Full-Scale Ozone Contactor Study [Project #630]

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BACKGROUND
A systematic approach to the design and operation of ozone contactors for assured disinfection has not been developed by the water industry. Considerable research has been conducted to define performance characteristics for ozone mass transfer, transfer efficiency, and chemical reactions between ozone and specific contaminants; however, a review of the literature indicates that incorporation of ozone chemistry and contactor hydrodynamics into a design and operational approach has not been done at full scale. Information deficiencies include lack of understanding of the interrelationships among contactor hydrodynamics, ozone residual development, and the spatial and temporal distribution of ozone within the contactor. This lack of understanding of full-scale ozone contactor performance can lead to inefficient designs and operation and perhaps even failure to meet new regulatory requirements for disinfection (i.e., USEPA CT criteria).

APPROACH
A cause-and-effect study approach was developed to assess design and operating criteria associated with ozone contacting. The effects caused by differences in contactor configuration and changes in operating parameters were investigated to determine their impact on process performance.

Five full-scale facilities were evaluated with respect to ozone residual characteristics and hydrodynamics. The facilities were physically different and during the study were operated at a variety of gas and water flow rates. Four conventional fine-bubble contactors and one turbine contactor were evaluated.

Conventional contactors with countercurrent and cocurrent contacting cells were evaluated at the Mery sur Oise and Neuilly sur Marne water treatment plants (WTPs), operated by the Suburban Paris Water Authority (SPWA), Paris, France, and the Sobrante and Upper San Leandro WTPs, operated by the East Bay Municipal Utility District (EBMUD), Oakland, Calif. The turbine contactor evaluated during this study is located at the Haworth WTP, operated by the Hackensack Water Company (HWC), Hackensack, N.J.

RESULTS AND CONCLUSIONS

Design and Operational Impacts on Ozone Residual
A significant finding in this project was that in full-scale fine-bubble contactors, the ozone residuals were generally homogeneous throughout the individual contactor cells as long as the horizontal length was greater than 8 ft and contactor depths were in the normal range of 20 ft. This finding is in contrast to Appendix O of the USEPA Surface Water Treatment Rule Guidance Manual (USEPA 1991), which assumes lower concentrations at the top of the contactor than at the bottom.

Another important finding was that design and operational factors could affect the average ozone residual developed for a given dose. Causes for the variability of the residual within the contactor cells included horizontal
length of the contactor cell as it affects the length/depth ratio; mode of contacting (i.e., countercurrent versus cocurrent flow); pneumatics associated with diffuser piping; sequence of ozone addition; gas flow rate; and liquid flow rate.

Design and Operational Impacts on Residence Time Distribution

Changes in the residence time distribution as measured by the ratio of the time necessary for 10 percent of the bulk flow to pass through the contactor or contactor stage to the theoretical mean residence time (T10/T) ratio can have a significant impact on the ozone residual required to meet the CT criteria. The most important factor in maximizing the T10/T ratio is the contactor horizontal length as it affects the length/depth (L/D) ratio. This research showed a clear inverse linear relationship between the contactor length and the T10/T ratio in the range of L/D between 0 and 1. Other factors that had minor but measurable impacts on the T10/T ratio included baffling, liquid flow rate, and mode of contacting (i.e., countercurrent versus cocurrent flow).

Modeling

A mathematical model was developed to describe the hydrodynamic characteristics of the Sobrante WTP ozone contactor. Using nonlinear least-squares regressions and transform functions to analyze the tracer test data, the model was able to define the effects of baffling, the mode of contacting, and gas and liquid flow rates.

Because the ozone residuals were relatively uniform and exhibited complete mix characteristics, whereas the tracer tests suggested plug flow in all cells except the cocurrent cell, it was impractical or inappropriate to attempt to merge ozone residual development with the hydrodynamics into a single model.

Another mathematical model was developed for the Haworth WTP ozone contactor. In that model, the ozone residual development characteristics did correspond with the hydrodynamic characteristics, and thus the two aspects of disinfection were merged. The model accurately correlated with the ozone profile and the tracer test results.

An empirical model was developed to use bench- or pilot-scale ozone demand and decay data and tracer test data to determine CT values under alternative design and operating scenarios. That model can be used by designers to analyze capital costs needed to increase CT credits and compare them to the savings in operating costs. The model can also be used by operators of existing ozone contactors to minimize operating costs while still meeting the CT requirements.

Implication of Study Results on Disinfection Credit

With the information developed during the tracer, ozone profile, and ozone chemistry evaluations, a number of approaches can be used to predict disinfection efficiency or alter design practices to enhance contacting efficiency. In fact, the approach used to measure or predict disinfection efficiency can result in significantly different results for the same data. It is possible to have a 6- to 8-fold variation in CT credit when considering the contactor as a completely stirred tank reactor (CSR) versus using a mathematical model to integrate total exposure of the water to the ozone. These results and evaluations demonstrate the significant impact the approach to determining compliance with CT requirements can have on design, operation, and regulatory reporting for ozone disinfection.