Evaluation of Ozone and Peroxone for Water Quality Enhancement at the Del Valle and Patterson Pass Water Treatment Plants

Project Report

Prepared for

Zone 7 of Alameda County Flood Control and Water Conservation District

October 16, 2009

WQTS
Water Quality and Treatment Solutions, Inc.
An environmental engineering and science consulting company.

EVALUATION OF OZONE & PEROXONE FOR WATER QUALITY ENHANCEMENT AT THE DEL VALLE AND PATTERSON PASS WATER TREATMENT PLANTS

PROJECT REPORT

PREPARED FOR:

ZONE 7 OF ALAMEDA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT

PREPARED BY:

WATER QUALITY & TREATMENT SOLUTIONS, INC.
LOS ANGELES, CALIFORNIA

WWW.WQTS.COM

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EXECUTIVE SUMMARY

Zone 7 of Alameda County Flood Control and Water Conservation District (Zone 7) serves drinking water to the cities of Pleasanton, Livermore, and Dublin. Zone 7's main water source is the Sacramento-San Joaquin Delta delivered via the South Bay Aqueduct (SBA). The water is treated at two surface water treatment plants; the Patterson Pass Water Treatment Plant (PPWTP) and the Del Valle Water Treatment Plant (DVWTP). Two other water agencies also draw water from the SBA: the Alameda County Water District (ACWD) and the Santa Clara Valley Water District (SCVWD).

SBA water commonly contains chemicals that impart objectionable taste and odor (T&O) into the water. These chemicals are produced by algae growing in the water, mostly during the summer and early fall. While algae can produce many chemicals, the primary T&O-related ones in SBA water are geosmin and 2-methylisoborneol (MIB). These chemicals have no known adverse health effects, but they are easily detected by customers at low nanogram per liter (ng/L) levels, resulting in customer complaints about the quality of their drinking water. In 2003, the Zone 7 Board of Directors adopted the *Zone 7 Water Quality Policy, Goals, and Targets*, which included a target of "no events" for earthy/musty T&O, where an event is defined as three or more complaints over a seven-day period. The document also included targets of no more than 9 ng/L of MIB and 4 ng/L of geosmin in the drinking water served to Zone 7's customers.

To address the T&O challenge, Zone 7 has relied on the addition of powdered activated carbon (PAC) at both plants. PAC is effective, but is difficult to handle and is more expensive than most water treatment chemicals. The high PAC doses needed to effectively remove MIB and geosmin also generate large volumes of sludge and can adversely affect plant performance. An alternatives analysis conducted by Zone 7 concluded that PAC can only be used as a short-term solution to the T&O problem, with ozone addition being the reliable long term solution. Ozone is used by ACWD and SCVWD, as well as numerous other California water agencies to destroy chemicals that cause T&O in drinking water.

Historical data indicate that the occurrence of geosmin and MIB in SBA water is seasonal and highly variable. Data analysis shows that MIB levels in SBA water exceed the Zone 7 goal of 9 ng/L approximately one to two months per year, while the geosmin levels exceed the goal of 4 ng/L approximately five (5) months of the year. The maximum geosmin and MIB levels recorded by DWR in SBA water from 2001 to 2007 were 17 ng/L and greater than 50 ng/L, respectively. If Zone 7 were to meet its goals 99% of the time, then the last six years of data suggest that the new T&O treatment process should achieve greater than 73% removal of geosmin and greater than 71% removal of MIB. Since MIB is more difficult to remove with ozone than geosmin, then the MIB removal requirement is expected to set the process design requirements. <u>For the purpose of this project, the ozone process will be evaluated with the goal of achieving no less than 71% destruction of MIB</u>.

OZONE APPLICATION IN DRINKING WATER TREATMENT

For decades, ozone has been used to disinfect drinking water and to destroy T&O chemicals and other micropollutants that may be present in water. In California, many agencies that draw water from the State Water Project (SWP) system use ozone for meeting the disinfection requirement as well as improving the overall aesthetic quality of their drinking water. In Northern California, the list of agencies that use ozone for water treatment includes the following:

- Alameda County Water District
- Santa Clara Valley Water District
- Contra Costa Water District
- San Francisco Public Utilities Commission
- East Bay Municipal Utilities District
- City of Vallejo
- Cities of Vacaville & Fairfield
- City of Napa
- City of Martinez

The downside to ozone use for water treatment is twofold: First, it is an expensive process to construct and operate. Second, when ozone is added to water containing elevated levels of bromide, it could generate bromate (BrO_3^-) above the maximum contaminant level (MCL) of 10 µg/L. SBA water used by Zone 7 frequently contains elevated bromide levels. In fact, an analysis of historical water quality data indicated that the 50th percentile bromide level in SBA water between 1993 and 2007 was 100 µg/L, while the 90th percentile was 290 µg/L. The maximum bromide concentration was recorded at >500 µg/L. At the typical ozone doses applied in drinking water treatment, bromide concentrations above 100 µg/L will result in bromate formation above the MCL unless a bromate control strategy is implemented in conjunction with ozone application.

OZONE VS. PEROXONE

Two configurations of an ozone system can be used for T&O control. The first is a conventional configuration where ozone is added into the water as it flows through a multi-chamber, over-under contactor with an average contact time of about 8 to 10 minutes. This contact time is required to give the ozone sufficient time to react with the target contaminants. This configuration is referred to in this report as Conventional Ozone. All the agencies listed above utilize conventional ozone contactors. This type of ozonation serves two purposes: destruction of T&O compounds and disinfection of microorganisms. The other configuration is a process in which ozone and hydrogen peroxide are added to the water. The combination of ozone and hydrogen peroxide generates hydroxyl radicals ($OH^\bullet$), which are stronger oxidants than ozone itself and require much shorter contact time to achieve T&O destruction. This process is referred to in this report as the Peroxone process. Due to the fast reaction time, a Peroxone process requires a significantly smaller contactor (2 to 4 minutes) compared to conventional ozone (8 to 10 minutes), and in some cases requires a lower ozone dose to meet the same T&O destruction goals. However, because of its short contact time, and the fact that the added hydrogen peroxide rapidly destroys the ozone residual, it cannot be used for disinfection of microorganisms. Therefore, if Peroxone is implemented at Zone 7's treatment plants, disinfection requirements must continue to be met with chlorine. None of the agencies listed above utilize Peroxone, although some were designed to be able to do so.

OVERALL PROJECT DESCRIPTION

This project assessed whether ozone or Peroxone should be implemented at the Zone 7 treatment plants, and identified the practical and financial implications of the implementation of either process. The specific activities included the following:

1. Conduct pilot-scale testing of ozone vs. Peroxone to determine the design criteria required by each process to meet Zone 7's T&O goals.
2. Using the results of the pilot testing, determine whether the ozone-based T&O process should be applied to the raw water, settled water, or filtered water.
3. Develop the design criteria, hydraulic requirements, and general layouts of an ozone or Peroxone process at each plant.
4. Develop probable costs for constructing and operating either process at each plant.
5. Identify the permitting requirements for implementing either process at each plant.
6. Identify the impact of implementing either ozone or Peroxone on the operation of each of Zone 7's water treatment plants.

A significant portion of this project was dedicated to the pilot testing effort. If conventional ozone were the only process being considered, pilot testing would not have been required since there is ample experience with ozone for the treatment of SBA water. However, since Zone 7's primary reason for the ozone process is T&O destruction and not disinfection, there was a reasonable expectation that the implementation of Peroxone instead of conventional ozone could result in a T&O control process that is less costly to build and operate. Unfortunately, there is little to no full-scale experience with the design and operation of a Peroxone process for drinking water treatment. In order to quantify the expected cost savings of a Peroxone process over a conventional ozone process, and to determine its design and operational requirements, it was necessary to conduct side-by-side pilot testing of the two processes.

PILOT PLANT CONFIGURATION & TESTING PLAN

The pilot plant was installed at the Del Valle WTP in Livermore and operated from May to October 2008. The pilot plant consisted of two parallel trains: a five-chamber conventional ozone contactor with a hydraulic residence time (HRT) of 10 minutes at a flowrate of 6.5 gpm, and a pipeline Peroxone contactor with an HRT of 2.6 minutes at a flowrate of 3.5 gpm. The pilot plant could be supplied with either raw water or settled water.

The ozone or Peroxone process could be inserted at the raw, settled, or filtered water locations at the Del Valle WTP, or at the raw or filtered water locations at the Patterson Pass WTP. In order to determine the best application point, information had to be gathered regarding the performance of each technology at each location, and its impact on downstream processes. Since chlorine is added upstream of the full-scale filters at DVWTP, it was not possible to obtained unchlorinated filtered water for pilot testing. For the purposes of this project, the settled water ozone performance results were assumed to apply to ozonation of filtered water.

Based on historical data, a T&O event is most likely to occur during summer/fall testing period. In order to gather sufficient data for the full-scale application, three rounds of challenge testing were conducted (June, August, and October). Each round took approximately two weeks to complete. During each round, tests were conducted to evaluate MIB and geosmin destruction with ozone and Peroxone under varying conditions of ozone dose, water pH, contact time, water source (raw or settled), chloramine addition for bromate control, and Peroxone ratio (which is the ratio of hydrogen peroxide dose to ozone dose). MIB and geosmin were spiked into the feed water to both contactors to simulate a T&O event.

In between the three rounds of challenge testing, operational stability testing was conducted to evaluate general operational requirements and limitations of each unit process when treating SBA water. These tests were designed to address issues related to the diurnal fluctuations in water quality, primarily pH and temperature, as well as the stability of the ozone residual in a conventional ozone contactor versus a pipeline Peroxone contactor.

Additional testing was done to evaluate the formation of various byproducts. Samples were collected from the contactor influent and effluent streams for Simulated Distribution System (SDS) disinfection by-product (DBP) formation testing. These tests were conducted to evaluate the impact of either ozone or Peroxone on the formation of THMs and HAAs upon subsequent chlorination. Samples were also collected for Assimilable Organic Carbon (AOC) from both processes as a measure of the amount of biodegradable organic matter created by each process. And finally, tests were performed to evaluate the expected levels of "emerging byproducts" by each process such as iodinated DBPs.

PILOT TESTING RESULTS

A large volume of data was collected from the pilot testing effort. The results provided great insight into the design, operation, and performance of the ozone and Peroxone processes for T&O destruction. Based on the results obtained and discussed in this report, the following observations and conclusions are made:

T&O Destruction in Raw Water

MIB and geosmin destruction testing in raw water was conducted at different pH levels and with or without prechloramine addition for bromate control. The following observations are based on the raw water testing results:

1. When applied to raw water without prechloramine addition, the ozone dose required to meet the MIB and geosmin destruction goals in the Peroxone process ranged from 1.2 to 1.5 mg/L, while that required in the conventional ozone process ranged from 2.0 to 2.5 mg/L. However, when prechloramine was added to the raw water for bromate control, the Peroxone process advantage greatly decreased, and the ozone dose required for both processes was approximately the same (2 to 2.5 mg/L). This suggests that chloramine may react with the hydroxyl radicals formed in the Peroxone process, reducing the overall process efficiency.
2. With bromide spiked to above 400 µg/L under most conditions, bromate formation without prechloramine addition was much higher than the MCL of 10 µg/L, even at the reduced pH of 6.5. The addition of prechloramine ahead of either process greatly reduced bromate formation. Nevertheless, under high bromide conditions, prechloramine must be combined with pH suppression to 7.5 or lower.
3. With the ozone doses required to meet the MIB and geosmin destruction goals, the ozone residual leaving the 10-minute conventional ozone contactor ranged from <0.05 mg/L to as high as 0.5 mg/L. On the other hand, the ozone residual in the water leaving the 2.6-minute Peroxone contactor were predominantly below 0.1 mg/L. For operator safety reasons, it is important that the ozone residual in the water exiting the contactor does not exceed 0.1 mg/L. This suggests that the conventional ozone contactor

operated to achieve high removals of MIB and geosmin will likely require the addition of an ozone-quenching chemical, such as calcium thiosulfate, in the last chamber of the contactor.

In summary, the raw water testing results showed that the addition of prechloramine for bromate control is necessary, but the added chloramine greatly reduced the advantage of the Peroxone process over the ozone process.

T&O Destruction in Settled Water

As was done with the raw water, MIB and geosmin destruction testing in settled water was conducted at different pH levels and with or without prechloramine addition for bromate control. The following are important observations made based on the settled water testing results:

1. The ozone dose needed for T&O destruction in settled water at pH 6.6 or 6.0 using conventional ozonation was very high. Under both pH conditions, a projected ozone dose of up to 4.5 mg/L could not achieve the target MIB destruction goal of 71% (this dose was projected from the MIB destruction curve). The Peroxone process was able to achieve the required T&O destruction in settled water at a reasonable ozone dose range of 1.2 to 2.1 mg/L. However, similar to the raw water results, prechloramine addition caused a slight deterioration in the T&O-destruction efficiency of the Peroxone process.
2. Without prechloramine addition, the bromate level formed in the ozone or Peroxone process was well above the MCL of 10 µg/L, even though the pH was at or below 6.6. The addition of prechloramine to the Peroxone process at pH 6.6 reduced bromate formation to a range of 9 to 10 µg/L.
3. Under all conditions tested, the ozone doses required for T&O destruction in settled water resulted in ozone residual levels in the effluent of each contactor that were well above the maximum desirable level of 0.1 mg/L. Therefore, an ozone residual quenching chemical would be required if either ozone or Peroxone is applied to the settled water.

In summary, the settled water testing results showed that only the Peroxone process is capable of meeting the T&O destruction goals, but that prechloramine addition is still required for bromate control, and a quenching chemical is required to destroy the high ozone residual leaving the contactor.

Operational Stability Testing

A significant portion of the operational stability testing focused on the impact of diurnal changes in raw water pH on the stability of the ozone or Peroxone process. In a single 24-hr cycle, the pH of the SBA water increase from a low of approximately 7.5 during the early morning hours to a high of 8.5 to 9.0 during the afternoon hours. The testing results demonstrated the strong impact of these diurnal changes on the ozone demand of the water. At low water pH, the ozone dose required to achieve a specific residual is much lower than the dose required at higher pH. Therefore, if a specific ozone residual is required at any point in the contactor, then the ozone control system much constantly increase and decrease the ozone dose to account for the variation in pH. However, a better approach is to utilize acid addition (e.g., carbon dioxide) to temper the pH fluctuations and maintain a relatively constant pH entering the ozone contactor. This would greatly stabilize the operation of the ozone system, as well as contribute to bromate control. This type of pH stabilization and resulting consistency of ozone residual was demonstrated during the testing period.

The Need for Biofiltration

The vast majority of ozone plants utilize biofiltration downstream of the ozone process. The reason is that ozone breaks down the natural organic matter present in all waters into smaller, more biodegradable, organic molecules. There is concern that the introduction of higher biodegradable organic matter into the distribution system will result in higher potential for bacterial growth. One way to reduce the amount of biodegradable matter is to remove it with biofiltration at the treatment plant. Biofiltration has been shown to be very effective at removing biodegradable organic matter. One way of quantifying the amount of biodegradable organic matter is using the Assimilable Organic Carbon (AOC) measurement. There are no public health concerns associated with the presence of biodegradable organic matter or AOC in drinking water, and therefore, they have no numerical limits.

Biofiltration was not evaluated in this project. However, AOC measurements were made in the effluent of the ozone and Peroxone contactors, and compared to the AOC levels in the raw water and treated water from the Del Valle WTP. For example, on June 1, 2008, the AOC level in the raw water at the DVWTP was measured at 37 μg/L, while that in the treated water from the plant was 151 μg/L. This increase is due to the use of chlorine at the plant. However, with the addition of 1.8 mg/L ozone to the raw water, the AOC level increased to 420 μg/L in the effluent of both the ozone and Peroxone processes. This is more than a 3-fold increase in AOC formation through the treatment plant. Similarly, upon ozonation of settled water, the AOC level increased from approximately 125 μg/L in the DVWTP effluent to a range of 220 to 420 μg/L in the water treated by either ozone or Peroxone.

Unfortunately, there is no specific AOC value that is used to gauge the need for biofiltration. However, based on the results obtained, and the desire to minimize the potential for additional bacterial growth in the distribution system, it is recommended that biofiltration be implemented in conjunction with either ozone or Peroxone.

Impact on the Formation of THMs, HAAs, and other DBPs

Simulated distribution system (SDS) testing was conducted to evaluate the potential impact of ozone and Peroxone on the downstream of formation of disinfection by-products (DBPs) after chlorine addition. SDS samples were collected from the raw water, raw water treated with ozone, and raw water treated with Peroxone. Each sample was dosed with chlorine for a one (1) hour contact time, and then dosed with ammonia to form chloramine. After exposure to chloramine for 24 hrs, the samples were analyzed for trihalomethanes (THMs) and haloacetic acids (HAAs). Similar tests were conducted with settled water, settled water treated with ozone and settled water treated with Peroxone.

The results showed that the DBPs formed in the chloraminated waters treated with ozone or Peroxone were consistently lower than those formed in the non-ozonated chloraminated water. In some cases, the reduction in THM and HAA formation was as high as 30%. DBP reduction at the full-scale treatment plant is expected to be greater because the free chlorine contact time will be shorter than one (1) hour. These results suggest that the implementation of ozone or Peroxone should greatly reduce the levels of THMs and HAAs in Zone 7's water distribution system.

While not initially planned, additional testing was conducted to address concerns over the potential formation of non-regulated DBPs. These DBPs included six iodinated THMs (I-THMs) and nine halonitromethanes (HNMs). Samples were collected from the raw water, current DVWTP effluent, and effluents of the ozone and Peroxone contactors treating raw or settled waters under various conditions. The samples were sent to Clemson University, South Carolina, for I-THM and HNM analysis. The results indicate that the I-THM and HNM levels formed with ozone or Peroxone implementation are expected to be equal to or lower than those formed under the current DVWTP treatment train. In general, the I-THM levels ranged from <0.5 μg/L to 2.3 μg/L, while the HNM levels ranged from 0.7 μg/L to 1.9 μg/L. Based on the results obtained, the utilization of ozone or Peroxone treatment at DVWP and PPWTP is not expected to increase the I-THM or HNM levels beyond the background levels currently formed at DVWTP.

SHORT-LISTED ALTERNATIVES

At the beginning of this project, there were six alternative configurations of the ozone-based T&O destruction process: 1) raw water ozone, 2) raw water Peroxone, 3) Settled water ozone, 4) Settled water Peroxone, 5) filtered water ozone, and 6) filtered water Peroxone. Due to the need for post-ozone biofiltration, the filtered water application point was ruled out. Based on the results of the pilot testing effort, the application of ozone or Peroxone to the settled water was eliminated from consideration for a number of reasons including the following:

1. With T&O destruction as the primary goal, the pilot testing results showed that conventional ozonation of the settled water could not meet the minimum MIB and geosmin destruction goals of >71% and >73%, respectively, with a dose as high as 4.5 mg/L. It was not apparent what dose, if any, would be able to meet these goals in the settled water within the 10 minute contactor. Therefore, only the Peroxone alternatives remain viable for the settled-water.
2. For settled-water application, the ozone residuals in the effluent of the 2.6-minute Peroxone contactor were consistently too high. This would mandate that either the contactor needs to be much larger (e.g., 10 minute HRT), or a separate ozone-quenching chemical would need to be added to destroy the ozone residual before the water exits the contactor. However, since the reaction between the quenching chemical and the ozone residual is not instantaneous, additional contact time would need to be provided after the quenching chemical addition. This would translate into a larger overall contactor.
3. Installing ozone or Peroxone anywhere other than the raw water at PPWTP is problematic because settled water ozonation is not possible on the membrane train due to the potential damaging effect of ozone or peroxide residual on the membranes. For the membrane train, the only viable locations are either raw-water ozonation or filtered-water ozonation. Filtered-water ozonation is problematic because ozone would be added downstream of any possible biofiltration using existing filters. Since biofiltration for AOC removal has been deemed necessary, filtered-water ozonation is not a viable option. This leaves raw-water ozonation at PPWTP as the only viable option.
4. Raw water ozonation has been shown by many water agencies to greatly improve the performance of the downstream chemical coagulation, flocculation, sedimentation, and filtration processes. These benefits would be greatly reduced with settled-water ozonation.

Therefore only raw water application of ozone or Peroxone was considered to be viable options for Zone 7's water treatment plants. As for the choice between ozone or Peroxone, the pilot testing results did not provide sufficient information for a clear selection. Each process had its advantages and disadvantages compared to the other. While the smaller Peroxone process would be expected to cost less to construct than the larger ozone process, the differences in ozone dose required was not as great as originally expected. In addition, the ability to satisfy the disinfection requirements of the Surface Water Treatment Rule with ozone but not with Peroxone gave a number of advantages to the conventional ozone process. Specifically, the need for biofiltration after ozone or Peroxone meant that chlorine addition would need to be moved downstream of the existing media filters. If Peroxone is used, then a new chlorine contactor would need to be constructed after filtration to meet the disinfection CT requirements. Such a contactor would not be needed under the ozone option since the CT requirements would be met through the ozone process. In addition, without a long free chlorine contact time, implementation of the ozone process would significantly reduce the levels of THMs and HAAs formed in the distribution system.

Due to the lack of a clear advantage of one process over the other, it was decided that both raw water ozone and Peroxone would be further evaluated, and that the cost of both processes would be estimated before a selection between the two processes is made.

FULL-SCALE DESIGN CRITERIA, LAYOUTS, & HYDRAULIC CONSTRAINTS

A careful analysis was conducted to identify the required modifications at both plants under the raw water ozone or raw water Peroxone option. Figures ES-1 and ES-2 include schematics of the required modifications at the DVWTP and PPWTP, respectively.

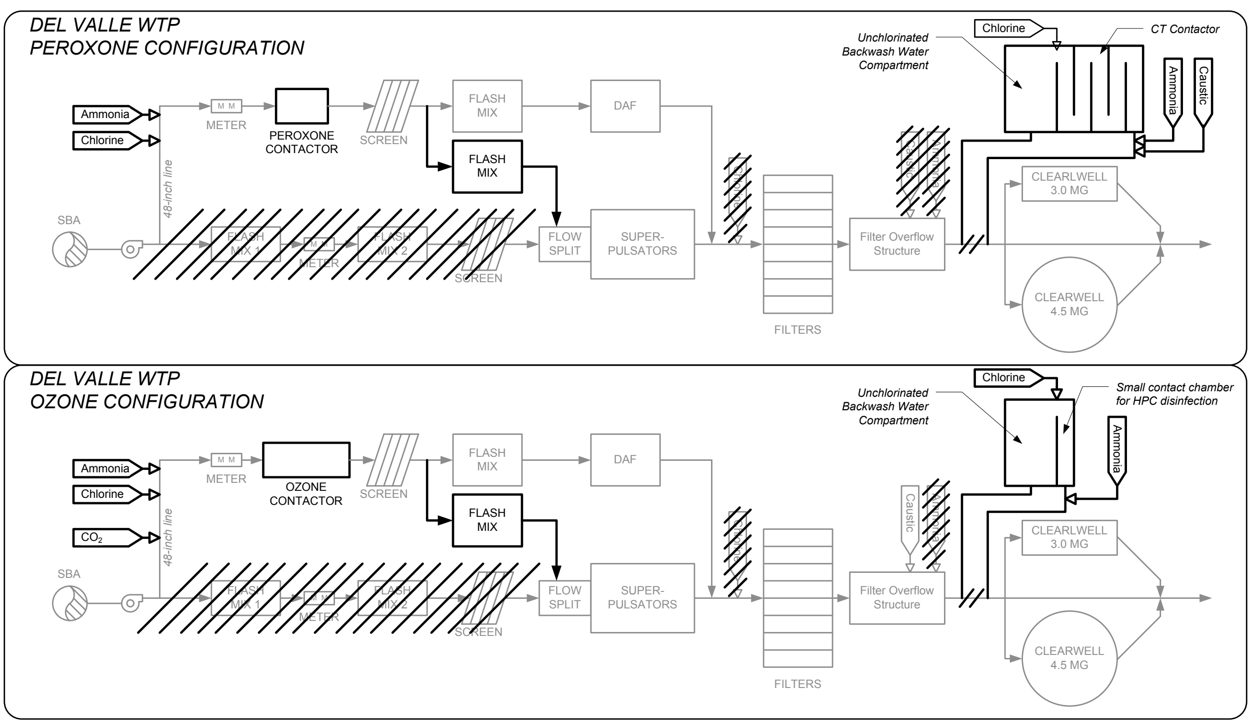

Figure ES-1 – Process Flow Diagrams for the Modified Del Valle WTP

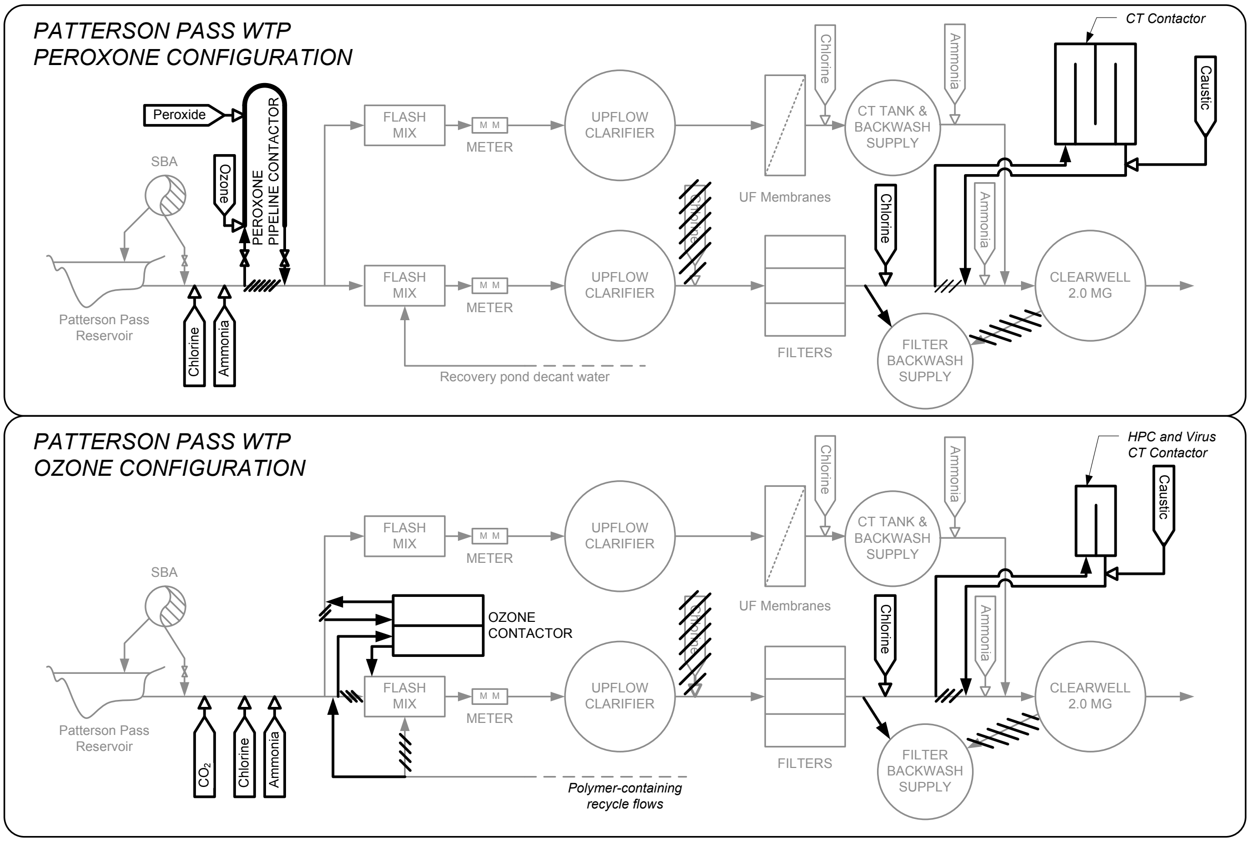

Figure ES-2 – Process Flow Diagrams for the Modified Patterson Pass WTP

As shown in Figures ES-1 and ES-2, implementing either ozone or Peroxone at DVWTP or PPWTP will require specific modifications and additions to each plant. For each plant, some modifications will need to be implemented with either technology, while some modifications are specific to just one technology. The following is a summary of the required modifications.

Required Modifications at the Del Valle Water Treatment Plant

The following modifications are required for the implementation of either ozone or Peroxone at the DVWTP:

1. Eliminate raw water pipe currently used to feed the Superpulsator® train, and feed the entire plant through the 48-inch diameter pipe currently feeding the DAF train. The existing influent meter station/vault will also be eliminated.
2. Retain the mechanical screen on the 48-inch diameter line.
3. Construct a new 48-inch line from the mechanical screen to the Superpulsator flow splitter box, and add a new flash mix on this line to allow for independent chemical treatment of the Superpulsator® train and the DAF Train.

4. Install new flowmeters on the DAF and Superpulsator® train feed pipes downstream of the mechanical screen.
5. Replace the existing 36-inch line between the raw water pumps and the 48-inch pipe with a 48-inch section.
6. Add a two-compartment tank in between the filtered water overflow structure and the clearwells. The first compartment will store unchlorinated backwash water source, and the second compartment will serve as a disinfection contact chamber.
7. Add a Liquid Oxygen (LOX) storage and feed system.
8. Add an air-scour system to supplement the water backwash system for the biofilters.

The following required modifications are specific to the implementation of ozone at DVWTP:

1. Add a CO_2 storage and feed system for raw water pH suppression.
2. Construct a multi-chamber ozone contactor
3. Construct an ozone-generation building containing three ozone generators and their ancillary equipment.

The following required modifications are specific to the implementation of Peroxone at DVWTP:

1. Construct a Peroxone contactor
2. Construct an ozone generation building containing two ozone generators and their ancillary equipment.
3. Add a hydrogen peroxide (H_2O_2) storage and feed system.

Required Modifications at the Patterson Pass Water Treatment Plant

The following modifications are required for the implementation of either ozone or Peroxone at the PPWTP:

1. Re-route the return washwater line (return flows without residual polymer) to a point in the raw water pipe upstream of the ozone or Peroxone process.
2. Add a LOX storage and feed system.
3. Add an air-scour system to supplement the water backwash system for the biofilters.
4. Re-plumb existing backwash water pump to draw from un-chlorinated filtered water to fill backwash water supply tank.
5. Possibly add new potable water supply, as it currently comes from backwash tank supply line.

The following required modifications are specific to the implementation of ozone at PPWTP:

1. Add a liquid CO_2 storage and feed system for raw water pH suppression.
2. Construct a dual-train ozone contactor with one train configured to serve the UF plant and one train configured to serve the conventional train.

3. Relocate the rapid mix of the UF train to a new location between the ozone contactor and the UF clarifier.
4. Relocate the return line of the pond decant to a location upstream of the conventional train ozone contactor.
5. Construct an ozone generation building containing three ozone generators and their ancillary equipment.

The following required modifications are specific to the implementation of Peroxone at PPWTP:

1. Construct a Peroxone pipeline contactor.
2. Construct an ozone generation building containing two ozone generators and their ancillary equipment.
3. Add a hydrogen peroxide (H_2O_2) storage and feed system.

OPINION OF PROBABLE COSTS

A planning level opinion of probable capital and annual O&M costs was developed for the application of ozone or Peroxone at DVWTP and PPWTP. The outcome of the analysis is presented in Table ES-1 below. It is noted that the ozone system was assumed to operate 365 days a year, while the Peroxone system was assumed to operate only 180 days each year, which is the anticipated maximum duration of the T&O season. The analysis demonstrated that the probable costs of implementing ozone and Peroxone at either plant are well within the accuracy of the cost projection. The total probable capital cost of implementing an ozone-based T&O control strategy at Zone 7's two treatment plants is projected at $33M, with the probable annual operating cost projected at $2.3 M/yr (both are in 2009 dollars). The average total probable annualized cost (capital and O&M) is projected at $5.3 M/yr. Using the annual Zone 7 water production in 2008 (45,216 AF), the impact of adding ozone or Peroxone at both plants is projected at $116/AF of total water produced.

Table ES-1 – Summary of Projected Probable Costs (2009 Dollars) of Implementing Ozone or Peroxone at DVWTP and PPWTP

Item	Del Valle WTP			Patterson Pass WTP			Probable Total
	Ozone	**Peroxone**	**Average**	**Ozone**	**Peroxone**	**Average**	
Capital Cost	$20.6 M	$20.0 M	$20.3 M	$13.3 M	$12.4 M	$12.9 M	**$33 M**
Amortized Capital Cost	$1.8 M/yr	$1.7 M/yr	$1.8 M/yr	$1.2 M/yr	$1.1 M/yr	$1.2 M/yr	**$3.0 M/yr**
Annual Operating Cost	$1.5 M/yr	$1.3 M/yr	$1.4 M/yr	$1.0 M/yr	$0.9 M/yr	$0.9 M/yr	**$2.3 M/yr**
Total Annual Cost	$3.3 M/yr	$3.0 M/yr	$3.2 M/yr	$2.2 M/yr	$2.0M/yr	$2.1 M/yr	**$5.3 M/yr**
Water Cost(1)	$73 /AF	$66 /AF	$70 /AF	$49 /AF	$44 /AF	$46 /AF	**$116 /AF**

(1) Based on 2008 total water production of 45,216 AF.

PROJECT SCHEDULE

The engineering portion of the project is expected to require 24 months from the selection of an engineering design firm, to selection of a construction contractor. Construction and startup activities are also expected to required 24 months. The exact start date for the project is not known at this time. However, based on an arbitrary start date of January 1, 2012, the ozone systems could be in operation by January 2016, a total of four years from start of design.

POTENTIAL IMPACT ON WTP OPERATIONS

The implementation of ozone or Peroxone at both plants is expected to result in improvements in the overall performance, and require changes in the current operations and maintenance practices at the plants. Specifically, the following impacts and changes are anticipated:

1. Pre-oxidation with either ozone or Peroxone is expected to result in lower filtered water turbidity and particle counts.
2. Pre-oxidation with ozone or Peroxone is also expected to significantly lower the ferric chloride coagulant dose required and the resulting sludge volume generated. The decrease in ferric chloride dose will also reduce the caustic soda dose required to raise the pH of the filtered water.
3. The need for biological filtration will require moving the chlorine addition point to a location downstream of the filters. This should not have an impact on the turbidity of the filtered water, but careful attention must be given to the selection of the appropriate filter aid polymer type and dose.
4. If conventional ozonation is implemented, the actual disinfection credit will change from the current value achieved with free chlorine. While the minimum requirements will always be met, the actual CT ratio during normal operation may be lower than the current values as plant operations will be set to minimize ozone usage.
5. Regardless of which option is implemented, the THM and HAA levels will be lower than those currently experienced at both plants.
6. If conventional ozone is implemented, the THM and HAA levels generated will be significantly lower than those generated under the Peroxone option. The reason is that under the Peroxone option, the disinfection requirements will still be met with free chlorine, while disinfection will be met with ozone under the conventional ozone option.
7. Implementing either ozone or Peroxone is expected to greatly improve the aesthetic quality of the water produced at both plants, including taste, odor, and color.
8. The Operations Plans for both plants will need to be updated with new Standard Operating Procedures (SOPs) pertaining to the various components of the ozone or Peroxone system.
9. A new disinfection sampling plan and calculation methodology will be needed, along with a new monthly report format.
10. Because both ozone and Peroxone will generate bromate, it will be important to monitor this regulated ozone by-product closely. When using ozone or Peroxone, monthly monitoring of

bromate is required, and the MCL of 10 μg/L must be complied with on a rolling 12-month average of monthly sampling results.

11. Additional online analyzers will be added with either ozone or Peroxone. These include ozone residual analyzers, as well as gas-phase ozone monitors.
12. Finally, implementing ozone or Peroxone at DVWTP and PPWTP will require staff additions. Specifically, one operator, one mechanic, one electrician, and one instrument technician should be added for both plants (i.e., half-time at each plant).

RECOMMENDED TECHNOLOGY

Based on the pilot testing results and all the analysis conducted in this effort, WQTS recommends that raw-water conventional ozonation be implemented at DVWTP and PPWTP. WQTS recommendation is primarily anchored in the following observations:

Cost – The primary reason for considering the Peroxone process was the belief that it is far less costly to construct and operate compared to a conventional ozone process. In the final analysis, these significant cost savings did not materialize, with the difference in the capital and O&M costs between the two processes being well within the uncertainty of the cost-estimating effort. While the cost of constructing a small Peroxone contactor is certainly less than that of a larger conventional contactor, a new filtered-water chlorine contactor is required under the Peroxone option, but not under the conventional ozone option. In addition, under some testing conditions, the ozone dose required for Peroxone was the same as that required under the conventional ozone option. This meant that the ozone generation system under the Peroxone option had to be designed to deliver the same dose as that under the ozone option. From an operational cost perspective, it was assumed that the Peroxone system will be operated only six (6) months each year, while the ozone system will be operated continuously (since it is the primary disinfection process). Even under this assumption, the annual O&M costs of the two technologies were similar.

Experience – To our knowledge, all California water agencies that use ozone utilize a conventional ozone system design. It is noted that disinfection, not T&O destruction, has been the primary goal of most other agencies. The experience gained by these agencies, which includes the two other SBA water users, ACWD and SCVWD, in the operation and troubleshooting of the conventional ozone system will help make the transition to ozone a smooth one. On the other hand, there is no known large-scale Peroxone process in operation at a surface water treatment plant. This lack of full-scale experience with the operation of this process means that Zone 7 staff would need to go through a long “learning curve” before they can comfortably operate the process.

Ease of Operation – In the operation of water treatment processes, there is always a benefit to a process that provides the operator with sufficient time to respond to operational upsets without compromising the overall treated water quality and water production. For example, large sedimentation basins in conventional treatment plants are more tolerant of sudden changes in water quality or interruptions in upstream chemical feeds compared to compact clarification processes. The same applies to a 10-minute conventional ozone process compared to a 2-minute or 3-minute Peroxone process. With such a short contact time, interruptions in the hydrogen peroxide feed system would almost immediately increase the ozone residual in the contactor effluent water to unacceptable levels before the operator has a chance to remedy the problem. Similarly, interruptions in the peroxide feed would have an immediate effect on the downstream chlorine residual. When applied to the treatment of a groundwater with stable water quality, a Peroxone process could be stable to operate. However, it is likely to be less stable when applied to the treatment of surface water with its constantly changing water quality.

In the final analysis, for Zone 7 to take on the risk of being the first to implement a large scale Peroxone process for T&O control, the process should offer a substantial economic advantage over the more-established conventional ozone process. This study showed that Zone 7 would not realize such an economic advantage. For this reason, WQTS recommends that a conventional ozone process be implemented at DVWTP and PPWTP for T&O control.