



Function-Related Dosage of Corrosion Inhibitors; The Development of An On-Site, Operator Deployable Technology

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Presentation Outline

- Who is LUX Assure?
- Background
- What are corrosion inhibitor micelles?
- Where are we now?
- What are we looking to achieve in the future?



LUX Assure Ltd

- A provider of on-site chemical detection products.
- Innovative approach; unique products; strong IP culture; POC to commercialisation
- Founded in 2001; focused on O&G industry in 2009
- Investors  Statoil    
- Headquartered in the UK, with worldwide agents
- Relevant to the North Sea, and beyond



➤ Our mission is to establish LUX Assure as a leader in innovative technologies that enable independent, cost effective, **better-informed chemical management** decisions




➤ Value for our customers:

- Cost savings (chemicals; analysis; fines)
- Simplifying operations
- Independence of data – not from chemical and service providers
- Improved accuracy
- Improving asset integrity management
- Minimising environmental discharges



LUX's Products:

➤ **Simple** to use **on-site** chemical detection kits

-  **MMICA™** - hydrate inhibitor management
-  **oMic™** - corrosion inhibitor management
-  **TRAXBiC™** - surfactant biocide mapping



Background



Informing Better Corrosion Inhibitor Management

Timeline

- Conversation with an operator in a corridor 2008 ← **Idea 2008**
 - Fact-checking
 - Technical evaluation (2008 POC shown) ← **Proof of concept 2008**
 - Commercial evaluation
 - IP evaluation
 - Decision point ← **Funding 2009**
 - Funding (Operator and TSB funding 2009)
 - Rapid incremental experimentation
 - Access to relevant test samples
 - Access to expertise
 - Access to fields (first field deployment 2011) ← **1st field trial 2011**
 - Further field work (2011-2013)
 - Commercialisation (2013) ← **1st sale 2013**
 - Field trials
 - Sales
 - Feedback from clients meant redevelopment 2015/16
- Last icorr presentation 2014

Why Bother With Corrosion Inhibitor Monitoring?

- Corrosion inhibitors are an important part of corrosion management
- Their dosing needs to be monitored and managed

Are they available at recommended dosage for the required amount of time?

Has the system changed?
Does their dosage need to change?

Is injection equipment working?

➔ Good management requires good monitoring

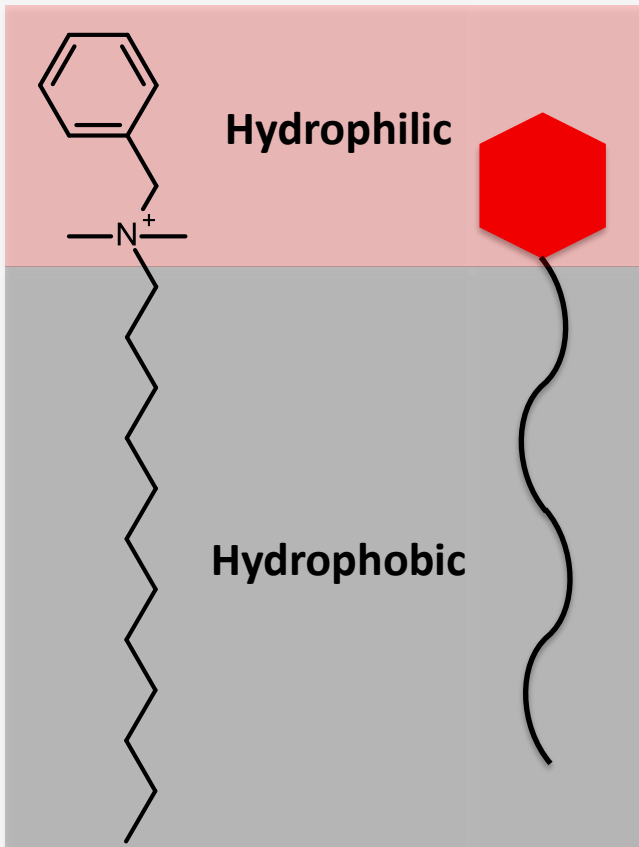
Corrosion Inhibitor Monitoring

- Some methods are excellent – LC-MS
 - Although sending samples to specialist labs for analysis takes time and is expensive
 - Often the only lab it can be sent to is the chemical vendor, so independence in monitoring is not possible
- Some methods can be used on-site
 - Sometimes they work OK
 - But lots and lots and lots of operators complain to us that they are inaccurate

Survey: More than 37% respondents said they strongly agreed that improving inhibitor management could have significant impact on reducing production upsets, reducing OPEX or improving long term asset integrity

There is an opportunity for a better on-site corrosion inhibitor monitoring tool

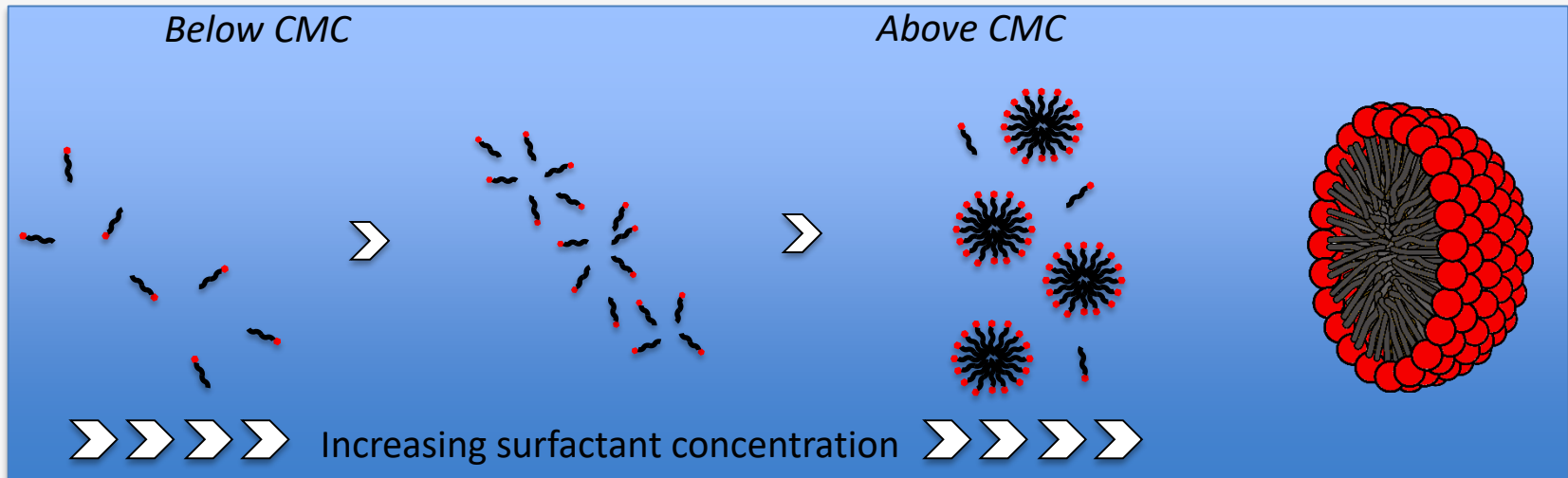
Surfactant



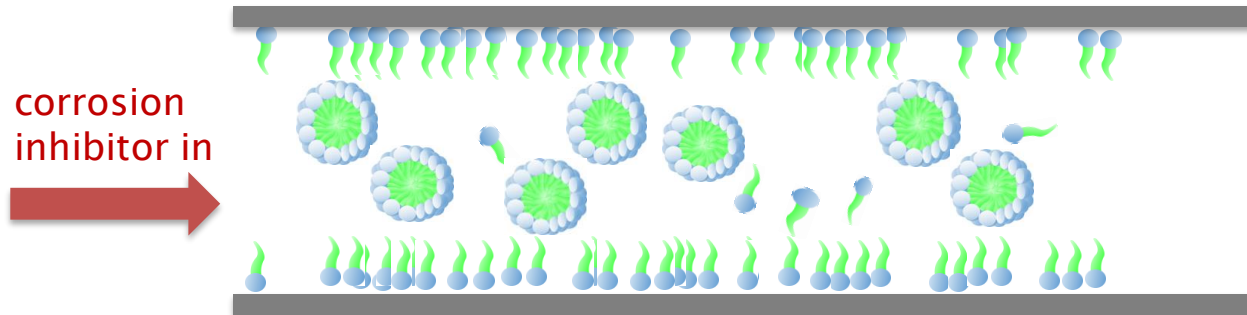
- Corrosion inhibitors (quats, imidazolines, phosphate esters)
- Surfactant biocides (quats)
- Form aggregate structures above chemical specific concentrations → micelles

Micelles and Critical Micelle Concentration (CMC)

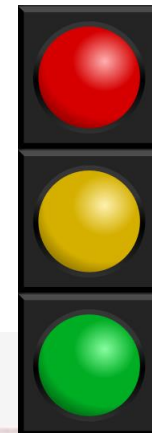
- ▶ CMC is defined as the concentration of a surfactant above which micelle formation occurs



- PREMISE: corrosion inhibitors form micelles once all available sites for adsorption (e.g. pipe wall) are occupied



Can these micelles be detected and used to inform corrosion inhibitor management? Not just amount but information...



Literature: Optimal Corrosion Rate = CMC

P. Dupin, A. De Savignac and A. Lattes *Mater. Chem.* **6**, 6, (1981), pp.443-453

D.P. Schweinsberg and V. Ashworth *Corros. Sci.* **28**, 6, (1988), pp.529-545

A. Frignania, M. Tassinari

N. Hajjaji, I. Rico, A. S.

M. Elachouri, M. S. Haj

M. Elachouri, M. S. Haj

M. M Osman, A. M. A O

J. A. Dougherty, *Corro*

V. Jovancicevic, S. Ran

R. Bäßler, M. Uhleman

E. E. Foad El Sherbini /

M. El Achouri, S. Kertit

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S. Rajendran, R. M. Jo

T. Moon, D. Horsup, Co

A.A. Atia and M.M. Saleh

Z. Wei, P. Doby and P.

M. Knag, J. Sjöblom, G

M. L. Free, *Corros. Sci.*

46, 12, (2004), pp.3101-3113

D. Chebabe, Z. Ait Chikh, A. Dermaj, K. Rhattas, T. Jazouli, N. Hajjaji, F. El Mdari and A. Srhiri, *Corros. Sci.* **46**, 11, (2004), pp.2701-2713

S. Algabera, E. M. El-Nemmaa and M. M. Saleh, *Mater. Chem. Phys.* **86**, 1, (2004), pp.26-33

B.P. Binks, P.D.I. Fletcher, J.T. Hicks, W. H. Durnie and D. I. Horsup, *Corrosion* **7**, (2005), pp.1-10

Z. Ait Chikh, D. Chebabe, A. Dermaj, N. Hajjaji, A. Srhiri, M.F. Montemor, M.G.

G. Mu X. Li, *J. Colloid. Interf. Sci.* **289**, 1, (2005), pp.184-192

M. M. Saleh and A. A. Atia, *J. Appl. Electrochem.* **36**, (2006), pp.899-905

D. John, A. Blom, S. Bailey, A. Nelson, J. Schulz, R. De Marco and B. Kinsella, *Ph*

"Progress in Corrosion Research", E. L. Bettini (editor), 1st ed. (New York, NY: N

M. A. Migahed and A. M. Al-Sabagh, *Chem. Eng. Commun.* **196**, 9, (2009), pp.105

A. M. Al-Sabagh, N. S. Tantawy, N. M. Nasser and M. R. Mishrif, *J. Disper. Sci. Te*

C. M. Murira, (2010), Ph.D. Thesis, Princeton University.

K. Tsui, J. E. Wong and N. Park, *Corrosion 2010*, paper no. 10326, (San Antonio, TX.: NACE 2010)

A. M. Badawi, M. A. Hegazy, A. A. El-Sawy, H. M. Ahmed and W. M. Kamel, *Mater. Chem. Phys.* **124**, (2010), pp.458-465

F. A. Ansari and M.A. Quraishi, *Port. Electrochim. Acta.* **28**, (2010), pp.321-335

J. Hu, D. A. Koleva, J. H. W. de Wit, H. Kolev and K. van Breugel, *J. Electrochem. Soc.* **158**, (2011), pp.C76-C87

BUT a review of 43 papers indicates that only ONE used formulated inhibitors, with the majority looking at single components e.g. an imidazoline and all tested in model systems, not in complex field fluids

Does the relationship hold true with formulated chemicals and in real fluids?

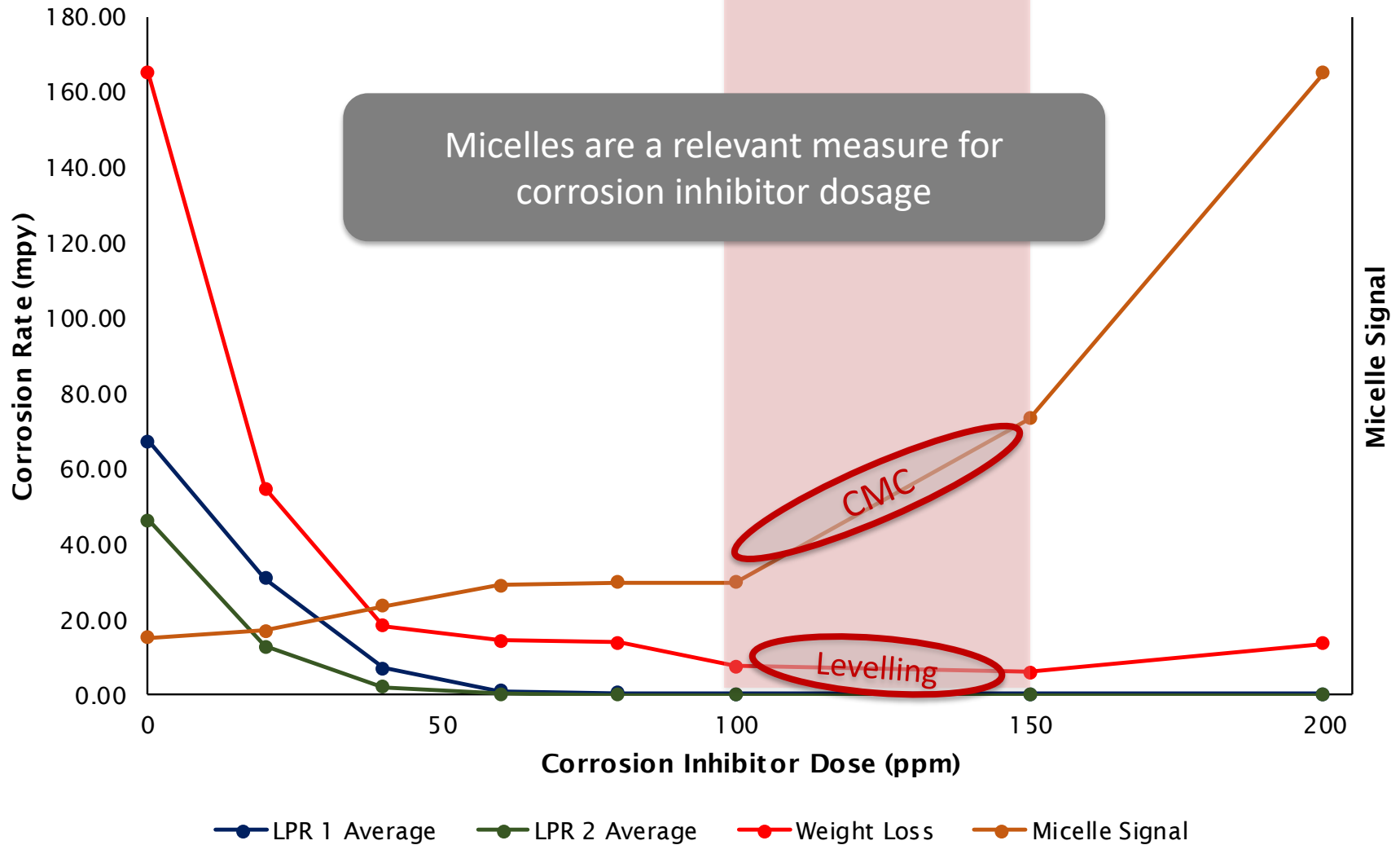
"The CMC should be used as the treatment rate in the field since maximum inhibition is achieved at this concentration"

Corros. Sci. **43**, 4, (2001), pp.267-

(NACE 2005)

Corros. Sci. **47**, 2, (2005), pp.447-459

Flow Loop Corrosion Rate and Micelle Correlation





A Product to Inform Corrosion Inhibitor Management

Improve operations: fewer upsets; are pumps functioning etc

Independent data on chemical management

Higher throughput corrosion inhibitor evaluation

Enhance long term asset integrity. Save future integrity costs

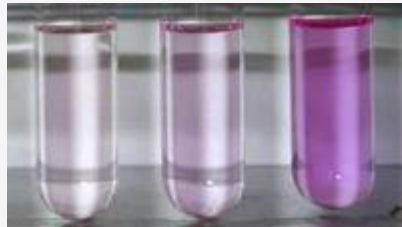
Save chemical costs in overdosed systems (up to £1k/day)

Using CoMic™



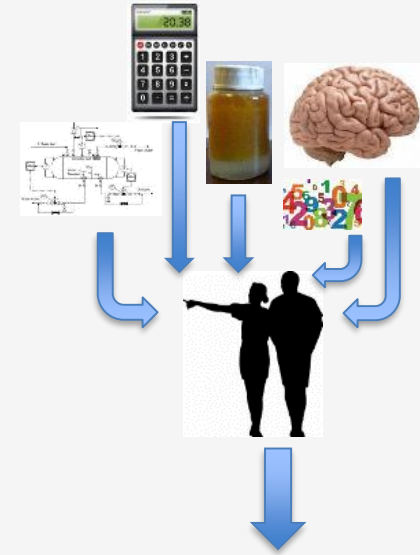
OPTICAL ANALYSER

+



DETECTION REAGENTS

+



DATA ANALYSIS

- We add nothing to the system – only take a sample from it for testing
- Water samples analysed by on-site operators using optical analyser and detection kits in on-site lab
- Data sent to LUX for analysis and reporting – quick turnaround

Since 2014 almost everything has evolved

- More work on the instrumentation; now an entirely new instrument
- More work on protocols → client deployable
- More work on the science; micelle link to the corrosion rate
- More chemicals tested
- More field deployments

Development continues to enhance the product

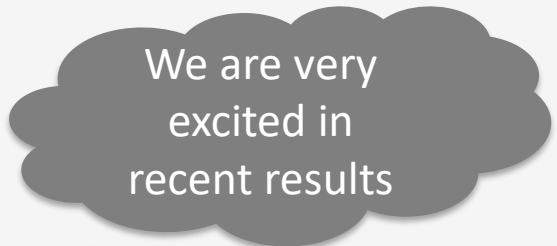
- Looking at surfactant biocides
- How to apply to systems below the critical micelle concentration
- More fields, more conditions, influence of other production chemicals
- Automated data processing

Evolution of CoMic™ - instrumentation and detection 'kits'




Effective assurance technologies for the oil and gas industry

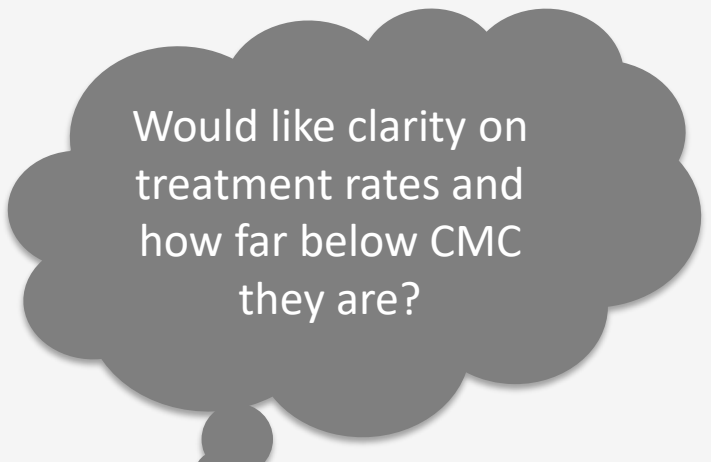
Feedback - examples



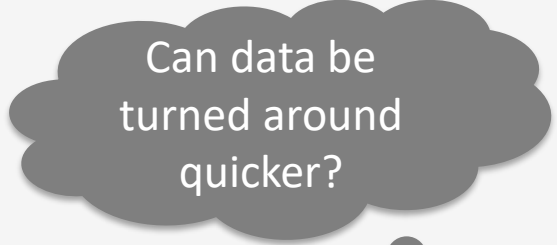
We are very excited in recent results



Very simple to use



Would like clarity on treatment rates and how far below CMC they are?



Can data be turned around quicker?

Steps in using CoMic™

- Site identified
- Safety data sheets send to LUX → reviewed
- Chemical/fluid tested @ LUX → confirmation is suitable
- Pre-deployment report sent → Confirmation of deployment
- Training of on-site personnel
- Equipment and kits sent to site
- Samples taken from system and taken to on-site lab
- Mixed with CoMic™ detection reagents
- Placed in instrument
- Data collected transmitted to LUX → data processing
- Report provided
- Data compared with other corrosion management tools to inform decisions e.g. coupons, probes, pump information

How to use CoMic™? How frequently?

➤ It depends on what the asset wants to know

"We want a better residual test"

- ➔ *if micelles can assist us with understanding residuals then we'll use CoMic™*
- ➔ *Use regularly (daily, weekly, monthly... depends on stability of the system, its criticality, the level of availability required, pump reliability)*
- ➔ *costs -£200-350 a sample; £350/day equipment hire. Lower or higher depending on frequency*

"Micelles can help us understand optimal dose and that's important to us"

- ➔ *We want to know if we're protecting our infrastructure as best we can, whether we can save money if we're overdosing, whether we can reduce production upsets*
- ➔ *Special project. Longer in duration, but may be a one off*
- ➔ *Costs - depend on frequency \$5,000 for a client-deployed test of a few samples lasting a few days to \$40,000 for a longer period using LUX staff*

We'll take CoMic™ into our labs to assist with chemical qualification and use it to inform field dosage and then use CoMic™ on-site to check this is being dosed

The Operating Envelope

- Is an optical technique
 - Oil can be present (1-2% water cut OK) but the separated water phase must have good enough sample clarity. Tight emulsions are not suitable
 - Ideally we can have 50 mL water to test



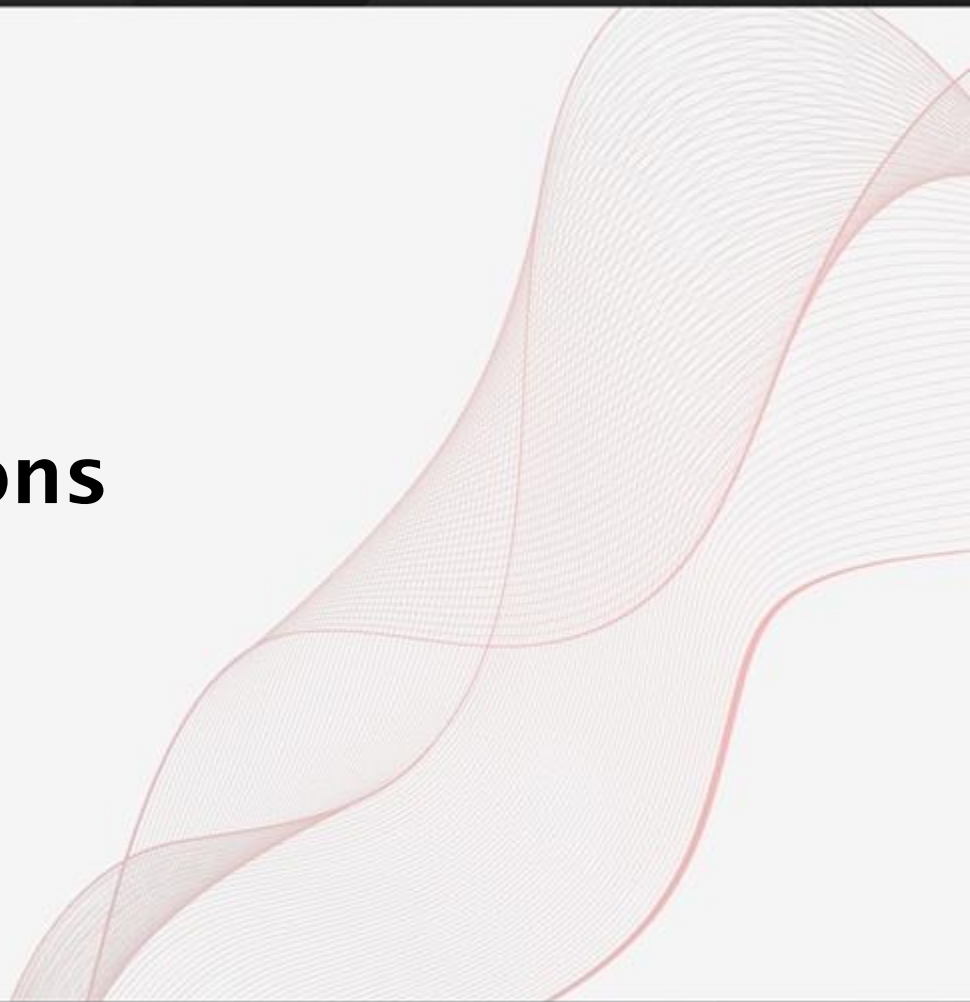
- Production chemicals can be present. Some may interfere (surfactant biocides; scale inhibitors potentially; KHIs potentially) and we ask to screen in advance of deployment
- Need some space in an on-site lab (1 m x1 m); need power source; need water

Common questions...

- ❖ Does it provide a residual concentration value for individual chemical components
- ❖ What if multiple chemicals are being used in different lines and the chemicals co-mingle
- ❖ Can it determine how effective the particular inhibitor is
 - If the client is using a bad chemical (e.g. it doesn't form a good film on the surface) then CoMic™ can only provide information on whether they are using the optimal amount of a bad chemical
- ❖ Can it measure where corrosion has occurred in an under-dosed system
- ❖ What is 'optimal'? Weld corrosion. Economics

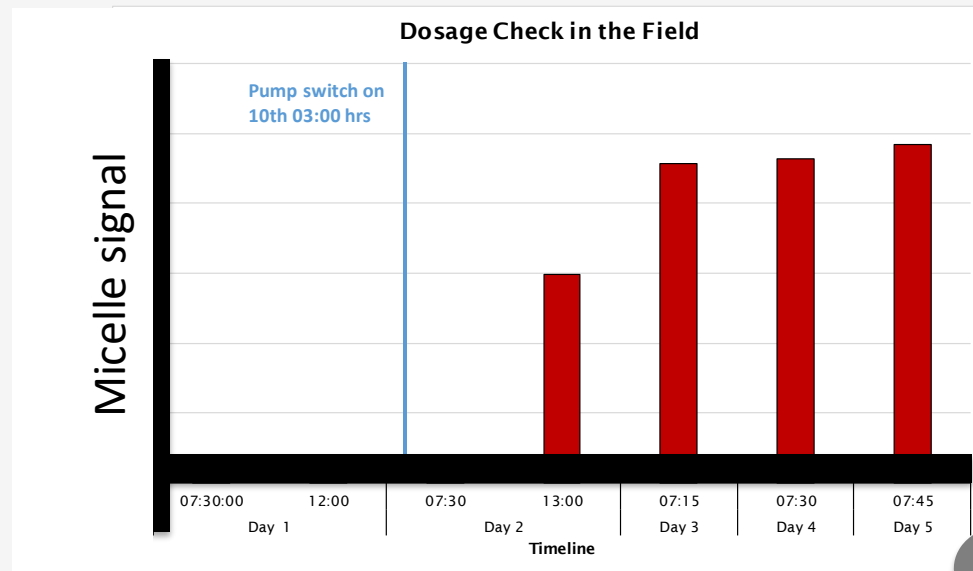


applications



Example 1: Improve Operational Management e.g. is The Pump Working?

- UK offshore field
- Samples from HP Separator
- Initial results showed no chemical – reported to operations
- Corrosion inhibitor pump found to be off
- Pump switched on – micelles detected after approx. 10 hours



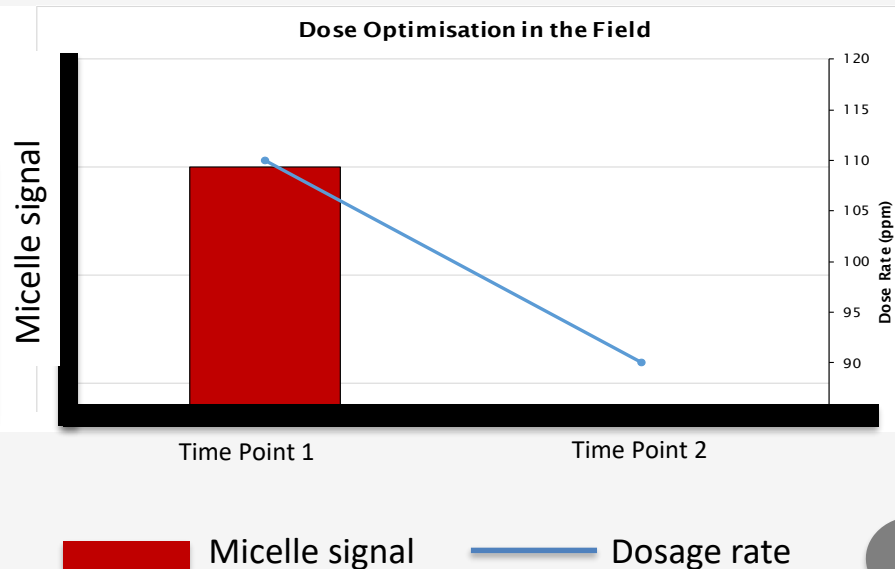
Deployed by operator

Improved chemical management

Example 2: Is the Amount of Chemical at an Optimal (Functional) Dose?

- Highly sour field and production system using wetting agent required optimisation
- Chemical detected in initial sample, but not after dose reduced (as part of optimisation study)
- Reducing dosage not recommended – original dosage was optimal

- Depending on the asset cost savings of >1k/day feasible
- Enhance long term integrity
- Improve oil in water separation



Optimal dosage shown

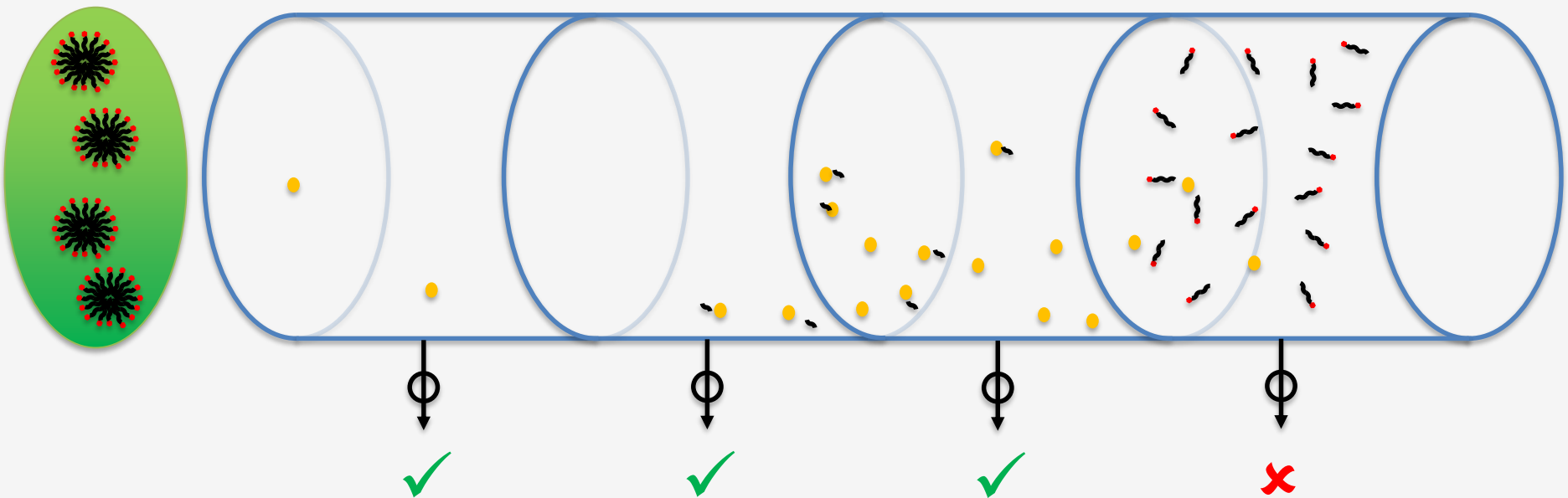
Example 3: Dosage optimisation

- North Sea
- Low water cut
- Production upsets; too much corrosion inhibitor?
- Sample taken → allowed to settle → water removed → CoMic™



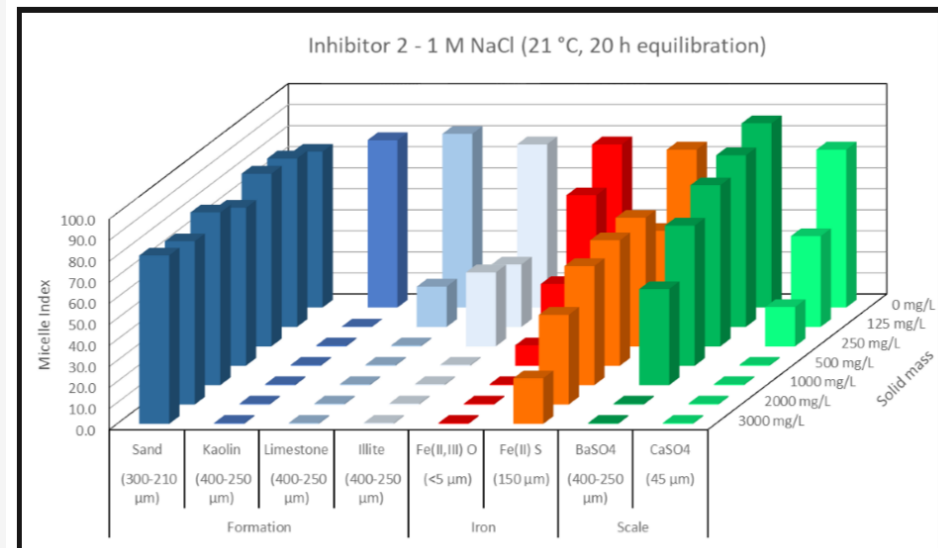
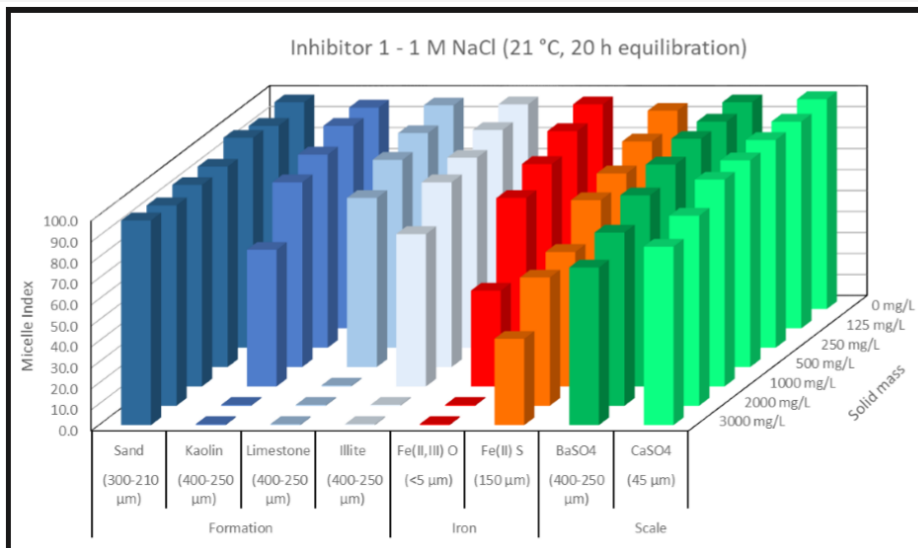
overdosing

Example 4: Impact of Solids



Example 4: Keeping on Top of Changing Conditions - Solids

- ❖ Solids production, water cut changes, chemical use etc will impact inhibitor availability and so the protection offered. Systems are dynamic and should be monitored routinely



- ❖ Different solids → different adsorption
- ❖ Different corrosion inhibitors → different adsorption
- CoMic™ has a place in informing corrosion inhibitor management following system changes

Summary



CoMic™

- Corrosion inhibitor detection. CoMic™ provides information on optimal amount not just data relating to concentration
- Commercialised in 2013, redeveloped 2016 to be more client friendly
- Client deployable version now in early commercialisation

What Next?

- Surfactant biocide mapping
- Automated data processing
- Online monitoring
- Feedback loop to pumps



Effective assurance technologies for the oil and gas industry