Simulating UV disinfection reactor performance

Christoph Buchner¹ (student presenter), Christoph Reichl² (company mentor), Norbert Vana³ (faculty mentor)

Technical University of Vienna, Austria

Aims

• Combine the different aspects of Ultraviolet Disinfection (UVD) into an overall simulation of a small UVD reactor (Figure 1). This include:
  • Computational Fluid Dynamics (CFD) simulation of the water flow
  • Particle tracking of micro-organisms in the water
  • Radiation modelling of the water

Current limitations of the radiation modelling exist:

Due to the unknown UV conversion efficiency of the lamp, the radiation models had to be calibrated to fit an available UV sensor reading. Thus, the calculated REF depends on the chosen efficiency value, and the radiation models can only be compared among themselves.

The radiation calculation results in a fluence rate distribution for the main reactor volume. As an example, fluence rate results are shown along an axial and radial path in the reactor volume in Figure 4.

Results and Conclusions

Fluence results for the whole set of particle can be arranged into a fluence histogram (Figure 5). A REF value is easily calculated from the fluence distribution. The resultant REF values were compared to experimental data for five sets of operational parameters.

For the different implementations of turbulence model, mean errors between 1 and 25% have been found. The standard deviations are relatively high, ranging from 8 to 15%.

CFD simulation

A small single-lamp reactor was modelled, measuring 1 m in along the main axis. Steady-state calculations have been computed using the realizable k-ε-turbulence model.

Particle tracking

Particle tracks were calculated by solving the force balance equation for the particle in question. The random nature of the used discrete random walk (DRW) model allowed the calculation of many particle tracks originating from a single grid cell (Figure 3). Approximately 26000 particle tracks were calculated for every case, enabling statistically reliable calculations.

Particle tracking results are shown along an axial (left) and radial (right) path in the reactor volume.

Radiation modelling

Several radiation models have been implemented, which exhibit different degrees of physical realism:

• Multiple Point Source Summation with Focus effect (MPSF-T)
• Multiple Point Source Summation with and without Focus effect (MSSS/MSSS-F)
• Line Source Integration with Focus effect (LSIF)
• Modified Line Source Integration with Focus effect (LSIF-F)
• Modified Line Source Integration with Focus effect (RADLSI)

For more information, please contact:
Christoph.Buchner@arsenal.ac.at or Christoph.Reichl@arsenal.ac.at or phone +43 (0) 50550 6605

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Literature cited
