PRACTICAL EXAMPLES TO MOVE OPERATIONS TOWARDS UN SUSTAINABLE DEVELOPMENT GOALS (SDGS) BY MANAGING CORROSION RISK

*Zoe Coull
ICE Dragon Corrosion Inc.
Suite 1 – 99 Braemar Ave, Toronto, Ontario, Canada, M5P 2L3
*(*Corresponding author: zoe@icedragoncorrosion.com)*

Brycklin Wilson, Muan Wei
ICE Dragon Corrosion Inc.
Suite 1 – 99 Braemar Ave, Toronto, Ontario, Canada, M5P 2L3

ABSTRACT

Proactive management of corrosion in critical physical assets is known to bring economic, social and governance benefits to mining operations. We have mapped out specific corrosion impacts versus the UN Sustainable Development Goals (SDGs) and can show that the intersection is surprisingly widespread. This paper will describe practical case studies from the perspective of this framework, showing real-life examples of the impact of asset corrosion on sustainability efforts. Each case study describes the practical actions carried out in each case to control corrosion using best practice corrosion management, data-driven predictive modelling, monitoring and technology adopted from other sectors.

KEYWORDS

Corrosion, Corrosion control, Corrosion management, Corrosion monitoring, Corrosion technology, Sustainability, UN SDGs

INTRODUCTION: CORROSION AND SUSTAINABILITY

The term sustainability means that our current actions should be sufficient to meet our needs without impacting the ability of future generations to meet theirs. It encompasses consideration of our natural environment but also our social and economic resources.

Currently in mining there is a strong momentum to move towards a stakeholder-centric approach to business, and away from a historic profit-based model. To do this, many companies are adopting the United Nations Sustainable Development Goals (SDGs) as a framework for systematically developing internal corporate change. There are 17 interlinked SDGs (Figure 1) that were set in 2015 by the United Nations General Assembly with the expectation that member countries would achieve the actions by the year 2030 (https://sdgs.un.org/goals).

The intent in this paper is to illustrate that these high-level goals can be practically interpreted by operations teams through 'boots on the ground' actions, and that stakeholders at all levels of an organisation are responsible for creating positive change within their own sphere of influence. Specifically, this paper looks at how taking care of asset integrity contributes to the wider effort to achieve sustainability within mining operations. The aim is to provide practical examples to make the subject of sustainability less abstract.

Figure 1: The UN Sustainable Development Goals

CASE STUDIES

Case study 1: Designing for durability beneficially impacts climate change (SDG #13)

SDG#13: Take urgent action to combat climate change and its impacts.

More frequent asset replacement has a direct impact on material of construction needs and their associated manufacturing emissions and energy upstream in the value chain. By choosing design options, which optimise repair and replacement requirements for an asset, we can have a beneficial impact on both asset service life and climate change.

Project Challenge

During the design of a northern Canadian gold mine, significant corrosion risk was identified to the structural concrete from the high salinity of the process water. Chloride ions are known to diffuse into concrete and destroy the passivity of embedded steel rebar, resulting in pitting corrosion and causing it to lose strength. Internal corrosion of the steel also forms expansive rust, which causes the concrete to crack, spall and fall off, requiring repair and replacement.

Control Actions

The repair and replacement of the concrete structures would be expensive, disruptive, introduce safety risks and would require additional materials of construction over the required service life. Design decisions were therefore made to improve the durability and hence the service life of the concrete by using pozzolanic cement replacement materials (silica fume, blast furnace slag) to reduce concrete permeability, and an organic amine corrosion inhibitor within the concrete mix to further protect the rebar steel.

Impact on SDGs

Some reports state that cement manufacturing makes up as much as 8% of anthropological global CO_2, making it a significant emission source (Monteiro, 2017). By optimising concrete mix design for durability, concrete asset life can be maximised, reducing the need for new concrete manufacture for repair or replacement material throughout the life of an asset. In addition, using cement replacement materials (like fuel ash and blast furnace slag) not only improves durability in a concrete mix, but can reduce emissions by 40-50% (Jacoby, 2020), decrease costs and use up waste products from other processes (Burris, 2015). Minimising the use of cement therefore directly impacts the life of mine carbon footprint at a site.

Value to Operations

Using concrete core testing and monitoring data from the field it was calculated that the decisions in design had doubled service life of the concrete, even in the most severe exposures. The physical characteristics of the concrete mean that the diffusion of detrimental chloride ions into the concrete have been slowed down, increasing the time to first corrosion on the rebar (i.e. time of initiation (t_{init}) in Figure 2). The team is continuing to monitor the concrete condition to allow an early and accurate prediction of any damage that occurs so that if intervention is required (e.g. if life of mine is extended) any work can be planned and budgeted for.

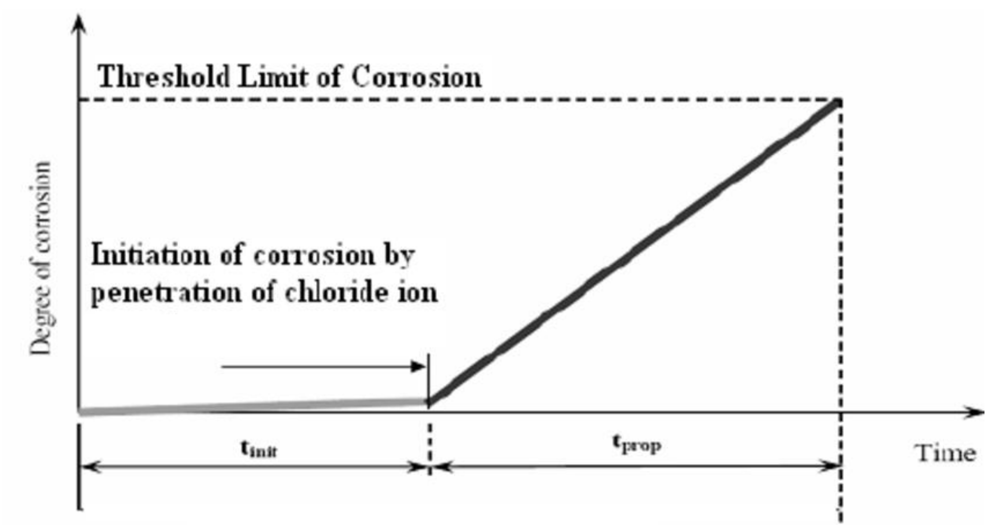

Figure 2: Schematic of a service life model approach for reinforced concrete (Tutti, 1982)

Case study 2: Analysis of corrosion risk improves worker safety (SDG #3)

SDG #3: Ensure healthy lives and promote well-being for all at all ages.

Corrosion is known to be a contributing factor in many historical catastrophic asset failures, which have led to fatalities and injuries therefore hindering efforts around SDG #3.

Project Challenge

During the design of a gold processing plant, a decision was made to select a galvanised steel culvert as a tunnel under a stockpile to house a conveyor. The design life of this structure was 35 years. Within 6 years of operation, through-wall holes were observed internally during routine visual inspections (Figure 3). The continuing structural integrity of this stockpile conveyor tunnel was required to ensure ongoing and safe production over the remaining life of mine (an additional 30 years).

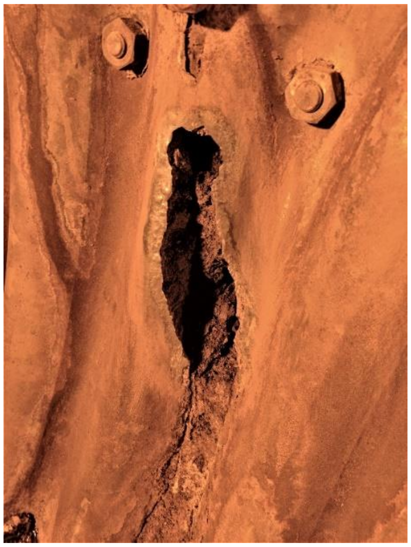

Figure 3: Example of corrosion damage noted internally in galvanised steel culvert.

Control Actions

Corrosion data were collected in the field to allow service life predictions to be made and determine intervention urgency. This work included structural inspection, corrosion coupons, ultrasonic thickness measurements, chemical analysis of the backfill, inspection pits and a review of the original design assumptions. These data were then used to carry out a structured corrosion risk assessment in line with the company's corporate risk process.

Impact on SDGs

The loss of structural integrity of this conveyor tunnel could have resulted in collapse, and multiple worker fatalities and injuries. Beyond the direct impact on safety, relationships with the local community (corporate reputation) would be damaged and the financial resilience of the company impacted due to long-term stoppage of the facility.

Value to Operations

Collecting corrosion data and using it to inform business decisions had the following benefits:

- A catastrophic failure and safety incident was avoided.
- Major financial risk was avoided (est. production losses of >10% loss ($100's M USD))
- The technical team were able to prove that urgent repairs were required within a 3-month window as the data-informed risk assessment process was persuasive for leadership.

- The design of the repair included consideration of accurate exposure conditions and addressed the corrosion risks resulting in a long-term fix, rather than replacing like with like.
- Repair was carried out in a planned, scheduled manner with accurate up-front budgeting (~$0.5M).

Case study 3: Promoting innovation culture with corrosion technology pilots (SDG #9)

SDG#9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

Corrosion technology and innovation is much further ahead in industries beyond mining, such as oil and gas and infrastructure. There is an opportunity for mining to adopt and adapt technology from adjacent sectors to improve how we manage operational corrosion risk, particularly in the space of monitoring and adoption of control techniques. Innovation is not just about the uptake of software and digital approaches, it includes practical hardware and solutions as well as new approaches and ways of thinking. It can be transformative or in the vein of continuous operational improvement; both are important.

Project Challenge

Due to the high relative humidity and airborne salts within a gold process plant, corrosion of electrical connections within panels was introducing a fire risk due to short circuits and a general concern with reliable performance.

Control Actions

A pilot trial is underway to determine the efficacy of vapour phase corrosion inhibitor pucks in protecting the internal surfaces of the electrical cabinets. This is a new technology for the site and the company and, if successful, could be adopted across other locations.

Impact on SDGs

Adopting and testing technology within a mining setting can be challenging. Small scale, well designed field pilots offer a low-risk, low cost option for companies to try new approaches and techniques to improve their operations.

Value to Operations

The expectation is that this technology will reduce corrosion within electrical boxes and be a cheap and easy solution to extend service life and promote safer operation. (Pucks are approx. $10-20 each, depending on size etc. and have a self-adhesive backing so they can be easily mounted inside an electrical box (Figure 4)).

The pilot trial is being carried out in close collaboration between the site team, the technology vendor and an independent third party. This approach will reduce replacement and repair costs and is expected to yield results within 6 months. The metrics of improved life are still being tracked and cannot be reported here yet.

The team are working directly with the company Innovation Team and the project supports the creation of an innovative culture at site with a tangible pilot. As a direct consequence of this pilot, the site team has become more open to corrosion pilot projects and are about to initiate another pilot on novel self-healing coating product for structural steel.

Figure 4: Example of a VPI puck installed inside electrical cabinet.

Case study 4: Ensuring sustainable production by adopting best practice corrosion management approaches (SDG #12)

SDG #12: Ensure sustainable consumption and production patterns

When corrosion risk is not dealt with in a systematic and proactive way it can have significant impacts on OPEX costs and unexpected production interruptions creating uncertainty within a mining operation.

Project Challenge

A gold mine was experiencing wide-spread and varied corrosion failures and risks. These were contributing to production losses (due to unexpected shutdowns) and maintenance spends of approximately $30M/year. To ensure ongoing reliable and cost-effective production, the site needed to move from a reactive maintenance culture to a proactive, structured, data-informed approach.

Control Actions

A best practice framework was adopted from the oil and gas industry to develop both a structured technical corrosion risk process and to create the required enabling management activities (ICE Flow Corrosion Management Process©). This innovative approach was done to ensure due diligence and control around a significant business risk.

The project continues to implement and improve the Corrosion Control Program at site, to iterate improved practices around corrosion risk management to ensure reliable production.

Impact on SDGs

By tackling the asset integrity issues using a structured, proven method, the site is taking steps to ensure safe, consistent and sustainable production.

Value to Operation

The site is creating a pro-active and structured culture around dealing with this business risk and the following benefits have been realised:

- Site is able to get ahead of failures through data-collection and planned inspection schedules.
- Repair and refurbishment work is prioritised and planned, using structured risk and data analysis.
- Annual maintenance spends for corrosion are calculated and predicted more accurately based on known costs and planned activities.
- Program KPIs are tracked automatically and give visibility to leadership on risk (e.g. financial risk, asset performance etc) to ensure due diligence.
- The process requires input from a range of stakeholders, increasing site knowledge, preventing siloed teams and improving resiliency of the program.
- Lessons learned are collected, shared and embedded in new designs.
- Formal training and communications at site reinforce risk awareness.

These benefits were expected and have been reported in other sectors where a similar framework has been adopted [NACE Impact Study, 2016].

CONCLUSION

To succeed at achieving sustainability goals within a company, all levels of people within the organisation must take a proactive leadership role. While site teams and engineers deeply understand the importance of sustainability, realising how our actions tie back into these overall efforts can sometimes be abstract. Here we have provided examples of how physical asset degradation is directly linked to specific UN SDGs. It is hoped that this will create an opportunity for further discussion and an awareness of our individual ability to contribute to sustainability efforts within our own realms of competence and influence.

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