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A solar-powered system for water disinfection with UV light for use in underserved communities

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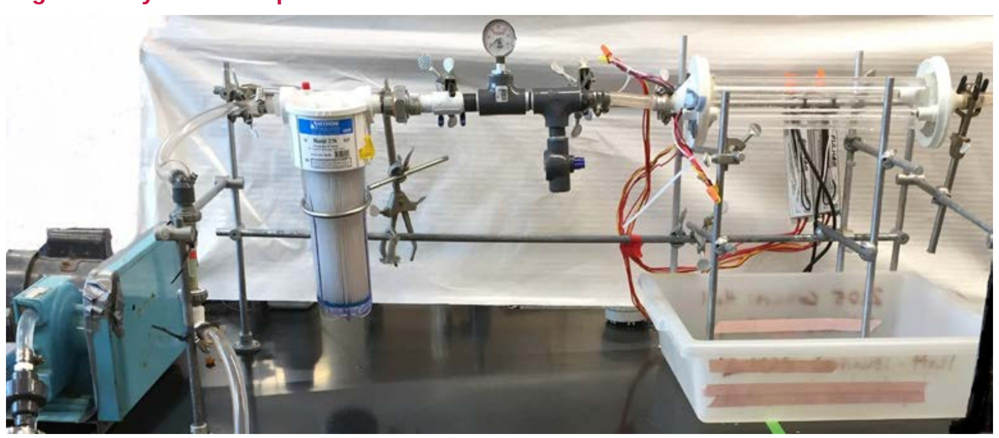
ABSTRACT

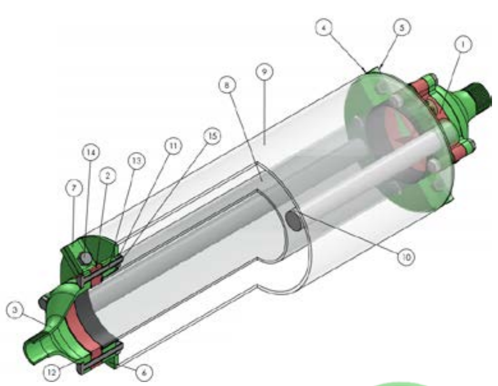
We developed a novel system for drinking water disinfection using UV light. The new system, which is specifically intended for use in underserved communities, is more robust, easier to install, cheaper to acquire and safer to operate than the commercially-available alternatives. The system was designed using advanced computer simulations of fluid flow, and was manufactured in part using 3D printing technology. Tests performed under controlled laboratory conditions and independently analyzed showed that the system was capable of delivering a UV dose of 215.6 mJ/cm^2, which significantly exceeds the requirements of 40 mJ/cm^2 set by the National Sanitation Foundation (NSF) for drinking water. The tests also showed that the system's performance was not significantly impacted by scaling from hard water or turbidity. Field trials were performed at a remote rural community in California in which the system was entirely power by a single solar panel. The results of these trials indicate that the system is ready and suitable for deployment in underserved communities to ensure the safety of their drinking water.

Fig. 1: UV system set-up in the CEE lab at UC Davis

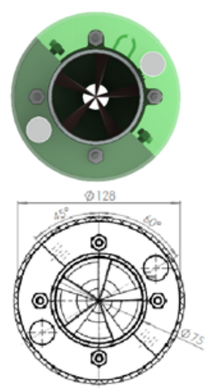


SYSTEM DEVELOPMENT

Fig. 2: Vortex Diffuser Assembly



1. Inlet Swirler Flange
2. Outlet Swirler Flange (No blades)
3. Inlet/Outlet Diffuser
4. Inlet Split Flange 1
5. Inlet Split Flange 2
6. Outlet Split Flange 1
7. Outlet Split Flange 2
8. Quartz Tube (75mm ID X 2.5mm NOM X 1/8" TH X LG 13-5/8")
9. Radiation Shield
10. UV Lamps (20mm Dia X 38.2cm LG)
11. ¼"-20 HEX NUT
12. O-Ring 1/16" TH X 2.75" ID
13. ¼"-20 Cap Screw (Thread LG 1-7/8 Full, Head: WD 7/16", HT. 5/32")
14. ¼"-20 Cap Screw (Thread LG 5/8" Full, Head: WD 7/16", HT. 5/32")
15. Rubber Seal



METHODS

The system was assess for the following parameters:

- CFD was used to predict hydraulic performance to optimize the system design before construction
- An tracer test was used to assess hydraulic performance of the completed system
- Biodosimetry was used to established the UV dose supplied by the system
- Germicidal efficiency was determined using *E. coli* and MS2 coliphage
- The performance of the system was measured when subjected to hard water and various levels of turbidity
- *In situ* testing was used to assess ease of use and maintenance needs

RESULTS

- CFD analysis was used to ensure the diffusor kept the hydraulic energy losses associated with the velocity change through the system to a minimum.
- UV system delivers a UV dose of 215 mJ/cm^2 - sufficient to inactivate most pathogenic bacteria, viruses, and protozoa.
- On average, the system achieved a 7.2 log reduction of E. coli and 6.6 log reduction of MS2.
- Fouling due to hard water was dominated by particulate fouling on the lamp facing sides of the system; however, this did not significantly impact the disinfection capability of the system.
- Also, turbidity levels from 0 to 18 NTU did not impact disinfection performance.
- *In situ* testing established that the system was able to completely inactivate the bacterial contamination in a rural community groundwater well and to seamlessly integrated with the routine operations of a veterinary medical facility.

Fig. 3: CFD Analysis (Cross-sectional contours of: (a) Turbulent viscosity, (b) static pressure and (c) eddy viscosity ratio).

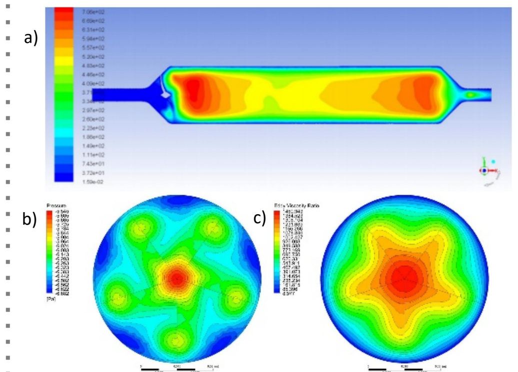


Fig. 4: (a) UV treatment system and (b) Solar Panel.

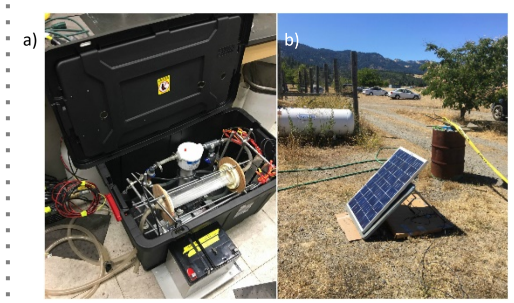
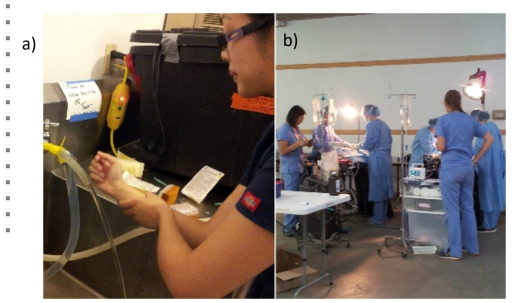


Fig. 5: Testing in Covelo, CA: (a) a veterinarian using the system to scrub-in for surgery and (b) surgery tables in use at the facility.



CONCLUSIONS

The system is characterized by the absence of contact between the UV lamps and the untreated water thereby avoiding the problem of lamp fouling. Tests conducted in an environmental laboratory showed that at a flow rate of 2.5 GPM the UV system was able to deliver a UV dose of 215 mJ/cm^2 - sufficient to inactivate most pathogenic bacteria, viruses, and protozoa. In addition, at the relatively low UVT of 75%, the system delivered a dose of 94 mJ/cm^2 which is also sufficient for inactivation of all common pathogens. The outcome of these tests, and others conducted in situ at a remote, underserved community indicate that the new system goes some way towards achieving the goal of the provision of an effective, robust, sustainable and affordable means for widening access to drinking water.

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