Understanding & Evaluating Corrosion in Wastewater Collection Systems

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Understanding & Evaluating Corrosion in Wastewater Collection Systems

Part 1:
The problem of corrosion in wastewater systems

Part 2:
Evaluating corrosion through proper inspection & condition assessment

Focus will be on gravity pipelines and manholes
Corrosion is a big problem!

- A primary cause of failure in wastewater systems
- Causes billions of dollars of damage annually
- Out-of-site, out-of-mind asset management approach not helping!

*ASCE assigned a grade of “D” to our nation’s wastewater infrastructure in 2013.*
Corrosion is a big problem!

$298$ Billion is needed over the next 20 years for America’s wastewater infrastructure!

**Key Concerns:**
- Capacity
- Corrosion
- Capital
What can corrode in wastewater systems?

**Does Corrode:**
- Unlined concrete manholes, pipes, structures
- Steel & metallic pipe, structures, components
- Mortar in brick manholes & pipes

**Does Not Corrode:**
- PVC, HDPE & plastic pipe, structures, components
- Fiberglass/ FRP, composite pipe, lining & structures
- Clay pipe and bricks
- High performance coating/ lining materials
Why is my wastewater system corroding?

Possible Common Reasons:

- Microbial-Induced Corrosion (MIC)
- Corrosive Soils
- Highly corrosive industrial waste dumping
- Cathodic protection issues (*metallic only*)

Most common cause of corrosion in wastewater pipelines and manholes is due to MIC
Microbial-Induced Corrosion (MIC)

- Deterioration of wastewater collection systems from biogenic sulfide corrosion
  - Headspace (vapor phase) environments above flow of the waste stream
  - Characterized by elevated levels of hydrogen sulfide (H$_2$S)
  - Biological oxidation of H$_2$S to H$_2$SO$_4$ within headspace areas of enclosed wastewater structures

\[
H_2S + O_2 \xrightarrow{Thiobacillus SOB} H_2SO_4
\]

- H$_2$SO$_4$ attacks the matrix of the concrete above the waterline (i.e., pipe crowns, walls, etc)
Microbial-Induced Corrosion (MIC)

Sulfate Reduction

\[ \text{SO}_4^{2-} + \text{Organics} \]

\[ \rightarrow S^{2-} \]

From Maier, Pepper and Gerba (2010)
Environmental Microbiology, AP
Microbial-Induced Corrosion (MIC)

Sulfide Partitioning

$S^{2-} \leftrightarrow HS^{-} \leftrightarrow H_2S$ Gas

From Maier, Pepper and Gerba (2010)

*Environmental Microbiology*, AP
Microbial-Induced Corrosion (MIC)

Sulfide Oxidation
\[ \text{H}_2\text{S} + \text{O}_2 \rightarrow \text{H}_2\text{SO}_4 \]

From Maier, Pepper and Gerba (2010)
Environmental Microbiology, AP
MIC Corrosion Bacterial Progression

from Islander et al. 1991, J. Environ. Eng. 117
Wastewater Corrosion Culprits

*Contributing factors of MIC wastewater corrosion:*

- Elevated HsS, CO₂, ammonias, other sewer gases
- Turbulent flows
- High sulfide levels
- Elevated temperatures
- High BOD sources
- Industrial waste
- Stagnant, septic sewerage
Typical Wastewater Corrosion Hotspots

Elevated H₂S levels & MIC sulfide corrosion common in:

- Forcemain outfall locations
- Locations with turbulent flows
- Areas with poor air handling
- Drop manholes
- Junction structures
- Wet wells
- Siphons
- Larger systems
Microbial-Induced Corrosion (MIC)

Corrosion in concrete manholes
Microbial-Induced Corrosion (MIC)

Corrosion in concrete manholes
Microbial-Induced Corrosion (MIC)

Corrosion in concrete pipelines
Microbial-Induced Corrosion (MIC)

Corrosion in wastewater vault structure
Microbial-Induced Corrosion (MIC)

Corrosion of mortar in brick manholes
Microbial-Induced Corrosion (MIC)

Corrosion of metallic manhole frame & cover
How to conquer corrosion problems:

- Education, training and experience
- Implement comprehensive inspection & condition assessment programs to identify corrosion problems before failures occur
- Proactive, instead of reactive asset management
- Understand your system, understand the problems...

Find the solution!
Education and Training

NACE (National Association of Corrosion Engineers)

- Extensive corrosion training & certification programs
  - CIP – Coatings Inspector Programs
  - Corrosion Technologist Programs
  - Cathodic Protection Specialist Programs
  - Pipeline Corrosion Integrity Management Programs
  - Corrosion General Education
NACE (National Association of Corrosion Engineers)

- Standards & Publications
  - Substrate corrosion evaluation standards
  - Surface preparation standards
  - Quality control standards
  - Published corrosion education materials

- Task Groups
  - Industry specific focus
  - TG 466 – Wastewater Corrosion
NACE (National Association of Corrosion Engineers)

• Task Group 466
  o “Identifying Corrosion Problems and Mitigation Strategies in Wastewater Systems”
  o Comprehensive document written by top industry experts
  o Wastewater corrosion overview
  o Rehabilitation solutions
  o Balloting in progress
SSPC (Society for Protective Coatings)

• Training & Certification Programs
  o Protective Coatings Specialist (PCS)
  o Concrete coatings/ linings inspection programs
  o Inspector and contractor training & certification programs
  o Coatings/ linings, corrosion education

• Standards & Publications
  o Surface preparation standards
  o Quality control standards
  o Published educational materials
Other good resources:

- **NASTT** (North American Society for Trenchless Technology)
  - Condition assessment educational resources
  - Trenchless rehabilitation educational resources
  - No-Dig Conference and numerous short-course programs

- **NASSCO** (National Association of Sewer System Contractors)
  - PACP/ MACP/ LACP condition assessment inspector training
  - CIPP pipe rehab inspector training & certification
  - Educational resources
Finding the Solutions...

Understanding corrosion, understanding your system

- Proper inspection & condition assessment provides foundation for asset management and rehabilitation
- Understanding your rehabilitation options:
  - Choosing correct rehabilitation/repair methods & products
  - Benefits of rehabilitation
  - Importance of surface preparation
  - Importance of qualified contractors
  - Understanding limitations
- Rehabilitation design QA/QC

*Do it right the first time!*
Evaluating Corrosion through Proper Inspection & Condition Assessment
Importance of Inspection & Condition Assessment

- Key component of successful asset management programs
- Proactive condition assessment prevents failures
- Basis for informed, risk management decision making
- Improves budgeting & capital management
- Critical for selecting rehabilitation/repair methods

Collecting & analyzing data is relatively straightforward; Understanding what to do with it and how to apply the results requires experience.
Different Wastewater Assets Require Different Condition Assessment Approaches:

- Gravity Pipelines
  - CCTV, Advanced Multi-Sensor Systems, Entry Inspection
- Manholes
  - Surface inspection, Entry inspection, Advanced Systems

Various inspection & condition assessment techniques should be considered *tools for the tool box*

- Total system understanding is important
- Focus initial inspections around “hot spots”
Regardless of approach taken and structure type inspected, having an expert involved with a trained eye is critical to performing inspection & condition assessment tasks properly.
Pipeline Inspection & Condition Assessment

CCTV Inspection

- Most pipeline condition assessment data today is collected using CCTV systems
- Basic visual inspection information, above the waterline
- Basis for NASSCO PACP/ LACP rating system
- Cost effective
- Readily available
- Helps identify defects

*Non-quantifiable* info
Pipeline Inspection & Condition Assessment

**NASSCO PACP Pipe Condition Rating System**
- Pipeline Assessment Certification Program
- Standardized condition assessment rating system for wastewater pipes
- Pipe condition & defects rated from 1 to 5 (1= good, 5= poor)
- Lateral condition assessment rating system (LACP)
- Features specific, detailed defect coding
  - Pipe structural defects (cracking, breakage, etc)
  - Corrosion
  - Infiltration
  - Deformation
  - Roots
Pipeline Inspection & Condition Assessment

Advanced Pipeline Condition Assessment Technology

- Cutting edge robotic, multi-sensor systems
- Provides comprehensive, quantifiable inspection data
- Most accurate, but most expensive
- Less reliant on defect identification by operator
- Long & deep deployments
- Composite results package
- All systems include CCTV
Pipeline Inspection & Condition Assessment

Advanced Pipeline Condition Assessment Technology

- Multi-sensor systems feature Laser Profiling, SONAR, Pipe Penetrating RADAR, HD-CCTV, Gas Detection, etc.
Pipeline Inspection & Condition Assessment

Advanced Pipeline Condition Assessment Technology

- **LASER Profiling** – Detects defects in 3-D, ovality, corrosion damage, deflection, and material loss
- **SONAR** – Detects defects under water, debris quantification
- **Pipe Penetrating RADAR** - Ability to “see through” pipe wall, assess rebar condition, corrosion extents, detects defects
- **HD-CCTV** - Higher quality CCTV picture that is correlated to multi-sensor data
- **Gas detection** - Can detect H2S gas levels within pipe, can be used to correlate corrosion patterns
Pipeline Inspection & Condition Assessment

Example inspection data from CCTV
Pipeline Inspection & Condition Assessment

Example 3-D inspection data from LASER profile/SONAR system
Pipeline Inspection & Condition Assessment

Example flat graph inspection data from LASER profile/SONAR system, with HD-CCTV image.
Pipeline Inspection & Condition Assessment

Example inspection data from PPR system
Manhole Inspection & Condition Assessment

Surface Inspection (Level 1)

- Provides basic visual impression of MH condition
- Faster & safer than entry inspection, but less accurate
- Requires no confined space set up & equipment
- Basic inspection info & be used to determine if entry inspection is necessary
- Inspection probes may be utilized
Manhole Inspection & Condition Assessment

Entry Inspection (Level 2)

- More accurate than surface inspections
- Comprehensive inspection from top to bottom
- Requires confined space entry
- Proper safety procedures MUST be followed
- Multi-person crew required
Manhole Inspection & Condition Assessment

Inspection information is only as good as the expertise of the people doing the actual inspection work and subsequent data assessment

Proper training, experience & safety is essential!
Manhole Inspection & Condition Assessment

Gathering Essential Information: Step by Step

Manhole Inspection Procedures

All Confined Space regulations are to be followed as per OSHA 1910.146

Courtesy of Joe Nuciforo - JPCI Services
Manhole Inspection & Condition Assessment

Step 1 – Inspect MH Frame & Cover, Exterior

- Missing chunks & cracks
- No mating surface due to rusting/ corrosion
Good flat mating surface minimum of 5/8” in width. Clean with minimal rust.

Courtesy of Joe Nuciforo - JPCI Services
Manhole Inspection & Condition Assessment

Photo E

Rounded, tapered edge from rust and wear

Photo F

Clean flat edges for load transfer.

Courtesy of Joe Nuciforo - JPCI Services
Manhole Inspection & Condition Assessment

Step 2 – MH Interior Inspection, Major Defect Identification & Safety Assessment

Exposed, Sharp Rebar

Missing barrel section

Courtesy of Joe Nuciforo - JPCI Services
Manhole Inspection & Condition Assessment

Step 3 – MH Entry Inspection – Measure & Quantify Extents of Corrosion

Courtesy of Joe Nuciforo - JPCI Services
Step 4 – Determine Total Material Loss due to Corrosion

- Clean spot on each side of manhole to solid concrete
- Measure distance across MH for new I.D.
- Typical 5’ dia. MH = 59” to 61” new
- \( \text{Material lost on walls} = \frac{(\text{New MH dia.} - \text{measured MH dia.})}{2} \)

Example:

New I.D. 67”  67” - 61” = 6”  6” / 2 = 3” lost

A new concrete barrel section is typically 6” to 7” thick so you know you have lost approximately ½ of the mass of the manhole.
Step 5 – Inspect Bench, Invert, and Pipes

- Probe bench & channel walls to measure extents of corrosion
- Inspect invert for irregular flow patterns
- Inspect pipe opening for cracks, failing PVC, other defects

Courtesy of Joe Nuciforo
- JPCI Services
Manhole Inspection & Condition Assessment

Record Inspection Information

- Inspection forms for each MH
- Keep track of photos
- Accurate, detailed information is critical
Manhole Inspection & Condition Assessment

NASSCO MACP Manhole Condition Rating System

- Manhole Assessment Certification Program
- Standardized condition assessment rating system for wastewater manholes
- MH condition & defects rated 1 to 5 (1= good, 5= poor)
- Features specific, detailed defect coding
  - Structural defects (cracking, missing sections, etc)
  - Corrosion issues
  - Frame & Cover Condition
  - Infiltration
  - Steps
Manhole Inspection & Condition Assessment

Advanced & Emerging MH Inspection Methods

- **Pole Cameras**
  - Close visual inspection from surface
  - Multiple people can see inspection footage
  - No confined space entry
Manhole Inspection & Condition Assessment

Advanced & Emerging MH Inspection Methods

- **Rapid Deployment 3-D Manhole Inspection Technologies**
  - Rapid deployment from surface
  - Complete capture of geometric and visual data
  - No confined space entry
  - 3-D Model verifies diameter & defects
The Importance of Doing Things Correctly...

- Inspection & Condition Assessment information are the basis for rehabilitation/repair designs.
- Critical asset management & budgeting decisions are based on the condition assessment info & prioritizations.
- Often times, inexperienced junior office & field staff perform inspection work and condition assessment ratings.
- Poorly managed inspection and condition assessment programs can lead to costly problems!
The Importance of Doing Things Correctly...

Getting *true experts* involved in your condition assessment & asset management programs will ensure:

- High quality, reliable inspection data is gathered
- Condition assessment ratings & prioritizations are accurate
- The right repair/ rehabilitation approach is recommended
- Proactive asset management strategies are implemented
- Less failures due to corrosion & fewer costly surprises
- More accurate budgeting, scheduling, and cost estimates
- Better details of existing conditions to contractors, thus reducing risk and ultimately bid prices
- More successful projects, better prices, less change orders

*Your asset management program is only as good as the information and expertise you are working with.*
Thank You!

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