

# UV/Peroxide Oxidation Process for Taste & Odor Control

Yujung Chang

HDR Engineering, Inc., 500 108th Ave. NE, Suite 1200, Seattle, WA 98004

## ABSTRACT

UV/peroxide oxidation process is an effective treatment technology for surface water taste & odor treatment. This paper presents results from a pilot testing conducted at a membrane facility at Kennewick, Washington to compare 3 different oxidation processes, including permanganate, ozone, and UV/peroxide process for T&O control. This study shows that at 2 mg/L of peroxide dosage, the UV/H<sub>2</sub>O<sub>2</sub> process can effectively reduce Geosmin from 12 ng/L to 1 ng/L. A conceptual cost estimation shows that amortized installed capital cost for this AOP is between \$0.02/kgal and \$0.03/kgal, and annual O&M cost (including energy, chemicals, and lamp replacement) is between \$0.02/kgal and \$0.03/kgal. Other design and engineering considerations presented in this paper include required ancillary equipment, energy consumption estimation, peroxide quenching, disinfection credit, peroxide delivery option, and residual peroxide monitoring.

## INTRODUCTION

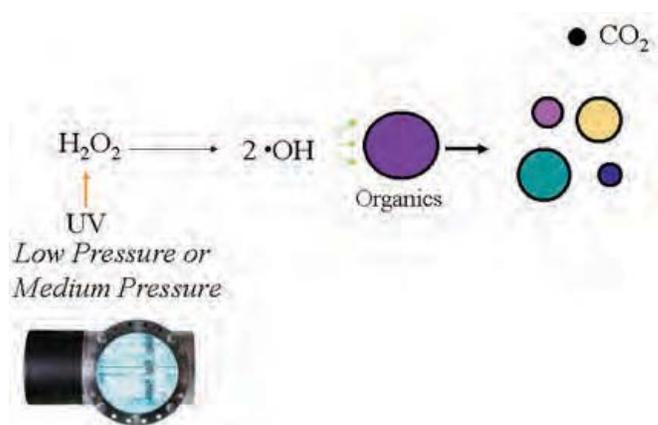
Taste and odor (T&O) has been a recurring issue that constantly challenges many drinking water facilities using surface water as water source. While T&O is not a directly regulated water quality parameter, the National Secondary Drinking Water Regulation, a non-enforceable guideline, suggests that the odor of a public supply should be less than 3 based on Threshold Odor Number (TON) testing. Surface water T&O is usually caused by organic compounds, such as MIB and Geosmin, released from algae. These organic compounds can be either removed by activated carbon or destroyed by oxidation processes. Powdered activated carbon and permanganate are the two most commonly used treatments for minor T&O events. For serious and persistent T&O events, granular activated carbon (GAC) and ozonation had been the best treatment technologies available. However, both processes are considered relatively expensive, and the ozonation process could generate undesirable brominated disinfection by-products (with the presence of high bromide concentration) and high biodegradable dissolved organic carbon (BDOC). The former is a regulated disinfection by-product, and the later could increase biological activity in the distribution system, causing additional T&O and/or internal corrosion. Also, ozonation is a very effective disinfection process at warm temperature, but the required dosage to achieve the same disinfection level would require much higher ozone dosage at lower temperature. **Table 1** lists the required CT value for 1 and 2 log Cryptosporidium by ozonation at 2 and 20 °C.

UV/H<sub>2</sub>O<sub>2</sub> is an emerging oxidation technology that has been used in the destruction of NDMA, MTBE, and other trace organic compounds in groundwater. The very same

**Table 1:** CT Value of ozonation disinfection for Cryptosporidium at warm (20°C) and cold (2°C) temperature.

	20 °C	2 °C
1 log	3.9	21
2 log	7.8	42

simple oxidation process (illustrated in **Figure 1**) could also be very effective in T&O control. Recent studies (Paradis et. al. 2006) have suggested that this technology could effectively oxidize T&O compounds without generating brominated compounds and will minimize the production of BDOC (compared to ozone).



**Figure 1:** Illustration of organic destruction mechanism by UV/H<sub>2</sub>O<sub>2</sub> process.

# PILOT PROJECT

## Pilot Description

The City of Kennewick's Water Filtration Plant (Washington) treats water from the Columbia River. The recent WFP Improvements Project converted the seasonally used 7.5-mgd conventional treatment plant to a 15-mgd membrane treatment plant for year-round water production. The Columbia River experiences seasonal taste and odor (T&O) issue in early spring and late falls, and the use of 0.5 mg/L permanganate didn't seem to be effective to control T&O. A pilot testing was conducted at the new membrane facility to compare 3 different oxidation processes, including permanganate, ozone, and UV/peroxide process for T&O control. Feed water used in the study was the membrane process effluent, which was pre-treated by coagulation and filtration prior to the membrane system. This membrane effluent has very good water quality, with a TOC concentration of 1.1 mg/L, turbidity less than 0.05 NTU, and UVT higher than 97%. A chlorine residual of 1.2 mg/L is also maintained.

## Pilot Unit Description

The UV peroxide pilot system (Figure 2) is a Trojan UVLogic™ (Model 0215AM) unit provided by Trojan Technologies. It utilizes two low-pressure-high-output lamps and has a maximum treatment capacity of 110 gpm for disinfection and 46 gpm for organic oxidation. The pilot unit is also equipped with a chemical injection port followed by an in-line static mixer. To ensure the maximum oxidation power, the flow rate was controlled at 2 gpm during the pilot testing at Kennewick.



Figure 2: UV/H<sub>2</sub>O<sub>2</sub> pilot skid with Trojan UVLogic 0215AM reactor.

## RESULTS AND DISCUSSION

The onsite oxidation testing involves the evaluation of 3 different oxidation processes, including permanganate, ozone, and UV/peroxide process for T&O control. The primary mechanism for T&O assessment was the Threshold Odor Number (TON) assessed by a panel consists of plant staff and HDR engineers who have demonstrated sensitive odor sensing ability. TON is the dilution factor (with

odorless water) that is needed to dilute the water sample to a point that the participants in the sensor panel cannot identify any odor in the dilution. It is a measure of how persistent the water smell is. The higher the number, the more persistent the odor is and hence the more it has to be diluted before it can no longer be detected. The initial tests placed the TON for the feed water at about 15 (Table 2). It should be noted that not all whole-numbered dilution factors had been tried during these tests. In a typical test, the dilution factors of 1, 3, 6, 10, 15, 20 and 30 were used. The determination of TON for any given sample was then based on the highest dilution factor at which odor was not reported by the majority of the test participants. In other words, for the sample that shows a TON of 10, the real TON could be between 7 and 10 inclusive.

Table II: Threshold Odor Numbers of Water Samples Treated by Various Oxidants.

Oxidant	Feed Water	Treated Water
KMnO <sub>4</sub> (2 ppm)	15	15
Ozone (Initial 0.58 ppm/Residual 0.37 ppm)	15	6
Ozone (Initial 0.58 ppm/Residual 0.37 ppm)	20	30
UV/H <sub>2</sub> O <sub>2</sub> (2 ppm)	20	10
UV/H <sub>2</sub> O <sub>2</sub> (3 ppm)	20	3
UV/H <sub>2</sub> O <sub>2</sub> (6 ppm)	20	10
UV/H <sub>2</sub> O <sub>2</sub> (9 ppm)	20	15

O<sub>3</sub> dosage applied to the feed water was estimated to be 0.58 mg/L, and the residual was approximately 0.37 ppm. The initial testing results seemed to be promising with O<sub>3</sub> treatment. The O<sub>3</sub> treated water has a TON of about 6. However, the subsequent O<sub>3</sub> treated water samples showed the TON values were not any better than that of the feed water. In one test, it was actually worse. A final O<sub>3</sub> tests was conducted and the TON evaluation suggested that O<sub>3</sub> treatment did not improve the water's odor. Samples were taken for external laboratory analysis (MWH Laboratory & Trojan UV Technology) for MIB & Geosmin.

In parallel with the O<sub>3</sub> tests, a jar tests was conducted to determine the effectiveness of KMnO<sub>4</sub> addition. KMnO<sub>4</sub> and Cl<sub>2</sub> had been used in Kennewick WTP treatment process to battle the T&O problem. KMnO<sub>4</sub> had been taken offline prior to this pilot testing to ensure most of the T&O compounds would pass through the treatment train and reach the pilot testing units. The WTP staff reported that KMnO<sub>4</sub> had not been very effective on T&O control. Results

of this jar test showed that even with as much as 2 mg/L of  $\text{KMnO}_4$ , the TON for treated water was 15, which was the same as that of the feed water. This results somewhat confirm WTP staff's comment.

The last oxidation process tested was the UV/  $\text{H}_2\text{O}_2$  AOP process. Since the UV output cannot be adjusted on this pilot unit, the UV dose cannot be varied once the flow rate is set. The only way to change UV dosage is to use a different flow rate. For this study, the flow rate was set at 2 gpm, and the UV dosage was internally measured to be 28.9  $\text{mW}/\text{cm}^2$ . At a peroxide dosage of 6 mg/L, the results were only slightly promising. The treated water TON was reduced from 20 to 10, but still odiferous. Subsequent UV/ $\text{H}_2\text{O}_2$  tests showed a remarkable improvement at a lower  $\text{H}_2\text{O}_2$  concentration of 3 ppm. Its TON was 3, acceptable under the National Secondary Drinking Water Regulation. In a blind-fold testing, the WTP staff described this sample as "the best water yet". At 2 ppm of  $\text{H}_2\text{O}_2$ , the odor was increased to a TON of 10. Samples were taken at 2 and 3 ppm and sent to the external laboratories for MIB & Geosmin analysis.

As shown in **Table 3**, the T&O event experienced at Kennewick was caused by Geosmin. The concentration of Geosmin in the plant finished water was 12 ng/L. At a dosage of 0.58 mg/L, ozone reduced Geosmin to 4.8 ng/L, a 60%. However, the TON increased from 20 to 30. Since the TON panel described this ozonated water exhibits "sweet and fruity" odor, it is possible that while reducing Geosmin, ozone generated other by-products, such as aldehydes, that could impart odor in the water, thereby increasing the TON number. Similar by-product formation mechanism could also occurred at higher peroxide dosage (6 mg/L) in the UV/ $\text{H}_2\text{O}_2$  process that caused the treated water a higher TON than that of the water treated by 3 mg/L peroxide.

**Table III:** Reduction of MIB and Geosmin by ozone and UV/ $\text{H}_2\text{O}_2$  Processes.

Oxidant	TOC <sup>a</sup> (mg/L)	MIB <sup>b</sup> (ng/L)	Geosmin <sup>b</sup> (ng/L)
Feed	1.14	1	12
Ozone (0.58 ppm/0.37 ppm)	1.01	ND	4.8
UV/ $\text{H}_2\text{O}_2$ (2 ppm)	1.04	ND	1
UV/ $\text{H}_2\text{O}_2$ (3 ppm)	1.06	ND	ND

a: MRL 0.3 mg/L

b: MRL 1 ng/L

## CONCLUSIONS

This paper compares 3 different oxidation processes for surface water T&O control at Kennewick's new membrane filtration facility. Geosmin was found to be the primary

constituent that that cause T&O event in Kennewick. Potassium permanganate (up 2 mg/L) showed virtually no effect on TON number of the water sample. Ozonation at a dosage of 0.58 mg/L could reduce 60% of the Geosmin, but actually change the characteristics of the odor profile and increased the TON number in the treated water. Results from this study suggest UV/peroxide process is a very effective oxidation for Geosmin and can reduce its concentration from 12 ng/L to a level below detection limit with 3 mg/L of  $\text{H}_2\text{O}_2$ . Increasing peroxide dosage to 6 mg/L also change the odor profile of the water and eventually increased the TON level.

## ACKNOWLEDGEMENTS

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## REFERENCES

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