Water disinfection in an open channel using computational fluid dynamics

Millions of people suffer from diseases by drinking dirty water each year. Public health data shows that 85% of child and 65% of adult diseases are due to waterborne pathogens and this disease rate is increasing. This systemic problem calls for more stringent standards on the microbiological pollution of water effluents. Several approaches are used for the water disinfection including ozonation, membrane filtration, chlorination and ultraviolet (UV) disinfection. In UV disinfection, the absorbance of UV light in the pathogens results DNA/RNA mutation and cross linking between neighboring pyrimidine nucleoside bases (thymine and cytosine) in the same DNA strand; resulting in blocking DNA transcription, and replication. The UV treatment has an advantage over chlorination/dechlorination is the absence of toxicity and by-product formation with comparable costs. UV treatment does not alter water chemically; nothing is added except energy. The other advantage of UV disinfection is it can also inactivate chlorine resistance pathogens (Cryptosporidium and Giardia). These properties have paved the way for the development of a UV disinfection technology.

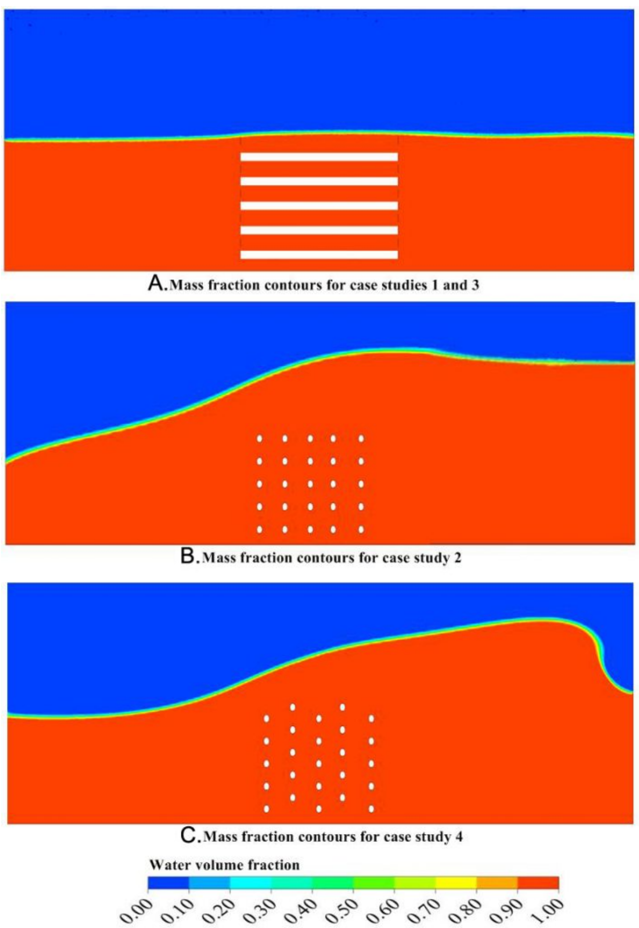

Fig. 1. A. Mass fraction contours for case studies 1 and 3. B. Mass fraction contours for case study 2. C. Mass fraction contours for case study 4.

A UV reactor consists of a reaction vessel that contains a number of UV lamps. The UV lamps are protected against the water by the quartz sleeves surrounding them. The water enters the reactor and flows around the quartz sleeves. The pathogens present in the water travel through the reactor and are irradiated by the UV light of the UV lamps. Water disinfection UV reactors are classified as: open channel and close channel. The difference in these two types is the existence of a free surface in the case of an open channel water disinfection UV reactor. Open channel UV reactors are becoming more common due to the higher flow rate capacity and lower installation cost. The open channel UV reactors are classified into two types (horizontal and vertical) based on the lamp configuration within the open channel. In the horizontal type UV lamps are placed parallel to the direction of the water flow, whereas in the vertical type, UV lamps are placed perpendicular to the direction of the water flow.

A cost effective approach is Computational Fluid Dynamics (CFD) by reducing the experimental approaches for possible design modification in a UV reactor. CFD has gained much interest for the quantification of inactivation credit of the UV reactor. Overall, the objectives of this research work are: the effects of the horizontal and vertical lamp positioning on the performance of open channel UV reactor, the effects of the parallel and staggered lamp positioning on the performance of the open channel UV reactor and the effects of reactor's wall roughness on the performance of open channel UV reactor. To our knowledge the above described objectives have not been addressed conclusively in the literature for open channel water disinfection UV reactor.

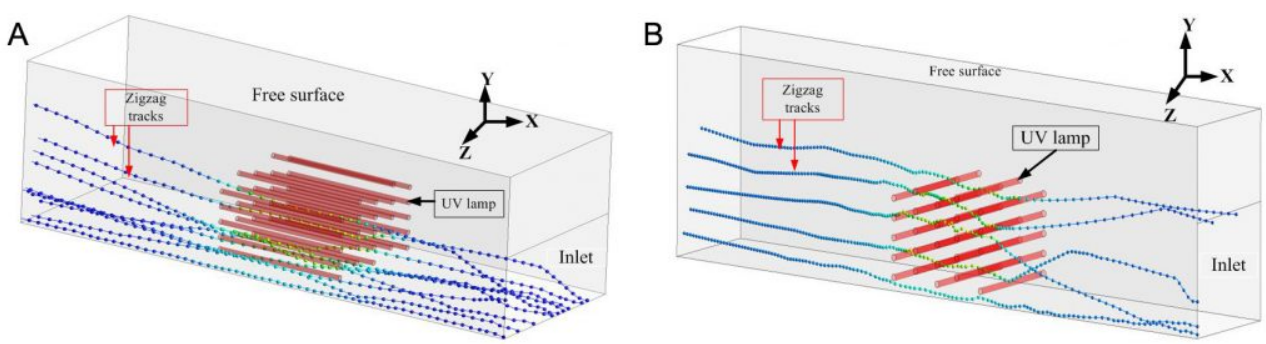

Fig. 2. A. Pathogen tracts for horizontal case. B. Pathogen tracts for vertical case.

The major contributions of this research work are as follows:

The lamps orientation within the reactor was found to play an important role for the

performance of the open channel water disinfection UV reactor.
- Vertical lamp configuration performs better as compared to the horizontal lamp configuration.
- The staggered lamp configuration results in better performance as compared to the parallel lamp configuration.
- The effects of reactor’s wall roughness for horizontal and vertical type UV reactor are Reynolds number dependent. At lower Reynolds number the roughness effects are more significant.
- The reactor’s wall roughness effects are more pronounced for vertical type open channel UV reactor.

The analyzed case of studies with different lamp configuration and roughness effect analysis can be utilized to improve the design and optimization of the open channel water disinfection UV reactors.

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