The Effects of Diffusing Ozone, Oxygen & Carbon Dioxide Into Golf Course Irrigation Water

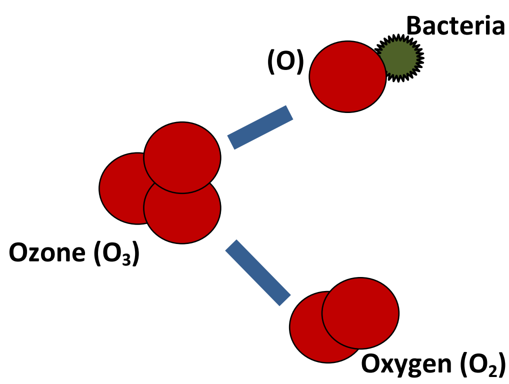
Introduction

Golf courses are increasingly required to use poor quality water for irrigation. Whether using effluent, well, brackish, or city water, diffusing such gases as ozone (O_3), oxygen (O_2), and carbon dioxide (CO_2) will improve the quality of lakes and ponds, irrigation water, and soil. Common golf course irrigation water issues such as high bacteria counts, high bicarbonates, lack of dissolved oxygen, and high pH levels can be eliminated with ozone, oxygen, and carbon dioxide diffusion. Ozone removes harmful contaminants and bacteria, and creates an aerobic environment that facilitates the decomposition of unwanted organic materials. Oxygen creates an aerobic environment in the soil, which, among other things, will increase percolation and root growth. Carbon Dioxide controls pH levels. With the proper gas diffusion system, golf courses can substantially reduce the use of chemicals. This paper provides the science behind ozone, oxygen, and carbon dioxide as they relate to the effects on golf course irrigation water and soil.

Ozone

Ozone is the tri-atomic form of oxygen. Due to its structure, it is highly unstable, and thus is inclined toward returning to the stable molecule O_2. The extra oxygen molecule then quickly binds with other components in order to stabilize, as illustrated below. This property of ozone makes it a very powerful oxidant, with an oxidation potential of 2.07V, making it ideal for sterilization, enhancing fertilization, and removing odors.

Golf course irrigation water frequently requires sterilization. Often remaining in holding ponds for days before it is used on the course, it breeds bacteria, viruses, cysts, and fungi. When this poor quality water is applied to turf it affects the health of the grass by importing unwanted algae and bacteria. Typically, irrigation water would be sterilized with chemicals, and persistent algal or fungal growths on turf grass would be managed with the addition of algaecides or fungicides. These solutions are not very environmentally friendly, can be harmful to the golfers, and require expensive and hazardous transport and storage.



Ozone Molecule Action

According to the Environmental Protection Agency, ozone is more effective than chlorine in destroying viruses and bacteria. When ozone is mass transferred into water with an inline diffusion system, removes pathogens and unwanted organic matter, killing algae, spores, and fungus by eliminating their food source, bacteria. As ozone is generated onsite, the need for transport and storage is eliminated. Additionally, no harmful residuals remain after ozonation, because ozone decomposes so rapidly.
Chemical fertilizers added to golf courses are a considerable expense, and might not even be effective because in some areas the soil lacks metals or the soil conditions do not allow for easy metal uptake. Ozone makes fertilizer more efficient. For metals present in the irrigation water, such as iron,

manganese, and calcium, ozone will also chelate the metals, making them more biologically available. Hence, you can apply less iron, calcium, and manganese but see better results due to the use of ozone injection. In addition, ozone causes heavy metals such as mercury or arsenic, which are undesirable in the turf, to react to their irreversible hydroxide forms, making them not biologically available.

Ozone removes odors by oxidizing volatile organics and removing H_2S, without leaving behind a residual odor like chlorine.

In addition to its highly reactive properties being ideal for sterilization, fertilization and odor removal, ozonation also elevates the dissolved oxygen (DO) concentration of the effluent. The increase in DO can eliminate the need for re-aeration.

Oxygen

When ozone is added to any system, it is only incorporated by a few percent by gas volume. Thus, the remaining oxygen is added as O_2. Furthermore, in some ozone reaction mechanisms, oxygen is reformed after it has reacted with organic molecules in solution. Oxygen benefits the turf by aerating the soil and increasing dissolved oxygen levels, producing numerous benefits.

Golf course aeration has undergone many changes over the past 100 years as superintendents strive to relieve compaction and provide their turf with oxygen, the most crucial element for turf survival. Oxygen has two means of introduction into the soil: atmospheric introduction through mechanical aerafication, and dissolved oxygen in irrigation water. Mechanical means of introducing oxygen have become quite advanced, but the next generation of aeration technology will focus on water quality and how it affects soil oxygen levels.

When mechanical aeration takes place, only 10% of the soil surface is exposed to oxygen. When oxygen is diffused into irrigation water, 100% of the soil surface being irrigated is exposed to oxygen.

The ability to dissolve oxygen into water to create a stable oxygenated state which can be used for golf course irrigation systems is very beneficial. This is accomplished by the use of an oxygen generator that conveniently concentrates oxygen on site. In doing so, the system ensures that oxygen is readily available in the soil/turf profile and prevents soil oxygen levels from becoming depleted by actively growing turf roots or soil microbes. The resulting elevated DO levels in irrigation water lead to higher DO levels within the soil pore water. This additional oxygen in the root-zone environment is then available for use by turfgrass roots and soil microorganisms.

Soil microorganisms are an essential part of the soil system since they are the main force driving nutrient movement in soils. Providing an aerobic environment for soil microbes to flourish is essential in any turf management system. Oxygen diffusion systems can accomplish this by increasing irrigation water DO levels to well above the approximately 5mg/L needed in order to maintain an aerobic environment.

By increasing the amount of oxygen available in soil pore space, oxygen diffusion supports critical soil microbial activity. Elevated oxygen levels within the soil pore space aid microbes in the mineralization of organic matter to useful forms of nutrients required for plant growth. Maintaining an aerobic environment not only helps break down organic matter, but also reduces the potential for formation of H_2S and CH_4 that prevail in anaerobic conditions.

Soil microbes also aid in the aggregation of root-adhering soil at the soil-root interface. This is the physical environment where roots take up O_2, water, and nutrients. Since soil productivity is dependent on aggregate formation, soil microbes have a direct influence on both soil fertility and productivity. By facilitating root growth and aerobic microbial activity, oxygen diffusion helps maintain a balanced turf/soil system and has the potential to reduce fertilizer requirements in the long run.

Partially decomposed organic matter or thatch is a major problem on turf, especially greens. This organic matter competes with the turf for oxygen at the soil surface. On many greens, the stress is so great that the turf can't survive. Oxygen will break down the organic/thatch layer. Two results follow this breakdown of the organic layer. First, the turf and soil will receive large amounts of oxygen producing the results mentioned in the preceding paragraphs, then this effect also allows nitrogen in the thatch layer to be released into the soil and the turf is able to use it.

Contrarily, if oxygen is not used, nitrogen applied to the soil in fertilizer will be wasted. Plant roots need oxygen as the terminal electron acceptor of the respiratory chain to gain energy for adenosine triphosphate synthesis. If oxygen deficiency exists, a biologically mediated process called denitrification will use nitrate or other oxidized forms of nitrogen as the terminal electron acceptors for respiration instead of oxygen. In fact, when turf is watered through irrigation or from rainfall, small sites within the soil profile can become oxygen limiting. As soil temperatures rise, nitrogen losses will increase as the turf's elevated respiration triggers more denitrification and a decreased efficiency in fertilizer use. Horgan's study proved that fertilizer losses can be significant even after light irrigation because not enough oxygen is available.

Carbon Dioxide

Along with oxygen and nutrients, pH plays a significant role in turf health. High pH soils promote unfavorable bacterial growth, whereas excessively low pH promotes fungal growth. Ideal turf pH should remain within 6.5-7.5 range (depending on the golf course). For turf to fend off disease and promote healthy growth, and to maintain a proper soil structure, a constant pH, suited to the region, should be employed. Upsets in the pH adversely affect all organisms, including grass. For most golf courses, water is one of the largest contributing factors for pH. For some courses, chemicals, either an acid or a base depending on the required adjustment, are used to control pH. Alternatively, if CO_2 gas is dissolved in to the irrigation water, pH control can be achieved.

For a number of years, sulfuric acid was used in water treatment facilities to control alkalinity. It’s a product that works, but it also has many potential problems. Sulfuric acid can be difficult to apply and control. It is potentially dangerous to store and handle. Safety showers must be installed and readily available to operating personnel who must wear special clothing for their protection. Additionally, the extremely corrosive acid requires special material for equipment and piping. Maintenance of the system demands frequent component repairs and replacement. Other acids that are used to decrease pH of golf course water, such as HCl, H_2SO_4, and CH_3COOH are also hazardous to handle due to their corrosive nature.

Carbon dioxide, alternatively, is safe to handle, easy to apply, efficient, and ecologically safe. Controlling pH is critical to a golf course’s process and effluent quality, and CO_2 is the cheapest, cleanest, and easiest alternative to chemical methods. The cost of carbon dioxide is very inexpensive, particularly when applied with efficient systems.

Carbon dioxide is safe to use because, in the absence of water, it is inert and non-corrosive. It does not require mechanical transfer or handling equipment. It becomes active only when dissolved in water. CO_2 leaks dissipate safely into the atmosphere, leaving no residue to be neutralized, and having no hazardous effects. Furthermore, carbon dioxide does not corrode metal equipment. No special alloy or plastic distribution piping is required for the CO_2 system.

Application and maintenance of carbon dioxide is easy; it is done using compressed gas cylinders. For most requirements, carbon dioxide is supplied with a 265 liter dewar, delivered by truck and stored on-site. The CO_2 storage tank is supplied, installed, and maintained by the supplier of the gas. Typically CO_2 is stored in pressurized vessels up to 300 psi which do not require feed or transfer pumps to supply the process. Systems are generally engineered to be pressure driven. With a minimum number of moving parts, this system offers continuous trouble free operation. Moreover, trained technicians can be rapidly dispatched to service the bulk CO_2 tank in the unlikely event of a problem. The systems also offer flexibility, with a turndown ratio in control of the CO_2 injection rate exceeding 10:1, the pH control system will efficiently and rapidly respond to any fluctuation of flow rate or incoming pH. Depending on the use at a given facility, a 265 liter dewar will last the course anywhere from one week to an entire month.

Using carbon dioxide is beneficial to the environment as well because there is no secondary pollution introduced into the treated water by salts such as chlorides (from HCl) or sulfates (from H_2SO_4). The introduction of CO_2 will contribute to the chemical equilibrium of water by forming neutral carbonates and bicarbonates.

Here is the chemistry behind CO_2; how and why it works. Carbon dioxide is a gas which produces carbonic acid, a weak acid, when dissolved in water. Carbonic acid is a mild acid present in water as ions H+ and HCO_3, which are highly reactive.

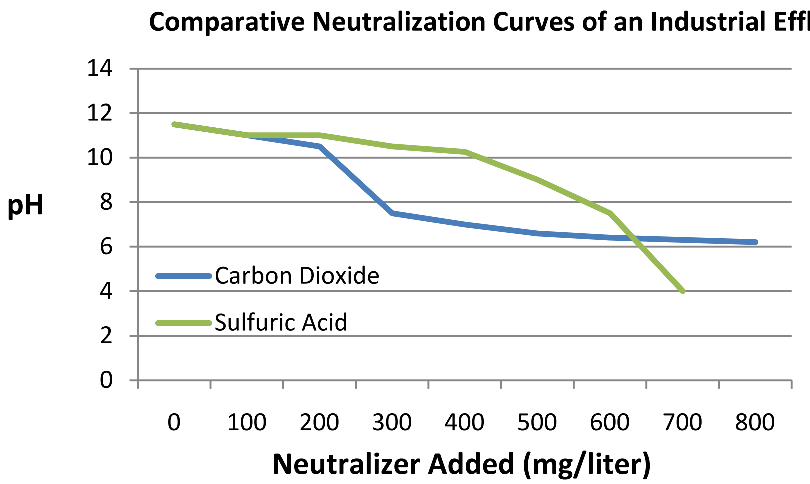
$$\mathbf{CO_2 + H_2O \rightarrow H_2CO_3}$$

The ions react immediately with alkalis such as caustic soda, sodium carbonate and dissolved lime, turning them into neutral carbonates and bicarbonate salts.

$$\mathbf{H_2CO_3 + 2NaOH \rightarrow Na_2CO_3 + 2H_2O}$$

$$\mathbf{H_2CO_3 + Na_2CO_3 \rightarrow 2NaHCO_3}$$

CO_2 is better than strong acids for controlling pH because it forms a mild but highly reactive acid which minimizes risks of overt acidification and rapidly responds to any variations of the incoming pH or water flow rate. Over or under treatment with mineral acids will often result in a pH which rapidly deviates from the compliance range.



The graph at left compares carbon dioxide and sulfuric acid as pH neutralizers. Note how, while the sulfuric acid curve dives sharply into a dangerously low pH range, the carbon dioxide curve levels out at a pH between 6.2 and 7.2, the ideal level for turf growth.

Conclusion

The benefits that a golf course can see after diffusing ozone, oxygen, and carbon dioxide into its irrigation water are staggering. Diffused ozone removes all algae in lakes and sprinkler heads, reduces bicarbonate levels to under 50 ppm, replaces algaecide and sulfur burning, and increases the effectiveness of fertilizer. Oxygen diffusion increases percolation, root growth, and dissolved oxygen levels. Effectively diffusing oxygen into irrigation water will provide over 500% more oxygen in the soil than aeration by mechanical means. Carbon dioxide diffusion will control pH levels. Though CO_2 will drastically increase bicarbonates in the water, ozone will counterbalance this effect, thus, in a golf course irrigation application it is recommended to use ozone injection in conjunction with CO_2. Calcium and acid injection can be replaced by diffusing CO_2, oxygen, and ozone at the same time. Now that the technology to economically and efficiently diffuse these gases into irrigation water is available, golf courses can stop using chemicals, improve their turf, and save thousands of dollars a year.

References

1. Pillar, Dean. Soil. Physical Properties Monitoring Oxygen for Success. Green Master, August 2006.
2. Papli, Gail et al. Biological Approaches to Sustainable Soil systems. Taylor & Francis Group, LLC, 2006.
3. Skorulski, Jim. Pond aeration, USGA Green Section Record, Vol 38, Number 1, Jan/Feb 2000. Turf Line News June/July 2000
4. Papli, Gail et al. Biological Approaches to Sustainable Soil systems. Taylor & Francis Group, LLC, 2006.
5. Beltran, Fernando J. Ozone Reaction Kinetics for water and Wastewater Systems. CRC Press LLC, 2004.
6. Spellman, Frank R. Choosing Disinfection Alternatives for Water/Wastewater Treatment. CRC Press LLC, 1999.
7. Zumdahl, M. Zumdahl Chemistry, Hughton Mifflin, 2000.
8. Seair Diffusion Systems Inc, www.seair.ca , January 2008
9. Sachs, Paul C, et al. Ecological Golf Course Management. Wiley, 2002.
10. Archambeau, Greg Dissolved Oxygen My Impact Turf Respiration, TurfGrass Trends 2003.
11. Roberts, Eliot C. PhD. Soil / Air / Water Plant Relationships, Landscape & Irrigation, 1990.
12. Smart, Bud. PhD. Maintain the Best Irrigation Water Quality on the Golf Course. USGA Green Section Record, 1999.
13. *Asti, Advanced Sensor Technologies, www.astisensor.com, 2007*
14. Simojoki, Asko. Oxygen Supply to Plant Roots in Cultivated Mineral Soils. Department of Applied Chemistry and Microbiology, University of Helsinki. 2001.
15. Horgan, Brian. Denitrification Impedes Fertilizer Effectiveness. Turfgrass Trends, 2003.