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# Treatment and Disposal of Gypsum Board Waste

## *Technical Paper*

### Part II

*Editor's note: This is Part Two of a two-part article on gypsum board waste. Originally developed as an "Industry Position Paper" by the Gypsum Association, the article is reprinted with permission of the Gypsum Association, Washington, D.C.*

#### **Introduction**

Part I of this article, which appeared in the February issue of *Construction Dimensions*, discussed the background of gypsum board--how it is made, sources of waste gypsum building material, and what is done with the waste. It was noted that the gypsum industry supports the goal of reducing the U.S. landfill burden and is working to recycle gypsum board waste where possible and investigate other uses for the waste.

Most gypsum manufacturing companies, many of whom in the past have been involved in some forms of limited recycling, are now learning how to increase the amount of recycling they are doing and are looking for new uses of waste material. Where the economics are favorable, independent recycling firms are also developing gypsum waste recycling systems. Any negative publicity on the disposal of gypsum waste, valid or otherwise, serves to generate more incentive to recycle, both for the independent recycler and the gypsum board manufacturer.

Coincident with the growing public concern over waste disposal and the environment, and the rapid rise in the cost of disposal of gypsum waste, there has been a growing base of very misleading reports that gypsum board, on its own, creates toxic hydrogen

sulfide gas when disposed of in landfill sites.

Gypsum and other sulfate minerals may decompose to hydrogen sulfide gas in landfill sites, but only in the presence of other materials and under specific conditions. Control of drywall landfilling so that it is separated from organic waste materials appears to eliminate or reduce hydrogen gas generation to below the nuisance level.

#### **Hydrogen Sulfide Gas Generation Process Background**

Hydrogen sulfide gas ( $H_2S$ ) occurs in nature and as a product of many industrial processes. It can be formed from sulfur compounds, including sulfates, or from sulfur itself.

As a frequent by-product of industrial processes, it is generated by the reaction of sulfur compounds with organic materials (reducing agents) at high temperatures (heat).

Coal gas, petroleum gas and some natural gas all contain  $H_2S$ , which has to be removed before use because of its toxicity and foul odor. Large volumes of  $H_2S$  are generated in the manufacture of petroleum coke, and can be recovered from "sour gas" wells. In nature, certain bacteria acting on a mixture of organic material and a sulfate will produce  $H_2S$  gas. The Yellowstone National Park sulfur hot

springs are well-known examples of this phenomenon.

#### **Toxicity and Safety**

Hydrogen sulfide gas ( $H_2S$ ) is both toxic and combustible. Its mixtures in air (from 4.5 to 45.5%) can be explosive at high temperature. Due to its very offensive odor,  $H_2S$  can be detected by the human nose at a level of 3 ppb (parts per billion) in air.

It is toxic to humans at levels of 50-1000 ppm (parts per million), while frequent exposure to  $H_2S$  at levels of 10-30 ppm can cause eye damage ("glassy eye"). It attacks the nerve centers and, although easily detectable in trace amounts, higher concentrations will paralyze the olfactory nerves and the gas will no longer be sensed. Levels of 1000 ppm of  $H_2S$  in air will cause rapid death. Symptoms of low level poisoning include headache, burning eyes and cloudy vision, all temporary symptoms.

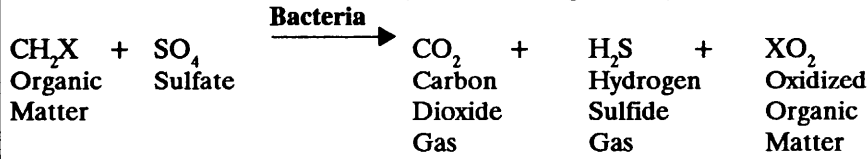
#### **Bacterial Reduction of Sulfates**

All soluble sulfates can be reduced to hydrogen sulfide gas by bacterial action in nature. While infrequent and only occurring under special conditions, the strongly offensive odor of the  $H_2S$  gas draws attention to the phenomenon.

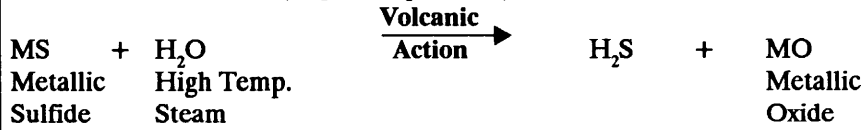
This is a very complex process, first described by Zelinsky in 1893.<sup>1</sup> An excellent review of the many studies carried out prior to 1965 was pro-

**Several simplified routes to H<sub>2</sub>S:**

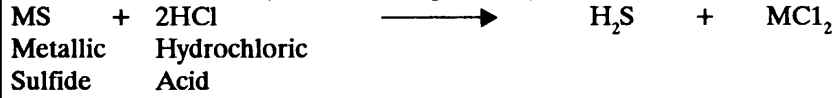
**1. Bacterial Reduction of Sulfates (Ambient Temperature)**



**2. Thermal Generation (High Temperature)**



**3. Chemical Reaction (Ambient Temperature)**



**4. Catalytic Combination (High Temperature)**

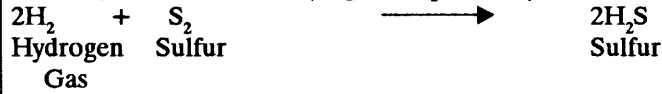


Table 1

vided by Postgate.<sup>2</sup> Several of these studies were prompted by the potential to develop an industrial process to recover sulfur from gypsum, by oxidation of the H<sub>2</sub>S gas generated by the sulfate reducing bacteria (SRB).<sup>3,4</sup> This oxidation step could be either chemical or bacterial, the latter route using sulfide oxidizing bacteria (SOB). **Sulfate Reducing Bacteria (SRB)**

While many microbes can generate H<sub>2</sub>S metabolically from sulfates, wherein they incorporate the sulfur into their cell structures and, through later degradation, evolve small amounts of H<sub>2</sub>S gas, the SRB are a special group which actually use the sulfur in soluble sulfates as electron acceptors in the oxidation of organic matter. That is, the organic matter provides a source of carbon to the bacteria for cellstructure growth, and the sulfate is reduced to hydrogen sulfide as a result--without being incorporated into the bacteria cell structure. Such bacteria require a continu-

ous supply of both organic material and sulfate ions in order to survive, and they evolve many times the amount of hydrogen sulfide gas which normal bacterial degradation does.

There are two genus of SRB, each having the capability to produce various species:

1. Spore producing -- Desulfotomaculum
2. Non-Spore producing -- Desulfovibrio

The desulfovibrio bacteria appear to be the most resistant and widely distributed in nature, which is reflected in the fact that most studies reference various strains of desulfovibrio, the most common being desulfovibrio desulfuricans.

A discussion of the metabolic route which SRB use to assimilate carbon and reduce sulfate to sulfide is beyond the scope of this documents.<sup>5</sup> However, several studies designed to determine the optimum conditions for sulfate reduction are very pertinent, since they provide some clues to minimize bacterial decomposition of gypsum board in landfill sites.<sup>6-12</sup>

The 1984 publication<sup>13</sup> "The Sulfate Reducing Bacteria, 2nd Edition" J.R. Postgate, Cambridge University Press, 1984 is the most recent comprehensive review on the subject. Conditions Affecting Bacterial Reduction of Sulfates

Sulfate reducing bacteria (SRB) require a continuous supply of organic material and sulfate ion in order to generate H<sub>2</sub>S gas. Different strains of desulfovibrio and desulfotomaculum have different optimum conditions of temperature and pH. As a whole, they are very resistant to variations in terrestrial conditions and occur throughout the world.

Hydrogen sulfide gas can be generated only when *all* of the conditions listed below exist:

1. Liquid water
2. Organic material available
3. Sulfate ions available
4. Absence of air
5. Presence of desulfovibrio or desulfotomaculum bacteria
6. pH of 4-9
7. Optimum temperature range

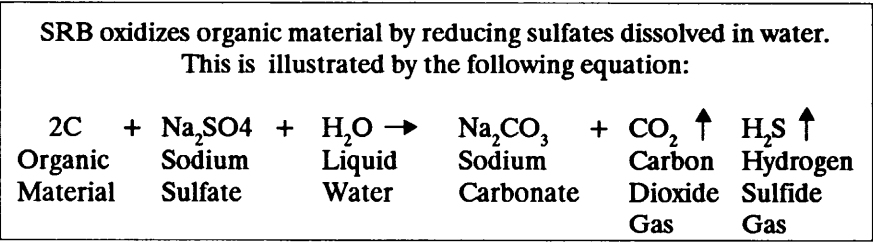


Table 2

**1. Liquid Water** -- The biological conversion of sulfate to H<sub>2</sub>S gas *must* occur in solution in water. The absence of water will stop the reaction --as will temperatures below freezing.

**2. Organic Material Available** -- Without carbon the bacteria cannot propagate and H<sub>2</sub>S will not be produced. Carbon is needed to build the cell walls of bacteria as they multiply.

**3. Sulfate Ions Available** -- SRB are unique in that they oxidize organic material (carbon) by reducing sulfates dissolved in water. Any soluble sulfate will work--including all by-product gypsum--in addition to natural gypsum and anhydrite. Many natural waters contain high levels of dissolved sulfates, including seawater, brine and "hard" water. Many industrial waste streams from processes which use sulfuric acid also contain soluble sulfates.

**4. Absence of Air** -- Oxygen will kill SRB.

**5. Presence of Bacteria** -- SRB are widespread throughout nature, in sewage, pulp mill effluent and landfill garbage.

**6. pH Control** -- Most SRB strains prefer a pH range between 7 and 8. At pH below 5 and above 9 little or no growth will occur and H<sub>2</sub>S will not be produced. Above pH 9 any soluble

iron will precipitate out of solution. Since iron is one of the essential trace nutrients for bacterial growth, they will die without it. Also, at higher pH H<sub>2</sub>S will not be released from solution, but will exist as SH and S<sub>2</sub>.

**7. Optimum Temperature Range** -- SRB need liquid water to propagate. Below freezing temperatures will arrest their growth and stop H<sub>2</sub>S production. Different strains have different ranges for optimum growth conditions. Typically 30-38° C appears to support rapid growth. In one study no bacterial growth occurred at or above 45° C.

Studies in which H<sub>2</sub>S gas was continuously removed from SRB growth cells resulted in 4-5 times the amount of H<sub>2</sub>S generated when compared to cells where the H<sub>2</sub>S was not continuously removed. This is because hydrogen sulfide gas is actually toxic to SRB. In landfill sites in which meth-

ane gas is also generated by other bacteria which are also acting on organic wastes, the methane acts as a carrier gas, both diluting and removing H<sub>2</sub>S from the vicinity of SRB.

### **Solutions--Gypsum Board Waste Management**

In addition to the waste management solutions mentioned in Part I in the February issue, another alternative being studied is ocean placement. Reef and island construction is another alternative to landfill, which may provide uses for several types of gypsum waste products. When properly used, ocean placement offers potential environmental benefits such as helping to establish marine growth, providing fish habitat (including artificial reefs), and controlling beach erosion. Studies of ocean environmental enhancement through the placement of gypsum waste products will continue as a priority in long-

term recycling answers.

Gypsum board waste does not normally create problems in landfills. However under extremely wet conditions (high water table) waste board can contribute to the growth of anaerobic bacteria, as previously addressed. Gypsum is simply a good "food source" for anaerobic bacteria. When wet landfill conditions occur it is suggested that board waste be separated from other wastes, especially organic wastes, and placed in a specific area of the landfill. At least one scientific study has shown that adding lime (calcium oxide) at a rate of 3-5 pounds per ton of gypsum will help protect against the growth of anaerobic bacteria. The lime will raise the pH of the gypsum to a level that inhibits the growth of anaerobic bacteria<sup>14</sup>. Wells can be placed (if desired) around the gypsum tilled areas to test and monitor for the presence of any leachate.

#### Landfill References

<sup>1</sup>Zelinsky, V. J. Russ. Phys. Chem. Soc. 25:298-305

<sup>2</sup>Recent Advances in the Study of the Sulfate Reducing Bacteria. J.R. Postgate, Bacteriological Reviews Vol. 29, No. 4, 425-441, Dec. 1965.

<sup>3</sup>Bug Process Recovers Sulfur, March 20, 1967, Chemical and Engineering News, page 21.

<sup>4</sup>Microbial Conversion of Hydrous Calcium Sulfate to Hydrogen Sulfide U.S. Dept. of the Interior, Bureau of Mines Report 7355, March 1970.

<sup>5</sup>Microbial Conversion of Sulfate to Sulfur--An Alternative to Gypsum Synthesis, D.J. Cork, Advances in Biotechnological Processes 4, p. 183-209, 1985.

<sup>6</sup>Some Studies on Microbial Reduction of Gypsum, v. Bihari, V.H. Potty, Chemical Age of India, Vol. 25, No. 11, Nov. 1974, 801.

<sup>7</sup>The Bacterial Sulphur Cycle as a Source of Sulphur, DC. Madigan, Australian Minerals Development Lab Bulletin 1971, No. 12, 14.

<sup>8</sup>Kinetics of Microbial Sulfate Reduction

AC. Middleton, A.W. Lawrence, Journal WPCF, July 1977, 1659-1669.

<sup>9</sup>Sulfate Decomposition: A Microbiological Process D.J. Cork, M.A. Cusanovich, Metallurgical Applications of Bacterial Leaching (Murr L.E., Torma A.E., Brierly J.A.) 1978, 207-221.

<sup>10</sup>Gypsum Bioconversion to Sulfur: A Two-Step Microbiological Process, R.A. Uphaus, D. Grimm, D.J. Cork, Development of Industrial Microbiology 1983, 435-441.

<sup>11</sup>Optimization of Desulfobacter for Sulfate Reduction D.T. Grimm, D.J. Cork, R.A. Uphaus, Development of Industrial Microbiology 1983, 709-716.

<sup>12</sup>Anaerobic Treatment Using New Technology for Controlling H<sub>2</sub>S Toxicity, E. Sarnek, B.G. Hultman, and A.E. Berglund, Feb. 1988 Tappi Journal, 41.

<sup>13</sup>"The Sulfate Reducing Bacteria, 2nd Edition," J.R. Postgate, Cambridge University Press, 1984.

<sup>14</sup>"Investigation of Means to Control Sulphide Production in Drywall Landfill Disposal Operations," Hardy Associates, British Columbia, 1984.