Computational Modeling to Optimize Chlorinator Design for a Drinking Water Treatment System in Rural Haiti

CLEMSON ENVIRONMENTAL ENGINEERING AND EARTH SCIENCES

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Background

The Cange Water System was first installed in 1985 by members of the Episcopal Diocese of Upper South Carolina after it was determined that water was one of the biggest needs for the people who had settled in the mountaintop community of Cange, Haiti. The system was later expanded and upgraded with the assistance of Clemson Engineers for Developing Countries (CEDC). Today, the system consists of a dam, three turbines and pumps, filtration, chlorination, four cisterns, and eight fountains.

Figure 1. Cange, Haiti located in the Central Plateau.

Figure 2. The Cange Municipal Water System

Chlorine is a known disinfectant that also provides residual treatment throughout the distribution system, however it can be difficult to use in developing communities for a variety of reasons. Through CEDC's work in Cange, several iterations of the chlorination process have been observed, each method with its own set of advantages and drawbacks. There are several main objectives that have been identified that must be considered for the chlorination process to be successful in resource constrained environments.

- Ease of Operations and Maintenance
- Operates Without Electricity
- Ability to Deliver Consistent Levels of Chlorine
- Cost Effective
- Robust Design

Figure 3. Objectives that need to be met in order for the chlorination system to be feasible.

Design

In March 2018 a fiberglass reinforced plastic (FRP) tablet feeder erosion chlorinator designed by CEDC and Fluidtrol Process Technologies, Inc. was installed in the system. The chlorinator lid opens to allow for the addition of 3" calcium hypochlorite tablets that the water erodes as it flows through effectively chlorinating the water. This tablet feeder has met many of the benchmarks deemed important as it does not rely on electricity, is simple to operate, has manageable costs, and can withstand the high pressures of the system. However, further refinement is needed to ensure a consistent dosage of chlorine.

Figure 4. The newest chlorinator in the Cange Water System installed in March 2018.

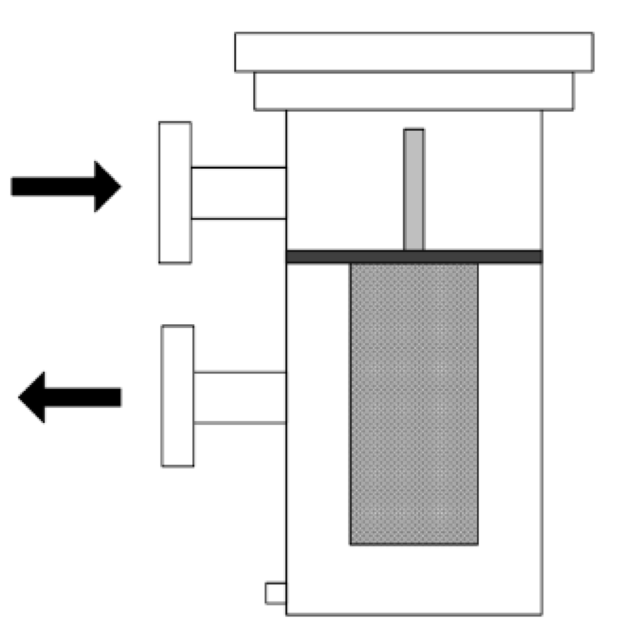

Figure 5. Water flows through a basket containing chlorine tablets.

Field Data Collection

Water data including the levels of free chlorine at the village fountains has been collected and recorded since July 2014 by a local Haitian, Greg Gracia. He was trained on how to correctly collect and test the water and completes the process three to six times a week. He also collects data for the influent and treated water including turbidity, TDS, and pH measurements. The data is then entered into a computer and uploaded to a cloud where it can be viewed and analyzed in Clemson.

Figure 6. Levels of free chlorine are tested in a water testing laboratory using the HACH DR 900 Colorimeter.

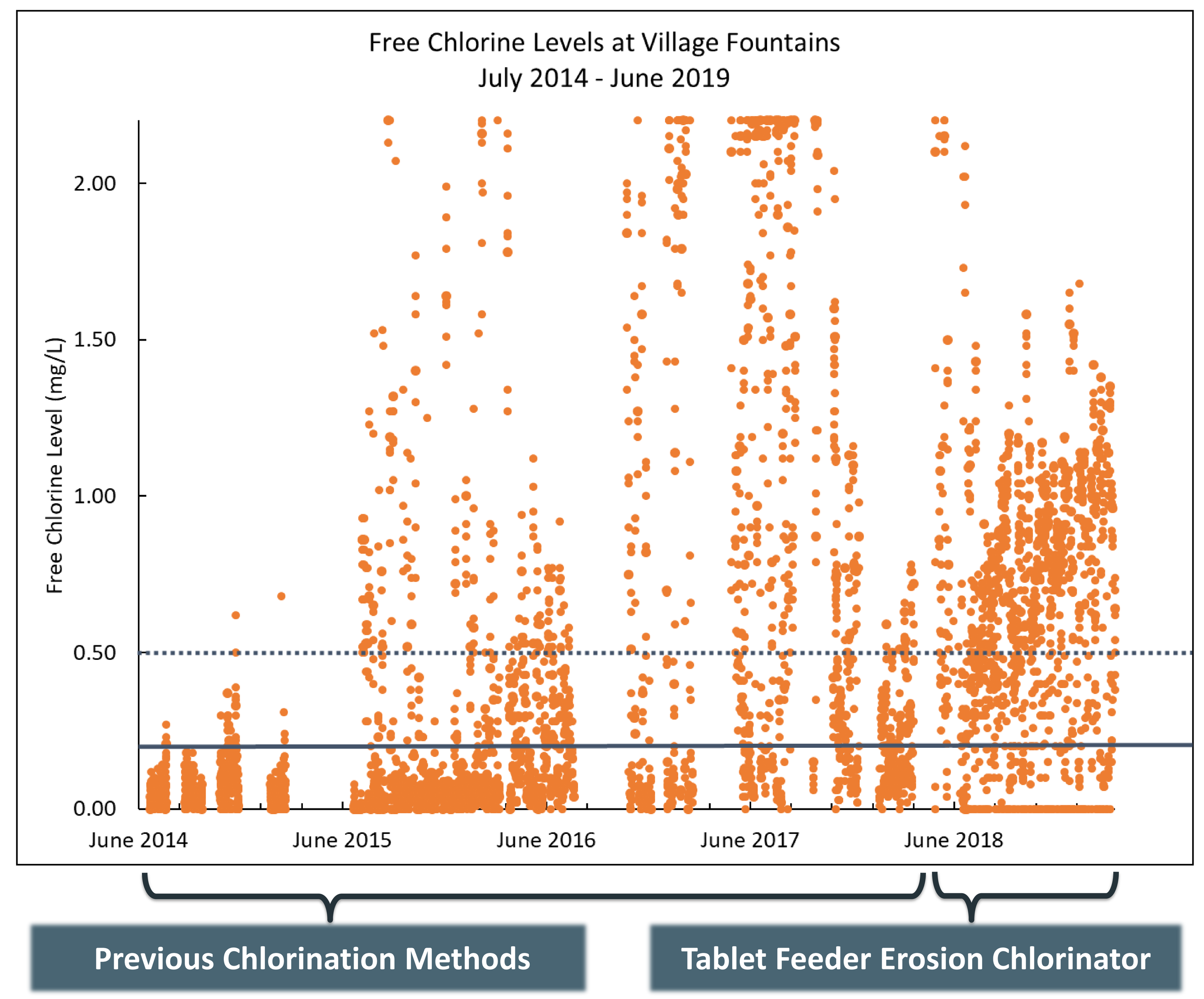

Figure 7. Free chlorine levels tested at the fountains since July of 2014.

By switching from previously used chlorination methods to the new tablet feeder erosion chlorinator, the levels of free chlorine present at the fountains has gone from meeting the desired level 26.9% of the time to 68.6% of the time. The data shows that this process has potential, but it needs further refinement to ensure quality drinking water is provided at all times.

Modeling

Computational fluid dynamics (CFD) and mass transport modeling was used to understand more clearly how both the flow through the chlorinator and chlorine tablet dissolution affect the overall chlorine dosage. This modeling was also used to capture nuances of the flow and offer insights for improvements in future designs. After the models have been validated using analytical solutions and data from the field and lab setups, new geometries can be modeled and tested for their feasibility reducing the number of prototypes needed. Collectively, implementing ideas from the modeling efforts can help ensure a constant mass flowrate of chlorine over time.

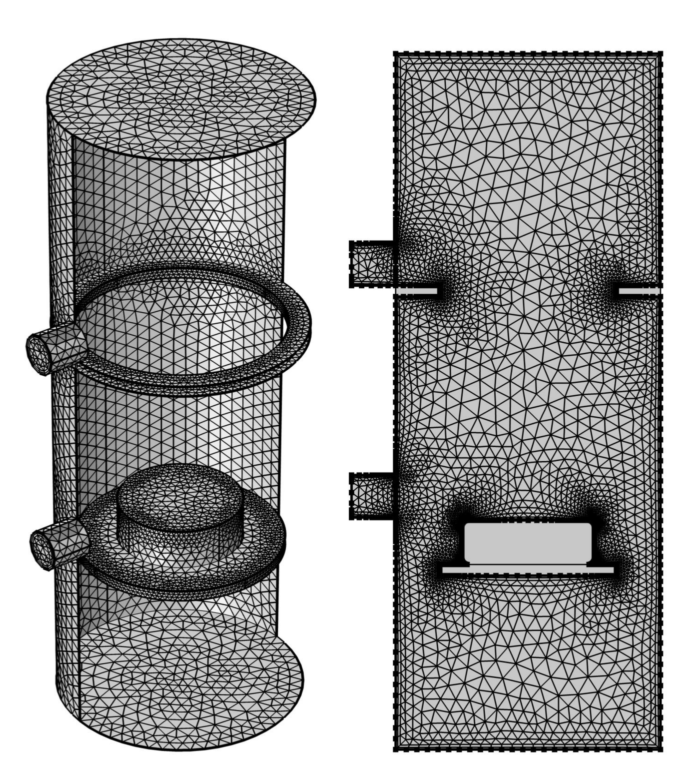

Figure 8. 2D and 3D chlorinators modeled using the software COMSOL Multiphysics.

Results

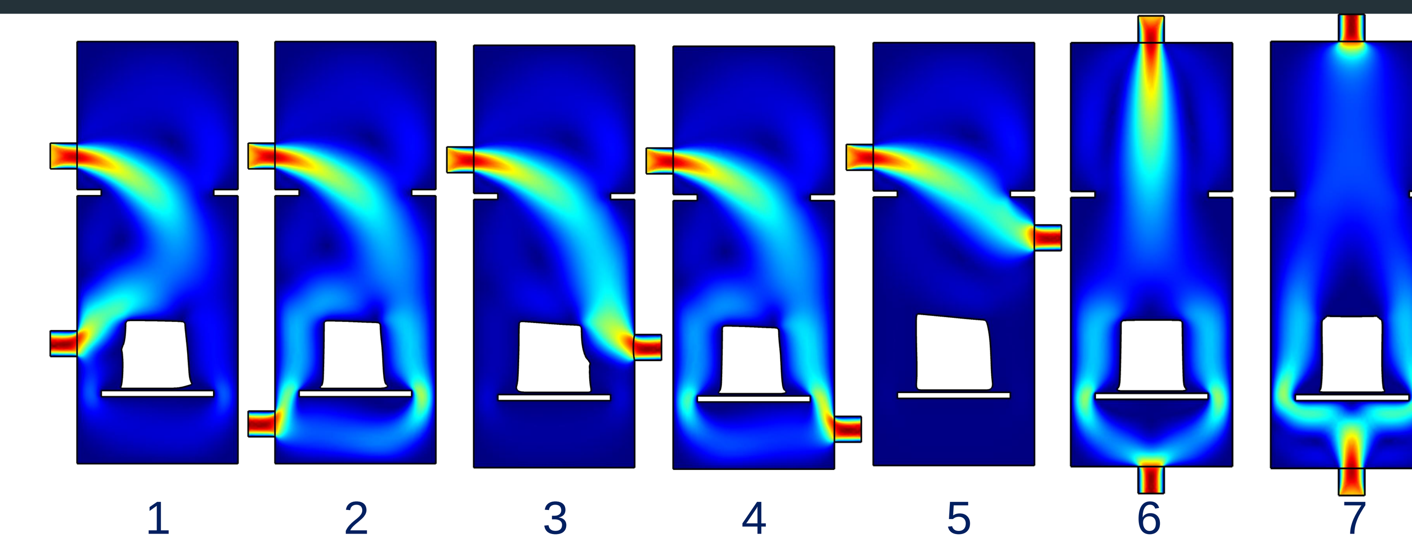

Figure 9. Different geometries modeled in order to determine how inlet and outlet location effects tablet dissolution.

After modeling different geometries, it was determined that the current model is performing as expected where the chlorine concentration leaving the chlorinator decreases over time. It was also determined from CFD modeling that having the inlet and outlet of the chlorinator towards the top of the chamber has the potential to result in a much more consistent dose of chlorine leaving the system. If the chlorinator can be designed to release a constant concentration of chlorine, the levels of free chlorine present at the fountains should be much more consistent as well. Being able to refine this process will result in better water quality and cost savings for the system as tablets can be used more efficiently.

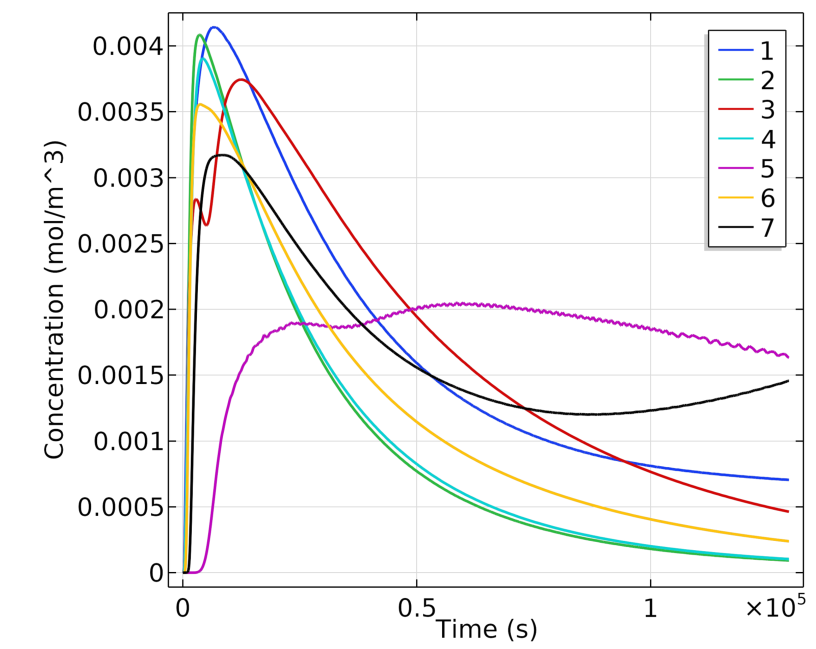

Figure 10. Levels of free chlorine at the outlet of the chlorinator for the geometries shown above.

Conclusions and Future Work

Figure 11. Lab setup that will be used to validate CFD modeling of the chlorination process.

- CFD Modeling can be a powerful tool in the design development of disinfection processes.
- Lab testing will be completed to validate the what the computer models are showing. Several different models will be tested and the results used to further the refinement of the models.
- Additional training will be done with the Haitian water team responsible for the system to improve knowledge of how the chlorinator works and how it can be operated most efficiently.
- The modeling results and field data will be used to make the system more cost effective when it comes to the use of chlorine tablets.

Acknowledgements

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