NACE International

An Action Plan for Reducing Pipeline Failures, Costs Associated with Corrosion in the Water Sector

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Executive Summary

When much of the nation's infrastructure was designed, in most cases more than 100 years ago, it was expected to function for 50 to 100 years. Today, U.S. bridges, pipelines, roads, power generation, transmission, and water treatment facilities are all reaching the end of their economically useful and serviceable life — primarily due to corrosion-related failure. As stated by former U.S. Secretary of Transportation Ray LaHood in a 2014 appearance on *60 Minutes,* "the U.S. infrastructure is on life support."

The cost of corrosion is staggering:

- Globally, the cost to the world's infrastructure is estimated to be more than $2.5 trillion.[1]
- Corrosion costs the U.S. drinking water and sewer system sector $79.6 billion — 75% of the annual cost of corrosion in the utilities category.[2]
- Replacing the aging water pipe in the U.S. with plastic or coated steel pipe has been estimated to cost $2.1 trillion.[3]

While the monetary impact of corrosion to water treatment/distribution systems is stunning, its impact on public safety can be catastrophic as in the case of Flint, Michigan, a cautionary tale of lead poisoning caused by the lack of action to counter the threats of corrosion.

Flint is an extreme case of what can go wrong without proper corrosion management, but it is an important one that effectively raises the awareness of the magnitude of the problem. It also spotlights how financial avoidance influences the ongoing infrastructure crisis in the U.S. water treatment sector. Fortunately, the expertise and tools needed to extend the life of existing systems, prevent costly infrastructure improvements, and avoid catastrophes like Flint are available to schools, agencies, and companies that must begin to consider the impact of corrosion on aging systems.

Introduction

The goal of this white paper is to help educate government bodies, professional societies, trade worker associations, influential organizations, private companies, the media, and the public on the threat of corrosion to the water treatment sector and the available ways in which to prevent it. It describes the U.S. drinking water infrastructure and explains the underlying reasons for its deterioration as well as those causes that contributed to the Flint water crisis.

Additionally, and perhaps most importantly, it recommends an action plan for:

- preventing or removing corrosion-related contaminants from public drinking water;
- mitigating external corrosion of buried steel and reinforced concrete pipes associated with water treatment; and
- improving asset management while reducing costs through proactive corrosion planning.

Corrosion in the Water Treatment Sector

A critical public service, the U.S. water treatment sector involves more than 151,000 drinking water systems and millions of miles of pipe. After removing solids and organics, organic and inorganic contaminants, these systems provide drinking water to more than 300 million people, as outlined in the "Water Treatment Process" diagram (Figure 1). Each year, these systems experience 240,000 pipeline leaks and breaks caused mainly by third-party damage or corrosion, wasting more than two trillion gallons of drinking water.[3]

Most at threat from the effects of corrosion are the systems' internal and external pipes. Current best practices for effectively combating corrosion of buried pipelines is the use of externally and internally coated steel pipe, reinforced concrete, and plastic pipe. Coated steel and reinforced concrete, however, require corrosion protection to maximize their service life and minimize public safety hazards caused by leaks and breaks.

To best manage pipeline corrosion, it is first necessary to understand what causes internal vs. external corrosion as well as the limitations of today's general corrosion mitigation best practices used to address these two forms of corrosion.

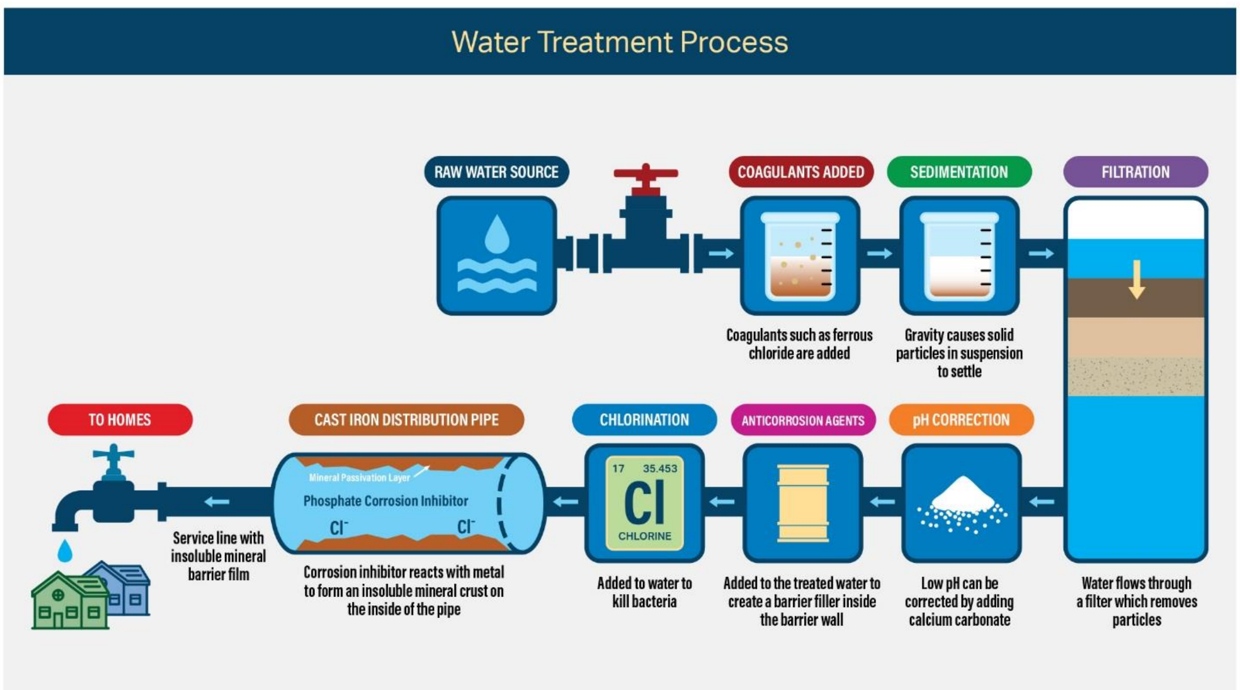

Figure 1. Water treatment process.[5]

Internal Corrosion

Internal corrosion of unlined steel, cast iron, or ductile iron pipe can shorten the service life of a pipe and can also result in poor water quality for consumers. Metals from the rusted pipe are released into the water being transported — water that consumers will eventually drink.

The first line of defense against internal pipe corrosion is an effective water treatment program. However, the quality of the water can degrade over time as it travels from the treatment plant to the consumer. For example, water that stops moving and becomes stagnant in the distribution system for several days or more can become corrosive as the chemicals used to disinfect the water are consumed during transit. Water system hydraulics (flow rates, consumer demands, pressures) control the amount of time the water remains in the distribution system. The consumers located farthest from the treatment plant or in areas where water stagnates, or where consumption is low, may receive water that is very different from the treated water that leaves the plant. Localized corrosion problems can then occur in remote and/or low-usage areas.

Inconsistent water quality over time can also cause corrosion. Systems that obtain water from multiple sources (often for security and reliability reasons) can be especially vulnerable to this problem as the inconsistent water quality prevents pipes from forming the sort of protective films that a corrosion inhibitor creates when properly added to the system. Replacing the millions of miles of aging U.S. water pipes with plastic or coated steel pipe is often considered as a solution to the challenges of internal corrosion, but with a $2.1 trillion price tag,[3] it is cost-prohibitive.

External Corrosion

External corrosion of unlined steel, cast iron, or ductile iron pipe used for water distribution is caused by the type of soil chemistry surrounding the pipe, which includes parameters such as low pH, salts, low resistivity, and the presence of bacteria — all conditions that can induce corrosion. The presence of oxygen is also required for corrosion to occur, and oxygen is typically dissolved in moisture; therefore, moist soil will cause corrosion of unprotected steel.

Cathodic protection (CP) is a corrosion prevention technology that can protect the exterior of the metal or reinforced concrete pipes using a sacrificial anode, thus making the metal inert or nonreactive so it will not corrode. And while corrosion will not occur on the outside surface of the pipe if a CP system is used, it must be properly monitored and maintained.

Corrosion and the Flint Water Crisis

Internal Corrosion—From Bad to Worse

The Flint water crisis began when the municipality changed its source of drinking water from Lake Huron, through an agreement with the Detroit Water Department, to the Flint River. The Flint River water was more corrosive compared to the water from Lake Huron. This was primarily due to contamination from excessive chloride, which got into the river as runoff from road de-icing salts used during Michigan winters. When introduced to the drinking water distribution system, the new Flint River water immediately caused extensive pipe corrosion, resulting in widespread health issues, particularly lead exposure.

Prior to switching the source of water, municipal staff failed to analyze, and then appropriately treat, the Flint River water with a corrosion inhibitor. Flint's older distribution system contained lead service lines, which quickly deteriorated when they came in contact with the highly corrosive Flint River water. Without a corrosion inhibitor to create a protective film inside the pipe, lead began to leach into the Flint drinking water supply.

Chlorine, added to control bacteria, reacted with the lead pipes rather than the bacteria. In its absence, bacteria multiplied. To resolve this issue, staff added more chlorine, and the excess created disinfection byproducts, or DBPs, which have been linked to liver, kidney, lung, heart, and central nervous system problems.

Crisis Aversion Was Possible

At its core, the Flint water crisis was caused by a lack of understanding of water chemistry, and the need to preemptively counter the threat of corrosion as described above. This crisis, however extreme as an example, effectively illustrated the magnitude of problems caused by the absence of proactive corrosion management.

Stakeholders may perceive the cost of corrosion management to be prohibitive yet, as the Flint tragedy so painfully proved, the cost of the risks—the public health crisis, water loss, system failures, and loss of trust in municipal officials—far exceeded the cost of prevention. Figure 2 shows the water treated with Detroit and Flint River water.

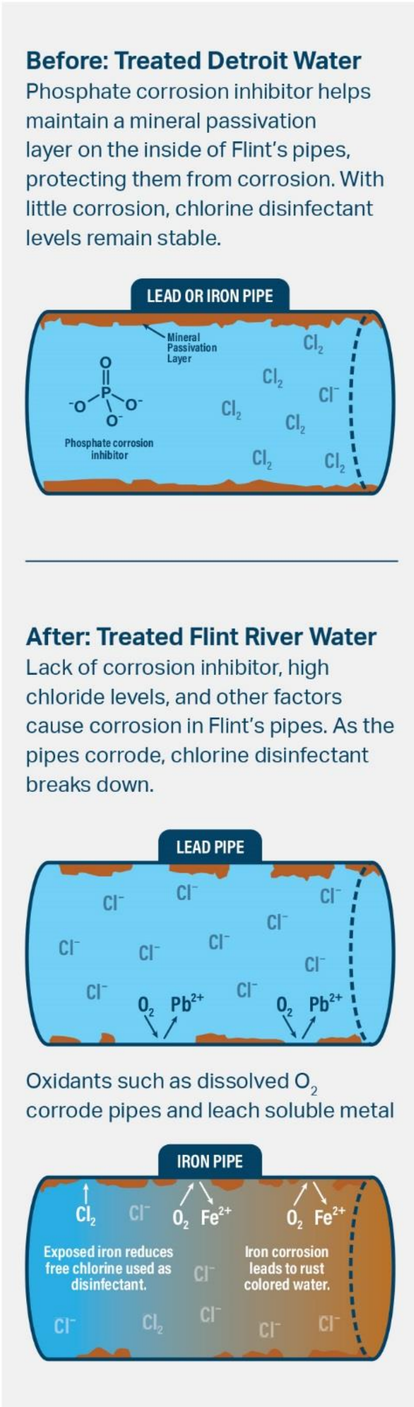

Figure 2. Before: treated Detroit water. After: treated Flint River water.

Reducing Corrosion Costs through Corrosion Management

The Flint case spotlights how financial avoidance has driven the ongoing infrastructure crisis in the U.S. water treatment sector. While what happened in Flint was an extreme case, it's an important caution to all utilities who have not given earnest consideration to a proactive Corrosion Management System (CMS).

When an effective CMS is implemented, the cost of corrosion prevention has a positive return on investment by providing a proactive approach that efficiently and cost-effectively protects public health, quality of life, and existing facilities.

Beyond Maintenance and Inspection

The process of controlling corrosion in water distribution systems starts with regular maintenance and inspection. With these ongoing programs in place, when a problem is detected, its cause can be found and evaluated in a timely fashion so the nature of the problem can be characterized and addressed quickly, and the severity of the issue can be minimized.

Yet while maintenance and inspection programs are straightforward and helpful, many problems can go undetected until widespread failures have occurred. To best identify and characterize corrosion issues, a comprehensive and preemptive approach or system to managing corrosion is required.

CMS Defined; Steps for Implementation

A CMS is a set of objectives, policies, processes, and procedures for planning and executing corrosion protection of existing and future assets.

The following outlines the fundamental steps needed to help ensure successful CMS implementation.

➢Step 1

A CMS must be integrated into an organization's asset integrity management system and embedded in the interaction between general and corrosion-specific management, as illustrated in Figure 3.

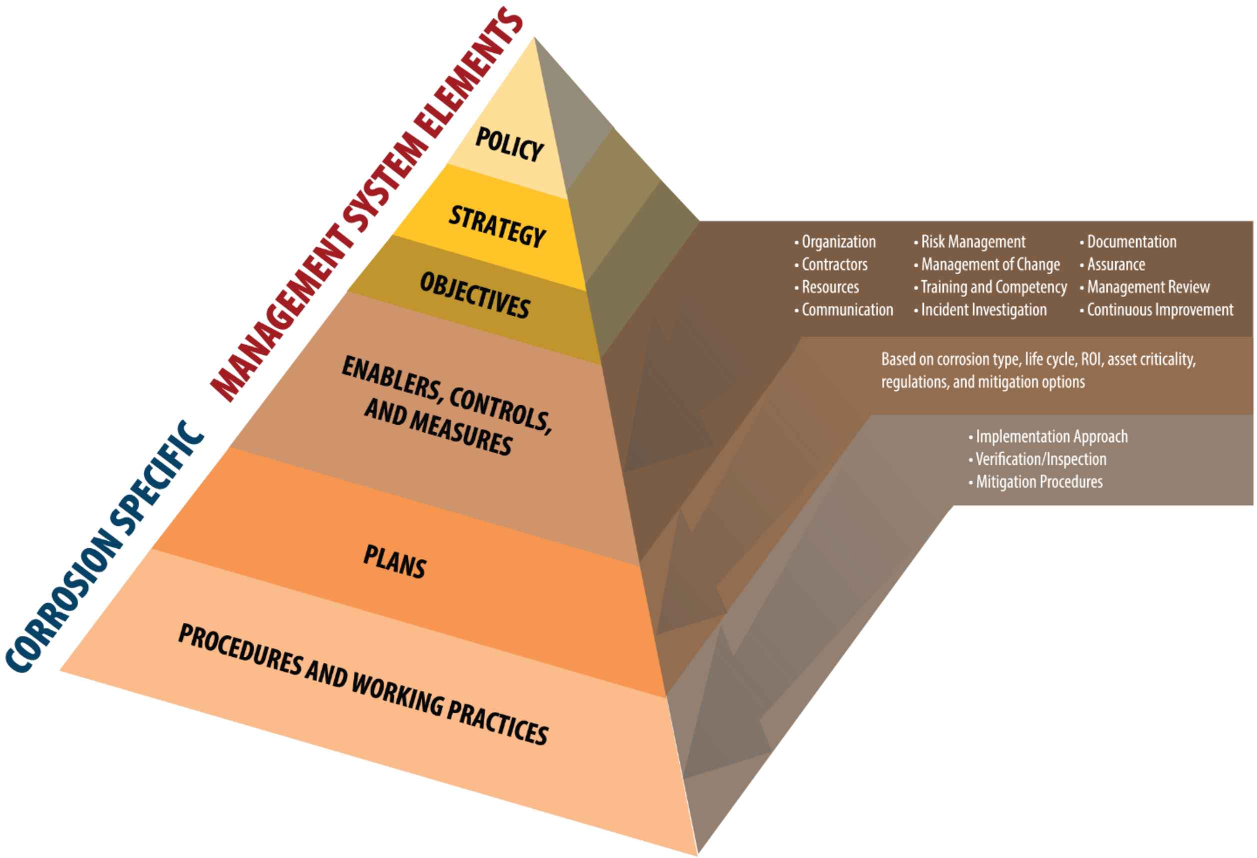

Figure 3. The CMS Pyramid—a framework for Interaction of management. Source: NACE International IMPACT (International Measures of Prevention, Application, & Economics of Corrosion Technologies) Study, published in 2016.

➢Step 2

Corrosion control must be designed into the water treatment system. Correct design ensures proper materials selection based on industry standards and the use of correct protective industrial coatings for protection of buried metallic and concrete pipes, and water and wastewater tanks. Corrosion specialists follow best practices to evaluate and design systems with the appropriate corrosion control technologies.

➢Step 3

Critical assets should be inventoried and evaluated for condition and performance. Evaluation should include a lifecycle cost analysis, which balances the cost of corrosion management over the life of an asset with the potential cost of corrosion., with the most effective lifecycle cost analysis taking into account the operational, regulatory, environmental, and social costs of the investment.

Tools for Facilitating Corrosion Management

Corrosion control in water treatment process and distribution systems is multifaceted, requiring consideration of many influencing parameters. A CMS takes into account these various influencing parameters with corrosion-related decisions and practices integrated into an organization's management system.

Sharing corrosion management activity information within an organization and putting CMS into a management context can, however, be challenging.

To support implementation of a strategic, site-specific CMS, the NACE International Institute developed IMPACT PLUS®.

Housed in a single, online portal, IMPACT PLUS is a cloud-based network of technical and business tools that help utilities and organizations access and analyze CMS in all areas of their businesses and provides information for improvement.

Specifically, IMPACT PLUS facilitates implementation of a CMS by providing:

- a common language and structure needed to ensure communication throughout all levels of an organization;
- a framework for organizations to identify gaps in their corrosion management processes (benchmark practices) that could lead to the reduced lifecycle of assets;
- a roadmap of strategies, investments, and best practices that lead to closing identified gaps and resulting in higher performance and improved corrosion management;
- a way to manage corrosion knowledge and information collected throughout the organization; and
- the availability of expert "navigators" to assist with developing a successful CMS

Knowledge—Industry's Most Important Corrosion-fighting Tool

In addition to IMPACT PLUS, NACE International offers an extensive menu of products and services to aid in corrosion prevention and mitigation. A nonprofit organization serving 36,000 members in 130 countries, it equips society to protect people, assets, and the environment from the adverse effects of corrosion through the dissemination of information including technical training and certification programs, conferences, industry standards, government relation activities, and publications.

WaterCorr News is one such NACE resource that keeps professionals updated on corrosion control technologies and best practices in the water and wastewater industry. For those seeking information on improving asset management in the water sector, a complimentary subscription to this triannual digital publication can be obtained at www.nace.org/resources/digital-publications/watercorr-news.

Conclusions

Implementation of existing corrosion control techniques can save the world up to $875 billion, or more than 3% of the GDP in most developed countries.[1]

Many U.S. municipalities lack a formal CMS and the additional short-term funds to support it. But the benefits of a CMS make a sound long-term investment:

- Added protection of public health
- Decreased maintenance, inspection, and monitoring costs
- Fewer failures, reducing lost water supply
- Less property damage and environmental release
- Life extension of the asset and potential postponement of capital expenditures

To avoid the monumental, long-term health risks and financial implications of an incident such as Flint, corrosion management must be recognized as an investment and not as a cost. In addition to implementing a CMS system, the water treatment and distribution sector must require employees to be proficient in water chemistry and treatment through training and education.

Corrosion management, when considered proactively and systemically, can reduce the economic, environmental, social, and human costs of water pipeline failures. Development of a CMS and a methodology for reducing corrosion cost through proactive corrosion planning is possible; innate challenges can be overcome with a corrosion management tool such as IMPACT PLUS, which allows organizations to more easily monitor and manage their corrosion activities.

Finally, information empowers organizations to achieve their corrosion management aspirations and improve asset integrity management. NACE International, known globally as the Worldwide Corrosion Authority, can serve as an important informational resource to that empowerment.

References

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3 American Water Works Association, https://www.awwa.org.

4 U.S. Environmental Protection Agency, https://www.epa.gov.

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