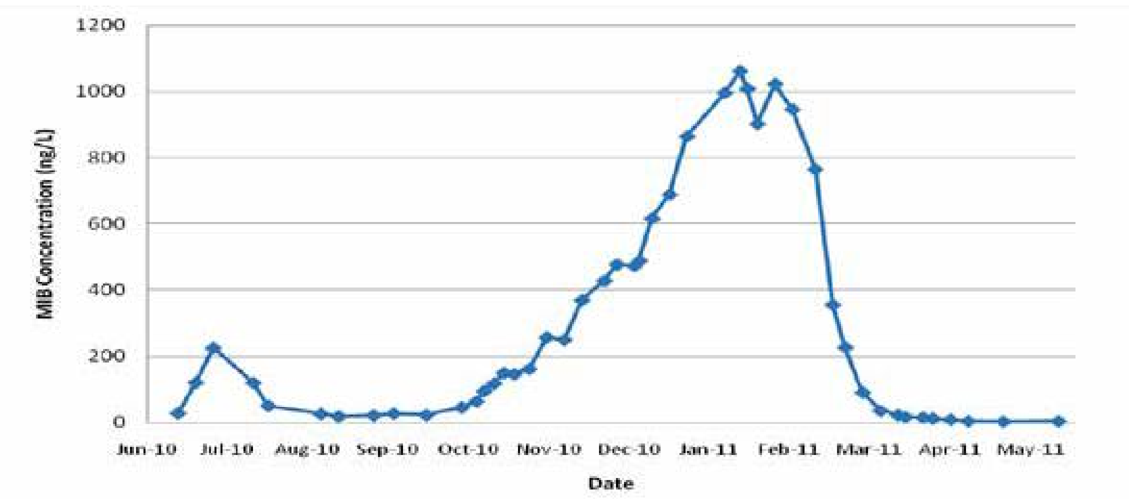
City of Alliance Water Treatment Plant: Solving a Taste and Odor Problem Step-by-Step

By: Terry Keep, Trojan UV, Said Abou Abdallah, ARCADIS, and Dr. Dean Reynolds, Superintendent, City of Alliance

The City of Alliance Ohio's water system has experienced annual Taste and Odor (T&O) events since the mid 1950's, when the first of two reservoirs, Deer Creek Reservoir, was placed into service. Nutrient contaminants, in particular phosphorous, in the watershed accumulate in the reservoirs causing algal blooms. The blue green algae, also known as cyanobacteria, produce two aesthetically offensive secondary metabolite compounds, 2-methyisoborneal (MIB) and trans-1,10-dimethyl-trans-9-decalol (Geosmin). Although both compounds occur in high concentrations in the reservoirs, frequent testing showed that MIB is the primary compound causing T&O problems in the city's drinking water. MIB can be detected by a few very sensitive persons as low as 7 ng/L (parts per trillion, ppt) but most people cannot detect MIB until it is greater than 20 ppt.

A particularly bad T&O event occurred in the winter of 2009 when the MIB level reached 340 ppt. The City was flooded with complaint calls. The Alliance Water Treatment Plant (WTP) fought the problem with the available treatment processes. The main process used for removing MIB was powder activated carbon (PAC). In addition, 24 in. of granulated activated carbon (GAC) capping the eight filter beds in the plant had shown some seasonal success at removing MIB. Concentrations for a typical 12-month period are presented for 2010 and 2011 in Figure 1. The highest MIB concentration during that time was 1100 ppt.

Figure 1. MIB Concentrations, June 2010-May 2011



MIB concentrations in raw water flowing into the Alliance WTP from Deer Creek Reservoir for a 12 month period from June, 2010 until May, 2011.

Since the 2009 T&O event, the WTP has learned much about the cause and frequency of T&O events in the reservoirs, and how to maximize MIB removal using the available processes. Testing has shown that MIB removal with GAC alone (without PAC) is excellent in the warmer months. This is attributed to the biological activities when of the GAC which is effective even at MIB levels of 1,000 ppt or higher. Once the raw water temperature decreases in the fall, usually in October, and during winter and spring months, GAC loses biological activity. It becomes incapable of removing MIB, unless the GAC has recently been replaced with reactivated or virgin GAC., usually within the last six months

Over the last five winter T&O seasons, the City of Alliance has spent a total of more than $1,000,000 to feed PAC for T&O removal and to make the water palatable. Changes in the treatment train have also improved MIB removal. By running the two treatment basins in series and using the first as a carbon contact tank prior to coagulation, the contact time with PAC was increased and MIB removal increased by about 15%. The WTP evaluated different PAC products to determine the best alternative for the limited PAC delivery system. The wood based PAC was used and found to be more effective than the charcoal based PAC although it was almost twice the cost.
The WTP strategy to remove T&O has been a two-pronged approach. The first is by sampling and extensive testing in the watershed to search for sources of nutrient contaminants, in particular phosphorus. Over 60 testing sites on tributaries and in the two reservoirs have identified multiple sites of contaminant origin. Two small villages have been found to be possible sources of septic. In these areas, septic overflow is discharged into the village's drainage system which flows directly into the reservoirs. At least one entire rural housing allotment in the watershed contributes to the contamination because their 1960 and 1970's era leach bed home septic systems are no longer functioning. Other homes have also been found to have essentially failed home septic treatment, and subsequently more of their septic waste flows into the reservoirs. Agriculture contribution, in particular from dairy operations also contributes to the phosphorus concentrations in the reservoirs. The City has been working with various governmental organizations to find funding and solutions to the many sources of nutrient contamination problems.

The second approach is at the treatment plant. The current treatment with PAC is inefficient at the high MIB levels produced in the reservoirs and the cost to treat is unsustainable. After the 2009 extreme T&O event, the search began for a more efficient and more cost effective treatment process. Increasing the capacity of the PAC feed system; the use of ozone with hydrogen peroxide in an Advanced Oxidation Process (AOP) and the use of ultraviolet light (UV) AOP with hydrogen peroxide were considered (Table 1).

Table 1. Comparison of PAC and UV-Oxidation Treatment.

	PAC	UV-Oxidation
Capital Costs	• Hopper • Feeding system	• Hydrogen Peroxide tank with hands-off dosing unit • UV reactors and panels
Operating Costs	• PAC supply (expensive and volatile) • Manual pouring of PAC into hopper • PAC can load downstream filter systems, requiring the use of a separate dewatering unit • Solids handling, disposal and transportation	• Hydrogen Peroxide supply • Electricity for UV lamps • Lamp replacement
Operator Safety Concerns	• Air-borne carbon particles is a health concern	
Removal Guarantee	• None (20-30% removal typical)	1.5-log MIB

continued on page 62

continued from page 61 - alliance

The addition of ozone to the plant involved the construction of a separate ozone generator building and contact chamber. The City of Alliance also previously considered the use of ozone for another problem but decided against it due to the capital investment. Ozone, used alone or combined with hydrogen peroxide, is widely used for controlling drinking water taste and odor problems.

Ozone, however, was not selected for the Alliance WTP because it requires higher capital cost, is more complex to retrofit and operate than UV AOP. Ozone is more suitable for year around operation where multiple long duration T&O episode occurs every year. Alliance water supply typically has seasonal T&O episodes per year lasting only for few months.

Because the plant was already using PAC as the primary T&O removal process, the advantages and limitations of the technology were known. PAC is a treatment process with relative low capital cost, but with high material cost. Over the last five years, PAC prices have been volatile and on the rise, making it very difficult to accurately project budget costs. There is also a health concern for operators handling PAC due to the air-borne carbon particles. One operator had injured their wrist lifting the 40 lb. bags of PAC, requiring surgery and Workers' Compensation time off. During extreme T&O events, the operators dedicated the majority of the work day securing the feed rates of the PAC system. The PAC feed system at the WTP consists of bag feeders with simple hoppers and gravity feed slurry systems. The two units were and in need of major refurbishing due to the extensive use over the past 20 years of operation. In order to expand the PAC feed system to address the extreme levels of MIB, a larger slurry type feed system with slurry tanks and larger feed equipment would be required. The limited available space at the WTP and the associated cost for the additional tanks, feed equipment and building made this option less appealing.

UV-Oxidation using hydrogen peroxide (UV AOP) for T&O removal was a new technology when Alliance began researching possible solutions in 2009. The equipment requirements involve feeding hydrogen peroxide using a hands-off dosing unit and UV reactors with control panels. Operating costs – consisted of electricity for UV lamps and hydrogen peroxide and chlorine (used for quenching the hydrogen peroxide after the UV units). Utilizing the UV AOP system would require no new tanks and a very small hydrogen peroxide feed building.

An attractive choice for Alliance was to destroy the MIB using UV AOP. After visiting one of the three such installations in North America, Alliance decided to implement the UV AOP process. This was initiated by engaging with ARCADIS, the City's engineering consultant to prepare the necessary documents a for constructing a UV AOP system at the Alliance Water Treatment Plant.

Table 2. UV AOP Design Criterion

Parameter	Concentration
pH	6.7-6.9
Nitrates	< 1 mg/l
TOC	< 3 mg/l
Hardness	120 mg/l (as calcium carbonate);
Alkalinity	50 mg/l
Iron	< 0.04 mg/l
Manganese	0.05 mg/
COD	5.2 mg/l
Turbidity	< 0.06 NTU
UVT	92%.
Average Design Daily Flow	5.5 MGD
Max Design Daily Flow	10.0 MGD

The engineering approach to address the implementation of the Alliance WTP UV AOP project was proposed in three steps. The first step was for the preparation of a feasibility study to identify the associated costs with a UV AOP system as compared to the proposed benefits. Subsequent to that, a procurement document would be needed to solicit bids for the purchase of the UV AOP equipment. Thirdly, a detailed design document would be prepared to construct the needed upgrades. The feasibility study was completed in July 2011, with the procurement process in late 2011.

Early on, a design criterion was established so that the design parameters would be clear and concise. This was essential, because these parameters governed the performance of the UV AOP system and the associated operation and capital costs. The filtered water at the WTP was sampled and tested to represent the water that would be entering the UV AOP system. Table 2 represents the design criterion that was used.

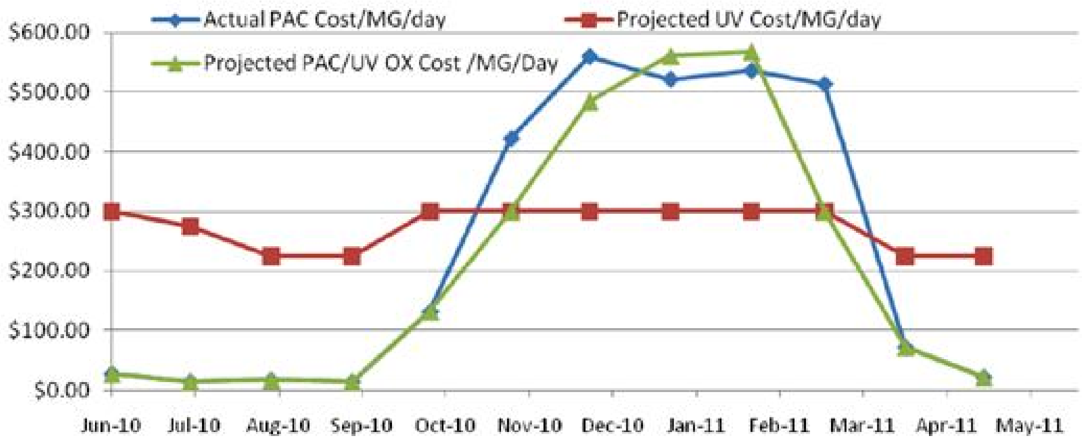
In addition, three scenarios were established using different MIB concentrations at different times and at different removal rates to represent the experience at the Alliance WTP. Two experienced UV equipment manufacturers were engaged to provide preliminary proposals for UV AOP for the following filtered water conditions:

1. **Influent MIB concentration at 300 mg/l, flow at 5.5 MGD and minimum 1.5 log removal.**
2. **Influent MIB concentration at 100 mg/l, flow at 5.5 MGD and minimum 1.5 log removal.**
3. **Influent MIB concentration at 60 mg/l, flow at 5.5 MGD and minimum 1.0 log removal.**

The manufacturers were requested to provide information specific to the total number of units that would be recommended; number of units in operation at each of the above listed conditions; associated electrical usage; hydrogen peroxide dosage; minimum log removal and projected chlorine dosage to 'quench' the hydrogen peroxide. Fixed unit costs were provided for electrical power, hydrogen peroxide and chlorine.

The information received from the two manufacturers was analyzed and applied to the period shown in Figure 1, June 2010 thru May 2011. The analysis was made to compare the actual cost of PAC used during the 12 month period to the cost of a UV AOP system. Costs were developed for each treatment process on a million gallon/day basis and then applied to the actual daily flows. Figure 2 identifies the costs for the 12 month period.

Figure 2. Cost Comparison (Million gallon/day basis)



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continued from page 63 - alliance

The results of the analysis are shown in Table 3. It was clear that during times of low MIB concentrations, the use of PAC was more cost effective. This was evident during the months of June, July, August, September and October of 2010 and April and May of 2011. However, when the MIB concentrations increased to 300 ppt and higher, and the water temperature decreased, the UV AOP system was more cost effective. The feasibility study projected that during the test period, the City would have realized a $102,600 in savings had a UV AOP system been used.

Table 3. Cost Comparison of PAC and UV AOP Treatment

Month and Year	Influent MIB (ng/L)	Average Flow (MGD)	Actual PAC Costs	Projected PAC/UV AOP Costs
June, 2010	125.53	3.2	$2,665.23	$2,665.23
July, 2010	86.50	3.7	$1,700.29	$1,700.29
August, 2010	23.07	3.5	$1,899.18	$1,899.18
September, 2010	25.90	3.4	$1,519.20	$1,519.20
October, 2010	112.33	3.2	$13,068.90	$13,068.90
November, 2010	326.63	3.0	$38,017.41	$27,000.00
December, 2010	549.46	3.2	$55,538.10	$48,087.57
January, 2011	967.06	3.3	$53,348.20	$57,364.10
February, 2011	911.53	3.3	$49,498.78	$52,469.39
March, 2011	125.67	3.2	$50,933.69	$29,760.00
April, 2011	11.05	3.2	$6,941.88	$6,941.88
May, 2011	4.65	3.7	$2,544.50	$2,544.50
12 Months Total			**$ 277,635.77**	**$ 245,020.24**

In addition to maintenance and operations cost, the feasibility study identified capital cost needs for the project along with non-cost factors. The capital, maintenance and operational costs included items equipment purchases, electrical and chemical usage, labor and personnel, UV lamp and ballast replacement, impact of the GAC filter caps and the need for more frequent replacement/regeneration, increased solids generation and disposal, etc. The non-cost factors included:

i. Reduction of carbon foot print due to the use of less PAC and no increase to the depletion of GAC.

ii. Reduced risk of injury from handling fewer PAC bags that require manual lifting into the feed chute.

iii. Reduction of labor needs for PAC system during times when MIB concentrations are high.

iv. Future ability to utilize the UV equipment for disinfection of the finished water after Ohio EPA evaluation and approval.

v. As water production increases, additional demand on the ability of the PAC system and GAC filter caps would be exerted. This would typically produce the need for equipment upgrade and more frequent maintenance costs.

The feasibility study recommended that the City utilize the UV AOP process for treating T&O at the Alliance WTP.

Upon City approval of the recommendations, a procurement process was initiated to select the UV AOP equipment. This was necessitated by the variations in the available equipment from the various manufacturers. Equipment variations were significant in power output, energy needs, hydrogen peroxide dosage and the associated chlorine feed rates. The physical characteristics of the equipment were also different. UV Module pipe diameter, location of ballasts and equipment control methods, were significantly different. Procuring the UV AOP equipment was initiated and a strategy was developed. The purpose was to balance qualifications, experience and costs of the available equipment in order to make the best selection for the City.

Procurement was established around several key parameters that included scope of equipment, specific and clear bidding conditions, warranty requirement, required proposal submittal data and operating criteria. The process also included analyzing capital cost vs. present worth and a decision process with weighted factors.

The manufacturer experience and past performance was required to demonstrate successful installations and acceptable equipment support and service. The equipment flexibility and operational needs, future capacity, level of automation and support were also included in the evaluation. Prior to receipt of the procurement documents, a selection committee consisting of five reviewers was established to represent the City's interests and comprised of legal, administrative, engineering, operations and treatment personnel. A workshop was developed to streamline the review process and to maintain continuity and uniformity with the evaluation and ranking process.

After receipt of the proposals from the equipment manufacturers, each reviewer performed their independent review. Some reviewers were assigned the duty of checking references, verification of financials, etc. and they reported to the selection committee. After the procurement committee completed its review, recommendations were provided to the City. The City then entered into agreement with the successful equipment supplier.

Table 4. Procurement Summary of Evaluations

Evaluation Category	Weight	Score for Manufacturer A	Score for Manufacturer B	Score for Manufacturer C
Compliance with Proposal Requirements	5%			
Score for Experience and past Performance	20%			
Score for Equipment Characteristics and Flexibility	15%			
Score for Life Cycle Cost Estimate	60%			
Total Score	100%			

continued on page 66

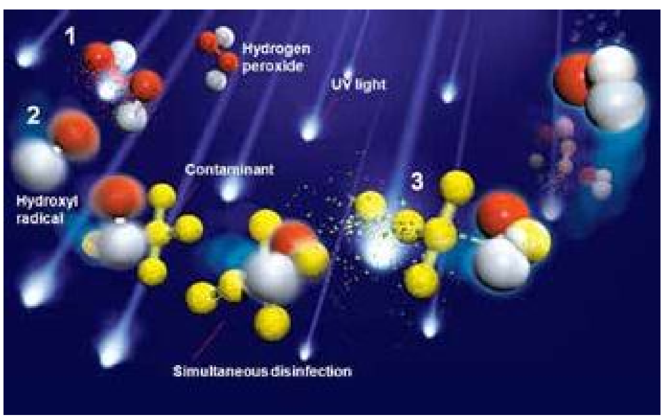
continued from page 65 - alliance

With the finalization of the procurement process, the detailed design phase of the improvements proceeded forward. The improvements were designed using the selected UV AOP equipment and that made the design more efficient and specific. Two UV AOP modules were required at 30 inch diameter each. The design also included a static mixer at the application point of the hydrogen peroxide in order to promote adequate mixing of the hydrogen peroxide prior to the UV units. A small separate building was added to house the hydrogen peroxide feed equipment. The largest change to the existing treatment facility was the modification to the chlorination feed system because of the seasonal variations of chlorine requirements due to the UV AOP operations. . The existing gas feed systems had to be replaced with four new gas feed chlorinators and one new chlorine evaporator to provide the needed chlorine capacity during the T&O season. The existing SCADA system was also modified to include the monitoring of the UV AOP system and the new chlorination system. The Alliance WTP uses "Cluster" type filters where the filtered water from the operating filters is used during backwash of a dirty filter. Thus, there is no filtered water discharge during that time. Because there is no discharge during backwash cycles, the UV AOP system had to be equipped with a cooling water line to maintain the temperatures of the bulbs within acceptable limits. The detailed design document advanced the requirements of the procurement documents for performance testing. After construction completion and startup of the UV AOP equipment, the manufacturer of the UV AOP system will prove, in two separate tests that the actual performance of the UV AOP equipment at three performance conditions meets the requirements set forth in the procurement documents.

The detailed design of the improvements was completed and received Ohio EPA approval by mid 2012. The bidding process occurred in late 2012 with construction start in December 2012. Currently, construction completion is anticipated in late 2013.

HOW UV-OXIDATION WORKS

To treat water, UV-oxidation requires two components: UV light and hydrogen peroxide



1. When UV light is introduced to the water, the diluted hydrogen peroxide molecules absorb UV light.
2. Highly energetic and reactive hydroxyl radicals are then formed.
3. Hydroxyl radicals break down the chemical bonds of toxic contaminants, reducing them to their safe, elemental components.

Many contaminants in freshwater are treated with this combination of UV light and hydrogen peroxide. Some, such as NDMA, require UV light alone to break them down.

Simultaneous Disinfection

UV, as part of a multi-barrier system, can act to simultaneously inactivate pathogens as well as destroy contaminants such as T&O compounds.