



MICROBIAL MONITORING AND DNA TECHNOLOGY **ADDS UP**

SGS OIL, GAS AND CHEMICALS SERVICES

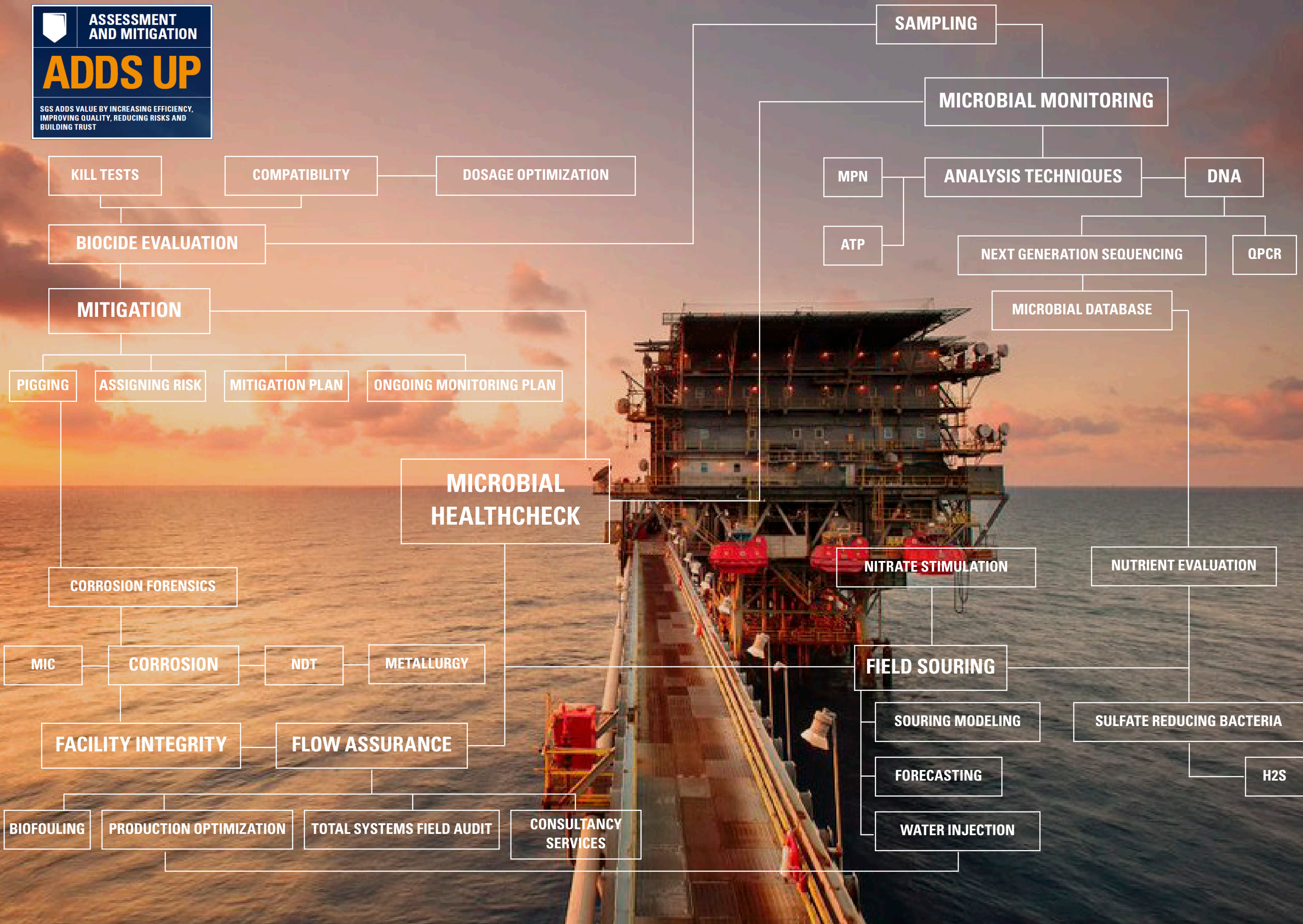
SGS



**ASSESSMENT
AND MITIGATION**

ADDS UP

SGS ADDS VALUE BY INCREASING EFFICIENCY,
IMPROVING QUALITY, REDUCING RISKS AND
BUILDING TRUST



INTRODUCTION

Microbes can flourish in a wide range of environments and are present in oil reservoirs, (geothermal) wells and topside facilities. These microbes preferentially survive as active biofilm under favourable conditions on pipe or vessel surfaces driving an increased asset risk through MIC (Microbiologically Influenced Corrosion), Biofouling and Souring.

The metabolic products of microbial activity like organic-acids and carbon dioxide add to the corrosion problem and constitute a massive threat to the well and facility integrity. This impacts safe field operations and can pose a significant hazard for humans and the environment.

Microbes not only cause corrosion, but the corrosion products they produce, their biomass, or their metabolic products, can clog up the pores in the reservoir rock or the pipes and filters at topsides (Biofouling).

Additionally, Hydrogen sulfide could be generated by microbes in the reservoir, driven by nutrients from injection water and by the cooling of the reservoir (Souring). This souring process is often initiated by field operations and has caused fields to shut-down, but has also resulted in the loss of lives.

The inhibition or remediation of the microbial contaminations is very important but is also a major cost factor for field operations. Monitoring of microbial populations to allow for effective actions to be taken is thus essential.

DAMAGE BY MICROBES

Although it is difficult to asses the true damage microbes cause, some studies indicate that up to 20% of all internal pipeline failures can be attributed to microbial influenced corrosion.

The total cost related to MIC is estimated to be 2 billion USD per year in the United States alone (Lee 1990).

In addition, there are CAPEX cost to protect facilities from microbial attack and OPEX cost for chemicals, cleanup operations and more stringent safety measures. Also the reputational damage done when accidents do happen can be detrimental.

MICROBIAL ANALYSIS TECHNIQUES

SGS offers several microbial analysis techniques that are deployed globally. We offer techniques that can be deployed on-site and off-site on both fluids and solids. Some technologies focus on instant quantification of microbes, while the others provide specific details based on DNA analysis. Typically we deploy a combination of the following Microbial Monitoring techniques:

- **ATP (Adenosine triphosphate)** allows for onsite enumeration of all active microbes.
- **MPN (Most Probable Number or serial dilution technique)** SGS offer a variety of growth media to quantify specific microbial groups in varied salinity and pH levels.
- **qPCR (quantitative Polymerase Chain Reaction)** is a DNA based technology to enumerate specific microbial groups and SGS offers a variety of assays (microbial target groups) both on-site and off-site.
- **NGS (Next Generation Sequencing)** is a very powerful technology that allows for the identification of all microbes present in a sample.



NEXT GENERATION SEQUENCING

SGS operates several laboratories where we perform DNA analysis via Next Generation Sequencing (NGS).

NGS is a technique which allows for the sequencing of numerous small fragments of DNA in parallel. Due to this parallel approach, the automatic detection of the nucleotides and the possibility of computers to process and reorganize large amounts of data, NGS has become the fastest and most cost effective method for sequencing DNA.

With this technology SGS can detect all microbial species or taxonomic groups in virtually any sample type. This provides unprecedented detail and does not require upfront selection of microbial target groups. Nor, does it require culturing or complex live sampling.

SGS recommends to deploy NGS technology during certain field operations and at multiple stages in a field life or monitoring program.

SGS MICROBIAL MONITORING SERVICES

SAMPLING

- On site sampling
- ATP & onsite qPCR
- Solids/ Fluids
- (Inline) Biostuds
- Corrosion Coupons
- Monitoring
- Inspection

TRANSPORT

- Global Coverage
- Fast Delivery
- Live transport
- Temperature Control

LABORATORY ANALYSIS

- MPN
- qPCR
- NGS
- QEMSCAN
- Microscopy
- Live Growth Tests

**INTER-
PRETATION**

- Proprietary Microbial Database
- Integrated Solutions
- Experienced Microbiologists
- Corrosion Forensics
- Tailored Solutions

MITIGATION

- Mitigation Screening
- Growth Tests
- Biocide Kill Test
- Nitrate Stimulation
- Corrosion Tests
- Biocide Optimization
- Total Systems Audit Approach
- Asset Risk Assessment

Our microbial monitoring services offer you a wide variety of analysis tools in the right combination to make them work. Our experienced petroleum microbiologists can design tailored solutions for your specific monitoring needs or microbial challenges.

With SGS’ global network of laboratories and inspection and sampling teams you get access to our technology anywhere, anytime.

Our global reach allows us to provide the newest technologies and expertise to the most remote locations. We offer our clients integrated solutions, monitoring your facilities integrity from the subsurface into the refinery.

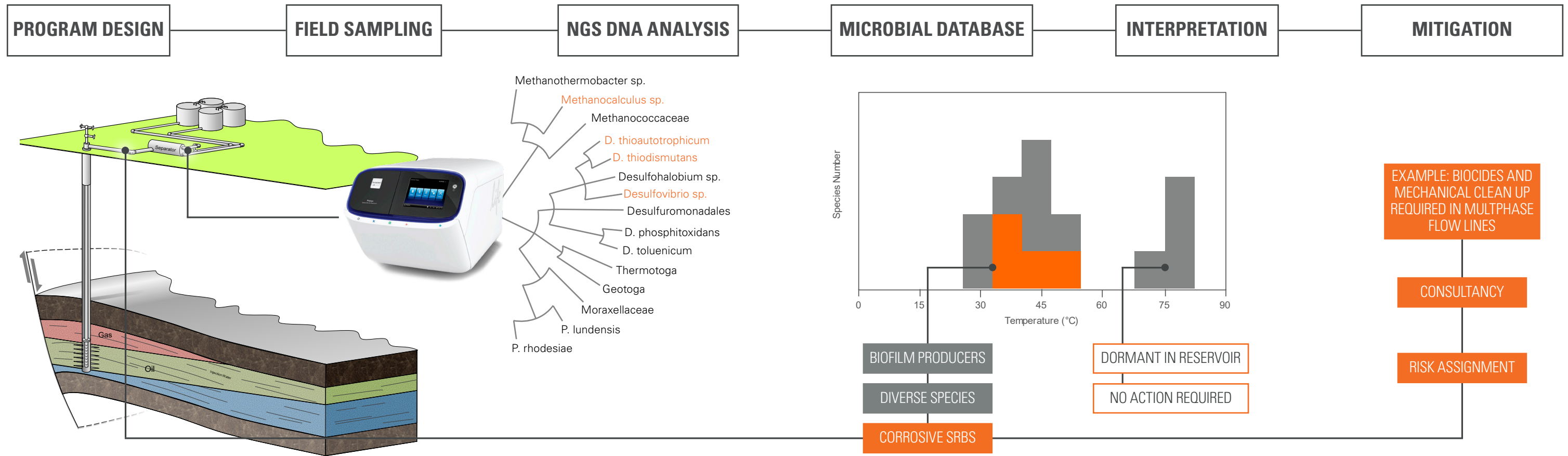
With SGS you do not only get access to industry leading microbial monitoring services, you get a fully integrated service offering from production optimization, fluid chemistry, metallurgy, mechanical and corrosion testing, failure

analysis, process optimization, (risk based) inspections, non-destructive testing, corrosion forensics and QHSE. This integrated approach provides our clients with Complete System information at the right time to make the best decisions to maintain the integrity of their facilities and infrastructure.

We offer independent advice regarding mitigation options and are dedicated to identifying the most cost effective and efficient solutions.

	MPN	ATP	QPCR	NGS BY SGS
Detection Limits				
Do you need a lot of cells to detect them?	✓✓	✓✓	✓✓	✓✓✓
Quantification				
Does it provide quantification of Cells?	✓	✓✓	✓✓✓	✗
Detects Live and Dead Cells				
Does it detect both active and inactive species?	✗	✓	✓✓✓	✓✓✓
Ease of Sampling & Handling				
How easy it to sample and transport?	✗	✓	✓✓	✓✓✓
Untargeted Identification				
Do I detect all species, even the ones I don’t plan to detect?	✗	✓	✗	✓✓✓
Detection of all Species				
Can I detect all species present?	✗	✓	✓	✓✓✓
Corrosion/Souring Risk Profile				
Do I get a risk metric for corrosion, biofouling or souring?	✓	✓	✓✓	✓✓✓

SGS (NGS) MICROBIAL MONITORING WORKFLOW



UNDERSTANDING MICROBIAL COMMUNITIES AND ENVIRONMENTS

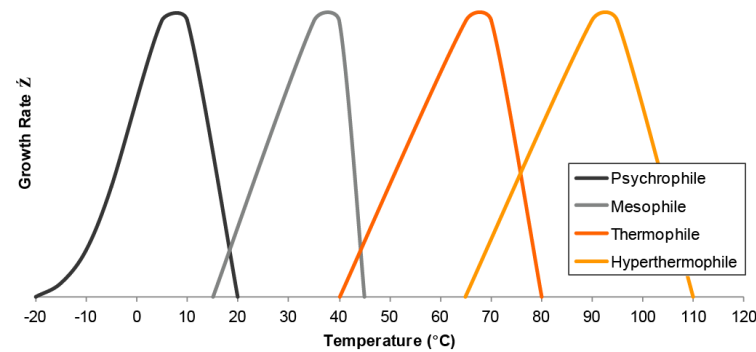
The occurrence of specific microbial species and communities are primarily controlled by environmental parameters such as temperature, oxygen presence, pH, water salinity and the presence of nutrients. The large range in operating windows and conditions within and oil field and its facilities does mean we can find many different species and types of communities within such a system.

For instance, species present in the reservoir may thrive under much higher temperature conditions than those present in the pipelines of a water injections system and associated wells.

Microbes are generally categorized into psychrophilic, mesophilic, thermophilic and hyper-thermophilic species when describing their optimum temperature windows.

The fluids and biofilms of each oil field and its facilities may thus have their specific 'microbial and chemical signature', which varies at each stage of the production process but may also change over time. In order to act effectively against microbial issues the determination of origin, location

and severity of microbial risk is essential. In addition, operators need to detect the changes in the diversity of the microbial communities, or in the chemical compounds they consume and produce.



Overview of nomenclature used to discriminate microbial species based on their growth temperature

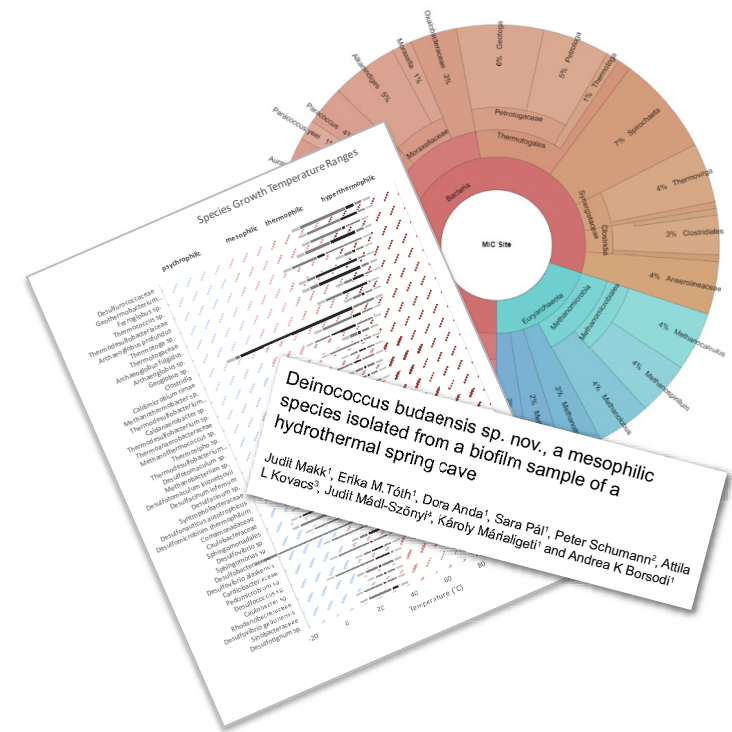
SGS' MICROBIAL DATABASE

After NGS analysis has identified all species in a sample, SGS utilises our proprietary Microbial Database to link species traits and assemblages to corrosion, biofouling or souring risk.

Our database is populated with all known microbial species, their metabolic pathways, their corrosion tendency and their environmental parameters (e.g. temperature, pH, salinity, oxygen tolerance, etc.).

On the basis of system temperatures and fluid chemistries, we can identify which species could not survive at the corrosion site. This helps us to filter out 'contaminations' originating further upstream or species introduced during sampling.

The result is a robust corrosion or souring risk assessment for specific areas of a subsurface reservoir or facility.





NEXT GENERATION SEQUENCING ALLOWS US TO CHARACTERISE ALL MICROBES IN A BIOFILM

MICROBIAL INFLUENCED CORROSION

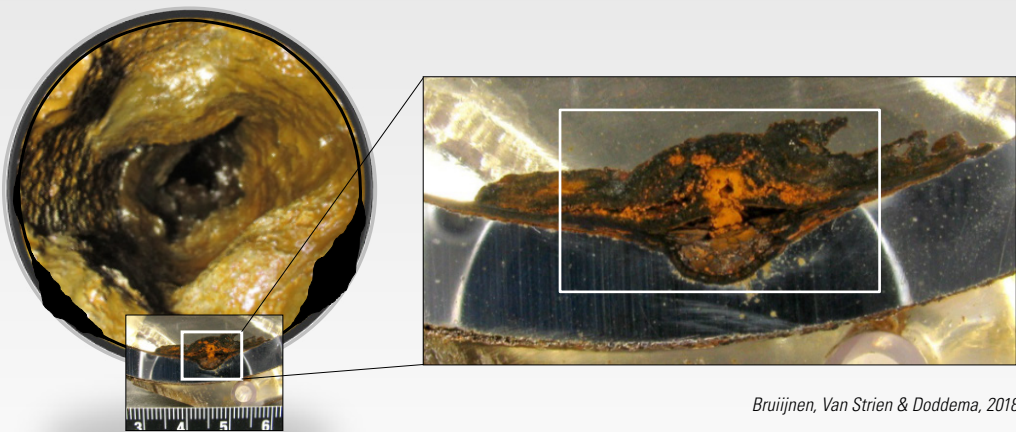
Both old and new infrastructure and many high grade alloys can be affected by microbial influenced corrosion. The microbes responsible for the corrosion live in biofilms bound to metallic surfaces of the field’s infrastructure.

The microbes can trigger anodic reactions, which leaches iron-ions from steel. This process can result in very localized corrosion, called pitting.

Pits have been found to develop with a rate of up to 5mm per year. They usually develop below a build-up (tubercle or biofilm) and have very small diameters. Pits are very difficult to detect and

require frequent and very accurate wall thickness measurements to be on time to allow for effective mitigation.

However, this is often impossible, due to accessibility and technological imitations or such monitoring is simply deemed too expensive. The only option that remains is monitoring pitting is by characterizing the microbial communities in the biofilms responsible for them.



Bruijnen, Van Strien & Doddema, 2018

THE KEY TO MIC: BIOFILMS

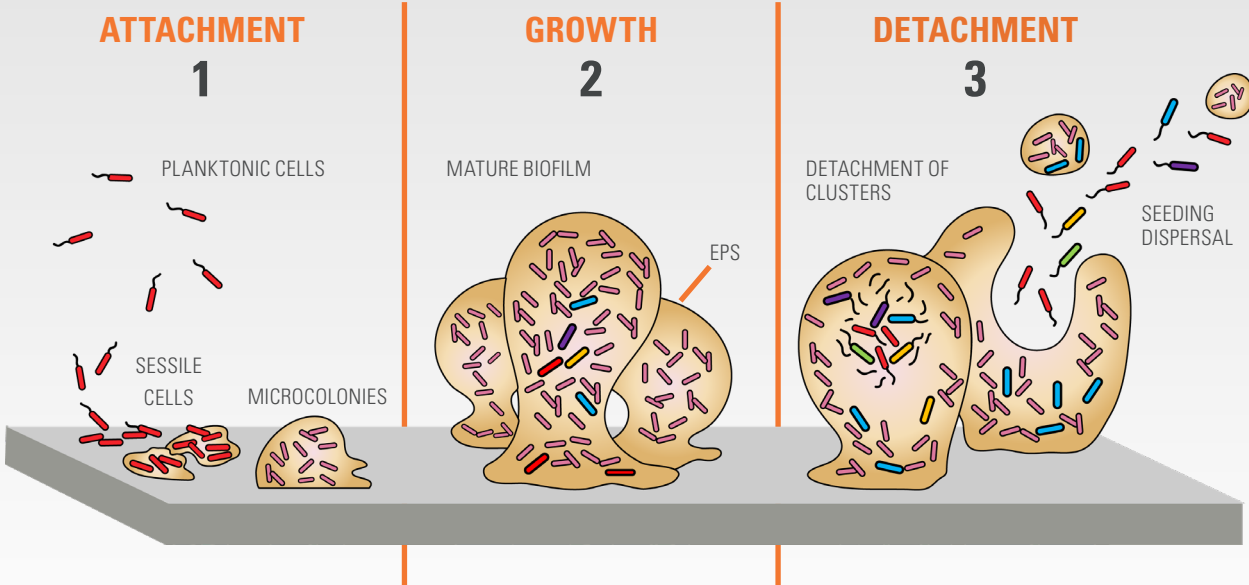
The growth of a biofilm into a ‘tubercle’ is key to the fast development of the underlying pits. Biofilms form by the adhesion of some initial microbes to a steel surface. Once certain microbes that can excrete extracellular polymeric substances (EPS) join the community the biofilm starts to take shape.

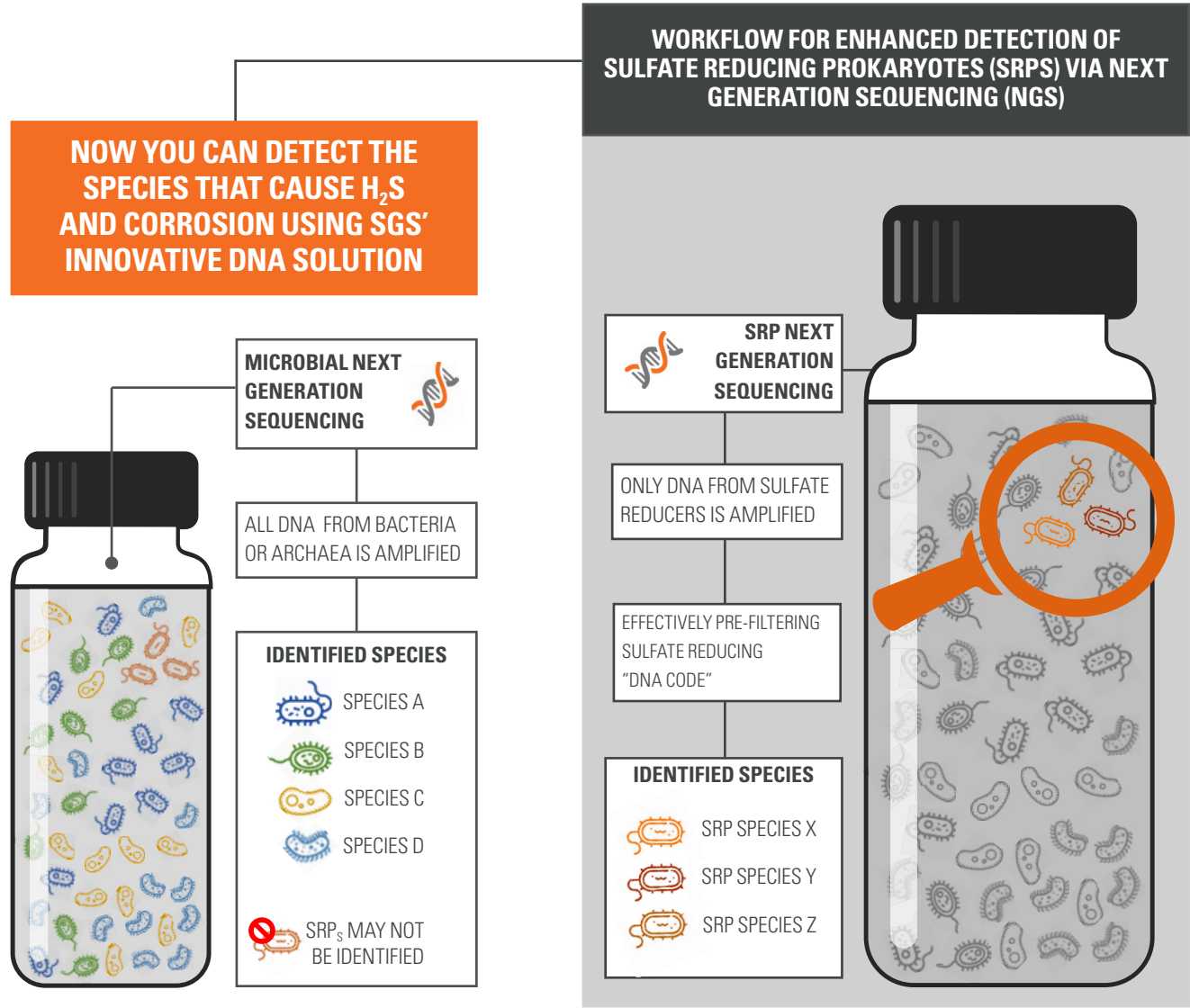
The EPS forms a substance in which other microbes can grow and it will trap particles traveling in the fluid stream. Certain metabolic products might react with each other or the corrosion products to form solids.

All these solids strengthen the EPS framework and form an intricate mesh in which the microbes can strive. In essence, the biofilm

starts to protect itself from outside dangers like changes in the fluid flow, flowing particles, oxygen levels, pH, certain chemicals and biocides.

Detecting growing biofilms allows for early prevention of MIC.





Next Generation Sequencing can be used to identify bacteria and archaea based on their DNA. However, sulfate reducing species can be overlooked if abundant other species are present as their DNA overprints that of the sulfate reducing species.

Using the new SRP specific DNA sequences developed by SGS, we can now target the SRPs DNA. During amplification only the DNA associated with sulfate reducing species is amplified, effectively 'pre-filtering' the DNA. In essence, this allows us to zoom in on the sulfate reducing species, the SRPs, and identify them much more accurately.

ENHANCED SRP DETECTION

Sulfate reducing prokaryotes (SRPs) can produce H₂S, which is a corrosive and lethal gas. Increased activity of the SRPs during production often requires costly facility updates. In addition SRPs are also often associated with MIC.

Early detection and identification of these SRPs throughout the production system (from subsurface reservoir to facility) is paramount to maintain operations and to prevent damage to field and facility.

For this reasons scientist at SGS Molecular have cracked the DNA code which is present in species that can reduce sulfate. SGS uses SRP-specific DNA sequences, in a newly designed workflow to offer enhanced detection and identification of SRPs using Next Generation Sequencing (NGS).

When other techniques fail to identify SRPs this technology allows for the identification of the specific sulfate reducing species.

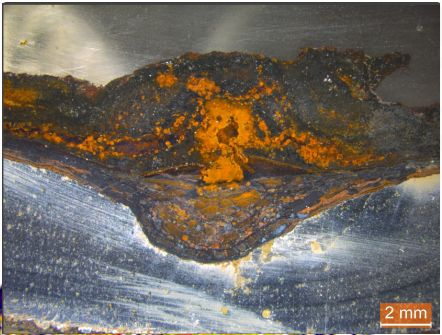
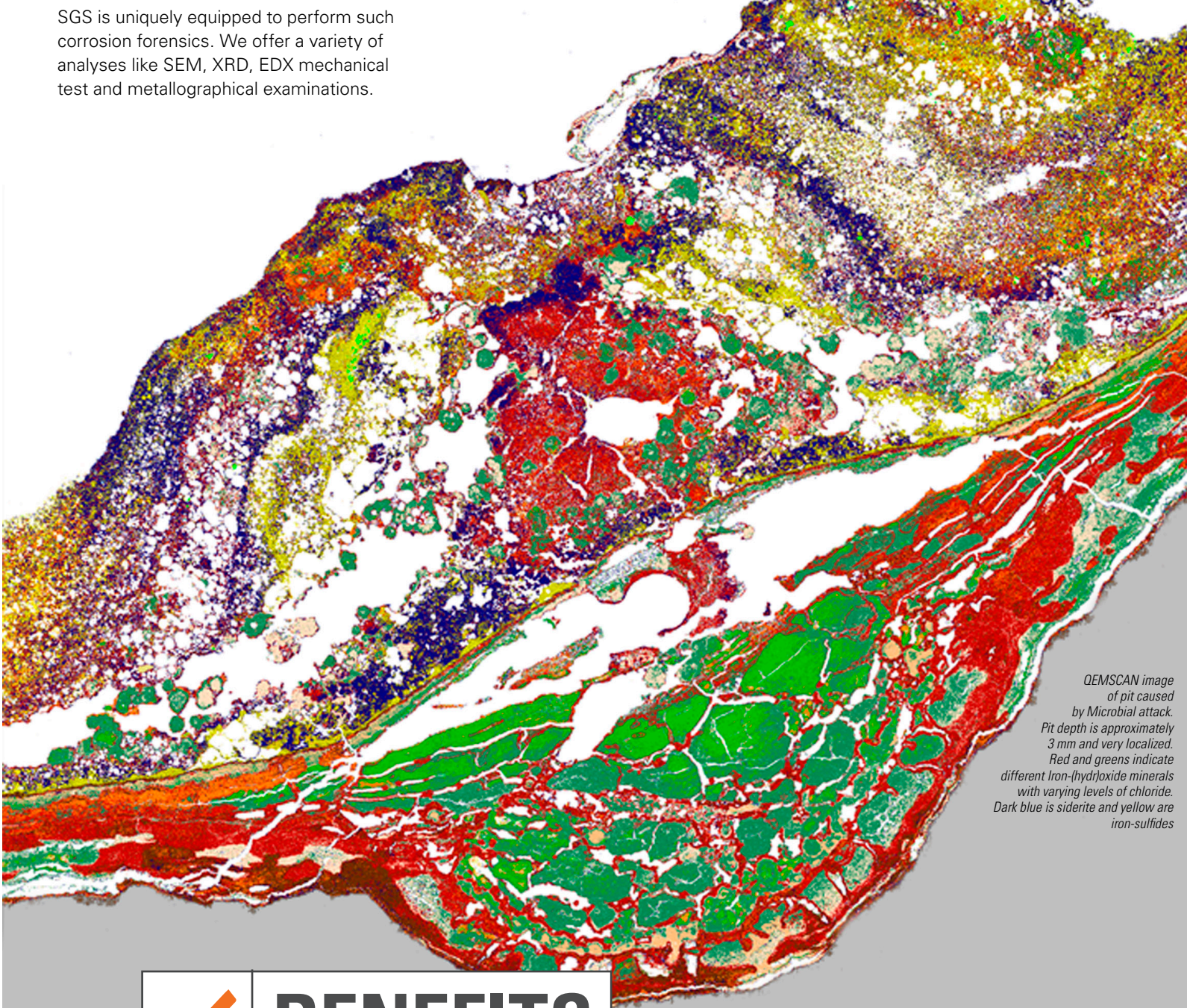
CORROSION FORENSICS

When a failure has occurred or corroded equipment is retrieved a detailed investigation should be performed to understand the corrosion mechanism. Such corrosion forensics will allow for optimization of the preventive measures taken in the past.

SGS is uniquely equipped to perform such corrosion forensics. We offer a variety of analyses like SEM, XRD, EDX mechanical test and metallographical examinations.

In addition, by using our tailored QEMSCAN analysis to assess corrosion products, we can identify the specific corrosion mechanism and recommend ways to prevent further failures in the future.

Microscopy of Pitting Corrosion in steel pipe



QEMSCAN image of pit caused by Microbial attack. Pit depth is approximately 3 mm and very localized. Red and greens indicate different Iron-(hydroxide) minerals with varying levels of chloride. Dark blue is siderite and yellow are iron-sulfides



BENEFITS



UNPRECEDENTED DETAIL



COST EFFECTIVE



INNOVATIVE TECHNOLOGY



PROVEN RESULTS

FACILITY INTEGRITY ASSURANCE

PREVENTION IS BETTER THAN REPAIR

Did you know?

- Microbial proliferation is exponential when unmitigated driving an accelerated risk to asset integrity, without monitoring and expert guidance on mitigation asset impacts are inevitable.
- Microbial Consortia have the ability to excrete polysaccharides which bind the biofilm matrix protecting the same from biocide interaction and providing a systems biofouling risk. This effect can also drive under-deposit corrosion and emulsion stabilization in process systems.
- In diverse and well developed microbial communities DNA is exchanged between species, causing important mutations and fast adaptation. This increases the communities protection against threats and certain biocides.
- There are studies that indicate microbes can communicate with each other to coordinate activity. Once important thresholds like high cell numbers or environmental conditions are met a mass attack can be initiated via “quorum sensing”.
- Microbes have a 4 billion year evolutionary history of adapting to harsh and ever-changing conditions. They are very resilient once present.

By identifying microbial communities early and monitoring frequently operators can assure they don't get a foothold.

IN-FIELD (NDT) TESTING AND INSPECTIONS

SGS Microbial Monitoring services can be deployed seamlessly with non-destructive testing (NDT) and (risk-based) infield inspections. Our corrosion engineers are trained to identify Microbial Influenced Corrosion issues and can acquire the necessary samples for further analysis.

With a worldwide reputation based on a proven track record, we are the complete and global infield inspection and non-destructive testing provider that you can trust. We offer you the most effective NDT methods to investigate the integrity of your equipment and assets.

Our comprehensive range of NDT methods can help you:

- Monitor the integrity of your assets using intrusive or non-intrusive methods
- Detect defects and irregularities before they result in severe damage or non-compliance
- Save time and money through fast and effective testing of your assets and equipment at every stage of their lifespan – from manufacturing through to on-site operation
- Ensure safe and reliable operation of your facilities

For your complete peace of mind, our qualified and certified inspectors provide inspections in accordance with international standards.

Best of all, with an network stretching across more than 40 countries, we can provide world-class non-destructive testing expertise and a local service, close to your operations – wherever and whenever you need them.

MICROBIAL MONITORING BY SGS

NEW TECHNOLOGY

New Innovative DNA and QEMSCAN technologies

PROACTIVE APPROACH

Gain better insights into microbial issues through our global database

FOCUSED OPERATIONS

Identify corrosion risk before it occurs

Optimize corrosion monitoring programs

Increase effectiveness of mitigation

INCREASE VALUE

Save cost on repair and replacement

Prevent downtime & production deferral

WHY SGS?

SGS is the world's leading inspection, verification and testing company. Recognized as a global benchmark for quality and integrity, we employ over 85 000 people and operate a network of more than 1 800 offices and laboratories around the world. We are constantly looking beyond customers' and society's expectation in order to deliver market-leading services wherever are needed.

We have a history of undertaking and executing large-scale, complex

international projects. With a presence in every single region around the globe, our people speak the language and understand the culture of the local market and operate globally in a consistent, reliable and effective manner. We provide innovative services and solutions for every part of the oil, gas and chemical industry. Our global network of offices and laboratories, alongside our dedicated team, allows us to respond to your needs, when and where they occur. Our reputation for independence,

excellence and innovation has established us as the market leader in providing services that improve efficiency, reduce risk and deliver competitive advantage for you.

FOR MORE INFORMATION ON SGS MICROBIAL MONITORING SERVICES CONTACT

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WHEN YOU NEED TO BE SURE

