CFD Modeling of Contact Basins

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Contact Basins

CFD simulation has become the preferred approach for modeling contact basins

- Through–flow physical models are expensive plus water/wastewater utilities may take exception to the large discharge rates required to run them
- Over the past 20+ years, validation comparisons against lab scale and on site tests show excellent agreement between CFD and real-world contact basin performance.

Contact Basins

Three aspects to evaluate in contact basin simulations:

- System Hydraulic efficiency of the basin geometry
- Mixing efficiency of the disinfectant chemical
- Kinetics of the disinfectant chemical
  - Chemical decay
  - Microorganism deactivation

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System Hydraulic Efficiency

Using a **time dependent** CFD model, tracer is introduced at the **basin inlet.** The concentration of the tracer is monitored over time as it emerges from the basin outlet.

Data gathered at the model outlet are used to plot a residence time distribution (RTD) curve. The slope and inflection points of the RTD curve are indicative of the hydraulic performance of the contact system. Data points T_{10}, T_{TDT} and T_{90} are inputs used for evaluation protocol.

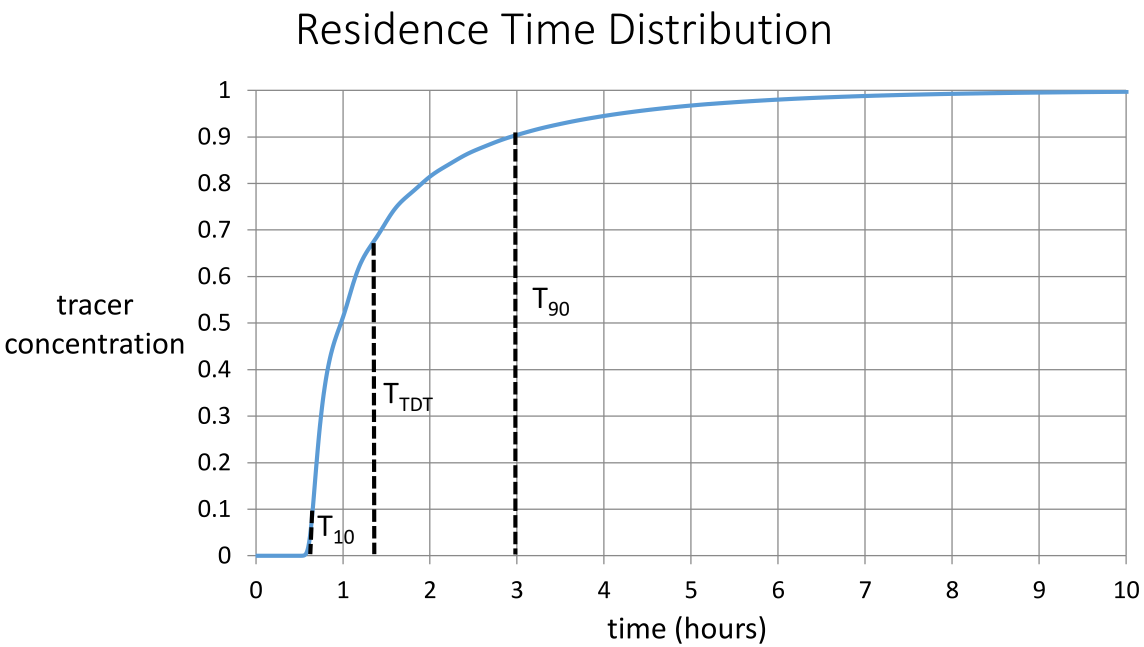
T_{10}: time at which tracer concentration has reached 10% of the target value

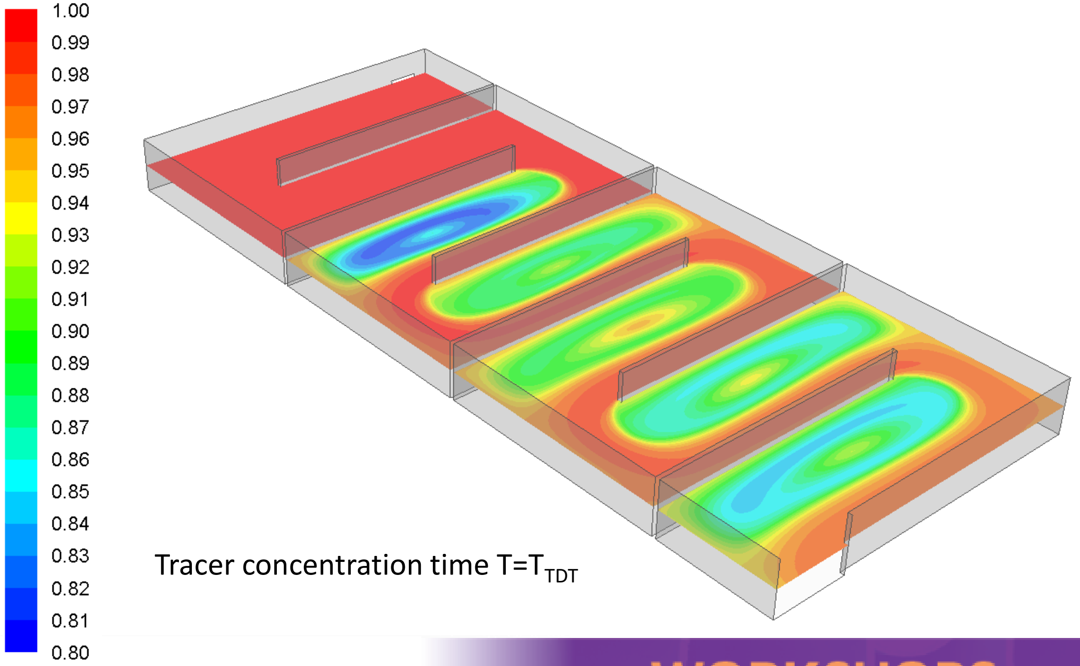
T_{TDT}: Theoretical Detention time ($Vol_{tank}/Q_{effluent}$)

T_{90}: time at which tracer concentration has reached 90 % of the target value

BF: Baffle Factor – T_{10}/T_{TDT} Values near 1.0 indicate good plug flow. Values lower than 0.3 indicate some short circuiting is taking place.

MI: Morrill Index - T_{90}/T_{10} Values greater than 5.0 indicate some flow is getting hung up in recirculation zones.





Tracer concentration time $T=T_{TDT}$

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Mixing Efficiency of the Disinfectant Chemical

Using a **steady state** CFD model, tracer representing the disinfectant is introduced at the **disinfectant injection point.**

Results will show what the disinfectant dispersion levels would look like if the system had been running with constant operating conditions for days.

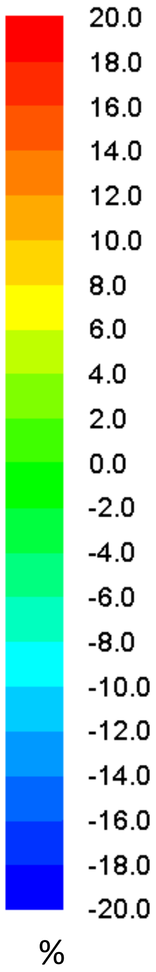
Contour plots of tracer concentration show qualitatively how well the disinfectant is mixing as it moves through the basin.

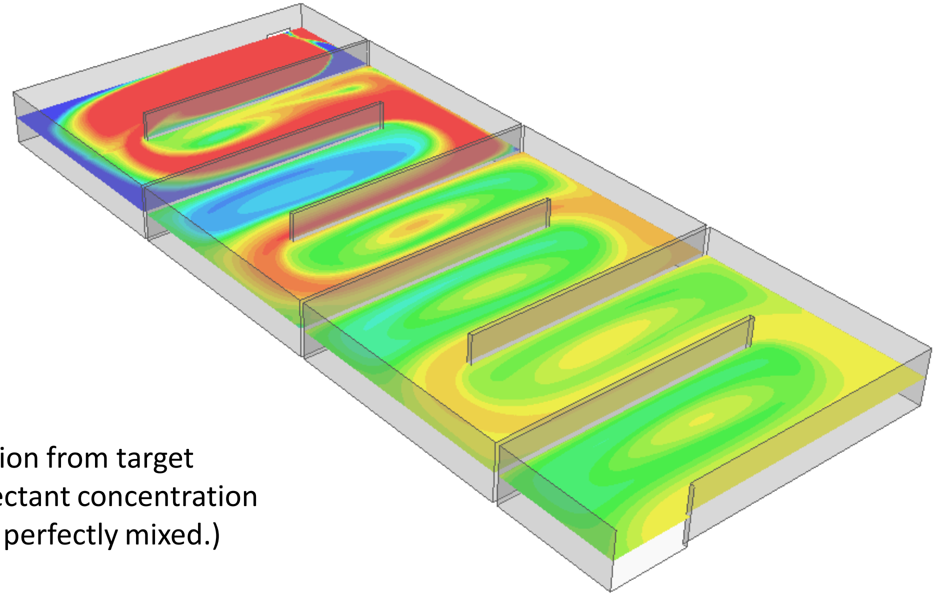
Deviation from target concentration can be used to quantify the output and is expressed as a percentage.

$$dev = 100 * \frac{(C_i - C_{target})}{C_{target}}$$ where C_i is the local concentration

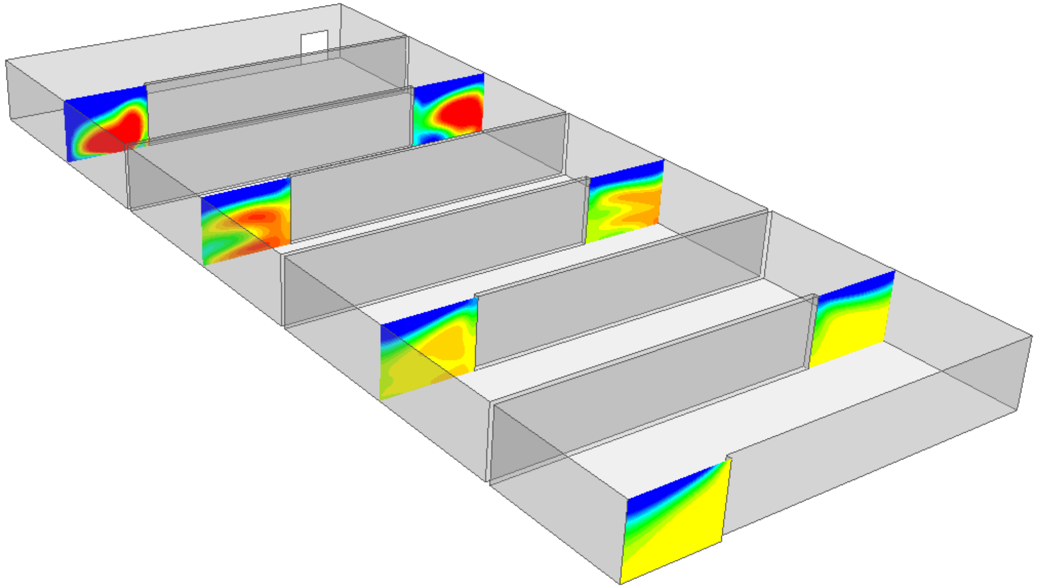
The data set can also be queried to determine coefficient of variation, *CoV*, either for a measurement plane of the entire volume.

$$CoV = \frac{s}{C_{ave}}$$ where s is the standard deviation of the sample data





deviation from target disinfectant concentration (0.0 is perfectly mixed.)



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Kinetics of Disinfectant Chemical

Disinfectant Decay

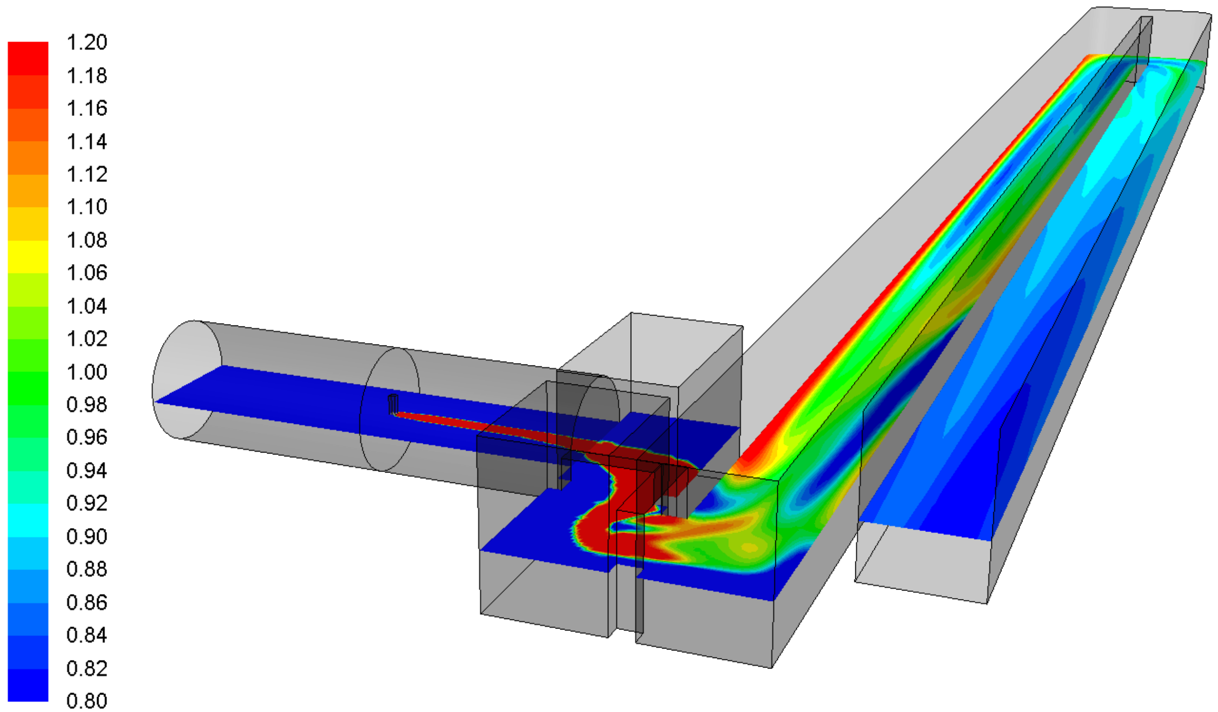
The efficacy of the contact system is dependent on the time the active microorganisms in the effluent are exposed to disinfectant at sufficient concentration to neutralize them.

Disinfectants currently in use like sodium hypochlorite or peracetic acid begin to decay immediately upon introduction to the effluent stream. Their levels of concentration are modeled by a *reacting tracer* whose behavior is specified by a user defined function (UDF) based on published data.

A commonly used first order approximation is:

$$C_t = C_0 e^{-kt}$$

Where:
C_t is the local concentration of PAA at time t
C_0 is initial fully mixed (target) concentration
K = 0.48 sec-1 (varies with disinfectant - 0.48 used here to model peracetic acid
t is time in seconds



Contours of disinfectant concentration normalized against target concentration level. Contour level 1.0 denotes the target concentration.

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Kinetics of Disinfectant Chemical

Neutralization of Microorganisms

The rates at which microorganisms are neutralized are specific to the disinfectant in use and the target microorganism. For example, different coliforms will have differing sensitivities to the disinfectant in use. Their neutralization is simulated using a second tracer input whose reaction to the disinfectant tracer is defined by UDF's based on published data.

For the microbial inactivation, Hom's model is commonly used:

$$\log \frac{N_t}{N_0} = -kC_t^n t^m$$

Where:

N_t is local colony forming unit number of microorganisms at time t

N_0 is colony forming unit count of microorganisms entering the basin

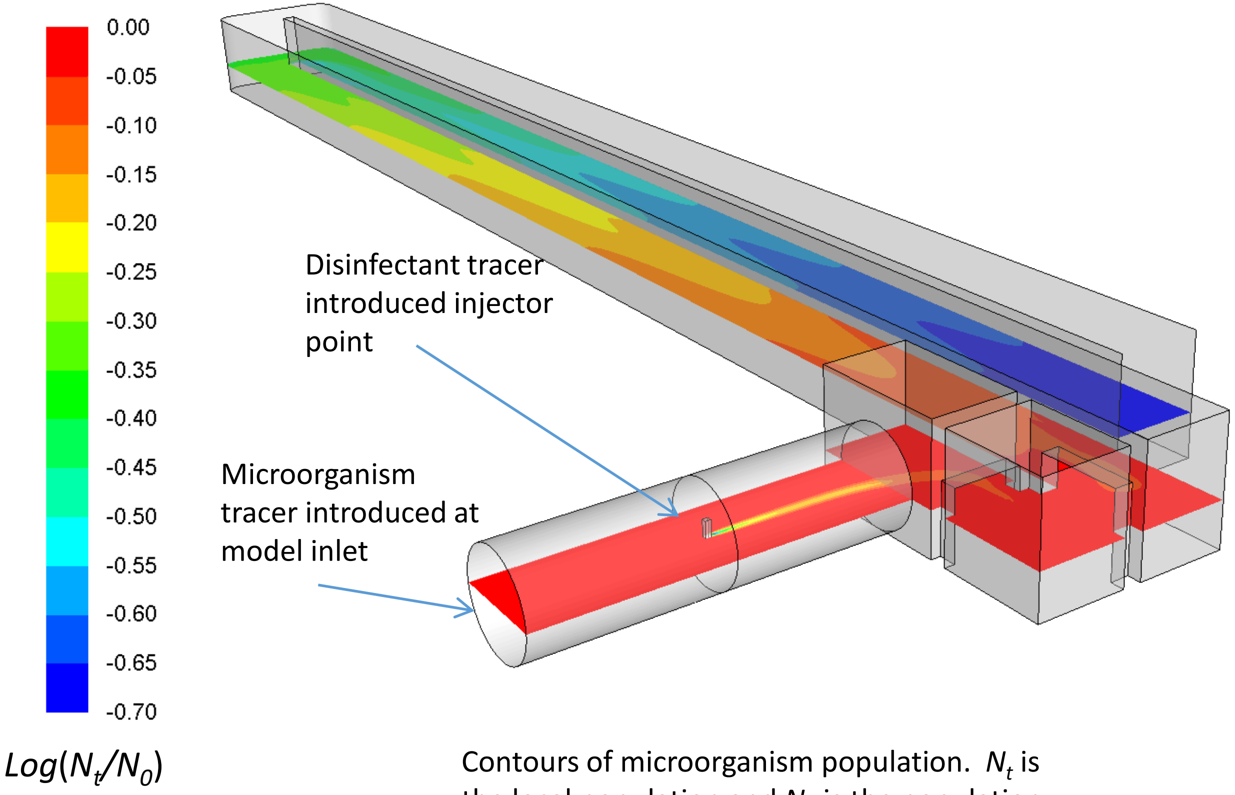
k = 0.208 (used for PAA)

C_t is the local disinfectant concentration (ppm) at time t

n = 0.502 (used for PAA)

m = 0.430 (used for PAA)

t is time in minutes



Contours of microorganism population. N_t is the local population and N_0 is the population in the effluent prior to exposure to the disinfectant.

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Publications

The use of CFD for contact tank evaluation is well documented. Some papers that can be downloaded for free…

Angeloudis, A. Stoesser, T. Falconer, A. *Predicting the Disinfection Efficiency Range in Chlorine Tanks Through a CFD Bases Approach*, 2014

Greene, D. Numerical Simulation of Chlorine Disinfection Processes in Non-Ideal Reactors, 2002

Haas, C. Joffe, J. *Disinfection Under Dynamic Conditions: Modification of Hom's Model for Decay*, 1994

Khan, L. Wicklein E. Teixeira, E. *Validation of a Three Dimensional Computational Fluid Dynamics Model of a Contact Tank*, 2006

Rauen, W. Angeloudis, A. Falconer, A. *Appraisal of Chlorine Contact Tank Modelling Practices*, 2012

Rossi, S. Antonelli, M. Mezzonotte, V. Nurizzo, C. *Peracetic Acid Disinfection: A Feasible Alternative to Wastewater Chlorination*, 2007

Santoro, D. Bartrand, T. Liberti, L. Notarnicola, M. Haas, C. *CFD Modeling of Municipal Wastewater Disinfection by Peracetic Acid (PAA) in Continuous Serpentine Reactors*, 2007

Wilson, J. Venayagamoorthy, S. *Evaluation of Hydraulic Efficiency of Disinfection Systems Based on Residence Time Distributions Curves*, 2010

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Questions or Comments?

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