Corrosion Evaluation Caused by Activity of Sulfate Reducing Bacteria (SRB) During Shutdown Period in Waha Oil Field

Abduraof Alamari[1], Hakim Shabani[2], Eslam Asser[2], Abdul Quddus Hosen[2]

1-University of Gharian faculty of Eng. Dept of Petroleum Eng. Gharian Libya.

2-Higher Institute of Sciences &Technology .Dept. of Chem. Eng. Gharian, Libya.

الملخص:

تعتبر الخطوط الرئيسية لنقل النفط الخام من أهم المنشآت الرئيسية التي تقوم بنقل النفط من الصحراء الى المحطات الرئيسية. حيث تظهر مشكلة تآكل داخلي للأنابيب والذي يحدث دائما أثناء عملية الانتاج وبالأخص أثنا التوقف (Shutdown) عن الانتاج . مما يؤدي إلى عدم القدرة لرفع معدلات الإنتاج إلى الكميات المطلوبة مجددا نتيجة للثقوب في الانابيب الناجمة عن التآكل . في هذه الورقة تمت دراسة التآكل البيولوجي داخل الخطوط الرئيسية لنقل النفط الخام أثناء فترة التوقف لحقل الواحة التابع لشركة الواحة للنفط والذي يحدث نتيجة النشاط البكتيري والذي يختص بنوع محدد من البكتيريا والمسمى بالبكتيريا المخفضة للكبريتات (SRB) , ومن المعلوم في حالة عدم معالجة هذا النوع من البكتيريا فان نشاطها يزداد في جميع مرافق الانتاج وخاصة في الخطوط الرئيسية للنفط الخام والذي ينتج عنه مشاكل تآكل كبيرة وتسربات والتي تحتاج الى صيانة بتكاليف باهظة الثمن وفي هذه الورقة تم دراسة امكانية إيجاد الحلول الممكنة لحماية الخطوط الرئيسية من التفاعل البكتيري والسيطرة على معدل التآكل لإبقائها في حالة جيدة أطول فترة زمنية ممكنة، وذلك باستخدام العديد من طرق المعالجة والتي يمكن أن تكون كيميائية أو ميكانيكية.

Abstract:

Pipelines are among the main facilities for the transportation of crude oil from production wells to main terminals. Internal corrosion of these pipes may lead to oil spills to surroundings and cause environmental problems as well as loss of production. Among the different types of corrosion responsible of such problems, biological corrosion initiated by bacterial activities maybe the main source for pipelines damage especially during periods of downtimes. In this study, biological corrosion was investigated within the main Al-Waha pipelines for crude oil

transportation. This study was conducted on Al Waha oilfield of Al Waha Oil Company during the long downtime due to the instability of the country and deterioration of the security situation. Field samples were taken during the downtime of Waha oil field. It was found that corrosion occurred in these pipelines as a result of bacterial activity, which is related to a specific type of bacteria called Sulphate Reducing Bacteria (SRB). If this type of bacteria is not properly treated, the activity of this type of bacteria will spread-out in all production facilities, and results in large corrosion problems and leakage, and increase maintenance costs. This paper highlighted different types of treatment processes, such as mechanical and chemical treatment processes. It was concluded that despite of effectivity of mechanical treatment process, chemical treatments maybe more effective especially for prolonged periods of downtimes. Examinations of chemical treatments using biocides found to be very effective, it can be used to control the corrosion rate and keep pipelines in good condition for as long as possible.

Key words: pipe line corrosion, sulfate reducing bacteria, biocides.

Introduction:

The oil transportation lines in all fields considered as one of the most important structure facility to export oil from desert to main terminals. the materials of these lines are subjected to degradation after some times in use, these would result in the loss of mechanical properties like strength, ductility, impact strength; and may lead to loss of materials, reduction in thickness and at times ultimate failure due to corrosion[1,2]. The reservoir fluids in oil and gas fields around the world vary greatly in composition. In some cases the reservoir fluids basically comprise of any one or combination of the following types of fluids with dissolved and suspended solids, based on the reservoir formation. The ageing reservoirs will be souring (increase in the acid gas-Hydrogen Sulfide level) and with the increase in the water cut. The corrosivity of the fluids increases as the well is being drained of the fluids. Where Corrosion is defined as the destruction of a metal by a chemical or electrochemical reaction. Corrosion occurs, when a metal in contact with water; forms a corrosion cell. The corrosion cell generally has four components, the aqueous phase (water), which acts as an electrolyte, ions migrate through forming an anode on the metal surface; where the metal itself considers a metallic path connecting the cathode to the anode[3]. Corrosion in oil and gas industry is mainly due to the reservoir and well fluids tapped during the exploration and production operation. Internal corrosion in oil and gas pipe lines is primarily caused by the

presence of water together with acid gases (carbon dioxide or hydrogen sulphide) or sulphate reducing bacteria (SRB)[4].Microbial corrosion can occur and advance through two main mechanisms. The first methods of microbial enhanced corrosion occurs from microorganisms producing acidic metabolic by products or from microorganisms participating directly in the electrochemical corrosion of the pipe. These mechanisms directly cause or promote the corrosion process. Microbial influenced corrosion can also occur from the presence of biofilms. These biofilms create a micro-environment which differs from the surrounding environment, forming a corrosion cell and initiating the corrosion process. Microbial corrosion commonly caused by Fungi as, Acid-Producing Bacteria (APB), Sulfate-Reducing Bacteria (SRB) and Iron Reducing Bacteria (IRB). In oil and gas pipelines, Acid Producing Bacteria and Sulfate Reducing Bacteria are commonly foud.

In practice Sulphate reducing bacteria are one of particular group of microbes that frequently induce corrosion in pipelines. Although different strains of SRB exist that flourish under different conditions, this group of bacteria all perform similar chemical reactions involving the reduction of sulfate in the pipeline fluid. Due to the prevalence of these bacteria, many studies on microbial corrosion focus on SRB in detail, and some studies have been conducted solely on the corrosive abilities of SRB[5]. Through metabolic processes, SRB reduce this sulfate to sulfide, which corrodes the pipeline interior through a reduction/oxidation reaction[6].Most sulphate reducing bacteria are anaerobic and thrive in oxygen-poor environments, such as within a biofilm[6]. In addition to reducing sulphate, different strains of this bacteria can also reduce other sulfur compounds such as sulfite or thiosulfate through different chemical reactions[7].although significant amounts of research have been performed on the corrosive effects SRB, the reaction mechanisms of SRB are still not fully understood. This lack of understanding is due to both the large number of different varieties of SRB as well as the fact that in a realistic environment, SRB will not be the only bacteria present and corrosion will be caused by all the microorganisms in the biofilm[7].Thus, laboratory experiments cannot take these factors into account. Nevertheless, many theories have been proposed about SRB mechanisms and research is still being conducted to better understand SRB. Sulphate Reducing Bacteria are active in promoting and accelerating corrosion of systems completely void of oxygen. While other microorganism such as sulfide or acid producing bacteria my play some role in corrosion, sulphate reducers are by far the most important and damaging in producing oil industry.

Treatment Considerations:

Basically two methods are used to treat the microbial problem, mechanical treatment and chemical treatment. Mechanical treatments are rather limited, both by nature and by their effect on microbial problems. From the standpoint of controlling the growth of bacteria in water injection system, these point may be considered:

- Selection of water sources can reduce or circumvent a potential problem.
- Aeration of water to aid in hydrogen-sulfide or iron removal will also tend to render the water less suitable to the growth or reproduction of strictly anaerobic bacteria such as sulfate-reducers.
- Coagulation, sedimentation and filtration Water treatment processes can effectively limit microbial growth and reproduction in the water system.

All these procedures usually tend to reduce the total bacterial population; as usually practiced. However, these methods are not very efficient in themselves for correcting a specific microbial problem. Usually at points downstream from these units, a progressive increase in numbers of microbes is found unless other treatments are used.

Pipe line pigging could be one of the most useful method to clean all main pipe line. Where pigs are devices inserted into and travel throughout the length of pipe line, driven by product flow. During the construction of the line, pigs can be used to remove debris that accumulates. Testing the pipeline involves hydro-testing and pigs are used to fill the line with water and subsequently to dewater the line after the successful test. During operation, pigs can be used to remove liquid hold-up in line, clean wax off the pipe wall[8]. Chemical treatment is one of the most effective ways to ensure complete control of the microbial problem. Chemical compounds used in treatment can classified into two main categories. One that kills bacteria and the other inhibits or delays the growth of bacteria but does not kill organisms[8]. The substances that give the same results against other forms of life are called biocides and bio state respectively. Biocides traditionally known as chemicals capable of destroying living organisms. The modern definition of biocide is a formulation containing one or more active substances that will-in very small doses-repel, render harmless control, or destroy harmful organisms. Two main classes of oil field biocides, Oxidizing biocides , oxidize organic matter leading to immediate death of the cell and quick killing rate these not have long lasting, and Non –oxidizing biocides, work by interfering with processes within

the bacterium e.g. reacting with amino acids in the cell wall to destroy cell wall and kill bacteria these have longer lasting effects .

Practical Study:

This study was conducted on Al Waha oilfield of Al Waha Oil Company during the long downtime due to the instability of the country and deterioration of the security situation. The study included two main pipelines for transporting the crude oil, (LA – 7 & LOC- 10). During the past four decades, there was no internal corrosion activity had occurred. In year 2011, Waha field (WOC) has been shut down for almost 10 months, with no harm recorded to the crude oil transmission pipeline, after a year and a half Waha field was shut down by force about two years and a half. Waha oil company implemented the integrity assessment of the pipe based on the results of intelligent pig survey accomplished in year 2007-2008 and appropriate recommended actions have been taken to increase their life time , however these two pipelines were subjected to frequent failure in year 2015, Where internal spills resulting from internal corrosion are found everywhere along the two-pipe line[9].

(Bs) & (W) Measurement:

water content in crude oil of transmission pipelines at Waha station gets a bit high reading in year 2017.when cleaning scrapping pig lunched through defa 20 and GAILO 30 as shown in Figure (1) and Figure (2) [9].

Chemical Treatment:

The biocide used for this study to treat SRB activity at Waha oil field are D(3986) , D(2947) the characteristics and specification as shown in table(A) [9]

Table(A) Characteristics and Specification of Biocides.

Biocide	Density(20^o)c	Viscosity(20^o)	appearance	PH(1% solution)
D(3986)	Appr.1.08g/ml	Low viscous	Colorless liquid	3.2 – 4.2
D(2947)	Appr.1.03g/ml	3mpa	Clear liquid	Appr. 8

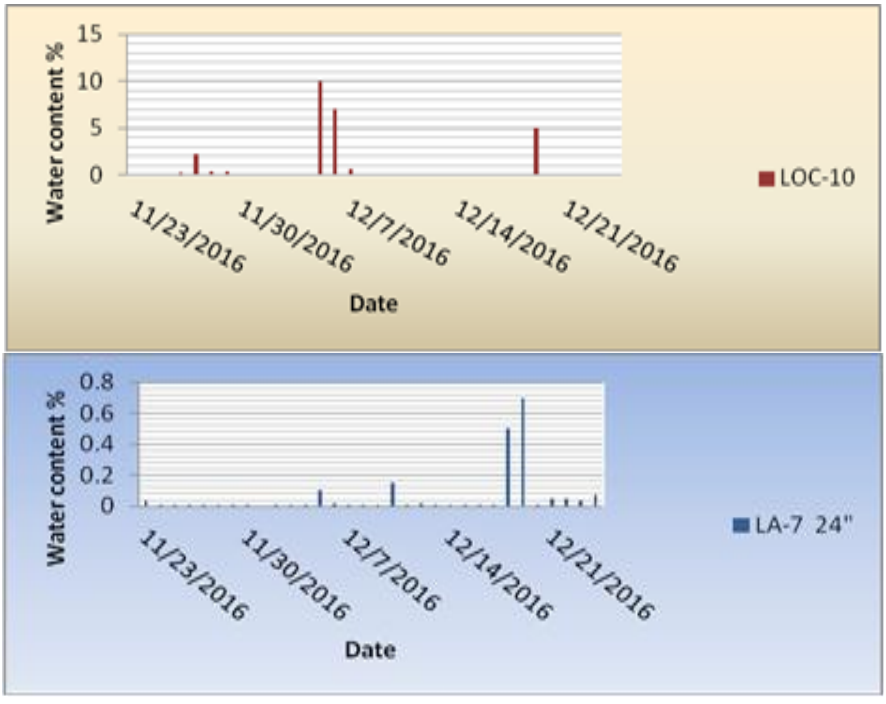

Fig (1) Water content on 2016

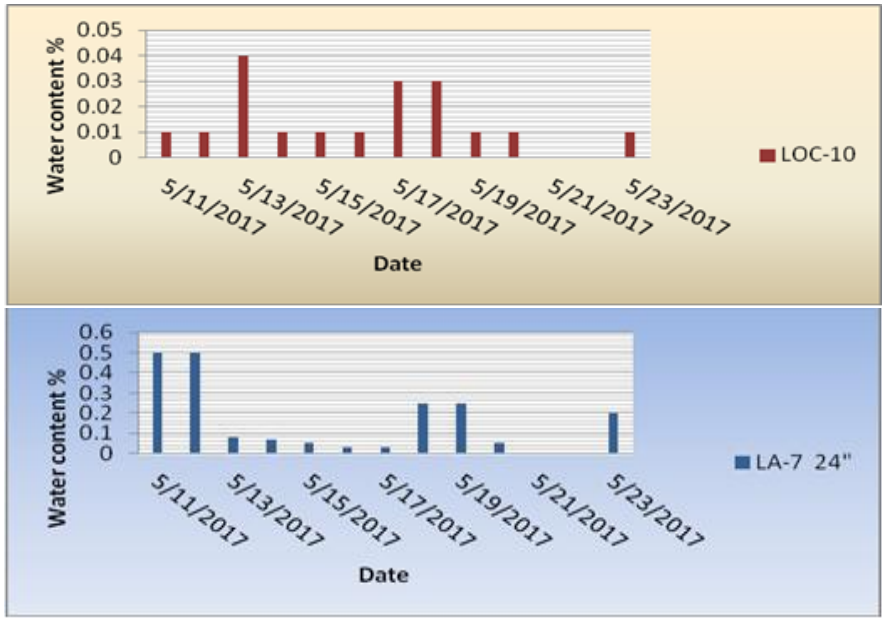

Fig (2) Water content on 2017

The chemical treatment was carried out at WSW (81, 83, 110, 385 & 463), the experiment have been done in Waha corrosion section on Dec-2017 to detect the SRB activity as follows:

The water sample were taken from six different wells in DEFA area of Waha field. the sample were treated before been subjected to sulphate reducing bacteria growth monitoring test using serial dilution as shown in Figure (3).

Serial dilution analysis was done, this method presents a procedure for growth pattern determined from a triplicate. Test was used to enumerate the number of bacteria per mil of the sample for a given period.

1)- A two dozen of vials containing 12 vials were taken Labeled on each pack is the sample location, with date of inoculation and time of inoculation. The top of the pack is divided into six sections as follows; 1a, 1b, 1c, 2a, 2b, 2c, 3a, 3b, 3c,4a, 4b, 4c, 5a, 5b, 5c and 6a, 6b, 6c. Using a new syringe, 1ml of the sample to be analyzed was picked, injected it into 1a, shaken, using the same syringe, 1ml of the sample to be analyzed was picked and inject it into 1b, and then shaken. The above steps were repeated for 1c, 2a, 2b and 2c shaken and then disposed.

2)- Same was done for 3a, 3b and 3c as well as 4a, 4b, 4c and 5a, 5b, 5c and 6a, 6b, 6c,For sulphate reducing bacteria, incubation was done at 31.5℃ (88.7℉) for 28days, bottles is then used to determine the Number of bacteria in the original sample using a statistically derived table.

3)- Twenty eight table monitoring sheet was generated to monitor the growth of the bacteria daily for 28 days by indicating positive sign (+) if any bottle changes its colure to black (indicating growth) and a negative sign (-) if no change in colure (no growth).as shown in Figure (3)

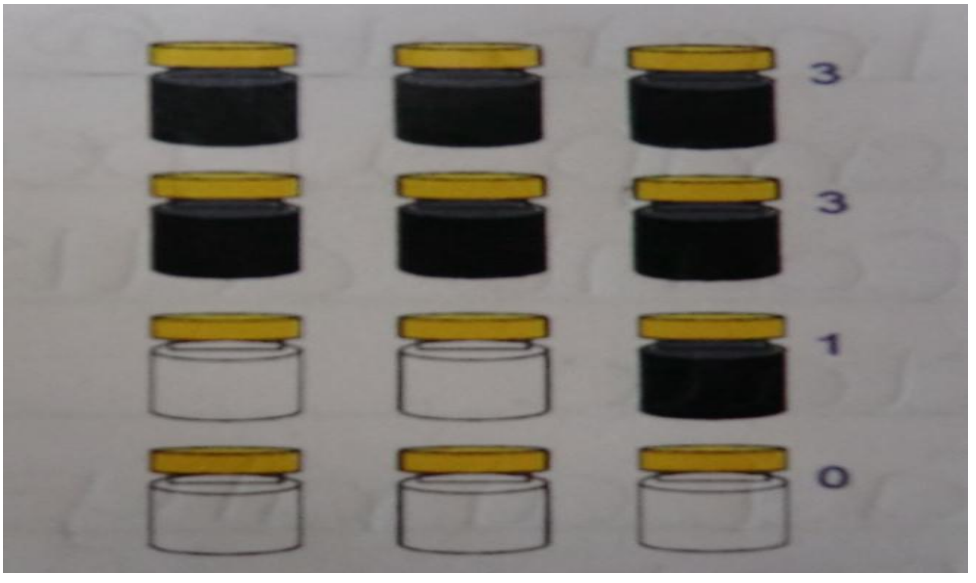

Fig 3: Dilution Samples

Results and Discussion:

The growth rate of bacteria after 28 days is shown in Table (B) as well as Figures from (4) to (7).

From the results of the growth rate of sulfate reducing bacteria in produced water sample carried out. It is clear from Figure (5) and Figure (6) there is no growth occurred during 28 days this indicates that the treatment of biocide**s** was probably working and should got excellent results from this treatment which was held every 7 days. The growth rate of the Sulphate Reducing Bacteria is very high when there is no treating done for the wells using biocides as shown in Figure (4) and Figure (7).

Table [B]: Water SRB Monitoring Report(monthly)

Location	Collected Date	1= 10 col/ml						2= 100 col/ml					3= 1000 col/ml																	
WSW-81	2-Dec	12/3	12/4	12/5	12/6	12/7	12/8	12/9	12/10	12/11	12/12	12/13	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/21	12/22	12/23	12/24	12/25	12/26	12/27	12/28	12/29	12/30	Result
		0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 col/ml
WSW-83	2-Dec	12/3	12/4	12/5	12/6	12/7	12/8	12/9	12/10	12/11	12/12	12/13	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/21	12/22	12/23	12/24	12/25	12/26	12/27	12/28	12/29	12/30	Result
		0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 col/ml
WSW-87	2-Dec	12/3	12/4	12/5	12/6	12/7	12/8	12/9	12/10	12/11	12/12	12/13	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/21	12/22	12/23	12/24	12/25	12/26	12/27	12/28	12/29	12/30	Result
		0 (-)	0 (-)	1 (+)	1 (+)	1 (+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	1000 col/ml
		0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	
		0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	
WSW-110	2-Dec	12/3	12/4	12/5	12/6	12/7	12/8	12/9	12/10	12/11	12/12	12/13	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/21	12/22	12/23	12/24	12/25	12/26	12/27	12/28	12/29	12/30	Result
		0 (-)	0 (-)	0 (-)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	10 col/ml
WSW-385	1-Dec	12/2	12/3	12/4	12/5	12/6	12/7	12/8	12/9	12/10	12/11	12/12	12/13	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/21	12/22	12/23	12/24	12/25	12/26	12/27	12/28	12/29	Result
		1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	100 col/ml
		0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	
WSW-463	1-Dec	12/2	12/3	12/4	12/5	12/6	12/7	12/8	12/9	12/10	12/11	12/12	12/13	12/14	12/15	12/16	12/17	12/18	12/19	12/20	12/21	12/22	12/23	12/24	12/25	12/26	12/27	12/28	12/29	Result
		0 (-)	0 (-)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	1 (+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	1000 col/ml
		0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	2 (+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	
		0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	0 (-)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	3 (+)	

Conclusion:

It is concluded that, when Sulfate Reducing Bacteria (SRB) are in the sample. sulfate reduced to hydrogen sulfide (H_2S) during incubation. The H_2S reacts with the ferrous iron in the vial to form black iron sulfide. This sulfide commonly forms in the vial, sulfate reducing bacteria typical grow in anaerobic conditions deep as a part of a microbial community**,** and the water sample turns black due to the high level of H_2S present in the sample. Sulfate reducing bacteria can cause problems such as strong odors, blackening of equipment, slime formations and the start of corrosive processes. After the shutdown period about three years for Waha oil field they found an increase for leaks on the main pipeline especially when pipe pigging is taken place, due to the stagnant water area. Many factor leads to cause corrosion one of these factor is a high activity of sulfate reducing bacteria which is leads to sour corrosion in the absence of oxygen. So the best period time to get best results that the treatment using biocide must be done every seven days.

The biocide treatment have an acceptable results of controlling the activity of SRB, But this treatment cannot terminate this bacteria which could leave the bacteria to grow and become billions of colonies in the absence of oxygen in the stagnant areas especially during shut down for long period of time.

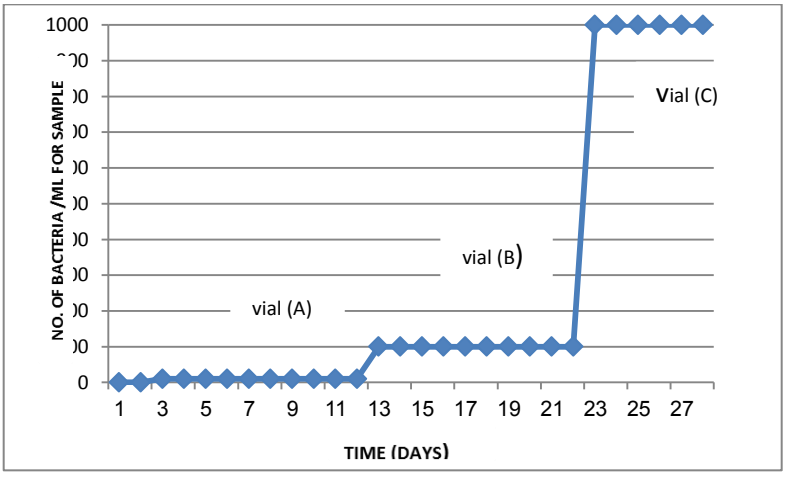

Fig 4: Bacteria Growth Over Time (WSW-463)

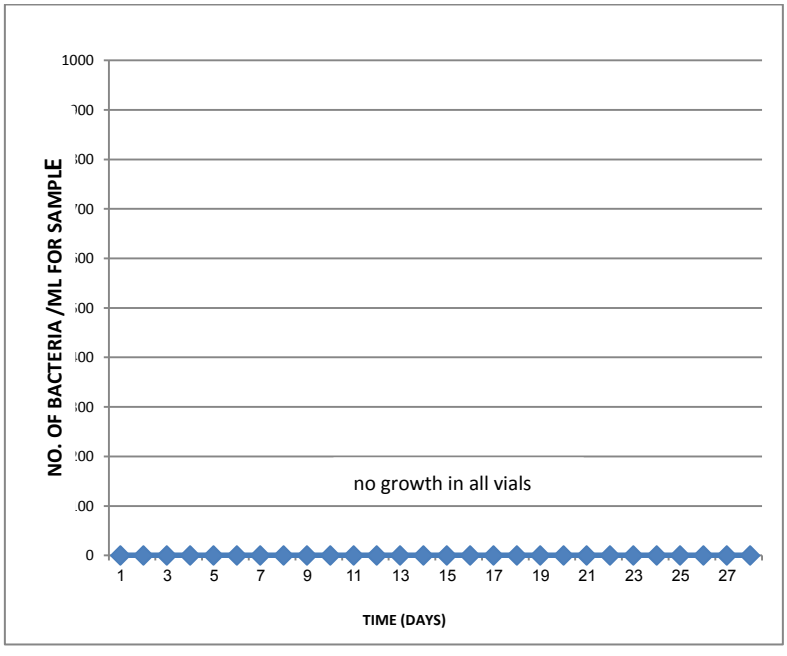

Fig 5: Bacteria Growth Over Time (WSW-81)

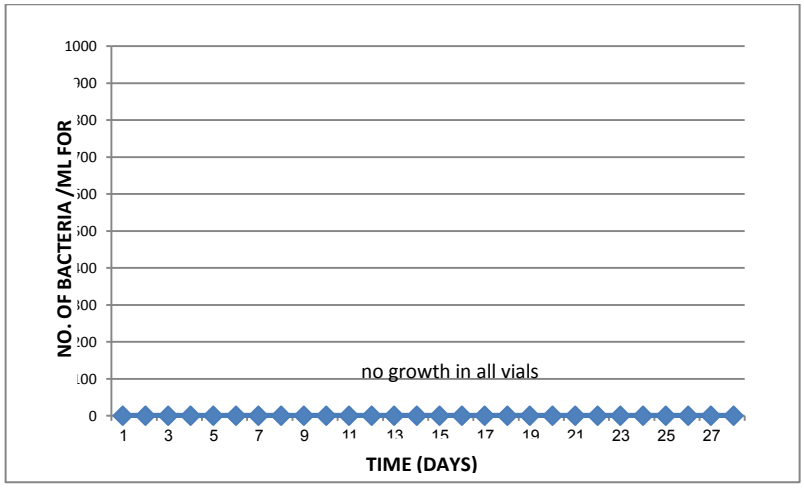

Fig 6: Bacteria Growth Over Time (WSW-83)

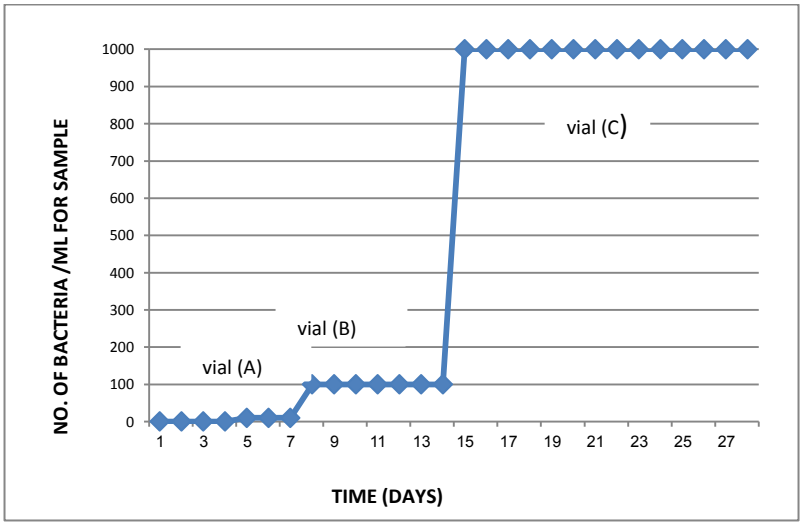

Fig 7: Bacteria Growth Over Time (WSW-87)

Recommendations:

1- Under deposit corrosion, one of the main factors that could lead to cause damage (leaks) to the main pipe lines, this type of corrosion must be treated using alternative treatments which could be chemically like biocide treatment and mechanically by using pipe pigging.
2- An action must be taken before the shutdown to minimize the distraction power of corrosion during the shutdown period
3- Chemical treatment should be carried out inside the main lines before stopping completely using the appropriate type of pipe pigs.
4- It is necessary to develop new methods to treat this bacterial activity ,there are many studies that use either nitrate/nitrite injection or ultrasound, as this technology is still under development.
5- The treatment for the (SRB) must be held within every 7 days.
6- Locate the damaged pipeline location (lowered down ground) , use internal coated pipe.

References:

[1] C.H. Achebe, Member, IAENG, U.C. Nneke, and O.E. Anisiji Analysis of Oil Pipeline Failures in the Oil and Gas Industries in the Niger Delta Area of Nigeria.

[2] L.K. Popoola et al. (2013, Sept.) Corrosion problems during oil and gas production and its mitigation.International Journal of Industrial Chemistry [Online]. 4(35), 1-15. Available: http://www.industchem.com/content/pdf/2228-5547-4-35.pdf

[3] Prof. K. A. Natarajan, IISc Bangalore. Advances in Corrosion Engineering(Corrosion: Introduction – Definitions and Types)**.**

[4] Roland Palmer-Jones U.K. Repairing Internal Corrosion Defects in Pipelines - A Case Study

[5] W. A. Hamilton."Sulphate-reducing Bacteria and Anaerobic Corrosion, " Annual Review of Microbiology, vol. 39, pp. 195-217, 1985**.**

[6] R Javaherdashti, Microbiologically Influenced Corrosion: An Engineering Insight. London, United Kingdom: Springer London, 2008, pp. 49-57.

[7] P. Marcus, Corrosion Mechanisms in Theory and Practice, 2nd ed. New York, NY: CRC Press, 2002, pp. 750-754**.**

[8] Dr.M.T.Pand. Microorganisms in Re-circulatory Water Systems and Their Significance in Fouling'**.**

[9] WahA Corrosion Section, 2016 and 2017 , investigation for the main pipe lines water contant, pigging and operating pressure.

