Understanding Hydrogen Sulfide in the Mushroom Industry

John W. Paul Ph.D.P.Ag. Soil Microbiology and Waste Management *Sept 2008*

Hydrogen sulfide is a gas produced by anaerobic bacteria in the presence of sulfur compounds and organic carbon under conditions where no oxygen is present. In the mushroom compost industry, gypsum (calcium sulfate) is added in the mushroom media preparation process. This additional sulfur increases the risk of hydrogen sulfide formation under anaerobic conditions, such as in the "goodie" water, or in large piles of spent mushroom compost Hydrogen sulfide has a "rotten egg" smell and can be annoying at low concentrations, but can be lethal with one lung full at high concentrations *(Health and Safety Authority Draft Code of Practice for Preventing Injury and Occupational Ill Health in Agriculture – Ireland 2006)*

Hydrogen sulfide is produced by bacteria from sulfur compounds under anaerobic conditions

Sulfur is an Essential Element

Sulfur is one of the most abundant elements in the earth's crust, and therefore is present in soil, with more present in clay and silt soil than in sandy soil. It is an essential element for plants, where is part of many enzymes, two amino acids, and chlorophyll. Plants with sulfur deficiency are yellow and do not grow well. In our bodies, sulfur is the third most abundant mineral. Sulfur is important for health.

How is Hydrogen Sulfide Produced?

Hydrogen sulfide is produced by anaerobic bacteria that use sulfur compounds as electron acceptors. Bacteria normally use oxygen as the terminal electron acceptor in respiration because it allows them to extract more energy from carbon compounds. When oxygen is used up, and there is still food available (carbon compounds), bacteria use other compounds as electron acceptors during respiration. There are specific types of bacteria adept at utilizing sulfate as the electron acceptor resulting in hydrogen sulfide under anaerobic conditions

Where is Hydrogen Sulfide Produced?

In our own human experience, we have hydrogen sulfide production and release in our own bodies, in the large intestine and colon, especially after consuming foods high in sulfur. Hydrogen sulfide is produced in swamps and wetlands. It is also found near coal and oil reserves because of the sulfur compounds present in the organic matter that produced the coal and oil. Hydrogen sulfide is produced in wastewater treatment plants, where most wastewater is handled and treated as a liquid, and hence anaerobic. Wastewater treatment plant operators are required to wear personal hydrogen sulfide monitors. Hydrogen sulfide is also produced during storage of animal manures as a slurry or liquid.

How is Hydrogen Sulfide Dangerous?

Hydrogen sulfide is a clear, colorless and highly corrosive gas that is heavier than air, and hence accumulates in depressions and lower areas. At low concentrations, hydrogen sulfide is an irritant in that it smells like rotten eggs. At higher concentrations, it irritates the eyes and nose. At concentrations over 150 ppm, it can paralyze the smelling ability of our noses. At very high concentrations it is a chemical asphyxiant, similar to gases such as carbon monoxide and hydrogen cyanide.

Hydrogen sulfide is heavier than air and accumulates in holes and depressions.

The following table indicates the health effects of hydrogen sulfide.

PHYSIOLOGICAL RESPONSE OF ADULT HUMANS TO HYDROGEN SULPHIDE **

Effect	Concentration Mg (H_2S)/1 Kg (Air)
Least Detectable Odour	0.01-0.7
Offensive Odour	3-5
Eye Irritation	10
Irritation Mucous Membranes and Lungs	20
Irritation of Respiratory Tract	50-100
Olefactory Nerve Paralysis	150
Headache, Dizziness	200
Nausea, Excitement, Unconsciousness	500-600
Rapidly Fatal	700-2000

** Source Nordstron, G.A.: J.B. McQuilty: "Manure Gases in the Animal Environment." University of Alberta - 1976.

Risks are Greater When We Add Sulfate to Organic Matter Under Anaerobic Conditions

The reason that we have banned drywall (gypsum) from landfills is because they increase the risk of hydrogen sulfide formation in the landfill. Landfills are anaerobic, this is why they produce methane. Any sulfur compounds added to landfill also are rapidly converted to hydrogen sulfide in the presence of organic waste in a landfill. Landfill workers also must carry personal hydrogen sulfide monitors for this reason.

What are the Risks in the Mushroom Industry?

In general, the risk of hydrogen sulfide production in the mushroom industry is low because the composting process used to produce the mushroom growing medium is aerobic, hence very little hydrogen sulfide is produced. In the past, mushroom media production occurred in the open air, with little collection of leachate. Any hydrogen sulfide that was formed was rapidly dissipated.

Hydrogen sulphide is has a rotten egg smell, but concentrations over 150 ppm paralyze the nose, and can no longer be smelled.

The potential risk of hydrogen sulfide production in the mushroom industry is higher than in sewage treatment plants or in animal agriculture because significant amounts of gypsum (calcium sulfate) are added in the preparation of the mushroom growing medium. The purpose of adding gypsum is to tie up the ammonia and balance the pH of the mushroom growing media.

This potential risk of hydrogen sulfide production is greater if the mushroom compost, leachate or water associated with it, or the spent mushroom compost is stored under anaerobic conditions.

The Best Environmental Management Practices Guide for Mushroom Growers in Canada produced in 2000 warns of the risk of odor and hydrogen sulfide production during anaerobic conditions.

The concern with hydrogen sulfide in the mushroom industry has been more commonly associated with storage of spent mushroom compost because it is sometimes stored on very large piles and becomes anaerobic. The mushroom growing media production is largely an aerobic process and has occurred outdoors until recent years.

Environmental regulations reducing the risk of air and water pollution have lead to new challenges in the mushroom industry. Requirements to enclose composting facilities to control odor emission has led to the corrosion and collapse of two mushroom media production barns in British Columbia in recent years. Requirements to collect and manage leachate and goody water in contained areas also increase the risk of hydrogen sulfide production

Biofilters Eliminate Hydrogen Sulfide

A well managed biofilter will eliminate hydrogen sulfide in composting gases. Hydrogen sulfide has a significant amount of energy in the H-S bond, and there are aerobic bacteria that can break this bond to obtain the energy. The resulting products are water and sulfate. This happens very readily in a biofilter, however, a biofilter is not able to manage large changes in hydrogen sulfide production.

Managing the Risk of Hydrogen Sulfide

There are some simple rules to follow to reduce the risk of hydrogen sulfide production and deleterious health effects.

1. Adequately train staff to understand how hydrogen sulfide is produced, where it can be produced, and the potential dangers of hydrogen sulfide.
2. Design storage and handling facilities to reduce potential production of hydrogen sulfide.
3. Have all staff carry personal hydrogen sulfide detectors
4. Ensure that all enclosed areas are properly ventilated
5. Avoid accumulation of leachate in enclosed areas

Workers must be aware of the risks and equipped with hydrogen sulphide detectors.

Where are the greatest risks?

1. Leachate collection and recirculation systems.

   Leachate associated with mushroom media production will contain readily available food for bacteria, as well as sulfur containing compounds, including poultry litter and gypsum will produce hydrogen sulfide because oxygen does not diffuse well through liquid. This includes “goody” water as well.

   Because hydrogen sulfide is heavier than air, it will concentrate in the liquid or in the air immediately above it. Any agitation, spraying or other exposure of the liquid to the air will release the hydrogen sulfide.

2. Enclosed mushroom media preparation facilities

   Although the mushroom media preparation in enclosed facilities is usually aerated and therefore produces little hydrogen sulfide, caution must be taken when there is a power failure or a blower failure resulting in anaerobic conditions and potential accumulation of hydrogen sulfide.

3. Large piles of spent mushroom compost.

   Large piles of spent mushroom compost are often left undisturbed for many months. As many of them are also stored outside, they become more anaerobic because of precipitation. Significant accumulations of hydrogen sulfide have been measured in large piles of spent mushroom compost.