ABSTRACT

"E. coli contaminated drinking water in rural Uganda: Using results to make an impact"

In January 2006, I worked with Community Based Integrated Nutrition (COBIN) to perform water quality testing and design & distribute health questionnaires to 40 households in the Lyantonde and Kiruhura districts of rural Uganda. Two types of water microbiology tests were used to test families’ drinking water for E.coli contamination: the Colilert MPN Test made by IDEXX Laboratories (presence/absence test) and the E.coli Count Petrifilm made by the 3M Company (quantification of E.coli). 46 total water samples were taken directly from homes. Over 90% of unboiled water samples were contaminated with E.coli. All samples from rainwater collection tanks were negative for E.coli. There were boiled samples that were positive for E.coli, most likely because after boiling the water, it was poured back into the same container that the water was collected with. This showed the need for multiple interventions. In January 2007, additional water testing was performed (samples taken straight from the source), and we provided clean clay pots with covers for water storage to village health workers at workshops titled “Home-based water purification trainings.”

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TITLE: *E. coli* contaminated drinking water in rural Uganda: Using results to make an impact

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Introduction

In Uganda, the top four causes of mortality in children under five years old are malaria, diarrheal diseases, malnutrition, and respiratory tract infections (D. Sserwadda, personal communication, January 2005). The impact of repeated or persistent diarrhea on nutrition and the effect of malnutrition on susceptibility to infectious diarrhea are reinforcing elements of the same vicious circle, especially among children (World Health Organization 2005). Access to a clean source of drinking water helps prevent both malnutrition and diarrhea, putting a stop in the cycle. In regards to the other top causes of child mortality, drinking unclean water can weaken a person’s immune system so that other diseases such as malaria and respiratory tract infections are harder to fight off. Diarrhea and nutritional deficiencies cause increased oxidative stress and immune suppression, which in turn causes increased HIV replication (F. Wabwire-Mangen, personal communication, January 2005). Therefore, clean water is important to prevent not only water-borne diseases but also other major illnesses that worsen with a weakened immune system.

In December 2004, I studied health and nutrition in Uganda with 13 other students through the College of Agricultural and Life Sciences short-term study abroad program. We spent time visiting hospitals, rural health centers, malnutrition clinics, and agricultural research centers. We also looked at water supply in rural villages. The problem of unsafe drinking water in Uganda is not different from rural areas of many other developing countries. Each day about 5,000 children worldwide die from infectious diarrhea acquired from unsafe drinking water. The UN set a goal of cutting in half the population without good water sources by the year 2015, which means that every day, 125,000 people must be provided access to clean water (Rotary International 2005).
The lasting image of people collecting dirty water for drinking from stagnant pools greatly affected us and when we returned to UW-Madison in early 2005 we applied for and received the Wisconsin Idea Undergraduate Fellowship, for the construction of four rainwater collection tanks. The idea was that UW-Madison students on the following year’s study abroad trip would help to construct the tanks as a service-learning project. We formed a student organization called “Village Health Project” and in the summer of 2005, applied for and received 501(c)3 non-profit status. As we began to apply for grants and give presentations to organizations such as Rotary International as a fundraising strategy for additional clean water projects, it became apparent that we needed specific data on the water situation in the two districts of Uganda we are working (Lyantonde and Kiruhura Districts, southwest Uganda). Funding organizations wanted to know exactly how bad the water situation is in these areas, and we had nothing to show them except pictures of brown, shallow pools of water. Data obtained from water testing is crucial in order to obtain funding for future projects aimed at improving the drinking water quality in rural Uganda.

We also realized that raising money for rainwater collection tanks and water filters is not enough; these technologies have to be supplemented with education. However, we had no starting point to implement any educational projects because we did not know the baseline knowledge of the communities in regards to the importance of water to health, how water gets contaminated, and how to obtain safe drinking water. Based on this, I returned to Uganda in January 2006 and January 2007 for my senior thesis project to answer the following research questions:
1) Are the drinking water sources in the Lyantonde and Kiruhura Districts of rural southwest Uganda contaminated with *E. coli* bacteria? If yes, how contaminated are they?

2) What are the educational needs of the communities in regards to the importance of water and practices such as water treatment and storage?

**Methods**

I returned to do a preliminary analysis of the water situation to obtain empirical evidence on the need for more dependable and innovative water sources. This analysis included testing water in the villages for *E. coli* bacteria, distributing questionnaires to individual households to determine current water practices and the educational needs of the community, and designing and implementing trainings for village leaders titled “Home-based water purification trainings.”

**WATER QUALITY TESTING**

Contaminated water, although known to be a major source of illness, is rarely tested microbiologically because standard methods require materials and facilities which are either not available or are unaffordable. Previous work in Tanzania and western Kenya demonstrated the usefulness of the Colilert MPN and *E. coli* count Petrifilm biological tests for point source testing for *E. coli* in 10 ml and 1 ml of water, respectively (Metcalf 2005). Colilert tubes and Petrifilms are inoculated and incubated at 35°C for 24 hours. MUG+ Colilert tubes, which fluoresce blue under a long wave UV light, indicate the presence of *E. coli*, and blue colonies with gas bubbles on the Petrifilms provide a specific quantification and a permanent record. These tests are simple to inoculate, do not require a laboratory, and provide clear results within
one day. Incubation on one’s body can substitute for a 35°C incubator while in the field until the samples can be taken to a place with electricity.

Water testing was carried out in collaboration with a local Ugandan project called Community Based Integrated Nutrition (COBIN). In 2006, 46 water samples were tested for *E. coli* contamination. These samples were taken directly from people’s homes in the villages that make up the Lyantonde and Kiruhura Districts of Southwest Uganda. There is no tapped water in the area, so the water that was tested had been collected at various water sources (usually shallow wells or dams) and was being stored in the home in jerrycans, which are 20-liter plastic containers with a small spout at the top to pour water out. This water was tested in order to find out the quality of the water that people were drinking; we wanted to test the water at the last stage before they drank it. Some families presented us with two different samples to test: one boiled sample and one un-boiled. Nine of the 46 samples were boiled. The households where water samples were tested were chose randomly by COBIN staff.

In 2007, 54 samples taken directly from water sources were tested for *E. coli* contamination. This was done to supplement the findings from the first year of the study, and to compare the quality of water taken directly from the source with water that was being stored in people’s homes and ready for consumption. About half of the samples were taken from villages that were visited in 2006 and the other half were taken from villages within the two districts that
were not included in the 2006 sample. Visiting the same villages gave the advantage of comparing results of water from people’s homes with results of water from the sources they collected from. This allowed for distinction between whether or not the borehole, for example, is pumping out contaminated water or if the water is clean but is getting contaminated in people’s homes. Visiting new villages allowed us to expand on our 2006 results and include additional communities in our sample.

COMMUNITY BASED EDUCATION

In fall of 2005, a general health questionnaire was developed in order to determine the educational needs of the communities. The questionnaire was designed at the University of Wisconsin and revised with the help of Dr. John Kakitahi at the Makerere University Institute of Public Health in Uganda. The questionnaire included 4 sections: Demographics, Health/Nutrition, Water Sources, and Education. [See Appendix I for a copy of the questionnaire].

The questionnaire was then distributed to 40 families in January 2006. A member of the COBIN staff read the questions to a member of the family (usually the mother) in the local language (Luganda or Runyankore, depending on the specific area) and recorded their responses in English on the questionnaire. The questionnaires were completed at the same households where water was tested. Their answers were entered into Survey Pro Apian Software and analyzed using the same program.

Based on results from the questionnaires and observations made by the researchers while in people’s homes (such as the type of container boiled water is stored in), an educational plan was developed and implemented at the village level. In collaboration with COBIN, three separate
workshops were held in January 2007 and in total, 76 village leaders were educated at these “Home-based water purification trainings.” At the workshops, we used printed educational materials (see Figure 2 below) and wrote participants’ responses to our questions on flip charts in order to teach the relationship between water and health.

We also asked participants to bring a sample of water from their usual water source to the workshop and they were taught how to test their own water for *E. coli*. See Figures 3 and 4.

**Figure 2.** An example of the educational materials used at the trainings. Developed by the Center for Affordable Water and Sanitation Technologies.

**Figure 3.** At the first workshop, village leaders test the water they brought from home for *E. coli* contamination. They will see the results the following day.

**Figure 4.** At the second workshop, Jenna Klink helps a village leader with the Petrifilm test. The results of this test will show him how many *E. coli* colonies are in 1 ml of his water from home.
We demonstrated boiling water at the workshops and presented two other ways of obtaining safe drinking water: solar pasteurization (using the sun to heat water and kill microbes) and BioSand water filters. These filters are available through COBIN and remove about 85% of bacteria and 100% of parasites and larger organisms from water filtered through (Centre for Affordable Water and Sanitation Technology 2005).

Results

Our 2006 results from 46 samples taken directly from homes show that *E. coli* was detected in 30/33 (91%) taken from families who collected the water from common sources (shallow wells, dams, boreholes, and lakes). The Petrifilm (quantification) test showed that seven of these samples had a moderate risk associated with drinking them (1-10 *E. coli* colonies / 10 ml water), 13 had a high risk (1-10 *E. coli* colonies / 1 ml water), and 10 had a very high risk associated with drinking (>10 *E. coli* colonies / 1 ml water).

All samples from homes who fetched from rainwater collection tanks (0/4) were negative for *E. coli*. In addition, *E. coli* was detected in 4/9 (44%) samples that were boiled.

See Table 1 below for data on the 2007 water testing results.

<table>
<thead>
<tr>
<th>Type of source</th>
<th># with <em>E. coli</em></th>
<th>Total # sample</th>
<th>% contaminated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tanks</td>
<td>8</td>
<td>17</td>
<td>47%</td>
</tr>
<tr>
<td>Wells</td>
<td>22</td>
<td>23</td>
<td>96%</td>
</tr>
<tr>
<td>Dams</td>
<td>5</td>
<td>7</td>
<td>71%</td>
</tr>
<tr>
<td>Boreholes</td>
<td>2</td>
<td>5</td>
<td>40%</td>
</tr>
<tr>
<td>Tap</td>
<td>1</td>
<td>1</td>
<td>100%</td>
</tr>
</tbody>
</table>

*Table 1.* Results from water samples taken directly from water sources. *N*=54 samples. 39/54 (72%) were contaminated with *E. coli* bacteria.
A risk assessment of the 39 contaminated water sources shows that 12 sources are moderate-risk sources (1-10 *E. coli* colonies / 10 ml water), 26 are high-risk sources (1-10 *E. coli* colonies / 1 ml water) and one is a very high-risk source (>10 *E. coli* colonies / 1 ml water). At the three educational workshops, of the 76 village leaders who brought water samples with them to test for *E. coli*, all but one was contaminated. The one that was not contaminated was the only sample brought in that was collected from a rainwater collection tank.

Results from the questionnaires indicated that many households do not have separate water collection and storage containers, meaning that they collect contaminated water and then after boiling the water to remove bacteria, pour it back into the same container used for collection, which re-contaminates it. There was limited understanding of water-borne diseases and the relationship between unclean water and physical health. These findings showed that the need for education on safe water practices is strong.

**Discussion**

Since the 2006 water testing results showed the presence of *E. coli* in boiled samples given to us by families, we concluded that some sort of re-contamination was happening. *E. coli* is killed at 60ºC, and water boils at 100ºC. Questionnaire results and our observations in people’s homes indicated that many people store boiled water in the same container used for water collection. The advantage of testing water straight from people’s homes in 2006 was that we

<table>
<thead>
<tr>
<th>Swamp</th>
<th>1</th>
<th>1</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>39</td>
<td>54</td>
<td>72%</td>
</tr>
</tbody>
</table>
could see exactly what people were drinking. We tested water straight from their drinking cups, to try to capture what is actually going into people’s bodies.

In 2007, the samples we took directly from water sources confirmed our hypothesis that many of the sources themselves are contaminated with *E. coli*. This data can now be used in presentations and proposals that Village Health Project (VHP) writes to donors to show the need for intervention. VHP’s two current projects are constructing rainwater collection tanks and starting a BioSand water filter project in Uganda.

When we took water samples from people’s homes, we found more ‘very high’ risk results (>10 *E. coli* colonies/ml water) than when we tested straight from the water source. This indicates that people’s current methods of storing water in contaminated containers are making their already unsafe sources even more unsafe for drinking. We designed educational workshops based on our questionnaire and water testing results and trained 76 volunteers, each representing one village, in January 2007. Clay pots for clean water storage were given to each participant at the workshops, to prevent water re-contamination after boiling. See Figure 5 below.

*Figure 5. At the third workshop, participants take home one clay pot each for clean water storage in their households.*
The following four goals were achieved at the workshops and represent the impact that the water testing and questionnaire research had on the communities that were studied:

1) Teach the relationship between water and health
2) Show participants whether the water they use in their homes is contaminated or not
3) Teach how to avoid contaminating water sources and how boiled/safe water gets re-contaminated
4) Demonstrate different ways to make unsafe water safe for drinking

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References


Metcalf, B. H. (June 2005). Transforming point source water testing in Kenya. Presented at the General Meeting, American Society for Microbiology in Atlanta, GA.
