Aquatest: Expanding Microbial Water Quality Testing for Drinking Water Management

A lack of adequately equipped laboratories and available skilled staff is a common problem for water quality testing in some developing regions, particularly in small-town or rural settings. In this article **Zarah Rahman**, **Ranjiv Khush** and **Stephen Gundry** talk about an international multi-disciplinary R&D project aiming to address this issue.

The single greatest health risk associated with inadequate or unsafe water, sanitation and hygiene is gastrointestinal illness, or diarrhea, which contributes to 39% of the disease burden associated with poor water, sanitation, and hygiene conditions (1). Approximately 4 billion cases of diarrhea occur globally every year, resulting in 1.5 million fatalities that are largely among children under the age of 5 (1, 2). Consequently, water supply management programs that improve drinking water quality and reduce diarrheal disease risk will provide significant gains in global public health.

Effective tools for collecting and managing water quality data are essential requirements for water supply improvement and maintenance. Regular operational monitoring by water suppliers and surveillance testing by health agencies can trigger corrective actions, provide justification for additional resources, and, as a result, facilitate overall improvements in water quality. Most accepted methods for microbiological water quality testing, however, require laboratory facilities and skilled technicians. While these resources exist in most large urban centers of the developing world, they are limited in smaller towns and rural communities.

The Aquatest research and development program comprises an international, multidisciplinary consortium that is dedicated to the development of microbial water testing and data management tools that are appropriate for resource poor settings. The consortium is led by the University of Bristol, UK, and is supported by a four year, USD 13 million grant, awarded to the University of Bristol by the Bill & Melinda Gates Foundation (see Box 1 for a list of Aquatest consortium members).

Upon completion of the research and development program in the fall of 2011, the Aquatest consortium expects to identify commercialization partners who will support the program's mandate to promote global access to new water testing technologies.

Aquatest Design Features

Diarrhea causing microbes enter water supplies with fecal contamination. In the absence of efficient diagnostic methods for the full range of diarrhea causing pathogens, which include many types of viruses, bacteria, and protozoan parasites, microbial water quality is determined by the level of fecal contamination, which serves as a proxy for health risk.

The internationally recognized indicators of fecal contamination are the fecal or thermotolerant coliforms, a subset of the coliform group of bacteria that predominantly reside in mammalian guts. Among the fecal coliform bacteria, *Escherichia coli* (*E. coli*) species are the most prevalent and are generally considered to be most closely associated with fecal contamination (3). The Aquatest diagnostic strategy, therefore, is based on *E. coli* detection.

Diagnostic development for microbial drinking water quality must address three significant challenges.

1) Sensitivity: Guidelines and regulations for drinking water quality generally stipulate that tests must be sensitive enough to detect single cells of fecal indicator species in 100 milliliters (mls) of sample. High levels of test sensitivity reduce the risk of 'false-negative' test results.

2) Specificity: Drinking water quality tests for fecal contamination must differentiate between targeted fecal indicator microbes and other environmental species. High levels of test specificity reduce the risk of 'false-positive' test results.

3) Live vs. Dead: Water treatment (for example chlorination or ultra-violet light exposure) that does not include a filtration process will inactivate contaminating microbes without removing them from the water supply. Drinking water quality tests must differentiate between live and dead microbial cells in order to reduce the risk of false-positive results.

To date, culture based assays with the ability to amplify and differentiate between small numbers of viable microbes in drinking water samples have provided the most effective strategy for meeting these three challenges. The Aquatest diagnostic tool continues to build on a culture based *E. coli*

Figure 1: The Aquatest microbial water quality testing device. The sixteen equally sized *E. coli* 'culture chambers' are visible through the clear plastic on the bottom of the device.

Box 1: Aquatest Consortium Members

University of Bristol, United Kingdom
University of Berkeley, USA
University of Cape Town, South Africa
PATH USA, Seattle, Washington
Aquaya Institute, USA
Health Protection Agency, USA
University of North Carolina, USA
University of Southampton, United Kingdom
University of Surrey, United Kingdom

detection platform, while incorporating unique features that focus on test applications in more isolated settings.

The defining feature of the Aquatest diagnostic design is that the device is entirely self-contained. It consists of a single plastic water sampling and testing unit for 100 mls of water that holds premeasured doses of both an *E. coli* growth medium and a chlorine based disinfectant (Figure 1). After collecting a water sample, a few simple steps mix the growth medium and segregate the sample into distinct chambers on the bottom of the device. Upon incubation at 37º C for 24 hours, the device displays levels of *E. coli* contamination based on the number of chambers that indicate *E. coli* presence. *E. coli* presence is indicated by fluorescent emissions upon exposure to ultra-violet light. A Most Probable Numbers (MPN) table translates the number of *E. coli* positive chambers into estimates of *E. coli* contamination in the starting water sample (see Box 2 for details of detection limits).

Taking a microbiological test out of the laboratory requires careful attention to health and safety. To alleviate the health risk of culturing microbes in water samples, the device has a robust seal that prevents any leakage after sample collection. In addition, the device contains a disinfectant that is released after the test is completed to kill any microorganisms that have multiplied during incubation.

The design group is also developing a small field incubator that does not require electricity (Figure 2). This field incubator contains a lining of Phase Change Material that will maintain an internal temperature of 37º C over a period of 24 hours after heating with boiling water. In settings that require high numbers of tests, conventional microbiological incubators with larger capacities will be more appropriate.

The first batch of devices and incubators is currently being manufactured for complete laboratory validation studies in the UK and subsequent performance verification in select field settings by the end of 2010.

Cell Phone Tools for Data Management

The Aquatest Consortium recognizes that effective and efficient information flow is essential for maximizing the impact of water quality information. Simple data reporting tools are especially important when testing is decentralized and on-site field staff may not have the tools and resources to address all water management challenges. In anticipation of the increasingly decentralized water testing that might be motivated by the Aquatest device and similar field tests, the Aquatest Consortium is also developing mobile phone based technologies for reporting water quality results and managing data.

The Spatial Data Management Group at the University of Cape Town (UCT) in South Africa, a member of the Aquatest Consortium, has produced an application for recording, storing and transmitting water test results to a central database that works with most mobile phones. Users are prompted to enter water quality and other water management information into forms that are then transmitted to a central database via General Packet Radio Service (GPRS), a low cost mobile data service.

Box 2: Most Probable Number Table

Number of Chambers	*E. coli* Count per 100ml	Risk Level
0	0	In conformity with WHO guidelines
1	1-10	Low Risk
2-14	11-100	Intermediate Risk
14+	>100	High Risk

Figure 2: The Aquatest Incubator. Current prototypes are designed to incubate a single testing device at 37º C without an external power source. The Aquatest design team is also investigating larger configurations that are capable of holding multiple tests.

The system can also be configured to send a text message to relevant authorities when samples fail to meet established parameters. This Water Quality Reporter application is built with JavaRosa, an open source platform for data collection on mobile phones.

Although the Aquatest device and incubator are still under development, the UCT team has been piloting the Water Quality Reporter in four rural South African municipalities since April 2009. Working with the local water management authorities, data collection forms were customized for each municipality by pre-loading information about the local sampling points and translating the application into local languages. With the Aquatest device not yet available for field use, the team provided 'sampling packs' containing gloves and tests for hydrogen sulphide producing bacteria to Environmental Health Officers and supply caretakers for on-site bacteriological testing. Since implementing a number of minor design changes identified by the pilot study, the UCT team has begun to evaluate the overall system and assess its impact on water management in the South African pilot sites.

Field Piloting of the Full Aquatest System

The final phase of the Aquatest Research Program will be field pilots of the full Aquatest system– including the device, incubator and cell phone data management system - with government authorities, water suppliers, NGOs, and community water groups in both urban and rural settings around the world. These field pilots will allow a global selection of organizations in the water sector to integrate Aquatest into their programming before it is manufactured on a large scale and made commercially available. Through the pilots, the Aquatest Research Consortium will be able determine the utility of the Aquatest system for increasing the capacity of water quality monitoring programs in a range of real world settings. This process of integrating the Aquatest system into water quality control and surveillance systems in a diverse set of developed and developing countries will allow a nuanced look at the role of new testing technologies for improving water quality monitoring and ultimately increasing access to safe water.

For on-going updates on the Aquatest research program, please visit the Aquatest website and sign-up for the quarterly newsletter.

References

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Supporting WSP Capacity Development in Africa

IWA, UNHABITAT and CAP-NET have joined forces with local training providers to provide WSP capacity building to African Utilities. In August 2009 IWA and Aguas de Portugal (AdP) organised a WSP sensitisation workshop for decision makers in African water utilities and regulatory authorities which was attended by representatives from 13 countries (Mozambique, South Africa, Zambia, Malawi, Mali, Cape Verde, Sao Tome, Uganda, Kenya, Ethiopia, Tanzania, Ghana and Angola). The workshop introduced participants to the WSP approach from a strategic, financial and operational perspective and highlighted the various benefits.

Following on from this workshop a training seminar was organised in September 2009 by IWA, UNHABITAT, CAP-NET and Rand Water. Each utility represented at the sensitisation workshop had an opportunity to nominate three employees to attend the seminar. Representatives of nine utilities from the following countries participated: Zambia (Kafubu Water & Sewarge Co; Southern Water & Sewerage Co.), Kenya (Mombasa Water & Sewerage Co; Nairobi Water & Sewerage Co), Ethiopia (Harar Water & Sewerage Authority), Ghana (Ghana Water Company), Namibia (City of Windhoek), Malawi (Southern Region Water Board). The training was over a five-day period and was structured so that a draft WSP was developed during the course and a series of follow-up activities was scheduled to monitor progress.

During the 15th African Water Congress in March 2010, three utilities who had participated in the training presented the progress they had made in implementing WSPs. Significant progress was identified in the following areas:

- System improvements (some low-cost, tangible benefits)
- Institutional (Internal – strategy, budgeting, CEO commitment; External – improved stakeholder cooperation)
- Incentives (Company-wide – regulatory driven (financing); Individual staff – performance assessments)

Significant challenges were identified in the following areas:

- Funding / Financing (Short term – capacity (training, additional staff); Long term – implementing improvement plans)
- Scaling-up (Building evidence base to inform policy (pilots); Policy frameworks to enable widespread WSP implementation)
- Monitoring / auditing (Monitoring progress; Regulatory auditing)

Training will continue throughout 2010 with course organised in Morocco (for French speaking African utilities) and Angola (for Portuguese speaking African utilities). For more information about this initiative, please contact Tom.Williams@iwahq.org