CONCRETEFiX 6:4

Using Colloidal Silica to Protect Concrete from BSA in Wastewater & Organic Waste Environments

Biogenic sulfuric acid attack — mechanisms, field evidence, and a colloidal silica mitigation strategy

ROADMAP

What we will cover

01

PART ONE

The Problem

Why a familiar building material fails fastest exactly where we need it most.

THE PROBLEM

The most costly form of concrete biodeterioration

$10B+ [1]

estimated annual BSA-related damage to concrete infrastructure in the U.S.

$14B [2,3]

yearly U.S. sewer asset losses attributed to biogenic sulfide corrosion

< 1 [4]

surface pH reached on heavily corroded concrete, vs. 5–8 in normal sewage

Biogenic sulfuric acid attack (BSA) is widely regarded as the most common and most severe biodegradation mechanism affecting concrete. It silently consumes the structures that carry and contain our waste — sewers, treatment plants, digesters, farm tanks, and processing floors — long before their intended service life.

[1] *Hou et al., Concrete International, 2020.* [2,3] *U.S. EPA, Report to Congress, 1991.* [4] *Okabe et al., Applied & Environmental Microbiology, 2007.*

DEFINITION

What we mean by “BSA”

One process, many names

BSA is a multi-stage biological process in which bacteria deposit **concentrated sulfuric acid** on concrete surfaces above the waterline, accelerating deterioration far beyond ordinary chemical attack.

Also called: MICC · MID · MIC · biogenic sulfide corrosion · hydrogen-sulfide corrosion

1. **SRB** Sulfate-reducing bacteria (e.g. Desulfovibrio) generate H_2S gas in the anaerobic waste stream.
2. **H_2S** Hydrogen sulfide escapes to the headspace and dissolves in moisture films on exposed concrete.
3. **SOB** Sulfur-oxidizing bacteria (e.g. Acidithiobacillus) oxidise sulfur to sulfuric acid on the surface.
4. **H_2SO_4** The acid dissolves cement paste — converting hardened concrete into soft gypsum and ettringite.

Terminology after Hou et al. (2020)[1] and Chaudhari et al. (2022).[6]

MECHANISM

How sewage becomes acid: the sulfur cycle

Anaerobic zone	Off-gassing	Condensation	Bio-oxidation	Attack
Submerged sewage	**H_2S → headspace**	**Moisture film**	**SOB → H_2SO_4**	**Paste dissolves**
SRB reduce sulfates to dissolved sulfide in the oxygen-starved waste stream.	Turbulence releases hydrogen sulfide gas above the waterline (> 2 ppm).	H_2S dissolves into condensation on the exposed concrete crown and walls.	Aerobic bacteria oxidise sulfur to sulfuric acid; surface pH falls below 1.	Acid reacts with cement paste, forming gypsum and expansive ettringite.

Key insight: the waste itself is nearly neutral (pH 5–8) — the damage is biologically manufactured on the concrete surface, where the acid is most concentrated.

Mechanism after Hou et al. (2020)[1]; thresholds per biogenic sulfide corrosion literature.[2,3]

MICROBIOLOGY

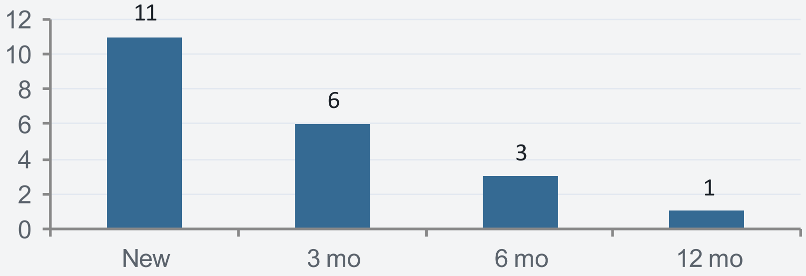
A shifting community drives the acid down

Over a single year of in-situ monitoring, the bacterial community on corroding sewer concrete shifts from near-neutral species toward extreme acidophiles as the surface pH collapses.

- At least six phylotypes of sulfur-oxidizing bacteria participate in sequence.
- Acidithiobacillus thiooxidans, a hyper-acidophile, dominates the heavily corroded layer.
- Acid production concentrates in the top ~1.5 mm, then penetrates to sound concrete below.

70% of cells in heavily corroded concrete were A. thiooxidans after one year in service.

Falling concrete surface pH over time



Succession and dominance data: Okabe, Odagiri, Ito & Satoh, Applied & Environmental Microbiology, 73(3), 2007.[4] pH trend illustrative of reported behavior.

RISK FACTORS

Conditions that accelerate the attack

H_2S concentration

Active corrosion needs headspace H_2S above ~2 ppm with oxygen and high humidity present.

Dissolved oxygen

Below ~0.1 mg/L, sulfides are emitted as gas instead of being re-oxidised in the stream.

Temperature

Warmer waste speeds sulfide generation and bacterial metabolism alike.

Flow & retention

Slow, flat, long-retention systems go anaerobic and produce more sulfide.

Concrete quality

High water-cement ratio and permeability give acid an easy path inward.

Aggregate type

Siliceous aggregates offer no buffering; carbonates partially neutralise acid.

Drivers synthesised from biogenic sulfide corrosion literature[2,3] and Hou et al. (2020).[1]

02

PART TWO

Where BSA Strikes

The same chemistry, three very different built environments — documented in the field.

Photo illustrative. Field behavior per Hou et al. (2020)[1] and Abu-Yosef, Armijos-Moya & Poston, ACI Materials Journal, 2023.[5]

Sewers, manholes & treatment plants

The classic setting for BSA: gravity sewers, pumping stations, manholes, wet wells, and digesters where H_2S accumulates in the headspace.

- Corrosion concentrates on the pipe crown and walls above the flow line.
- Cement paste is replaced by soft white gypsum; aggregate falls away.
- Oxygen injection in digesters can intensify BSA activity and acid output.

Photo illustrative. Per Maraveas, Applied Sciences, 2020[7] and Assaad, Jofriet, Negi & Hayward, Univ. of Guelph.[8]

Slurry stores, manure tanks & barn floors

Stored manure and silage effluent release hydrogen sulfide, ammonia, and sulfates that attack tanks, channels, and slatted floors.

- Poultry, cattle, and swine manure all carry corrosion-inducing chemicals.
- H_2S is identified as the most aggressive agent in farm structures.
- High water-cement ratio (e.g. 0.50) markedly worsens durability.

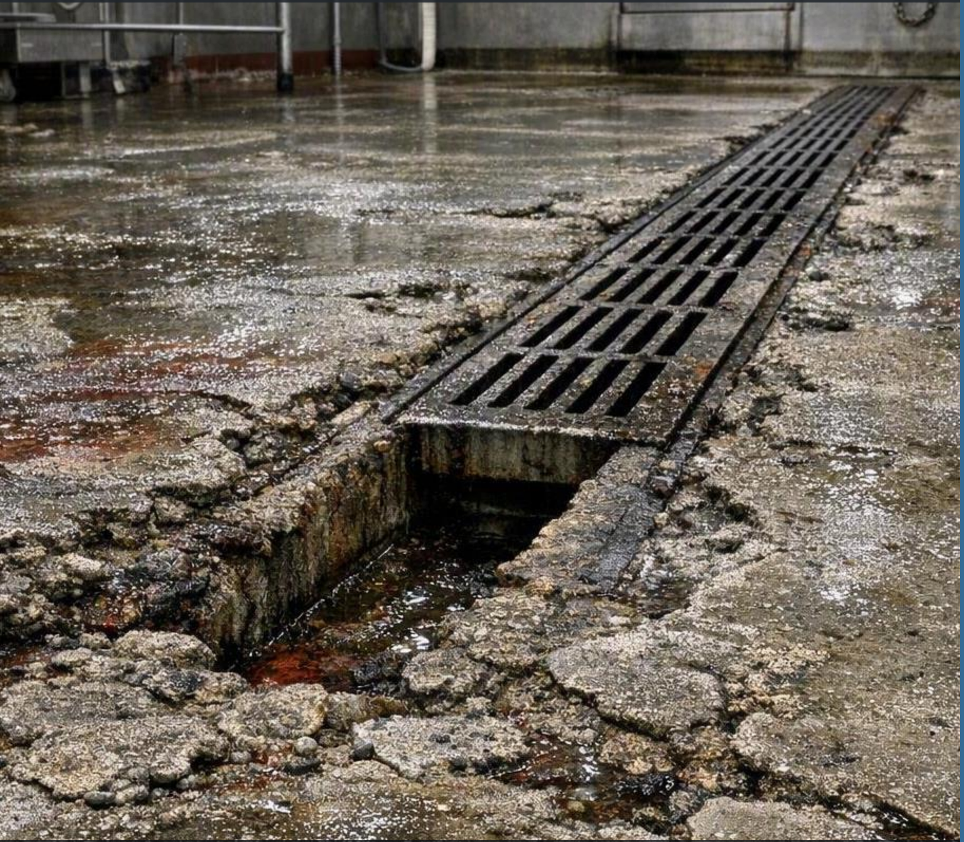


Photo illustrative. Mechanism consistent with organic-waste BSA literature.[6,7]

Slaughterhouse floors & drainage

Protein-rich, sulfur-bearing wastewater plus warm, wet, frequently washed-down floors create an ideal incubator for biogenic acid.

- Organic sulfur from blood and tissue feeds sulfate-reducing bacteria.
- Drains and channels concentrate effluent and corrosion alike.
- Surface erosion exposes aggregate and reinforcement, risking hygiene failures.

PATHOLOGY

How the concrete actually breaks down

From hardened paste to mush

1. **Acid neutralises the alkaline reserve** H_2SO_4 consumes calcium hydroxide (portlandite), dropping the pore pH.
2. **Cement hydrates dissolve** C-S-H gel — the binder holding concrete together — decalcifies and loses strength.
3. **Expansive products form** Sulfate forms gypsum and ettringite, generating internal pressure and spalling.
4. **Section is lost** A soft, friable corrosion layer sloughs off, exposing aggregate and steel.

Diagnosing BSA in the field

Visual & pH mapping — Soft, light-coloured surface layer with surface pH often below 2.

Petrography — Thin-section evidence of gypsum/ettringite fronts and paste loss.

Microbial culture & qPCR — Confirms sulfur-oxidizing populations in surface biofilm.

Environmental logging — H_2S, oxygen, temperature, and moisture in the headspace.

Degradation chemistry per Hou et al. (2020)[1]; assessment methods per Abu-Yosef et al. (2023)[5] and Chaudhari et al. (2022).[6]

03

PART THREE

Mitigation with Colloidal Silica

Densify the concrete, starve the acid of a pathway, and buy decades of service life.

CONTEXT

Where colloidal silica fits among the options

Our focus →

Better concrete

- Low water-cement ratio
- Supplementary cementitious materials (fly ash, slag, silica fume)
- Acid-resistant or carbonate aggregates

Barrier systems

- Polymer & epoxy coatings
- Calcium-aluminate or geopolymer liners
- Sacrificial / antimicrobial layers

Nano-densification

- Colloidal (nano) silica additive
- Spray-applied silica penetrant
- Pore refinement + pozzolanic reaction

Option landscape per Chaudhari et al. (2022)[6], Maraveas (2020)[7], and Heger, Pumper, 2024.[14]

What colloidal silica is

Colloidal (nano) silica is a stable water-borne dispersion of amorphous silicon-dioxide particles — small enough to stay suspended, yet chemically reactive thanks to abundant surface silanol groups.

1-100 nm	typical particle size — fine enough to enter capillary pores
Amorphous SiO_2	highly pozzolanic; reacts readily with cement chemistry
Since the 1970s	field-proven dispersion technology, now engineered for concrete

Colloidal silica applied to a concrete surface

Material description per Collet, Rollins & Andres, PCI, 2018[11] and AlTawaiha et al. (2023).[13]

WHY IT WORKS

Two reinforcing mechanisms

1. Pozzolanic reaction

Reactive silica consumes free calcium hydroxide — the most acid-soluble hydrate — and converts it into additional, durable C-S-H binder. Reported 3% dosing lowered the interfacial Ca/Si ratio from 3.18 to 2.22.[10]

2. Pore refinement

Nano-particles and new C-S-H fill capillary voids, refining pore size and cutting permeability. Less connected porosity means acid and sulfate have no easy route inward.[10,11]

Porous, attacked paste (left) vs. dense, sealed surface (right)

Net effect

Fewer soluble targets for the acid, and a tighter matrix that resists ingress — strength and durability rise together. Removal of harborage sites for bacteria.

Microstructure & Ca/Si data: Wang, Lu, Ma & Tan, Nanomaterials, 12(18), 2022.[10] Permeability: Collet et al., PCI, 2018.[11]

Two ways to put it to work

As an admixture

Dosed into the mix (commonly ~1–3% by binder)

- Densifies throughout the section, not just the surface
- Promotes early hydration and higher strength
- Best specified for new construction

As a surface penetrant

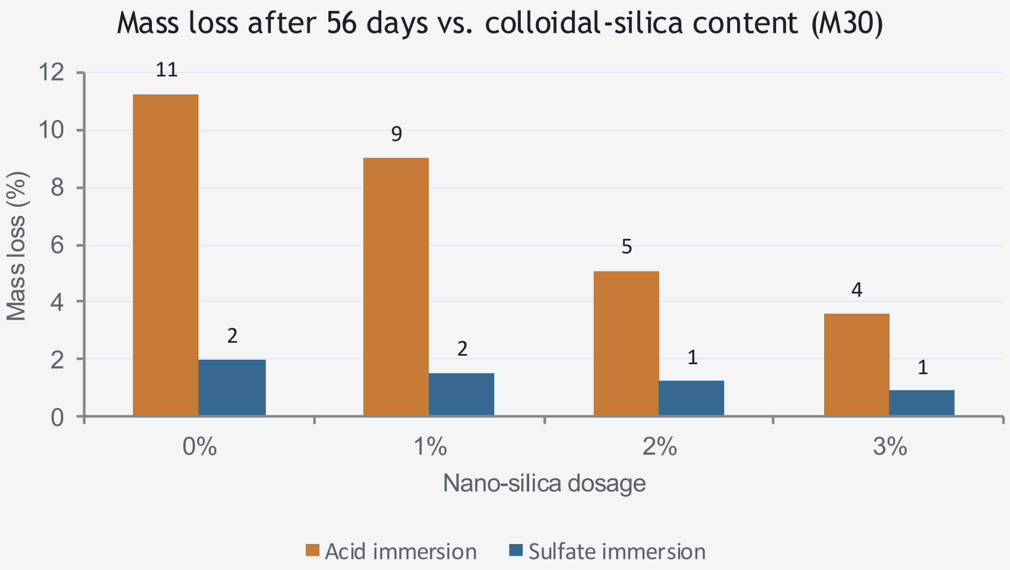
Spray-applied to new or existing concrete

- Penetrates and seals in-place structures during rehabilitation
- Reduces permeability of the cover zone where acid attacks
- Low-disruption retrofit for live assets

Application modes per Collet et al. (2018)[11], Ibrahim et al. (2024)[12], and Heger, Pumper, 2024.[14]

EVIDENCE · 1

Nano-silica cuts acid mass loss sharply



≈ 68%

lower acid mass loss at 3% nano-silica versus the plain M30 control.

Sulfuric acid was the harshest exposure tested — yet the silica-rich mixes were consistently the most durable across both acid and sulfate.

Data: Rajput & Pimplikar, "Chemical Resistance of Nano Silica Added Concrete," IJITEE, 8(12), 2019.[9]

EVIDENCE · 2

Tighter pores, longer service life

≥ 80% [11,14]

targeted reduction in concrete permeability with optimised colloidal-silica treatment.

3.18 → 2.22 [10]

interfacial Ca/Si ratio at 3% dosing — less weak portlandite, denser matrix.

1-year field [11]

spray-applied nano-silica lowered permeability and chloride ingress on a marine wharf.

Convergent evidence: across laboratory acid tests, microstructural analysis, and multi-year field cores, colloidal silica consistently lowers permeability — the single property most tied to BSA resistance.

Sources: Wang et al. (2022)[10]; Collet et al. (2018)[11]; permeability-reduction targets per industry review.[14]

COMPARISON

How it stacks up against alternatives

Approach	Mode of protection	Strength	Watch-out
Colloidal silica	Pore densification + pozzolanic	Integral; new build or retrofit	Needs correct dosing & coverage rate
Silica fume / fly ash / slag	Supplementary cementitious	Proven, economical	Mix-design stage only
Polymer / epoxy coatings	Surface barrier	High initial acid resistance	Bond & pinhole failure over time
Calcium-aluminate / geopolymer	Acid-tolerant binder	Strong intrinsic resistance	Cost; specialised placement

Colloidal silica is the only listed option that both works integrally and retrofits existing structures — with no separate barrier to debond.

Comparison synthesised from Chaudhari et al. (2022)[6], Hou et al. (2020)[1], Ibrahim et al. (2024)[12], and Maraveas (2020).[7]

PRACTICE

Recommendations — and honest limits

Put it to work

- Start with quality concrete: low water-cement ratio and good curing.
- Specify nano-silica (with SCMs) for new digesters, tanks, and farm structures.
- Use spray-applied silica to extend the life of existing assets in rehab.
- Pair material upgrades with H_2S and ventilation control at the source.

Keep expectations honest

- Densification slows acid ingress — it does not make concrete acid-proof.
- Dosage, dispersion, and curing strongly affect results; over-dosing can backfire.
- Most acid-resistance data are lab immersion tests; long-term sewer field data are still maturing.
- Best treated as one layer in a defense-in-depth strategy.

Cautions per Rajput & Pimplikar (2019)[9], AlTawaiha et al. (2023)[13], and Ibrahim et al. (2024).[12]

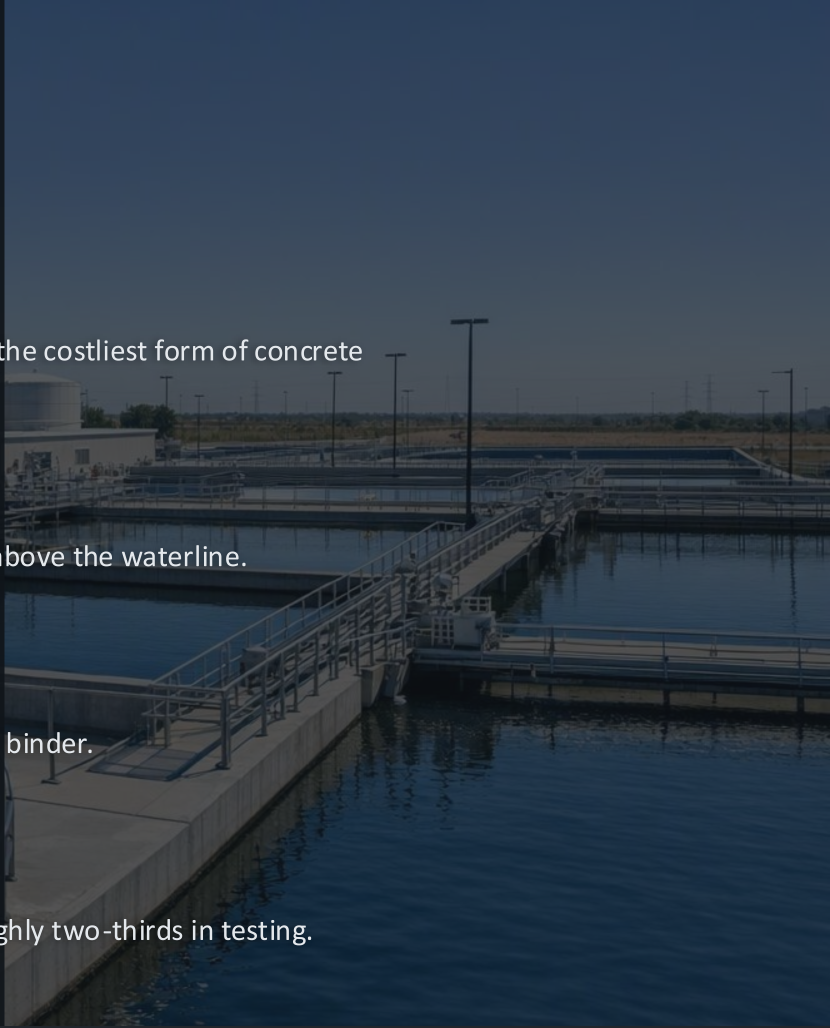
KEY TAKEAWAYS

1. **BSA is biological, not just chemical.**
Bacteria manufacture concentrated acid on the concrete surface — the costliest form of concrete biodeterioration.

2. **It spans wastewater, farms, and abattoirs.**
Anywhere organic waste off-gasses H_2S, exposed concrete is at risk above the waterline.

3. **Permeability is the master variable.**
The tighter the pore network, the less acid and sulfate can reach the binder.

4. **Colloidal silica attacks that variable.**
Pozzolanic reaction plus pore densification cut acid mass loss by roughly two-thirds in testing.



31% Hydrochloric Acid Testing

1 hour

2 hour

REFERENCES

Sources & further reading (1 of 2)

1. Hou, X., Steiner, K. A., Fraczek, J., & Mahaney, J. A. (2020). Biogenic Sulfuric Acid Attack and Case Studies. Concrete International, 42(5), 33–38.

2. Biogenic sulfide corrosion — reported U.S. sewer asset losses (≈ $14B/yr); summary of EPA-derived figures.

3. U.S. EPA (1991). Hydrogen Sulfide Corrosion in Wastewater Collection and Treatment Systems — Report to Congress. Washington, DC.

4. Okabe, S., Odagiri, M., Ito, T., & Satoh, H. (2007). Succession of Sulfur-Oxidizing Bacteria in the Microbial Community on Corroding Concrete in Sewer Systems. Applied & Environmental Microbiology, 73(3), 971–980.

5. Abu-Yosef, A., Armijos-Moya, S., & Poston, R. (2023). Field Assessment of Biogenic Acid Attack in Concrete Structures. ACI Materials Journal, 120(6), 71–80.

6. Chaudhari, B., Panda, B., Šavija, B., & Paul, S. C. (2022). Microbiologically Induced Concrete Corrosion: A Concise Review. Materials, 15(12), 4279.

7. Maraveas, C. (2020). Durability Issues and Corrosion of Structural Materials and Systems in Farm Environment. Applied Sciences, 10(3), 990.

Generated figures and photographs are representative illustrations of documented phenomena, not images of specific cited structures.

Sources & further reading (2 of 2)

8. Assaad, V. F., Jofriet, J. C., Negi, S. C., & Hayward, G. L. Corrosion of Concrete in Farm Buildings. University of Guelph, School of Engineering.

9. Rajput, B., & Pimplikar, S. (2019). Chemical Resistance of Nano Silica Added Concrete. Intl. Journal of Innovative Technology and Exploring Engineering, 8(12).

10. Wang, J., Lu, X., Ma, B., & Tan, H. (2022). Cement-Based Materials Modified by Colloidal Nano-Silica: Impermeability and Microstructure. Nanomaterials, 12(18), 3176.

11. Collet, P., Rollins, A. B., & Andres, V. (2018). Concrete Porosity Reduction by Colloidal Silica Nano Technology, Part 2: OneYear Results from Djeno Wharf. PCI Convention Paper.

12. Ibrahim, A. M., Bassuoni, M. T., Carroll, J., & Ghazy, A. (2024). Performance of Concrete Superficially Treated with Nano-Modified Coatings under Sulfuric Acid Exposures. Journal of Building Engineering, 108957.

13. AlTawaiha, H., Alhomaidat, F., & Eljufout, T. (2023). A Review of the Effect of Nano-Silica on the Mechanical and Durability Properties of Cementitious Composites. Infrastructures, 8(9), 132.

14. Heger, S. (2024). Options Emerge to Reduce Microbially Induced Corrosion of Concrete. Pumper.

Generated figures and photographs are representative illustrations of documented phenomena, not images of specific cited structures.

QUESTIONS?

Carl White
carl@spraylockafrica.co.za
+27 76 366 7135
www.spraylockafrica.co.za

Brent Rollins
abrollins@concreteprotection.com
+1 423-593-6674
www.concreteprotection.com