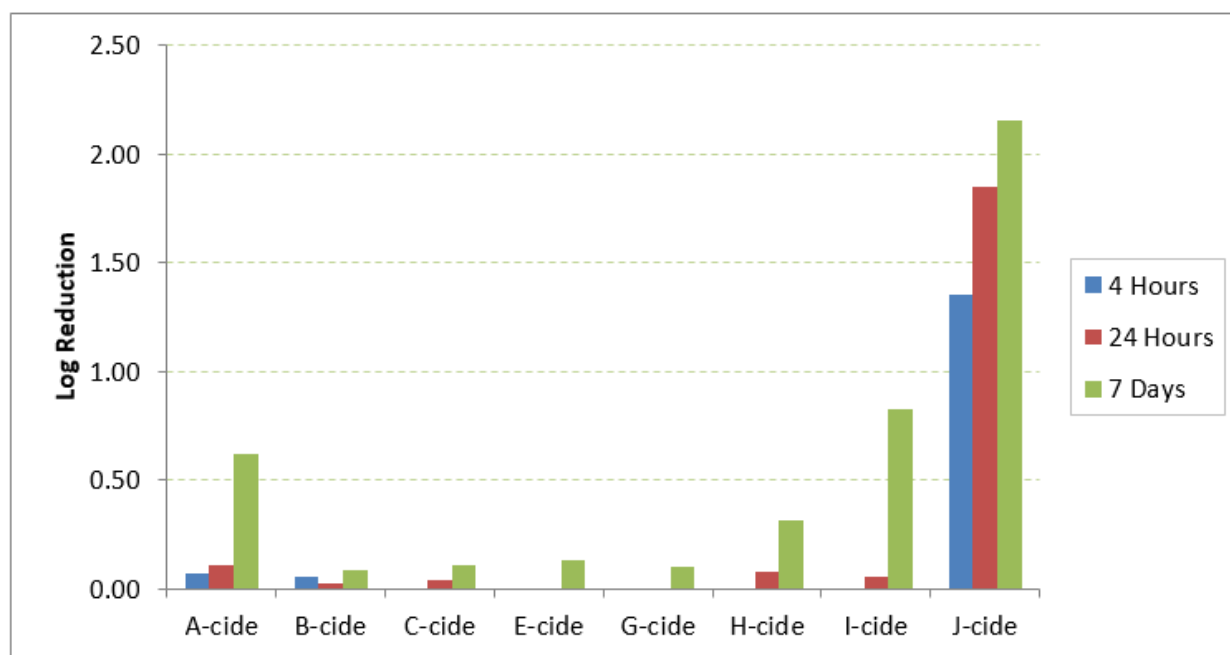


Figure 3. Efficacy of biocidal treatment against FL-3 water sample.

Culture vials were then dosed with biocides representative of what is listed on the EPA Pesticide Label. As shown in Figure 4, biocidal efficacy can vary greatly depending on the identity of the biocide. In this example, the efficacy of the biocide shows no significant difference between dosage concentrations, which will allow us to reduce the biocide concentration and, therefore, reduce cost to the customer. The concentration of active ingredient in the biocidal treatment is not always equivalent across biocide types and this information must be taken into account when designing a microbiological treatment program. Another constraint which must be taken into account when designing an appropriate treatment program is the allowable pesticide applications on the label. Many biocides that might be the optimum fit for a particular application is simply not allowed by the the EPA label. Biocides selected in Figure 4 are those that are allowed by the EPA Pesticide Label for pigging operations.