Status Report on UV Waterworks: Water Disinfection for the Developing World

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UV Waterworks Technology

About one billion people worldwide lack access to safe drinking water, and this number is increasing. UV Waterworks is an ultraviolet water disinfection device designed specifically for the purpose of providing safe drinking water to communities in the developing world. The device renders harmless ("deactivates") the bacterial and viral content of surface water or groundwater, improving the chance for infants to avoid the diarrheal diseases that, according to UNICEF studies, killed 3.8 million children under age 5 in 1993.

Ultraviolet (UV) water disinfection is not a new technology. However, the small-scale, energy-efficient and low-maintenance design of UV Waterworks has created a uniquely affordable and effective device: disinfecting water using the equivalent of a 40-Watt lightbulb at a cost of 2 cents per ton of water treated, treating 15 liters (or approximately 4 gallons) per minute, enough for 500-1500 people. As a result, UV Waterworks offers the first practical means of providing many communities in developing nations with readily accessible, disinfected drinking water.

Specific capabilities of the device include:

- Works with unpressurized water
- Deactivates bacteria and viruses in clear water
- Does not need a trained operator
- Maintenance every 6 months
- Rapid disinfection (water passes through unit in 12 seconds)

Limitations of the device include:

- Does not treat non-biological water pollution (chemical/mineral content)
- Does not treat Giardia or Cryptosporidium (these must be filtered out)
- Does not treat turbid water (again, water must be pre-filtered - the same filter that removes Giardia and Cryptosporidium should be sufficient to remove turbidity)
- Does not make potable water from waste water or raw sewage
- Does not provide residual protection - water can be re-infected through improper handling

- Disinfection by deactivation is not permanent, so treated water must be consumed with 36 hours or should be re-treated.
- Does not work without electricity - where grid power is not available, photovoltaic panels or other renewable energy source would raise the cost from 10 cents to 40 cents per person per year. These costs include the full annualized costs, including electricity, consumables, and amortization.

UV systems compare favorably with other water disinfection systems in terms of cost, labor, and the need for technically trained personnel for operation and maintenance:

Deep tubewells fitted with handpumps, while perhaps the simplest system to operate, require expensive drilling rigs, are immobile sources, and often produce hard water that some communities find distasteful. In some areas, long term use of deep-drop toilets in the vicinity has begun to contaminate borehole-supplied water with fecal pathogens;

Chlorine disinfection treats a broader range of organisms and offers residual disinfection, but systems are expensive with their need for special operator training and need of a supply chain of a potentially hazardous material;

Boiling water over a biomass cookstove is the most reliable treatment method, but it demands labor, and imposes high economic, environmental, and human health costs. Boiling is slower and, in terms of primary energy use, approximately 20,000 times less efficient than UV treatment.

The UV Waterworks unit is designed to deliver a dose of UV (measured in microWatt-seconds per square centimeter) sufficient to reduce bacterial counts of 100,000 colonies per 100 mL to less than 1 per 100 mL, so the water meets EPA's and WHO's bacterial standards for drinking water.

The Birth Of The Idea

In the summer of 1993, prompted by the outbreak in India of a mutant strain of cholera ("Bengal" Cholera) against which there was no vaccine, we initiated a design effort for a low-cost, robust, and low maintenance device for drinking water disinfection. Using funds from Dr. Gadgil's Pew award and $10,000 each in seed funding from USAID and from LBNL's Center for Building Science, we reviewed existing technologies, initiated a design effort, and held a workshop in Washington, D.C. in November, 1993, to address the issue.

We found that one could disinfect water with a UV dose of 40,000 mW-s/cm2 at an attractively low cost of 2 US cents per metric ton of water. However, the available UV water disinfection systems had two drawbacks: they all (1) required a pressurized source of water, due to various filters integral to the devices, and (2) used a UV-transparent sleeve to separate the UV lamp from the surrounding water stream. This sleeve fouled with biofilm and chemical deposits, reducing its UV-transparency, and thus required frequent mechanical and chemical cleaning. This was beyond the technical and time resources of the communities we hoped to help.

Our goal was to disinfect communities' drinking water collected by hand from surface sources, or with handpumps. The water entering the device might have a pressure of only a few centimeters of water column. Thus, we decided to do away with any integrated filter (and the need for pressurized water to push it through the filter). If filtering was necessary, it would have to be done outside the device, using a slow sand filter, or an in-line filter cartridge if one had a pressurized line. We circumvented the sleeve fouling problem with a design having a bare UV lamp supported below a reflector, above the free surface of flowing water. There are no solid surfaces prone to fouling between the water and the UV lamp. We set the maintenance interval of the design conservatively at 6 months. Our initial design was wholly of welded stainless steel sheet, consumed 40 Watts, disinfected 30 liters per minute (lpm), and cost about US$900.

Site: Bhupalpur, India. Standing villager using handpump that supplies water to UV disinfection unit (inside cement structure).

After a second workshop in India in May, 1994, we field-tested this design at several sites in India, including at Bhupalpur, in 1994-1995 (Figure 1). The Indian communities informed us that the flow capacity of the device was much higher than necessary, and the devices were too bulky and costly. In response, we developed the lab prototype (Figure 2) that still uses 40 Watts, but now disinfects 15 lpm, is much more compact, and has a substantially lower manufacturing cost. The unit is designed to treat water with a UV extinction coefficient equal to that of the average effluent from US municipal wastewater treatment plants. (Water with higher UV extinction coefficients will absorb more of the UV energy and have reduced disinfection performance unless flow rate is correspondingly reduced.) This design effort, completed in December, 1995, exhausted all project funding. The design has seen only minor modifications since this time, as the project effort has shifted to testing, troubleshooting, and promotion.

Initial Funding

The UV Waterworks project has grown out of three years of work at the Energy Technologies Area of the Lawrence Berkeley National Laboratory in Berkeley, California, with seed funding and support from the Energy Efficiency Program of USAID in 1993. Additional seed funding from USAID in 1993-1994 helped us to obtain significant project support in funds from the US DOE Policy Office, the Rockefeller Foundation, the Joyce-Mertz Gillmore Foundation, the International Network of Resource Information Centers; and in-kind donations of UV bulbs from Philips and GE. Ashok Gadgil also received funds from the Pew Award, which he applied toward the project. These public and private funds supported the development of the prototype 30 lpm device and subsequent design of the 15 lpm device. The 1994-1995 field test in India of this device used funds from UNICEF-India and the Lipton-Brook Bond Tea Foundation.

Technology Rights And Private Development

With the 15 lpm design completed in December 1995, the Lab was in a position to license the technology and initiate its transfer to the private sector for manufacture, marketing, and distribution. Two companies are now involved in this effort: Urminus Industries, Ltd. received its license for the India market in 1995; and WaterHealth International, Inc. was chosen in June 1996 from among nearly a dozen solicitors for the license to the rest of the world market.

These companies have developed prototype production models (Figures 3 and 4). The Lab has applied for a U.S. patent. The patent is based on UV Waterworks' design innovations of using unpressurized water with a UV bulb suspended above - and not immersed in - the water being treated. Both companies are also actively field-testing their devices, and expect to deliver their first production models in late 1997. Private activity is discussed further below.

Awards And Press Coverage

The product received significant attention in the summer of 1996 after it received both the ***Discover*** and ***Popular Science*** 1996 awards for environmentally significant innovations. Subsequent press coverage included articles in such varied print media as ***Business Week, U.S. News & World Report***, and ***Physics Today***; as well as local and foreign publications (a sampling of the coverage is attached). Dr. Gadgil was interviewed by local TV stations and by CNN for their environmental-focus news series, and then-secretary O'Leary presided at a demonstration of the device during a 1996 visit to the Lab.

Dr Gadgil regularly receives inquiries from around the world citing these sources as having introduced them to the technology. The inquiries come from current Peace Corps volunteers, students, academics, professionals, and commercial interests.

Field Tests

Following the device's receipt of the two 1996 awards, the Department of Energy (DOE) offered to make funds available to support the first field test of the 15 lpm device, which is now underway in South Africa. The field test has been incorporated into the ongoing sponsored projects of the U.S-South Africa Binational Commission, Sustainable Energy Committee. We have two partners in this effort: the Natural Resources Defense Council in the U.S.; and the South African Centre for Essential Community Services (SACECS), which is a consortium of the U.S. private electric utility-funded Electric Power Research Institute (EPRI), the South African national electric utility ESKOM, and other South African stakeholders, with interests in a broad arena of developmental infrastructural issues.

The primary objectives of the field-test are to: (1) identify and correct any design problems and unanticipated technical flaws in the device, and ensure its compatibility with the user preferences and requirements in South African communities; (2) evaluate and document the field performance of the device and its effectiveness in limiting the occurrence of waterborne biological contaminants in drinking water; (3) determine appropriate media and delivery systems for (a) community placement and acceptance of the device, (b) the necessary user education to assure sanitary and exclusive use of disinfected water for drinking and food preparation, and (c) relevant community education in public hygiene and sanitary practices; and (4) determine the content and delivery systems for technical training of maintenance personnel, local management systems for community ownership and operation of the device to ensure its ongoing functioning.

UV Waterworks unit installed on the exterior wall of the kitchen at the Lily of the Valley HIV-Hospice near Durban, South Africa. A few orphans and their caretakers can be seen in the kitchen windows. Durban Metro Water plumbers and a Berkeley Lab researcher stand below the just installed unit (August, 1997).

After initial testing of the device using the laboratory facilities of the municipal water utility supply in Durban, we installed the device at the first test site in July 1997 (Figure 5). The test site is in a rural area near Durban, at a hospice for abandoned infants who have tested positive for the HIV antibody. These infants presumably received the antibodies from their HIV-infected mothers; many of them turn out to not be infected with the actual virus. Still, a number of the infants do ultimately test positive for HIV, and through the hospice's history, 20% of its patients have died from AIDS complications. Providing clean drinking water for these high-risk children is a very significant step toward improving their chances of living with HIV (Figure 6).

Infants at the Lily of the Valley HIV-Hospice for orphans near Durban. This is the first site for the field test of UV Waterworks in South Africa (August, 1997).

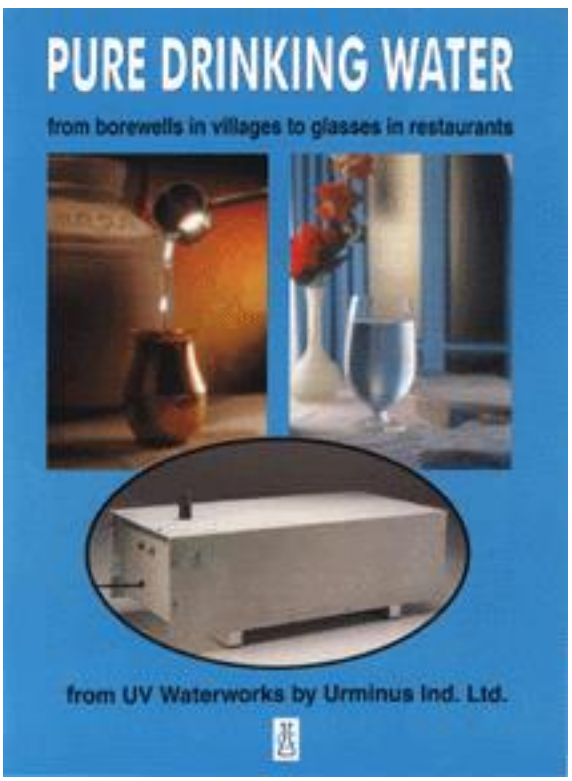
The first results from the field show that UV Waterworks successfully treated contaminated groundwater from the borehole on which the hospice depends. Before entering the UV Waterworks unit, the water contained an average of 4000 colony forming units (CFU) per 100 mL, including 200 fecal coliforms per 100 mL. Water leaving the unit showed no detectable coliforms. The UV Waterworks unit indeed seemed to be eliminating all bacteria of concern in this case.

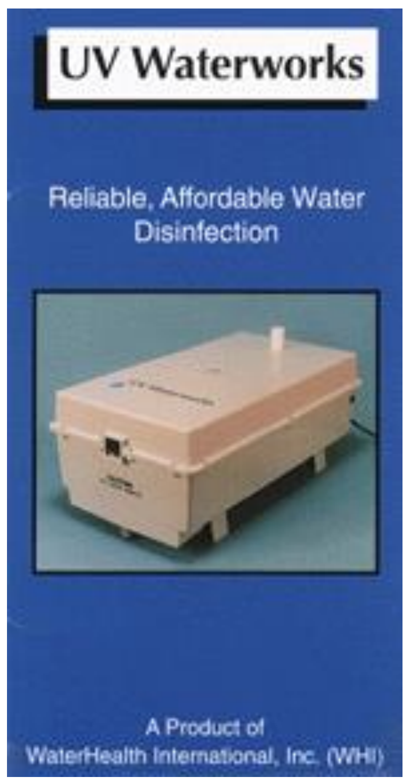
We plan to place UV Waterworks at a total of 8 locations in a phased manner, thus enabling us to improve our approach in the later stages of the work from the lessons learned in the early stages. Of these 8 installations, 3 will be intensively monitored (about 50 samples a week for 50 weeks) for the bacterial contamination along the drinking water chain, from the outlet of the device, to the household storage cisterns, to the water in the drinking cups. The other 5 sites will be monitored less frequently (about 10 samples a week for about 20 weeks).

The community placement of the device, and community education and management of the technology will be organized by working with local NGOs who have the trust of the community and who understand the local customs, politics, and issues. We will document the outcome of various approaches to address these important dimensions of the problem. An interim report of initial field test findings (report number LBNL 40360, "Field-testing UV Disinfection of Drinking Water") will be presented at and published in the proceedings of the 23rd WEDC conference "Water & Sanitation for All," to be held in Durban, South Africa during September 1-5, 1997.

Public Sector Promotion
LBNL has identified public sector and private sector avenues for the rapid dissemination of the UV Waterworks technology in the developing countries markets. The private sector approach is described in the following section. The public sector approach seeks adoption and promotion of the technology by international health and development agencies (e.g., UNICEF, WHO, World Bank, Peace Corps) for its wide-scale dissemination and use. A precondition for this adoption is the availability of results of extended scientific field trials and demonstrations of UV Waterworks. While we currently lack this data, the tests underway in South Africa are our first step towards filling this void. Even without full field test data, we see value in making these same agencies aware of the technology, its market availability, and of the private sector progress.

To accomplish these two goals of raising awareness and exploring possible field test partnerships, we held an executive dialogue and roundtable in Washington, D.C. in June 1997. The event was sponsored by USAID as a program-end event to round out its multi-year support of UV Waterworks through the Energy Efficiency Program. The roundtable featured content provided by representatives of the Pan American Health Organization (WHO's agency in the Americas) and the UNICEF's Water, Environment and Sanitation cluster, as well as by Ashok Gadgil and the two private licensees (WHI and Urminus). Additional participants included representatives from USAID, DOE, and a handful of NGO's and private organizations. By the end of the half-day event, the 21 participants had discussed at length the benefits of different implementation models that public agencies may follow, but the hurdle of identifying additional field testing opportunities - or funding to support such an effort - remained uncleared.





Private Sector Investment

The technology rights for the device have been granted to two companies, Urminus Industries (for sales in India only) and WaterHealth International, Inc. (WHI) for sales in the rest of the world. These companies are taking the invention and bringing it to the stage of commercial production, with the first mass-produced units set to be available in September, 1997. Urminus Industries has raised approximately US$800,000 in support of their expanded manufacturing capacity for the product. WaterHealth International was formed specifically around the UV Waterworks unit, and to date has raised approximately $2.7 million in private capital.

After obtaining the technology rights for the India market from the Laboratory, Urminus Industries had its model tested and certified by two labs and then test marketed in rural areas with encouraging results. The Indian Institute of Management (IIM) Bangalore completed initial concept testing and market research, confirming that the unit is cost-effective and will reduce infant mortality. Additional units were recently installed at public places through Sulabh International and other institutes. With feedback from past tests, Urminus designed and is testing a compact new sand filter for removal of suspended particles prior to the unit. Urminus has constructed a factory at Pune near Mumbai (Bombay) to manufacture a 15 lpm unit, with the first manufactured units expected this Fall.

WHI, a small company incorporated in California, has obtained exclusive global (except for India) manufacturing and distribution rights for UV Waterworks from the Laboratory. WHI is now seeking indigenous companies from countries around the world to serve as its distributors in those countries.

WHI is developing three UV Waterworks units using the same core box and disinfection chamber: a basic unit with minimal automatic controls, a unit with some automatic controls, and a unit for emergency response programs that will provide extreme portability and self-sufficiency, while sacrificing some of its energy efficiency.

To bolster the marketing potential in these countries, WHI has determined to establish a few high profile demonstration projects in each country over the next three years. WHI is working cooperatively with groups like the Peace Corps in Bolivia and UNICEF and PAHO as well as public health agencies in other countries to set up and manage these demonstrations. These demonstration projects will be implemented when WHI's manufacturing begins in August of this year, but the planning is underway in many countries.

Finally, WHI takes full advantage of the commercial assistance services offered by the Department of Commerce and the Department of State in these and other countries around the world in WHI's efforts to find and qualify distributors and other partners.

Summary

After four years, UV Waterworks is now a reality. It is an example of nearly $335,000 in public funds and $105,000 in private foundation support that has produced over $3.5

million from the private sector to create a new product in the commercial market. LBNL continues to provide technical assistance to WHI and, to a lesser extent, to Urminus. The WHI-LBNL partnership promises to produce additional improvements to the UV Waterworks device, as well as altogether new water quality technologies and products as a result of WHI's promise of over $100,000 in in-funds support over the next few years.

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Figures

1. Field testing of 30 lpm device in Bhupalpur, India, 1994-1995.
2. LBNL Prototype 15 lpm device, December, 1995.
3. Urminus production prototype (from brochure)
4. WHI production prototype (from brochure)
5. Field testing of 15 lpm device outside Durban, South Africa
6. First beneficiaries of UV Waterworks at field test site

Known Print Media Coverage

*"How to Tackle the Third World's Massive Travails? One Small Piece at a Time," U.S. News and World Report, Dec. 30, 1996-Jan. 6, 1997, p. 69.

"The Best of What's New--Water Cleaner," Popular Science, Dec. 1996, p. 72.

"Brighter Light, Better Water," Environmental Health Perspectives, October 1996, vol. 104(10), pp. 1046-1048.

*"LBNL Creates Water Purifier for Developing Countries," Physics Today, July 1996, p. 57.

"Reines Wasser fźr alle," GEO (German natural sciences magazine), July 1996 (No. 7), p.148.

*"Water, Pure and Simple," Discover Seventh Annual Technology Awards, July 1996.

"Acqua pura per tutti," Panorama (Italian news and culture magazine), June 1996, p. 165.

*"Using UV Light to Clean Water Inexpensively," Biophotonics International, March/April 1996 vol. 3(2), pp. 30-31.

"Safer Water for Poorer Nations," Science News, March 2, 1996, vol. 149, p. 138.

"Device Cleans Water with Light," UPI Science Writer, February 12, 1996.

*"Purifying Water for a Penny a Ton," Business Week, May 29, 1995, p. 87.

*Article Attached