

Comparison of Sampling Analysis Findings and RBI Assessment in Corrosion Forecasting

Yousef Khuraibut, Saleh Al-Sulaiman, Arnab Gupta, Mithun Mitra, Hasan Bu Taleb
Inspection & Corrosion Team
Kuwait Oil Company
Ahmadi, Kuwait

Periodical chemical analysis of samples (Fluid / Solid Deposits / Gas), is one of the most important aspects in determining prevalent damage mechanisms in oil and gas facilities. In a sense, the trends for the different variables (such as, water content, pH, H₂S, CO₂, bacterial growth, sulfates, sulfides...etc.) will provide insights for the environmental condition of a specific process stream. If the findings are critical, it will have a significant impact, as it will enable asset owners to determine the immediate corrosion risks, taking proper preventive and mitigating actions and also aid in forecasting future integrity/reliability concerns that companies may encounter.

In this paper, the authors will discuss sampling results of a specific process stream, analyze the data, and compare the results to the overall risk generated from RBI software. This will have significant added value to other operators and companies, as it will show that sound chemical analysis and interpretation is capable to confidently predict the corrosion susceptibility and help an organization to align its asset integrity plan to sustain reliable operation.

Key words: Sample Analysis, Parameters, Assessment, Corrosion Forecasting, RBI

INTRODUCTION

Periodical chemical analysis of samples (Fluid / Solid Deposits / Gas), is one of the most important aspects in determining prevalent damage mechanisms in oil and gas facilities. In a sense, the trends for the different variables (such as, water content, pH, H₂S, CO₂, bacterial growth, sulfates, sulfides...etc.) will provide insights for the environmental condition of a specific process stream.

In Kuwait Oil Company (KOC), the internal corrosion program is well established, carrying out periodical sampling analysis of fluids / deposits / gas for process streams for the past two decades. The availability of trends / analysis for specific time periods, providing “**aid**” in assessing the condition and environment changes / excursions for specific process streams.

Therefore, it is highly important for oil & gas companies / operators to have a well-defined internal corrosion program, which continuously / periodically carry out analysis of samples, in order to effectively identify the parameters that may affect the integrity of the assets.

Although the sample analysis does not provide the extent of corrosion or damages for specific locations in the process stream, probability of corrosion and the risk to the piping & equipment can be forecasted based on findings.

In this study, the probability and likelihood of corrosion will be assumed, based on the sample analysis data, then these assumptions will be compared to Risk Based Inspection (RBI) probability & likelihood software, to determine the accuracy of the conclusions.

The results of this study will aid companies that are not utilizing RBI software for forecasting probabilities & likelihood of damages, and are limited to sampling analysis, to have confidence in their assumptions.

The results are discussed in this paper.

METHODOLOGY

Based on the internal corrosion program sampling analysis trends for the past 20 years, three risk categories were established for determining the corrosion risk:

- **Low**
- **Medium**
- **High**

These categories are based on the overall assessment of the process variables observed in the sampling analysis, such as iron content (Fe), manganese content (Mn), pH, water cut (%), sulfates (SO₄⁻²), H₂S content, conductivity, chlorides and bacteria levels (both planktonic & sessile).

These variables are detrimental to the corrosivity of process streams, and their effects are well documented. There are other variables (such as oxygen levels in crude...etc.) that will also provide additional insights to the process corrosive environment; however, laboratory capabilities, limitations, awareness of the facility historical trends and management decisions (economical / time restraints), all factor on what variables are deemed “**critical**” to assess.

The importance of these variables for the assessment is briefly summarized for the reader as follow:

Iron (Fe) content:

The presence Iron signifies active corrosion in the process streams. Free iron will react with water to form iron hydroxides / iron oxides or iron sulfides (**in sour environment**) deposits. These deposits

are almost always, cathodic to the piping / equipment and will lead to accelerated corrosion at specific pockets. As a general rule of thumb, the lower the iron content, the lower risk of general /under deposit / localized corrosion taking place in process streams.

Manganese (Mn):

As a general rule of thumb, manganese is not naturally occurring in formation waters (exception, Barnett Shale formation). Manganese is an alloying material utilized in the steel milling process; therefore, its presence can be an indicator of active corrosion of metallic components¹. The manganese levels are generally analyzed in conjunction with iron counts.

pH:

The pH is one of the most important variables for analyzing process streams, as it a measurement of the acidity, or alkalinity of water. The lower the pH number, the higher concentration of hydrogen ions will be present, leading to expedited corrosion mechanisms in process streams.

Water Content (%):

Higher water content will increase wettability of piping / equipment and will promote general / localized corrosion in process streams.

Sulfates (SO₄⁻⁴):

Sulfates are nutrients for bacteria, and it is needed in the respiration process that allow SRB strains to produce H₂S in the process streams. Further, sulfates will react with free iron to form iron sulfates deposits that may be cathodic to the piping / equipment at specific pockets, leading to general /under deposit / localized corrosion.

H₂S:

H₂S is indication of acidic environment in process streams. Hydrogen sulfide may be associated with the service (from wells) or it may be present from sulfate reducing bacteria activities. In all cases, presence of H₂S is known to lead to the formation of iron sulfide (which may be cathodic to the piping / equipment) and subsequently, promote general/under deposit/ localized corrosion and cracking mechanisms in process streams.

Conductivity:

The higher the conductivity, the higher the concentration of ions are available, the faster the current flows in process streams, and potentially leading to higher corrosion rates / risks.

Chlorides Content:

Chlorides and conductivity are usually linked with each other in sampling analysis assessment, as with increasing chlorides comes increasing conductivity and thus, increased corrosion potential in the process streams.

Bacteria Levels:

By far, the microbiological species most associated with corrosion has been Sulphate-Reducing Bacteria (SRB). However, one cannot neglect the ability of other bacteria frequently found in oil and gas environment, such as general aerobes and general anaerobes to cause corrosion by biofilm production². Therefore, presence of bacteria in high levels will likely promote Microbial Induced Corrosion in process streams.

TRENDS ASSESSMENT

FLUID ANALYSIS

Separator outlets TK-09 (**Table-2**) and TK-10 (**Table-3**) showed high chloride content, which indicates high water cuts in the production streams, confirmed by the actual water content found from testing. In addition, the pH levels from the analysis were in the range of 5.8 to 6.4 for both low pressure crude streams, which is in the acidic direction.

High amounts of sulfates were observed, which indicate the availability of electron donor for microbial sulphidogenesis². Additionally, sulfate reacts with free iron to form deposits that may be cathodic to the metallic surface at specific pockets, leading to general /under deposit / localized corrosion, as mentioned previously.

The iron content was found in the range of 1.8 to 44.1 mg/l, and Mn content was between 0.4 and 1.3 mg/l, indicating active corrosion in the process stream.

The H₂S levels were continuously low (traces) between 0.002 - 0.005 ppm, with the exception to the 0.2 ppm observed in February 2019, which is considered high.

The conductivity was extremely high in all analysis from both outlets, indicating faster electrical flow / current movement. Subsequently, increased corrosion rates / corrosion reactions are anticipated in the process streams.

Planktonic bacteria analysis (**Table-4**) showed high bacterial counts, with extremely high amounts of *GAB* and *GnAB* levels (between 100 to 10000 counts/ml) and zero to low counts for *SRB* strain (10 counts/ml). The planktonic bacteria levels indicate that bacterial activities are likely to increase and likely lead to the formation of colonies in the process stream.

DEPOSIT ANALYSIS

TK-10 separator was opened and deposits were collected for analysis. Similar results were observed in the wet chemistry analysis of these deposits (**Table-5**).

The pH of the deposit sample is low (5.5), indicating acidic environment in the process. Chlorides were found in significant amounts (6008 ppm), which indicates produced water accumulation. These conditions are known to promote corrosion, confirmed by the Fe to Mn ratio and the iron content (41%) from the samples.

Further, the sulfate content found was high (3227 ppm) indicating availability of electron donor for microbial sulphidogenesis and the possibility for the formation of iron sulfate deposits.

Qualitative analysis was also done for the samples for the presence of sulfides. The testing was positive, which suggests the involvement of H₂S in the process, and confirmed by the presence of FeS from the XRD analysis in **Table-6**.

The sessile bacteria culturing for the deposit sample showed zero *SRB* counts and extremely high amounts of *GAB* / *GnAB* strains (**Table-7**).

Even though analysis did not show *SRB* in the sessile form, few fluid sampling services showed their presence in low counts in planktonic form. Hence, they may be present in the process or even in sessile form, but they were not present in the deposits collected from these spots in the separator. *SRB* presence may be confirmed by the sulfides / the formation of FeS observed in the wet chemistry / XRD analysis, as *SRB* strain is known to produce sulfides and lead to the formation of iron sulfides³.

**All tables are available in Appendix-1.*