DISCUSSION

Of: **Tertiary Treatment Using Microfiltration and UV Disinfection for Water Reclamation,** D. Jolis, R. Hirano, P. Pitt, **71**, 224 (1999).

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This paper presented the valuable observations that when reclaimed water is microfiltered, the disinfection requirements of the California Wastewater Reclamation Criteria, known as Title 22, may be met with a considerably lower UV dose than the 1400 J/m^2 recommended by the National Water Research Institute and the California Department of Health Services. Because power consumption is the largest component of the cost of UV disinfection systems, a significant reduction in the dose that a system needs to deliver may significantly improve the economics of disinfection. The authors have done the research community a service by reporting measurements that provide a preliminary indication of the reduction that may be possible when microfiltration precedes disinfection and thereby removes many microorganisms and particles that could shelter pathogens from irradiation. (Incidentally, this suggests that microfiltered water would also be easier to disinfect by other methods, including chlorination.)

However, there is apparent near constancy in the observed inactivation factor at differing calculated doses in the first lamp bank of the test apparatus and a weak dependence of observed inactivation on calculated dose in the second bank, differing from the expected first-order kinetics. The authors attribute these differences to a departure from ideal hydraulic conditions in the reactor and attempt to quantify this departure by fitting the results from the second bank to a model consisting of a series of continuously stirred tank reactors (CSTRs). Because the best fit occurs for a series of seven CSTRs, they conclude that the second bank results show considerable backmixing, contrary to the conclusion of a tracer hydraulic study (Darby et al., 1993) that indicated that flow in this type of unit, a Trojan UV2000 (Trojan Technologies, Inc., London, Ontario, Canada), is a close approximation to ideal plug flow. Moreover, the authors state, without elaboration, that the way to improve the hydraulic design is to take care with "lamp configuration and distribution within the wetted area." All of this prompts the following comments and questions.

Have any specific suggestions been formulated for changing the lamp configuration and distribution within the wetted area? Are the authors familiar with the work of Blatchley and his colleagues at Purdue, as reported in a refereed journal paper (Blatchley et al., 1995, and Iranpour and Straub, 1997)? It seems that Figures 3 and 4 in this paper are particularly relevant for understanding the hydraulics in this kind of UV disinfector because these figures show that a flow with directly observed backmixing is smoothed into plug flow by passing through an array of UV lamps and that a boundary layer was present near the bottom of the channel.

Also, have the authors considered the possible role of boundary layers, as described in basic fluid mechanics texts (Currie, 1974), in causing departures from ideal plug flow? The CSTRs of the authors' model are merely mathematical fictions, providing an intuitively grasped justification for the formulas used in the model. On the other hand, boundary layers are well known to exist physically and to play an important role in many fluid systems.

Have the authors had access to the report by Anderson and Tchobanoglous (1995) on a thorough hydraulic study carried out in Orange County, California, on a UV2000 system that was not perfectly level? The close approximation to plug flow observed in the Orange County study may be a counterexample to the authors' hypothesis that the postulated backmixing may have resulted from imperfect leveling of the unit. Also, Anderson and Tchobanoglous mention that the ratio of lamp array length to lamp diameter in this system is large enough to induce a close approximation to plug flow, which is consistent with the observations by Blatchley et al. (1995). These considerations are discussed at greater length in Iranpour et al. (1998), which also explains why the hydraulics in the horizontal array in the large disinfection channel used by Blatchley et al. are similar to those in the smaller UV2000.

Comparison of the authors' original report (Jolis and Hirano, 1993) with the published paper shows that the dose estimation method was presented more clearly in the report. The authors stated there that the calculation by the single point source summation method was actually carried out by Trojan Technologies, resulting in the following formula used by the authors:

$$D = (1344 e^{0.0263\%T})/Q \tag{1}$$

Where

Q = flow rate, gal/min;
T = percent transmittance at 254 nm; and
D = dose, mW·s/cm^2.

Evaluating Q in units of L/min and D in J/m^2 as in the paper, this equation becomes

$$D = (3551 e^{0.0263\%T})/Q \tag{2}$$

Comparison of the dose plot in Figure 2 in the paper with the corresponding plot in Figure 4-4 of the report, which are identical except for trivialities of graphical presentation, shows that the authors have not changed their method of dose determination since the report was written. Hence, it is worth noting that this formula assumes plug flow and that departures from plug flow cause some volume elements of the water to receive other doses. This is why, in the comments above, care was taken to distinguish between the authors' observed inactivation and their calculation of the dose. Future work could be improved by returning to the explanation of the dose estimation method given in the report because it is fundamental to any interpretation of the measurements.

Let us emphasize that although the authors could have made a more physically realistic and informative choice of a hydraulic model to interpret their observations, this criticism does not diminish the importance of the observations themselves. Indeed, the presentation of these results in Jolis and Hirano (1993) led Iranpour et al. (1999) to suggest that the apparent departure from first-order kinetics should be called the Jolis–Hirano effect to recognize the significance of a phenomenon that to their knowledge had not been reported before. Moreover, we agree that the observed disinfection effect results from a departure from plug flow, and hence modification of the reactor hydraulics to achieve a closer approximation to plug flow is the way to obtain better disinfection efficiency. The authors are urged to give more consideration to the hydraulics because better understanding of the hydraulics offers the best hope for achieving the advances that their results suggest may be possible.

Acknowledgments

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References

Anderson, J., and Tchobanoglous, G. (1995) Hydraulic Characterization of the Trojan UV2000 Pilot-Scale Disinfection System. Green Acres Water Reclamation Facility. Rep. Orange County Water District, Fountain Valley, Calif.

Blatchley, E.R., III; Wood, W.L.; and Schuerch, P. (1995) UV Pilot Testing: Intensity Distribution and Hydrodynamics. *J. Environ. Eng.*, **121**, 3, 258.

Currie, I.G. (1974) *Fundamentals of Mechanics of Fluids*. McGraw–Hill, New York.

Darby, J.L.; Snider, K.; and Tchobanoglous, G. (1993) Ultraviolet Disinfection for Wastewater Reclamation and Reuse Subject to Restrictive Standards. *Water Environ. Res.*, **65**, 169.

Iranpour, R.; Magallanes, A.; Jugo, T.; Ludwig, K.; Mansell, C., Jr.; and Flaig, K. (1998) Challenges in Guaranteeing the Virus Disinfection Performance of Microfiltration/Ultraviolet Irradiation Systems in Wastewater Reclamation. *Proc. Disinfection '98, Wastewater Disinfection Water Environ. Fed. Spec. Conf.*, Alexandria, Va., 183.

Iranpour, R.; Garnas, G.; Moghaddam, O.; and Taebi, A. (1999) Hydraulic Effects on Ultraviolet Disinfection: Modification of Reactor Design. *Water Environ. Res.*, **71**, 1, 114.

Iranpour, R., and Straub, B. (1997) Of: UV Pilot Testing: Intensity Distribution and Hydrodynamics. *J. Environ. Eng.*

Jolis, D., and Hirano, R. (1993) Microfiltration and Ultraviolet Light Disinfection for Water Reclamation. Bureau Eng., Dept. Public Works, City County San Francisco, Calif.