Biogenic Corrosion & Cementitious Repair Materials

SEWPERCOAT®

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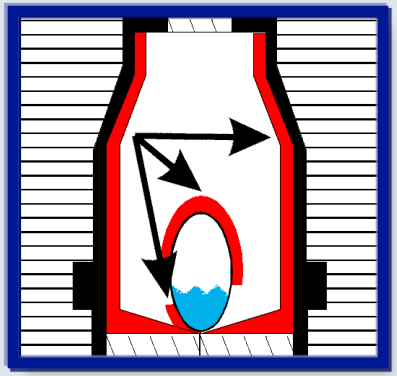
ICRI Presentation

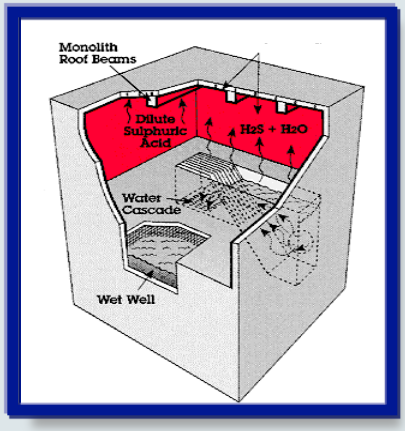
kerneos™
ALUMINATE TECHNOLOGIES

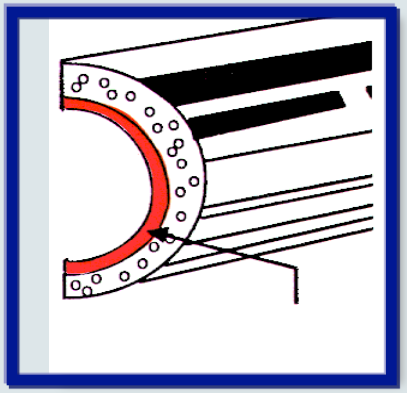
The Problem...

Biogenic (H_2S) Corrosion in Municipal Sewer Systems

- Manholes
- Wet Wells
- Lift Stations
- WWTP Structures
- Pipe Lining







The Problem...

Products Available

- **Cementitious Mortars**
  - **Portland Cement Mortars – *Structural Properties***
    - Portland Cement blended with natural aggregates
    - Portland Cement and pozzolons blended with natural aggregates
    - Bacteria Inhibiting admixtures are also available
  - **Calcium Aluminate Blended Mortars– *Mild Corrosion Resistance and Structural Properties***
    - Calcium Aluminate cement blended with natural aggregates
  - **100% Calcium Aluminate Mortars– *Excellent Corrosion Resistance and Structural Properties***
    - 100% Calcium Aluminate cement and Calcium Aluminate aggregate mortars

Products Available

- **Inert Coatings and Linings**
  - **Epoxies and Urethanes**
    - 100% solids generally recommended in underground applications
    - Excellent chemical resistance
    - Installer dependent
  - **Thermoplastic Sheet Liners**
    - Excellent chemical resistance
    - Installer dependent – seam welding is critical
    - Labor intensive – used with mastic or cementitious underlayment
  - **Cured-in-Place Liners**
    - Excellent chemical resistance and structural properties
    - Installer and equipment dependent
    - Annular space must be properly addressed

Evaluation Methods

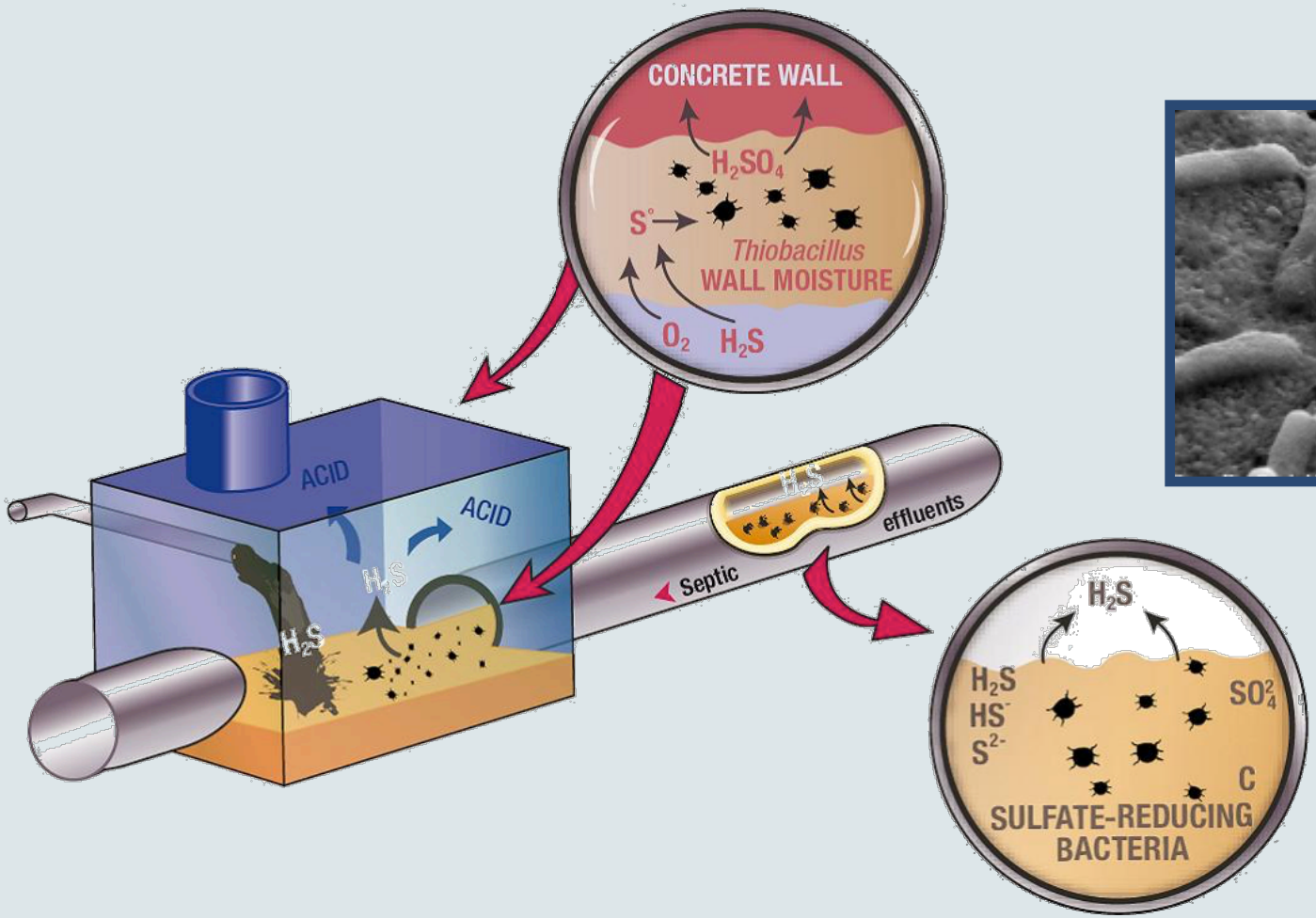
Previous Evaluations of Concrete Corrosion Considered Only Acid Chemical Attack

- Wet Acid Test Method
- Does not consider "bacterial aspect"
- Inability to reconcile lab results with field results

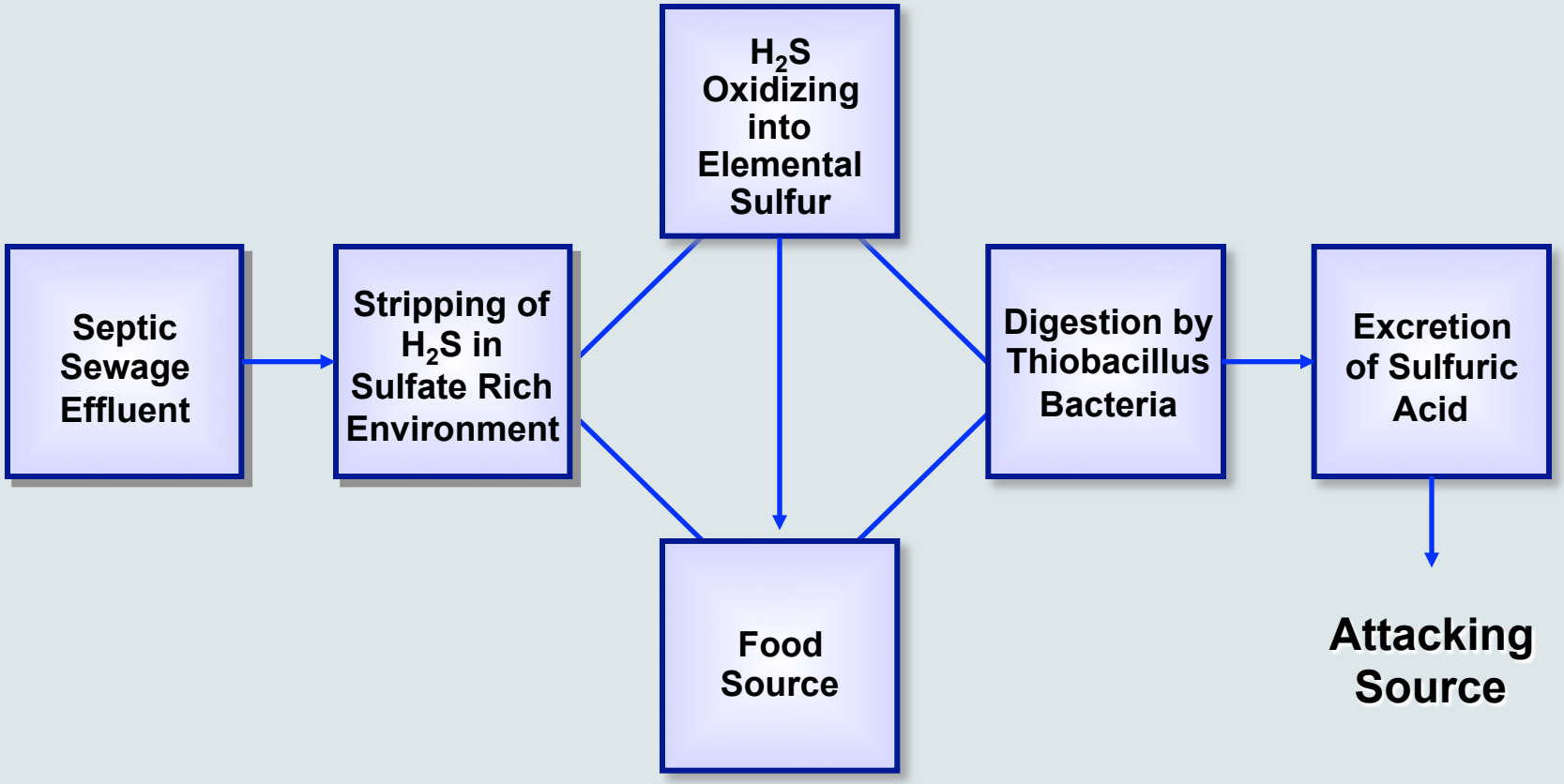
Corrosion Types

- **BACTERIAL - The #1 Problem**
  Hydrogen Sulfide Atmosphere (H_2S)
- **ACID CHEMICAL - Diluted and Concentrated Liquids (H_2SO_4)**
- **SULFATES - Soil or Water (SO_2^- ions)**
- **ALKALINE - (OH^- ions)**

Biogenic Corrosion



Biogenic Corrosion Kinetics



Crown Corrosion

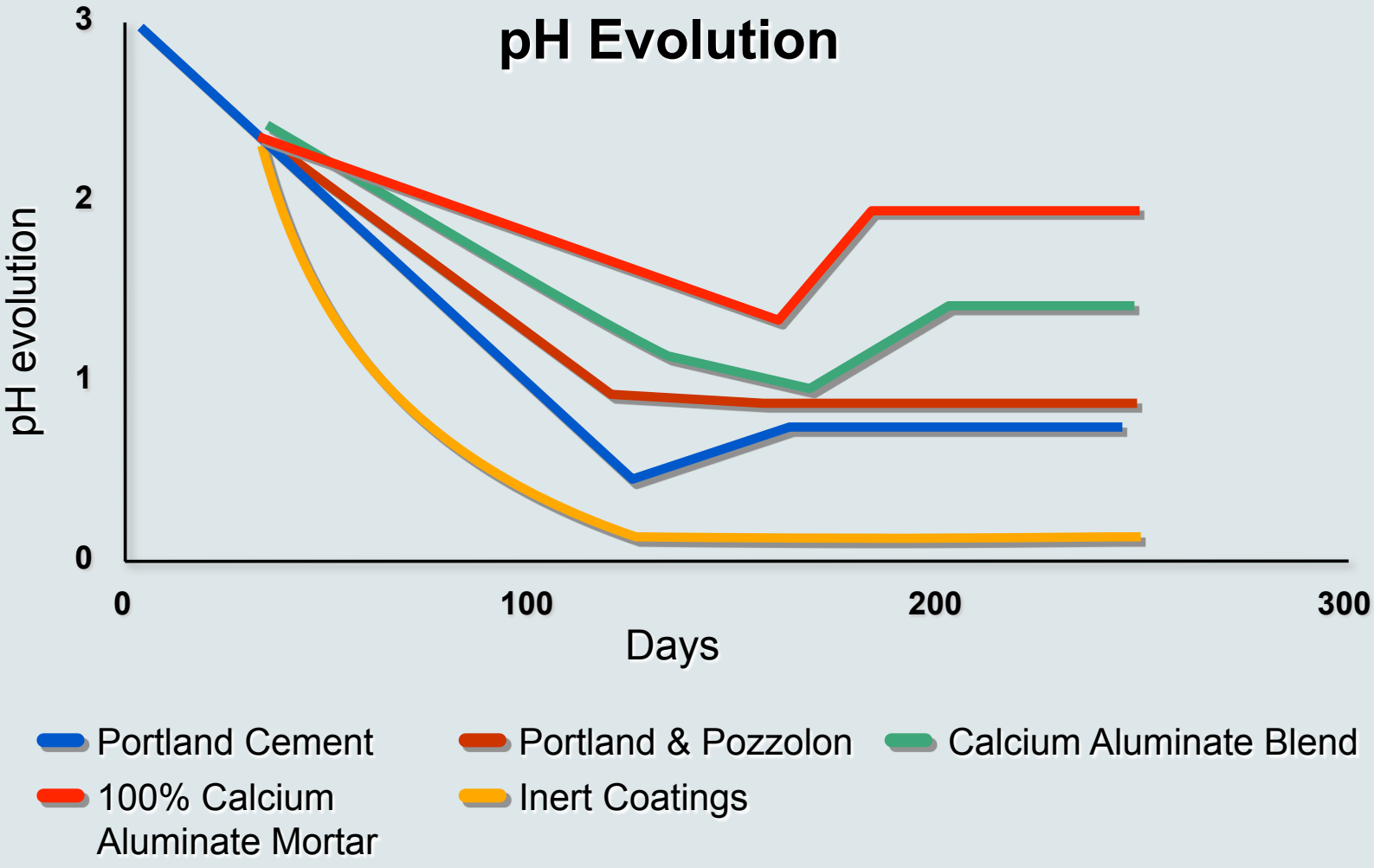
Research & Evolution of Evaluation Methods

The Hamburg University Test Chamber

- Duplicates biogenic corrosion
- Municipal effluent and bacteria are used
- Temperature, humidity, H_2S ppm are controlled
- Corrosion calibrated to harshest level (1 to 24 ratio for the portland cement based control mortar)

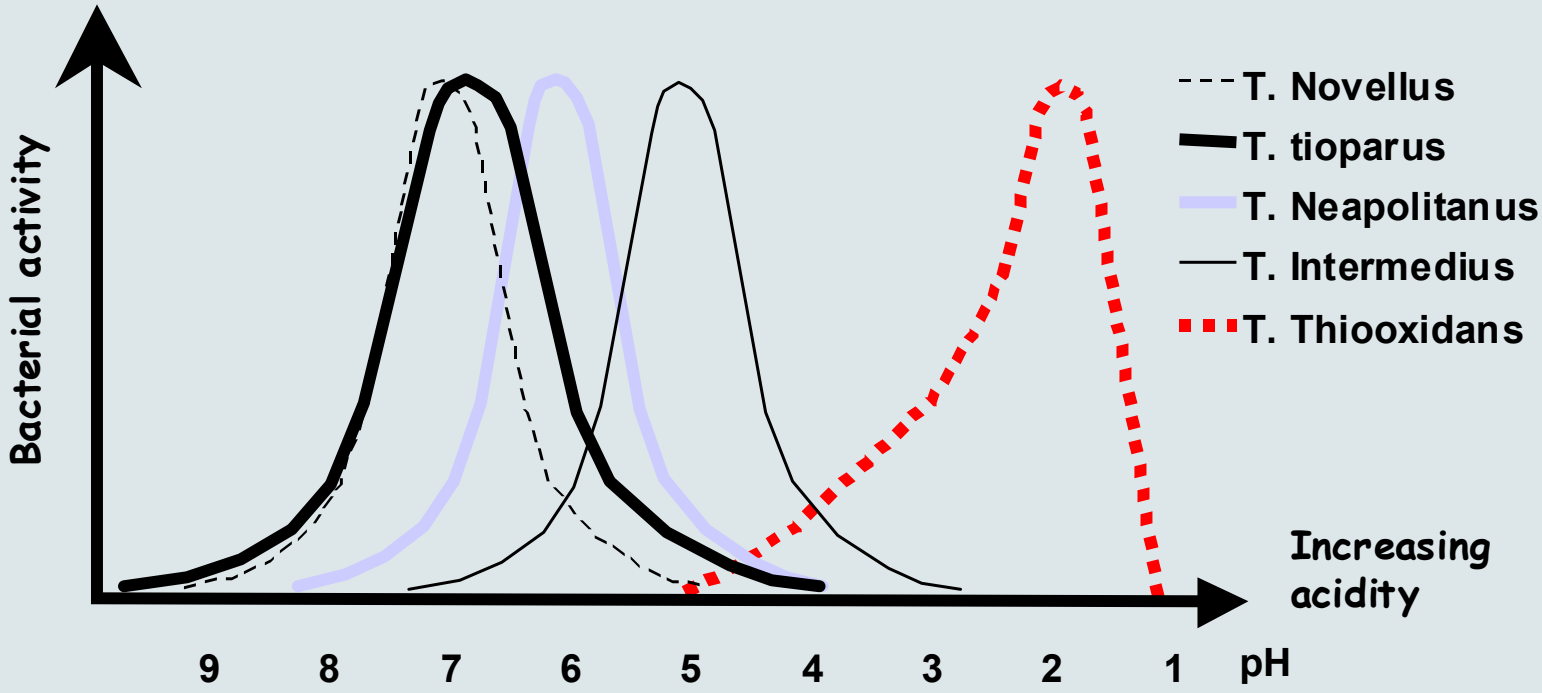
*** BIOGENIC AND CHEMICAL SULFURIC ACID CORROSION OF MORTARS –**
JOURNAL OF MATERIALS IN CIVIL ENGINEERING / NOVEMBER 1999

pH Evolution & Biogenic Corrosion (H_2S)



Understanding of Bacterial Activity:

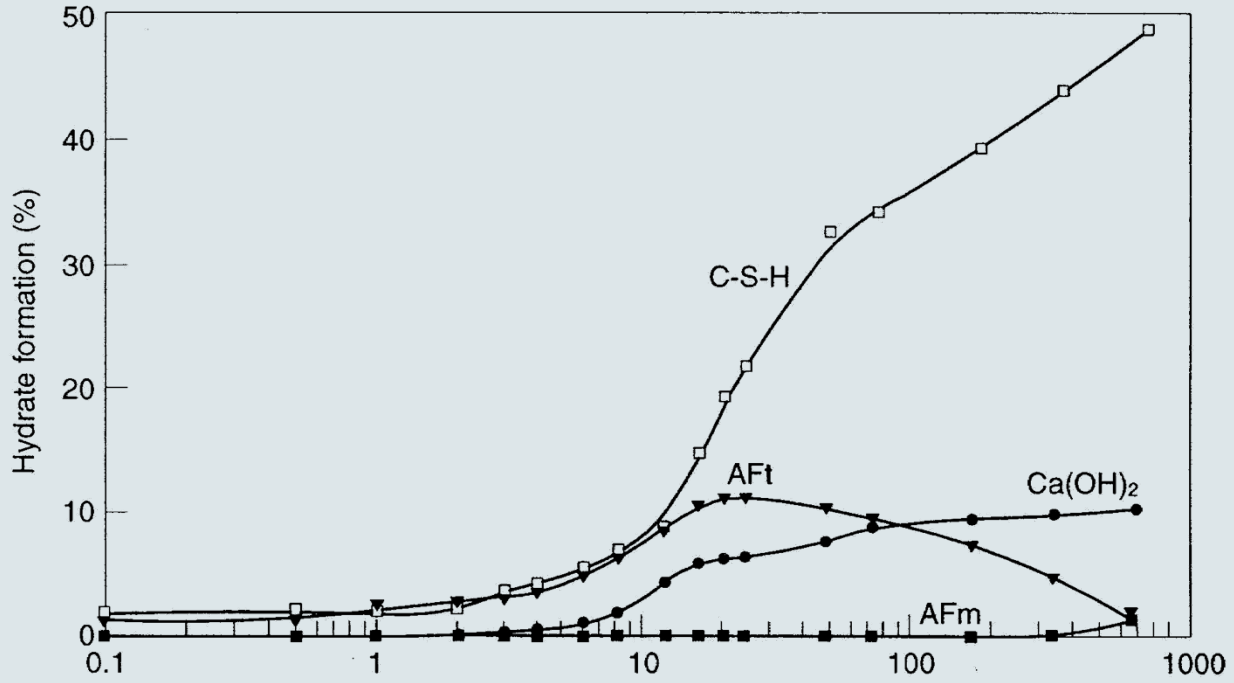
There are different strains of Thiobacillus adapted to each pH range environment



Current Research activity into Microbiological Corrosion

- **ASTM Committee C13 on Concrete Pipe**
  - **C13.03 subcommittee formed in 2005 on "Determining the Effects of Biogenic Sulfuric Acid on Concrete Pipe and Structures"**
  - **Organizing Industry funding to Michigan State University to complement pending NSF grant**
  - **Goal is to identify specific thiobacilli with modern DNA sequencing**
  - **This bacteria would then be used to innoculate material specimens to start the corrosion cycle and then maintain in a controlled chamber**

Portland Cement Hydration Kinetics



- **As Portland cement hydrates, calcium hydroxide [$Ca(OH)_2$] is inescapably liberated.**

Ongoing Disruptive Phenomena

- **The "Ongoing Disruptive Phenomena" is the means of attack and failure of Portland cement based materials.**
- **The sulfuric acid produced by the bacteria attacks the calcium hydroxide (lime) liberated during hydration:**

$$Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4 + 2H_2O$$

Lime + Sulfuric Acid → Gypsum + Water

Delamination of Inert Coatings

Protective – Reactive Barrier

- Calcium Aluminate cement liberates "gibbsite" (AH_3) upon hydration.
- Alumina gel inhibits the bacterial activity of the Thiooxidans strain.

- Alumina gel also neutralizes the acid produced by the consumption of hydrogen ions:
  - $\{AH_3 = Al_2(OH)_6\} + 6H^+ \rightarrow 2Al^{3+} + 6H_20$

How CA Mortars Work

$$\{AH_3 = Al_2(OH)_6\} + 6H^+ \rightarrow 2Al^{3+} + 6H_20$$

- H_2SO_4 in solution becomes:

  → $H^+ + SO_4^{2-} + HSO_4^{2-} + H_20$ (hydrogen, sulfate, bisulfate ions & water)

- CA cement mixed with water hydrates to become:

  → $C_3AH_6 + C_2AH_8 + AH_3$

- AH_3 is cement notation (shorthand) for $Al_2(OH)_6$

- **pH = -log[H^+]** , or the negative log of the molecular concentration of hydrogen ions in solution

- **AH_3 consumes H^+ ions** yielding:

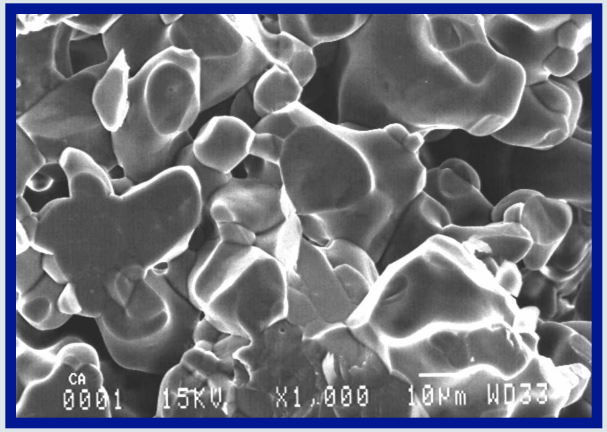
  → $2Al^{3+} + 6H_20$ (or Alumina ions and water)

- Consumption of **H^+** ions from solution reduces the **H^+** molecular concentration, therefore the pH is locally increased.

How 100% CA Mortars Work

$$\{AH_3 = Al_2(OH)_6\} + 6H^+ \rightarrow 2Al^{3+} + 6H_20$$

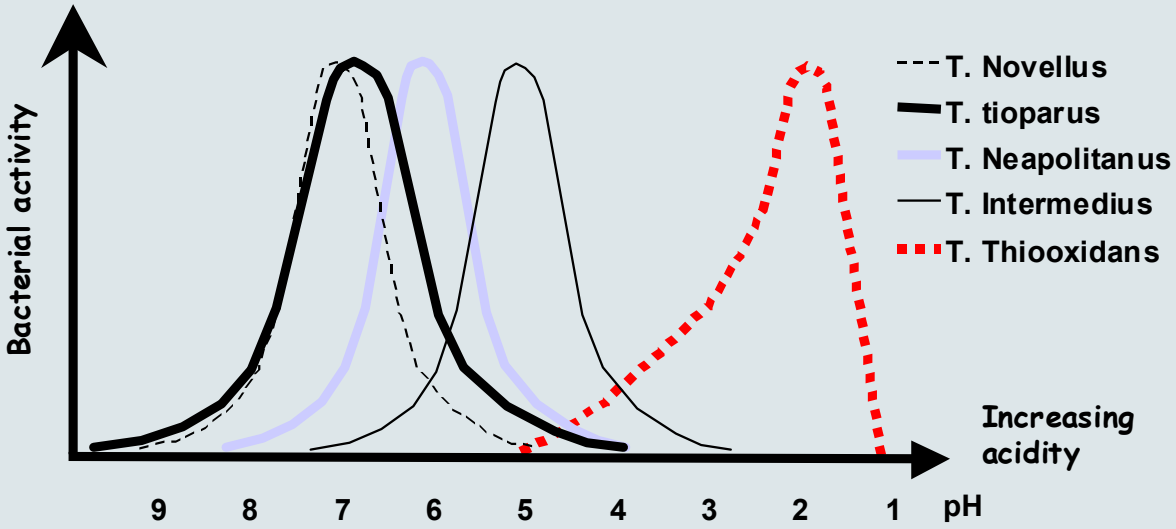
- The CA aggregates are the key…
- As AH_3 is consumed, an abundance of CA in unreacted cement and **CA aggregates** continue to hydrate in a humid sewerage environment, continuously forming more AH_3.



Anhydrous (unreacted) CA grains

- This is how a 100% Calcium Aluminate mortar can continue to locally raise the pH in this environment, taking us back to the bacterial strain graph…

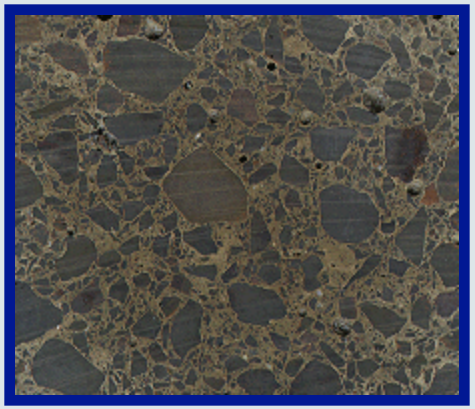
100% Calcium Aluminate Materials Inhibit Bacterial Activity:

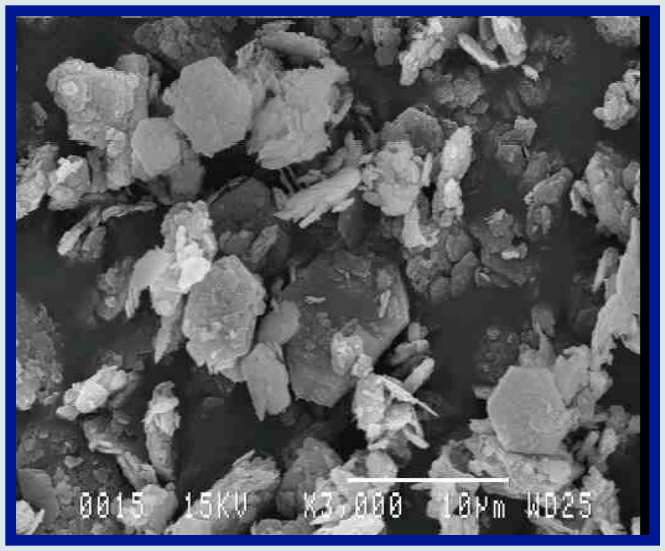


- 100% CA mortars keep the system in a state of minimal bacterial activity (between pH 3.0 and pH 4.0).
- The AH_3 that is continually released from the aggregate system can be enough to neutralize the additional H^+ ions produced by the bacteria.

Total Calcium Aluminate Barrier

- Combines the Protective-Reactive Barrier effects of both calcium aluminate cement and manufactured calcium aluminate aggregates.
- Calcium aluminate aggregates are hydraulic and reactive.





- Both cement and aggregates have the same chemistry and mineralogy.
- This creates unmatched neutralization capacity and produces both a physical and chemical bond upon hydration.

City of Ormond Beach, Florida: Reference

- 1”- 4” deterioration of Portland cement concrete in 5 years
- Exposure of reinforcing steel
- H_2S readings > 30 ppm

After 3 years in service the external attack on the discharge line, installed 1 year later than the lining, clearly demonstrates the corrosive nature of this environment.

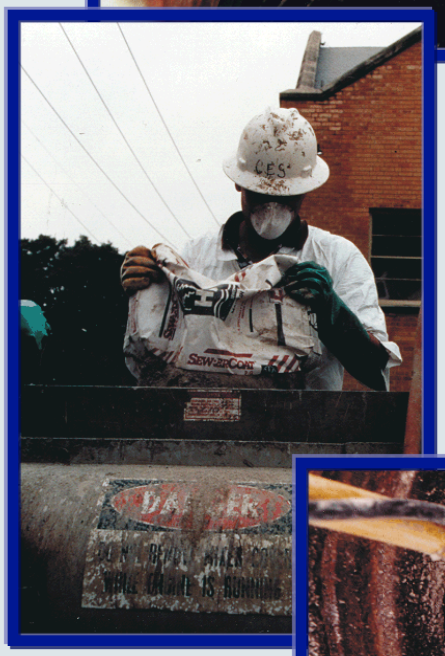
After 9 years the state of lining remains excellent. Trowel marks are still present in the corners…

Installation

- Cementitious Materials are relatively easy to install…
  - Cementitious Mortars are designed for “wet” installations
- Contractor Qualifications are very important
  - Insist upon some type of manufacturer designation…
    - Certification
    - Approved
    - Qualified
  - Similar work requirements…
- The Installer can be the most important factor for success with any rehabilitation material.

Manhole Rehab Process

Old manholes can be very irregularly shaped and even have brick missing



Materials are easily mixed by just adding water

Spray-applied mortars are easily applied into the large voids

A masonry brush can be used for finishing to provide a different look

Once applied, mortars can quickly be finished to provide a smooth lining

Before & After Rehabilitation

Before…

…After

Total Protective – Reactive Barrier Process

Ongoing Disruptive Phenomena is apparent with existing portland cement based materials

The clean, prepared, and reinforced structure receives a 100% Calcium Aluminate mortar installation

The finished product exhibits the Protective – Reactive Barrier effect of a 100% Calcium Aluminate structural lining

Typical Wet Well Rehab

Existing Wet Well

After Rehabilitation

Box Structure Rehab

Existing channel box in deteriorated condition

Sluice gate installed and structure coated

Typical Wet Well Rehab

Existing Wet Well

Rehabilitated Wet Well

Manhole Rehabilitation

Existing Brick Manhole with Tidal Infiltration

After Cementitious Rehabilitation

Manhole Rehabilitation

Deteriorated Precast Manhole with Bench & Invert Problems

Rehabilitated Entirely with Cementitious Mortar

Manhole Rehabilitation

Precast Manhole with Failure of Existing Coating

Existing Coating Removed and Mortar Installed

Questions
&
Answers