MIC IN CONCRETE SEWERS

Protecting New Sanitary Sewer Structures From Inside the Concrete Matrix

Angus W. Stocking, L.S.

Unprotected sanitary sewer structures are vulnerable to microbiologically induced corrosion (MIC). MIC, also commonly known as hydrogen sulfide corrosion, is a serious problem throughout sewer systems, including manholes, force mains, treatment facilities, and lift stations. The service life of concrete structures suffering from MIC is often less than 10 years. Damaged structures can cause emergency failures and associated repair and remediation costs, with potential results including sinkholes, collapsed roads, and even flooding of nearby neighborhoods. This paper will provide an overview of how MIC attacks concrete sanitary structures and the best method for protecting these structures. Several case studies featuring successful municipal sewer district installations will demonstrate the effective use of an antimicrobial in differing project types:

Upgrade and Expansion of Black Point Wastewater Treatment Facility
Miami-Dade (FL) Water and Sewer Department

96" Concrete Sanitary Sewer Tunnel
Metropolitan St. Louis (MO) Municipal Sewer District

Concrete Box Culvert Connecting Storm and Sanitary Waste Culverts to Detention Ponds
Sanitary District of Hammond (IN)

MIC Lifecycle

Hydrogen sulfide (H_2S) gas generated in liquid sewage by anaerobic S*ulfur Reducing Bacteria* (SRB) is transformed into powerful sulfuric acid through the action of aerobic *sulfur oxidizing bacteria* (SOB – e.g. Thiobacillus *spp.*) (See figure 1 to the right.) This sulfuric acid corrodes concrete by simply dissolving the calcium-based binder system. This is a *surface* attack and requires no penetration of the concrete. The colonization of bacteria in the sewers is a complex process involving many factors.

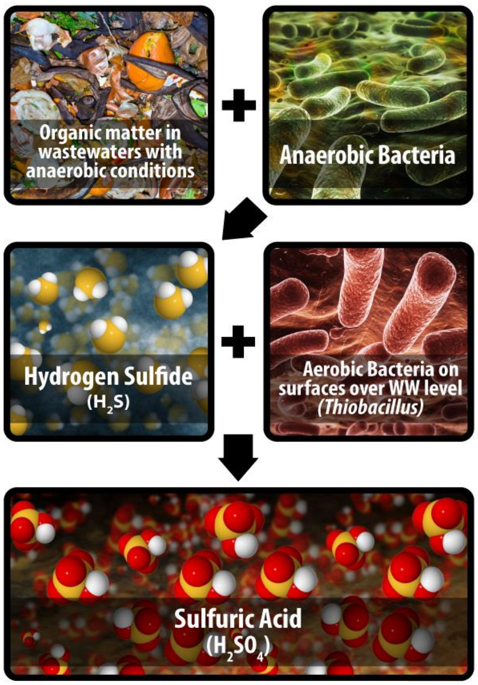

Figure 1: MIC Lifespan

On fresh untreated concrete surfaces exposed to hydrogen sulfide, bacterial colonization often starts in a matter of months. But first the high alkalinity of the surface must be reduced from approximately a pH of 13 down to 9. This transformation is brought about by carbonation, the humid atmosphere and H_2S gas itself. At this reduced pH, colonization by the first strains of SOB begin. They consume H_2S, water vapor, and oxygen from the air and begin to generate small amounts of very dilute acid. They slowly reduce the pH of the concrete surfaces to approximately 5 with a new more powerful strain of bacteria taking over, and serious concrete corrosion begins. Over the course of months or a few years, three more powerful strains of Thiobacillus sequentially evolve each producing stronger acids in ever increasing quantities. Ultimately acids are produced with a pH near 0.

Figure 2: Concrete damaged and crumbling due to MIC

Stopping *Sulfur Oxidizing Bacteria* (Thiobacillus *spp.*) From Forming

This corrosive process can be prevented with the use of quat-based disinfectants which carry a positive charge. Bacteria, viruses, and fungi carry a negative charge. When a bacteria-laden surface is sprayed or mopped with a disinfectant, the charge distribution of the bacteria cell changes from negative to positive. This results in the disruption of the bacteria cell wall and eventual death to the microbe. A commercially available and effective quat-based disinfectant, Con^{mic}Shield®, is a liquid additive that prevents MIC of concrete sewer pipe and structures. It is dosed directly into the concrete or mortar at the time of mixing. Con^{mic}Shield is not a surface treatment or a coating that can wear off, wash off, delaminate, or peel. There is no loss of effectiveness over time since Con^{mic}Shield is molecularly bonded to each cement particle. If the interior is damaged or eroded, the protection is still intact. Incorporating this additive into precast and ready-mix structures protects the concrete by stopping *sulfur oxidizing bacteria* (Thiobacillus *spp.*) from forming and converting the hydrogen sulfide gas to sulfuric acid which destroys the concrete no matter how dense or water tight it is.

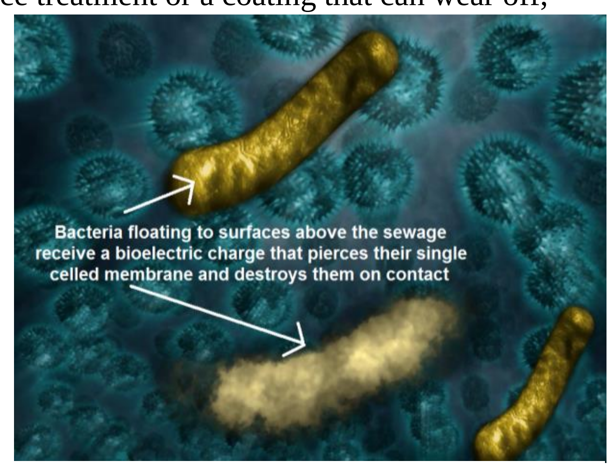

Figure 3: Illustration of concrete treated with quat-based biocide, ConShield®

MIAMI-DADE WATER AND SEWER DEPARTMENT ADDRESSES PERSISTENT MIC ISSUE

Microbiologically induced corrosion (MIC) was a persistent maintenance issue for Miami-Dade (Fla.) Water and Sewer Department (MDWASD), costing the utility millions of dollars over several decades. The combination of high ground water and warm weather contribute to making MIC a serious problem in Florida.

MIC prevention in Miami-Dade traditionally involved epoxy coating or embedded plastic lining. MDWASD's structural design unit, and the chief engineer on the Black Point upgrade, found that linings are okay in straight sections, but they are quite problematic in fittings, making them a less desirable solution overall. In 2001, the department tried Con^{MIC}Shield antibacterial additive manufactured by ConShield Technologies.
The EPA-registered antibacterial additive was mixed into the concrete at the batch plant to prevent MIC in the concrete pipe and structures on MDWASD's upgrade and expansion of its Black Point Wastewater Treatment Plant.

The additive is nontoxic to humans and animals but permanently inhibits single-celled organisms like Thiobacillus bacteria that creates sulfuric acid from hydrogen sulfide gas. The liquid additive is easy-to-use and dust-free, a plus for precasters and ready-mixers, as it does not contribute silica dust particulates to the air, and does not require related safety measures.

Prior to the Black Point Wastewater Treatment Plant installation, Miami-Dade tested the additive in a precast manhole in Key Biscayne with aggressively severe MIC conditions. Without any damage after eight years of continuous service, Miami-Dade approved its use. Based on this success, the division began using the additive in its manhole rehabilitation program and specified Con^{mic}Shield extensively in a \$600 million (USD) upgrade of the district's Black Point Wastewater Treatment Plant. Con^{mic}Shield additive was used in the new oxygenation train, and for four new, 200-foot diameter clarifier tanks. The amount used is in the thousands of yards, and may be as much as 30,000 yards.

Figure 4: Construction of Black Point Wastewater Treatment Plant upgrade and expansion

Figure 5: Completed section of upgraded Black Point facility

MDWASD: Mixing, Installation, and Quality Control

The use of Con^{mic}Shield as an additive has no effect on the structural and application aspects of a concrete mix. ConShield Technologies reviews all precast and ready-mix concrete mix designs for compatibility prior to shipping material. Close attention to quality control ensures the Con^{mic}Shield additive performs as expected within the concrete matrix. In the case of MDWASD, no changes to the mix design were needed. The only change to their previous design was the elimination of the added expense and application of coatings. The two contractors who poured the tanks could not tell the difference. No specialists were needed.

Mixing Con^{mic}Shield into concrete is also straightforward. The additive is introduced at the batch plant, at the rate of one gallon per cubic yard. For quality control, mix tickets are reviewed, which determines a list of concrete components for each truck. MDWASD had no issues with the mix.

Quality control is also achieved by ongoing testing. In the tanks, for example, stainless steel screws were placed so that the distance from screwheads to concrete surface can be measured, which allows measurement of any loss over time. After six months of use, parts of the oxygen train were taken out of service. Minimal concrete loss was found in some tanks below the liquid level, but was attributed to surface latents, like form oil, that are being washed off. Overall, the treated concrete above the liquid waste level where corrosion occurs looked really good.

MDWASD: Conclusion

The Black Point upgrade is an important project for MDWASD. It increased the plant's peak capacity from 225 mgd to 285 mgd, and substantially improved water quality to bring the plant into line with new EPA standards. It's also a further test of a product that is beginning to see major use in Miami-Dade. By thoroughly understanding the source of the MIC problem and then evaluating results conservatively, the Miami-Dade Water and Sewer Department is finding new ways to reduce downtime and maintenance costs, thus serving their district more efficiently.

THE METROPOLITAN ST. LOUIS SEWER DISTRICT FIGHTS UNDERGROUND CORROSION

The Metropolitan St. Louis Sewer District (MSD) faced a problem familiar to many big city wastewater departments managing underground assets. A large (72-inch) sanitary sewer needed to be replaced with an even larger line to handle wet weather flows and eliminate sanitary sewer overflows (SSOs). In the years since initial installation, the above-ground area had become heavily developed.

The Coldwater Creek project was handled in three phases. The shortest phase was a 2,300-foot stretch that passes (at an average depth of 20-25 feet to flow line) under Lindbergh Boulevard. It also passes under a 20-inch gas line, a 24-inch water main, a condominium complex lake, the parking lot and the improvements for a driving range. The projected cost to restore surface disruptions is getting so high on these kinds of projects that tunneling is becoming more and more cost effective.

Figure 6: Pipe ramming 96" ConShield-protected concrete sewer tunnel in MSD

Tunneling made so much sense on this phase of the project that the bid-winning contractor, SAK Construction LLC, decided to use 96-inch pipe, rather than the specified 90-inch, in order to use a tunnel boring machine (TBM). But choosing the right material for 2,300 feet of very large diameter pipe created its own set of challenges.

MSD: Choosing Concrete

While PVC pipe might have been a good choice, it's not available at that size. And fiberglass wouldn't work at the depth of this project; the extra shoring and bedding required, along with its cost, made it too expensive for this project.

Concrete could stand the stresses of being jacked in behind the TBM; it didn't need special shoring or bedding, and it is inherently inexpensive compared to other options. And with the city's location on the Mississippi River, near sources of cement, limestone and sand, concrete pipe makers are easy to find in St. Louis.

But there is a valid concern with concrete pipe in sanitary sewer applications, with regard to potential corrosion. Fighting MIC can be a challenge. Chemicals like potassium permanganate, chloride, and oxygen can be injected into flows to combat hydrogen sulfide build up, but regular chemical addition is quite expensive.

Concrete pipe can also be lined with vinyl but it is very labor intensive. Each piece must be welded at the joints by hand, and it is subject to nicks and pinholes, which allow gas penetration. If linings are compromised, bacteria and gas can easily work together in the space between the lining and pipe, causing serious deterioration, which is hard to detect with TV inspection until there is a catastrophic failure.

MSD: Specifying a Solution

MSD specified the use of Con^{mic}Shield to protect the new concrete tunnel from MIC damage.

MSD first used Con^{mic}Shield eight years previously with excellent results on the Maline Drop Shaft, near Chain of Rocks Bridge. MIC had corroded more than five inches of the walls in the lower third of the 50-foot deep structure.

The MSD Materials Engineer who had supervised the Maline restoration deemed the project a success. Prior to restoration, the drop shaft had been found to have severe deterioration in the bottom third—it was completely eaten out by gases. Since restoration, MSD continues to monitor the shaft, and eighteen years since that first project, they are still pleased with the results.

MSD: Quality Assurance Measures

The MSD Principal Engineer, Greg Tolcou, P.E., worked closely with Independent Pipe, the precaster selected to cast the Coldwater Creek pipe. Tolcou visited the plant personally to witness dosing, mixing, and pipe production. Independent Pipe took extra steps as well, working with ConShield Technologies and MSD to certify their approach, and purchasing a new delivery system that interacted with their computerized mixing system to give them more control over the process. Con^{mic}Shield replaces an equal volume of mix water, but does not affect the strength, flow or set times Independent Pipe had designed. When batching the product, their computer guaranteed proper dosing.

Independent Pipe also made test cylinders from each day's production. These cylinders can be tested at independent labs to ensure all bacteria are killed, thus providing effective verification that the anti-microbial agent has been integrated properly. The fact that Con^{mic}Shield is *designed for concrete applications*, is mixed *into* the concrete, and isn't a coating applied to the pipe's surface, is what makes it effective in long-term applications.

Figure 7: ConShield-protected 96" reinforced concrete pipe (RCP)

MSD: Conclusion

Concrete treated with anti-microbial agents is proving useful in St. Louis for rehabilitation of large sanitary sewer installations. It's also restoring the reputation of concrete pipe for sewer applications. When you look at the life cycle analysis and the ease of installation, pipe treated with Con^{mic}Shield is definitely a very cost-effective solution.

INDIANA SANITARY DISTRICT PREVENTS MIC IN COMBINED STORM AND SANITARY WASTE CULVERT

To prevent sewer overflows, the Sanitary District of Hammond (HSD), in Hammond, Indiana (population 80,000, part of the Chicago metro area) installed new detention ponds in one of its wastewater treatment plants, and also needed to build a new structure to serve those ponds. A large concrete box structure, measuring 1,700 feet of 11'6" by 10'6", was built to bring combined storm and sanitary waste from existing culverts to the new ponds.

Considering the project cost, protecting this investment against MIC was definitely a requirement. There are no good ways to prevent gas buildup in most sewers, so operators have tried various external coatings. But coatings often fail, as even small gaps and holes can provide a foothold for *Thiobacillus*… and if you give *Thiobacillus* an inch, it will take a sewer.

HSD: Controlling MIC And Costs

Knowing this culvert would combine sewage and stormwater in a low oxygen environment, Hubbell, Roth & Clark, Inc. (HRC) wanted to do everything they could to reduce the potential for MIC damage. Based on the reliable testimonials for Con^{mic}Shield, HRC specified it for the Hammond project.

However, the size of the structure meant they would need a large amount of Con^{mic}Shield to protect the entire concrete sewer structure—all 1,700 feet of it—and could have been prohibitively expensive. HRC took advantage of the fact that the sewer would nearly always be about half full (or sure, half empty) with seasonal flows only occasionally raising the water level over six feet. Since hydrogen sulfide and *Thiobacillus* can't form underwater, this meant that about half of the sewer *didn't* need to be made with Con^{mic}Shield-treated concrete.

Figure 8: Construction of the new combined-system culvert begins

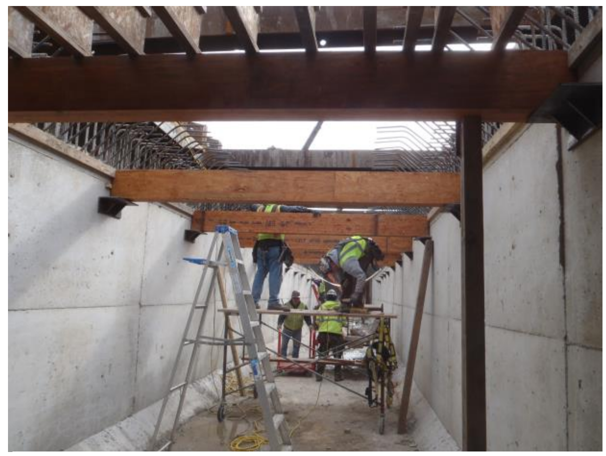

Figure 9: Preparing to pour the top of the pipe in place

Figure 10: Completed Con^{mic}Shield-protected HSD box culvert

HSD: Construction and Quality Assurance

Ellas Construction Company, Inc. took on the task of building a concrete sewer with two different kinds of concrete. Regular concrete and Con^{mic}Shield-enhanced concrete were made with the same texture, so there was no issue with bonding. Ordering the correct mix at the right time, and using the correct truck, was the key to a successful installation. Ellas Construction built the culvert in 120-foot sections. First the base and footing were poured, and then the wall was poured in strips that are three feet high. The elevation for the Con^{mic}Shield-protected concrete is marked on the plans, and Ellas usually overlapped downward by a foot or so, to be sure all exposed concrete was protected against MIC. Making sure the right concrete was used wasn't difficult but it was a little tedious; Marty Zurbriggen, Ellas' general manager monitored wall height, ordered concrete trucks with the right mix, and double checked the truck tickets prior to pour. Additional quality assurance was conducted by subcontracted inspector Paul Knueppel, a senior project manager at Garcia Consulting Engineers. Most production days, 21 cubic yards of material with Con^{mic}Shield, and 32 cubic yards without Con^{mic}Shield, were batched and installed. One of Kneuppel's main responsibilities was to check the ticket and be sure the right mix was being used.

The concrete was prepared at Smith Ready Mix, in nearby Valparaiso, Indiana. Sales Manager Scott Massom says mixing the Con^{mic}Shield at short notice was not a problem. Their whole process is automated, so once the Con^{mic}Shield was mixed and stored in an admixture tank, it was not a problem to make a batch on short notice. They just selected the tank, and everything was standard procedure after that.

HSD: Conclusion

Using anti-microbial concrete in just a portion of the concrete box was a good idea that significantly reduced the cost of MIC-prevention in this structure. The Sanitary District of Hammond's concrete sewer infrastructure is fully protected by the best available anti-microbial technology, at a cost that's less than half of what it could have been.

SUMMARY

Miami-Dade, St. Louis, and Hammond installed three very different sanitary sewer structures, each with a different role to play within their systems. But each found a simple cost-effective way to protect their structures from future MIC, thereby saving their districts millions in future rehabilitation or replacement costs.

# # #

Angus W. Stocking, L.S. is a licensed land surveyor who has been writing full time on infrastructure topics since 2002. www.InfrastructureWriting.com