Corrosion Management in Plants and Pipelines: Costs, Consequences and Management Options

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Discussion Outline

• The Cost of Managing Corrosion vs. the Consequences of Not Managing Corrosion
• Management of Corrosion in Treatment Plants
• Management of Corrosion in Collection Systems
The Cost of Managing Corrosion vs. The Consequences of Not Managing Corrosion
Consumptive Cost of Corrosion:

One recent evaluation for a large, multi-city regional system: The cost of corrosion-related capital projects averaged over $3.5 million annually system-wide, adjusted for inflation.

- This does not include substantial chemical injection costs aimed at slowing corrosion
- In this example, the cost of replacing assets damaged or consumed by corrosion averaged
  - 10 cents per thousand gallons conveyed and treated
  - Approximately $10 per residential connection per year
  - Over a span of 20 years, the cost of corrosion totaled nearly half of the plant’s annual electric power cost

Corrosion Can Make Your assets Disappear!
Costs of proactively managing corrosion:

- Piping
- Force mains / air release valves
- Gravity sewers
- Manholes
- Siphons
- Process equipment
- Lift stations
- Meter stations
- In-plant structures
- Air handling / conditioning systems
Force Mains & Air Valves

- PVC, FRP, CCFRP, HDPE, and other corrosion-resistant materials are preferred if pressures and burial depths aren’t limiting.

- Avoid metallic and concrete pipe at high points (near air release valves) (No DIP fittings on PVC pipe at high points)

- In smaller diameters (up to 24”) corrosion-resistant pipe materials are typically cost-competitive with other materials

- If metallic or concrete pipe must be used, even if lined, make provisions for inspection & repair (How can it be taken out of service if the lining needs maintenance?)

- Consider plastic or SS air valves; SS can be 3-4 times the cost of a cast iron valve.

- **Vent the valve outside the vault!**
Non-Pressurized Lines

- PVC, FRP, CCFRP, HDPE, and other corrosion-resistant materials are preferred if burial depths and other factors aren’t limiting.

- Avoid metallic and unlined concrete pipe where feasible. OK for non-corrosive internal streams (filter backwash, treated effluent, etc.)

- There’s rarely a cost advantage to using a metallic or concrete pipe in smaller diameters. If metallic or concrete pipe must be used, even if lined, make provisions for diversions for inspection & repair.
Manholes

• Consider Fiberglass where feasible, especially where traffic loadings allow.

• Consider polymer concrete manholes as an alternate to Portland cement concrete.

• The cost and consequence of diversions for lining inspection and replacement is a key consideration in selecting a liner or alternate manhole materials.

• Manholes can be made from HDPE (common in industrial applications; much less common in municipal applications), CCFRP, polymer concrete, and other materials.

• Corrosion-resistant materials can make manholes cost 2-3 times the cost of an unlined concrete manhole.
Siphons

• Sewers carry both air and wastewater. Air hits a dead end at the siphon, pressurizing the headspace and building H$_2$S if provisions for air movement aren’t made. Upstream ends of siphons are very common “traps” for corrosive air.

• Because the purpose of a siphon is often to cross a watercourse, corrosion failure or bypass pumping for repairs can be very expensive and sensitive.

• Consider air “jumpers” if not prohibitive due to the width of the stream or the magnitude of flood events.

• Construction to allow bypasses of individual barrels and coating / lining repair can cost considerably more than “textbook” configurations.
Corrosion at Siphons
Corrosion at Siphons
Process Equipment & Structures

• In preliminary, primary, and biosolids treatment areas, consider non-traditional materials of construction.

• Clarifier mechanisms, screens, etc. can sometimes be fabricated from 316SS at an *installed* cost not significantly different from painted steel or cast iron. The *raw material* cost is considerably more, but coating costs are avoided.

• DIP, PCCP, and other “rigid” piping materials are often used for drains beneath structures; these can fail beneath basins, requiring very expensive repairs. Consider reinforced, encased FRP or PVC instead.
Lift Stations

• Where pipe pressure class is not a limiting factor, consider 316SS or FRP instead of DIP in wetted exposures.

• FRP, HDPE, and polymer concrete wetwells are available for submersible stations and would be preferable to unlined concrete in corrosive environments.

• For cast concrete wetwells, numerous coating and lining products are available. Costs and effectiveness vary widely. The cost and consequences of an extended shutdown for lining inspection and repair is a key consideration in lining selection.

• When practical, a dual wetwell with full isolation capability for each side provides lots of flexibility for inspections and repairs.
Junction Structures

• Junction boxes, whether intended or not, often become a “single point of failure” for a treatment plant or collection system.

• Having a plan for bypassing the box, for inspection or repairs, is vital. More robust and expensive corrosion prevention measures are justified by more risky and expensive bypass operations.

• For covered boxes serving raw or primary treated wastewater, frequent inspections are needed; repairs can be much less costly if caught early.

• Anchor bolts and fasteners must penetrate expensive coatings and linings. Coordinate these penetrations with the liner manufacturer.
Air Conditioning Systems

• Today’s VFD’s, PLC’s, and control systems often require buildings with “conditioned” air (sometimes requiring both cooling and H₂S removal).

• Conventional AC units near corrosion-prone processes may need to be replaced annually. Coated coils drive up costs, but improve longevity.

• Water-cooled units may be appropriate for lager plants.

• Positive pressurization of control rooms, and treatment of air using proprietary media absorbers, can substantially prolong the life of electronics.
Management of Corrosion in Treatment Plants
Early Detection and Prevention

• A preventive maintenance schedule should include regular inspection of concrete, steel, and coatings in corrosion-prone areas. Consider inspections at least annually for known problem areas.

• Sometimes inspections can detect problems early enough to facilitate “spot repairs” before more invasive corrections are needed.

• Coating repairs, when feasible, are much less expensive than structural rehabilitation.
Inspection
Concrete Repair

• Often bid on a unit price basis, “per cubic foot” of repair mortar. Typical cost $200 - $225 per cubic foot.

• Someone has to measure the quantity!

• Removal and replacement of exposed / corroded rebar: Typical cost $25 per linear foot. (Splice lengths onto sound rebar must be achieved)

• Coating or lining cost after concrete repair: $4 to >$40, depending on the product selected.
Coating & Lining Selection

• Many good coating and lining products are on the market. Not all have experienced and skilled applicators in all regions of the country.

• Surface preparation is vital! Cure time needs to be considered for new concrete. Hydrostatic pressures can affect some coatings.

• **Critical question in coating / lining selection:** How disruptive and costly is a failure?

• Cheaper spray-on coatings may be a good solution for redundant structures easily drained and accessed. For “critical” structures, bypassing and access can cost *much* more than the coating.
Protecting Electrical Equipment

- VFD’s, PLC’s, and other sensitive electrical equipment need to be protected from hydrogen sulfide and excess heat.

- Adsorbent media “scrubbers” positioned inside the room, with an HVAC system designed to maintain a positive pressure within electrical and control rooms, can significantly prolong the life of electrical and control equipment.

- This can add $30 to $100 per square foot (plus media costs) to the cost of a small control room, but can prolong the life of more expensive electrical gear.
General Comments

• Corrosion rarely gets better with time.
• For corrosion repairs pursued with capital funds, the extent of corrosion can sometimes grow significantly worse from the time of the first inspection until a contractor can be on site to do the repairs. Consider unit-price bid items and/or contingency bid items to account for surprises.
• Consider having plant personnel or an on-call contractor available on relatively short notice to repair minor corrosion detected during routine inspections. Strive to develop the capability to fix minor problems before they become major problems.
Management of Corrosion in Collection Systems
Consequences of Failure
Potential Physical Issues Affecting Repairs

• Ovality: loss of side support, soil voids
• Does liner need to provide *structural* capacity?
• If so, hydraulic capacity can become an issue
• Availability of access points for inspection and repair
• Sediment, debris, and grease in pipe – how will it be handled and disposed of?
• How will flow be handled during rehabilitation?
• Is surcharging common?
# Trenchless Techniques for Pipeline Rehabilitation

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<th>Technology</th>
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| Relining   | Lining material inserted into deteriorated pipe  
* Cured-in-place pipe: Resin-impregnated fabric is heated, hardens, bonds to host pipe  
* Fold-and-formed pipe: Folded plastic pipe is heated and expands to create snug liner | Can be installed from manholes without excavations  
Service connections made from within pipe | “Point” repair of existing collapsed and out-of-shape conduits required  
Fold-and-formed generally only suitable for round pipe under 24 inches in diameter |
| Sliplining | New pipe inserted into deteriorated host pipe  
Space between pipes is grouted | Relatively inexpensive  
Suitable for 18 to 96-inch diameter pipe | Access pits required  
Can result in loss of hydraulic capacity  
Needs external access to re-establish service connections |
| Spiral Winding | Spiral-wound, ribbed PVC tube fed into deteriorated pipe by winding machine  
Space between original pipe and tube is grouted | Limited surface disruption  
New interior pipe is resistant to corrosion | “Point” repair of existing collapsed and out-of-shape conduits required  
Service connections require excavation from surface |
| Resurfacing | Wire mesh applied to wall of deteriorated pipe  
Slurry material (e.g., shotcrete or grout) is manually sprayed onto pipe wall | Simplicity  
Relatively inexpensive | Pipe must be large enough to permit manned entry  
May require additional liners to combat corrosive atmospheres |
| Spot Repair | Partially collapsed band of pipe pulled into conduit and expanded to fit against inside wall of repair location, OR  
Small robot moves through defective pipe identifying repair locations which are then grouted | Minimal street excavation, traffic disturbance, and flow disruption  
Relatively inexpensive | Viable only if host pipe in relatively good condition |

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Slip Lining

www.oxfordplasticsinc.com/sliplining.htm

ontargetleakdetection.com/…/

www.midwestmole.com/slip-lining.php
Sliplining by continuous pipe

- Provides maximum flow with an independent fully structural solution
- Results in a smaller ID than the host pipe
- Improvement in internal friction often minimizes flow loss – “C” factor
- Grouting of the annular space between the existing and new pipe is usually required
Sliplining by continuous pipe
Sliplining by Segmental Liner
Sliplining by Segmental Liner
Cured-in-Place Pipe Lining
Cured-in-Place Pipe Lining

trenchlessinternational.com/.../000863/
Inert Liners

T-Lock and Spiral Wound
TYPES OF COATINGS

1. Cementitious
2. Epoxy
3. Polyurethane and Polyurea
CEMENTITIOUS COATINGS

- Portland cement
  - no corrosion resistance
- Calcium aluminate
  - mild corrosion resistance
- Calcium aluminate cement
  used for spot repair; prep for polymer coating or lining
- Can be applied by trowel, spray, pour
POLYMER COATINGS

• Epoxy, polyurethane and polyurea provide high corrosion resistance
• Proper surface preparation is essential for success
• Used widely for manhole rehab, spot repairs
• Coating must be free of pin-holes and defects
REQUIREMENTS FOR A SUCCESSFUL COATING

1. Surface Preparation!!!
2. Quality Application
3. Testing before and after application
Comments

• Noise, odor and traffic control can be significant for certain repair techniques. Jacking and access pits can be disruptive and expensive
• Temporary easements may be needed for access to install liners or other rehabilitation
• Rehabilitation can often cost more than a new pipe. If adequate and open real estate exists, consider a new pipe.
• Bypass pumping can be a very large percentage of the total project cost for methods requiring it.
Comments

• Sample costs: 60” Pipe:
  • Unlined RCP $300 – 400 /LF
  • CIPP Rehabilitation $350 – $600 / LF  Slipline Rehab $300 - $400 /LF
  • Spiral Wound $300 - $600 / LF
  • 48” Manholes
    • FRP: $4000 - $8000  Concrete $2400 – $4000
    • Rehab of Corroded MH: $3000 - $7000
    • Large diameter and deep manholes can cost significantly more ($30,000 & up)

• For new pipe, choose corrosion-resistant materials!

• Mechanical ventilation and chemical treatment can significantly slow the progression of corrosion, but they can’t fix a corroded pipe.
Questions

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