Palmdale, CA Water District Chooses GAC Treatment to Meet TTHM Guidelines for Today and Tomorrow

By Palmdale Water District, Palmdale, California

Named one of the fastest-growing cities in America in the 1990s, the City of Palmdale has experienced tremendous growth and prosperity over the last two decades. The more than 152,000 Palmdale residents enjoy big city conveniences in a comfortable, "hometown" feel.

With the median age just under 30 and a strong commitment to families, the city offers abundant recreational opportunities and some of Southern California's most affordable homes even though it is located just 60 miles north of Los Angeles. It is also the location of a burgeoning aerospace industry, making it the "aerospace capital of the world."

With the area's continued dynamic growth, the Palmdale Water District is committed to delivering high quality water to the population it serves. The District delivers water to roughly 27,000 locations serving approximately 75% of the City of Palmdale's total population. The District's treatment facility produces between 30 and 35 millions of gallons per day (MGD).

Palmdale Water District's system treats both the California State Water Project surface water from northern California and the local surface water from the San Gabriel Mountains. When the District's old treatment system (built in the 1980s) began to show its age, Palmdale looked for treatment alternatives. The goal was to not only deal with any seasonal taste and odor problems, but also comply with the U.S. Environmental Protection Agency (EPA) Stage 2 Disinfectant By-products Rule (DBPR). This rule is designed to help reduce potential cancer and other health risks in drinking water through the reduction of Total Trihalomethanes (TTHM) and/or Haloacetic Acids (HAA)

CalgonCarbon

Addressing the Issues

Background – System TTHMs Levels

In 2002, the Palmdale Water District began collecting TTHM samples at the sixteen (16) DBPR Stage I monitoring locations. The system-wide average from January of 2002 through October of 2008 was 58 µg/L. Currently, the maximum contaminant level (MCL) for TTHM is 80 µg/L, which is based on a running annual average of quarterly results. However, the Stage 1 DBPR will soon be amended to Stage 2 DBPR levels which require compliance to be based on a Locational Running Annual Average (LRAA). This will mean that all locations have a TTHM running annual average of less than 80 µg/L. This presented a problem for Palmdale as several of the locations within the distribution system have historically had LRAAs greater than 80 µg/L.

Beginning in 2004, the Palmdale Water District, in cooperation with the American Water Works Association (AWWA), evaluated several different methods for meeting the upgraded water standards most effectively, including ion exchange, additional chemical treatment, and treatment with granular activated carbon (GAC).

The District wanted to look at all the relevant water treatment technologies that were available to them, so they began with what they thought would be the least expensive process improvements. Palmdale also piloted ozone and some other processes, but again the mineral content and brominated species in the water produced high levels of bromates. It seemed that for every problem these treatments solved, one or more additional problems were created.

Palmdale then piloted GAC for removal of the organic disinfectant by-product precursors. The subsequent full-scale implementation of GAC technology allowed them to achieve the total organic compound removal levels they needed while reducing their taste and odor problems.

Pilot Studies Demonstrate Viable GAC Economics

Initially, GAC was not deemed economically feasible; operation and maintenance (O&M) costs were first estimated to be as high as $7 million per year. However, as the GAC pilot program continued, actual costs were shown to be much lower. Changes in the activated carbon industry also helped bring projected costs down to approximately $4 million per year.

Then, as the GAC pilot program showed increasingly better results, projected GAC costs dropped to approximately $2 million per year, making the choice of GAC as a primary water treatment medium both economical and effective. GAC was chosen as the best alternative for meeting both state and EPA Stage 2 DBP requirements. GAC also has the potential of meeting Stage 3 regulations depending on their final form.

Testing

Pilot Plant Operation

Palmdale Water District operation and maintenance staff constructed a GAC pilot plant that consisted of six contactors. Water from the combined filter effluent (the same water that feeds the full size GAC contactors) flowed into the top of each contactor and flowed out the bottom after traveling through a bed of GAC. The volume and flow was adjusted to achieve an empty bed contact time (EBCT) of 15 minutes for each contactor. Flow meters were placed on the discharge line of each contactor to record the total volume of water treated.

Regular samples were collected from the pilot plant influent as well as individual contactor effluents. These samples were analyzed for total organic carbon (TOC). Each paired sample was used in conjunction with the flow data to calculate the pounds of TOC removed.

For the purpose of the initial pilot plant study, Palmdale Water District pre-determined that the GAC in a pilot contactor would be considered "expended" when its TOC removal capacity was reduced to 30%. This happened in a matter of weeks for the wood- and coconut-based GAC products, but took nearly four months for the three coal-based GAC products. The testing of the three coal-based products was concluded on the day when one of the three reached the 30% level. It is believed that if these pilot contactors were allowed to remain in service for several more months, a TOC reduction in the range of 25 to 30% would have been achieved, assuming the same performance for the full-scale contactors. Palmdale Water District will be conducting further studies to track the TOC reduction rates.

GAC Selection Process

Palmdale Water District operation and water quality staff obtained GAC samples from different vendors to test in the pilot plant. To ensure a fair comparison, a GAC with a mesh size of 8 x 30 was requested from each vendor. The physical properties of each GAC sample were analyzed by the Palmdale Water District laboratory staff to ensure uniformity in mesh size. GAC manufactured from different materials was tested to determine which material was most effective at removing the TOC in the California source water.

These base materials included:
- Bituminous Coal
- Coconut
- Wood

Additionally, Palmdale Water District wanted to compare the quality of imported GAC against that of domestic GAC. Table 1 shows the results of the different GAC samples tested in the pilot plant. It is evident from these results that GAC manufactured from bituminous coal is better suited to remove TOC from the State Water Project water than is GAC manufactured from coconut or wood.

Adsorption Testing

GAC removes TOC by the process of adsorption. An accepted standard used to determine the adsorptive capacity of GAC is the Iodine Number. In simple terms, the Iodine Number for a particular GAC is the number of milligrams of Iodine that a gram of the GAC can adsorb. It is worth noting that the Iodine Numbers for the coconut and wood tested by Palmdale were approximately 15% higher than the Iodine Numbers for the coal-based products. The results of this pilot testing showed that the coal-based products performed remarkably better than the wood- and coconut-based products. For this reason, Palmdale Water District will not use the Iodine Number as a basis to compare the adsorptive capacity of various GAC. However, Palmdale Water District will continue to use the Iodine test as a quality control check for each load of GAC received.

Pilot vs. Full Scale

The data collected to date indicate that the pilot plant performance is very similar to the full-scale contactor performance. When comparing the weight requirements of GAC to remove a pound of TOC, the pilot plant showed that for GAC #6, fifty pounds of GAC were required for every one pound of TOC removed. Keeping in mind that the test was concluded with GAC #6 continuing to remove greater than 30% of the TOC, it is likely that this 50 pound number could be reduced to 30 pounds or less of GAC per pound of TOC removed in actual plant operation.

Full Scale Operation Begins

In November 2008, the Palmdale Water District began using GAC contactors for the primary purpose of reducing TTHM levels in the distribution system. The new plant was designed by Carollo Engineers of Fountain Valley, CA, and went into service in December 2008. The new plant allows operators to blend the State Water Project surface water and the local surface water that goes through the system. It also allows them to bypass the system when appropriate, thereby providing a high degree of flexibility in meeting water quality standards. Since that time, the entire filtered effluent production has been pumped through the GAC contactors. Graph 1 shows the average TTHM levels within the distribution system from January 2008 to February 2010.

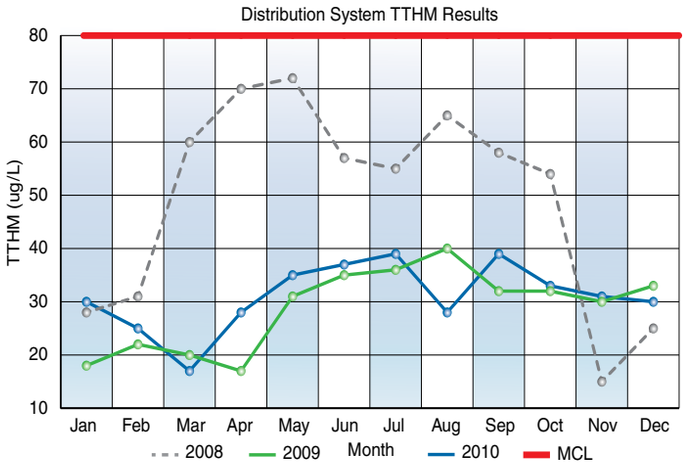
Table 1[1]

Pilot Contractor	Source of GAC	GAC Weight (lbs)	TOC Removed (lbs)	GAC/ TOC (lbs)
GAC #1	Domestic Coconut GAC	60	0.21	286
GAC #2	Imported Bituminous Coal GAC	67	1.23	54
GAC #3	Imported Coconut GAC	61	0.23	265
GAC #4	Domestic Wood GAC	35	0.31	113
GAC #5	Domestic Bituminous Coal GAC	67	1.09	61
GAC #6	Domestic Bituminous Coal GAC	67	1.35	50

Results

GAC Treatment Drops Average TTHM Levels Significantly

From January 2008 until October 2008, just prior to bringing the GAC contactors online, the average monthly TTHM for Palmdale was 54 µg/L. For the comparable period from January 2009 to October 2009, the average was 29 µg/L. The average TTHM from November 2008 to February 2010 was 28 µg/L. This meant that using GAC resulted in an approximately 47% reduction in average distribution system TTHMs.



GAC Report - Graph 1[1]
Graph taken from April 2010 report

The GAC contactors went online in November of 2008 and have resulted in a marked reduction in TTHM levels within the distribution system. Table 2 shows the system Running Annual Averages for TTHMs from 2002 to 2010, with 2009 and 2010 representing full years of operation with GAC.

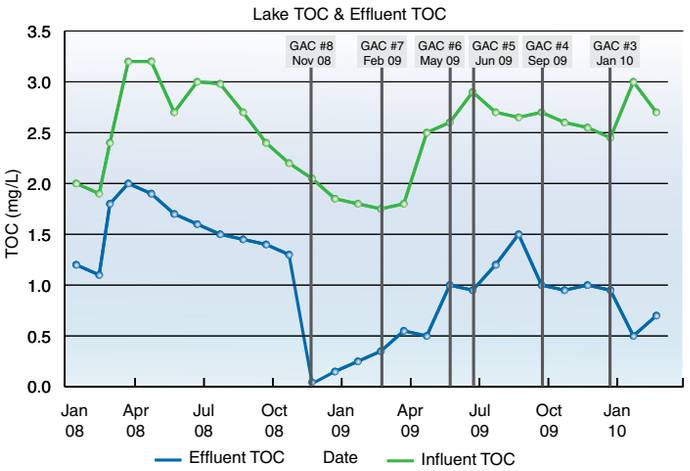
Table 2[1]

Year	TTHMs RAA (µg/L)	Year	TTHMs RAA (µg/L)	Year	TTHMs RAA (µg/L)
2002	73.5	2005	53.7	2008	54.4
2003	73.0	2006	51.1	2009	29.1
2004	49.5	2007	54.6	2010	30.9

When evaluating these numbers, it is important to note that there was a shift towards using more surface water in 2009. In 2008, the ratio of ground water to surface water was 39% to 61%. In 2009, the ratio was 35% to 65%. This shift towards surface water should have resulted in higher TTHMs. However, it appears that due to the use of GAC, TTHM levels did not increase from 2008 to 2009.

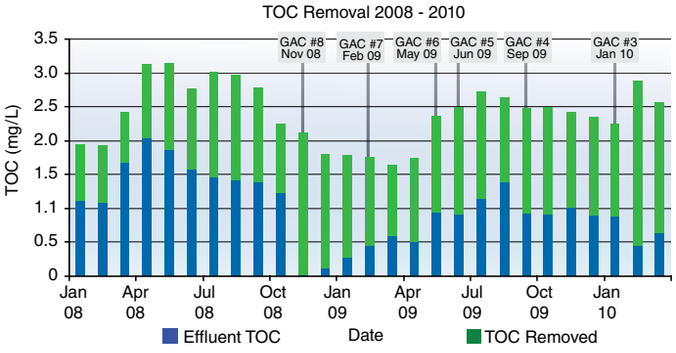
Raw Water Quality and Plant Effluent TOCs Improved

Graph 2 displays raw water and plant effluent TOC data from January 2008 through February 2010. Additionally, it shows the sequencing of the GAC contactors. When a new contactor came online, the prior contactors remained in service.



GAC Report - Graph 2[1]
Graph taken from April 2010 report

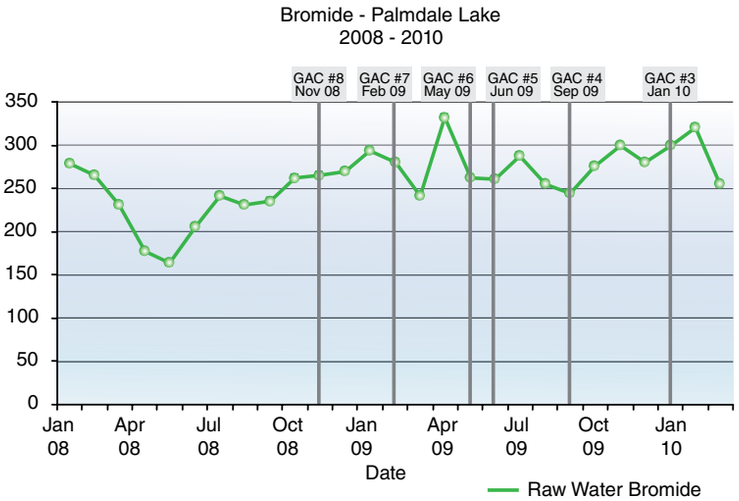
The average TOC from January 2008 to October 2008, prior to the use of GAC, was 2.6 mg/L raw and 1.5 mg/L effluent, for an average reduction of 42%. For the comparable period after the GAC contactors came online – from January 2009 to October 2009 – the average TOC was 2.2 mg/L raw and 0.8 mg/L effluent, for an average reduction of 64%. The average TOC since the introduction of GAC, from November 2008 to February 2010, was 2.3 mg/L raw and 0.7 mg/L effluent, for an average reduction of 70%. The data clearly demonstrate that the introduction of GAC improved TOC reduction 22 percentage points (from 42% to 64%) over a comparable period, constituting an improvement of 52%. Graph 3 displays percentage removal of TOC for the same time period.



GAC Report - Graph 3[1]
Graph taken from 2010 report

TTHM Removal Remains Constant Despite Bromide Increase

Chlorination of drinking water when bromide is present can result in the formation of brominated TTHMs. Research has indicated that increased levels of the bromide ion in the water lead to increases in TTHM, with increases of bromodichloromethane (BDCM) being especially pronounced[2]. The average raw water bromide levels for Palmdale's water between January 2008 and October 2008 was 230 µg/L. The average raw water bromide levels for the same water from November 2008 to February 2010 increased to 270 µg/L. This represented a 17% increase in average bromide between the two time periods. Consequently, there should have been an increase in Palmdale's TTHM levels from November 2008 to February 2010. However, despite the increased bromide levels, no increase in TTHMs was observed from the point of introduction of GAC as a treatment medium. The GAC contactors proved fully capable of dealing with the increase.



GAC Report - Graph 4[1]
Graph taken from April 2010 report

Cost Analysis

Post filtration GAC contactors have been shown to be very effective in the reduction of Total Organic Carbon. The current issue that Palmdale Water District confronts is balancing the cost of treatment with achieving water quality goals. From a financial perspective, the question is: "How much does this technology cost per acre-ft of water treated?" There is not a simple answer to this question, as each water source and treatment plant is unique. Palmdale Water District endeavored to create a "rule of thumb" that may be helpful to other water districts considering the use of GAC. Looking at the last 26 months of operation using GAC contactors, the Palmdale Water District was able to determine the cost per acre-ft of water treated at current market cost for GAC. Following is the summary data used to calculate treatment cost.

Two-Year Totals[1]	
Plant Flow (acre-ft)	28,783
GAC Used (lbs)	1,760,000
TOC Removed (lbs)	59,609
GAC/TOC (lbs)	30
GAC Cost/lbs ($)	$1.25
Cost/acre-ft ($)	$76.43

Conclusions

The predominant cost associated with GAC has been the purchase of the GAC media. The addition of GAC has affected the way in which the plant is operated and, as the operation has changed, so have the associated costs. The following is a summary of operational changes in the Palmdale Water District and how they have affected the cost of treatment:

1. Coagulation

The addition of GAC for TOC removal means that there is now more flexibility in how the primary coagulant is dosed. The Palmdale Water District no longer carries the burden of achieving high levels of TOC removal within the coagulation sedimentation process. This has allowed the District to dose its primary coagulant strictly with turbidity removal in mind, leading to a reduced dosage and resultant cost savings in the chemical budget.

2. Taste and Odor Control

Prior to the addition of GAC, powdered activated carbon (PAC) was used to reduce taste and odor problems typically associated with algal blooms. Since the addition of GAC to the process, PAC is no longer needed, and taste and odor complaints have fallen off dramatically. The elimination of PAC has reduced the cost of treatment by $4 to $7 per acre-foot, depending upon raw water conditions. Costs are expected to fall even further as a result of the decision to reactivate and reuse the GAC when spent, as opposed to replacing the spent GAC with virgin GAC.

3. Boosting

Filtered water must now be boosted to the GAC contactors. This has added to the plant's overall power consumption, though the additional cost seems to be offset by lower chemical costs to achieve approved treatment levels.

What it all Means

The Palmdale Water District's choice of GAC is helping it achieve compliance with currently regulated DBPs, while also providing a solution to the District's taste and odor challenges. The versatility of GAC is also expected to help the District meet future U.S. EPA regulations covering such issues as emerging DBPs and other contaminants of emerging concern (CECs). Projected results show a triple bottom line benefit for the District's use of GAC including a reduced carbon footprint (through the use of reactivated GAC), a cost effective means of meeting current and future regulations, and an emphasis on quality through broad range contaminant removal.

4. GAC Media Usage – Economics and the Environment

Given Palmdale's typical TOC and bromide ranges, the District believes that Stage 2 DBPR compliance can be achieved with 4 to 5 change-outs of the system's eight contactors each year depending on the raw water quality. This works out to a cost of approximately $80 to $100 per acre-ft if fresh GAC is used in each change-out. Assuming that custom reactivated GAC performs as well, the cost could be reduced to $60 to $75 per acre-ft. Reactivation represents both a potential economic and environmental gain for Palmdale. Through reactivation, spent carbon from the plant can be safely recycled, eliminating the costs and long-term liability associated with disposal. In addition to the economic benefits, custom reactivation of GAC also provides an environmental advantage over disposing of the spent GAC and replacing it with newly manufactured virgin carbon. Typically, custom reactivation generates only 20% to 25% of the emissions associated with the manufacture of new GAC. Taken in conjunction with the obvious benefit of eliminating the need to landfill or incinerate spent carbon, custom reactivation clearly improves the environmental aspects of activated carbon use.

5. Moving Forward

Staff at the Palmdale Water District is currently pursuing the potential for further cost savings through introduction of enhanced coagulation on a limited basis and in conjunction with GAC use. While using enhanced coagulation as the sole means of achieving Stage 2 compliance was ruled out in the early stages of the project, it is thought that a limited use of enhanced coagulation in tandem with the use of GAC may allow the District to operate the facility using extended GAC contactor run times and with fewer GAC change-outs.

References:
1. *Granular Activated Carbon – A Review of Operations and Testing.* Prepared by the Palmdale Water District Water Quality and Operations staff, January 12, 2010.

2. *Investigating effects of bromide ions on trihalomethanes and developing model for predicting bromodichloromethane in drinking water.* Chowdhury S, Champagne P, James McLellan P. Department of Civil Engineering, Queen's University, Kingston, ON, Canada K7L 3N6. shakhawat@ce.queensu.ca. Erratum in: Water Res. 2010 May;44(10):3311.

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