

Economical and Simple Ways to Remove Hydrogen Sulfide (H₂S) From Construction Sites through Chlorination Using House Bleach

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Abstract: Hydrogen sulfide (H₂S) can pose hazards to people's health if it reaches certain concentrations. Construction sites are prone to hazards which may include dangers from hydrogen sulfide. There are various ways in order to remove hydrogen sulfide from construction sites. This paper aims to determine the ability of chlorination using house bleach (Clorox) to remove hydrogen sulfide from construction sites. Various related literature was able to show that using chlorine in removing hydrogen sulfide is economical and simple to use.

Keywords: hydrogen sulfide; Clorox; chlorination; house bleach; hazards.

1. INTRODUCTION

At low concentrations, hydrogen sulfide, also known as H₂S, sewer gas, swamp gas, stink damp, and sour damp, emits a pungent rotten egg odor. It is extremely flammable and toxic. H₂S toxicity was first described in 1713 and a large part of H₂S research has been focused on its toxic effects (Kimura, Hydrogen sulfide as a neuromodulator, 2002). Hydrogen sulfide in current drinking water standards is not considered a primary or secondary contaminant. However, if the concentration of hydrogen sulfide in water exceeds 0.5 parts per million (ppm), it produces a disagreeable odor. It will corrode iron, steel, copper, and brass in the casing, plumbing, or bathroom fixtures. Moreover, tarnish or discolor copperware, silverware, and brassware; stain laundry and bathroom fixtures with black or yellow; and discolor beverages (U. Saha, 2016).

Sulfate is listed as a secondary contaminant with a secondary MCL of 250 ppm. Sulfate levels above 250 ppm have a bitter taste, have a laxative effect, cause dehydration, and are especially harmful to the health of infants and young animals (U. Saha, 2016).

The removal of environmentally toxic and corrosive hydrogen sulfide from gas streams with varying overall pressure and H₂S concentration has long been a problem for the oil and gas industries (A. G. Georgiadis, 2020). H₂S has long been known to be found during excavation inside work sites such as refineries, landfills, and other plants. The majority of these facilities are subjected to constantly changing conditions, with connections harmed by the highly corrosive properties of H₂S. Although H₂S exposure is expected during project execution, overcoming this toxic gas when encountered on project sites has always been a challenge, resulting in a cost and schedule impact (Alberta, 2006).

Construction is one of the most dangerous occupations, accounting for one in every five worker fatalities in 2018. The dangers of a construction site go beyond the four fatalities reported by Occupational Safety and Health Administration (OSHA) which are falls, electrocution, struck-by-objects, and caught-in-between to those that are difficult to detect. Hydrogen sulfide is the second most common cause of workplace gas inhalation fatalities, trailing only carbon monoxide (Detillier, 2020).

The colorless and flammable gas is produced naturally as a byproduct of organic decomposition and is also emitted as a byproduct of many industrial processes (Detillier, 2020). This toxic gas has also been recognized as a signal molecule as well as a cytoprotectant. As a signal molecule, it modulates neuronal transmission, regulates the release of insulin, relaxes smooth muscle, and is involved in inflammation. Its function as a cytoprotectant has been overlooked because of its reputation as a toxic gas wherein the nervous system and the cardiovascular system are protected from oxidative stress

(Kimura, Hydrogen sulfide: Its production, release and functions, 2010). Cytoprotection is understood to be a process by which chemical compounds provide protection to cells against harmful agents. H₂S is produced by three enzymes, cystathionine Beta-synthase, cystathionine Y-lyase, and 3-mercaptopyruvate sulfurtransferase along with cysteine aminotransferase. In addition to an immediate release of H₂S from producing enzymes, it can be stored as bound sulfane sulfur, which may release H₂S in response to physiological stimuli. However, the toxicity of hydrogen sulfide is given more attention. H₂S is relatively common and frequently lethal resulting in occupational hazards (Kimura, Hydrogen sulfide: Its production, release and functions, 2010).

Previous research has shown that chlorine bleach can effectively remove medium to high levels of hydrogen sulfide of more than 6 mg/L. During the oxidation process, the chlorine in the bleach chemically reacts with the hydrogen sulfide, removing the rotten egg odor. Chlorine bleach also disinfects water supplies by reacting with iron or manganese (Larrison, 1981). The majority of water treatment plants that rely on groundwater have required treatment to remove sulfide from their water. Except for isolated cases where the source of contamination such as synthetic and volatile organics, sulfide is the only contaminant that is readily identified by consumers due to its rotten egg smell and can impact quality, therefore, removing it from groundwater supplies is very important (S. J. Duranceau, 2010).

The objective of this paper is to explore chlorination using household bleach to remove hydrogen sulfide from construction sites.

HYDROGEN SULFIDED FORMATION

Hydrogen sulfide can be found naturally in crude petroleum, natural gas, volcanic gases, and hot springs. It's also present in groundwater. It is emitted by stagnant or polluted waters, as well as manure or coal pits (Chou, 2003). It is a colorless, flammable gas with a rotten egg odor that is produced both naturally and as a result of human activity. Natural sources include non-specific and anaerobic bacterial reduction of sulfates and sulfur-containing organic compounds. Natural sources contribute approximately 90% of the total hydrogen sulfide in the atmosphere (Chou, 2003). Because the gas is heavier than air, it can congregate in low-lying areas such as sewers, pits, tunnels, and gullies (Alberta, 2006).

Many oil fields, particularly mature ones, can emit high levels of hydrogen sulfide, which is lethal even at low concentrations. Because drilling and completions are frequently performed in remote areas, getting to the nearest hospital in time to respond to an exposure event may be impossible (Emerson, 2022). Workers are most commonly exposed to hydrogen sulfide while drilling for natural gas, crude oil, and petroleum products. The biodegradation of gypsum drywall has been linked to the generation of hydrogen sulfide at construction and demolition (C&D) debris sites. H₂S generation was observed in the laboratory when drywall was co-disposed with various C&D debris constituents (K. Yang, 2006).

Stagnant or polluted waters, as well as manure or coal pits with low oxygen content, emit hydrogen sulfide. Some plant species emit hydrogen sulfide as a byproduct of sulfite metabolism. The terrestrial emission rate of hydrogen sulfide is estimated to be between 53 and 100 million tons of sulfur per year. Estimates of ocean sulfur emissions range from 27 to 150 million tons per year (Chou, 2003). The high inventory of hydrogen sulfide in the Black Sea environment makes this sea the largest anoxic basin on earth (Neretin), the city in New Zealand is exposed to hydrogen sulfide due to its location over a geothermal field (M. N. Bates, 2002), and the occurrence of hydrogen sulfide in the groundwater of Kuwait are some examples to show that hydrogen sulfide is prevalent around the world (A. Mukhopadhyay, 2006).

HYDROGEN SULFIDE EFFECTS ON HUMANS AND THE ENVIRONMENT

Hydrogen sulfide emissions may result from the unintentional release or improper disposal of materials as a result of these processes. The majority of environmental releases are in the form of emissions to the ambient air, where the chemical is likely to last less than one day but may last up to 42 days in winter. Depending on temperature and pH, hydrogen sulfide may easily evaporate from water, but it is unlikely to bioconcentrate and biomagnify in the food chain. In unpolluted areas, the concentration of hydrogen sulfide in the air is very low, ranging between 0.03 and 0.1 g/m³ (Chou, 2003).

Because hydrogen sulfide exists as a gas at atmospheric pressure, air partitioning is likely to occur following environmental releases. However, because it is soluble in oil and water, it may partition to surface waters, groundwaters, or moist soils and travel long distances. Furthermore, hydrogen sulfide from the air may be absorbed by soils and plant foliage (Chou, 2003).

Exogenous hydrogen sulfide is primarily inhaled by humans, and the gas is rapidly absorbed through the lungs. The oxidation, methylation, and reactions with metalloproteins or disulfide-containing proteins are the three pathways by which hydrogen sulfide is metabolized (Chou, 2003). The acceptable concentration limit for hydrogen sulfide exposure, according to the Occupational Safety and Health Administration (OSHA), is 20 ppm for an eight-hour period, with a maximum peak exposure of 50 ppm for ten minutes (Kimura, Hydrogen sulfide: Its production, release and functions, 2010).

The gas is rapidly absorbed through the lungs, although it is easily noticed from its strong smell but people's noses get used to the smell quickly, a process called olfactory fatigue. Exposure to hydrogen sulfide may cause eye and respiratory system irritation (J. W. Elrod, 2007). It can also cause apnea, unconsciousness (Kilburn, 2003), convulsions; headache, dizziness, weakness, irritability, insomnia; stomach upset, and if liquid, can cause frostbite. The effects of exposure to high concentrations of hydrogen sulfide on human health are well-known (Edwards, 2011). However, the potential health hazards posed by low-level chronic environmental hydrogen sulfide exposure are still being debated. Studies have shown that respiratory symptoms in humans were the more consistently reported symptoms (Copley, 2014).

2. METHODS OF REMOVING HYDROGEN SULFIDE

The removal of hydrogen sulfide from various source processes is critical because this compound can cause corrosion and environmental damage even at low concentrations. Porous materials provide a wide range of chemical architectures with tunable pore size and high surface area that are very promising for adsorption. Hydrogen sulfide removal in gas purification processes can be accomplished in a variety of ways, including the use of highly porous materials such as zeolites, carbon materials, activated carbon, porous metal oxides, mesoporous silica, and metal-organic frameworks as highly effective adsorbents (M. Khabazipour and M. Anbia, 2019).

Replacing Hot Water Heater Magnesium Rod

There could be a problem if the smell of hydrogen sulfide is detected in a hot water faucet. Inside the water heater, the magnesium corrosion control rod (anode rod) can chemically react with sulfate to form hydrogen sulfide. This matter can be averted or reduced by replacing the magnesium rod with an aluminum or zinc rod. An aluminum rod can be used if the water temperature is kept above 150°F (Larrison, 1981). Remedy for rotten egg odor includes replacing magnesium anode rods and removing cathode-protection anodes (Hack, 2000).

Granular Activated Carbon

A granular activated carbon (GAC) filter will reduce the unpleasant odor and taste if the hydrogen sulfide level in the water is less than 0.3 ppm. A GAC filter may be quickly exhausted due to its limited capacity to adsorb hydrogen sulfide. As a result, activated carbon may be ineffective at removing hydrogen sulfide concentrations greater than 0.3 ppm from drinking water. Tannins, trichloroethylene, and other dissolved organic compounds can also be removed by these filters. A granular activated carbon filter is a proven option to remove certain chemicals, particularly organic chemicals, from water. GAC filters can remove objectionable odors and tastes from water such as hydrogen sulfide (Larrison, 1981).

Catalytic Carbon

Catalytic carbon technology advancements recently provide an appealing alternative to chemical treatment. Catalytic carbon possesses all of the adsorptive properties of conventional GAC, but it also has the ability to convert hydrogen sulfide to elemental sulfur. Adsorption of hydrogen sulfides onto the carbon surface is the first step in the treatment process, followed by oxidation of adsorbed hydrogen sulfide to elemental sulfur in the presence of dissolved oxygen. Catalytic carbon, in this capacity, is similar to manganese greensand and chlorination systems that remove sulfides through oxidation. As a result, catalytic carbon units can treat significantly higher hydrogen sulfide concentrations than conventional GAC filters. It differs in that it uses no chemical additives and maintains consistent catalytic activity (oxidation) to treat sulfur water. One of the several factors that affect catalytic carbon performance is the contact time with the filter. This is the time required for water to travel from the top of the carbon filter to the bottom. A satisfactory performance usually takes three to five minutes. Another feature that is recommended is the ability to backwash with treated water to remove any solid or filtered material such as elemental sulfur (Larrison, 1981).

Hydrogen sulfide and dissolved oxygen concentrations in water are also important. For the complete oxidation of hydrogen sulfide to elemental sulfur, a dissolved oxygen level of 4.0 ppm is required. To increase dissolved oxygen in water with less than 4.0 ppm dissolved oxygen, aeration or the addition of chemical oxidants must be used. To remove higher concentrations of hydrogen sulfide, higher levels of dissolved oxygen are required (Larrison, 1981).

Aeration

Because hydrogen sulfide gas escapes quickly from water, causing an odor, it can also be removed by aeration. The procedure involves bubbling air through the water tank and then separating or stripping the hydrogen sulfide in the air by venting it outside. An air compressor or blower is typically used to introduce a large volume of air into the water, either in a tank specifically designed for hydrogen sulfide removal or by replacing the bladder-style pressure tank with an older-style pressure tank. The hydrogen sulfide in the air bubbles volatilizes (Larrison, 1981).

A pocket of air in the upper third or upper half of a well-designed aeration tank or older-style pressure tank allows the hydrogen sulfide gas to vent outside the home before the water is distributed throughout the house. Aeration is considered to be most effective when the hydrogen sulfide concentrations are less than 2.0 ppm. This process may not reduce hydrogen sulfide to undetectable levels on its own. Following the aeration system, a GAC filter may be used to remove any remaining trace amounts (Larrison, 1981).

Aeration systems designed specifically for hydrogen sulfide removal are capable of removing high levels of iron and manganese if a sediment filtration system is added after the aeration process to filter out the solids formed. Aeration can also help to remove radon gas. No chemical additives are required. This is the main benefit of the aeration system as it does not use any chemicals compared to other treatment systems that can be harmful, especially when used in high volumes. A properly designed aeration system is less expensive to maintain than many chemical-based treatment systems (Larrison, 1981).

The disadvantages of aeration are that it may not be effective during long periods of high water usage, the air pocket in the top of the tank may be frequently be lost and the introduction of oxygen may cause problems if some hydrogen sulfide is oxidized to sulfide, bisulfide, or solid sulfur particles which are all not air-strippable and must be filtered out of the treated water, and off-gassing of the hydrogen. Other disadvantages may include the higher cost of aeration equipment, higher operating costs, higher maintenance requirements, and the possibility of required monitoring to check the dissolved oxygen level in the liquid (Larrison, 1981).

If the bacteria are not removed first, aeration can actually exacerbate bacterial sulfur problems. Some water treatment professionals prefer to install chlorinators before aeration to kill bacteria and reduce sulfur levels. Bacterial slime and other substances that build up in aeration tanks, spray nozzles, and trays must be removed on a regular basis. Aeration emits a strong hydrogen sulfide odor near the aerator, which can be bothersome if it is near a living area (Larrison, 1981).

Manganese Greensand Filter

A point of entry in a filtration system containing manganese greensand is capable of removing up to 10 ppm hydrogen sulfide in addition to iron and manganese. A manganese greensand filter has a manganese oxide coating that converts hydrogen sulfide gas to solid sulfur particles, which are then filtered out. When the majority of the manganese oxide coating has been consumed and the oxidizing capacity of the filter medium has significantly decreased, the greensand filter medium is regenerated or recoated with weak potassium permanganate solution, a purple oxidizing chemical, to restore the oxidizing capacity. This process is similar to regeneration in water softeners and must be repeated at one to four-week intervals, depending on the chemical composition of the water, the size of the unit, and the amount of water processed (Larrison, 1981).

Concentrated potassium permanganate is a poisonous skin irritant that should be kept out of the reach of children and animals. In contrast to chlorine, there should be no potassium permanganate in the treated water. If potassium permanganate is present in the water, a faint pink tinge appears (Larrison, 1981).

Natural and synthetic manganese greensand are both available. The synthetic gel removes the same amount of contaminants as natural greensand, but it requires less backwash water and softens the water while removing hydrogen sulfide (Larrison, 1981).

If the pH of the water is less than 6.7, increasing it to 7.5 to 8.3 will help with hydrogen sulfide removal. A pre-chlorination step is frequently advised to convert the majority of the hydrogen sulfide to elemental sulfur and extend the life of the manganese greensand filter. Otherwise, the filter may become clogged with solid sulfur particles on a regular basis, necessitating more frequent replacement or regeneration. These filter systems are highly specialized, and the manufacturer's installation and operation instructions must be strictly followed (Larrison, 1981).

Chemical Oxidation by Chlorination

Chemical oxidation by chlorination is another method of treating hydrogen sulfide at the point of entry. Continuous chlorination can effectively remove hydrogen sulfide levels ranging from low (6 ppm) to high (75 ppm), especially if the water pH is between 6.0 and 8.0. When chlorine is added to water, it rapidly oxidizes sulfide, hydrogen sulfide, and bisulfide to form compounds that do not have unpleasant tastes or odors. Yellow sulfur particles may be produced as well, which should be filtered out using a fine-retention sediment filter. They can otherwise form a yellow film on clothing and fixtures. However, due to excess free chlorine (greater than 2 ppm) in the water, this process may produce an unpleasant taste (Larrison, 1981).

To obtain chlorine-free water for cooking and drinking, a granular activated carbon filter can be used. Chlorination systems are available in pellet-drop or liquid-chemical feed configurations. During the pumping cycle, the pellet-drop system automatically dispenses a measured amount of chlorine down the well casing or into the retention tank. A chemical-feed system typically delivers chlorine as sodium hypochlorite solution or household liquid bleach via a small feed pump that runs in tandem with the well pump (Larrison, 1981).

When the combined concentration of iron and manganese exceeds 10 ppm, chlorination followed by a fine-retention sediment filter is also recommended. In water, iron and manganese can coexist with hydrogen sulfide. Chlorine oxidizes dissolved iron and manganese, resulting in solid particles that are filtered out of the water. Backwashing the filter every few days or weeks is required to flush out the accumulated particles (Larrison, 1981).

When chlorinating, it is critical to consider the concentration of chlorine as well as the contact time. The dosage of sodium hypochlorite is determined by the concentrations of hydrogen sulfide, iron, and manganese. The table below presents typical dosages required in chlorination treatment (Larrison, 1981).

Active sulfur-reducing bacteria can be found in the plumbing system, well casing, or aquifer. If the water tests positive for coliform bacteria and has a rotten egg odor, many laboratories conclude that sulfur-reducing bacteria are present. Shock chlorination can eliminate the rotten egg smell caused by sulfur-reducing bacteria in well water. This can be accomplished by pouring a single high dose of ordinary household bleach at 5.25 percent hypochlorite into the well, circulating it through the plumbing system, allowing 12 to 24 hours for the bleach to kill the bacteria, and then flushing the added bleach out. The chlorine concentration used in shock chlorination is 100 to 400 times higher than that found in treated city water. Chlorine is a good disinfectant that is capable of killing most disease-causing bacteria, viruses, protozoa cysts, and iron, manganese, and sulfur bacteria if the concentration and contact time are adequate. Iron and sulfur bacteria can be difficult to kill because they grow in thick layers and are shielded by a slimy secretion. If two shock chlorination attempts fail to solve the hydrogen sulfide problem, continuous chlorination or other methods may be required (Larrison, 1981). If bacteria are present in the groundwater, the system will be contaminated again when that water is pumped into the plumbing. This calls for continuous chlorination or other disinfection methods.

It is not necessary to remove all of the sulfates from the water. Only potable water must be treated. In most cases, a point-of-use distillation or reverse osmosis system is sufficient. A whole-area ion exchange treatment can be used to treat extremely high concentrations. This system can also soften hard water and reduce the levels of iron and manganese in drinking water (Larrison, 1981).

For chlorination at excavation sites, there is a simple but effective chlorination method. A high value of hydrogen sulfide was reported in a few sites along Saudi Arabia's coast, and a simple method of chlorination was used, chlorination in the form of household bleach Clorox, and it successfully removed all of the hydrogen sulfide present in the water (Larrison, 1981). As a rule of thumb, Clorox used 0.45 to 1.80 liters for one cubic meter of water. An easy way to oxidize hydrogen sulfide in water is to use Clorox disinfecting bleach, which is available at any supermarket. The sodium hypochlorite concentration in Clorox disinfecting bleach is 7.4%. The amount required to completely remove hydrogen sulfide (33 mg/L) in 1 m³ of groundwater is 0.45 to 1.80 L Clorox. A minimum injection of Clorox of 4.5 L is required to treat 10 m³ of this hydrogen sulfide-laden groundwater. The concentration of hydrogen sulfide in the water should be tested after injecting 4.5 L Clorox into the 10 m³ groundwater (Larrison, 1981).

Table 1. Approximate Dosage of Chlorine and Household Bleach for Oxidation Based on Concentration of Selected Minerals (Saha, 2016)

Containment	Value	Chlorination by - Household Bleach (5.25% Sodium Hypochlorite)
Hydrogen Sulfide	2.2 ppm for 1ppm (or mg/L) hydrogen sulfide	33.4 mL/100 gallons or approximately 1 1/8 fl. oz./100 gallons for 1 ppm hydrogen sulfide
Iron	0.64 ppm for 1 ppm iron	9.7 mL/100 gallons or approximately 1/3 fl. oz./100 gallons for 1 ppm iron
Manganese	1.3 ppm for 1 ppm manganese	19.7 mL/100 gallons or approximately 2/3 fl. oz./100 gallons for 1 ppm manganese

Based from this table, contact time or exposure is determined by the type of contaminants, water temperature, and pH. Iron and hydrogen sulfide oxidizes instantly, while manganese oxidizes more slowly. Before reaching the storage tank, chlorine should be introduced into the system. The tank must be large enough to allow for at least 20 minutes of contact time between the water and the chlorine (Larrison, 1981).

In addition to oxidizing bacteria, chlorine kills iron and manganese bacteria, sulfur- and sulfate-reducing bacteria, and other harmful bacteria. Bacteria containing iron and manganese can clog a water softener or oxidizing filter. The complexity of chemical reactions and equipment maintenance are two disadvantages of chlorination. Because they require the continuous addition of chemicals, chlorination systems can be difficult and costly to operate (Larrison, 1981).

Other studies have shown that the most effective way for developing countries to disinfect water is through the use of chlorine or sodium hypochlorite (bleach). A solution of bleach can kill microorganisms and is effective against many bacteria, lipid and nonlipid viruses, fungi, slime-forming algae, protozoa, and nematodes (Doherty, 1899). Other studies also reveal that three gallons of household bleach could be required as a treatment alternative to removing hydrogen sulfide. It is not even necessary to use bleach in excess of the recommended amount.

3. CONCLUSION

In the end, chlorination using household bleach (Clorox) could be explored as an option for removing hydrogen sulfide (H₂S) from construction sites. As shown in some studies, chlorine bleach can effectively remove medium to high levels of hydrogen sulfide as the chlorine in bleach chemically react with the hydrogen sulfide eliminating the rotten egg odor. The advantages of using bleach are it is economical and simple to use due to its availability and the processes involved in chlorinating hydrogen sulfide.

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