Ozone, Oxygen Transfer into Water

What method works best and why?

By Jeff Roseman

Researching and developing water treatment products and components reveal a lot of information and observations. A recent study on the efficacy of porous PTFE tubing for the transfer of gases, such as ozone or oxygen, into water proved some very interesting theories and revealed some additional data. One test done on lake water (*Water Quality Products*, December 2004)[1] proved very beneficial in reducing bacteria. The comparison of ozone transfer against several sizes air stones and a venturi in this test was also very interesting. Dissolved ozone and dissolved oxygen measurements were made and compared. Physical and chemical characteristics of ozone, oxygen and water, plus Henry's Law played a role in the theory of the project and outcome. Each of the different modes of transfer also portrayed some interesting findings and gave insights to possible applications. Each method has its own limitations, and understanding these limitations and characteristics helps the system designer overcome issues in design that will prevent failure, provide manufacturers with sound water treatment components, and provide consumers with reliable products.

pTheories

The first theory was to try and determine a length of tubing as compared to different sizes air stones. The second theory was to try and measure ozone and oxygen increases in the water when using the PTFE tubing or an air stone. The third theory was to compare these results with a venturi to show any significant increase in ozone and oxygen when using a pressurized method. By understanding Henry's Law, these ideas showed us several, very easy to understand design parameters. This information will be very useful in designing systems that will be practical, economical and successful in achieving desired results.

Henry's Law

Henry's Law is a chemistry law that states that the weight of a gas dissolved (at a given temperature) in a liquid is proportional to the pressure of the gas above the liquid. The partial pressure controls the number of gas molecule collisions with the surface of the solution. If the partial pressure is doubled the number of collisions with the surface will double, thus causing more gas to dissolve into the liquid. By understanding this model, one can understand the fact that an atmospheric tank can have higher levels of dissolved oxygen at sea level, than a tank operated in the mountains at thousands of feet above sea level. This also explains why water boils at a lower temperature at higher elevations. Temperature also plays a role in the formula for Henry's Law, which is named after the English chemist William Henry. The most common formula is $p = kC$, where p is the partial pressure of the solute of the gas above the liquid, C is the concentration of the gas in mol/L, and k is Henry's Law constant which has the units L*atm/mol.

It can also be understood that ozone or oxygen injected under pressure by a venturi can increase significantly depending on the pressure and the vessel the ozone or oxygen is injected. Therefore, it stands to reason that either one of these gases would have higher concentrations in a pressurized vessel, as compared to bubbling them into an atmospheric tank and that once they are released back into an atmospheric environment they will dissipate back to normal levels.

Another note to keep in mind is that this law also states that the amount of the gas dissolved is dependent upon how the gas reacts with the solvent. If the solvent is water and there are contaminants, such as iron, manganese, COD (chemical oxygen demand) or BOD (biological oxygen demand) there will be a reaction with the contaminants. Ozone and oxygen will oxidize these contaminants, thus reducing the amount of measurable gas being dissolved.

Tests

We tested three sizes of air stones (Figure 1) and compared them with lengths of Porous PTFE tubing (Figure 2) to determine if there were any advantages of using the tubing or the stones, plus we tried to determine a sizing correlation between the two methods of gas transfer. The water temperature was fairly constant and varied only a few degrees from test to test with that temperature being on average at 60° F (15.5° C). Ozone and oxygen dissipate faster in warmer water.

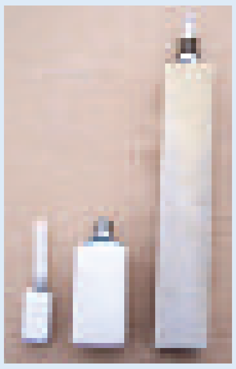

FIGURE 1: Air Stones

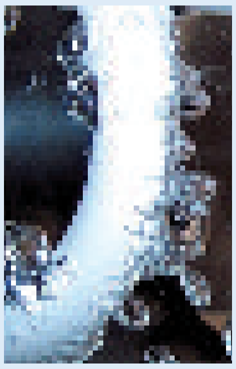

FIGURE 2: PTFE Tubing

Oxygen and ozone dissolve in water as the bubble rises through the water. The longer the rise time, whether that comes from deeper depths of water or baffles to slow down the reaction, the more transfer can be expected. This test used an 8.3 ft. (2.5 meters) tall tank and the tests were somewhat compromised since the best scenario would be a water column or depth of at least 6 meters or 20 ft. However, the tests did prove ozone and oxygen transfer, but they were not the optimum that could have been expected. The size of the bubble also plays a role and the best diffuser would be 2 to 3 mm radii. These types of contactors have proven levels of performance and efficiencies of at least 90%. The air stones had a larger radii bubble than the PTFE tubing. They were difficult to measure, but a good estimation would be a 3 to 4 mm bubble for the stones and 1 to 2 mm for the tubing. This estimation would be observed from the dispersal point of the medium used.

Ozone and oxygen levels were measured at an average of .05 ppm and 9.5 ppm respectively. Neither the stone nor tubing method showed any better results. They both worked very well in transferring the gas into the water. An ORP monitor was also used and the average mV reading was 299 mV for both methods and the different sizes.

Two types of ozone generators were used. A UV system was used and a Corona discharge unit was used. Ratings on the output were unable to be measured as percentage of ozone by weight. Both were fed ambient air with an air pump. The manufacturer's rating for the Corona system was specified at .7g/hr with ambient air or 1.5g/hr with a feed gas of 5 SCFH from an oxygen concentrator. The UV system was estimated at 50 mg/hr per bulb and had a four-bulb system, but the ozone levels vary greatly with the UV system, because of physical and design characteristics of ozone produced with UV. (Ozone - A Reference Manual, Water Quality Association)[2].

FIGURE 3: Venturi

The ozone was injected using a venturi (Figure 3) in the last test to compare the differences of bubbling and pressure injection. The pump pressure was only 20 psi, but did a good job of drawing the ozone into the water. We used the natural head pressure of the 8.3-ft. tank and dispersed the ozone to the bottom of the tank and it was able to rise back to the top under atmospheric pressure. The average reading from the Corona Discharge generator was .49 ppm of dissolved ozone and the UV system only produced on average .1 ppm. The ORP levels were higher, than the bubbling method, at 630 mV with the CD system and 480 mV with the UV system. A hand-held ORP meter also revealed some comparative levels. Dissolved oxygen levels were also increased and the average recording was at 13.2 ppm.

The pH of the water was 7.2, and an iron filter removed the iron and manganese from the water. The TDS of the water was 485 ppm. The removal of the iron and manganese helped reduce the reaction of the ozone and oxygen with the water to obtain more accurate results, since water was the solvent.

Conclusions

A thorough understanding of ozone and oxygen's chemical and physical characteristics helped in drawing conclusions to these tests. Both have some unique attributes. Ozone dissolves in water more readily than oxygen. It is also more reactive because of its instability and oxidative tendencies.

The measurement of ozone and oxygen were about the same when comparing the tubing and the air stones. There were no significant elevated levels to say whether one was more efficient than the other. Both worked very well in transferring ozone and oxygen into the water.

It was hard to determine a length of tubing that would correlate to the same amount of transfer that a stone could produce, but we did have some estimates. The stone's bubbles were more concentrated and the tubing, as stated earlier, were spread out. At least a 15-ft. length would be comparable to the large stone, a 10-ft. length to the medium sized stone and approximately a 3-ft. length to the small stone. Again, these are estimations based upon visual observation. Measurements of dissolved ozone and dissolved oxygen did not differentiate enough to make any factual assessment. The tubing showed a better method of reaching dead spots in storage tanks, fishponds, and aquaculture applications, because of this spread out bubble quality. Cooling towers could benefit from this type of ozone delivery to help reach areas that don't receive enough water movement and could help control bio-slimes. The biggest downside of the tubing would be backpressure on the pump and trouble with larger, deeper tanks in producing enough pressure to open the pores to release the ozone or oxygen. Some applications would not be suitable for the tubing because of this reason.

The venturi was the best method of transfer, but this was a known going into the study. This method is under pressure and the venturi is also an efficient method of transfer. This did however prove some good points on how efficient the ozone generators produced ozone. The CD system produced about four to five times the ozone that the UV system produced. As stated earlier, the CD system had readings of .49 ppm compared to .1 ppm of the UV system.

Overall, the study revealed some excellent data on air stones, PTFE tubing and venturi's for ozone and oxygen transfer into water. Each method revealed unique positive characteristics and limitations. The data gathered helps understand further development of the product components and possible applications.

Air stones are best used in ponds or deeper water, since they don't have as much backpressure. They also do a good job of creating a current by moving the warmer water to the top during the winter months and preventing the pond from freezing. Areas where freezing is not a factor do not see this phenomenon. They provide a good method of ozone and oxygen transfer into the water.

FIGURE 4: Pond

The PTFE tubing shows remarkable promise in using this type of tubing on shallow waters, since the air bubbles are smaller and tubing can be manipulated in hard to reach areas and dead spots. Ponds, fish tanks and aquaculture (Figure 4) systems show great benefits of using this type of component to enhance the water quality. Increased oxygen levels help aerobic activity in these ponds to help reduce algae growth and other bacterial issues.

Understanding ozone, oxygen and water chemistry can be complex. One should always consult the manufacturer when designing a system to be sure all the parameters are considered before implementing the system so desired results will be achieved the first time. Nothing is more frustrating to a consumer than products that fail or don't deliver satisfactory results, because a variable was miscalculated or omitted. When in doubt, run a pilot study and gather the data for proper design. *wqp*

References:

1. *"Porous PTFE Tubing - Testing and Applications of Porous PTFE Tubing for Transferring Ozone into Lake Water to Reduce Bacteria, Coliform and E.coli",* Water Quality Products*, December 2004*

2. *"Ozone – A Reference Manual", Prepared and distributed by The Water Quality Association, Lisle, Ill.*

About the Author

Jeff Roseman CWS-V is owner of Aqua Ion Plus+ Technologies, La Porte, Ind. He has a background in chemistry and physics from studies in Electrical Engineering at Purdue University. Roseman is a member of the Editorial Advisory Board of *Water Quality Products*. He can be reached at 219.362.7279, or by e-mail at jeff@aquaionplus.com; www.aquaionplus.com.

LearnMore! For more information related to this article, visit the web at www.wqpmag.com/lm.cfm/wq060505

For more information on this subject, write in 1015 on the reader service card.