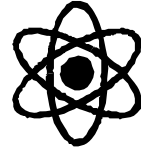


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“Innovative Methods in Wastewater Disinfection”

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Abstract

Wastewater can have several meanings, depending on the industry or application. Blow down from cooling towers is considered wastewater, leachate recovery water in greenhouses contaminated with pathogens can be considered wastewater, and water processed in sewage plants is very definitively considered wastewater. Finding new methods to disinfect these waters before they are introduced back into the ecosystem or by disinfecting the water to be used from reclamation has always been a challenge. Reducing costs of disinfection has always been the biggest concern for decades. But environmental concerns have driven researchers, operation managers, or maintenance employees to look at alternatives or innovative methods to achieve bacterial reduction or elimination.

The biggest factor in alternative methods seems to always revolve around cost. The initial capital required overshadows the long-term benefits. Initial capital investment expense and long-term return on investment (ROI) need to be analyzed closely. Often times the ROI, over a longer period of time, can actually save thousands of dollars in chemicals and maintenance costs. There are methods of pre-treating incoming water sources to remove contaminants that can help reduce chemicals and labor costs, reflecting major savings. The water used for cooling towers can be costly when purchased from municipal sources and the surcharges for blow down exacerbate these expenses. Even when well or bore water is used, the chemicals used to control iron, hardness, and other contaminants can cause elevated chemical use and labor costs. This in turn creates more frequent blow down and if discharged to municipal sewer systems, the surcharges again ultimately increase the cost of operation. As one can see, the overall analysis of system design needs to be evaluated closely to reflect actual savings from the capital investment expenditure. By using alternative methods of disinfection, long-term costs can be reduced and chemicals introduced into the ecosystem diminished.

What are the Alternatives?

Let's look at some alternative methods of disinfection, their uses, capital investment, and return on investment. These alternative methods are ozone, ultraviolet light, copper ionization, and filtration. These methods can be employed as stand alone systems or used together in a synergistic fashion to compliment their disinfection and contaminant controlling qualities. The reduction of chemicals, and the labor associated with their use, has proven to be surmountable by using alternative methods. Capital investment and third party testing has been an obstacle, which has kept these methods from being widely used. Tried and true chemical use is the norm and alternatives have been long pressed for acceptance because of the initial investment.

Advances in ozone production equipment are helping make ozone a very viable alternative for disinfection. Cost reduction, sizing requirements, and reliability are helping to make this method more attractive. There are many experts that understand how to use ozone safely and effectively. Ozone use has been approved and considered safe by the EPA and the USDA in food processing and is accepted as GRAS (Generally Regarded As Safe). Too many times systems are designed poorly and the anticipated results were not achieved because a crucial parameter was omitted or not factored thoroughly.

One of the biggest problems in sizing ozone systems is the fact that many don't understand how ozone reacts with different materials. Ozone compatible materials must be used in order to keep the system from premature failure. Piping, contact chambers, pump seals, and any other part of the system that comes in contact with the ozone must be able to resist breakdown from the highly oxidizing effect and corrosiveness of O₃. Stainless steel pump heads made up of 304L and 316L grade stainless must be incorporated in design. Hypalon or Gortex seals and other materials must be used to keep systems from failing. Off gas chambers and ozone destruct units must be implemented to direct excess ozone from areas that could be sensitive to the oxidizing effects and health related issues for humans.

Another big miscue of ozone failure is load factor. The load factor can be caused by BOD's (biological oxygen demands), COD's (chemical oxygen demands), and other inorganic substances, such as iron, manganese, or sulfur contaminants. If the load is not measured properly, or a pilot study conducted to gather information, the ozone amount is generally not sized correctly and subsequently too much ozone can be injected or in most cases not enough. Ozone reacts with many contaminants at different rates and these determinations must be made in order to achieve desirable results and a smooth running system. Capital costs may seem pricey, but overall long-term benefits have shown rapid payback in most installations. Savings in chemicals, labor, and equipment replacement costs all factor into the investment return.

Ultraviolet light systems are affected the same way that ozone systems are in determining successful installation. Understanding all the factors that affect UV water treatment needs to be considered. Flow rates, turbidity, demand, and transmission levels,

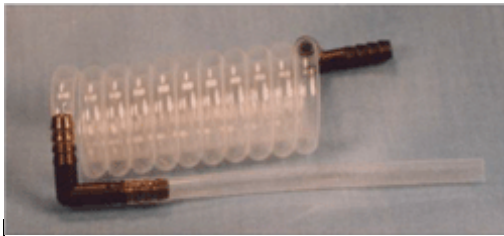


Figure 1

etc. are some of the factors that must be considered in UV light water treatment. TOC (total organic carbon) removal can be very successful when applied correctly. Maintenance issues must be considered in this type of treatment and conducted on a regular basis to keep the system clean and running efficiently. UV bulbs and protective quartz sleeves require maintenance and replacement at regular intervals. Newer coiled fluoropolymer tubes

(*Figure 1*) are a great alternative method of bulb protection that helps reduce cost and maintenance. The coiled tubes offer easier and safer replacement compared to quartz sleeves, since they do not break, are less expensive, and therefore are cost effective. There are very clear fluoropolymers that provide good transmission levels and the turbulence caused by the coiled structure reduce shadowing and increase contact time, thus creating a good UV dosage rate. The Markel Corporation, in Pennsylvania, has been very instrumental in producing very clear polymers that provide high UV transmission levels.

Copper ionization is a method of reducing bacteria and also helps reduce scaling in pipes and holding tanks. This method is not very widely used and should be looked at closer because of the synergistic effects when used in conjunction with ozone, UV, and filtration. Cooling towers and produce washes are very good applications for use with this type of technology. Chlorine use can be reduced drastically and other biocides to control bacteria or algae can be used in moderation. Copper must be controlled when the effluent is entered back in the ecosystem, but this method is still a very viable alternative. Low levels of copper are all that is needed to control algae, fungus, and bacteria. A copper level

below the MCL (maximum contaminant level) established by the EPA is 1.3 ppm. Levels of .5 to .7 ppm are very effective in controlling algae and bacteria, thus reducing expensive chemical use.

Filtration is another control method that is being employed in wastewater systems. Advanced membrane technology is becoming more effective in removing bacteria and virus. Reduction in cost and the footprint is making this alternative more attractive. These systems can filter millions of gallons of water per day and the efficient membranes keep initial costs lower, maintenance easier, and less expensive.

Defining the Methods.

Now that each of these methods have been introduced, let's go back and get a little more definitive on how these technologies operate and how the chemistry of the technologies compliment each other. Let's first look at the different ways ozone can be utilized as an alternative method of disinfection.

Ozone can be bubbled into water systems and used to reduce bacteria, algae, and other pathogens. Porous PTFE Tubing (*Figure 2*) works very effectively in bubbling ozone into water. The PTFE Tubing is porous, flexible, and well suited for many applications.



Figure 2

PTFE tubing works great with atmospheric tanks, since ozone gas rises up through the water to oxidize contaminants. The longer the rise and contact time of the ozone, the better the effect for bacterial control and contaminant oxidation. This method can also help in reducing dead spots within a system. The dead spots happen when ozone is sucked into the water with a venturi, but doesn't get circulated properly to all areas and bio-slimes build up because of the lack of proper ozone dosage. The tubing can help keep the water moving to reduce this problem, because it can be placed in hard to reach areas throughout the tank to alleviate dead spots. Air stones are

another method that is used to distribute ozone into atmospheric tanks.

The bubbling method of applying ozone can be compromised and might not provide the bacterial reduction required, if the contact time is not long enough or too low of an ozone dose is administered. Ozone is very good for oxidizing iron and manganese in atmospheric tanks. Again if the ozone dose or contact time is too low the dose rate will not sufficiently kill the bacteria or virus needed for bacterial control. Systems must be designed to overcome the load factor and all parameters must be considered. Baffles in the tank can help slow the rise of ozone and assure better transfer into the water.

Another method of injecting ozone into the water is by using a venturi along with contact tanks to get maximum ozone transfer into the water. These tanks allow longer contact time and are under pressure so the ozone can dissolve more efficiently into the water. Sizing a tank to provide the proper resident time, for the flow rate needed, is one of the main parameters to successful system design.

The effectiveness of using Ultraviolet light (UV) generated ozone or Corona Discharge (CD) is also another consideration. Ozone dosage must be applied properly or results will be marginal. The production of ozone with UV is limited, because of various factors. UV ozone cannot produce the percentage by weight that CD units can produce, but

have their place in many applications. Inconsistent output from UV bulbs, and variable airflow, is one technical consideration. On the other hand no by-product production of nitrous oxide, from UV bulbs, is a positive consideration in certain instances. Corona Discharge units produce very high levels of ozone by percentage by weight. Oxygen concentrators and air dryers reduce the nitrous oxide produced from CD units. When used correctly ozone is one of the best methods of oxidizing contaminants. Calculating the proper dose can be accomplished, but a pilot study proves to be the best method for optimum evaluation. Understanding the load factor plays a significant role in success or failure of a system.

A recent test study using PTFE tubing, in ozone transfer, revealed some very interesting observations on this method of ozone injection. Bacterial tests were conducted on lake water using UV and Corona Discharge ozone generation. Both methods of ozone contact and various ozone levels were also evaluated. The study results appear in an article entitled, "Testing and Applications of Porous PTFE Tubing", in the December 2004 issue of Water Quality Products magazine and can be viewed online at www.wqpmag.com. Simply go to the archives and do an author search for Jeff Roseman. There are many studies available on ozone and its use. Please refer to the references, at the end of this paper, for more information. Every water source, application, and desired result is different.

UV light systems used to reduce and control bacteria have proven to be very reliable. Understanding the water quality and determining the dosage rate of the UV needed is very important for proper application. The formula to determine the dosage rate is as follows: $\text{Dose (mW-sec/cm}^2\text{)} = \text{Intensity (mW-sec/cm}^2\text{)} \times \text{Time (sec)}$. Dose may also be expressed in mJ-sec/cm^2 , which is becoming the new standard expression. The UV lamp power determines intensity. Time is calculated by the exposure duration of the process fluid to the UV. The dose rate is affected by factors such as:

- Flow rate;
- Water temperature;
- Water quality;
- Lamp life;
- Bulb protection materials.

Flow rate:

Flow rates are the principle variable in any water treatment application. Typical disinfection systems are rated at the maximum flow that will provide a 30,000 mW-sec/cm^2 dose at the end of the lamp's usable life.

Water temperature:

Water temperature is only a factor in low-pressure lamp systems since the operating temperature is lower. Low pressure UV lamps, which are very similar to standard fluorescent bulbs, operate between 120 V and 240 V and obtain power outputs ranging to over 100 Watts with current draws of less than 500 mA. Low pressure UV output drops drastically if process water rises above or drops below the optimum temperature. Medium pressure lamps, which are stable under all temperature conditions, have a higher operating temperature; hence the output is not affected.

Water quality:

Turbidity and other contaminants block and/or absorb UV light, while organic and inorganic materials increase the dose required. Other factors are color, metals and/or suspended and dissolved solids.

UV light technology is not new, but improved use of UV technology can enhance disinfection systems. Side streaming UV in wastewater is becoming a good method of controlling bacteria in cooling towers and other wastewater applications. This allows for lower flow rates, but still provides very good control of pathogens and bacterial control. The coiled tubing has proven to help designers overcome sizing problems, since it allows longer contact times and more turbulent flows. A company in Australia has designed a system for Onsite Wastewater Treatment using the coiled tube. The coils are used with UV on the effluent water as a contingent disinfection method.

Copper and silver ionization has been used for centuries. Egyptians used copper and silver containers to control bacteria in their water. Pioneers used copper and silver coins in their water barrels to keep their water fresh. Today's technologies use electronic controllers to emit copper and/or silver into water with an electrical charge. Copper or copper/silver electrodes are used to emit positively charged ions into the water for disinfection purposes. These ions disrupt enzymes in bacteria to stop the proliferation. The electrical charge offers de-scaling properties, since these charges react oppositely with the metallic ions in the water. Low levels of copper are very effective in controlling many bacterial and algal issues. Copper use works well with this type of bacterial control since it is more widely accepted and not as regulated as silver. Both need to be monitored in order to keep levels low and not disrupt the ecosystem.

Membrane technologies used in filtration systems have evolved over the years. These membranes can filter out smaller particles, but yet have less effect on flow rate, are cost effective, and easy to maintain. Another factor is the footprint. For example, a unit that once used twenty-five – 8-inch membranes can now be accomplished with five – 18 inch membranes and still deliver the same quality and quantity of water. This results in tremendous savings on initial start up and maintenance costs without compromising water quality. Many municipal systems are using this technology to conserve water by filtering the backwash and reusing this water in the main system. Wastewater is being filtered by this method to reduce bacteria and other contaminants before reentry to the environment.

Conclusions

Without going into a lot of explanation of how to calculate the dose rate, let it be said that an ozone manufacturer or technician can help with procuring the correct information for any application that might be addressed. Many books have been written on ozone. One good reference book, that touches many different applications, would be; "Ozone – A Reference Manual". This book is prepared and distributed by the Water Quality Association, which is known internationally. Other articles that help explain ozone and ORP (oxidation reduction potential) can be read online in the archives of Water Quality Products, www.wqpmag.com. There is a plethora of information that can be found

at the International Ozone Association web site, www.int-ozone-assoc.org. Ozotech, Inc.'s, founder and owner, Ken Mouw, is a very reliable source of information for multiple ozone treatment applications. Markel Corporation has been very instrumental and progressive in developing PTFE, FEP, and PVDF tubing for the water treatment industry.

UV light systems seem to be more widely used within the wastewater industry. Wastewater treatment plants worldwide have proven this technology is a viable alternative for disinfection if monitored and maintained properly. The coiled fluoropolymer tubing is a product on the horizon that brings newfound ease for installation, maintenance, and safety issues. These coils replace quartz sleeves and help designers reduce size requirements while improving safety issues and overhead expenses.

Ionization is coming into its own, because more installations and third party testing proves its usefulness and integral part in system designs. When monitored and used at low levels, this technology will enhance synergistic effects in scale reduction along with good bacterial control. When ionization is used with ozone, UV, and filtration, these technologies will enhance each other and provide the consumer with a very good alternative for disinfection, ultimately reducing the costs and environmental impact of chemical use.

Filtration speaks for itself, but it too must be sized accordingly and used properly or marginal results will be obtained. Whether RO or Ultra-filtration membranes, ion exchange, de-ionization, or multimedia filters are used, they must all be applied correctly. Proper water analysis must be performed on the influent water, if not the desired results will not be seen and there will be no return on investment.

No matter what technology or combination of technologies that are used for alternatives for disinfection, it must be understood that these technologies usually have higher initial capital investment. It must also be understood that all water treatment equipment has maintenance and other related costs to keep equipment working optimally. The alternative treatment methods discussed in this paper, in most cases, provide a rapid payback, when compared to chemical costs, maintenance, storage, and labor associated with traditional treatment methods. Over the long run Ozone, UV, ionization, and filtration are economical and environmentally feasible.

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a background in chemistry and physics from studies in Electrical Engineering at Purdue University. His specialty certifications are in ozone, disinfection, and RO/Ultra-filtration technologies. He has been instrumental in developing systems using copper ionization as an alternative to using chlorine.