CFD-I Modeling of UV Disinfection Reactors with Stochastic Evaluation of System Variables

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Introduction:

Ultraviolet (UV) irradiation is an effective disinfection method used in water treatment to inactivate waterborne microbial pathogens and/or indicator organisms. UV disinfection does not involve chemical oxidants, and generally is less prone to production of disinfection by-products than chemical methods.

The objective of the current research is to apply combinations of computational fluid dynamics and irradiance field models (aka, CFD-I models) to simulate the performance of UV disinfection systems, including variability.

The input parameters of the systems are measured using standardized experimental methods and on-site measuring devices. Variability and uncertainty in the input parameters will be accounted for by applying stochastic methods and uncertainty analysis techniques. The central hypothesis of this research is that this stochastic approach will accurately simulate reactor performance, including variability. As such, this approach has the potential to yield numerical simulation results that can be used to refine reactor design and tailor operating conditions, so as to improve reactor performance and efficiency.

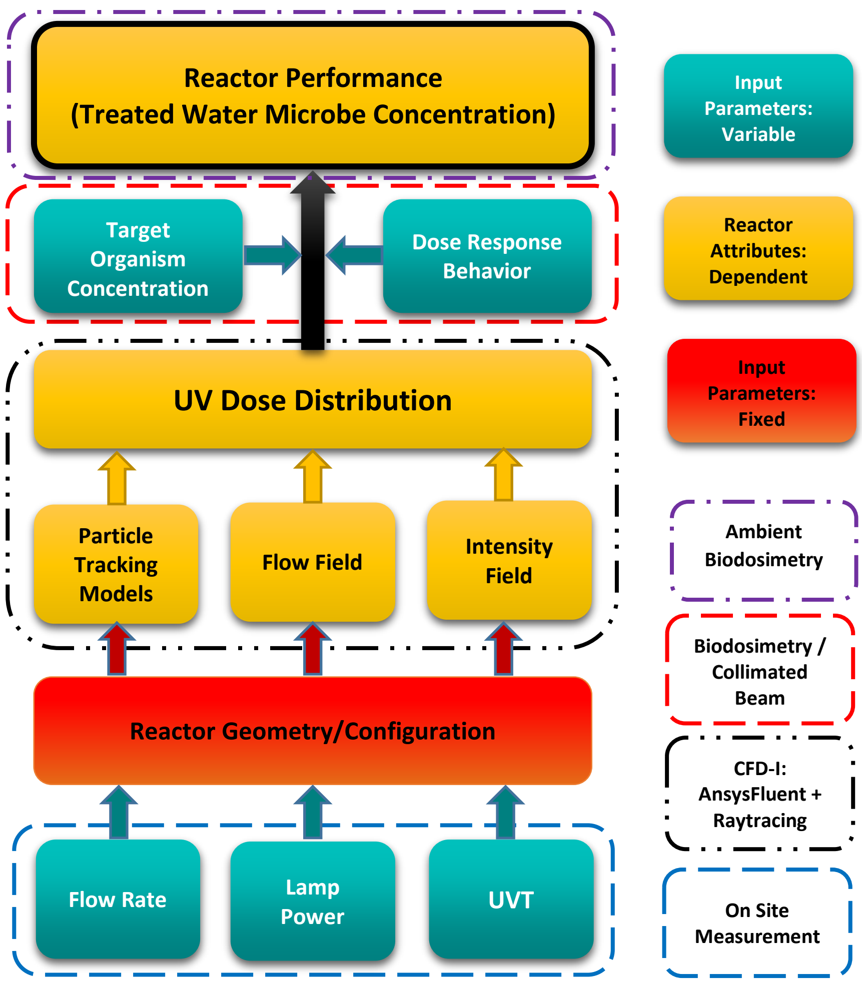

Figure 1: Factors and parameters of UV disinfection Photo-reactors

Figure (1) is a schematic illustration of the parameters and attributes of UV disinfection systems that are needed to evaluate the performance of the reactor and to determine the efficiency of UV disinfection.

Methods:

The simulations will be carried out on various UV disinfection systems, ranging from small, bench-scale devices to full-scale systems. An example of the latter is the existing UV disinfection system at the Belmont WWTP in Indianapolis, IN (see Figure 2), which comprises 7 channels, with 384 LPHO UV lamps in each channel.

Figure 2: UV disinfection System in Belmont Waste Water Treatment Plant

Ansys Fluent software is used for the CFD modelling to obtain the flow field of the water (see Figure 3) and the motion of particles in the UV reactor. Most of the UV reactors are characterized by high Reynolds number and turbulent flow, hence turbulence flow modeling is necessary. CFD simulation is employed also to determine the particle tracks using the particle tracking capabilities of *Fluent*.

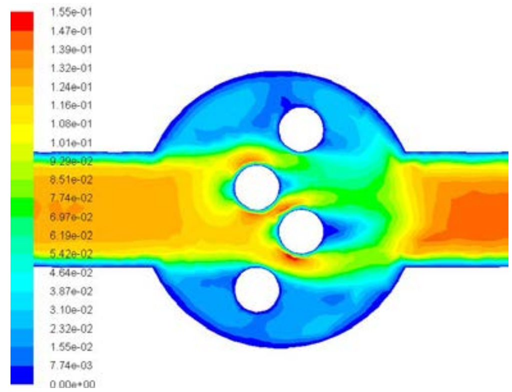

Figure 3: Velocity field CFD simulations

Fluence rate distributions are being simulated using Photopia software, Figure (4), which is based on the ray tracing technique. Ray tracing is fundamentally different than most conventional fluence rate field models, in that it allows simulation of large number of UV rays that emanate from randomly-selected locations within the radiation source(s) of the system. Ray tracing allows for a thorough accounting of the physics (optics) that govern fluence rate fields, including reflection, refraction, absorption and dissipation among all media that comprise a system.

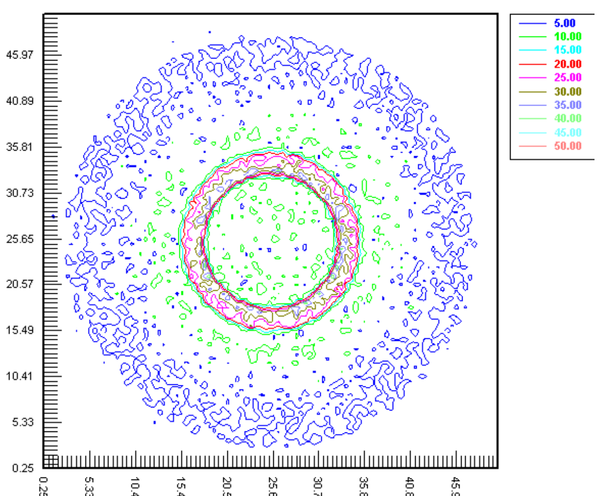

Figure 4 : Fluence rate field cross-section, as simulated by Photopia.

Implications:

The central hypothesis of this research is that CFD-I models (which are essentially deterministic, by nature) can be applied via a stochastic approach, to simulate process performance, including variability, by allowing appropriate variations in input variables. If this hypothesis is demonstrated to be correct, it may allow for UV system designs to be implemented that are more efficient and more reliable than current design approaches.