ORIGINAL RESEARCH PAPER

Environmental Chemistry

HYDROGEN SULFIDE CORROSION OF CONCRETE IN WASTEWATER SYSTEMS: STAGES IN AEROBIC PROCESSES AND PREVENTION

KEY WORDS: Hydrogen sulfide corrosion; Sulfuric acid; and Sulfur reducing bacteria.

Dr. C. P. Kaushal Associate Professor, Department of Chemistry, MLSM PG College, Sundernagar-175018, H.P., India.

ABSTRACT

Background: Hydrogen sulfide corrosion in wastewater systems is a result of dilute sulfuric acid (H_2SO_4) dissolving the cement matrix. The acid is produced by a complex process of chemical and biochemical reactions. Hydrogen Sulfide (H_2S) is produced by an action of Sulfur Reducing Bacteria (SRB) in the liquid phase, and then in time, this gas is converted by Sulfur Oxidizing Bacteria (SOB) into H_2SO_4. The last conversion occurs above the liquid level under aerobic condition.
Objective and Methodology: The objective of this study is to review previous years' literature and understand the aerobic processes stages in H_2S corrosion and suggest preventive measures to reduce/eliminate it.
Result: The literature review suggests that SRB under anaerobic conditions in the submerged part of sewers facilitate reduction of sulfate ions and the production of various forms of sulfides.
Conclusions: The formation of H_2S and its escape from the liquid sewage is the reason for the H_2S corrosion processes in the wastewater systems. Aerobic bacteria colonize on surfaces above the water line and convert H_2S gas into dilute H_2SO_4 by means of a complex biochemical process.

INTRODUCTION:

H_2S corrosion of concrete is recognized as one of the main processes for degradation of concrete-based wastewater networks worldwide. It has been increasingly triggering high economic expenses, as well as severe health and environmental concerns [1, 2]. It is estimated that the cost to replace the deteriorated sewers is $50 billion per year, globally. There is a need to spend around $600 billion within the next twenty years to keep the existing wastewater infrastructure operational [3, 4, 5].

The H_2S corrosion is caused by dilute H_2SO_4 continuously being generated by bacteria from H_2S. SRB present under the waterline inside the sanitary sewers produces this foul-smelling gas. The problem of H_2S corrosion is not limited to certain climates or geography. It occurs in all wastewater systems to some degree [6, 7].

OBJECTIVE AND METHODLOGY:

The objective of this study is to review previous years' literature and understand the aerobic processes stages in H_2S corrosion and suggest preventive measures to reduce/eliminate it.

DISCUSSION:

Stages in the Aerobic Process

A significant amount of research has been conducted on the complex mechanisms involved with H_2S corrosion. Based on the typical biological and physical-chemical reactions and their resulting by-products, H_2S corrosion is broken down in three stages.

Stage 1: Colonization of Neutrophilic Sulfur Oxidizing Bacteria

The beginning of the colonization is marked by the presence of various strains of neutrophilic sulfur oxidizing bacteria (NSOB) which adopt to the moist concrete surface and pore structure at pH around 9 to 9.5. NSOB possess the ability to utilize different sulfur compounds to form H_2SO_4 under moist conditions [8].

Stage 2: Attack of Acidithiobacillus Bacteria

The next deterioration stage begins once a pH of 4 approaches. The acidophil bacteria start to dominate the biofilm, with Acidithiobacillus thiooxidans being the most common one. While the central role of *A. thiooxidans* is well described in the literature, little information exists regarding the contribution of other bacterial species, especially, the impact of *Acidithiobacillus ferrooxidans*, a chemoautotrophic ASOB. These organisms are well known from acid mine drainage environments and cause deterioration of strongly deteriorated systems [9, 10].

Stage 3: Loss of Material

The third and last stage of H_2S corrosion of concrete is associated with massive loss of material. During the biotic cycle of H_2S corrosion, the appearance and dominance of SOB (both NSOB and ASOB) is controlled by pH, trophic properties and the ability to utilize different sulfur compounds such as H_2S, S_0, and S_2O_3 [11, 12]. Besides SOB, heterotrophic bacteria and fungi have also been found in biofilms observed in various deteriorated wastewater systems. The importance of fungi, algae, and lichens in colonization of stone and concrete buildings especially under extreme environmental conditions is well documented [13].

H_2S Corrosion Control

Following three ways can control H_2S corrosion and improve concrete durability:

Reducing Calcium Compounds

The use of pozzolans such as fly ash and colloidal silica in concretes offer excellent mechanical properties and low permeability. This helps to control deterioration of concrete. Pozzolans work in two ways to improve the basic mechanical properties. First, as pozzolans are rich in amorphous silica, they will react over time with the calcium hydroxide hydration by-products to form additional calcium silicate hydrates [14]. Second, use of pozzolans can improve the workability of concrete allowing for reduced water content when used in conjunction with high range water reducing admixtures. Many studies over the years have demonstrated that simple cement substitutions with pozzolans produced modest improvements in deterioration of concrete [15].

Reducing Permeability of Concrete

Permeability can be reduced by a combination of two means: cement modifiers and crystalline forming water proofing admixtures.

Cement Modifiers. There has been significant amount of work done in reducing permeability with additives. This include the combination of water reducing admixtures, cement substitutions with pozzolanic materials as mentioned above, and cement modifiers such as latex and acrylic emulsions. These concepts have their applications especially where the attack is due to penetration of the hydrate structure by a mobile ion [12, 13].

Crystalline Forming Water Proofing Admixtures. These admixtures are based on certain minerals that contain combinations of rare earth metal oxides. They promote a complex growth of solid crystals within the watery pore space of hardened Portland cement paste. They have two important functions: (a) they dramatically reduce the permeability of even mediocre concretes, and (b) the crystalline growth can continue if there is moisture, space and reactive mineral complexes available within the cement gel structure [14].

Buffering the Concrete with Limestone Aggregates

This concept is to use coarse fraction of the aggregates that consume some of the acid and protect the lime rich cement paste. This requires a firm understanding of factors like age, material, length of sewer, flow rates, retention times, seasons, rain water count, ventilation, BOD, COD, type of sulfides produced and sewer temperature. These factors are often difficult to obtain in new construction. From these factors, an appropriate loss rate can be calculated and then the wall thickness of structure is increased to compensate for the loss of concrete. In many instances the wall thickness is not increased, and the life span is incorrectly determined from 100% of the base wall thickness [11, 12, 13].

Action of Antimicrobial Admixtures

A completely different approach to protect concrete from H_2S corrosion is to render it uninhabitable by the bacteria that convert the H_2S into H_2SO_4. The chemical is readily dispersible in a high pH wet concrete mix [13]. The key is to protect the fresh highly alkaline concrete before it hardens. It remains active and effective in the hardened concrete over a long term. As a thin liquid, the additive readily disperses throughout the concrete mix and ultimately bonds molecularly with all the concrete's ingredients [14].

Cement-based Rehabilitation Methods

In addition to H_2S corrosion control methods, there are several cement-based renewal methods like shotcrete, cast-in-place concrete, and spin-cast that can be used to increase the life span of deteriorated concrete structures.

Shotcrete

Shotcrete is the method of pneumatically spraying fresh cement-based mixtures on a deteriorated surface of pipe or any other structures through a hose at a very high velocity [10]. There are two types of processes: dry-mix and wet-mix. In the dry-mix process, water is added at the nozzle, while, in the wet-mix process, all ingredients are mixed with water before being introduced to the delivery hose and the nozzle [15, 16].

Cast-in-Place Concrete Method

Another effective renewal technique for various sewer shapes is cast-in-place concrete method. The designed steel mesh is affixed to the existing pipe in the form of reinforcement. The gap between the formwork and the pipe wall is the annular space that is filled later [13]. A venting or overflow hole is required at the highest point of the formwork that not only provides a path for air to escape when fresh concrete is injected but also intimate the worker to stop grouting when it overflows. After the formwork, a grouting pipe is laid in the crown of the deteriorated sewer pipe [13, 14, 15, 17].

Spin-cast Method

In addition to shotcrete and cast-in-place concrete, spin cast is another automated process that uses centrifugal force to spin cementitious materials onto the deteriorated pipe surface. It is an effective rehabilitation method for circular or almost-circular sewers. At first, a pumping plant is set up on the ground. Similar to cast-in-place method, all ingredients are introduced and mixed in here.

CONCLUSIONS:

It is concluded that the biological activity in the wastewater systems is complex and produces corrosive H_2SO_4 irrespective of location, climate or geography. The formation of H_2S in the wastewater systems during H_2S corrosion process is misapprehended. It is produced from sulfates in the wastewater stream by anaerobic SRB located in the slime layer. The thickness of slime layer ranges between 0.3 and 1.0 mm, and depends on the flow velocity and solids abrasion in the municipal sewage. This process is complex as there is a competition between various other microorganisms attempting to break down phosphates and nitrates.

It is also necessary to identify and develop more effective coatings, and safe antibacterial agents that can be used during construction of sewers to inhibit colonization of SOB over exposed portion of the sewers.

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