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Microbial Monitoring and Mitigaiton in Cementing Operations

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Abstract: Microbial contamination and bacteria growth in the cementing makup water impact cementing operation and integrity. To avoid the premature cement setting caused by microbial growth, the water is usually treated with biocides for microbial control before mixing. This treatment will also prevent biodegradation of the added polymers and stabilize the slurry rheological properties. Make-up water and cementing mix samples were collected from active drilling rigs in the field. In 12 hours biocide addition program, the tested biocide at 50, 100, 250, and 500 ppm for cementing operations revealed acceptable control of both GAB and SRB numbers in one Field, but not in another Field. In 24 hours biocide addition program, revealed varying levels for control microbial contamination in cementing operations, with higher efficiency with Field B samples opposed to field A, and with better control at higher concentrations of tested biocide at 250, and 500 ppm. As a recommendation therefore, usage of another biocide with a different chemistry at Field A is encouraged once a new biocide is selected.

Keywords: Cementing operations, microbial contamination, mitigaiton.

1. Introduction

Well cementing is a process of introducing cement to the annular space between well-bore and casing. This process is essential for oil excavation to support vertical or radial loads applied to casing, protect casing from corrosion and to confine abnormal bore pressure [1].

Cementing additives like drilling additives, contain iron and silica-based particles that give cementing mix its durability and viscousity [2, 3], as well as containing high concentration of nutrients for the sustenance of subsurface microorganisms [4]. [As the microorganisms introduced into drilling process, a number of problems are causing that can lead to significant costs for the industry. Numerous studies they have shown that biogenic sulfide production induced corrosion in oil and natural gas fields have led to a number of problems, including reservoir plugging, reservoir souring, reduced product quality, and corrosion of metal-containing equipment [5-11]. One essential mechanism of controlling microbial activities in down-hole processes that would affect rhelogical properties of cementing mix, is through the utilization of biocides for inhibition of key microbial metabolic activities [12, 13].

In recent years, numerous state-of-art technologies have been developed to address some of cementing operation challenges such as: movement of gas from subterranean zone through cement slurry. This causes huge losses of entrapped gases in high pressure zone due to its migration to low pressure zones and the failure of cement mix to seal the annulus [14-16]. Some of those developed technologies, utilize the use of fluid loss or gelling agents avoiding cementing fluids loss, and plugging surrounding channels through which gas migrates respectively [17]. There are two types of cementing technologies, which are primary, and secondary cementing technologies. The purpose of primary cementing technology, is to fix the casing to surrounding environment, and prevent it from corrosion, however, secondary cementing

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technology is used for inhibition of drilling fluid circulation losses, plugging generated pinhole leaks, and sealing unproductive zones through which fluids migrate. [18]

In this study, make-up water and cementing mix samples from reserve tank and mixing tank were collected from two drilling rigs in Saudi Aramco oilfields to determine the microbial contamination and most effective treatment regime of KBE-35A under aerobic conditions (oxygen). The Most Probable Number (MPN) method was used for bacterial enumeration at every 12 hrs. or 24 hrs time-period depending on the used regime. The method would take one week to enumerate the general aerobic bacteria (GAB), and up to four weeks to enumerate the slow growing sulfate-reducing bacteria (SRB) [19].

The paper presents a case study of assessing microbial contamination in the current cementing practice within Saudi Aramco. The study recommended the cementing mix operation and field best practice for microbial control to be implemented in all Saudi Aramco drilling rigs.

2. Sampling and Sample Description

The appropriate drilling rigs were selected based on its drilling depth and temperature at the time of sampling. The make-up water and cementing mix samples were collected on July, 24, 2016, for microbial assessment from Rig X (Well 1) in Field A and Rig Y (Well 2) in Field B. All selected gas well rigs used water based drilling mud. In each drilling rig, two water samples were collected from site- formation (To which cementing additives are added) and cement mixing tank (after addition of cementing additives), designated as formation water and cementing mix, respectively. To preserve sample integrity, all samples were delivered in ice igloos and stored at 4°C before analysis.

At the time of collection, the drilling depth was between 5100 and 10248 ft., and Down-hole Circulating Temperature (BHCT) temperature between 43.3°C, and 93.3°C (Table 1). All cementing mix samples were collected when tank was in stagnation for between 8-18 hours depending on location.

Table 1 Well and cement mix information.

	Field	A	B
Rig/well info	Rig	X	Y
	Well#	1	2
	Cementing target Depth (ft)	5100	10248
	Bottom Hole Circulating Temp (BHCT) (°C)	43.3	93.3
Biocide dosing	Biocide name	KCB-310A	BE3SA
	Biocide concentration (ppm)	1000	50
	Time interval (hrs.)	8	14-18
	Mixing of biocides with chemicals	Mix discarded if not used within 1 day	Used within 12-36 hrs after initial biocide injection.

3. Cementing Operation Conditions

According to drilling engineer, regarding biocide dosing, the process is start by mixing biocide with the field formation water, and cementing chemical additives in surface facility at 370C. After mixing, mixture would await cement engineer decision to decide the time for the cement to be added to the mixture, followed by pumping to downhole. This stagnant time varies with operational conditions from 8 to 18 hours. This stagnant time is diverse from location to other location. Therefore, cement mixture (cement mix fluid) is subjected to microbial contamination.

At Field A, Rig X (Well 1) the biocide dosing regimens uses high concentration of biocide (1000 ppm) with short time intervals of 8 hours of biocide addition. After that, mixture would be used within 1 day after mixing. But, biocide dosing regimens at Field A, Rig Y (Well 2) is different. The biocide concentration is 50 ppm, with very long time intervals of biocide addition from 14 to 18 hours. After that, mixture would be used within 12-36 hours from initial biocide injection.

4. Experimental Design

Lab tests were designed to evaluate microbial contamination in cementing jobs based on the worst operational conditions. Therefore, microbial assessment test for the cement job formation water was conducted using a bottle test system to enable observation of bacterial changes over a 48 hour period (2 days) before and after the addition of biocide KCB-310A under aerobic conditions. The test was conducted in a matrix of different contact times before and after biocide addition.

Two test bottles set-up system were used to evaluate the biocide efficiency in cement job using two different time intervals of biocide addition of 12, and 24 hours at 40°C for 48 hours. Moreover, Most Probable Number techniques were used to enumerate SRB and GAB to determine the microbial contamination before and after biocide addition.

Tables 2 & 3 show experiment designed for cement job biocide addition. Baseline samples were removed from both Field A, and Field B formation water samples (original sample) for microbial analyses to determine microbial population numbers in mixed fluid samples. After that, each cement mixed fluid sample from both fields were divided to four bottles to receive four different biocide concentrations.

Table 2 Cementing job 12hrs intervals/frequency program.

Biocide Concentration	Sampling (1)	Biocide addition (2)	Samples	
			Well#1	**Well#2**
50 ppm	@ 12, 24, 36 and 48 hrs	0 h, 12 h, 24 h and 36 h	Mix fluid	
100 ppm	@ 12, 24, 36 and 48 hrs	0 h, 12 h, 24 h and 36 h	Mix fluid	
250 ppm	@ 12, 24, 36 and 48 hrs	0 h, 12 h, 24 h and 36 h	Mix fluid	
500 ppm	@ 12, 24, 36 and 48 hrs	0 h, 12 h, 24 h and 36 h	Mix fluid	

Table 3 Cementing job 24hrs intervals/frequency program.

Biocide concentration	**Sampling (1)**	**Biocide addition (2)**	**Samples**	
			Well#1	Well#2
50 ppm	@ 24, and 48 hrs	0 h and 24 h	Mix fluid	
100 ppm	@ 24, and 48 hrs	0 h and 24 h	Mix fluid	
250 ppm	@ 24, and 48 hrs	0 h and 24 h	Mix fluid	
500 ppm	@ 24, and 48 hrs	0 h and 24 h	Mix fluid	

KCB-310A biocide was added to both test bottle systems at concentrations of 50, 100, 250, 500 ppm to determine microbial population numbers during long stangnant and shut-down times with biocide addition. In case of 12 hours intervals time (Table 2), biocide was added at zero time and after 12, 24, and 36 hour. However, Table 3 show that biocide was added at zero time and after 24 hours for the other test bottles set-up with 24 hours intervals time program. During this period, samples for microbial analyses were removed from mixed fluid test bottles at zero time, after 12, 24, 36, and 48 hours.

The GAB and SRB media composition were listed in Tables 4 & 5. The pH of the media was adjusted to 8.0, and the media were prepared in 10% of Arabian Gulf seawater, which simulates the salinity and pH of

Table 4 Composition of GAB growth media.

Items	Amount
Bacteriological Peptone	0.5 g
Yeast Extract	0.5 g
Qurayyah Seawater (10%)	Make up to 1 liter

Table 5 Composition of SRB growth media.

Items	Amount
Ammonium Chloride	1.0 g
Calcium Sulfate	1.0 g
Magnesium Sulfate	2.0 g
Sodium Lactate	3.5 ml
Yeast Extract	1.0 g
Ascorbic Acid	0.1 g
Resazurin Solution	4.0 ml
Sodium Thioglycollate	0.1 g
Ferrous Sulfate	0.5 g
Potassium Hydrogen Phosphate	0.5 g
Qurayyah Seawater (10%)	Make up to 1 liter

make-up water, and the pH of drilling mud samples during operational downtime.

5. Results

Table 6 shows microbial result for cement mixed fluid experiment with biocide addition at different concentration with12 hour's intervals time using two different field samples from Field A, and Field B wells.

The result for Field B with biocide at 50 ppm indicated that, GAB number decreased slightly over the first 12 hours (to 104/mL). However, after 24 hours of the biocide addition, GAB number slightly increased to 105/mL. Hence, GAB number again decreased to 103/mL, and 10^2/mL after 36 and 48 hours respectively. In contrast, SRB number was slightly increased to 23/mL after the first 12 hours but remained unchanged (at 23/mL) for the remainder of the 24 hours. After that, SRB was slightly decreased to 1.1/mL after 36 hours, then SRB increased to 43 /mL by the end of the experiment after 48 hours. The result for GAB at biocide concertation of 100, 250, 500 ppm decreased for the 12 hours to 10^6, 10^1, 10^2/mL respectively. After that, GAB number continued to decrease at different intervals to reach 102/mL at the concentration of 100 ppm at 48 hours. GAB number were below the detection limit at the concentration of 250, 500 after 48 hours.

For Field A samples, the GAB results were indicated that the number were remained unchanged at 107/mL for the remainder of the test experiment up to 48 hours; even with the biocide addition at the concentration of 50, 100, 250 ppm. But, with biocide addition at 500 ppm GAB number was slightly decreased to 106/mL after 12 hours. Later, GAB number was decreased to 10^5, 10^4, 10^3/mL after 24, 36, 48 hours respectively. Moreover, SRB results indicated that the number was increased between 10^2 -10^3/mL during the test experiment; after 12, 24, 36, 48 hours, even with the addition of biocide at different concentration 50, 100, 250, 500 ppm.

Table 7 shows microbial result for cement mixed fluid experiment with biocide addition every 24 hours with different concentration using two different field samples from Field B, and Field A well.

Result for Field B with biocide treatment at 50, 100 ppm indicated that, GAB number remained unchanged at 10^7/mL for the rest of the test experiment up to 48 hours. However, with biocide addition at 250, 500 ppm, GAB number was reduced between 10^2/mL to below detection limit (< 0.4/mL) after 24, and 48 hours of biocide addition. Comparable result was detected for SRB growth. Biocide addition at 50 ppm manage to slightly decreased SRB number to below detection limit (< 0.4/mL) after 24, 48 hours. Also, SRB number was slightly decreased to 0.4, and 0.7/mL with biocide addition at 100 ppm after 24, and 48 hours respectively. But, with biocide addition at 250 ppm there was no clear change in the SRB number and remain between 1.5 and 2.1/mL after 24, and 48 hours. Hence, SRB number was slightly increased to 102/mL after 48 hours. For Field A samples, the GAB results were indicated that the number remained unchanged at 10^7/mL for the remainder of the test experiment up to 48 hours, with all added biocide concentration of 50, 100, 250, 500 ppm. Alternatively, SRB number was increased to 103/mL during the test period of 48 hours with no clear effect of the biocide addition at different concentration (50, 100, 250, 500 ppm).

Table 6 Result of experimental set-up for cement mixed fluid with biocide addition every 12 hours.

	12hrs				24hrs				36hrs				48hrs			
	Field B		Field A		Field B		Field A		Field B		Field A		Field B		Field A	
	GAB	SRB	GAB	SRB	GAB	SRB	GAB	SRB	GAB	SRB	GAB	SRB	GAB	SRB	GAB	SRB
Baseline (Mix Fluid)	2.3×10^7	1.5	2.3×10^7	2.1×10^1												
50 ppm	4.3×10^4	2.3×10^1	2.3×10^7	4.3×10^2	9.3×10^5	2.3×10^1	2.3×10^7	9.3×10^2	7.5×10^3	1.1	2.3×10^7	4.3×10^3	4.3×10^2	4.3×10^1	2.3×10^7	2.3×10^3
100 ppm	9.3×10^6	2.1	2.3×10^7	1.5×10^3	1.5×10^2	2.1	2.3×10^7	9.3×10^2	2.3×10^2	2.3×10^1	2.3×10^7	1.5×10^3	2.3×10^2	2.1	2.3×10^7	9.3×10^3
250 ppm	9.3×10^1	2.1	2.3×10^7	2.3×10^2	0.7	1.5	2.3×10^7	4.3×10^2	< 0.4	< 0.4	2.3×10^7	2.3×10^2	< 0.4	< 0.4	2.3×10^7	2.3×10^3
500 ppm	4.3×10^2	< 0.4	9.3×10^6	2.3×10^2	9.3×10^1	0.7	9.3×10^5	2.3×10^2	4.3×10^1	0.4	9.3×10^4	2.3×10^2	< 0.4	< 0.4	4.3×10^3	9.3×10^2

Table 7 Result of experimental set-up for cement mixed fluid with biocide addition every 24 hours.

	24hrs				48hrs			
	Field B		Field A		Field B		Field A	
	GAB	SRB	GAB	SRB	GAB	SRB	GAB	SRB
Baseline (Mix Fluid)	2.3×10^7	1.5	2.3×10^7	2.1×10^1				
50 ppm	2.3×10^7	< 0.4	2.3×10^7	7.5×10^3	2.3×10^7	< 0.4	2.3×10^7	1.5×10^3
100 ppm	2.3×10^6	0.4	2.3×10^7	4.3×10^3	2.3×10^7	0.7	2.3×10^7	4.3×10^3
250 ppm	< 0.4	1.5	2.3×10^7	2.3×10^3	2.3×10^1	2.1	2.3×10^7	2.3×10^3
500 ppm	2.3×10^2	2.1	2.3×10^7	4.3×10^2	9.3×10^2	4.3×10^2	2.3×10^7	9.3×10^2

From above result, it can be summarized that biocide treatment with different concentration 50, 100, 250, 500 ppm and with two different intervals time after 12 or 24 hours indicate various results to control microbial contamination in cement mix fluid. However, biocide addition every 12 hours at the concentration of 500 ppm was the best treatment regimens to control GAB and SRB activities. This is applicable for in Field B samples but not for Field A samples. Therefore, it is important to use different biocide chemistry to treat Field A. This issue needs to be addressed in a separate study once a new biocide is selected.

6. Conclusions

Under Saudi Aramco Current cementing operations, current practice (1000 ppm KCB-310A every 8 hrs) is sufficient for microbial control.

1) Biocide KCB-310A, 500 ppm every 12 hrs is also expected to provide sufficient microbial control.
2) Continuous mixing of cement mixing fluid may improve SRB control.
3) Biocide BE3SA not tested. The effectiveness of dosage and frequency (50 ppm every 14-18 hrs) unknown.

7. Recommendations

As a result, from this study; it is recommended that the following to have effective microbial control for Cementing operations.

1) 500 ppm KCB-310A every 12 hrs is recommended for effective microbial control in cement mixing fluid.
2) Continuous mixing of cement mixing fluid is recommended for improvement of SRB control in cement mixing fluid.

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