RUST NEVER SLEEPS:

UNCOVERING THE HIDDEN BUSINESS RISKS FROM PHYSICAL ASSET DEGRADATION

*Z. Coull

ICE Dragon Corrosion Inc.

OnRamp, 200 College St, Toronto

*(*Corresponding author: zoe@icedragoncorrosion.com)*

ABSTRACT

The global annual cost of corrosion across industries is estimated as USD$2.5TR ($8000 a second). Indirect costs (e.g. from loss of production) are expected to be a similar order of magnitude or higher. Specifically mining operations do not always have visibility on what their risks are costs are, or how physical asset degradation could affect their HSE risk profile and undermine their ability to ensure sustainable production. This paper will explore the source and magnitude of these risks and will introduce a framework of best practices for proactive corrosion management in mining operations.

KEYWORDS

Corrosion, Materials degradation, Wear, Failure risk, Corrosion Management, Asset Management, Costs, Operational Risks, Safety, Environment

INTRODUCTION

The annual cost of corrosion across industries is estimated at US$2.5 trillion, or $8000 a second! This number only accounts for direct costs of corrosion, such as materials, chemicals, asset replacement and repair. The indirect costs due to loss of production, service or asset availability are harder to measure, but are likely to be substantial. Corrosion is also linked to other serious business risks (see table below).

The estimated costs provided here were determined by the National Association of Corrosion Engineers (NACE) in the Impact Study in 2016. This survey pulled out information on corrosion cost from 243 global companies across a significant number of different industries. It was interesting to note the lack of involvement from Mining companies, suggesting that the Mining industry is behind the curve when it comes to dealing with corrosion risk.

CORROSION CAUSES RISKS TO:	POTENTIAL IMPACT
Safety	Injury / Fatality Legal fees Fines / Penalties
Environmental	Release / Spill Clean-up costs Fines / Penalties Permit suspension
Stewardship / Social Responsibility	Loss of social license Permitting difficulties Adverse share price reaction / investor sentiment Loss of talent
Direct / Indirect Costs	Unavailable / non-performing asset Production loss / business interruption Replacement / Repair cost Maintenance cost (person-hours on corrosion) Insurability and cost of insurance Cash flow volatility Credit rating impact Access to capital

CORROSION IN MINING

Mine sites can experience a wide range of different corrosion concerns. The severity is a function of many variables including climate, geography, location, age, type of ore, process, water source/quality, design etc. Corrosion and wear can impact production critical equipment such as tanks, vessels, piping, pumps etc. However, it can also affect fixed infrastructure assets (structural steel, concrete, civil structures) and mobile equipment fleets.

The corrosion mechanisms seen in mining range from general corrosion due to aggressive climates (e.g. coastal locations, hot humid tropical locations) to microbiological attack from bacteria in process water to highly aggressive process conditions. Each of these mechanisms requires identification, selection of suitable control methods and then long-term monitoring. However, often site teams are not fully aware of the risks each of these mechanisms introduce and there is no formal process for creating the visibility required to manage them.

Unfortunately, this has meant that corrosion has been a vital contributing factor for multiple catastrophic failures in Mining. These failures have resulted in fatalities, environmental events as well as production shutdowns. Examples of the business impact this can have are now discussed.

HUMAN SAFETY

While mine operations have a clear focus on production and shareholder value, the impact of corrosion on human safety should be foremost in mind. The importance of social license to operate and ensuring responsible stewardship is higher than it's ever been. Therefore, companies who do not foster a culture of 'health anxiety' around corrosion risk and its impact on safety, will increasingly find themselves punished by adverse share price reaction.

Corrosion-related failures are not 'acts of God'; they are preventable. An example is discussed below.

Shiploader Cable Corrosion

In 2018 shiploader operator Jorge Chilcumpa started his early morning shift, loading and unloading iron ore concentrate at a port in Chile. He never made it home from his shift.

That morning the tensioned cables holding up the crane and the operator cabin had corroded to the point of failure. The shiploader collapsed. The port closed for an extended duration.

ENVIRONMENT

The recent, well publicized tailing dam collapses in Brazil, and the obliteration of people and entire ecosystems, have brought global focus to the mining industry for all the wrong reasons. While these failures have largely been contributed to design, there has been one reported case where corrosion was noted as a contributing factor to the failure. Given that tailing dams must essentially last forever in many cases, the long-term durability of tailing dam components must be considered.

Coal Ash Tailing Dam Collapse

In 2014, 39,000 tons of coal ash spilled into the Dan River due to the failure of a tailing dam owned by Duke Energy. Drainage pipe corrosion beneath the facility was a contributing factor. Tailings and supernatant water flowed into the broken pipes and flowed miles down the river.

COST OF CORROSION IN MINING

While the NACE Impact Study provided us with a good estimate for the general cost of corrosion, no mining companies took part in the survey. We have found that very few operations can provide specifics on direct and indirect corrosion costs and the data tend to be hidden in other financial metrics. If leadership do not have visibility on the cost of corrosion to their business, they are not able to make strategic decisions or accurately allocate resources. The cannot ensure due diligence around management of the risk.

Since 2016, we have been collecting some initial baseline data for direct and indirect corrosion costs in mining from a small number of operations. These following data are averaged ranges from sites processing various commodities:

Mine	Average Direct Cost	Estimated Cost to reach life of mine
Mine 1	$1-4 M	$ 64 M
Mine 2	$3 M	$ 90 M
Mine 3	$5-10 M	$ 300 M

Mine	Annual Indirect Production Losses	Estimated Life of Mine (LOM) Cost
Mine 3	$15-20M	$ 600 M

Single Failure Type	Incident Indirect Production Losses
Tank microbial corrosion failure	$ 5 M
Pipe failure in Autoclave circuit	$ 50 M

Although there is insufficient data here to estimate a full cost of corrosion for the mining industry, these data present some interesting initial points:

- The average direct cost spend varies significantly from site to site as is a function of climate, location, age, water quality, ore type, knowledge of the site team etc.
- While Mine 3 might be an outlier in terms of corrosion risk, when direct and indirect costs are added over the expected facility lifetime, the costs are close to $1 BN. (This assumes that failure rates will remain linear with time, which as the plant ages is an unlikely assumption.) This is a significant level of loss that was previously hidden from leadership view. Corrosion can no longer be considered as “something we live with”.
- Often in the design of these facilities, corrosion was either not considered or was cut from capital build costs, resulting in many costly legacy issues. It is unclear how the impact for this cost cutting vs. operational cost is evaluated upfront (by both engineers and accountants), and how this would even be achieved without accurate financial data. There is an opportunity to create more accurate, long-term financial decisions.
- Finding the historical data on corrosion in these cases required much much manual forensic accounting as these costs are often bundled with other maintenance activities. Operating systems used at sites are not set up to isolate corrosion costs, making it difficult to record them accurately.

COMMON ROADBLOCKS IN MINING FOR MANAGING CORROSION RISK

In spite of the human safety, environmental and cost implications, Management can sometimes not be fully aware of the risks and can interpret the fact that "nothing terrible has happened yet" to mean "nothing will happen." The current status quo of corrosion management in mining shows common challenges:

- Lack of Strategic Approach: Corrosion business risks are not visible and therefore cannot be included in strategic leadership risk planning.
- Reactive Maintenance: Often corrosion work is not planned proactively.
- Siloed Thinking: Each site independently implements solutions and there is a lack of wider discussion in the industry around solutions.
- Lack of data: The right data is not always being collected in the right way or being used to improve decision-making.
- Lack of Technology Awareness: Existing corrosion technology solutions are not adopted in a systematic manner.
- Establishing skillset: Mine sites are often building teams from scratch through training and experience but corrosion awareness in many disciplines can be low.

THE PATHWAY FORWARD

Given the implications of corrosion for the mining industry, forward thinking operations are looking for structured and proactive approaches to manage this risk.

The NACE Impact Study 2016 also contains a set of collated best practices for proactive corrosion management. This framework is structured similarly to existing Asset and Risk Management standards (e.g. ISO 55000, ISO 31000) and is therefore familiar to those working in asset management and reliability. It has a risk-based corrosion planning process, which deals with specific corrosion engineering challenges, and a management structure based on collated best practices (Figure 1). Corrosion risks are identified and tracked to inform the strategic balance of mitigation efforts versus cost and asset performance/availability.

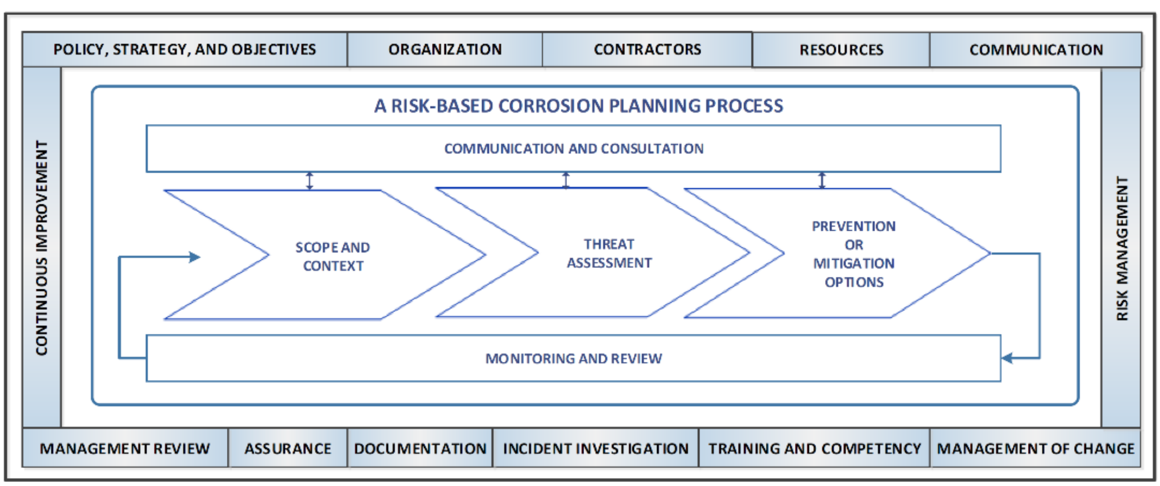

Figure 1: Best Practice Corrosion Management Framework (NACE Impact Study 2016)

The foundation for success of these programs rests on establishing leadership, organisation, roles and responsibilities and having high-quality technical and business data (Figure 2).

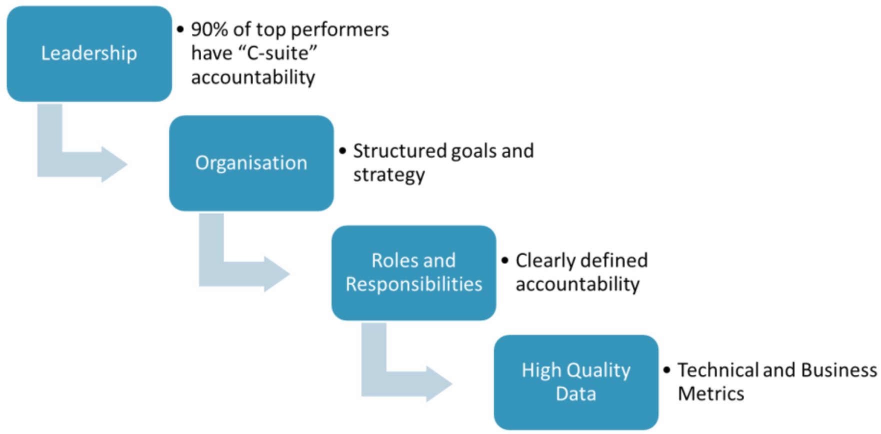

Figure 2: Core Foundation Elements for Corrosion Management Planning

A company that creates this foundation will demonstrate an enabling culture that will ensure that:

- Personnel roles are well defined, and accountability is tracked
- Deep, systematic risk assessments and detailed audits are carried out
- Positive personnel behaviour and risk reporting feedback loops are cultivated
- Lessons learned are integrated into their systems and processes proactively
- Excellent communication plans are implemented
- Strong management of change processes are created and followed

The Oil and Gas industry, being highly regulated, has some of the top performers in Corrosion Management. In this sector, adherence to Corrosion Management Best Practices creates the following self-reported benefits for companies:

- Improved leadership visibility on corrosion risk, allowing informed strategic business decisions
- Fewer failures that reduce lost production time
- Maintenance costs decrease over time (an average of 15-30% savings has been reported)
- Decreasing injury risks / property damage / environmental release incidents
- Ensuring due diligence around the management of HSE risks
- Life extension of assets
- Monitoring and inspection intervals increase

By adopting and adapting these best practices in mining, the intent is to improve the overall corrosion risk management approach within Mining and safeguard people, the environment and businesses from the impact of corrosion failures.

Corrosion Management in Mining is a relatively new concept and even in Oil and Gas, where it is better established, there is room for improvement (Figure 3).

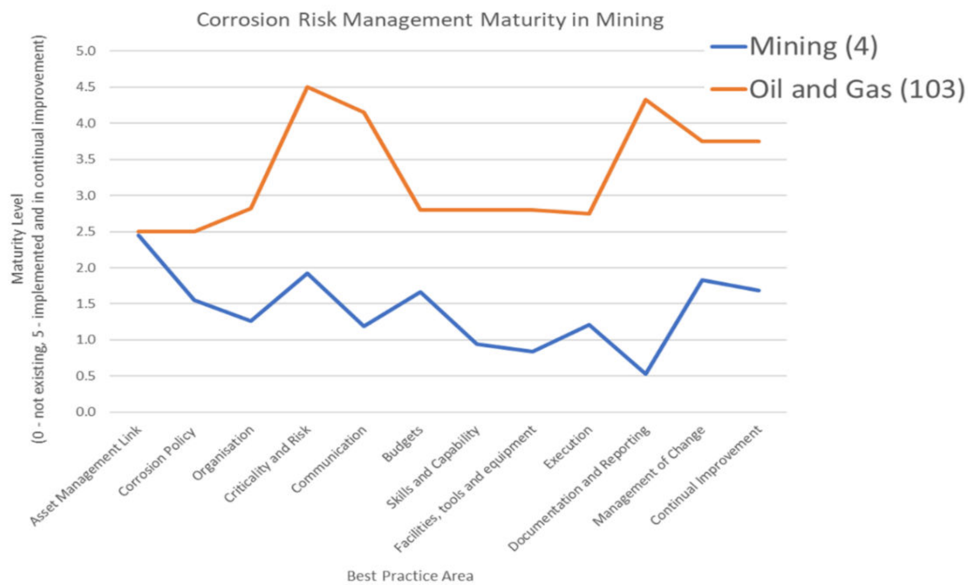

Figure 3: Comparing maturity (0 = not existing, 5 = implemented and in continual improvement) between the averaged performance of 103 oil and gas companies versus early findings from 4 mining companies

CASE STUDY

In this example, the mine operation had multiple corrosion concerns resulting from the following:

- Humid, warm climate
- Acidic, high sulphur material
- Bacteria in water that caused microbiologically influenced corrosion (MIC)
- Lack of assessment / awareness of corrosion at the design stage
- Lack of construction QA/QC for coatings and welding

At the start of the project, leadership were aware that corrosion was an operational risk, however they had minimal visibility on the risk, could not plan strategically and challenges were dealt with in a reactive manner. There was a lack of systematic approach for predicting issues, prioritizing them and planning work. There were insufficient budgets and personnel resources allocated to tackle the issues.

Over the course of a year (2018 – 2019), the team started to proactively tackle the top corrosion risks for the site and to develop a Corrosion Management Plan using the NACE Best Practice Framework (Figure 1). Improvements are already being reported, for example:

- Created a strategic policy based on NACE best practices that sets the direction for the team
- Created a systematic method for identifying and prioritizing corrosion risk vs. asset criticality
- Identified and tackled the top 5 corrosion risk concerns for the site

- Tracked various business metrics to allow baseline visibility on risks and costs, thus improving accuracy of budgets and work planning and providing justification for resource allocation
- Improved inspection and corrosion data collection for critical assets, creating data-driven decisions
- Created a dedicated team specializing in corrosion
- Developed awareness training program to improve understanding of wider responsibilities (rolled out to +800 site personnel)
- Introduced Asset Performance Management software to increase speed of inspections (45% reduction in field time), improve documentation and speed up reporting

Implementation is continuing into 2020 and progress is being tracked through self-assessment and independent assessment versus the best practice framework (Figure 4).

Beyond the technical approaches being developed at this site, the most important change is the slow but steady change in culture, which is becoming increasingly risk-informed, strategic, data-driven, systematic and proactive. The best practice framework is a strong tool to help leadership direct and sustain much needed change.

SUMMARY

Corrosion within the mining sector can undermine our efforts to safeguard people, the environment and our businesses. By adopting and adapting existing corrosion management best practices for mining, we can drive the imperative to improve our approach. These best practices are known to work well in other industries and early stage adoption by proactive mine operations is already showing value.

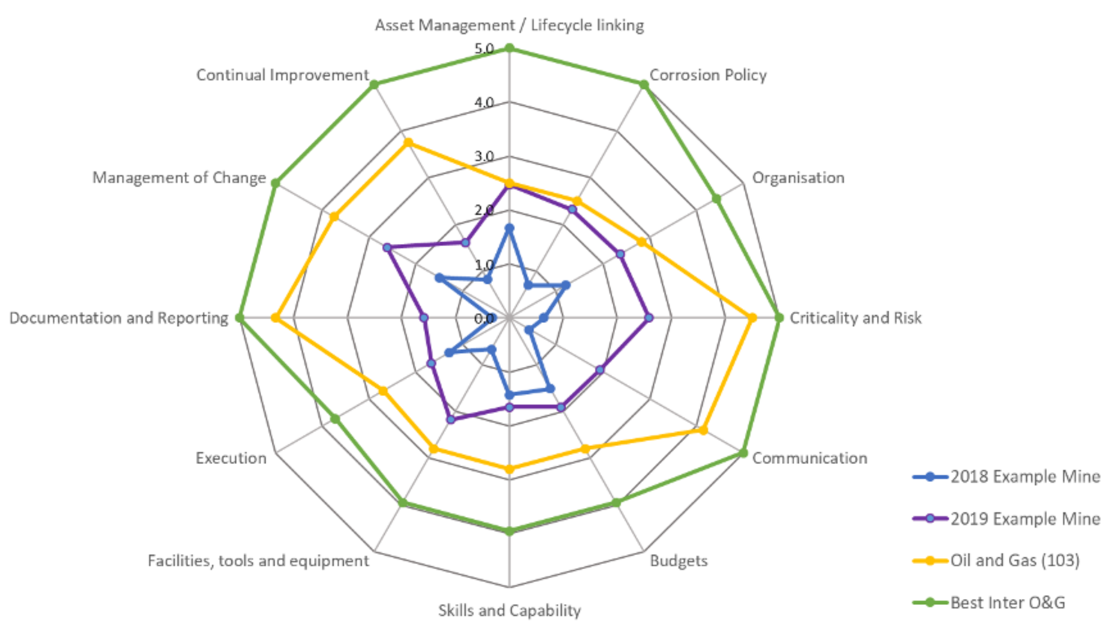

Figure 4: Tracking implementation progress at Example Mine, versus aggregated average of 103 Oil and Gas companies, versus the top performing International Oil and Gas company