600 MGD . . . What About 2 MGD?

Small Municipal Water Treatment with Ozone

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Abstract

Much attention is given to large water treatment facilities throughout the world that have successfully applied ozone to their treatment process. Large surface water plants have, after all, been the historical patron to ozone technology. These facilities were the only clients with the pocketbook and manpower to run complex ozone systems.

With changes in ozone generation and transfer technology, the modern ozone system has become more simplified and durable. With more affordable generators on the market, small municipalities are now able to take advantage of the many benefits ozone has to offer.

This presentation will take a look at some of the small municipal plants in the heartland. Many are finding that ozone can be affordable. Their systems are simple yet effective. With large surface water facilities finally gathered behind ozone technology, the new fertile territory is small facilities. Surface water or ground water – ozone technology is gaining momentum.

Key words: Ozone; ground water; iron; manganese; municipal.

Las Vegas. Dallas. Milwaukee. San Francisco. San Diego. All are wildly successful water treatment plants in which ozone is applied. Each, enormous facilities with hundreds of millions of dollars invested. All treat millions and millions of gallons of water each day. They are referenced often and have become popular showcase facilities for the ozone treatment industry.

Many more facilities of similar size have joined these to become the face of the ozone industry. For those facilities ozone was selected over competing technologies because of the many advantages it provided to the treatment of raw water.

It has taken many years for the concept of ozone treatment to gather momentum, gain recognition and attain popularity. Much of the senior leadership of the International Ozone Association (IOA) endured the tough, uphill battle to acquire acceptance of ozone technology in the engineering community. With this foundation, ozone has become an established tool for municipal treatment in large surface water plants.

One should asking the question: What is the next mountain to climb? Where is the next frontier of ozone application in municipal water treatment? In 2007, the EPA estimated that there were approximately 156,000 public drinking water plants in the United States. Figure 1. shows the distribution of these plants in relation to their size. Of this group, 94% are ground water systems. 2.7% (4,141) of the group serve populations greater than 10,000 people. A mere 0.2% (402) serve populations greater than 100,000 people. Conversely, 97% of the water treatment systems in the U.S. can be considered small to mid-size (less than 10,000 customers served) by the EPA's definition. It is the goal of this paper to propose that the next mountain to conquer is that of bringing ozone technology to small to medium size plants. It is these plants which are ready to take advantage of the many benefits of ozone application.

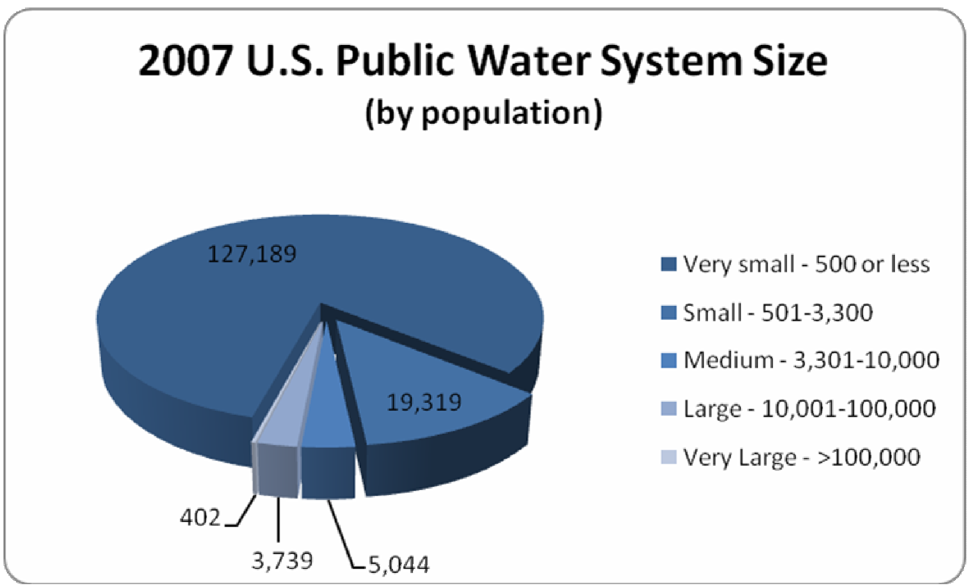


Figure 1. – The number of public water systems in the United States by population served.

In order for a technology such as ozone to be successfully applied to a small water system, there are several challenges that must be acknowledged and overcome.

The challenges:

1) Simplicity
2) Low operator numbers
3) Low cost
4) Durability
5) Training (no 'black box')

Simplicity. A typical municipal ozone system contains much more equipment than an ozone generator. Most modern systems include a liquid oxygen feed system or oxygen concentration plant, injection system, ozone destruct system, monitoring system, multiple dissolved ozone sensing sites, and PLC systems. This complex array needs simplification if expected to be employed in a small plant.

Low operator numbers. Unlike a large water plant, the staff of a small or midsize water plant is usually less than 5 employees. Most small plants are limited to one operator. Additionally, this operator is the same worker who maintains the distributions system, cares for the town streets (including snow plowing), and completes other odd jobs. These operators are limited in the amount of time they can commit to the water treatment equipment.

Low cost. Historically, ozone systems have been relatively high in capital cost. The current competition to ozone technology is traditional aeration, filtration, chlorination plants (for iron and manganese removal). Traditional technology is typically lower in capital cost.

Durability. Historically, ozone systems and the air (or oxygen) preparation equipment required to feed the generators were sensitive to the environmental conditions. This equipment required steady maintenance to ensure operation. Small and midsize plants are limited in both manpower and maintenance funds to handle equipment failure typical of traditional ozone systems.

Training. Most water plant operators dislike any equipment which may be labeled a ‘black box’. Lack of understanding leads to lack of guardianship. After time, the equipment breaks down for unknown reasons and is eventually replaced with ‘simpler’ technologies.

Some manufacturers and municipalities are finding ways to tackle these challenges and apply ozone in effective ways. This paper will examine three such facilities.

Lewisville, Indiana

Lewisville, Indiana is a small, rural community located 45 minutes east of Indianapolis. By December 2002, the town’s water treatment plant operator, Richard Beach, was frustrated. Less than a year earlier, the town had completed construction on a brand new package water treatment plant, complete with a 14,000 gallon aeration tank and gravity sand filter. The $1.2 million facility, completed in November 2001, was designed to handle 400 gpm pumped from Lewisville’s two wells. Iron levels in the finished water measured an average 1.6 mg/L - nearly the same amount found in the raw water. Beach countered by injecting more chlorine in the hopes of ensuring disinfection and reducing some of the iron and manganese.

Breaking Point

Customer complaints of rusty water and chlorine taste and odor were received weekly. Beach focused on maintaining the status quo. By the summer of 2004, the plant was put on notice by the Indiana Department of Environmental Management (IDEM) for exceeding the maximum total trihalomethanes (TTHM) limit.

With funding already stretched thin, the town wasn't prepared to construct a second new filtration plant. Engineers suggested ways to maximize use of the current plant by adding pre-treatment systems. Two such systems suggested were UV and ozone. Beach was leaning toward UV when he mentioned the problem to a fellow operator who worked for Ingalls, a town one hour northwest of Lewisville. Ingalls had been in a similar situation when the town went through a major growth period during which the plant was upgraded. The backbone of the upgraded plant was an ozone system. With a similar system working successfully, Lewisville was prepared to invest in ozone.

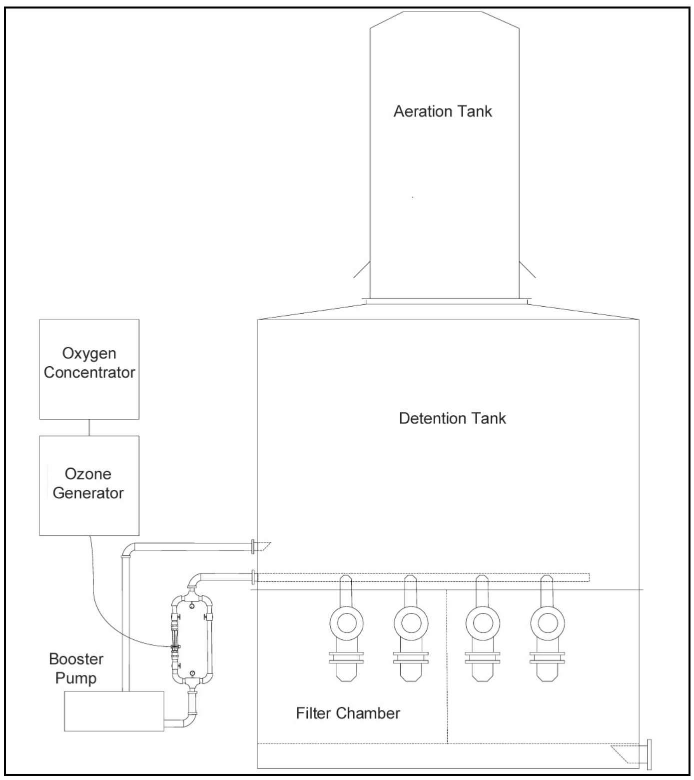


Figure 2. – Layout of the ozone retrofit to the existing water treatment package plant at Lewisville, IN.

Decision Made

By the winter of 2004, the ozone system was installed; it consisted of 3 oxygen concentrators, a 12 lbs./day ozone generator (manufactured by Ozonia), 2 venturi-type injectors and the associated pumps, piping and controls (see Figure 2). The system now fits into a 30 sq. ft. portion of a converted storage room. Raw water bypasses the aerator and fills the detention tank. A booster pump draws a portion of the water out of the tank where it is injected with ozone gas via venturi injectors. The ozonated water is returned to the detention tank where it is mixed into the tank with a lateral distributor. Water moves by gravity to the mixed-media gravity filters located directly below the detention tank. Anthracite in the filter media quenches any residual ozone. Once the water leaves the filters, the process remains unchanged – chlorination and pumping to the distribution system.

Table I. – Raw and finished iron levels at Lewisville, IN. The operator attempted to spike the plant with chlorine to help remove bacteria and iron prior to installing ozone equipment.

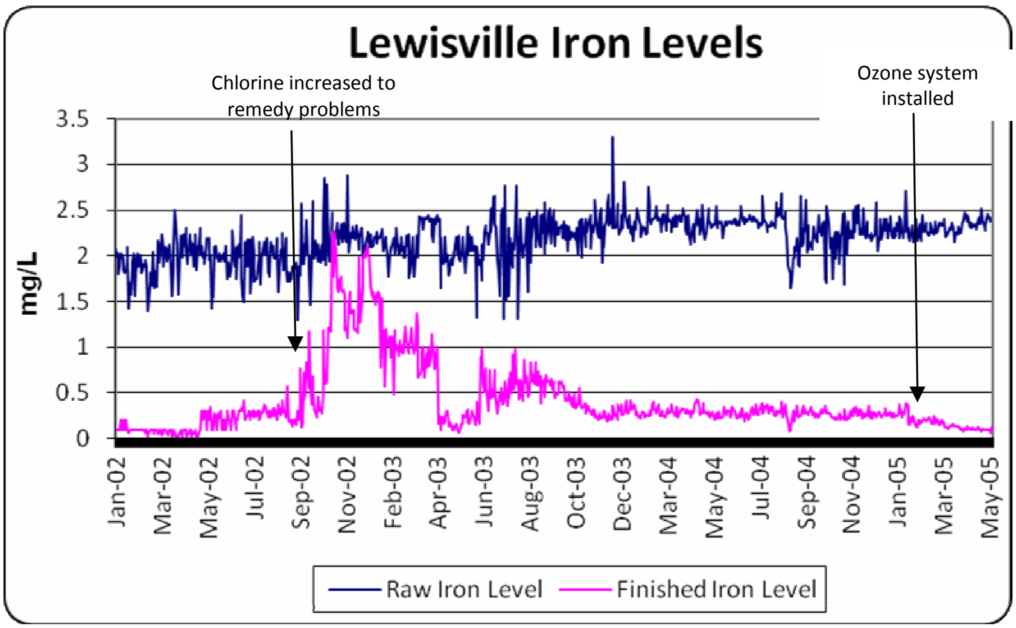
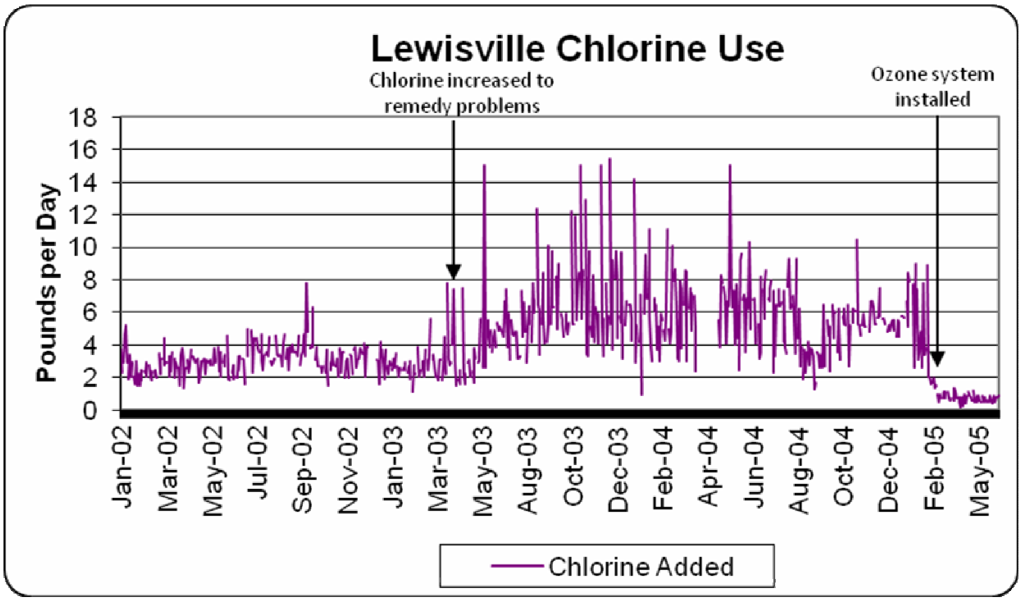


Table II. – Chlorine use at Lewisville, IN over time. The operator attempted to spike the plant with chlorine to help remove bacteria and iron prior to installing ozone equipment.

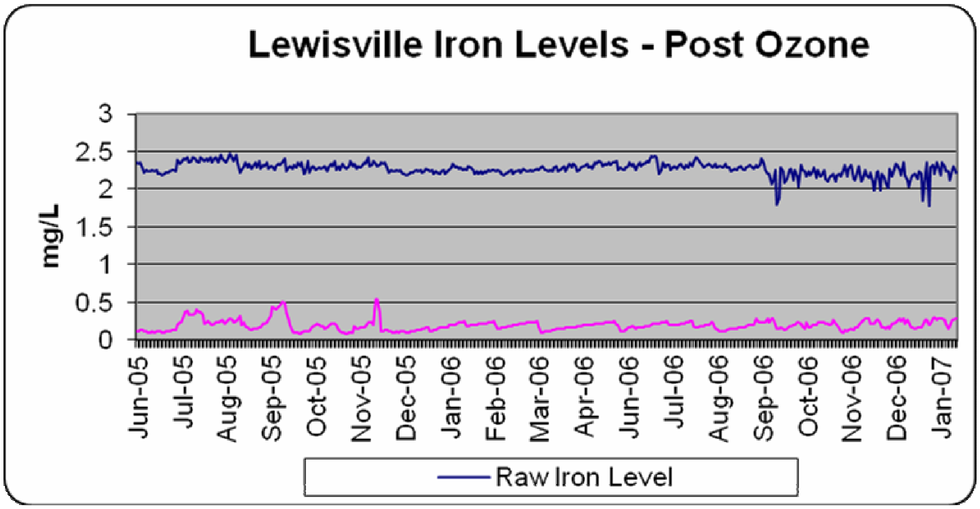


Initial start-up worried the operator. The plant was continuing to produce water with high iron and manganese levels. It was only later that Beach discovered that the ozonation process had been actually stripping iron and manganese deposits from the piping and filter of the plant. Valves once clogged and unmovable were restored to working condition. It took about 30 days for all the residual iron and biofilm to be removed from the plant and distribution system.

Post-Ozone

After the first month of cleansing, the ozonation process – in conjunction with the unchanged gravity filters - was reducing the iron level to 0.10 mg/L. This drop, along with a bacteria count of zero, allowed Beach to progressively decrease the chlorine use. The operator was able to reduce chlorine dose from five pounds per 35,000 gallons to less than one half-pound. Additionally, the TTHM and HAA5 levels fell to zero. Customer complaints decreased by 95%. Prior to ozone, the plant would be backwashed 3 to 4 times per week. With ozone, backwash occurs once every three weeks with less water used per backwash. Although this is highly unconventional, the operator insists that the plant can reduce iron to below .3 mg/l effectively on this backwash schedule. The adjustment has reduced the plant's sewage costs by almost 90% each month.

Table III. – Raw and finished iron levels since the installation of ozone equipment at Lewisville, IN.



Ozone monitoring is achieved with a simple ORP probe with a digital readout. The ozone room has a simple control panel with an ambient ozone monitor. The control panel signals a ventilation fan based on the ozone level in the room and is also capable of cutting power to the ozone generator and powering an alarm if needed.

In the case of Lewisville, the town was able to upgrade to ozone with a mere 5% of the cost of the 2001 plant. The town is an excellent example of how a small municipality can apply ozone in a successful and cost-effective way.

Danville, Indiana

In 2003, the city of Danville, Indiana was shopping for the best way to upgrade their aging water treatment plant. The plant, constructed in 1960, consisted of conventional aeration, filtration and chlorination to treat raw water obtained from 160-ft deep wells. The pressure filters were biological and would develop mud balls over time. On average the media had to be removed and replaced every 1.5 to 2 years when the filters became unmanageable.

The current plant was designed to treat a flow of 1,400 gpm (2 mgd) based on raw water which contained about 2.5 mg/L iron, 0.05 mg/L manganese, and iron and sulfur-reducing bacteria. Upon the successful results of an early pilot study, the engineer and city elected to employ ozone for iron and manganese oxidation as well as removal of any bacteria.

The ozone system is fed by a 7,000-gallon liquid oxygen tank. The air is dirtied with an ambient air compressor system. Two 40 lbs/day ozone generators (manufactured by Wedeco) convert the feed gas to 10% (by weight) ozone gas. The system employs side-stream venturi injectors to mix the ozone into solution. Two ozone reaction tanks are operated in series – the first tank has a 7,000-gallon capacity and the second tank is identical, but with an effective capacity of 5,500 gallons (due to the plant hydraulics). Two heated catalyst ozone destruct units handle the off-gas from these tanks.

The filters are open-top gravity filters, employing an anthracite/sand media. Final disinfection is achieved with chlorine gas.

Problems and challenges

The ozone system at Danville is worth mentioning in this paper because it was a challenge. There were many obstacles to overcome and the plant continued to produce issues and headaches long after the start-up period. Fortunately for the town, the plant superintendent and consulting engineer were committed to making their new ozone facility operate successfully. There were many lessons learned and they pushed through each challenge.

The first issue which arose was associated with plant communications. Sensors, meant to communicate feedback to control systems, did not produce the correct feedback. In some cases the control systems were programmed incorrectly and functioned in unexpected ways in responding to sensor feedback. Making the issue more complicated was the fact that all the sensors and controls were not supplied by one manufacturer, but were provided by several different companies. This made troubleshooting and service very difficult.

Typical ground water does not contain significant amounts of Total Organic Carbon (TOC); therefore, the plant was not designed around the presence of TOC in the raw water. Ammonia is another rare contaminate in groundwater. Danville's wells were producing water with 3 mg/L of TOC and 3 mg/L of ammonia. One of these contaminates in raw water is challenging enough. The presence of both caused a troublesome chain-reaction.

By definition, TOC can be one or many different compounds which may be simple, oxidizable molecules or long, complex molecular chains. Ozone will oxidize many of these long-chain molecules into smaller organic compounds. In some cases, these smaller molecules can eventually be cracked into carbon dioxide, water and/or other harmless molecules. However, in many cases ozone will succeed only in breaking long-chain molecules into simpler organic molecules. In essence, ozone breaks down complex bacterial food into simpler, more consumable bacterial food (assimilable organic carbon or AOC) . Ozone is used in some wastewater applications to achieve this exact end. In the case of Danville; however, ozone was creating 'easily-digestible' bacterial food in the water supply.

As long as the water would remain disinfected, the presence of simple TOC would not pose a great risk. The existence of significant ammonia; however, created issues. In order to reach breakpoint chlorination and convert all 3 mg/L of ammonia to nitrogen gas, the addition of up to 30 mg/L of chlorine would be required. Danville feeds much less (2.0 to 2.5 mg/L), which results in the formation of chloramines and residual ammonia. No free available chlorine was measureable in the distribution system.

To sum up the issues described above, ozone was creating AOC and without the presence of a strong residual disinfectant, microorganisms were able to survive in the dead ends of the distribution system. The microorganisms thrived off of the AOC and the ammonia. Formation of black slime and foul odors occurred in the distribution system. Even with a rigorous flushing schedule, customer complaints were high.

After exploring many technologies including biological filtration, MIOX and breakpoint chlorination, Danville settled on adding Re-Ox (a chlorine-based product which helped to maintain a strong residual disinfectant). Customer complaints have subsided and the issue seems resolved at this time.

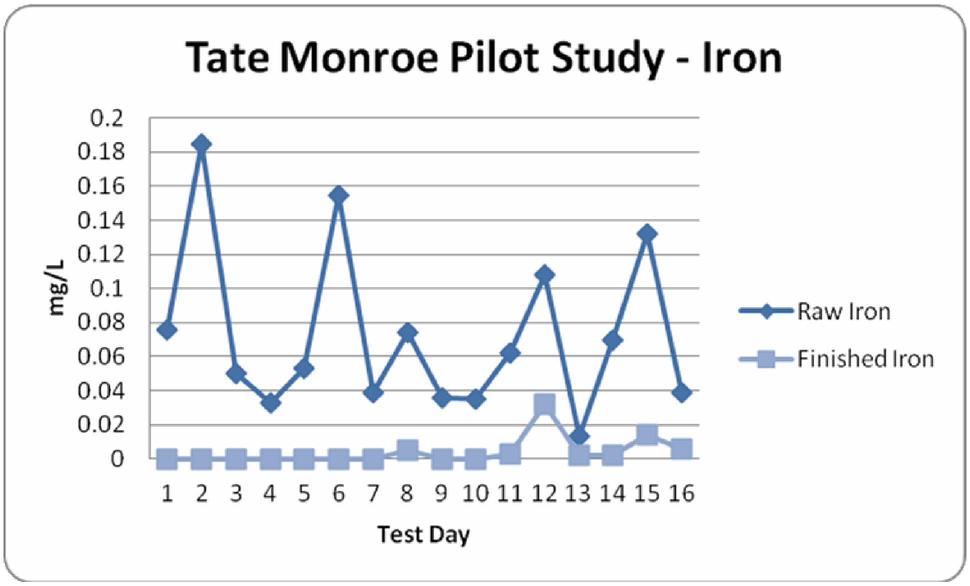
Danville is exemplified not to show that ozone doesn't work, but that ozone is not a panacea for all problems. Applying ozone to small ground water facilities will not be a trouble-free endeavor. Challenges arise and will require commitment and patience from the engineer, manufacturer and operator. The city of Danville was fortunate in that both the engineer and operator were resolved in solving each challenge. All parties are very pleased with the performance of the current water treatment plant.

Tate Monroe Water Association

Unlike the municipal installations reviewed thus far, Tate Monroe Water Association is a privately-held water treatment plant. The plant is located in New Richmond, Ohio along the Ohio River just east of Cincinnati. The association serves a wide area and the current water treatment facility is rated at 4.0 mgd. The facility draws raw water from eleven wells, each with varying capacities. Raw water contains approximately 0.3 mg/L manganese and 0.1 mg/L iron. Prior to adding ozone to the treatment process, the plant employed two induced-draft aerators. Permanganate was added for iron and manganese oxidation. Open-top detention tanks provided 45 minutes of contact time prior to filtration. Filtration consisted of five horizontal pressure filters with greensand media. The plant used an ion-exchange softening system for hardness reduction. Chlorine was added prior to filtration and post-filtration.

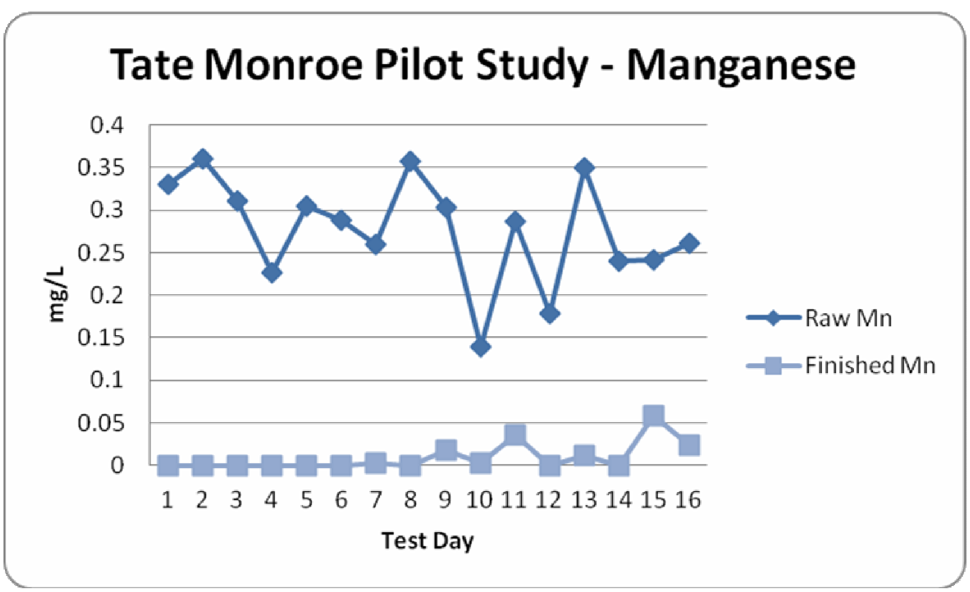
With disinfection byproducts becoming an issue, the facility superintendent began looking for ways to alter the treatment process and still achieve efficient oxidation, move away from chemical addition and reduce the formation of (TTHMs). A conversion to ozone seemed to answer all three issues. The association board elected to pilot an ozone system for 30 days to determine both the feasibility and economy of such a plan.

Table IV. – 30-day pilot study results for iron at Tate Monroe Water Association.



The pilot plant was rated at 7 gpm and employed a small oxygen concentrator which fed an ozone generator rated at 0.8 lbs/day. A venturi injector added the ozone gas to the raw water. Water flowed through a detention/contact tank and a mixed media pressure filter. An inline ozone analyzer was utilized to measure the dosage of ozone being applied. After 30 days, the results were promising (see Tables IV. and V.) The highest finished manganese reading was 0.058 mg/L. The highest finished iron reading was 0.032 mg/L. Seven separate TTHM tests were completed during the 30-day study. All readings for TTHM levels were beyond the detectable limit.

Table V. – 30-day pilot study results for manganese at Tate Monroe Water Association.



With a successful pilot study completed, the association proceeded with retrofitting an ozone system to the facility. The aerators were removed and a building constructed to house the three 24 lbs/day ozone generators and associated air prep equipment. The permanganate feed was removed. The greensand media was replaced in the pressure filters with sand and anthracite.

Ozone is now injected via venturi into the raw water. The water continues to the existing open-top detention tanks for contact time. A partial hood system was constructed to collect any off-gas and route it to a destruct unit. Construction was completed in November 2007.

Post-ozone

In the six months following installation, the ozone system has been more effective at iron and manganese removal. Finished water manganese is beyond the detectable limit and only trace amounts of iron have been detected. The operators report a significant drop in chlorine use. The chlorine is more stable and free chlorine lasts longer in the distribution system. Prior to the ozone installation, TTHM was found as high as 70 µg/L. 80 µg/L is the maximum contamination limit for TTHM according to the EPA's Stage 1 DBPR. TTHM is now at 38 µg/L and is continuing to decline.

The entire project including engineering, construction and equipment cost approximately US $1 million. The engineer accomplished this by focusing on simplicity in the system design. Because such a small amount of ozone would be off-gassed, expensive heated catalyst destruct units were replaced with carbon-based destruct units, saving money. Ground water changes very little on a day-to-day basis; therefore, the ozone feed rate can be set and requires very little adjustment. The entire ozone system does not require the use of a PLC. These are just a few examples of how the system was simplified to reduce capital cost and operation requirements. The association is very pleased with the results of their new water plant and considers the project a wise investment for their customers.

Summary

At the time that Steve Wozniak and Steve Jobs developed the Apple II computer, computing devices were expensive, complex machines used by universities, industries and the government. Computers were exclusive devices employed only by those with a very large budget and the substantial education required to operate them. The Apple II had an incredible impact on the world by being the first personal computer. It was computer that was affordable to most middle-class families. By simplifying the computer and making it useable and affordable, the founders of Apple were able to bring this powerful device to the rest of the population. It took the development of the Apple II for the computer revolution to begin.

97% of the municipal water systems in the United States would benefit from ozone technology, yet challenges such as cost, complexity and lack of training discourage the use of ozone over more conventional means. This is a substantial untapped market and should be an impetus for development. The examples above show that ozone can be successfully employed in small and midsize water treatment facilities. It is the author's hope that this trend continues to rise as challenges are overcome.

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