Best Management Practices
For Soluble Sulfur Problems On Putting Greens

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Some golf courses in the southwest have become concerned about sand-based putting greens having possible reactions with soluble sulfur to cause black layer problems. The interest in this potential problem is most acute in arid climates with the associated low precipitation levels being more at risk for salt-related problems, such as black layer, since the natural flushing of excess salts is diminished in lower (i.e. 3-15 inches per year) precipitation climates. As a result, some superintendents have actually decided to stop using their irrigation water sulfur burner treatment systems. This article will explain the physical and chemical topics involved in arid climate putting green management focusing on the management procedures necessary for maintaining effective rootzone gas exchange and water percolation to avoid black layer problems.

Due to space limitations, this article will not cover all the complexities of salt-affected turf management but will focus instead on our current understanding regarding black layer formation and management. The information presented is based on field observations, references cited at the end of the article, and conversations with university researchers.

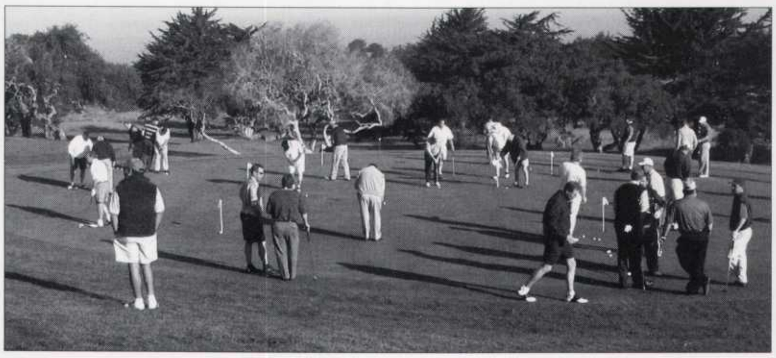
Black layer overview

Black layer symptoms result when rootzone soil conditions develop impeded percolation, waterlogged zones of poor drainage, and anaerobic conditions. Black layer symptoms can occur in as few as five to six days after these wet anaerobic conditions occur. Symptoms develop due to cyanobacteria (blue green algae) growth, which produces gel-like substances that coat soil particles and plug soil macropores thereby reducing oxygen levels and water drainage.

The microbial-induced biochemical reactions include conversion of soluble sulfur (i.e. sulfate ion, $SO4^{2}$) to elemental sulfur (S^{2}) followed by hydrogen sulfide (H2S), iron sulfide (FeS), and manganese sulfide (MnS) production. The rotten egg smell comes from the H2S and the black layers seen are due to the microbial produced biofilms of FeS and MnS. As is evident from these chemical reactions, sulfur is important as a secondary factor contributing to black layer formation.

Factors contributing to waterlogged and anaerobic soil development include:

- **Clay or organic matter colloid migration**
- **Salt deposition layering** (NaCl, CaSO4, Na, $HCO3^{2}$)
- **Natural layer development** (e.g. thatch)
- **Irrigation induced layering** (e.g. frequent light irrigation)
- **Cultivation pan** (e.g. repeated core aeration at the same depth)



Black layer management practices

Since wet anaerobic conditions are essential to black layer formation, cultural practices that alleviate these conditions are the critical first step in black layer management and prevention. Frequent core aeration especially at multiple coring depths in conjunction with sand topdressing is essential for maintaining rootzone oxygen levels and percolation.

A common problem also seen on putting greens is a zone of water, colloid, and/or salt accumulation usually found at a 3 to 4 inches depth caused by repeated light irrigation (i.e. daily). Cultivation, in conjunction with infrequent irrigation (i.e. 3 days per week supplemented by hand watering of hot spots), will reduce this problem significantly. Wetting agent application to improve infiltration and percolation is also recommended. In arid climates, leaching every three to four weeks during periods of active growth is another successful way to avoid water and salt-related (i.e. sulfate, sodium, salts, gypsum) layering. Other benefits seen from leaching include improved putting surface firmness and colloid movement below the rootzone. Improved rooting achieved by increased rootzone oxygen content also results in a healthier turf grass plant that has improved stress tolerance.

Sulfur management practices

Sulfur is an important secondary turf nutrient. Since sulfur is highly mobile in the soil by leaching it is surprising that sulfur deficiency symptoms are not commonly seen. This fact is apparently due to the turf being so efficient in sulfate uptake and because sulfur is routinely added. Examples of sulfur addition include grass clippings and water treatment such as acid injectors, sulfur burners, and as a component in many fertilizer applications.

If levels of sulfur are a concern when based on soil and water test results, excess sulfur can be easily removed by lime application. As an example, one pound of 100 score calcium carbonate (CaCO3) lime will react with and remove one pound of sulfate ion ($SO4^{2}$) by producing gypsum (CaSO4). PH concerns due to lime application is tempered by the fact that the buffering characteristics of this chemistry will maintain soil pH in the 7 or 8 range unless sodium levels are in the permeability hazard zone. The ideal way to apply this lime is lightly every four weeks to maintain active free calcium and reduce layering of the material.

Calcium sand reactivity

The potential for calcareous sand deterioration is currently being researched by Dr. Eric Miltner at Washington State University. While the potential for these reactions exist, it must be pointed out that in silica sand-based greens, the results of decreased percolation and porosity are typically seen two to three years following construction.

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Since porosity and percolation deterioration commonly occurs in silica-based sand greens, the concern about calcareous sand degradation may be less important than previously thought. Research has clearly shown the reduction in percolation and porosity over time in both silica and calcareous based greens is due to the layering described above and from a decrease in soil macropores due to organic colloid migration. The organic colloids are a natural by-product of turf grass growth. Maintaining root zone aeration and percolation with frequent cultivation is the key to maintaining adequate macropores for healthy greens regardless of sand type.

Additional considerations

If water and/or soil sulfur levels exceed turf needs, removing the excess sulfate is easily done by frequent cultivation in conjunction with lime application and leaching. (Soil and water testing can assess adequate or excess sulfur levels for turf needs.) Additional considerations for best management practices where putting green black layer concerns exist include the following:

- Reduce sulfur inputs by avoiding sulfur containing fertilizers until black layer symptoms disappear.
- Fertilize lightly and frequently (e.g. 0.1 – 0.25 lb N/1000 square feet/application).
- Use a comprehensive analysis of soil and water chemistry from a reliable laboratory. Salt-affected turf management in arid regions can be complex. To illustrate the complexity involved in salt-affected turf management the following is a partial list of factors for consideration in development of a comprehensive turf management plan: **a)** Analysis of total dissolved salts (TDS, ECw), **b)** sodium permeability hazard (Adjusted SAR, ESP, Na), **c)** pH (i.e. acidity and alkalinity measurement scale), **d)** cation exchange capacity (CEC), **e)** residual sodium carbonate (RSC), **f)** cation levels and relative cation proportion, **g)** micronutrient and metal levels.
- Following laboratory analysis of water chemistry and soil fertility a comprehensive management plan for turf fertility and salt management should be developed. If irrigation water acidification is required to manage excess bicarbonate and sodium, there is no reason to stop the treatment due to black layer concerns provided frequent cultivation is maintained for aeration, drainage, and removal of excess sulfate.
- Leaching in conjunction with acidifying fertilizer application (e.g. ammonium sulfate, ammonium nitrate) and deep tine core aeration is another management tool for removing lime, gypsum, or sodium layers found in the arid region root zones. In high calcium and high sulfate conditions, cultivation and leaching are key in successful management to maintain percolation and aeration.

Conclusion

A comprehensive management plan including cultivation, deep infrequent irrigation, and spoon-feeding fertility applications combined with best management practices for all salt related problems will produce consistent healthy putting greens. Balancing sulfur inputs with removal procedures and cultivation can easily resolve any black layer concerns. If irrigation water acidification is needed to manage sodium and /or bicarbonate problems, there is no reason to stop the practice due to black layer concerns since any percolation or aerification reduction is easily managed.