WHITEPAPER

COMMON CORROSION TYPES IN WASTEWATER SYSTEMS AND PROTECTIVE COATINGS TO ADDRESS THEM

Stephen Bowditch, Global Product Line Director, A. W. Chesterton Company
Michael Wachinger, Regional Sales Manager, A. W. Chesterton Company

CHESTERTON®
Global Solutions, Local Service.

CONTENTS

ABSTRACT

The right protective surface coating can greatly extend the working life of components within wastewater systems. However, because the different components and materials in such systems are subjected to different environmental stresses, choosing an appropriate coating for each can be a challenge. One solution is to gain a better understanding of the types of corrosion that various parts are prone to. This, in turn, can help to identify the key performance indicators (KPIs) for potential surface coatings, making product selection simpler. While other factors, such as health and safety, cost, and technical support requirements may impact on the final decision, from an engineering and operations perspective identifying a product that meets the KPIs should be the first step.

1.0 INTRODUCTION

Wastewater plants play a critical role in keeping society functioning. By managing, treating, and making safe the wastewater produced through both domestic use and industrial processes, they help to manage a valuable resource and to protect the environment.

As populations grow throughout the Asia Pacific region, major investments are being made in upgrading and expanding public wastewater facilities. At the same time, demand from society for greater environmental protections is leading to increased regulation of privately operated facilities. Industrial wastewater facilities are being subjected to ever more stringent regulations aimed at avoiding overflows, leaks, and cross contamination. Older plants are being called on to raise standards and improve efficiency.

One key way for plant operators to ensure compliance and increase longevity is to increase their knowledge of common corrosion issues. Understanding how such issues contribute to failures – and having knowledge of what types of protective coatings can hinder and prevent their action – is useful across all stages of plant life, from commissioning to maintenance, repair and replacement.

This paper addresses some of the most common corrosion issues in wastewater plants and provides pictorial examples of their actions. It also provides the reader with the KPIs of the types of protective coatings required to inhibit each kind of failure. Armed with this information and knowledge of their individual plant, operators can speak to an appropriate coating specialist and proactively address corrosion failures long before they arise.

2.0 DISCUSSION

The following observations and images are based upon A.W. Chesterton Company's experiences in North America. However, they are equally applicable to plants throughout the Asia Pacific region.

The key focus area of the content is the corrosion mechanisms most commonly effecting process equipment such as screens, clarifier rake arms, decanters, pumps, valves, mixers as well as structures such as clarifiers, bar screen chambers, thickeners, manholes junction boxes and wet well/lift stations. The paper then provides the key performance indicators required of a protective coating aimed at addressing the problem. It is hoped the paper will constitute a useful guide for businesses working through options for a protective coatings strategy.

2.1 Corrosion of Metals - Pitting Corrosion

Pitting corrosion occurs on carbon steel and cast-iron alloys when the passivated natural oxide (Fe_2O_3) layer on a metallic surface is disturbed. This results in the exposed region assuming an anodic reaction, while the covered areas remain cathodic. As the anodic region is likely to have a smaller surface area than the cathodic region, corrosion 'pitting' commences in the anodic region. As corrosion progresses the pit deepens, and the pH levels continue to drop. This causes the anodic/cathodic reaction to continue, albeit at a faster pace. Eventually the pit will exceed the wall thickness of the vessel and leaks and structural failure risks increase.

Stainless steels do not form a layer of oxides like a carbon steel or cast iron but are also prone to pitting corrosion under certain circumstances. In the presence of oxygen or oxygenated water flow, stainless steels containing chromium at a level >11%, form a passive layer of chromium oxide. This layer prevents corrosion from occurring. If the surface is covered by biofilms or a gasketed connection or a

Figure 2.1 Pitting corrosion occurring on thickener tank under a biofilm layer

KPI's of Coatings Intended for Pitting Corrosion Exposures

- High tensile adhesion (>20 MPa) to resist under film corrosion
- High abrasion resistance to resist losses exposing regions that can become anodic
- Low permeability
- General resistance to thermal, chemical exposures

Fig 2.2 Graphitic Corrosion on Primary Intake Pipes

KPI's of Coatings Intended for Graphitic Corrosion Exposures

- High tensile adhesion (>15 MPa) to better resist under film corrosion.
- High tensile properties for resistance to soil shear stress
- Impact and abrasion resistance for buried pipe
- Low permeability

fabrication detail creates an area of low/no flow, oxygen levels in these regions would be reduced due to little or no flow. These oxygen depleted zones become anodic (lower pH) and corrosion commences.

Pitting corrosion rates on stainless steels can be further exacerbated by chloride levels. These levels can be impacted if using ferric chloride (FeCL3) as a flocculating agent or to reduce sulfides. Type 304 and 316 stainless are prone to excessive pitting corrosion with chloride levels >300 ppm, even in neutral pH solutions.

Aluminium is a thermodynamically reactive metal, so it is prone to corrosion compared to other more noble metals. Within pH ranges of 4.5-8.5 aluminium is corrosion resistant but, if used in enclosed head spaces in wastewater exposures where hydrogen sulfide gases can build up and result in pH <4 pitting corrosion can occur on the aluminium oxide layer as well.

2.2 Corrosion of Metals – Graphitic Corrosion

This form of corrosion is most commonly seen in cast iron and ductile iron when buried in acidic soils or exposed to mildly acidic waters. Under these conditions the iron (Fe) leaches out of the casting into the soil or water flows, leaving behind a weakened matrix of graphite and iron oxides. Casual observation will not indicate any damage, but the remaining matrix of graphite and iron oxides are weak and soft and, if left unaddressed, can lead to collapse or structural failure. This form of corrosion is very slow so many systems will not show evidence for decades. In Chesterton's home market in the United States, many cities have cast and ductile iron pipes, which have been buried for nearly 100 years or more, and these are now presenting ongoing issues to municipalities as they strive to upgrade their distribution/collection pipe network. This form of corrosion is dependent on the acidity of the soil pipes are buried, which can be further influenced by moisture content of soil and any soil contamination.

2.3 Corrosion of Metals – Galvanic Corrosion

This form of corrosion is caused by two dissimilar metals with different electromotive potentials being in contact with one another in the presence of a common electrolyte. The less noble metal becomes anodic in this case, and goes into ionic solution, sacrificing itself to protect its more noble cathode. The rate and severity of corrosion losses are related to electromotive potential differences between the anode and cathode, pH and conductivity of the electrolyte the dis-similar metals are exposed to, proximity of the two metals to one another, and finally the relationship of the anodic region's surface area compared to the cathodic region's surface area. If the anodic region is large compared to the

Fig 2.3 Galvanic Corrosion of Aluminium Cladding Sheets in contact with Stainless Steel Screws

KPI's of Coatings Intended for Galvanic Corrosion Exposures

- High tensile adhesion (>20 MPa) to resist under film corrosion
- High dielectric resistivity
- Resistance to cathodic disbondment
- Low permeability
- General resistance to thermal, chemical exposures

cathodic region, corrosion rates will be slower than if the anodic region is significantly smaller than the cathodic region.

Treatment plant operators should be concerned with zinc galvanized surfaces in contact with unprotected carbon steel as well as aluminium structures such as trash racks or gates which might be electrically coupled to imbedded reinforcing rods in the concrete by way of carbon steel anchor bolts, carbon steel frames by way of anchor bolts.

2.4 Corrosion of Metals – Microbiologically Influenced Corrosion (MIC)

MIC is commonly found in wastewater treatment collections and treatment facilities in both aerobic as well as anaerobic conditions. The primary form of MIC in wastewater treatment plants is biogenic sulphide corrosion which occurs when anaerobic sulphate reducing bacteria (SRB) metabolize the sulphate (SO2-4) ions which are rich in the untreated wastewater flows. The SRB's metabolic process consumes oxygen, and the resulting by product is the sulphide ion (S2-). This ion is released into the water flows. The sulfide ions combine with hydrogen in the water flows to form hydrosulphide or bisulfide (HS-) ions. These ions react further to form hydrogen sulfide (H2S) which continues to build to saturation levels. In turbulent flows the H2S gas, as well as carbon dioxide (CO2) are released into the humid enclosed head spaces commonly seen in manholes, wet wells and lift stations, junction boxes, collection

Fig 2.4 Biogenic corrosion of pipe brace/ support in wet well

pipe, junction boxes and then into the plant in bar screen chamber, grit chambers as well as primary and secondary clarifiers. These gases combine with the humid atmosphere and form weak thiosulphuric and carbonic acid which depresses the surface pH. Once the pH drops below 9.5, naturally occurring sulphur oxidizing bacteria (SOB) can colonize on the surface and they in turn metabolize the H2S generating a weak sulfuric acid. This can result in surface pH <5. Mild steel and ductile iron, present in closed head spaces such as piping, valves, pumps, and associated structural members are then subject to accelerated corrosion rates from the acidic environment.

Fig 2.5 Biogenic corrosion in enclosed head space of concrete bar screen chamber

KPI's of Coatings for Metal/Concrete Surfaces Intended for MIC Corrosion Exposures

- High tensile adhesion (>20 MPa) to resist under film corrosion on steel
- Resistance to Low pH (10% H2SO4)
- Resurfacing and barrier topcoats with edge retentive capability to prevent pinholes in applied films when being applied on heavily pitted surfaces
- Low surface energy to reduce biofilm build-up

2.5 Corrosion of Concrete - Microbiologically Influenced Corrosion (MIC)

The same processes stated above, that generates the dilute sulfuric acid, is present in enclosed head spaces of many wastewater associated concrete structures such as manholes, wet well/lift stations, junction boxes, collection pipe (force and gravity flow), bar screen chambers clarifiers and sludge tanks. Unfortunately, the corrosion reactions are significantly faster and more dramatic when concrete is the substrate exposed. This is primarily due to the alkaline nature of concrete (12.5 when freshly poured) reacting with the dilute sulfuric acid, which can easily assume pH levels of <2. The acid reacts with and converts the cement calcium hydroxide to calcium sulphate salts which are easily dissolved in water. This leads to the loss of the cement paste and the release of the aggregate and sand constituents in concrete, eventually exposing any structural members embedded into the concrete. The resulting surface can be exceptionally rough and difficult to coat with thin (<1mm) coatings.

2.6 Corrosion of Concrete - Acid Attack

The same acid base reaction occurs when many process chemicals used in wastewater treatments plants encounter unprotected concrete. Chemical attack occurs frequently when sulfuric acid is present and used as a buffer, as well as when ferric chloride and alum are used as flocculating agents. The areas which are more prone to attack tend to be containment and dose mixing stations, but the result is like MIC attack. Initially etching of the concrete, progressing as the cement paste is broken down, to exposed aggregate, and eventually, if left unaddressed to rebar corrosion and spalling.

Fig 2.6 Acid attack of concrete in sulfuric acid containment

KPI's of Coatings for Concrete Surfaces Intended for Chemical Exposures

- Resistance to low pH from concentrated and dilute H2SO4, FeCl-, NaOH, NaOCl)
- Impact and abrasion resistance
- Low coefficient of thermal expansion for when thermal cycling exists
- Resurfacing and barrier topcoats with edge retentive capability to prevent pinholes in applied films when being applied on heavily pitted surfaces

3.0 CONCLUSION

Armed with the knowledge about common types of corrosion and the KPIs required of protective coatings, wastewater system operators can make more informed decisions about which products are needed.

4.0 RECOMMENDED STEPS

A good way to precisely identify which coating is suitable for a particular application is to consult with the product experts at Chesterton®.

Chesterton's ARC Industrial Coatings have a four-decade proven global track record of enhancing critical industrial equipment and structures. They are engineered to protect metal and concrete surfaces from the damaging effects of abrasion, erosion, and chemical attack.

One example is ARC S1HB, a single coat, low VOC barrier coating that protects both metallic and cementitious surfaces from corrosive exposures. Its high-build, edge-retentive properties ensure maximum coating coverage over hard 90° edges and corners with minimal thinning at the sharp edges. ARC S1HB is resistant to a broad spectrum of corrosive agents including H2S, hydrocarbons, wastewater flows, brackish and marine water exposures, as well as mild acid and caustic solutions.

Chesterton is a world leader in helping industrial companies improve the reliability and efficiency of their equipment. The business has over 450 sales and service locations in 113 countries. Our 1,200 factory-trained local specialists and technicians work closely with customers in the field to help solve specific sealing and equipment reliability challenges.

Visit our website at www.chesterton.com or email an enquiry to enquiries_apac@chesterton.com.

5.0 ACKNOWLEDGEMENTS

The authors would like to thank NACE instructor and mentor, Lou Vincent, who taught that fighting corrosion is a worthwhile but never-ending battle against nature.

FOOTNOTES/REFERENCES

1 https://infrastructurereportcard.org/cat-item/wastewater/

2 John Redner, Randolph N]His, Edward Esfandi, "Evaluating Coatings for Concrete in Wastewater Facilities: An Update" Journal of Protective Coatings and Linings, December 1994; pg. 48-59. https://www.paintsquare.com/library/articles/eval_12-94.pdf

3 Jose Villalobos; Graham Bell, Chapter 13, "Corrosion in Wastewater Systems" Volume 13C; Corrosion: Environments and Industries; ASM International; 2006 https://doi.org/10.31399/asm.hb.v13c.9781627081849

Visit: arcindustrialcoatings.chesterton.com
Email: enquiries_apac@chesterton.com