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Improved Contaminant Mixing Models for Water Quality Modeling in Water Distribution Networks

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Abstract:

Contaminant and solute transport in municipal water distribution systems is a significant concern because of the potential for accidental or intentional contamination events. Understanding how contaminants move and mix through a network of pipes and junctions is therefore critical. However, nearly all water distribution models assume that mixing of solutes and contaminants within pipe junctions is perfect (i.e., instantaneous and complete). As a result, solute concentrations are assumed equal in all flows exiting a junction. Recent studies have shown that mixing within pipe junctions is incomplete, and the assumption of complete mixing can lead to significant errors in estimating the water quality at downstream locations (Orear et al., 2005; Ho et al., 2007). Impinging flows within a cross junction (Figure 1) were observed to bifurcate rather than mix completely in experimental and computational simulations.

This paper presents a review of mixing models for different junction configurations used in water distribution systems. Fundamental processes are elucidated using computational fluid dynamics simulations that are validated with experimental data. In addition, a new bulk advective mixing (BAM) model is introduced that allows for incomplete mixing at pipe junctions. The new model has been compared to experimental results and accurately represents the bulk transfer and mixing of fluid entering and leaving a junction at different flow rates. The new model has been implemented in a new version of EPANET, a software package that models the hydraulic and water quality behavior of water distribution piping systems (Rossman, 2000). The new software, EPANET-BAM, has been developed, and examples using the new mixing model are provided. In particular, comparisons between the complete-mixing and incomplete-mixing (BAM) models are provided for different scenarios (Figure 2).

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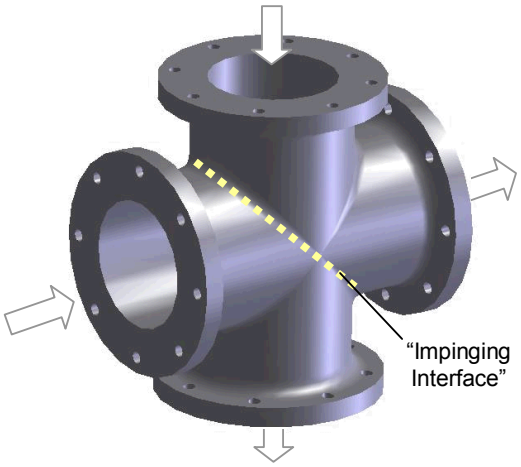

Figure 1. Cross-junction fitting for water distribution systems (from Ho et al., 2007).

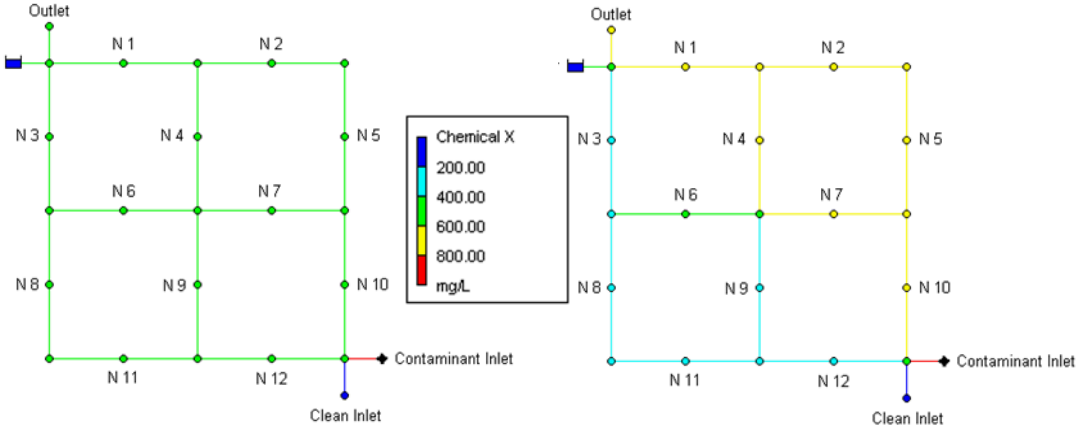

Figure 2. Comparison between complete-mixing (left) and incomplete-mixing (right) models using EPANET-BAM to predict contaminant distributions in a laboratory-scale network.

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