I&E INDUSTRIES & ENVIRONMENT

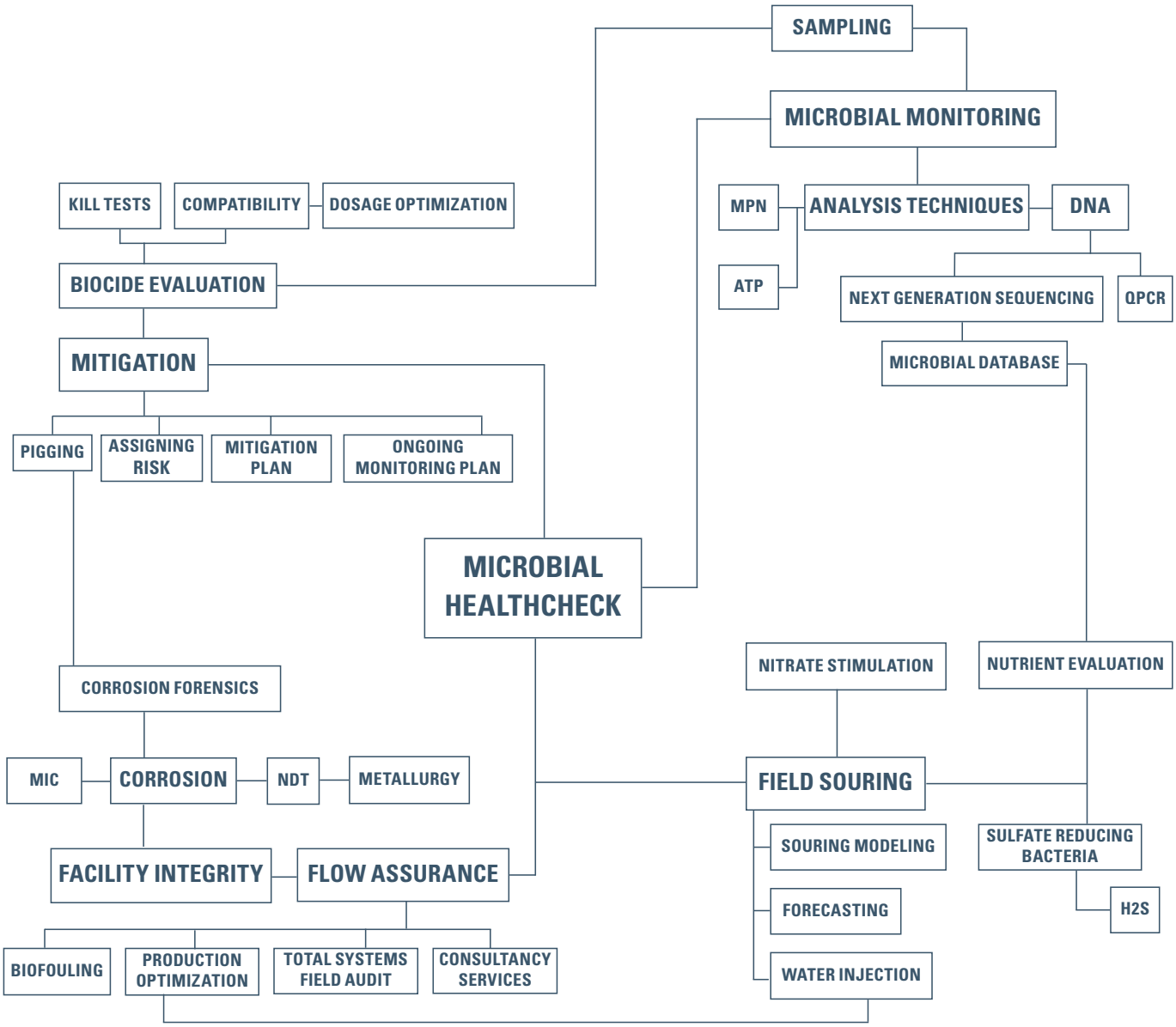
SGS MIRAS - Microbial Risk Assessment Services

SAFER
GREENER
SMARTER

SGS

Accurate fluid properties and optimised extraction

Independently identifying the most time optimal and cost-effective mitigation strategy for specific MIC, biofouling and / or biogenic souring challenges



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 he 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.

SGS MIRAS GLOBAL 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

INTERPRETATION

- Propietary 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 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 ans corrosion forensics.

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.

SGS MIRAS 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.
- **ADP, AMP measurement including EAC and AMPi calculations** to review microbial dormancy and interfered stress
- **NGS (Next Generation Sequencing)** is a very powerful technology that allows for the identification of all microbes present in a sample.
- **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.

NEXT GENERATION SEQUENCING

DNA analysis via Next Generation Sequencing (NGS) is performed in our Global Biosciences Center in Lisbon, Portugal.

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.

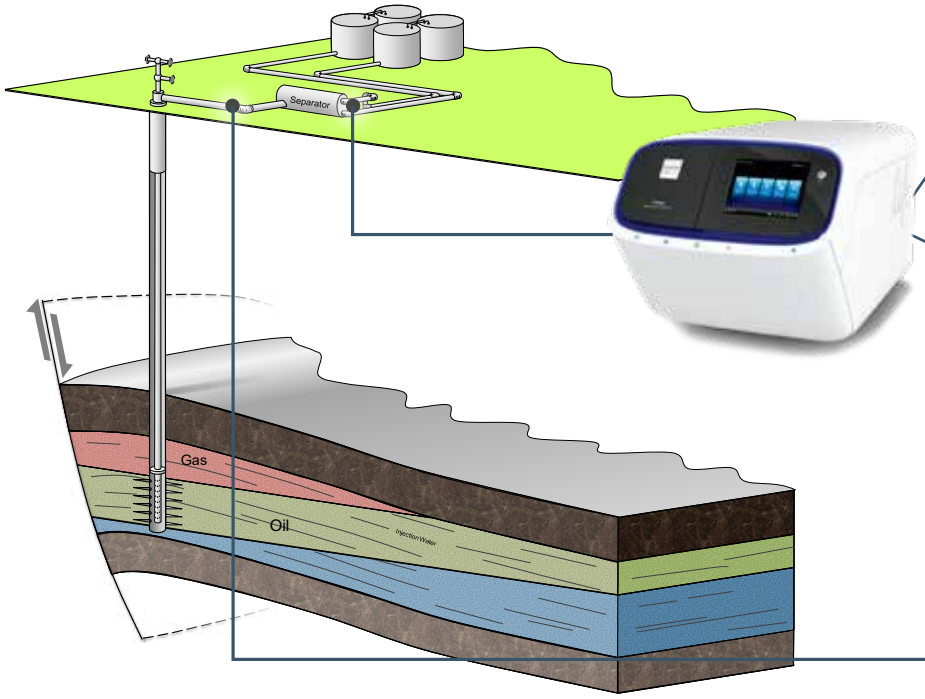
SGS recommends to deploy NGS technology during certain field operations and at multiple stages in a field life or monitoring program.

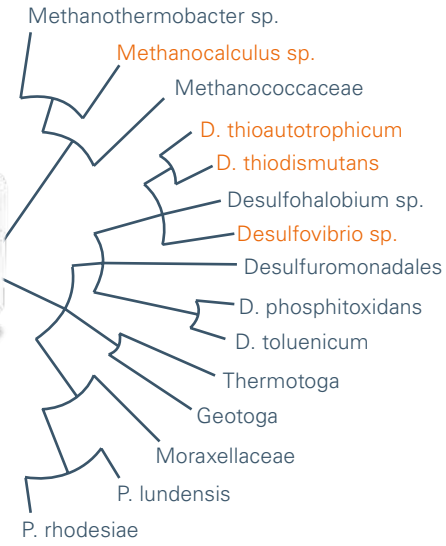
SGS MICROBIAL MONITORING SERVICES

	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 MIRAS Workflow

PROGRAM DESIGN — **FIELD SAMPLING** — **NGS DNA ANALYSIS**





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.

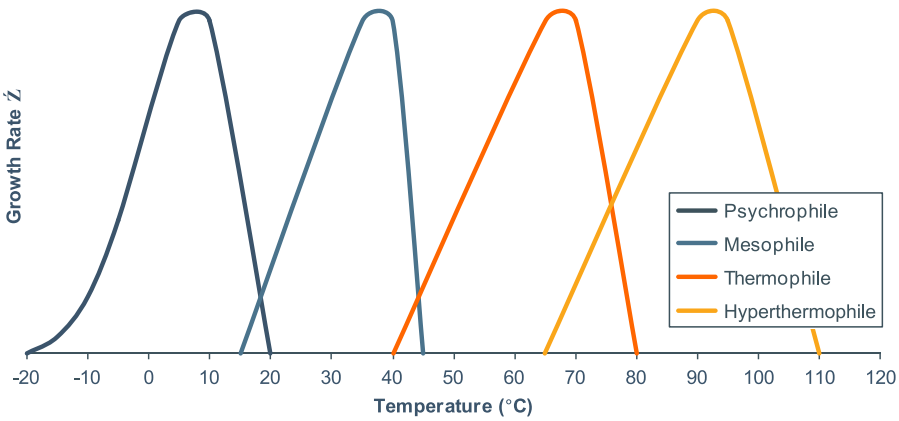
The large range in operating windows and conditions within and oil field and its facilities does mean we can find many different species and types of communities within such a system.

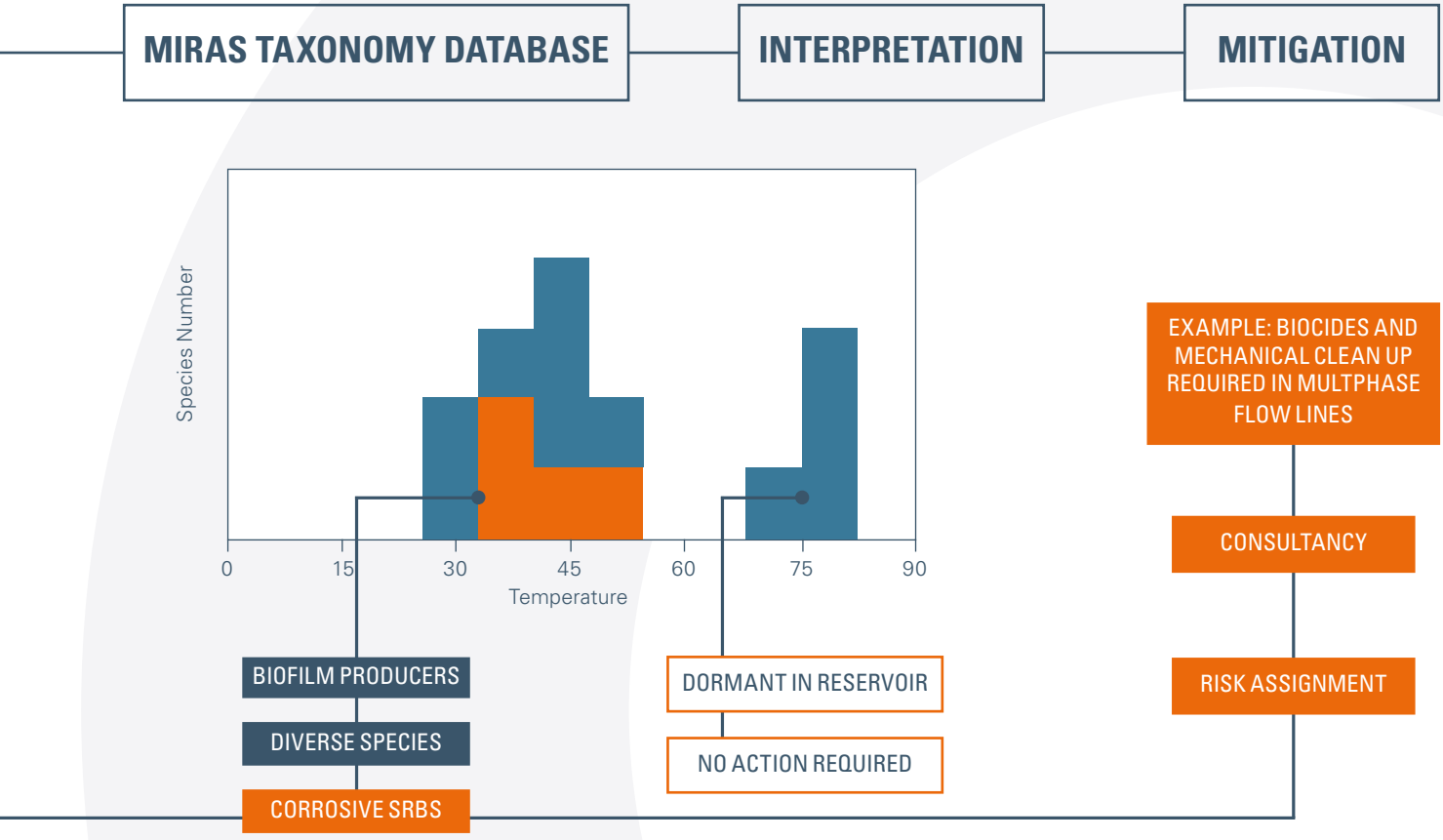
For instance, species present in the reservoir may strive under much higher temperature conditions than those present in the pipelines of a water injections system and associated wells.

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.





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 any industrial process.

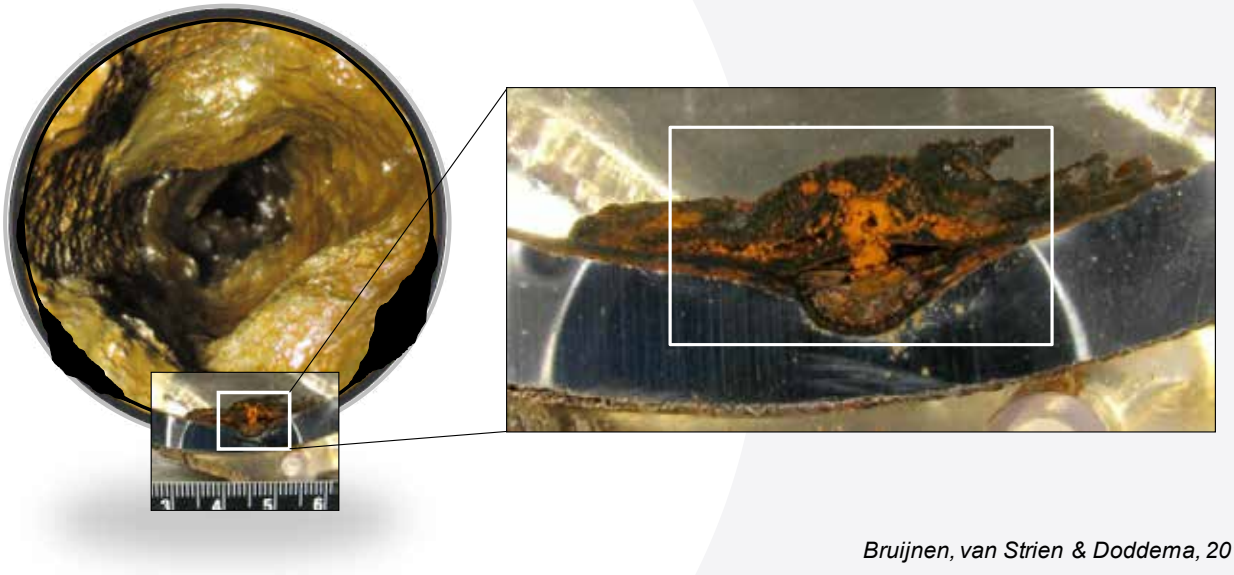
Microbiologically influenced corrosion

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

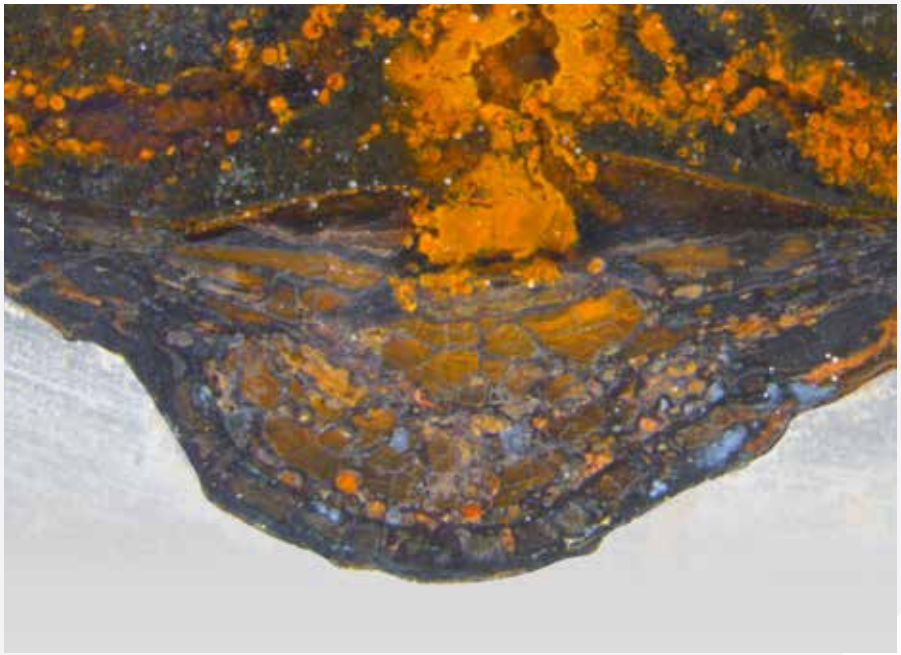
The microbes can trigger anodic reactions, which leaches iron-ions from steel. This process can result in very localized corrosion, called pitting.

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.

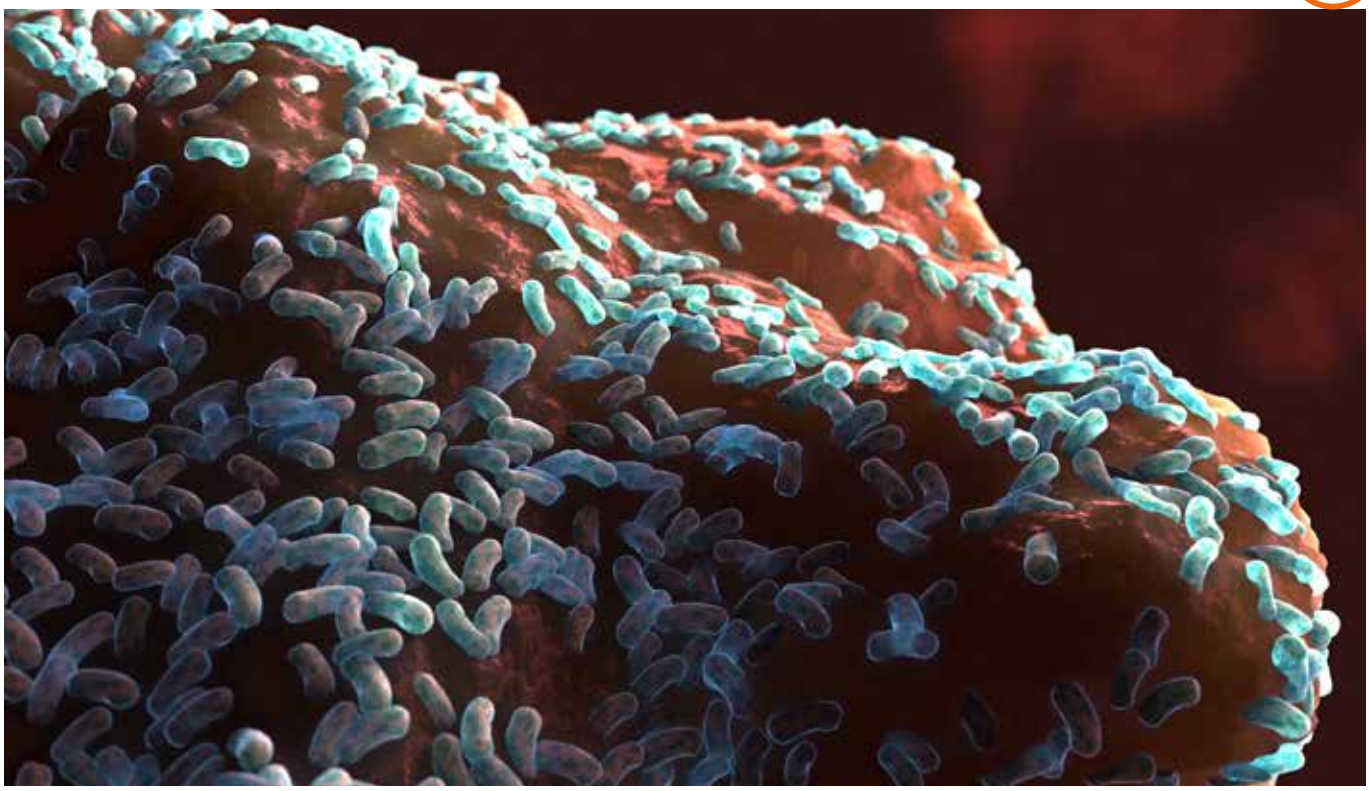
However, this is often impossible, due to accessibility and technological imitations or such monitoring is simply deemed too expensive. The only option that remains is monitoring pitting is by characterizing the microbial communities in the biofilms responsible for them.



Bruijnen, van Strien & Doddema, 2018



Next Generation Sequencing (NGS) is an identification tool. With NGS, it is possible to map every microbe (organism) based on the specific DNA basis



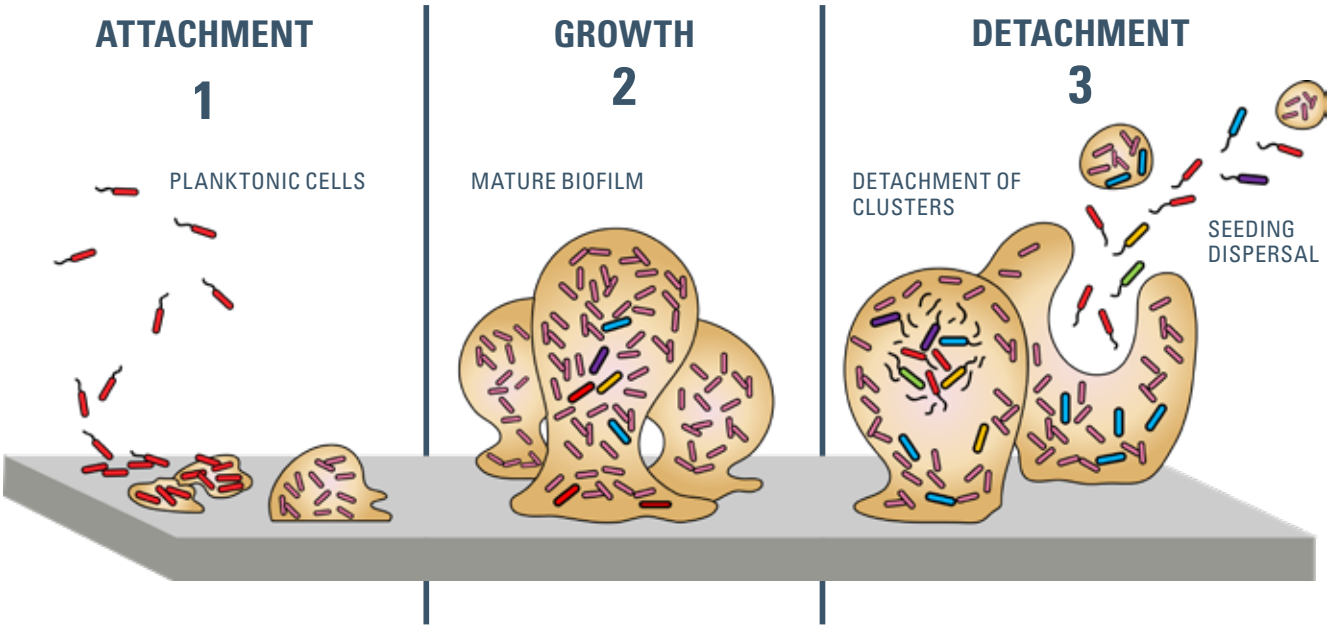
The key to MIC: biofilms

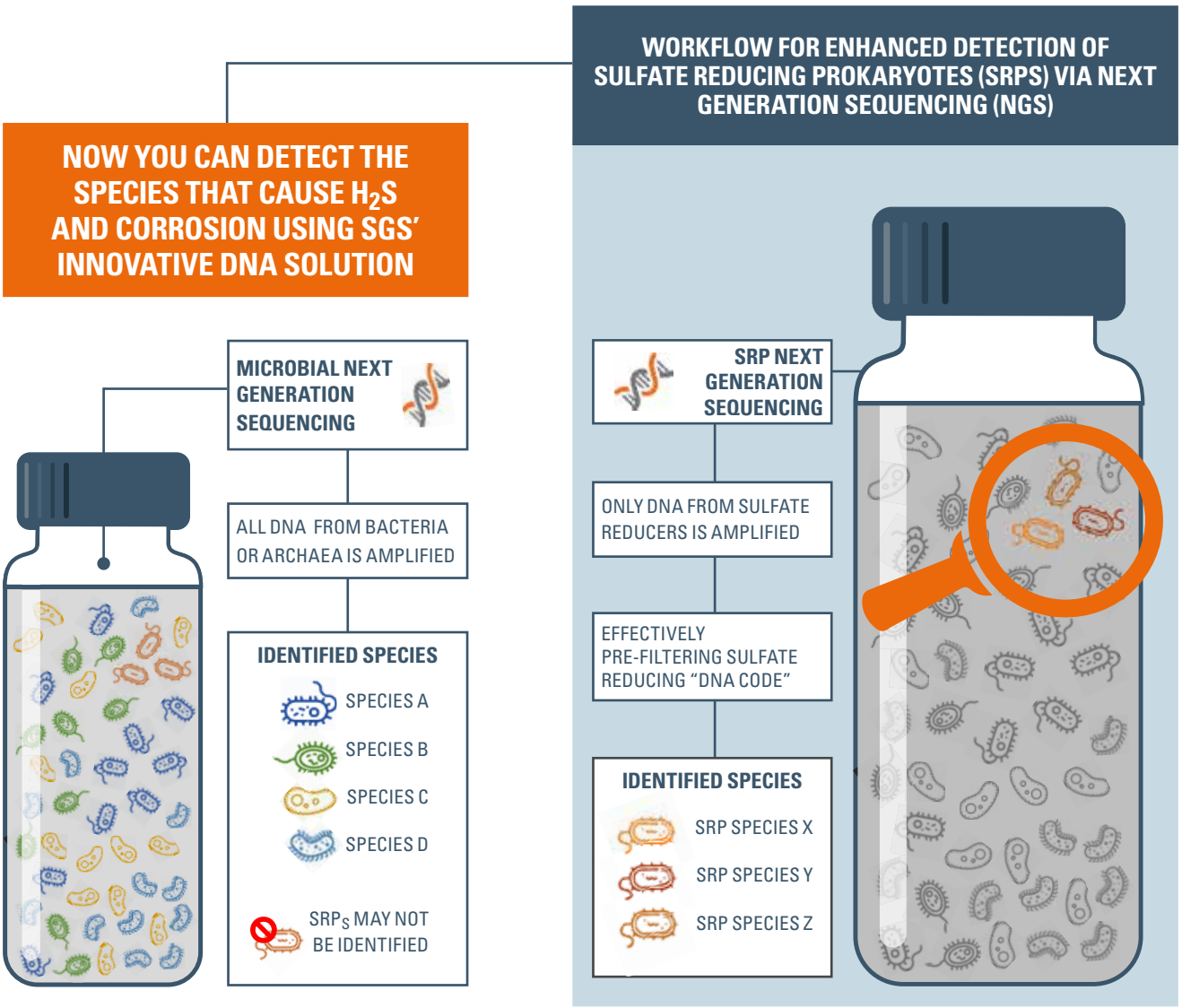
The growth of a biofilm into a 'tubercle' is key to the fast development of the underlying pits. Biofilms form by the adhesion of some initial microbes to a steel surface. Once certain microbes that can excrete extracellular polymeric substances (EPS) join the community the biofilm starts to take shape.

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 identiify 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 'prefiltering' 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 additional 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 reason, scientists at SGS 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.

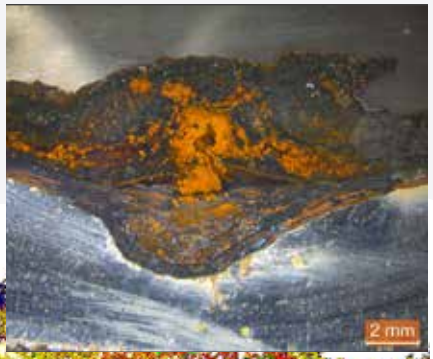
Corrosion forensics

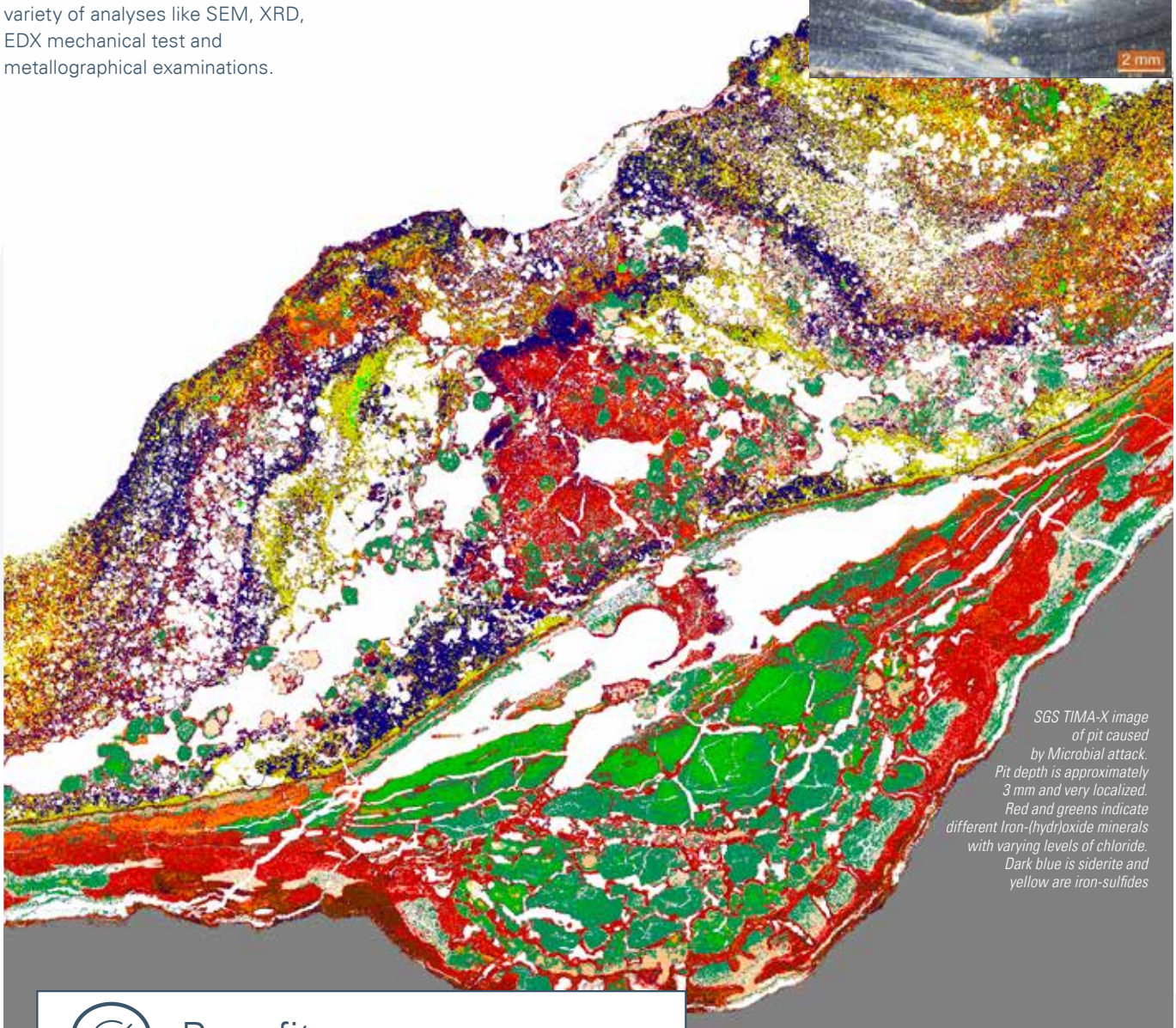
When a failure has occurred or corroded equipment is retrieved a detailed investigation should be performed to understand the corrosion mechanism. Such corrosion forensics will allow for optimization of the preventive measures taken in the past.

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 SGS TIMA-X analysis to assess corrosion products, we can identify the specific corrosion mechanism and recommend ways to prevent

Microscopy of Pitting Corrosion in steel pipe





SGS TIMA-X image of pit caused by Microbial attack. Pit depth is approximately 3 mm and very localized. Red and greens indicate different Iron-(hydr)oxide 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 polysacharides 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 everchanging conditions. They are very resilient once present.

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

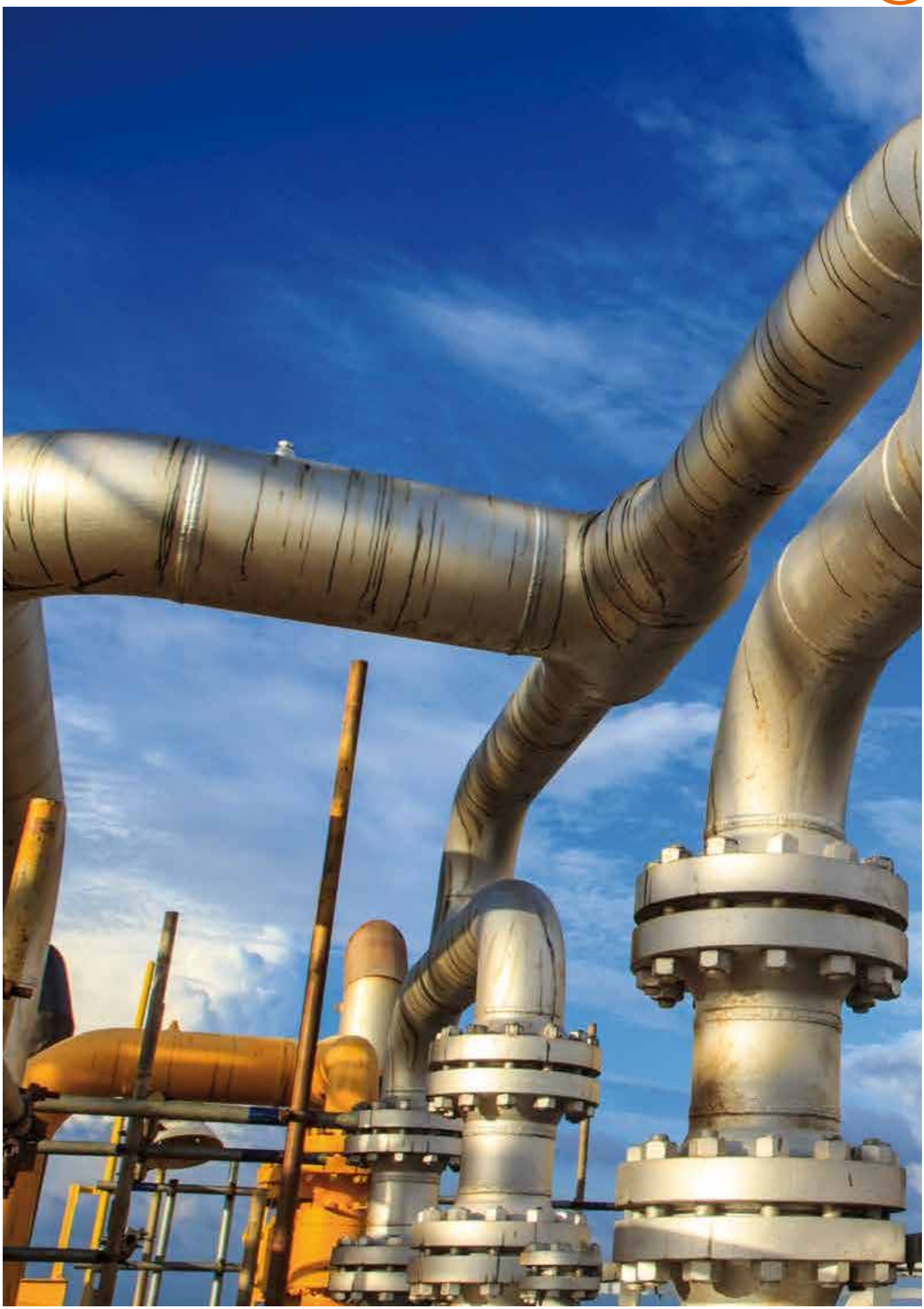
Microbial monitoring by SGS

New technology		Proactive Approach	Focused operations		Increase value	
Advanced innovative technology basis including Molecular Microbial Methods (MMM)	Gain better insights into microbial issues through our global database	Identify corrosion risk before it occurs	Optimize corrosion monitoring programs	Increase efectiveness of mitigation	Save cost on repair and replacement	Prevent downtime & production deferral

Why Rely on SGS MiRAS Studies?

SGS integrated microbial services provide operational value and assist with:

- Improving understanding of Asset Risk and plan accordingly for Facility Integrity and Microbial Control.
- Independently identifying the most time optimal and cost-effective mitigation strategy for specific MIC, biofouling and / or biogenic souring challenges.
- Reducing OPEX on chemical biocide spend
- Planning of field (re)development with a strategy around Microbial Control eradicating the impacts of corrosion, biofouling and H2S reservoir souring.
- Implementing robust reservoir souring and corrosion management strategies securing asset operational safety.



Why SGS?

The SGS Global Biosciences Center in Lisbon develops and guides the deployment of integrated services for a wide range of industries and sectors.

Our experts work on new methods and services that leverage molecular and micro-technologies. We work with governments and industry leaders to create new testing methodologies that you can trust. We also collaborate with academia to develop and pilot new methods and bring immediate value to your organization.

Most importantly, we work with you to find innovative and tailored solutions to solve even the most complex challenges.

FOR MORE INFORMATION ON SGS MICROBIAL MONITORING SERVICES CONTACT INDUSTRIES.ENVIRONMENT@SGS.COM

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WHEN YOU NEED TO BE SURE