EVOQUA WATER TECHNOLOGIES

Studying the Impact of Hydrogen Sulfide on Concrete Corrosion in Wastewater Collection Systems

WEF eShowcase

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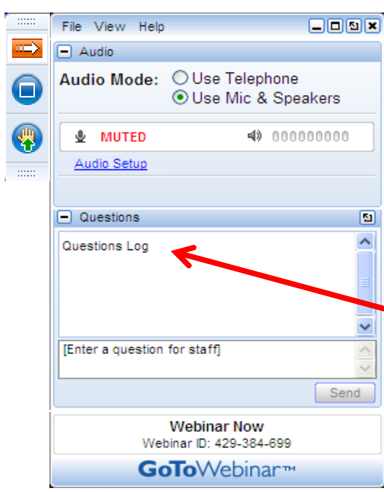

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- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

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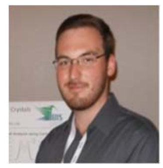
Introduction

- Calvin Horst
  - Product Manager
  - BS Chemical Engineering
  - 5+ years experience

- Justin Stewart
  - Application Engineer
  - MS Chemical Engineering
  - 4+ years experience



- Vaughan Harshman
  - Technical Sales Manager
  - BS Chemical Engineering, PE (FL)
  - 30+ years experience

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Topics

- Background
- Objectives
- Test Methods
- Results
- Treatment Methods

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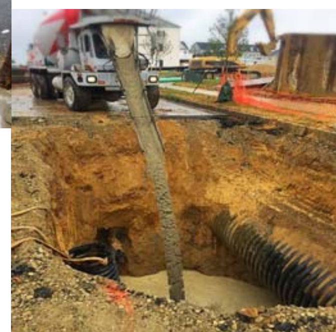
Corrosion Causes Infrastructure Failure

- System outages
- Pollution release
- Public danger
- Expensive & disruptive repairs
- Headline news



Is failure acceptable?

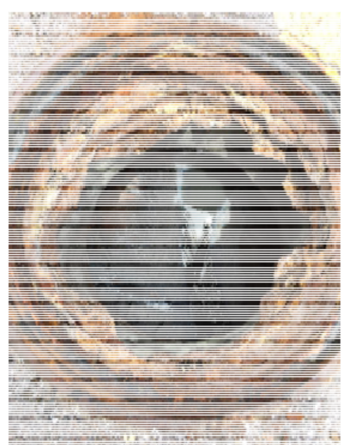
Do we have to wait for failure?

Can failure be avoided?

Corrosion's Economic Impact

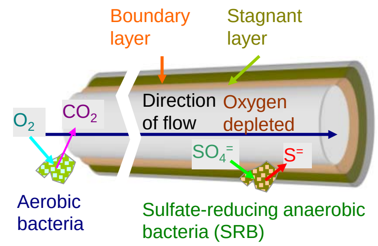
1991 EPA report to Congress

- 89 cities participating in the survey
- $6 billion spent on sewer rehabilitation
- 32 cities reported sewer collapses
- 81% were believed to be due to hydrogen sulfide corrosion
- 70% of the respondents reported hydrogen sulfide corrosion at the treatment plant



How is Hydrogen Sulfide Generated?

1. Oxygen in wastewater is consumed by aerobic bacteria
2. Once oxygen is depleted, bacteria will shift to a different oxygen source
   - Nitrate oxygen
   - Sulfate oxygen
3. Nitrate oxygen is not typically present in wastewater, leaving only sulfate
4. Sulfate is reduced to hydrogen sulfide



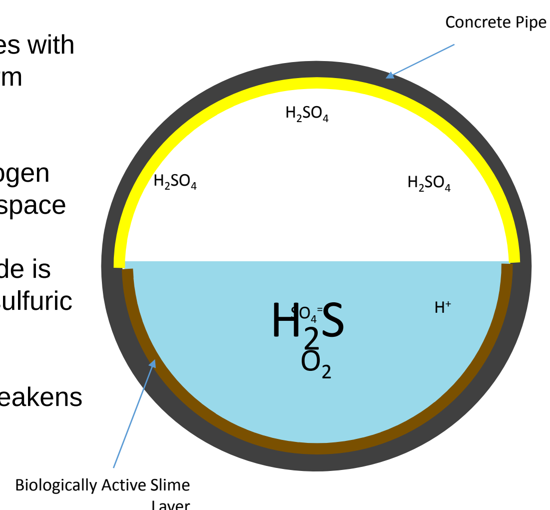
How Hydrogen Sulfide Corrodes Concrete

Step 1– Sulfide combines with wastewater acidity to form hydrogen sulfide

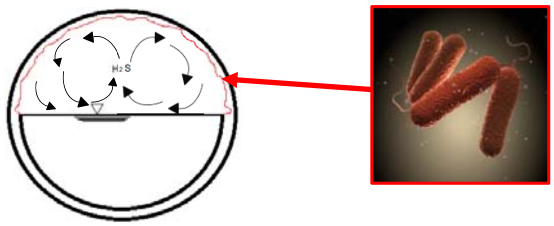
Step 2 – Insoluble hydrogen sulfide escapes to headspace

Step 3 – Hydrogen sulfide is biologically oxidized to sulfuric acid

Step 4 – Sulfuric acid weakens the concrete structure



What Is Microbial Induced Corrosion (MIC)?



$$H_2S + 2O_2 \xrightarrow{\text{Sulfur Oxidizing Bacteria}} H_2SO_4 \text{ (sulfuric acid)}$$

Genus: Acidithiobacillius
Autotrophs – use inorganic substances to fulfill their energy needs
Obligate – need sulfur, oxygen and carbon to survive
Acidithiobacillus Intermedius pH ~ 4
Acidithiobacillus Thiooxidans pH ~ 2

Measuring Microbial Induced Corrosion (MIC)

Hypothesis:

MIC rates in wastewater collection systems vary based on a number of factors – mainly hydrogen sulfide concentration. Infrastructure failure can be predicted by the amount of hydrogen sulfide concentration.

Measuring Microbial Induced Corrosion (MIC)

Test Method:

- Expose test specimens to varying H_2S concentrations
- Monitor mass loss
- Monitor changes in compressive strength

Duration: 2 Years

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MIC Measurement Test Sites

Two Sites Selected:

- Exposure to high and low H_2S concentrations

Similar Force Mains:

- Same collections basin/water quality
- Similar retention time
- Similar atmospheric conditions (rain, temp, humidity, etc.)

Parameter	Airport PS - Untreated	Centerplex PS - Treated
Average Daily Flow (MGD)	0.191	0.11
Forcemain Length (feet)	9,820	4,400
Forcemain Diameter (inches)	6	8
Average Retention Time (hr.)	1.8	2.5

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Hydrogen Sulfide Control Methods

Treated Location – Centerplex Pump Station

H_2S Control Product	Target Average H_2S	Actual Average H_2S
Bioxide® Solution	< 5 ppmv	4 ppmv

Bioxide Solution:
60% Calcium Nitrate Solution
Non-hazardous
Removes H_2S
Prevents formation of H_2S

Other H_2S Control Products:
Alkagen® Solution
Odophos® Solution (Iron Salts)
VX-456 Solution, H_2O_2 (Oxidizers)

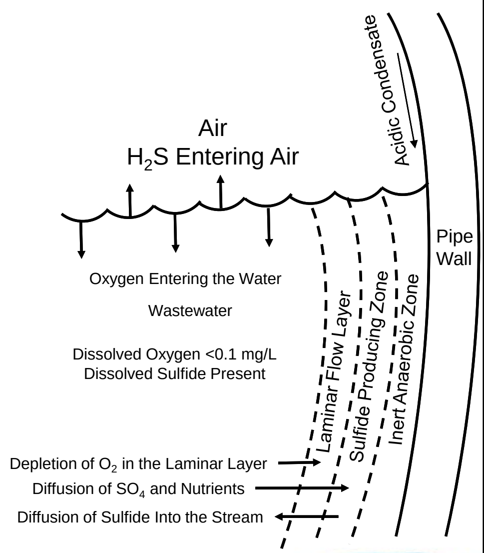
No Air Scrubbers

How Bioxide® Solution Prevents Hydrogen Sulfide

Wastewater biology oxygen sources and respiration byproducts

1. Oxygen → Carbon Dioxide and Water
2. Nitrate → Nitrogen gas
3. Sulfate → Hydrogen Sulfide

Adding nitrate to wastewater prevents the reduction of sulfate to sulfide



EPA Design Manual (1985)

Using Chemical Feed Systems Efficiently

- Care must be taken when using any chemical feed to:
  - Mitigate operational control issues
  - Minimize negative impact at the treatment plant
  - Optimize control effect vs. the end user's budget

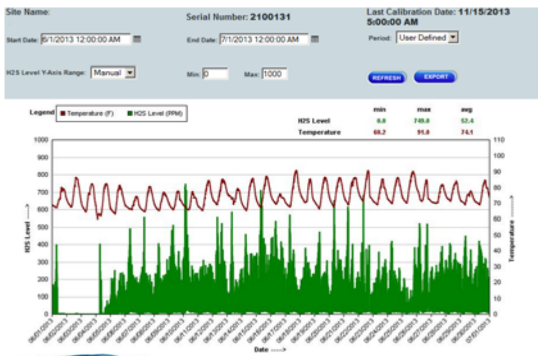
Calcium Nitrate Dosing

Calcium nitrate was dosed to obtain a slight residual at the control point

	Feed Rate (GPD)		Nitrate Residual (mg/l)	
	2012	2013	2012	2013
January	34.1	32.4	2	4
February	29.9	16.5	4	0
March	28.5	16.9	4	0
April	30	16.2*	4	0
May	28.5	17.5*	3	
June	30.8	35.8	1	0
July	41.7	36.2	2	
August	45.7	33.3	2	4
September	36.2	32.7	3	
October	34.9	47	4	
November	34.7	47.1	2	
December	34.1	27.2	4	3
AVERAGE	32.0		2.4	

Sulfide Monitoring Process

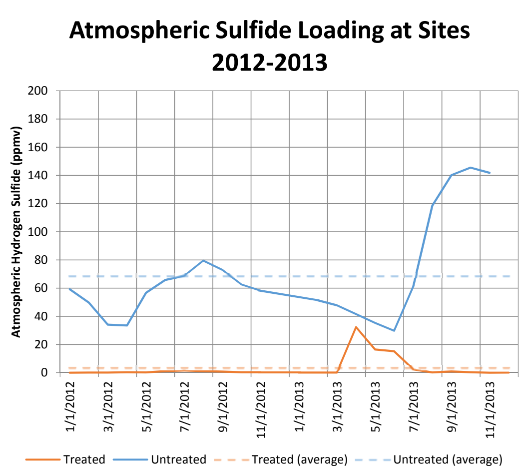
- **Hydrogen Sulfide Vapor Concentration**
  - 5 min. intervals
- **Dissolved Sulfide**
  - monthly



Atmospheric Sulfide: Treated vs. Untreated

Airport PS – Untreated
- 69 ppmv average H_2S
- 146 ppmv peak

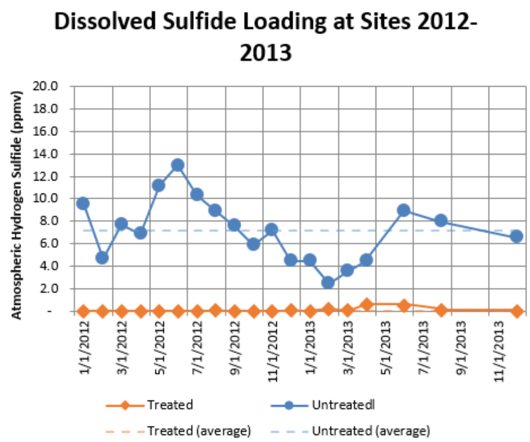
Centerplex PS – Treated
- 4 ppmv average
- 32 ppmv peak



Dissolved Sulfide: Treated vs. Untreated

Airport PS - Untreated
- 7.2 mg/l avg DS
- 8.9 mg/l peak DS

Centerplex PS – Treated
- 0.08 mg/l avg DS
- 0.6 mg/l peak DS



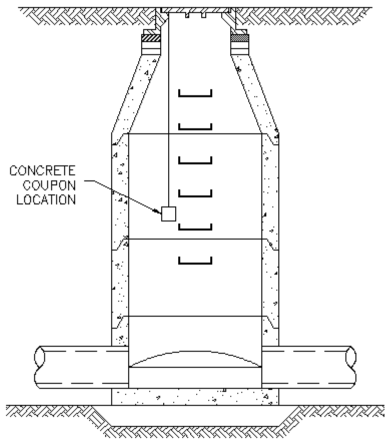
Fabricating Concrete Test Specimens

Concrete test specimens
- Fabricated by third-party contractor
- Type II Portland cement
  - *Performed in accordance with ASTM C150*
- Testing and curing
  - *Performed in accordance with ASTM C192*

Concrete Coupons Curing

Preparing Concrete Test Specimens

Concrete coupons
- 8 coupons exposed per site
- Treated
- Untreated



Weighing Concrete Samples

Prior to each weight measurement:
- Samples were washed to remove attached growth
- The scale was calibrated with a 1.000KG standard

Sample weighing was performed on samples at 6-month intervals

Compression Testing Methods

Compression Testing

- performed by a certified third-party contractor
- performed as outlined in ASTM C39
- Forney FHS Series Premium Compression Tester

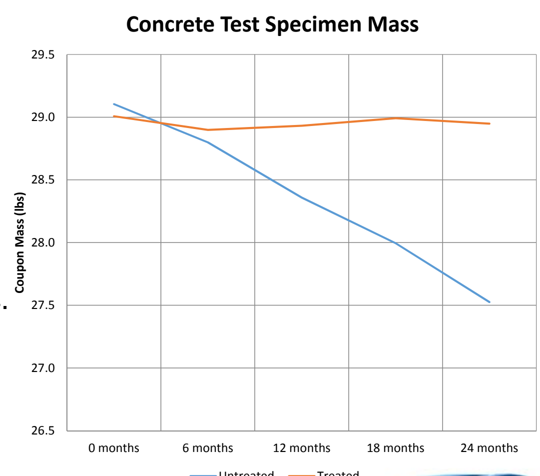
Specimen Mass: Treated vs. Untreated

Airport PS - Untreated

- Avg. wt.
  29.1lbs. to 27.5 lbs.
- 5.4% loss of mass

Centerplex PS -Treated

- Avg. wt.
  29.0 lbs. to 28.9 lbs.
- 0.2% loss of mass



Specimen Strength: Treated vs. Untreated

Untreated for H_2S

- Compressive strength reduced 13%

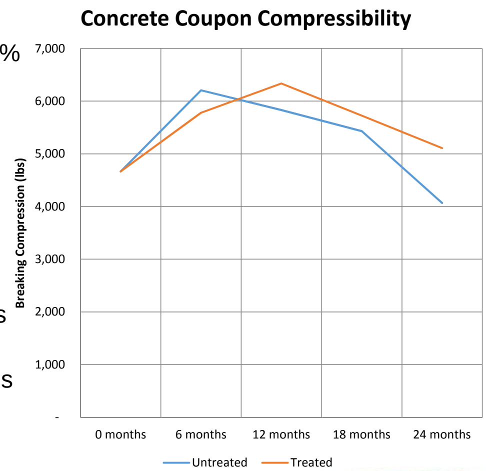
Treated for H_2S

- Compressive strength higher

Initial breaks on samples 4,667 PSI

Continued hydration accounts for increase in compressive strength

- Strengthening peaked at 6 months for untreated coupons.
- Strengthening peaked at 12 months for control coupons.



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Compressive Strength Maintained (Treated)

Exposure to an average of 3.5 ppmv (2-year period)

- **No loss in compressive strength During 2-year test duration**
- **0.2% reduction in weight**

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13% Compressive Strength Loss (Untreated)

Exposure to an average of 69 ppmv (2-year period)

- **13% loss of compressive strength**
- **5.4% reduction in weight of samples**

H_2S Triggers Concrete Strength & Mass Loss

1. Presence of > 60 ppmv H_2S impacted specimens
2. Presence of H_2S resulted in mass loss of concrete (5% less)
3. Presence of H_2S resulted in loss of compressive strength (13% lost)
4. Treatment to eliminate H_2S resulted in improved concrete condition

7-Year Payback: Treatment Costs vs. Rehab

Historical CIPP Lining Cost in 2003 ($/LF)*	**$25.00**
Adjusted CIPP Lining Cost per ENR CCI ($/LF) • ENR CCI 1998-2017 – 1.80	**$45.00**
Cost to rehab • 4,400 lineal feet	**$198,000**
Annualized treatment cost • $2.50 per gallon • Annualized average feed rate of 32 gpd • Metering equipment included in price per gal. • Routine monitoring and optimization included in price per gal.	**$29,200**
Payback on treatment	**~7 years**

* US EPA 1999 – Collection Systems O&M Fact Sheet

Research Next Steps

1. Add to the data set – study ongoing
2. Comparison of different H_2S exposure levels
3. Measure pH of specimens
4. Better define H_2S neutralization cost benefits
5. Better define infrastructure life benefits
6. Better define the test
   - Shape of specimen
   - Cement composition
   - Timespan
   - Comparison with a new installation

Best Practices: Prevent Infrastructure Failure

1. Infrastructure protection planning
   - Identify weak points (roadways)
2. Monitor weak points
3. Look at cost benefits for protections
4. Implement Protections:
   - Operational Changes
   - Materials – Linings
   - H_2S Capture or Neutralization

Questions & Answers

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