



# BLACK LAYER IN TURFGRASS MANAGEMENT

 turfcoach



## EXECUTIVE SUMMARY

IN THIS WHITEPAPER, WE EXPLORE THE PHENOMENON OF BLACK LAYER IN TURFGRASS, AN OFTEN INVISIBLE BUT HIGHLY DAMAGING CONDITION CAUSED BY ANAEROBIC SOIL PROCESSES. COMMON ON HIGH-STRESS FOOTBALL PITCHES, BLACK LAYER RESULTS FROM COMPACTION, POOR DRAINAGE, AND EXCESSIVE IRRIGATION, LEADING TO DISRUPTED WATER FLOW, TOXIC GAS BUILDUP, AND ROOT DAMAGE. WE BREAK DOWN THE BIOLOGICAL AND CHEMICAL PROCESSES BEHIND ITS FORMATION AND EXPLAIN HOW TO ANTICIPATE ITS DEVELOPMENT THROUGH KEY INDICATORS SUCH AS LOW OXYGEN LEVELS, HIGH SULFATE CONTENT, REDOX POTENTIAL, AND SOIL COMPACTION. ULTIMATELY, THE PAPER UNDERSCORES A SIMPLE TRUTH: EARLY DETECTION THROUGH DATA-DRIVEN MONITORING IS CRITICAL TO PREVENTING LONG-TERM TURF DEGRADATION. WITH SYSTEMS LIKE TURFCOACH, GROUNDSKEEPERS CAN SPOT EARLY WARNING SIGNS AND TAKE ACTION BEFORE THE PROBLEM SURFACES.



## **UNDERSTANDING BLACK LAYER AND ITS IMPLICATIONS:**

**EVERY TURF EXPERT KNOWS: A HEALTHY SPORTS TURF IS THE RESULT OF INTENSIVE CARE AND OPTIMALLY COORDINATED USE. BUT ESPECIALLY ON HIGHLY STRESSED FOOTBALL PITCHES, AN UNEXPECTED PROBLEM ALWAYS SHOWS UP – BLACK LAYER. THE COMBINATION OF FREQUENT GAMES, MECHANICAL STRESS DUE TO MAINTENANCE MEASURES AND INTENSIVE IRRIGATION CAN CHANGE THE SOIL STRUCTURE IN SUCH A WAY THAT AN ANAEROBIC, BLACK LAYER GRADUALLY FORMS. THIS NOT ONLY IMPAIRS THE WATER FLOW AND GAS EXCHANGE IN THE SOIL, BUT ALSO ENDANGERS THE VITALITY OF THE SWARD IN THE LONG TERM.**

**ALTHOUGH BLACK LAYER OFTEN ONLY BECOMES VISIBLE WHEN THE DAMAGE IS ALREADY NOTICEABLE, THERE ARE WAYS TO TAKE COUNTERMEASURES AT AN EARLY STAGE. BUT BEFORE THAT, IT SHOULD BE CLARIFIED HOW EXACTLY THIS LAYER IS FORMED. WHICH BIOLOGICAL AND CHEMICAL PROCESSES PLAY A ROLE – AND ABOVE ALL: WHAT PREVENTIVE MEASURES CAN GREENKEEPERS TAKE TO PREVENT THE PROBLEM FROM ARISING IN THE FIRST PLACE? A SCIENTIFICALLY SOUND ANALYSIS PROVIDES ANSWERS TO THESE CRUCIAL QUESTIONS**



# CHEMICAL PERSPECTIVE AND PROCESSES

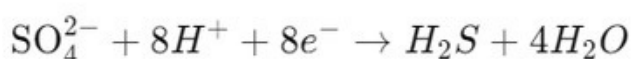


FROM A CHEMICAL POINT OF VIEW, BLACK LAYER IS ESSENTIALLY THE RESULT OF REDOX REACTIONS UNDER THE ABSENCE OF OXYGEN (ANAEROBIOSIS). THE MOST IMPORTANT CHEMICAL PROCESSES THAT PLAY A ROLE IN THIS ARE:

## REDUCTION OF SULFATES TO HYDROGEN SULFIDE (H<sub>2</sub>S)

A HEALTHY SOIL CONTAINS SULFATES (SO<sub>4</sub><sup>2-</sup>) AS NATURALLY OCCURRING COMPONENTS. UNDER NORMAL CONDITIONS, SULPHATES ARE NOT REDUCED BECAUSE SUFFICIENT OXYGEN (O<sub>2</sub>) IS AVAILABLE FOR THE AEROBIC METABOLISM OF SOIL BACTERIA. HOWEVER, WHEN THERE IS A LACK OF OXYGEN, ANAEROBIC BACTERIA, ESPECIALLY SULFATE-REDUCING BACTERIA (E.G. DESULFOVIBRIO SPP.), SULFATES AS ELECTRON ACCEPTORS TO GENERATE ENERGY. (SEE BERNDT, N.D.)

THE REACTION PROCEEDS ACCORDING TO THE FOLLOWING EQUATION:



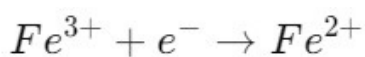
THE RESULTING HYDROGEN SULFIDE GAS (H<sub>2</sub>S) IS HIGHLY TOXIC TO PLANT ROOTS AND SOIL MICROORGANISMS. IT ALSO REACTS WITH METALS SUCH AS IRON (FE), FORMING BLACK IRON(II) SULFIDE DEPOSITS (FES) – THE CHARACTERISTIC FEATURE OF THE BLACK LAYER (SEE BERNDT, N.D.)

FORMATION OF IRON(II) SULFIDE (FES) AND IRON SULPHIDES (FES<sub>2</sub>) (SEE BERNDT, N.D.) IRON (FE) IS PRESENT IN SOILS IN TWO MAIN FORMS: AS TRIVALENT IRON (FE<sup>3+</sup>) UNDER OXIDATIVE CONDITIONS AND AS DIVALENT IRON (FE<sup>2+</sup>) UNDER REDUCING CONDITIONS.

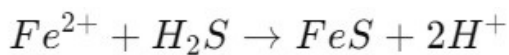
# CHEMICAL PERSPECTIVE AND PROCESSES



**IN THE ABSENCE OF OXYGEN, FE<sup>3+</sup> IS REDUCED TO FE<sup>2+</sup>:**



**THE RESULTING FE<sup>2+</sup> THEN REACTS WITH THE TOXIC HYDROGEN SULFIDE (H<sub>2</sub>S) TO FORM BLACK IRON(II) SULFIDE (FeS): (SEE BERNDT, N.D.)**



**IN EVEN MORE REDUCED CONDITIONS, FeS CAN BE FURTHER CONVERTED TO PYRITE (FeS<sub>2</sub>), FURTHER ENHANCING THE BLACK COLOR AND DENSE STRUCTURE OF THE BLACK LAYERS.**

## **REDUCTION OF NITRATE AND ACCUMULATION OF ORGANIC MATTER:**

**IN ADDITION TO SULFATES, NITRATES (NO<sub>3</sub><sup>-</sup>) ARE ALSO REDUCED IN THE ABSENCE OF OXYGEN, RELEASING GASEOUS NITROGEN (N<sub>2</sub>). AS A RESULT, AN IMPORTANT SOURCE OF NITROGEN FOR PLANT GROWTH IS LOST. AT THE SAME TIME, THE DEGRADATION OF ORGANIC MATERIAL SLOWS DOWN BECAUSE AEROBIC MICROORGANISMS ARE NO LONGER ACTIVE. THIS LEADS TO AN ACCUMULATION OF DEAD PLANT MATERIAL, WHICH FURTHER INTENSIFIES THE LACK OF OXYGEN AND MAKES THE BLACK LAYER LAYER EVEN DENSER. (SEE USGA, 2022)**

# FACTORS THAT LEAD TO BLACK LAYER

THESE REACTIONS ARE FAVORED OR TRIGGERED BY THE FOLLOWING FACTORS:

## SOIL COMPACTION:

DUE TO FREQUENT EXPOSURE AND THE USE OF HEAVY MACHINERY, THE SOIL STRUCTURE CAN CHANGE IN SUCH A WAY THAT PORE SPACES ARE CLOSED AND GAS EXCHANGE IS HINDERED.

## POOR DRAINAGE:

WATER RETENTION DRASTICALLY REDUCES OXYGEN LEVELS IN THE SOIL AND PROMOTES ANAEROBIC CONDITIONS.

## HIGH SULPHUR CONTENT IN WATER OR FERTILISER:

EXCESSIVE SULPHUR APPLICATIONS IN THE FORM OF SULPHATES (E.G. BY AMMONIUM SULPHATE) PROVIDE SUBSTRATE FOR THE SULPHATE-REDUCING BACTERIA. (SEE GOLFMAN & GREENKEEPER, N.D.)

## EXCESSIVE WATERING:

A PERMANENTLY SATURATED SOIL MEANS THAT OXYGEN CANNOT FLOW IN.

## HIGH ORGANIC LOAD:

TURF CLIPPINGS AND INSUFFICIENTLY DEGRADED ORGANIC MATTER CONSUME OXYGEN DURING MICROBIAL DEGRADATION AND AMPLIFY ANAEROBIC CONDITIONS.

## INSUFFICIENT VENTILATION:

A LACK OF AERATING MEASURES, SUCH AS HOLLOW SPOONS OR SLOT DRAINS, EXACERBATE THE PROBLEM. (SEE GOLF CLUB HUBBELRATH, 2020)

# RESEARCH REVIEW

## EFFECTS OF BLACK LAYER ON THE SOIL



**THE FOLLOWING CHEMICAL PROCESSES THAT LEAD TO THE FORMATION OF BLACK LAYER ARE SIGNIFICANT:**

### **RESTRICTED WATER DRAINAGE:**

**THE DENSE BLACK LAYER PREVENTS WATER FROM SEEPING INTO DEEPER SOIL LAYERS, LEADING TO WATERLOGGING AND INCREASED DISEASE PRESSURE.**

### **LACK OF OXYGEN FOR ROOTS:**

**PLANT ROOTS CANNOT ABSORB  $O_2$ , WHICH SEVERELY INHIBITS THEIR GROWTH. ROOT DAMAGE CAUSED BY TOXIC  $H_2S$  — HYDROGEN SULFIDE INHIBITS THEIR FUNCTION.**

### **NUTRIENT IMBALANCES:**

**DUE TO THE REDUCTION OF NITRATE AND THE BINDING OF IRON, IMPORTANT NUTRIENTS ARE NO LONGER AVAILABLE IN SUFFICIENT QUANTITIES.**

### **GENERAL WEAKENING OF THE TURF:**

**THE TURF LOSES ITS RESISTANCE TO DISEASES AND MECHANICAL STRESSES.**

# RETAILRICZHA TRIEON EAWS A MEASURE TO BLACK LAYER

TARGETED FERTILISER MANAGEMENT CAN MAKE A DECISIVE CONTRIBUTION TO AVOIDING BLACK LAYERS. BERNDT AND VARGAS (1996) SHOWED THAT THE USE OF NITRATE-BASED NITROGEN FERTILIZERS CAN EFFECTIVELY SUPPRESS THE FORMATION OF BLACK LAYERS. CONTRAST TO AMMONIUM NITROGEN, WHICH PROMOTES REDUCING SOIL CONDITIONS UNDER ANAEROBIC CONDITIONS, NITRATE ACTS AS AN OXIDIZING AGENT AND THUS SUPPORTS AEROBIC SOIL CONDITIONS. REGULAR APPLICATION OF NITRATE IMPROVES OXYGEN AVAILABILITY IN THE ROOT AREA AND INHIBITS THE ACTIVITY OF ANAEROBIC MICROORGANISMS THAT LEAD TO SULFIDE FORMATION. A BALANCED FERTILISATION STRATEGY SHOULD THEREFORE NOT ONLY TAKE INTO ACCOUNT THE NUTRIENT REQUIREMENTS OF THE GRASSES, SONDER AUCH DIE REDOXBEDINGUNGEN IM BODEN AKTIV STEUERN, UM DIE BILDUNG DER CHARAKTERISTISCHEN SCHWARZEN SCHICHT FRÜHZEITIG ZU VERHINDERN. (SEE BERNDT AND VARGAS, 1996)

## COMBATING BLACK LAYER

SO BLACK LAYER IS A SERIOUS PROBLEM FOR THE HEALTH OF FOOTBALL TURF THAT SHOULD SPECIFICALLY COMBATED AND, ABOVE ALL, PREVENTED. THE RIGHT STRATEGY INCLUDES MECHANICAL MEASURES, CHEMICAL ADJUSTMENTS, REGULAR MEASUREMENTS AND MODERN DIGITAL MANAGEMENT TO DETECT AND CONTROL NOT ONLY BLACK LAYERS BUT ALSO OTHER TURF PROBLEMS AT AN EARLY STAGE. (SEE USGA, 2022; GOLF CLUB HUBBELRATH, 2020)

PREVENTION IS KEY TO AVOIDING BLACK LAYER. THROUGH REGULAR MONITORING AND DIGITAL TURF MANAGEMENT, NOT ONLY BLACK LAYER, BUT ALSO A VARIETY OF OTHER TURF PROBLEMS CAN BE DETECTED AND PREVENTED AT AN EARLY STAGE.

## MEASUREMENTS FOR EARLY DETECTION



REGULAR MEASUREMENTS ARE REQUIRED TO DETECT CHANGES IN THE SOIL AT AN EARLY STAGE.

### MEASURE OXYGEN CONTENT IN THE SOIL:

LOW OXYGEN LEVELS ( $< 10\%$ ) INDICATE THAT ANAEROBIC CONDITIONS ARE DEVELOPING. MEASUREMENTS CAN BE CARRIED OUT WITH SOIL OXYGEN SENSORS OR MEASURING LANCES.

### REDOX POTENTIAL ANALYSIS: (SEE BERNDT, N.D.)

A STRONGLY NEGATIVE REDOX POTENTIAL ( $< -100$  mV) INDICATES ANAEROBIC CONDITIONS. MEASURING DEVICES WITH PLATINUM ELECTRODES CAN HELP IDENTIFY PROBLEMATIC AREAS.

### PH VALUE CONTROL:

A SHARP DROP IN PH CAN BE AN INDICATOR OF PROBLEMATIC MICROBIAL ACTIVITY. REGULAR SOIL SAMPLES HELP TO DETECT DEVIATIONS AT AN EARLY STAGE.

### MEASURE SULPHATE CONTENT AND HYDROGEN SULFIDE:

HIGH SULPHATE LEVELS ( $> 500$  mg/kg) IN THE SOIL MAY INDICATE AN INCREASED RISK OF GROUNDWATER CONTAMINATION.

LABORATORY TESTS FOR  $H_2S$  CAN BE PERFORMED IN SUSPICIOUS SOIL SAMPLES.

### MEASURING SOIL COMPACTION:

PENETROMETER MEASUREMENTS SHOW WHETHER THE SOIL IS COMPACTED BY MECHANICAL STRESS. (SEE GOLFMANAGER & GREENKEEPER, N.D.)

A HIGH PENETRATION RESISTANCE FORCE ( $> 2$  MPa) INDICATES A NEED FOR SOIL LOOSENING.

## **DIGITAL MONITORING AND MANAGEMENT – TURFCOACH AS A SOLUTION**

**A DIGITAL TURF MANAGEMENT SYSTEM SUCH AS TURFCOACH CAN HELP TO EVALUATE THE COLLECTED DATA AND CONTINUOUSLY MONITOR THE CONDITION OF THE PITCH. BY DOCUMENTING ALL MAINTENANCE MEASURES FOR A LONG-TERM ANALYSIS AS WELL AS VISUALIZING SOIL CHANGES OVER TIME, THE FORMATION OF UNPLEASANT CHANGES IN THE SOIL SUCH AS BLACK LAYERS CAN BE PREVENTED.**



## REFERENCES:

- **BERNDT, W. L. (N.D.). BLACK LAYER IN TURF: ITS DEVELOPMENT, DETECTION AND ALLEVIATION. GCMONLINE – GOLF COURSE MANAGEMENT**
- **UNITED STATES GOLF ASSOCIATION (USGA). (2022). WHAT TO DO FOR THE BLACK LAYER BLUES. USGA GREEN SECTION RECORD.**
- **GOLF CLUB HUBBELRATH. (2020). BLACK LAYER IN THE ROOT ZONE MIX OF OUR GREENS.**
- **GOLFMANAGER & GREENKEEPER. (N.D.). CAUSES OF TURFGRASS DAMAGE AND THE IMPORTANCE OF ABIOTIC FACTORS**
- **GOLFMANAGER & GREENKEEPER. (N.D.). REDUCING THE EFFECTS OF PORE STRUCTURE FAILURE IN THE CONSTRUCTION OF GOLF GREENS [SCIENTIFIC THESIS]**





# BLACK LAYER IN TURFGRASS MANAGEMENT

 turfcoach

