Sulfur Cycling in Swine Lagoon Systems

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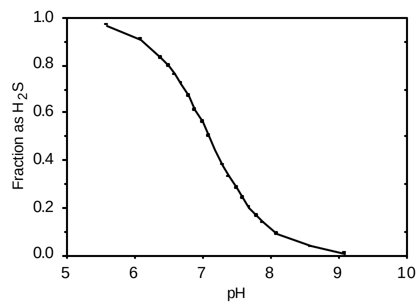
The sulfur cycle in wastewater treatment lagoons, including those used to treat swine waste, dictate the flux of sulfide leaving the water and entering the air. This sulfur cycle can be divided into two parts: i) sulfate reduction and ii) sulfide oxidation. The relative rates of sulfur reduction and oxidation will dictate the sulfide flux out of a lagoon. A brief overview of the sulfur cycle in swine lagoons is provided below.

Sulfide Production

- **Sulfide production in swine lagoons is facilitated by Sulfate Reducing Bacteria** (including: *Desulfovibrio*, *Desulfotomaculum*, and *Desulfomonas*) **under anoxic conditions.**
- **Sulfide production rates in lagoon systems can be very high**. The rate of sulfide generation has been well correlated to the organic concentrations in the lagoon influent (when an excess of sulfate is present) and the lagoon water temperatures. Rates of sulfide production have been shown to be as high as 1.2 grams/Liter/day (0.63 grams S/gram VSS/day) (du Preez and Maree, 2000)
- **Sulfide concentrations in the lagoon water typically range from 1 – 10 mg/L, but may greatly exceed this range in extreme cases.**
- **At pHs below 8.0, a significant fraction of the hydrogen sulfide is present in the unionized (H_2S) or dissolved gas form**.



- **Hydrogen sulfide in water will enter the air above at a relatively high rate, resulting in high atmospheric concentrations**. For example air in equilibrium with water containing 0.1 mg/L of H_2S will contain up to 10-ppm sulfide. The flux rate of sulfide from swine lagoons was determined by Zahn, et al, (2000) to range from 1.1 to 1.2 kg sulfur/1,000 m^2/day.

Sulfide Reduction by Purple Sulfur Bacteria

- **Purple Sulfur Bacteria are photosynthetic (algae-like) bacteria that use sunlight for energy while concurrently oxidizing sulfide to sulfate.** When present in large numbers, the PSBs may reduce, but not eliminate, the sulfide concentration.
- **Publications describing so-called purple lagoons provide only anecdotal information on role of purple sulfur bacteria in swine lagoons.** Scientific data on PSB numbers and sulfide oxidation rates are not found in the commonly available literature. Zahn, et al (2000) state that phototrophic populations of 40 mmole/L of bacterial-chlorophyll a were measured in lagoons with significant sulfide reduction. This represents a moderately high mass of phototrophs in the systems
- **Growth of Purple Sulfur Bacteria in swine lagoons is slow and unpredictable**. Factors effecting their activity include: a) light penetration (turbid and colored waters prevent significant growth of PSBs), b) ammonia concentration (**ammonia is inhibitory**), c) the presence of copper (inhibitory) and other disinfectants (inhibitory), d) sulfide concentration (1-6 mg/L aqueous concentration appears to be optimum), and e) sufficient nitrate for growth.
- **The establishment of PSBs in a lagoon may take longer than one year**. If a die-off occurs for any reason, it may take almost a year to recover.
- **The activity of Purple Sulfate Bacteria varies throughout the year based on water temperature, photoperiod, and lagoon loadings. Even ponds with large populations of purple sulfur bacteria will have low rates of sulfur oxidation during the winter months.**
- **Sulfide concentrations below 1.0 mg/L in water are typically not achieved by the PSBs.** This is largely because mass transfer becomes unfavorable and the kinetic rate of sulfide oxidation becomes very slow at low concentrations (Kobayashi, et al., 1983). Even at 1.0 mg/L, the transfer of sulfide to the air could be very large, with atmospheric concentration over the pond greatly exceeding 10 ppm. (10,000 ppb). **The requirement for sunlight restricts activity to the well-lit upper layer of the lagoon**. In turbid or colored lagoons, this may represent a small fraction of the total depth. Therefore, much of the lagoon volume may not support sulfide oxidation. However, almost the entire volume will support sulfate reduction and the rate of hydrogen sulfide production often exceeds the rate of oxidation
- **High organic/ammonia loading rates will also prevent the establishment of PSB**. Typically, loading rates must be below 4.5 lbs volatile solids per thousand cubic feet per day in North Carolina. High ammonia rates are typical in swine lagoons. Ammonia concentrations range between 410 and 1,260 in swine manure influents (Prudence et al., 2002) . The high influent ammonia values are often inhibitory to purple sulfur bacteria in swine lagoons. To allow the PSBs to grow in large numbers, a significantly lower loading rate is needed.

Conclusions

Base on the results of a review of the available literature, the following conclusions are made:

1. The reduction of sulfate to sulfide in a swine lagoon may occur at a high rate.
2. Sulfide flux rates from a swine lagoon to the air, are often high, resulting in high concentrations in the surrounding air.
3. Purple Sulfur Bacteria (PSBs) may reduce the concentration of sulfide in the water by oxidation back to sulfur or sulfate.
4. PSBs do not remove the entire mass of sulfide. A residual of over 1.0 mg/L may remain. This concentration allows the potential for high atmospheric sulfide concentrations to persist. Even for swine lagoons with active PSB populations, there will still be substantial hydrogen sulfide releases to the atmosphere.
5. PSB activity is inherently unstable. Environmental factors (i.e., light, temperature) and the toxic nature of swine waste (i.e., high ammonia and copper salts) may reduce activity or kill the PSBs outright.

Dr. Clifford R. Lange received a B.A in Biology (1981) and a B.S (1985), an M.S. (1988) and a Ph.D (1993) in Civil Engineering, from the State University of New York at Buffalo. He began teaching at Auburn University in 1993 and currently is an Associate Professor in the Department of Civil Engineering. His major areas of research are wastewater microbiology and the treatment of industrial and municipal wastewater. He has recently completed studies of hydrogen sulfide levels in and above eight municipal wastewater lagoons in Alabama, several municipal sewer systems (Daphne, AL; Albertville, AL; Pine Bluff, Arkansas; Lufkin, TX; and Lake Jackson, LA), thirteen paper mill lagoons, and three poultry lagoons.

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