created by the responsible bacteria in turn results in the formation of iron and manganese suphides, the latter causing the black colour. Also associated with the reduction of sulphur compounds is the formation of hydrogen sulphide which gives rise to the "rotten egg" odour. Furthermore, hydrogen sulphide is a weak acid which can be very toxic and damaging to the turf root system

There are four prerequisites necessary for the formation of the black layer: 1) an anaerobic (oxygen deprived) atmosphere in the soil, 2) an organic material available for microbial decomposition, 3) a source of sulphur compounds, and 4) the occurrence of sulphur reducing bacteria. Without any one of these conditions the black layer will not form.

The first condition is satisfied any time you have a poorly drained or waterlogged condition. The waterlogged condition may result from a perched water table or a permanent water table caused by a number of factors. With regard to the second prerequisite decomposable organic material is always present in soils where the root system is in a continuing process of regeneration. Sulphur compounds occur in all soils and are constantly being added as a product of acid rain and in fertilizers. Sulphur reducing bacteria are found in all soils and can soon be spread by dust to pure sand root zones and rapidly proliferate when the conditions are right.

What are the cures?

It is obvious from the four prerequisite noted above that one, the occurrence of sulphur reducing bacteria, cannot be eliminated. Likewise the occurrence of decomposable organic material cannot be avoided. Steps, however, can be taken to reduce the impact of the other two.

The ultimate cure is in the beginning, during construction of the facility. At this stage the design and construction should be to insure adequate drainage to avoid potential anaerobic situations. Prudence requires that the final contouring be done on the subgrade, not the final surface. Thus the depth of the root zone will be uniform and the water content will remain constant across the field with no localized wet spots.

Table 1: The formation of black layer and turf quality resulting from the source of nitrogen used for turf production under poorly drained conditions.

Nitrogen Source	Black Layer Rating*	Turf Quality
	(ave. 25 labels)	(rating**)
Ammonium sulphate	3.36	1.96
Urea	3.08	3.44
Ammonium nitrate	0.76	0.68

*On a scale 0 -4, where 0 was no peg discoloration

** On a scale 0 -5, where 0 was no injury and 4 was death of the turf.

The ultimate cure is in the beginning, during construction of the facility.

As part of the system to remove excess water is the system used to provide water - the irrigation system. Excess irrigation through reliance on electronic gadgets and not through thoughtful use of weather data adds to the drainage problem.

At the construction stage uniform, offsite mixing of the sand, organic source and any soil materials is essential to avoid localized interruption in drainage flow. When a cross section of the root zone has the "marble cake" appearance one may be suspicious of poor mixing being the cause of the black layer. Some designers of fields will place 20 cm of pure sand below a final 10 cm of sand:soil:organic mix - "the two layer cake." Again a condition for a perched water table is created, which in combination with the other three prerequisite conditions may lead to black layer.

Since the black layer condition reflects a lack of oxygen in the root zone and as it occurs in the top 10 cm of the profile, deep coring, with hollow tines, and removal of the cores will give temporary relief. Observations by sports turf managers have found the black layer to disappear in the area of the core hole and in the core itself as it is exposed to the atmosphere.

Where topdressing is practiced it is imperative that the material used conforms as closely as possible to the existing material to avoid layering. Changing topdressing materials from year to year result in the "multi-layered cake."

The use of nitrate fertilizers can afford some relief. Work by Drew Smith at Saskatoon demonstrated that a nitrate source of nitrogen could alleviate the condition. The nitrate ion acts as a substitute for oxygen under the waterlogged conditions associated with the black layer. Using wooden plant labels which discoloured according to the degree of black layer formation, he assessed the effect of sources of nitrogen applied to turf growing in pots of course sand which were kept in an waterlogged condition for approximately six weeks (Table 1). The data clearly show nitrate forms of nitrogen were superior to urea and ammonium sulphate in deterring black layer formation.

When black layer is a problem avoiding sulphur containing fertilizers by substituting nitrate carriers for the nitrogen source will provide some degree of relief.

My thanks to Pam Charbonneau for her extensive file on the Black Layer.