In the rural Mityana District of Uganda, 65-km northwest of Kampala, a team of engineers from the SAME Kaiserslautern and Boston Posts, sponsored by the Veolia Foundation, visited eight remote villages to help provide water treatment solutions and improve the quality of life for those living in these communities.

Providing Bacteria-Free Water

Engineering Cost-Effective Treatment Solutions in Uganda

Chlorine disinfection and solar power systems can provide cost-effective and locally available solutions for bringing water to acceptable drinking standards in rural and developing countries.

By Michael Ottensmann, P.E., M.SAME, Bill Naughton, PG, M.SAME, and April Whitbeck, P.E., M.SAME

Rural Uganda, like many areas in Africa, suffers from a contaminated water supply, including high concentrations of bacteria. Small water holes fed by groundwater and surface water runoff are used by a majority of the population, including farm animals. Approximately 22 children die each day from diseases caused by drinking unsafe water.

Providing water treatment to these rural populations presents unique challenges. For one, the cost of traditional treatment is well beyond the $0.50/day wages of much of the populace. Treatment systems also can be hindered by a lack of local utilities. The nearest reliable electricity may be one hour away by car. The ideal system would be built with locally available materials, a minimal financial investment, and, to be accepted, fit within the daily rhythm of village life. Chlorine disinfection and solar power technologies are two cost-effective solutions that fit this criteria.

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In rural Uganda, potential water treatment systems, to be accepted and effective, need to fit within the daily rhythm of village life. PHOTOS COURTESY VEOLIA FOUNDATION

The engineers field-tested two water treatment procedures for effectiveness in providing clean drinking water: a salt chlorination prototype adapted to the local culture of rural Uganda; and an ultrafiltration membrane filter. Both methods reduced the bacteria count from in the thousands down to three to four colonies.

INITIAL CONCEPT

In principal, salt chlorination is obtained by nothing more than passing a current through a salt solution, using titanium electrodes to separate the sodium from the chloride elements. The team's lead engineer developed a simplified salt chlorinator prototype, based on a more complex GE system, consisting of a bucket of saline solution, two titanium electrodes, a car battery, and a solar panel to recharge the battery.

The prototype produced a consistent 6-l solution of 2.2-mg/l chlorine overnight. Integration into the culture would require a local to run the salt chlorinator overnight and then distribute several teaspoons of chlorine solution into each of the villagers' water jugs (jerry cans) in the morning before they fill them at the water supply.

PERFORMING FIELD WORK

The project in Uganda was an opportunity to test two procedures that could potentially have a positive impact on the health of people in rural communities. In June 2016, the team traveled to Uganda to field test both the chlorination generation and treatment process and the Veolia Force #5 ultra-filtration system.

Water samples were taken and bacteria counts were analyzed at 11 different sources. The untreated water supplies had bacteria counts in the thousands ("too numerous to count" or TNTC). Secondary water quality parameters for color (visible), and turbidity (measured) were very high. Most water sources had a green or light brown color, with some containing floating algae. The team chose five sources for chlorine disinfection testing.

Raw water samples were collected at each of these sources. Drinking water chemical standards set by the World Health Organization were met with a few exceptions. All samples exceeded the iron and phosphate levels and indicated moderately low pH levels.

A handful of villages were chosen for further investigation. Of greatest concern was the turbidity level of the raw water. Chlorine disinfection is considered to be less effective for raw water with levels above 5-NTU (Nephelometric Turbidity Unit). With very few exceptions, the water sources had turbidity levels in the mid-40s.

REDUCING BACTERIA COUNTS

Field tests demonstrated the effectiveness of adding chlorine to reduce bacteria counts. One hour of chlorine generation resulted in a chlorine concentration of 500-mg/l. This level reduces the potential health hazards associated with handling higher levels of liquid chlorine. Jerry cans of water from each source were dosed and tested at 1-mg/l and 2-mg/l to determine the appropriate chlorine concentration to eliminate bacteria.

Two types of bacteriological testing were used: 3M Petrifilm, which measures total bacteria; and the Wagtech Membrane Filtration unit and Incubator, which measures coliform bacteria and total bacteria. While chlorine proved to be very effective in initially reducing the bacteria

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counts in high turbidity water sources, the effect was not consistent.

Turbidity provides a measure of protection for bacteria. Consequently, the bacteria count of "disinfected" turbid water was not stable and disinfection was not complete.

The only low turbidity source tested during the field trials was a well in Kyamagamule, Uganda. During a prior visit in March 2015, the well tested negative for bacteria. Results in 2016 showed a count of over 200.

However, since the well had been refurbished in the interim, the team suspected that bacteria were likely introduced onto the pump and well screen, rather than being present in the aquifer. Using chlorine generated onsite, the well was shock-chlorinated. Although long-term results were not obtained during the short duration of the trip, all the results of the testing three days post-chlorination resulted in zero bacteria counts.

ULTRA-FILTERED SAMPLES

The Aquaforce #5 filter is a fist-sized ultrafiltration device that uses membranes with a pore size of 0.1-µ designed to remove bacteria, viruses and other solids from the water supply. These filters are designed to supply up to 10,000-l of bacteria-free, clear water with minimal maintenance before requiring replacement.

Turbidity testing of the filters demonstrated effectiveness in reducing turbidity. Seven of eight samples had turbidity of less than 1-NTU and one sample measured less than 4-NTUs—all within acceptable drinking water standards set by the Environmental Protection Agency for this limited sample testing.

The microbial contamination (total coliforms) was measured by the Wagtech filtration unit. Testing results demonstrated significant lowering of bacteria in all nine tested samples. Seven of the nine samples showed no visible coliform colonies and two samples had very low (2 and 5) coliform colonies.

ADAPTABILITY OF SYSTEMS

With the exception of titanium electrodes, all materials were locally available for the chlorine disinfection system. Solar panels with German-made solar elements are readily available in Kampala. The total cost for one system serving a small village (about 100 people) is $325.

The Veolia Force #5 filter is not currently available for purchase. When it is, a single #5 micro filter will provide sufficient potable water to meet the needs of up to five people per day. The cost of such a filter will have to be considered in relation to average earnings of $1/day or less. High volume production of the filter, and/or subsidization of the cost by the Ugandan Government or an international development agency could make it a viable option.

INTEGRATION INTO VILLAGE LIFE

Dosing proved the greatest challenge. Both chlorine generation and disinfection processes require proper dosing for consistently effective results. Graduated beakers and teaspoons are preferred measuring tools, but they are easily lost and not necessarily uniform in size locally. Jerry can caps, on the other hand, provide roughly 20-ml each and they are in plentiful supply.

While 45-ml of salt per 6-l of water is needed to generate a consistent amount of chlorine, dosing salt with two jerry can caps per 6-l of water proved to be an effective ratio. Similarly, chlorine must be dosed at 1-mg/l for disinfection, but less than 3-mg/l for taste and odor. Chlorine dosing was calculated at one capful.

TAKING THE NEXT STEPS

The salt chlorination system proved easy to use and provided effective disinfection. The acceptance level of the process was high and the solar power created the additional benefit of an electrical source for villagers.

When the water source had turbidity below 5-NTU, the disinfection was complete. Even where the turbidity was above 40-NTU, the reduction in bacteria count was substantial. To overcome the turbidity issue, additional measures, including rapid sand filtration, are being investigated.

Rapid sand filtration is a basic and easy-to-operate-and-maintain method to reduce turbidity using local materials. A simple prototype was developed by members of the SAME team. A 98 percent reduction in turbidity was achieved, with no filtered samples exceeding 3-NTU. Still, field-testing of both cistern type and cascade sand filters built with local materials needs to be completed to determine their effectiveness and applicability in the region.

Based on the limited samples tested, the Veolia Force #5 membrane filter was very effective at improving the secondary water quality parameters and producing very clear water while significantly lowering bacteria counts—both of which appear to be acceptable to the local villagers. Unit costs will have to be at an acceptable purchase level for villagers for this to be considered an appropriate methodology.

For sustainability of the chlorination method, a local villager will need to be trained to test and maintain the disinfection system. Local resources also will have to develop funding through micro-financing procedures and local entrepreneur structures to ensure long-term viability of the treatment method.

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