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Wastewater System Design and Evaluation

As Simple as A, B, C ..... Z

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How does an engineer design a wastewater system to counter the corrosion effects of hydrogen sulfide gas [H2S]and sulfuric acid? The simple answer is, ... reduce the conditions that generate H2S. Even so, this is not always possible nor economical. Excluding piping, approximately 40 percent of a wastewater system is made up of concrete structures. Therefore, some means of reducing the corrosion of concrete must be utilized. It must be effective and economical.

This paper presents the "state of the art" information, circa 1995, for solving the problem of Microbial Induced Corrosion in sewer systems. It contains a total systems approach for design, known as H2S MODELING DESIGN METHOD, which utilizes a time-tested method for estimating hydrogen sulfide generation and subsequent corrosion in sewer systems. This systems approach also addresses products such as high alkalinity concrete, antimicrobial concrete,[3] impervious coatings, inert liners and inert pipe. These products can be used alone or in combinations, as the levels of protection warrant.

The work of C.D. Parker, reported in 1945 in the Australian Journal of Experimental Biology and Medical Science, identified Thiobacillus genus bacteria as the source of Microbially Induced Corrosion (M.I.C.) also known as H2S Sewer Corrosion.

It is beyond the scope of this document to explain in detail the intricacies of M.I.C. For further information, see ASCE Manual of Practice NO. 69. [1] One can consider, however, that T. thioxidans, T. neoplitanus and T. tioparus bacteria act as microbial agents that metabolize elemental sulfur into sulfuric acid. The formation of the elemental sulfur is due to the oxidation of the hydrogen sulfide gas. Initially, sulfuric acid starts to form when H2S reacts with moisture at the crown of the pipe. The pH of the concrete above the flow line starts to drop from an initial pH of 10-12, and as the pH drops, the activity level of the sulfuric acid producing bacteria increases and can eventually drive the pH of the concrete down to less than 1. Thus, the sulfuric acid is the active agent in wastewater system deterioration, i.e. corrosion of metals and destruction of concrete surfaces. The H2S by itself is corrosive to copper, iron and silver, but by reducing the growth of the Thiobacillus genus bacteria, the deterioration of concrete can be reduced. There are now two new products on the market to combat MIC. Both have been tested and proven to be effective in reducing microbial growth. Today's design professional faces the challenge of designing new wastewater systems that will not experience the corrosion and deterioration problems of existing problematic systems. Certainly, new wastewater system construction should utilize the lessons of the past and look toward the advanced technology of the future. Designers must, for example........

A: Accept H2S as a wastewater system problem and design to combat it. H2S is not a rare occurrence or someone else's problem.

B: Successfully design economical M.I.C. resistant wastewater systems for the future.

C: Utilize the best known rehabilitation methods for existing wastewater systems while at the same time minimizing M.I.C.

D: Minimize wastewater system odor releases.

At present, the H2S MODELING DESIGN METHOD, utilizing computer programs, can provide the most efficient design method to reduce initial costs (IC) as well as, operations, maintenance and replacement (OMR) costs of wastewater collection and treatment systems.

Manual methods for estimating sulfide generation and corrosion in wastewater collection systems have been in use for approximately 29 years. The accepted formulas and range of values introduced in the Pomeroy - Parkhurst equations (ASCE Manual of Practice No.69) for pipes have been tested and used on numerous projects. [1] Likewise, the equation for concrete corrosion has been tested extensively.

One of the most significant changes to occur in the last 15 years is the development of computer programs for sulfide and corrosion prediction. The most recent versions of these programs allow the user to analyze an entire system for sulfide generation and corrosion potential. When verified and calibrated, the model is a powerful tool which can be used to analyze the varying conditions anticipated throughout the life of the wastewater collection system. Using the manual method, this same analysis would require extensive time and severely limit the size of the project which could be analyzed and the detail of analysis which could be performed. With a computer supported modeling technique, the model can now be used as a O&M tool. The impact of diversions, future flows, and changes in wastewater characteristics can all be analyzed before potentially costly decisions are made.

The most recent generation of programs published for sulfide generation and corrosion prediction are HS and Sulfide Works. Both were published in 1991. HS was developed through the American Concrete Pipe Association. Sulfide Works was developed by MicroComp Systems. HS may be purchased from American Concrete Pipe Association, 8618 Westwood Center Drive,
Suite 105, Vienna, VA 22182, (703) 821-1990 directly, or from The University of Florida at Gainesville. Each program is provided with documentation and is based on the Pomeroy - Parkhurst Equations and the Corrosion Rate Predictive Model. The HS program is limited to pipes flowing partially full. This limitation requires manual input

when modeling siphons or force mains. Sulfide Works' program handles either full flowing pipes or partially full pipes.

When evaluating a system's sulfide potential, it may be necessary to simulate varied conditions. The programs provide various options, including constant or variable quantity or depth of flow and incremental life analysis, to account for variable flow quantities of depths during the sewer life, and will take into account the effect of input sulfide at junctions.

For primary data input, sewage characteristics required are: climatic BOD, sewage temperature, design life [which may be broken into increments], acid reaction factor "k", pH of the sewage, upstream total sulfide level, insoluble sulfides, and the climatic ratio "c".

The programs prompt for the number of reaches to be analyzed; then for the pipe diameter, slope and length of reach for each reach in succession, beginning at the upsteam end of the sewer.

H2S MODELING DESIGN METHOD GIVES THE DESIGNER A SNAPSHOT OF THE PHYSICAL PROPERTIES OF A WASTEWATER SYSTEM AT A SPECIFIC POINT IN TIME.

With the information provided by the H2S MODELING DESIGN METHOD system, and more specifically the instantly obtainable information available by utilizing the ACPA Hydrogen Sulfide Prediction software, the designer can work with different "what if" scenarios to determine the performance characteristics of the wastewater system that are important to the specific application, both at present and in the future.

TYPICAL QUESTIONS MAY BE:

"What initial design or rehabilitation is necessary for the addition of 9,000 new homes to an existing wastewater line?"

"What if the flow rate of a part of the system is changed due to changes in demographics effecting a wastewater system?"

"How can one overcome past failures in a particular wastewater system as design additions and improvements are applied to that system?"

By utilizing H2S MODELING DESIGN METHOD, can one accurately forecast the service life of the wastewater system being designed now, and anticipate the many possibilities of change in the future?"

ANSWERS:

The physical characteristics of past failures and problems as well as the anticipated performance characteristics of the future of a wastewater system can be studied in detail by utilizing the H2S MODELING DESIGN METHOD parameters. The instantly available design and service life information can aid the designer in engineering the most cost effective and long life system possible for any municipality.

Maintenance costs of the future can be estimated by utilizing H2S MODELING DESIGN METHOD information.

Initial installation costs are not the only costs that must be considered in wastewater system design. In some cases, the maintenance (OMR) costs on a system can exceed the initial costs (IC).

H2S MODELING DESIGN METHOD FOR FUTURE NEEDS

Today's wastewater designer must consider future maintenance costs. Unfortunately most engineering workstations do not come equipped with a fully functional crystal ball. One of the tools for the wastewater design professional to look into the future is the ACPA H2S MODELING DESIGN METHOD software.

Today's designer can have the modern day equivalent of a crystal ball which allows the estimation of tomorrow's OMR costs. H2S MODELING DESIGN METHOD software is used in estimating the future costs of wastewater systems. Pipe and all the other components of the wastewater system can be initially designed, rehabilitated or studied for future design and maintenance costs. Community expansion, real time and planned, can be accommodated by the H2S MODELING DESIGN METHOD program. Design professionals can utilize H2S MODELING DESIGN METHOD to determine future needs.

Deterioration of present systems can be determined prior to the system becoming major problem.

H2S MODELING DESIGN METHOD information is not only valuable at design time but also at rehabilitation time. Annual maintenance budgets can be accurately predicted by effectively utilizing the H2S MODELING DESIGN METHOD software on a periodic scheduled time frame. Design professionals can now have accurate input into wastewater system maintenance costs. Graphic presentations can be presented to city officials to support budget requests and to illustrate the construction and rehabilitation needs of the city's wastewater system.
As with any software of mathematical concept, H2S MODELING DESIGN METHOD is only as good as the data input. The accuracy of the data, and the skill and knowledge of the operator, are key factors in successful H2S modeling.

BECAUSE THE FACTORS CONTROLLING SULFIDE GENERATION IN SEWERS

ARE SO COMPLEX, it would be unrealistic to expect that sulfide concentrations can be accurately predicted on an hour-by-hour basis. Even predictions of average sulfide conditions in a sewer are not considered precise, but they will be adequate for many design and operation purposes. The Pomeroy equations that have been devised have coefficients that can be modified to meet the objectives of the engineer, giving results that will approximate average performance of all sewers represented by any given set of parameters or that will give results with varying degrees of conservatism. Thus, a sulfide prediction may show a concentration that will rarely be exceeded in any sewer, or one that will be exceeded only part of the time in any sewer or in few sewers, or one that will be an average value where septic conditions prevail. The level of understanding of sulfide generation mechanisms and corrosion of both cement bonded and ferrous materials allows a relatively accurate assessment of anticipated conditions in sewer systems and the cost-effective design of control measures.

THE H2S MODELING DESIGN METHOD IS NOT LIMITED TO ONLY THE CONCRETE PIPE IN THE WASTEWATER SYSTEM.

Historically, design professionals have applied H2S MODELING DESIGN METHOD parameters primarily on concrete pipe only utilizing AZ design. The concrete pipe industry has viewed the H2S MODELING DESIGN METHOD criteria as a method of design which would only be applicable to those cases where H2S problems existed. It has been this discounting of the H2S MODELING DESIGN METHOD criteria which has in the past, led many municipalities to consider replacing failing concrete pipe with synthetic based components.

The plastic pipe industry has enjoyed a surge of growth in the wastewater treatment industry. The prevailing myth that concrete pipe was, by design, destined to fail and plastic would last forever is false. Even plastic pipe is susceptible to attack by microbes which can cause corrosion. Studies has shown fiber reinforced polymer composites containing fluorinated polymide resin and glass fiber are susceptible to fungal attack. The dominant fungi was identified as Aspergillus versicolor and a Chaetomium species, both commonly found in natural enviroments. [2]

In many cases, the shortcomings of plastic pipe, such as pipe soil dependency, non-rebuildable sections and microbial induced corrosion, has been overlooked. Plastic pipe is often chosen for wastewater systems as the lesser of two evils. Contrary to these myths, concrete pipe has for years been designed to meet the required service life of many wastewater applications. Concrete can also quite efficiently be rehabilitated, while failed plastic pipe has to be removed and replaced.

THE H2S MODELING DESIGN METHOD AIDS IN DESIGN AND REHABILITATION OF ALL COMPONENTS OF THE WASTEWATER SYSTEM.

Structures, manholes, tanks and the treatment plants can benefit from the use of H2S MODELING DESIGN METHOD evaluation. This concept allows for the selecting of methods to minimize the corrosion of all concrete and metallic elements.

H2S MODELING DESIGN METHOD MINIMIZES H2S OUTGASSING.

H2S MODELING DESIGN METHOD CAN BE USED TO MINIMIZE THE FORMATION OF SULFURIC ACID.

By utilizing the **H2S MODELING DESIGN METHOD** the following major factors can be addressed to minimize the formation and presence of sulfide in sewage systems.

Limit the use of closed conduit systems [force mains, siphons, and surcharged sewers].

Provide for velocities in both gravity and pressure pipes that are adequate to prevent deposition and accumulation of solids, especially during periods of low flow.

Provide velocity in gravity trunk sewers and interceptors, such that surface reaeration is adequate to prevent sulfide build-up.

Eliminate direct discharge of sulfide to the wastewater collection system from industrial and septic waste sources.

Minimize the accumulation of solids in the treatment plant at any location where they will become anaerobic and septic.

OTHER METHODS OF CONTROLLING THE GENERATION OF SULFIDE IN WASTEWATER

Numerous methods are available to control the generation of sulfide in wastewater. Methods affect the oxygen balance in sewage, oxidize generated sulfide, react chemically with dissolved sulfide to form insoluble sulfide, or affect the sulfide generation capability of the sulfate or organic sulfur reducing organisms. The methods include: [1] Oxygen injection in force mains, inverted siphons, U-tubes, hydraulic falls, and sidestreams; [2] chlorination; [3] hydrogen peroxide; [4] iron and zinc salts; [5] shock dosing with sodium hydroxide; [6] ;potassium permanganate; [7] sodium nitrate; [8] ozone; and [9] bacterial cultures and enzymes.

In conclusion, engineers designing wastewater collection and treatment systems should view the models for sulfide generation and corrosion as useful tools to indicate sulfide trouble spots. The models are not accurate within 5% to 10%. Therefore, emphasis by designers should be on redesign of the predicted sulfide trouble spots, to further reduce the generation of sulfide, and incorporation of protective measures into the system to minimize hydrogen sulfide attack, odor nuisance, and toxic hazards to personnel.

Protective measures such as the following, include products with unique properties and tested performances. Depending upon the degree of protection desired, they may be used in combination where compatible. Those listed by name are for guidance and reference purposes.

A: For New Construction

1: Reinforced Concrete [Pipe and structures]- utilizing Az design

(A (alkalinity) x z (cover) = service life)

2: Alkalinity level of the initial concrete.

Original concrete should exhibit sufficient alkalinity to resist MIC produced H_2SO_4. The use of calcareous aggregates is most effective.

3: Proper cover per ASTM C-76

Initially, concrete structures must have the proper cover over reinforcing steel. The amount of cover is specified in ASTM C-76. This proper cover of concrete over reinforcing steel is the cornerstone of good concrete based wastewater system design.

4: Additional concrete cover, [in addition to No. 3 above].

5: Concrete with antimicrobial properties to inhibit MIC.

6: Coatings:

7: Liners

8: Inert Pipe

B: For Rehabilitation:

1: Coatings:
a: cementitious
b: polymeric
c: pneumatically applied

2: Pipe Insertion

3: Pipe Bursting

4: Folded Liners

5: Soft Liners

References

1. ASCE Sulfide Task Group, Sulfide in Wastewater Collection and Treatment Systems,

MOP #69, 1982.

2. Ji-Dong Gu, et al., Microbial Deterioration of Fiber Reinforced Composite Materials, 1995 International Conference, NACE.

3. Antimicrobial Concrete Sources:

a. Any concrete containing Fibermesh with Microban "B" as an additive.Fibermesh with Microban "B" is manufactured by the Fibermesh Division of Synthetic Industriess, Chattanooga, TN. Phone 423/892-72

b. SewperCoat 2000HS by Lafarge Calcium Aluminates as a dry gun shotcrete coating.
Manufactured by Lafarge Calcium Aluminates, Chesapeake, VA. Phone 804/543-8832.

4. Coatings and Liners:

a. Corropipe by Madison Chemical Industries, Inc., Milton, ON, Canada. Phone 905/878-8863

5. Inert Pipe:

a. No-Dig by M.C.P.Industries, Inc., Pittsburg, KS. Phone 800/835-0320

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