Ozone & Biofiltration Improve Port City's Water Quality

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Wilmington, is a coastal town in the Cape Fear region of southeastern North Carolina. The Sweeney Water Treatment Plant is a surface-water treatment facility serving a population of 75,000. The city completed a three-year major expansion and upgrade at the facility in 1998 in order to achieve three objectives:

1) To expand the facility from 15 million gallons per day (MGD) to 25 MGD capacity in order to facilitate population growth in Wilmington and the surrounding county.
2) To meet present and future Safe Drinking Water Act (SDWA) regulations such as the Enhanced Surface Water Treatment Rule (ESWTR) and others.
3) To improve the water quality regarding esthetics and consumer confidence at the tap.

The plant consists of two facilities operating simultaneously and parallel to one another. One, referred to as the South Plant, is a conventional 15-MGD facility utilizing the clarification of raw source water received from the pre-raw water ozone contactors. Primary ozone dosages range from 3 to 7 mg/l.

After additional alkalinity adjustment by either lime or caustic, both a primary coagulant (alum) and a secondary coagulant (a cationic polymer) are added prior to rapid and slow mix (flocculation). This coagulated water is then clarified by gravity separation of solids in conventional sedimentation basins. The clarified water then gravity flows to the intermediate ozone contactors to receive an ozone dosage of 0.75-4.0 mg/l O_3 for primary disinfection purposes and contact time.

The other facility, referred to as the North Plant, is a 10-MGD facility utilizing solids contact—upflow clarification of coagulated water following primary ozonation of the raw water source as described above. After the water has undergone this SuperPulsator technology, the clarified water is conveyed to the intermediate ozone contactors, experiencing the same conditions as described above.

Intermediate ozonation consists of five contactors that handle up to 25 MGD of settled water from both plants. At the entrance of the contactors, ozone is applied at a dosage rate of 0.75 to 4.0 mg/l, depending on water-quality conditions and O_3 demand factors as needed for contact time compliance.

The contactors consist of five cells, giving water a complete mixing with the ozone solution. Hydrogen peroxide is applied at the effluent ends of the contactors for complete removal of any O_3 residual before the water enters the filtration process.

Ozonated settled water from both plants is pumped through an intermediate pump station and then enters the biological activated carbon filters. The South Plant has 12 filters operating to a maximum rate of 2.5 gallons per minute (gpm) per square foot. They are composed of 12 inches of support gravel, six inches of silica sand, and 21 inches of granulated activated carbon (GAC). The North Plant has four filters operating to a maximum rate of up to 4.0 gpm per square foot, composed of three inches of support gravel, 15 inches of silica sand, and 48 inches of GAC.

All filters are operated as biological filters, utilizing microorganisms to break down and remove biodegradable organic matter and disinfection byproducts (DBPs). Biological filters, like conventional ones, also provide excellent particle and turbidity removal.

All effluents from the 16 filters are combined and final chemical adjustments are made, including pH adjustment with either caustic or lime, addition of sodium hypochlorite for secondary chlorination, and addition of fluoride and a corrosion inhibitor before the water flows to on-site ground storage.

Finished water flows first into a 12-million-gallon concrete closed reservoir, then into a 4-million-gallon concrete closed reservoir for storage before being pumped into the distribution system. Water flows from this reservoir system by two separate finished-water pumping areas, where sodium hypochlorite is applied for chlorine residual maintenance. Aqueous ammonia for chloramination is available to control DBPs if necessary.

Solids from the South Plant sedimentation basins are removed by a TracVac removal system within each basin. North Plant pulsator sludge is discharged by a blow-down system.

All sludge flows to a splitter box, where it is divided equally between two gravity thickeners equipped with mechanical rakes. All backwash water is discharged into a holding basin and then withdrawn to a solids contact upflow clarifier for clarification. Settled solids are removed by a TracVac system again to the splitter box.

All clarified supernatant is discharged by NPDES permit into the Northeast Cape Fear River. All thickened sludge is then pumped through a six-inch force main to the city's Northside Wastewater Treatment Plant and applied to a belt press. Upon pressing, the water treatment plant solids are combined (50/50) with wastewater treatment plant biological sludge and then transferred to another facility for land application.

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Bench & Pilot Scale Testing

Prior to the expansion and upgrade, the city had commissioned the engineering consulting firm CDM to conduct bench and pilot scale testing with the following objectives in mind:

1) To optimize the water-treatment process and water treatment plant under existing SDWA regulations.
2) To determine the optimum process methodology and flexibility requirements for the 10-MGD expansion
3) To identify, refine, and provide allowances for possible treatment scenarios from future regulations.

The pilot program tested and evaluated alternatives for preoxidation, coagulation, sedimentation, filtration, disinfection, and corrosion control. CDM made the following recommendations as a result of the study:

- Ozone was recommended to supersede chlorine dioxide for preoxidation. Future regulations governing chlorine dioxide residuals, as well as taste and odor complaints regarding this oxidant, indicated that ozone be implemented to oxidize taste and odor compounds, organics, iron and manganese.
- Ozone was recommended for primary disinfection to meet contact time requirements of the Surface Water Treatment Rule, allowing compliance with existing and future disinfection byproduct regulations while phasing out chlorine dioxide. Also, ozone disinfection would provide better protection from microorganisms such as *cryptosporidium* and *giardia*, which are not as readily inactivated by other disinfectants.
- Chlorine would remain as the secondary distribution residual disinfectant, with chloramine capabilities included in the expansion to prepare the plant for the most stringent DBP regulations.
- Coagulation should be optimized with a primary coagulant (alum) and a secondary coagulant (cationic polymer-MecFloc). pH maintenance in the general range of 5.8 – 6.0 s.u. was found to provide effective coagulation.
- The SuperPulsator flocculator-clarifier technology was recommended for the

Continued on page 42

Continued from page 41

expansion as a result of comparable treatment performance to the existing plant. Estimated cost savings were $900,000.

- GAC filter media were recommended in the new filters to help control regrowth potential in the distribution system, and to provide benefits of lowering DBPs. Pilot scale testing results indicated excellent color and turbidity removal and long filter run times at high rates using GAC. A filter-loading rate of 4 gpm per square foot was recommended.
- Existing corrosion control process was found satisfactory.

Source Water Quality

The raw-water source supply for the Sweeney Water Treatment Plant is the Cape Fear River upstream of Lock and Dam No. 1 at Kings Bluff in Bladen County. The city operates its own pumping station at this location, which is 30 miles from Wilmington.

Lock and Dam No. 1 at Kings Bluff separates upstream freshwater from the downstream estuarine portion of the Cape Fear River Basin. The estaurine portion has excessive salt concentrations, which preclude its use as a cost-effective water supply source.

The pumping station serves as the city's primary source of raw water with a rated pumping capacity of 15 MGD. Water is pumped through a 30-inch pipeline to Toomers Creek, and then through two 48-inch pipelines to the Sweeney Plant. The city utilizes as a secondary source of raw water the Lower Cape Fear Water and Sewer Authority's access vault at a rate up to 15 MGD. The source of this water is also the Kings Bluff area above Lock and Dam No. 1 at the authority's pumping station.

Raw water quality from this section of the Cape Fear River basin is generally in a degraded state. Water is characteristically described as low turbidity, low alkalinity, high color, and high Total Organic Carbon (TOC). Turbidity generally averages about 20 ntu, with ranges of 5 to 100 ntu. Raw water color may average 78 cu with ranges between 45 and 250 cu. Raw-water pH levels tend to range between 6.0 to 7.4 su with a general average of 6.6 su. Total alkalinity ranges between 12 and 26 mg/l, with a typical average of 22mg/l. Raw-water iron and manganese have exhibited levels as high as 4.00 mg/l for each metal.

TOC has ranged from a low of 4.0 mg/l to an all-time high of 15.0mg/l. Bromide levels have not been of any significant level, typically less than detection limits. As one can clearly deduce from the preceding data on this source water, the Sweeney Plant is definitely challenged to perform at its best optimal level. This high level of treatment must be maintained in order to satisfy the esthetic qualities of drinking water, as well as existing current and future SDWA regulations.

The Ozone System

<u>Reasons for Ozone use at the Sweeney WTP</u>

- Bacterial disinfection
- Inactivation of *cryptosporidium* and *giardia* cysts
- Viral inactivation
- Oxidation of soluble iron and manganese
- Decomplexing organically bound manganese by oxidation
- Color removal by oxidation
- Taste and odor removal
- Algae removal by oxidation
- Oxidation of organics, phenols, detergents, and pesticides/herbicides
- Micro-flocculation of dissolved organics
- Micro-flocculation to enhance coagulation of high-color, low-turbidity source waters
- Turbidity and suspended solids removal by oxidation
- Oxidation of inorganics, cyanides, sulfides, nitrites
- Pretreatment for biological processes by oxidation

<u>Points of Ozone Application</u>

1) Pre-ozonation: Raw source water prior to the coagulation process at dosage rates of 3-7 mg/l.
2) Intermediate ozonation: Post settled water prior to biological filtration at dosage rates of 0.75-4.0mg/l.

<u>System Description</u>

The ozone system for the Sweeney Water Treatment Plant operates to supply ozone for raw water and pre-filtered water treatment by application of a maximum of 1,380 pounds of ozone per day at a maximum plant flow rate of 25 MGD. The ozone system is composed of the following sub-systems:

- Oxygen System: liquid oxygen(LOX) to gaseous oxygen(GOX).
- Ozone Generation System (three horizontal tube, water-cooled generators capable of producing 690 lbs/day each at a 10-percent ozone concentration by weight of dry oxygen). Electrical support provided by three power supply units to supply high voltage and medium frequency to power the generators.
- Dissolution System (ozone fed to pre-contactors by side-stream venturi-injection and intermediate contactors by the diffused method using fine-pore bubble diffusers).
- Destruction System (off-gas from the contactors drawn through dimester elements and passed across a heater element and catalyst bed to convert ozone back to oxygen for atmospheric release). Ozone contactors operate under a negative pressure, creating a vacuum for undissolved O_3 gas draw-off.
- Cooling Water System (cooling water pumps are provided to remove heat from the generator vessels and power supply units).

Results

<u>Water Quality</u>

Ozonation and biological filtration of Wilmington's water treatment began in March 1998. Numerous reported benefits, as well as an improved water quality at the tap, have been reported to date. Reduction of TOC from raw source water to settled water has been reported in the range of 64 to 69 percent, with an additional reduction of 26 to 40 percent as a result of biological filtration.

Iron levels in the raw source water reported up to 0.9 mg/l have been reduced to levels in the finished water of less than 0.020 mg/l. Manganese levels in the raw source water, typically in the 0.06 mg/l range but sometimes as high as 4.0mg/l, are reduced to finished-water levels of less than 0.01 mg/l. This reduction is attributed to the oxidative capacities of ozone treatment.

Reduction of the organic carbon in the raw water has resulted in TOC levels remaining in finished water at 2.0-2.5mg/l, reducing the probability of Trihalomethane formation potential during secondary chlorination. Total Trihalomethane levels typically average 60ug/l. Total Haloacetic Acid levels showed a decrease from 48.5 ppb in 1997 to 21.37 ppb in 1999.

<u>Estimation of Daily Ozone Operating Costs</u>

- Average Daily Flow = 12 MGD
- Total Ozone production = 500 lbs/day
- Daily ~Energy cost = $135
- Daily LOX cost = $175
- Daily cost of kW and LOX = $310
- Cost/MG of water treated by ozone = $25.85

Chlorine/Chlorine Dioxide to Ozone: Lessons Learned, Lessons Earned

Advantages include safety, with no chlorine gas storage on site. Ozone must be produced on site. In the event of an ozone leak, generation ceases and ozone breaks down and dissipates rapidly (~20min).

Ozone is the most powerful oxidant/disinfectant; benefits mentioned early in this article tend to substantiate this statement. Ozone enables utilities to meet SDWA compliance with DBP formation potential. Most important, it is a better enhanced water treatment, resulting in superior water quality at the tap.

Disadvantages of ozone treatment include greater operational costs due to LOX and electricity. Operation and maintenance of the system is greater. The facility as well as this process may require greater technical skills from operational staff, requiring in a higher level of training and expertise.

Ozone treatment produces byproducts that must be treated. Biological filtration is invaluable in removing the biodegradable organic carbon and assimable organic carbon to a reduced form so as not to affect the distribution quality of the drinking water.