KENYA 2012

POST-TRIP REPORT



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A JOINT COLLABORATION BETWEEN THE UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN, UNIVERSITY OF NAIROBI, BONDO UNIVERSITY COLLEGE, AND BONDO DISTRICT WATER

CEE449
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Introduction

To create solutions for water quality issues in developing regions, an integrated approach between engineering, chemistry, and sociology is necessary. In order to ensure sustainability of the solution, it is essential that an in-country presence is maintained throughout the implementation process. As a result, the University of Illinois initiated collaboration with the University of Nairobi and Bondo University College to begin addressing the issues surrounding water quality in the Bondo region of Kenya. A group of eight students led by Professor Benito Mariñas, Theresa Vonder Haar, Aimee Gall, and Lauren Valentino were joined by the University of Nairobi Chemistry and Sociology and Social Work Departments, Bondo University College, and representatives from the Bondo Water District Office. Vincent Madadi, Nicholas Mwenda, and Nusrat Beckham from the University of Nairobi's Chemistry Department have worked on this project with the University of Illinois since 2010. Dr. Robinson Ocharo, the department head for Sociology and two of his students, Phantus Wambiya and Rehema Leilah joined the team this year. Once the team arrived in Bondo, they were joined by Maurice and Maurice from the Bondo Water District Office who organized the site visits throughout the week. Michael Oloko and Daniel Ongor from Bondo University's Engineering College also participated in site visits throughout the trip.

Figure 1. Members of the teams from University of Illinois and University of Nairobi

The University of Illinois team arrived in Kenya on February 14, 2012. After spending several days in Nairobi, the team traveled to Bondo, a town in the Nyanza province of Kenya, where they resided until their departure on February 25, 2012. Table 1 shows a full schedule of the team's trip. In this time, they were able to experience the Kenyan culture through visits to the homes of national heroes and historical figures, safaris through national parks, and everyday travels with university students. From February 20-23, the team visited several drinking water sources in Bondo to conduct water sampling and community surveying. In total, two water pans, one water kiosk, one shallow well, one treatment plant, and five homes were sampled. Quantitative water quality data was collected on site using handheld probes and a colorimeter as shown in

Figure 2. Samples were collected and brought back to a portable laboratory set up in Bondo's West End Hotel for further analysis as shown in Figure 3. Furthermore, water samples were brought back to the University of Illinois for additional coagulation and disinfection experiments and ICP-MS analysis. On-site surveys were conducted with the help of two University of Nairobi students, Phantus Wambiya and Rehema Leilah, both fluent in the local language Luo. Through these surveys, the team was able to grasp the seasonal water quality trends, water practices, education, health, and priorities of the local people. With thorough data collected, the team returned home, prepared to begin design on appropriate water treatment systems and maintain the relationships with collaborators in Kenya.

Table 1. Kenya trip schedule.

Wednesday February 15	Visited University of Nairobi – Chiromo campus
Thursday February 16	Toured Nairobi National Park with Nairobi students, visited University of Nairobi-Main campus
Friday February 17	Drove to Bondo, stopped at Nakuru National Park
Saturday February 18	Went to Mbita Island by ferry on Lake Victoria
Sunday February 19	Hiked to the water storage tanks that serve the Lake Victoria treatment plant, prepared for site sampling
Monday February 20	Went to the Bondo Water District office, Bondo University College, and Auwor Pan
Tuesday February 21	Surveyed the Majengo Pan, visited Kogelo
Wednesday February 22	Visited the Mabinju Dispensary, the Lake Victoria Treatment plant, a water kiosk, and held a lecture with Dr. Ocharo
Thursday February 23	Surveyed a shallow well, visited St. Lazarus Primary School, and held a final dinner with collaborators
Friday February 24	Returned to Nairobi, toured Lake Naivasha National Park on drive back from Bondo
Saturday February 25	Maasai Market in Nairobi, visited The David Sheldrick Wildlife Trust's elephant orphanage, said goodbye to faculty and students from University of Nairobi

Figure 2. Students testing the water quality and collecting samples

Figure 3. Students working in the portable laboratory in the West End Hotel

Sites Visited

Sampling Sites

As shown in Table 1, the team visited two water pans, one water kiosk, one shallow well, and one treatment plant. The locations of each of these sites are shown in Table 2 and Figure 4. On-site water quality analyses were performed, and additional samples were collected for laboratory analyses. In addition, the team visited fives homes surrounding the main sites. Drinking water samples were taken at these homes to test for possible differences in contamination levels due to improper storage or transport. Site visits were pre-arranged by the Bondo District Water Office giving the team the opportunity to interact with the communities' water committees and residents. The sites described in this section are those from which water quality samples were taken.

Table 2. GPS coordinates of site locations

Location	GPS Coordinates	
	Latitude (°S)	Longitude (°E)
Bondo University College	.0925	34.2569
Awuor Pan	.1101	34.2537
Majengo Pan	.0633	34.3792
Yawo Shallow Well	.0635	34.3792
St. Lazarus Primary School	.0698	34.3729
Mabinju Dispensary	.1815	34.3692
Elevated Storage Tanks	.1576	34.1373
Lake Victoria Treatment Plant	.1740	34.1217

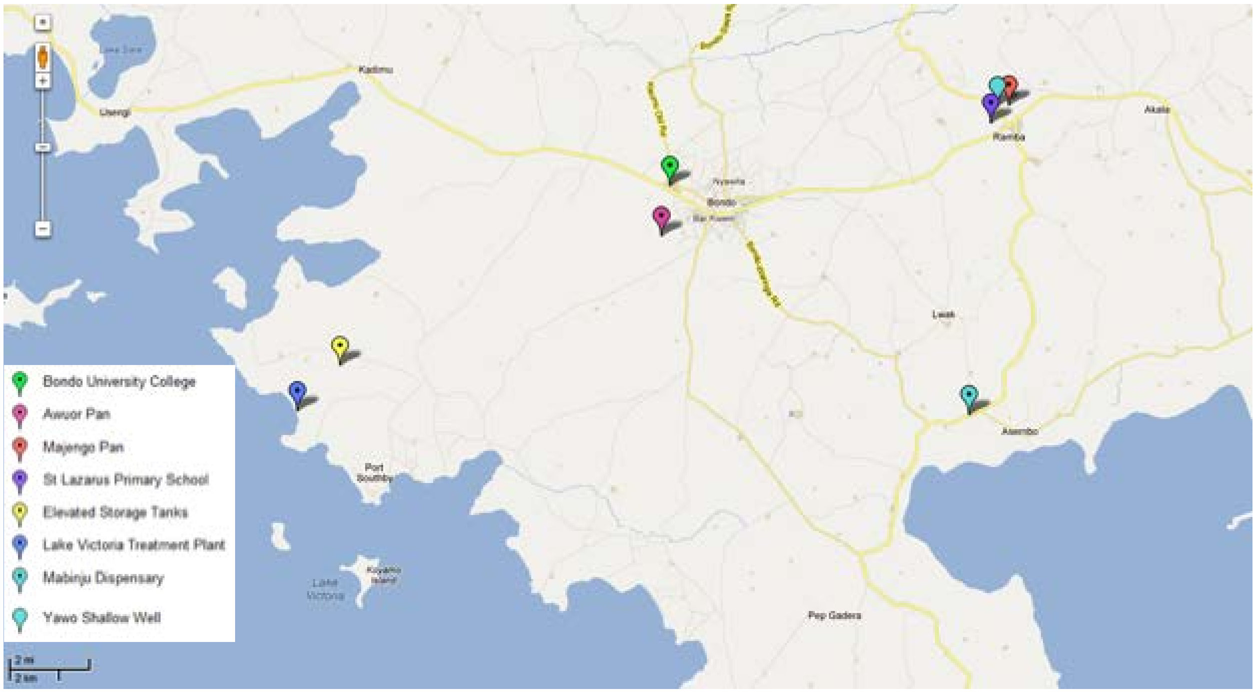

Figure 4. Map showing relative locations of sites visited

The sites visited by the team during this trip all fell under SIBO Water and Sanitation Company Limited, which manages the water distribution system and treatment plants. These treatment plants collect water from either Lake Victoria or Yala River. According to SIBO officials, about 25% of people in Bondo have access to a running water tap. For those who do not, there are kiosks that sell water for 5 shillings/20 liter jerrycan. Many people also drink water from the ponds, which are fed by rainwater and also used for many purposes including livestock hydration. They tend to lose capacity as the dry season progresses. Other possible sources of water include boreholes and shallow wells. While these wells had low levels of microbial contamination, the team also encountered wells that were dried out or too salty for use as a drinking water source.

Site 1: Awuor Pan. The Awuor Pan services 21 villages, each with an average of 700 residents. The pan is located in the Bondo district in the Atili sub-location, which is primarily a Luo community. While the pan is the primary water source in the area, villagers also harvest rainwater and collect water from the kiosks serviced by the Yala River. Most residents grow some or all of their own food and rely on small business for income. A photo of the pan is shown in Figure 5.

The community had formed a water committee surrounding the pan, comprised mainly of men (Figure 6). Interviews with the members revealed a great deal of knowledge and concern for the community's water quality. However, their sentiments were sharply juxtaposed by the women who felt that most water treatment practices were too time and resource intensive. Additionally, it should be noted that since our visits were pre-arranged, the interviewees had previously agreed to meet and discuss water quality issues with the team; this may indicate an above average interest in water safety and health.

Figure 5. Awuor Pan

The pan itself was built in 1992 by a Swiss organization. The perimeter measures 46 x 27 meters, and the depth varies with season. Once the pan is full, the supply of water collected during each rainy season, in November and from March through May, generally lasts 1.5 months into the subsequent dry seasons, depending on use and precipitation. In 1997, a Dutch organization attempted renovations by digging a well, a second pan, and weir. The second pan, intended for sedimentation, was constructed adjacent to the first, with a 3 meter wide channel connecting the two. However, the channel was soon clogged by sediment, and lack of maintenance rendered the sedimentation pond useless. It is unclear why the well was never functioning.

Figure 6. Introductory meeting between the full team and community members of Awuor Pan

The majority of the people the team spoke with retrieved their drinking water from a water kiosk located near Bondo University, approximately 2 kilometers from the village. Community members recognized that the tap water is cleaner, and most preferred its taste. Most families collected from the tap several times a week, so this task was usually performed by women and children who travelled by foot, bicycle, or mule. Water is normally 5 shillings/jerrycan; however, prices were reported to increase with scarcity. Additionally, the tap is somewhat unreliable and periodically closes for a few days to weeks at a time.

There were a number of treatment methods used in the community surrounding the Awuor Pan. The most common were WaterGuard, dawa, and boiling. WaterGuard could be purchased in town (a 20-30 minute journey by foot) and was viewed as expensive and time consuming. Information about proper usage was also inconsistent. Boiling was a less widely used practice and was described as laborious and resource intensive. Dawa is a type of rock that can be bought in the market. The rock is believed to function as a coagulant and was often referred to as chlorine by the residents of Awuor. The rock is swirled in turbid water for approximately 30 seconds, and the water is then allowed to settle for 5-10 min. This treatment is reserved for non-drinking water. Dawa was also a reported treatment for tooth aches.

The community members the team spoke with were generally knowledgeable about clean water. Most were able to identify sources of contamination and knew of various treatment options though specific information on technique varied, and some of their information was inaccurate or incomplete. Health classes were offered biannually through a government-NGO initiative to promote basic health practices and knowledge. Some of the topics covered were clean water practices such as cloth filtration and WaterGuard use, when and how to wash your hands, using a pit latrine, and burying trash. When asked about this, a group of women from the village all consented to knowing the information, but few actually practiced the prescribed actions.

The primary concern of the community was a more reliable clean drinking water source to compliment the pan, which would be reserved for other water uses. Increased storage capacity for rainwater was also suggested.

Samples taken from this site include:

- **1.1: Awuor Pan.** Sample was taken directly from the Awuor Pan at the location where residents typically gather water (Figure 7).

Figure 7. Local child collecting water sample from Awuor Pan

- **1.2: Margaret Abongo's multi-purpose water.** Sample was taken from a storage tank in Margaret Abongo's home. She had collected the water from the Awuor Pan water, added dawa for 30 seconds and allowed it to settle for 5-10 minutes (Figure 8). She uses this water for washing dishes and clothes and cooking.

Figure 8. Margaret Abongo showing the use of dawa in her multi-purpose water

- **1.3: Margaret Abongo's drinking water.** Sample was taken from a jerrycan stored in Margaret Abongo's house (Figure 9). The water had been transported there by jerrycan from the Bondo University kiosk and was used solely for drinking.

Figure 9. Home of Margaret Abongo

Site 2: Majengo Pan. The Majengo Pan, as shown in Figure 10, serves approximately 4,000 people from 5 surrounding villages. The pan has been used since the 1930s but first opened to the public in 2007 after the Ministry of Water expanded the pond. Only half of the construction was completed resulting in some water flow around the pond rather than into it during rain events. There were also plans to install a tank on a hill above the pond, but these were cancelled due to insufficient funds. The pond was measured to be about 47 meters in diameter. Community members had dug a small ditch near the pond in an effort to capture excess water flow during rain events.

The Majengo Pond is managed by a water committee. They organize events to maintain the pond and make decisions regarding its use. In times of low water availability, they have people guard the pond so no livestock can access it. According to the chairman of the water committee, many animals perish as a result of this policy. At the time of the visit, the pond had receded significantly and the chairman was concerned about it drying out, despite the fact that the rainy season was expected to begin in a few weeks.

Figure 10. Majengo Pan

Other sources of water exist in the area including kiosks and groundwater. Many people surrounding the pan chose to buy their drinking water from kiosks instead of taking it from the pan. All these kiosks received water from the South Sakwa Water Treatment Plant. The closest kiosk, located in Majengo, did not have a water storage tank and constantly broke down because of issues with electricity and piping. Because of this, most community members had lost faith in it. Many people choose to travel to kiosks located about 10 kilometers away in Akoko and Bondo with storage tanks. The kiosk charge is 5 shillings/jerrycan. There were also several boreholes dug in the area. Most of them were 80-90 feet deep but did not reach water. The only borehole that could pump water was reportedly too salty for human consumption.

Community members recognized that the water coming from the Majengo Pan was harmful to their health, and they acknowledged that it causes stomach pains and sickness. They have witnessed feces and diseased animals in the water. There were also water education seminars organized in the area at least once a month. Despite this, many people did not treat the pan water before drinking. This is because the community viewed as WaterGuard expensive and resulting in a bad taste. Some community members filtered the pond water with cloth but complained that it is still cloudy after filtration. Boiling appeared to be the most commonly used and effective water treatment option for those using the pond water, but it is very energy intensive and, therefore, expensive. For these reasons, many members of the community that were frustrated with the kiosks drank pond water either with no treatment or only with settling overnight.

From the team's interactions with the community, the main priority of community members was a larger pond and better access to clean drinking water through the kiosk system. The men interviewed identified the pond as a priority because they see it as a source of their livelihoods. They believe that construction must resume so that the rainwater catchment system is improved. The kiosk system is still used by community members and could be improved by adding a storage tank to the nearest kiosk. Most people in the community did not seem to be open to more point-of-use treatment options.

Samples taken from this site include:

- **2.1: Majengo Pan.** Sample taken directly from the Majengo Pan where residents typically gather their water (Figure 11).

Figure 11. UIUC and UoN students testing water at Majengo Pan where samples were taken

- **2.2: Rebeka Achieng Opany's untreated drinking water.** Sample taken directly from jerrycan used to transport water from Bondo kiosk to Rebeka's home (Figure 12).

Figure 12. Rebeka Achieng Opany with her stored untreated drinking water

- **2.3: Rebeka Achieng Opany's untreated & transferred drinking water.** Sample taken from the same jerrycan as Sample 2.2, but it was first transferred to a 5-gallon bucket and then scooped with a cup into a pitcher; simulates handling of water before drinking (Figure 12).

- **2.4: Rebeka Achieng Opany's multi-purpose water.** Sample taken from 5-gallon bucket used to allow Majengo Pan water to settle and cool overnight (Figure 13 and Figure 14).

Figure 13. Rebeka Achieng Opany showing how she separates pond water from settled particles

Figure 14. Rebeka Achieng Opany's separated settled multi-purpose water

- **2.5: Chairman's drinking water.** Sample taken from super drum. Water taken from Akoko kiosk and transported by jerrycan (Figure 16).

Figure 15. Chairman's home

Figure 16. Chairman's drinking water storage container called a super drum

- **2.6: Chairman's multi-purpose water.** Sample taken from closed super drum with Majengo Pan water allowed to settle for at least one hour.

Site 3: Mabinju Dispensary. Mabinju Dispensary is located 12 kilometers outside of central Bondo and serves a population of 4,219 with a staff comprised of both volunteers and 17 community health workers, 5 of which are registered nurses. Each health worker at the clinic sees approximately 20 people per day with the majority of patients being women suffering from waterborne illnesses. The clinic only treats outpatients and refers any cases requiring hospitalization to Bondo District Hospital, located 10-15 kilometers away. Round trip hospital visits cost approximately 300 shillings, a price that is prohibitively expensive for many referrals. However, medication provided at the hospital and dispensary is free after paying an initial registration fee of 20 shillings. Figure 17 shows the team outside of the Mabinju Dispensary.

Figure 17. Introductory meeting between the full team and staff of Mabinju Dispensary

The clinic currently receives funding from Kenya Medical Supply Services; however, delivery of supplies often takes months, which is too slow for the clinic's high demand. Still, the clinic distributes either Pur or WaterGuard supplied by local NGOs. Water used on site is collected in a rainwater catchment system that is composed of two 10 cubic meter tanks that receive water conveyed from the roof as shown in Figure 17. The water taken from the taps of the tanks is treated with WaterGuard. At the time of the team's visit, the tank in front of the dispensary was at approximately one third of its capacity. Upon closer inspection, it was observed that this tank was leaking at a rate of 125 mL/minute. If the tank continued to leak at this rate, it would be expected to drain completely in only 19 days.

The clinic primarily focuses on child welfare, vaccinations, and care for expectant mothers. The clinic most commonly treats the following ailments: malaria, respiratory infections, diarrhea, HIV complications, and skin infections. An estimated 50% of the patients suffer from waterborne illness, a problem exacerbated in the rainy season, when diarrheal illness increases five-fold. Most patients experiencing bouts of diarrheal disease live in close proximity to ponds and rivers. Clinic employees also commented on the ratio of women to men who are admitted due to waterborne illnesses. Women's role in handling water at the household level (cooking, cleaning, drinking water, etc.) places them at a greater risk of exposure, and thus they are more commonly admitted for diarrhea than men.

When patients experience diarrhea, the clinic offers them two forms of treatment. The first is an oral rehydration salt, which serves to replenish important electrolytes. Most oral rehydration salts contain a basic solution composed of sugar, salt, and water. This is paired with a zinc tablet which has been proven to significantly reduce the severity and duration of the diarrhea. However, the clinic was concerned because their stock of zinc tablets was depleted and they were unsure of when a new shipment would arrive.

The clinic offered weekly educational talks on site and holds monthly community outreach presentations on safe health and water practices, covering topics such as water storage and handling, hygiene, latrine usage, and water treatment techniques. Most people seemed to understand the connection between water and health, but this didn't always impact their habits. Many people who claimed to treat water do so improperly, if at all.

The last large-scale outbreak was in 2006-2008, when the waterborne illness cholera spread due to improper wastewater disposal and contamination of pipe systems. The Ministry of Water responded by closing beaches of Lake Victoria and providing materials for additional latrines and rain collection tanks for community members.

The clinic workers felt that future treatment should be focused at the source since most community members drink surface water without treatment because of convenience or necessity and, for many, WaterGuard is difficult to obtain. Additionally, they recommended an increase in rainwater catchment and storage facilities. With regards to the tap water, the clinic workers felt that the Water Ministry should be more lenient with customers.

Samples taken from this site include:

- **3.1: Dispensary's multi-purpose water.** Sample taken from spigot at base of closed tank used to store rainwater (Figure 18).

Figure 18. Storage tank collecting rainwater at Mabinju Dispensary

- **3.2: Dispensary's drinking water.** Sample taken from spigot of closed container used to store rainwater treated with WaterGuard (Figure 19).

Figure 19. Storage container for treated drinking water at Mabinju Dispensary

Site 4: Lake Victoria Treatment Plant. The Lake Victoria water treatment plant, as shown in Figure 20, is located in the South Sakwa Sub-Location in the Nyangoma Division of Bondo. The project was first initiated in 1978, and the treatment plant was commissioned in 1993. The current system provides water for about 10,000 people and pumps 600 cubic meters per day to 11 kiosks and 379 communal water points. The distribution network covers approximately 28 square kilometers and is increasing as more water kiosks and communal water points are being installed.

Figure 20. Lake Victoria water treatment plant

The treatment plant can only be reached by a small service path about 0.5 km from the nearest road. If maintenance and operational changes are recommended, accessibility could be a hindrance. Much of the site has swarms of bees, flies, and birds that surround many of the building entrances.

The original intake was a 135 cubic meter concrete sump. As the water level in Lake Victoria began to decrease, the concrete sump became inoperable. As seen in Figure 21, the concrete sump was filled with weeds, and the current intake system was comprised of one 100 millimeter intake pipe that drew water from Lake Victoria by a submersible pump. The pump is capable of pumping 85 cubic meters per hour. The initial design included three pumps, two of which are presently inactive. As shown in Figure 22, the water from Lake Victoria is pumped toward the treatment plant.

Figure 21. Concrete sump at treatment plant intake

Figure 22. Pipes leading from intake to treatment plant

The water conveyed from the Lake Victoria reached the mixing tank (Figure 23) located on the second floor of the water treatment plant office. This was originally designed as the location for addition of coagulant. Currently, water was allowed to flow directly to the coagulation tanks. The water treatment plant operator and local official stated their opinion that the water is not turbid enough to justify the use of coagulant.

Figure 23. Mixing tank

The water flows by gravity from the mixing tank through a pipe with four different outlet valves. There are four coagulation tanks that contain six concrete flanges in each. The flanges are used to change the flow direction causing more effective precipitation and coagulation. The visible concrete flanges force water downward while submerged concrete flanges (in between the visible flanges) force flow back up. A single coagulation tank is shown in Figure 24.

Plan drawings for the structures around the treatment plant were not available, so rough estimates and measurements were taken to approximate their size. Each coagulation basin is said to have a capacity of approximately 180 cubic meters, and the measured radius of the tank was about 3.8 meters.

After the flow has been directed around the coagulation tank, it enters filtration through the pipe in Figure 25. Filtration occurs in a separate tank in the middle of the coagulation tank (covered by a metal plate as shown in Figure 24). These tanks look well designed but are in need of maintenance. Some of the pipes are corroded, stagnant water is causing algae to form in some of the wells as shown in Figure 24, and in Figure 26 the coagulation basin is leaking.

Figure 24. Coagulation tank showing algae growth on water surface

Figure 25. Pipe directing water from coagulation tank to filtration media

Figure 26. Side view showing leak in coagulation tank

The plant operator was not knowledgeable as to the specific filter material. However, there is a concrete box full of stones next to the operating house suggesting that stones serve as the filter media. According to the operator, the filter is periodically backwashed, but further details could be provided.

After filtration, water enters the clear water tank for disinfection. The tank had an unknown storage capacity but had a measured radius of approximately 3.8 meters. On top of the clear water tank, a box is designated for the mixing of calcium hypochlorite. The calcium hypochlorite is added to water (Figure 27) and then drained into the clear water tank through a hose. At the base of the box, there is a small valve that regulates the flow of the disinfectant.

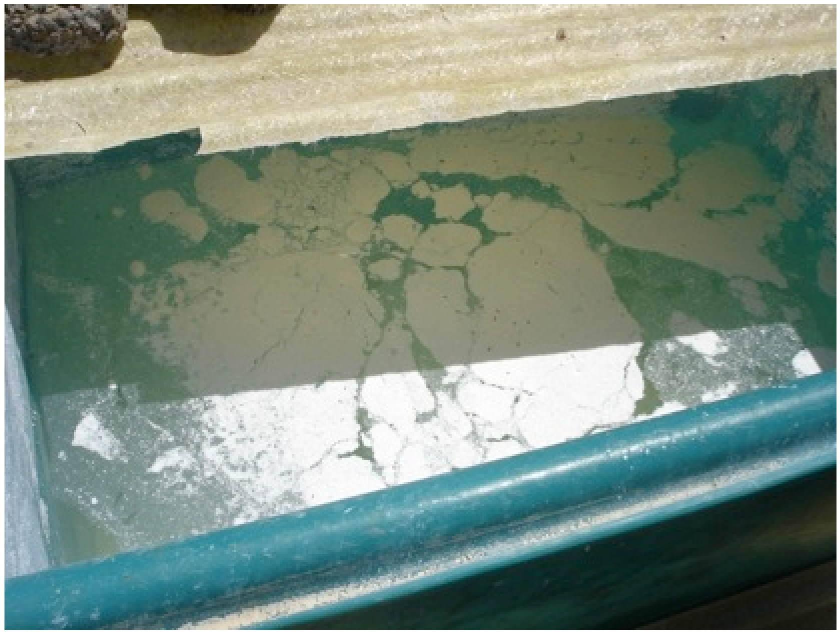

Figure 27. Calcium hypochlorite mixing with water

There are currently no clear operating guidelines for the disinfection process. After speaking with the operator, he had been advised to add 1.5 kilograms of calcium hypochlorite (powder form shown in Figure 28) and water to the box every morning at 5 am and ensure that all disinfectant has drained by 6 pm. The flow rate of disinfectant to the tank is only regulated based on the operator's daily judgment of how quickly the solution is draining. At 6 pm, the operator turns off the plant until 5 am the next morning when he repeats the process of adding calcium hypochlorite to water in the box. The district manager says that more disinfectant is added during the dry season, but no specific value could be provided.

Figure 28. Powder form of calcium hypochlorite

Water is pumped from the clear well to distribution tanks located 2.45 kilometers from the treatment plant. The treatment plant originally utilized three high lift pumps that were capable of pumping at 65 cubic meters per hour. There is only one pump that is currently in operation. The pump that is currently in operation is leaking quite a bit as shown in Figure 29. The energy loss due to this issue cannot be calculated, but the leak is most likely increasing operational costs and limiting water output.

Figure 29. Leaky pump

Samples taken from this site include:

- **4.1: Influent to the water treatment plant.** Sample was taken from water at concrete sump near influent pipe in Lake Victoria (Figure 30).

Figure 30. Collecting water quality data at inlet to water treatment plant.

- **4.2: Effluent from the water treatment plant.** Sample was taken after clear water basin in which chlorine is added. The pump to storage tanks was turned off, and the sample was taken directly at the pump outlet.

- **4.3: Mixing tank water.** Sample taken from the mixing tank (Figure 31). Water pumped from the lake enters here and then travels to the coagulation basins. If the treatment plant were using a coagulant, this is where it would be added.

Figure 31. Mixing tank for potential coagulant application

- **4.4: Coagulation basin.** Sample was taken from the far right coagulation basin in Figure 32. The sampled water had passed through the coagulation basin but not yet through the filtration media.

Figure 32. Coagulation basins

- **4.5: Kiosk.** The Waye Community Development Kiosk is located about 2 kilometers east of the water treatment plant and is shown in Figure 33. It was constructed 3 years ago by the NGOs Western Flood Mitigation and World Bank. The community had offered the land to construct the kiosk. The area was fenced in and consisted of a kiosk with a 10 cubic meter tank, 2 troughs for animals (Figure 34), a latrine center, and additional land designated to start a community garden. The kiosk is run by a committee of 11 community members and consists of a chairman, secretary, treasurer, operator, and 7 members. All positions are unpaid except for the operator, whom earns 700 KSH a month for spending approximately 60 hours per week at the kiosk. Water currently costs 5 shillings per 20 L jerrycan. The purpose of the kiosk was intended to supply water to the community, but it has yet to do so as the lack of customers, price of water, and unreliability of the water from the kiosk are all prohibitive issues. The kiosk is connected to the distribution system that supplies the entire community. Whenever there is a pipe leak or disconnection, the water treatment plant must turn off the entire distribution system to fix the one problem. It usually takes 2-3 days for a pipe to be fixed, which is a sufficient amount of time for the tank to run dry. The electricity is also unreliable, and if electricity is not available, the tank can run dry in about 2 days. Alternative water sources in the area include Lake Victoria, private homes with water connections that sell water, and other nearby kiosks.

Figure 33. Waye community water kiosk

Figure 34. Water troughs at the Waye community water kiosk

Site 5: Yawo Shallow Well. The Yawo Shallow Well (Figure 35), measuring 70 feet in depth, was first built in 1996 by Catholic missionaries from the. At the time of its construction, both the men and women of the village were provided with three weeks of training on pump usage. It broke down in 2005 and was repaired by UNICEF within the year. The Nyandiek Women's Group was then formed to manage the distribution of water. Water was collected using a funnel and a jerrycan and is primarily used for drinking and cooking. Other sources such as the nearby pond were used for washing.

Figure 35. Yawo Shallow Well

As previously mentioned, the community surrounding the Yawo Shallow Well organized the Nyandiek Women's Group to manage the well and collect water usage fees. Their success seemed to be in part due to the sense of community ownership of the well. The 70 foot well was dug by community members on a voluntary basis, with an engineer overseeing the project. Their hard work provides them with water, so the project is seen as their own. The women took pride in the well and the ability to provide water year round for the community at a fair price.

The price of water depends on whether or not one is a member of the Nyandiek Women's Group. For members, there is an initial registration price of 50-70 shillings and a monthly fee of 30 shillings which allows unlimited access to the well. For non-members, water costs 3 shillings/jerrycan, a price which the women felt to be affordable for people of the surrounding area. Fees are collected by one of the three caretakers and placed in an account that is used to pay for any repairs the well may need. This is rare and the last time the well broke or leaked was about a year ago, but the repair fees are high.

The quality of water is accepted by the community, and the only complaints are the salty taste and that the water hardness makes it difficult to lather soap. Because the water is of such high quality, only about half of the community treats their water. When treatment is applied, WaterGuard is used; one woman said her treatment was a precaution that she learned helps reduce sickness. Two women separately described how they allow water treated with WaterGuard to sit overnight before drinking it and then store it in a ceramic pot. Since the well was constructed, stomach pains and sickness have been reportedly less frequent; community members believe this is because they no longer use the nearby pond. This reduction extends to the approximately 70 households that visit the well per day, and those who go to the nearby borehole, pond, and stream were not spoken for.

The women really want to ensure that their water source is safe from theft and that they can properly protect it. The well is locked overnight and from the hours of 12-3 pm. During hours of operation, the well is managed by the caretaker, yet theft is still common, and the lock is frequently replaced. For this reason, their first priority was to have a fence with a gate and lock built around the well. Their second priority was to have the well treated with a chlorine shock, as this was done by UNICEF when they repaired the well in 2006. There was a slight misconception regarding the effects of this shock treatment, as they believed it would clean the water itself and not the system. Although they were not well informed about chlorination shocking, they had been educated during chief assemblies and through radio broadcasts, where they have learned to treat with WaterGuard or boiling. Overall, they had a great concern for their water's quality and the community in which they live and show an eagerness to learn more.

Samples taken from this site include:

- **5.1: Yawo shallow well.** Sample taken directly from spigot of well pump (Figure 36).

Figure 36. Sampling from Yawo Shallow Well

- **5.2: Risper Atieno's drinking water.** Sample taken from closed clay pot and scooped out with cup (Figure 37). Water taken from Yawo shallow well.

Figure 37. Risper Atieno's drinking water storage and collection of sample

- **5.3: Risper Atieno's neighbor #1's water.** Sample taken from super drum storing rainwater for drinking.

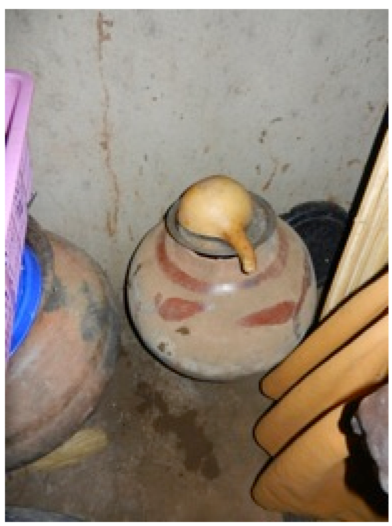

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Figure 38. Risper Atieno's neighbor #1's water storage container

- **5.4: Risper Atieno's neighbor #2's water.** Sample taken from open 5-gallon bucket storing water from Yawo shallow well (Figure 39).

Figure 39. Risper Atieno's neighbor #2's water storage

- **5.5: Spring water.** Sample taken from natural spring about 0.5 km from well (Figure 40). Water is used as drinking water.

Figure 40. Spring near the Yawo Shallow Well

Other Sites Visited

In addition to the drinking water source sites listed previously, the team visited the University of Nairobi and Bondo University College campuses to gain a better understanding of the organization and resources available to these universities. Furthermore, the team visited Bondo's District Water and Water Utility offices to understand the structure and operation of Bondo's water services. Finally, in an effort to engage the community, the team visited St. Lazarus Primary School to emphasize safe drinking water and sanitation practices to the students. A great deal of useful information was gathered from these sites, but no water samples were collected.

University of Nairobi. The Chiromo Campus is home to the College of Biological and Physical Sciences at the University of Nairobi. The team was greeted by Vincent Madadi, from the department of Chemistry, who collaborated with the 2011 CEE 449 class and was a WaterCAMPWS researcher at the University of Illinois in the summer of 2011. Vincent graciously gave a tour of the campus, which included the chemistry labs, surrounding buildings, library, and a student-run business which sold soaps and detergents. Figure 41 shows the team in front of the Chemistry building on campus.

The team also had the opportunity to visit the University of Nairobi main campus, where Rehema Leileh gave a tour of the Sociology building, the main quad, and several other buildings on campus. At the end of our trip we returned to the UoN main campus, where Dr. Ocharro presented the Illinois team with University of Nairobi crested shirts from the school's bookstore.

Figure 41. UIUC and UoN Chemistry Department teams at the Chiromo campus

Bondo University College. The Bondo University College is in its third year of existence and is located just outside the town center of Bondo, Kenya. The School of Engineering is entering its second year, with an expected enrollment of 50 students. There are plans for a satellite campus along the coast of Lake Victoria, which will focus on water and environmental issues. Classes are in session from April-July and September-December meaning that classes were not in session during the team's campus visit. The team was greeted by the Principle and Professor of Horticulture (Steven), The Dean of Finance and Professor of Economics (Washington A.), The Head of Academic Affairs and Professor of Chemistry (Theresa K.), and Professor of Agriculture and Bio-Engineering (Michael). The team's primary goal was to form an official partnership between the University of Illinois, The University and Nairobi, and Bondo University College; this agenda was met with enthusiasm, and discussion focused on future collaborations regarding research and the possible exchange of students and professors among the schools. A photo taken during this meeting is shown in Figure 42.

Figure 42. UIUC and UoN teams meeting with Bondo University College administration

Porridge Kiosk. Adjacent to the Mubinju Dispensary was the Porridge Kiosk (Figure 43) operated by a local woman and teenage boy. The kiosk was located approximately 50 meters from the dispensary in an open-air hut. The woman prepared the porridge at her nearby home and sold it to dispensary patrons for 10-15 shillings/mug. The porridge was prepared using Millet, which the woman had fermented overnight, and boiled water. She obtained her water for 5 shillings/jerrycan at a water kiosk located approximately 200 meters away. In addition to water collected for her business, the woman also obtained all of her drinking water from the nearby water kiosk. She explained that she would collect water in surplus and store it in super drums, jugs, and jerrycans, in case of shortages. She treated her drinking water with WaterGuard, and would let it settle overnight in ceramic pots.

Figure 43. UIUC and UoN team members conducting surveys at a porridge kiosk near Mabinju Dispensary

District Water Office. Prior to beginning work in Bondo, the team met with Jodwar David, from the Bondo District Water Office. He explained the inadequacies in the water supply, citing that only 25% of Bondo has access to piped water. Furthermore, because the demands are so high, the facilities are running beyond their intended capacities, thus degrading the quality of the effluent. David attributed these problems to a rapid increase in the overall demand, an outdated water treatment system, and deficient pipe networks. Additionally, because the price of water increases with distance from the treatment plants, rural areas experience the most severe water quality issues. A photo outside of the District Water office is shown in Figure 44.

Figure 44. The Bondo District water office

Water Utility. Before visiting the water treatment plant, the team visited the Water Utility office where they met with Roseline Atieno, an officer who worked for the utility company. The Utility manages several water treatment plants in the area. Roseline described the company's billing system, explaining that customers are charged on a monthly basis according to a graduated pricing distribution, pending water consumption. This distribution is depicted in Figure 45. Essentially, customers pay a flat meter fee in addition to a rate per cubic meter of water consumed, and a 1% levee based on this rate. For example, a customer falling in the 0-6 cubic meter bracket would pay a 50 shilling meter fee, a rate of 400 shillings/cubic meter water, and a 4 shilling levee. Customers incurring a debt of 1000 shillings are disconnected; though this is rare (approximately 10 customers are disconnected monthly).

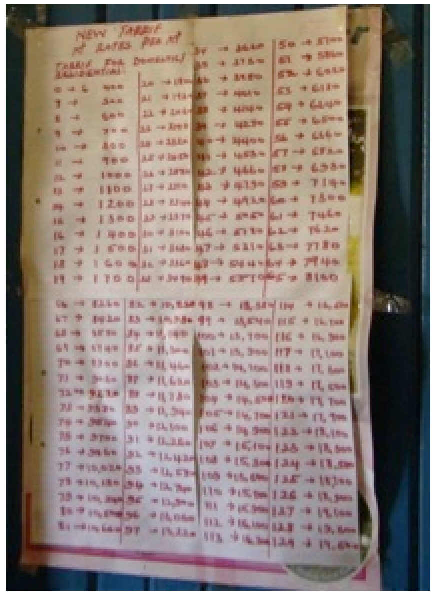
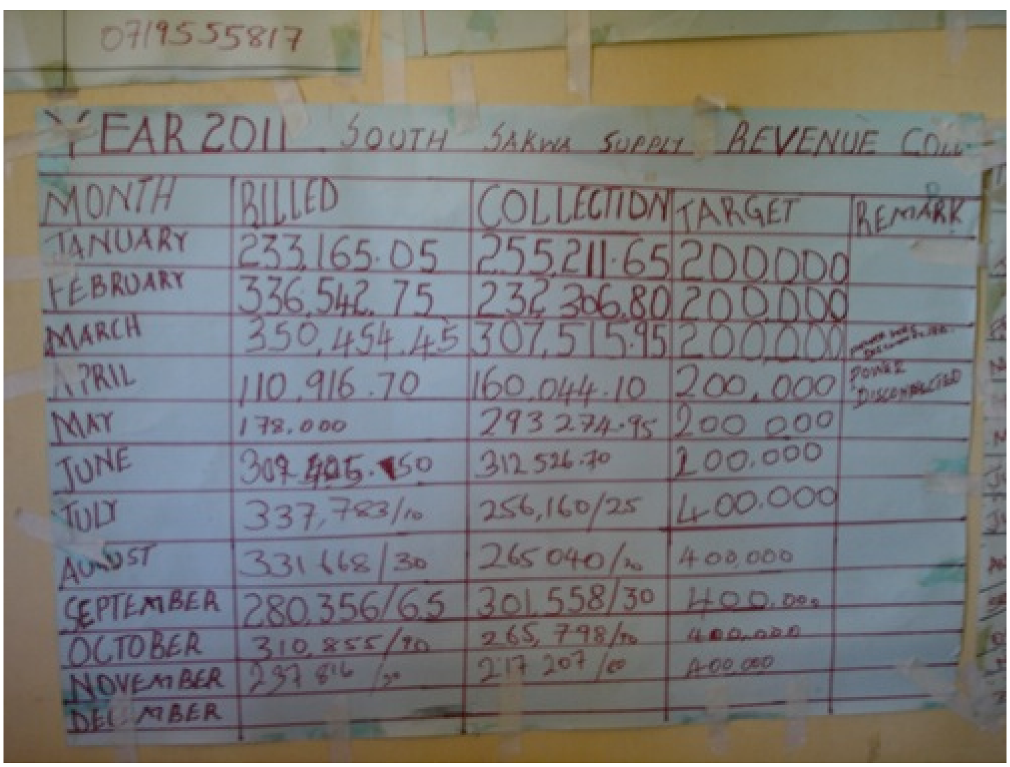


Figure 45. Graduated pricing of water at Water Utility office

Figure 46 depicts the financial records for the South Sakwa Supply for the past year, which was posted among several records on the office wall. The amount billed correlates to the amount collected in the following month. There are some discrepancies which suggest that the rate of defaulters is greater than 10 per month, though some of the problems were attributed to power outages.



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YEAR 2011 SOUTH SAKWA SUPPLY REVENUE COL

MONTH	BILLED	COLLECTION	TARGET	REMARK
JANUARY	233,165.05	255,211.65	200,000	
FEBRUARY	336,542.75	232,306.80	200,000	
MARCH	350,454.45	307,515.95	200,000	
APRIL	110,916.70	160,044.10	200,000	POWER DISCONNECTED
MAY	178,000	293 274.95	200 000	
JUNE	[illegible]	312 526.70	200,000	
JULY	337,783/10	256,160/25	400,000	
AUGUST	331 168/30	265 040/10	400,000	
SEPTEMBER	280,356/65	301,558/30	400,000	
OCTOBER	310,855/90	265,798/10	400,000	
NOVEMBER	237 816/30	217 207/60	400,000	
DECEMBER				

Figure 46. Financial records for South Sakwa water supply

St. Lazarus Primary School. St. Lazarus Primary School was one of several schools that the 2011 CEE 449 class had visited. This year's team chose to return in hopes of building on the relationship formed last year. The nearly 920 school children ranged in age from 5-14 and were very excited to have visitors. Classes were taught in English, which most of the older children spoke fluently. The school itself was comprised of two main buildings, one of which was condemned but still in use. Two cement water collection tanks were situated below this building for rainwater collection; however, both were dry at the time of the team's visit. The University of Illinois plans to help in the design and implementation of new rain catchment basins for the newer buildings at the school. Measurements were taken to determine the roof area. During this visit, the team presented a storybook about clean water practices with the help of Phantus (University of Nairobi, Department of Sociology), who translated the English into Swahili and Luo and did an amazing job engaging the children (Figure 47). It was wonderful to realize that most of the kids had been exposed to some of the information before, and a more in depth lesson may have been appropriate. After the story, the team gave a demonstration on cloth filtration and chlorine disinfection using tap water spiked with gravel and leaves. Afterwards, the assembly of students sang a song for the class and then joined in for a song the team had created about hand washing.

Figure 47. UIUC and UoN teams teaching about water treatment and hand washing at St. Lazarus Primary School

Water Quality Testing & Results

Equipment

GPS Unit. GPS, or Global Positioning System, is used to locate the approximate latitude and longitude of the user's position. GPS units use satellite-based navigation systems, in which the receiver (hand-held unit) takes information from satellites orbiting the earth and performs triangulation to locate the user's position. The team used three hand-held GARMIN GPS units in addition to the Horiba meters, which have built-in GPS capabilities. The GPS devices were utilized to record the location of the test samples and site visits.

YSI Probes. The YSI Professional Plus handheld multiparameter meter is manufactured by YSI Incorporated, based out of Yellow Springs, OH. The device provides the user with the ability to measure a variety of water quality parameters. The tool contains two (known as a duo probe) or four (known as a quatro probe) different probes that are robust for field sampling. To ensure protection of the probes, a perforated metal casing can be attached. The probes are lowered into the water and swirled lightly or lifted up and down to remove air bubbles. Water characteristics are reported to the user via the display screen. The quatro was used by the team to determine pH, conductivity, temperature, dissolved oxygen, and ammonium concentration, and the duo was used to determine nitrate and chloride concentration. The probes were used on-site for measurements of these characteristics in pans, Lake Victoria, and the shallow well.

Horiba Probes. The Horiba U-52 G Multiparameter Water Quality Meter is manufactured by HORIBA Instruments Incorporated, based out of Irvine, CA. The probe is a handheld meter that provides the user the ability to measure a variety of water quality parameters. Water quality characteristics measured by the Horiba Probe included temperature, pH, ORP (Oxidation Reduction Potential), conductivity, turbidity, DO (Dissolved Oxygen), TDS (Total Dissolved Solids), and SSG (Seawater Specific Gravity). This provides additional water characteristic information beyond that of the YSI probes. The Horiba probe head is lowered into the water and then swirled lightly to remove air bubbles within the metal casing. For both probes, it is important to the accuracy of testing to remove any air bubbles from the sensors and ensure a fresh sample is continuously supplied to the DO sensor. As the device reaches equilibrium with the water, the screen displays as many as 11 parameters simultaneously. The probe was used on-site in pans, Lake Victoria, and the shallow well.

Hach DR 890 Portable Colorimeter. The DR 890 Portable Colorimeter is manufactured by Hach Company, which is based out of Loveland, CO. The device is a compact spectrophotometer that can test for ninety different parameters using four wavelengths: 420, 520, 560, and 610 nanometers. To use the colorimeter, a blank solution, composed of either deionized water or sample water, is initially prepared to zero the meter. Next, samples are prepared in the sample cells using powder packets provided by Hach for the various tests. Absorbance is measured at a specific wavelength, and this is used to calculate the concentrations of various constituents. Because of its size, the DR 890 colorimeter was used on-site to test for constituents that can easily degrade over time, such as ammonia, bromine, free chlorine, and total chlorine.

Hach DR 2800 Portable Spectrophotometer. The DR2800 Portable Spectrophotometer, manufactured by Hach Company (Loveland, CO), is a powerful tool that can be used to process data for over 240 analytical methods. Similar to the DR 890 procedure, each test involves preparing two solutions: a blank solution for zeroing/equilibrating the meter (comprised of deionized water or the water being tested) followed by a sample of the water being tested with an added reagent provided by Hach. These samples and solutions are placed in cuvettes, wiped with a kimwipe to remove fingerprints, and inserted into the machine for measurement. Similar to the colorimeter, absorbance is measured at a particular wavelength and then used to calculate a concentration. The DR2800 has the capabilities to test a wide range of parameters, and the parameters that were tested in Kenya were ammonia, bromine, free chlorine, total chlorine, chromium (VI), copper, fluoride, iodine, iron, manganese, nitrate, nitrite, react phosphate, silica, sulfate, and sulfide.

Hach Digital Titrator, Model 16900. The Hach Digital Titrator (Model No. 16900) is manufactured by Hach Company (Loveland, CO) and gives the user high-precision dispensing of a reagent into solution. The tool uses a prepared cartridge of titrant that when inserted can have the included titrant released at intervals of 0.00125 milliliters/digit. The tests performed by the digital titrator were acidity, alkalinity, calcium, chloride, sulfite, and hardness.

Hach 2100Q Portable Turbidimeter. The Hach 2100Q Turbidimeter, manufactured by Hach Company (Loveland, CO), measures the light scattered by suspended particles in solution to determine the turbidity of a water sample. The machine is calibrated using standard solutions of 20 NTU, 100 NTU, and 800 NTU. Then, the water sample is placed into the machine for measurement by a tungsten filament lamp source. The meter is able to measure turbidity in the 0-1000 NTU range and meets the EPA Method 180.1.

pH Test Strips. pH strips are chemically-treated paper that reacts with acids and bases in solution, resulting in a visible color. To perform simple pH measurements, pH strips were employed on-site allowing for verification of pH measurements taken by the probes.

3M Petrifilm E.coli/Coliform Count Plates. The 3M Petrifilm plates are manufactured by 3M with corporate headquarters in St. Paul, MN. For each sample, three of the prepared agar plates were used to test for the presence of total coliforms and *E. coli*. One milliliter of water was added to the center of each of the preloaded media using a pipet. The plates were then placed in a 35°C incubator for 48 hours. After this incubation period, coliform colonies could be counted. Indicator dye in the plates distinguishes total coliform colonies as red/pink and fecal coliform colonies as blue with gas bubbles. The plate growth medium contains lactose, and the top film of the plates traps gas produced by coliforms, therefore only colonies surrounded or next to gas bubbles are counted. The total coliforms counted include the count of *E. coli*. Figure 48 (left) shows a student adding water to a 3M plate, and Figure 49 shows several of the plates after the incubation period. The numerous red and blue dots indicate a great deal of microbial contamination.

Coliform-Test Broth. The P/A Broth with MUG ampules are manufactured by Hach Company (Loveland, CO). The P/A broth solutions were also used to determine the presence or absence of total coliforms and fecal coliforms. A 100 milliliter water sample was added to each jar and incubated at 35°C for 48 hours. After this incubation period, the solution changed from a reddish purple to a yellow or yellow brown color to indicate the presence of total coliforms. A UV light was then used on jars with total coliforms. If the jar's contents fluoresced under a UV light, it was determined that the sample also contained *E. coli*. These were used in addition to the 3M plates because a larger sample can be examined allowing the team to better determine the overall characteristics of the water source. Figure 48 (right) shows a student performing a coliform test with the P/A Broth.

Figure 48. UIUC team members performing microbiological plate (left) and jar (right) tests

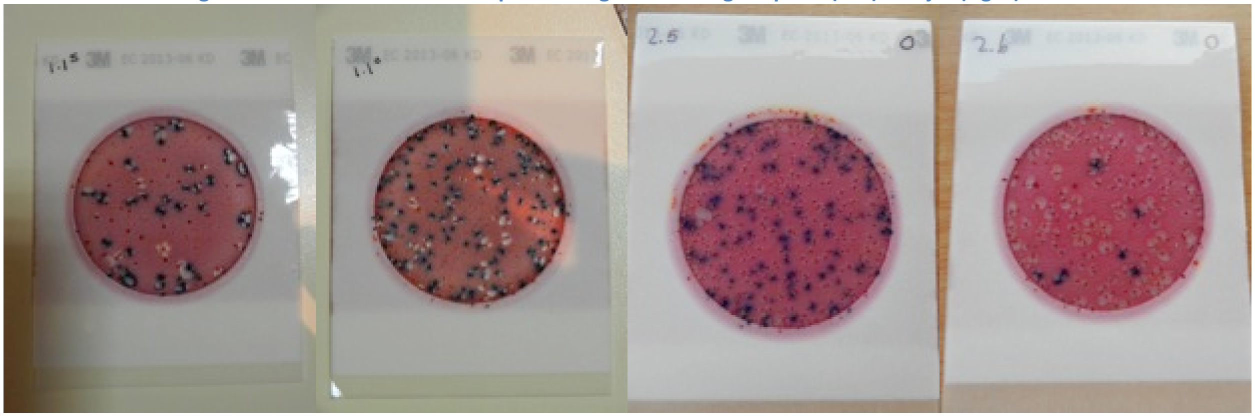

Figure 49. Microbiological test results from samples 1.1, 2.5, and 2.6

Field Testing

While visiting sample sites, the GPS units, pH strips, YSI probes, Horiba probes, 2100Q Turbidimeter, and DR 890 were used perform on-site data acquisition. Upon arrival to each sample site, the probes were turned on to allow time to warm up. During this period, the GPS was used to determine site coordinates. The probes were then used to perform initial water quality testing with one student handling the meter/display to confirm equilibrium and record data and another student holding the cord and allowing the meter to rest underwater. The data was stored in the handheld meter and was also recorded in notebooks to ensure that measurements would not be lost. After sampling with the probes, various other water samples were taken from the local pan, surrounding homes, shallow wells, etc. and tested using the DR 890. The important characteristics to test on-site using the DR 890 were bromine, free chlorine, total chlorine, and ammonia. Finally, turbidity was tested with the turbidimeter to perform quality assurance of the data from the Horiba probe; this was sometimes done on-site and other times done with samples brought back to the lab.

Water Quality Results

The results displayed here highlight only the water quality data that does not meet criteria as specified by the United States Environmental Protection Agency, the World Health Organization, and/or Kenya's national regulations. More detailed charts showing all test results can be viewed in Appendices B and C. Also included, Appendix D provides a comprehensive list of regulated waterborne contaminants. In addition, Table 14, Table 15, Table 16, Table 17, and Table 18 in Appendix D contain the Kenyan, US EPA, and WHO regulations pertaining to these contaminants in water as well as the known human health effects and possible sources of contamination.

Sample 1.1: Awuor Pan. Table 3 shows that the turbidity measured in the Awuor Pan excels the Kenya, WHO, and US EPA regulated values, and the fluoride value exceed boths the Kenya and WHO maximum contaminant levels (MCLs). The hardness was found to be 82.4 mg/L as CaCO3, which is lower than the WHO and EPA recommended guidelines that range from 100 to 300 mg/L as CaCO3. There was 0.08 mg/L of iron found in the water, which exceeds the Kenya MCL of 0.05 mg/L. However the recommended iron MCL is a preference of taste and odor rather than contamination. The fluoride, iron, and hardness are naturally present in the minerals. Additionally, total and fecal coliforms were present, indicating that the microbiological contamination in the water could lead to illnesses like diarrhea.

Table 3. Water quality data for Awuor Dam

	Measured Value		Regulation (mg/L)		
	Site Number		Kenya MCL	WHO Guideline	US EPA MCL
Parameter	**1.1**	**1.2**			
Ammonium/Ammonia (mg/L as N)	1.42-1.62	0.058	N/A	35	35
Turbidity (NTU)	756-981	95.4	5*	1*	0.3-5*
Fluoride (mg/L as F-)	1.72	-	1.5	1.5	2
Hardness (mg/L as CaCO3)	82.4	31.6	N/A	100-300	100-300
Iron (mg/L as Fe)	0.08	-	0.05	N/A	N/A
Manganese (mg/L as Mn)	0.7	-	N/A	0.4	0.05
***E. coli* (CFU/mL)**	169	0	N/A	0	0
Total Coliforms (CFU/mL)	278	1	0.3#	N/A	0.05#

Key to Violation:		ALL		Kenya & WHO		US EPA		WHO		Kenya		WHO & EPA

- indicates that parameter was tested for during analysis
* indicates units of NTU
\# indicates units of CFU/mL

Sample 2.1: Majengo Pan. The Majengo Pan had the most turbid water out of all the water sources tested. In fact, the on-site value of turbidity was higher than the probe's range of measurement implying that it was greater than 1000 NTU. The related EPA regulations require a value between .3 and 5 NTU indicating that the Majengo Pan water sample was over 200 times higher than the regulation. The high turbidity could possibly be attributed to the high-sloped walls of the pan and lack of vegetation that existed in comparison to the Awuor Pan. Furthermore, the pan did experience higher fluoride and manganese concentrations than WHO, Kenya, and EPA regulations. Conversely, the hardness of this pan was significantly higher than the Awuor Pan, placing it within the range of the EPA. Additionally, total and fecal coliforms were present, indicating that the microbiological contamination in the water could lead to illnesses like diarrhea. A summary of water quality parameters that were measured to exceed regulations is shown in Table 4.

Table 4. Water quality data for Majengo Pan

	Measured Value						Regulation (mg/L)		
	Site Number						Kenya MCL	WHO Guideline	US EPA MCL
Parameter	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**	**2.6**			
Ammonium/ Ammonia (mg/L as N)	2.68-3.04	-	-	-	-	-	N/A	35	35
Turbidity (NTU)	>1000	8.96	19	28	12.4	160	5*	1*	0.3-5*
Fluoride (mg/L as F-)	2.01	-	-	-	-	-	1.5	1.5	2
Hardness (mg/L as CaCO3)	146.8	-	-	-	-	-	N/A	100-300	100-300
Iron (mg/L as Fe)	0.01	0.19	-	-	0.28	-	0.05	N/A	N/A
Manganese (mg/L as Mn)	1.6	-	-	-	-	-	N/A	0.4	0.05
***E. coli* (CFU/mL)**	38	0	0	0	99	8	N/A	0	0
Total Coliforms (CFU/mL)	105	22	20	53	>300	214	0.3#	N/A	0.05#

Key to Violation:		ALL		Kenya & WHO		US EPA		WHO		Kenya		WHO & EPA

- indicates that parameter was tested for during analysis

* indicates units of NTU

# indicates units of CFU/mL

Sample 3.1: Mabinju Dispensary. The data presented in Table 5 indicates that the water tested at the Mabinju Dispensary met MCL recommendations except for microbial contamination and hardness. The hardness was measured to be 9.6 mg/L as CaCO3, which is far below the EPA and WHO MCL recommendation range of 100 to 300 mg/L as CaCO3. However, this is a secondary recommendation solely for odor and taste quality rather than contamination. Additionally, total and fecal coliforms were present, indicating that the microbiological contamination in the water could lead to illnesses like diarrhea.

Table 5. Water quality data for Mabinju Dispensary

	Measured Value Site Number		Regulation (mg/L)		
Parameter	**3.1**	**3.2**	**Kenya MCL**	**WHO Guideline**	**US EPA MCL**
Ammonium/Ammonia (mg/L as N)	0.025	-	N/A	35	35
Turbidity (NTU)	1.6	0.58	5*	1*	0.3-5*
Fluoride (mg/L as F-)	0.05	-	1.5	1.5	2
Hardness (mg/L as CaCO3)	9.6	-	N/A	100-300	100-300
Iron (mg/L as Fe)	0	-	0.05	N/A	N/A
Manganese (mg/L as Mn)	0	-	N/A	0.4	0.05
***E. coli* (CFU/mL)**	16	0	N/A	0	0
Total Coliforms (CFU/mL)	61	0	0.3#	N/A	0.05#

Key to Violation:	(orange)	ALL	(purple)	Kenya & WHO	(red)	US EPA	(blue)	WHO	(green)	Kenya	(dark red)	WHO & EPA

- indicates that parameter was tested for during analysis
* indicates units of NTU
# indicates units of CFU/mL

Sample 4.1: Lake Victoria Treatment Plant. The Lake Victoria Treatment Plant did have some elementary filtration and sedimentation processes as the water flowed through the coagulation and flocculation basins but did not actually inject any coagulant. The operators justified the absence of coagulant to the low turbidity of Lake Victoria; however, the turbidity is still well above the Kenya, WHO, and EPA guidelines. Here, recorded values ranged from 19.7 to 41.8 NTU. Still, these values are significantly lower than the turbidity recorded in the two pans. In addition, the fluoride concentrations are the largest for the treatment plant effluent with a value of 2.59 mg/L, exceeding all Kenya, WHO, and EPA regulations. Iron is also above Kenya regulations, which can most likely be attributed to corroded piping and pumping channels. Finally, the hardness in the treatment plant was low at 25.6 mg/L as $CaCO_3$. Although this hardness is outside of the EPA recommended range, a value below the recommended hardness is not a serious concern. Additionally, total and fecal coliforms were present, indicating that the microbiological contamination must be treated before it is expelled into the distribution system. A summary of water quality measures that exceed regulatory limits is shown in Table 11.

Table 6. Water quality data for Lake Victoria Water Treatment Plant

	Measured Value					Regulation (mg/L)		
	Site Number					Kenya MCL	WHO Guideline	US EPA MCL
Parameter	**4.1**	**4.2**	**4.3**	**4.4**	**4.5**			
Ammonium/Ammonia (mg/L as N)	0.337-0.447	0.08	-	-	-	N/A	35	35
Turbidity (NTU)	19.7-41.8	3.11	14.9	5.13	1.21	5*	1*	0.3-5*
Fluoride (mg/L as F-)	2.59	-	-	-	-	1.5	1.5	2
Hardness (mg/L as CaCO3)	25.6	-	-	-	-	N/A	100-300	100-300
Iron (mg/L as Fe)	0.12	-	-	-	-	0.05	N/A	N/A
Manganese (mg/L as Mn)	0	-	-	-	-	N/A	0.4	0.05
***E. coli* (CFU/mL)**	4	0	1	2	0	N/A	0	0
Total Coliforms (CFU/mL)	20	0	8	14	0	0.3#	N/A	0.05#

Key to Violation:		ALL		Kenya & WHO		US EPA		WHO		Kenya		WHO & EPA

- indicates that parameter was tested for during analysis
* indicates units of NTU
# indicates units of CFU/mL

Sample 5.1: Yawo Shallow Well. Of all of the sites tested, the Yawo Shallow Well water quality data was the most encouraging. As shown in Table 7, only the fluoride and manganese levels were higher than regulatory limits. Although it had a measured fluoride concentration of 1.65 mg/L, which lies above Kenya regulations, it does fall below the US requirement. As expected, the shallow well did have a high concentration of manganese at a value of 0.9 mg/L, which falls above all regulations. This data is consistent because infiltrating groundwater gets naturally filtered through the earth's crust, lowering some contaminant levels. No fecal coliforms were found in the well water, but total coliforms were still present in low concentrations. This indicates that the well water is much safer than other sources but still requires some form of disinfection to ensure its quality.

Table 7. Water quality data for Yawo Shallow Well

	Measured Value					Regulation (mg/L)		
	Site Number					Kenya MCL	WHO Guideline	US EPA MCL
Parameter	**5.1**	**5.2**	**5.2**	**5.2**	**5.2**			
Ammonium/Ammonia (mg/L as N)	0.38-0.51	-	-	-	-	N/A	35	35
Turbidity (NTU)	0-1.1	-	-	-	-	5*	1*	0.3-5*
Fluoride (mg/L as F-)	1.65	-	-	-	-	1.5	1.5	2
Hardness (mg/L as CaCO3)	222.4	-	-	-	-	N/A	100-300	100-300
Iron (mg/L as Fe)	0.1	-	-	-	-	0.05	N/A	N/A
Manganese (mg/L as Mn)	0.9	-	-	-	-	N/A	0.4	0.05
***E. coli* (CFU/mL)**	0	0	1	0	0	N/A	0	0
Total Coliforms (CFU/mL)	1	24	>300	>300	34	0.3#	N/A	0.05#

Key to Violation:		ALL		Kenya & WHO		US EPA		WHO		Kenya		WHO & EPA

- indicates that parameter was tested for during analysis
* indicates units of NTU
\# indicates units of CFU/mL

Future On-Campus Testing

The following sample volumes were transported back to Illinois in order to perform further testing.

- Sample 1.1: 13.8 L
- Sample 2.5: 0.5 L
- Sample 4.1: 2 L
- Sample 4.2: 250 mL

The team intends to use the Awuor Pan water (Sample 1.1) to perform a jar test using alum ($AlSO_4$) and possible the dawa stones obtained from Kenya. The other three samples can be used for disinfection tests using samples of WaterGuard and Pur.

In addition to the samples listed above, small volumes of Samples 1.1, 1.2, 2.1, 4.1, and 5.1 were brought back for potential ICP-MS heavy metals testing.

Conclusion

This report outlines the data and team's knowledge regarding the water situation in the Bondo community. It summarizes the information gathered during a two-week visit to Kenya and the conclusions drawn from the experience. A report containing further analysis and suggestions on future steps to be taken will be completed by May 2012.

Beyond the conclusions made above, the trip further reinforced the collaborations between the University of Nairobi, Bondo University College, Bondo District Water, and the University of Illinois. After surveying and sampling the communities together and becoming aware of the water situation in Bondo, Kenya, the collaborations will continue to build capacity and propose drinking water treatment solutions to these communities. Through analytical and sociological analyses, the scope of Bondo's water supply issues is more thoroughly understood. Information was gathered through water sampling and testing at water pans, kiosks, treatment plants, resident's homes, and a dispensary. Oral surveys were also conducted at each of these sites to better understand individual water practices and habits, the variability of each of these sources, and general thoughts and concerns about water related issues.

The team's most concerning issue is the water quality of the water pans that showed high levels both total and fecal coliforms, which are indicators for microbial contamination and directly related to negative health effects. Many sites were also found to have levels of iron and fluoride exceeding the EPA, WHO, and Kenya limits. Conversations with residents indicated that they are aware of the poor quality of certain water sources but have no other option. They are constrained to use the water they do because of financial restrictions, time constraints, and a lack of other water sources.

Perhaps the most advantageous aspect of this project is the diverse array of parties involved. Through collaborating with a local, a national, and an international university as well as the local water district this project has people coming together from many different levels and backgrounds. Those stationed in Nairobi and Bondo can provide detailed local information and understanding of the current situation, while the University of Illinois team can provide advanced technical analysis and assistance in regards to the water quality. Involving experts in water engineering, chemistry, and sociology will ensure that the project is approached properly. Projects such as this one that directly affect people's lives must be technically and socially sound if they are to reach a sustainable solution.

Acknowledgements

The CEE 449 students have many people to thank for making the team's trip to Kenya so memorable and productive. Among them are:

University of Nairobi Department of Chemistry

As the team's original contacts with the University of Nairobi, the team is very grateful for the faculty and students who assisted our interactions in Kenya. The team appreciates Professor Wandiga's support as well as the collaboration of Vincent Madadi, Nusrat Beckham, and Nicholas Mwenda. Their technical expertise and experience with the area was invaluable during the team's travels. The team would especially like to thank Vincent Madadi for coordinating all the efforts between Bondo Water District and for arranging all logistics within Kenya. Without Vincent, the fieldwork and collaborations would not have been possible.

University of Nairobi Department of Sociology

The team would especially like to thank Dr. Robinson Ocharo for his undying support, care, and dedication for the University of Illinois team and this project. His unparalleled expertise and passion for his people, combined with his natural leadership and interpersonal skills compelled us to reach higher than our wildest dreams. The team would also like to thank Phantus Wambiya and Rehema Leilah for their insight into a field that engineers have little background. Their assistance has and will be vital in ensuring work done by the project is relevant and practical for those living in the community.

Bondo University College

The team's connection with Bondo University College is very exciting especially considering its recent establishment as an official university. The team was happy to meet with the administration and welcomes their collaboration in future. It was especially beneficial and appreciated to have Michael Oloko and Daniel Ongor participate in field work in order to form a more robust relationship.

Bondo Water District

The local water district is an influential government organization within the community. Without their advice and willingness to bring the University of Illinois group to water distribution infrastructure sites, the team would not have been able to understand the complex system that provides water to many people within the Bondo District boundaries. The team would like to extend a special thanks to Maurice and Maurice for sharing their first-hand experience and knowledge about Bondo's water infrastructure. The team is especially grateful for Maurice for arranging all meetings with the local communities, utilities, and schools visited in Bondo and for being so welcoming to the University of Illinois team.

Bondo Community

The team would like to thank the community of Bondo and the Awuor Pan Committee, Majengo Pan Committee, and Nyatiek Women's Group at the Yawo Shallow Well. These groups welcomed the team into their communities and gave us their patience during interviews and sampling. The team looks forward to continue working with the people of Bondo.

Accommodations and Travel

The hospitality we received throughout our week at the West End Hotel was greatly appreciated. The staff were welcoming and always accommodated our large group, making sure the team were well-fed during our busy schedule. The team is also grateful for the dedication of our drivers from Lindberg Holidays, who helped the team arrive safely during all of our in-country travels.

University of Illinois at Urbana-Champaign

The CEE 449 students would like to sincerely thank the University of Illinois for giving the class the opportunity to expand our educational horizon. Among the organizations that made the trip possible, the students would like to specifically recognize IPENG for their travel expertise, WaterCAMPWS for extending their projects into the classroom, and the entire CEE department for encouraging the class to apply technical skills in the field. We are especially grateful for the funding support during the fieldwork. The students would also like to add a special thanks to Professor Benito Mariñas, whose technical expertise, positive attitude, and travel enthusiasm have not only made our trip educational, but also memorable, and teaching assistants Aimee Gall and Theresa Vonder Haar, and graduate mentor Lauren Valentino, whose guidance in the use of field equipment and hours of preparation for travel and trip content were absolutely invaluable to the success of the trip.

Appendices

Appendix A. Water Quality Testing Results

Table 8. Results from probes and spectrophotometer tests: Samples 1.1, 2.1, 3.1, 4.1, 5.1

Parameter Name	Site #1.1 Awuor Dam	Site #2.1 Majengo Dam	Site #3.1 Mabinju Dispensary	Site #4.1 Lake Victoria WTP	Site #5.1 Yawo Shallow Well	Kenya MCL (mg/L)	WHO Guideline	US EPA Guideline MCL (mg/L)
pH (pH unit)	6.8 8.09	7.47 8.5	5	6.8 9.07	6.73 6.95	N/A	N/A	6.5 8.5
pHmV (mV)	-62 -50	-55 -52		-138 -115	-8			
Conductivity (mS/cm)	0.2 0.23	0.404 0.426		0.098 0.11	0.522 0.539			
Temperature (°C)	30.77 32.07	25.4 26.92		28.9 29.1	25 25.16			
DO (% DO)	81.7 89.6	28.2 45			52 65.7			
DO (mg/L O2)	5.39 8.02	2.01 3.54			3.73 5.31			
Ammonium (mg/L NH4-N)	1.30 1.32	2.19 2.55		0.23 0.34	0.38 0.51	N/A	35	35
Nitrate (mg/L NO3-N)	2.54 2.72	0.55 0.97	1.6	0.3 0.9	1.2 1.77	10	11	10
Chloride (mg/L Cl)	5.6 11.02	10.2 33.45		4.33 9.56	2.6 5.44	250	N/A	250
ORP (mV)	218 283	171 193		175 227	119 149			
Turbidity (NTU)	756 981	>1000	1.6	19.7 41.8	0 1.1	5*	1*	0.3* 5*
TDS (g/L)	0.130 0.134	0.263 0.27		0.064 0.066	0.334 0.345	N/A	N/A	0.5
SSG (σt)	0	0		0	0			
Alkalinity (mg/L as CaCO3)	72	202.4	29.6	96	278			
Ammonia (mg/L as NH3)	0.14	0.6	0.03	0.13	0			
Bromine (mg/L as Br2)		0.1			0.2			
Chlorine, Free (mg/L as Cl2)		0						
Chlorine, Total (mg/L as Cl2)		0						
Chromium 6+ (mg/L as Cr6+)	0.01	0.02	0.01	0.02	0.005			
Copper (mg/L as Cu)	0.1	0.02	0.02	0.11	0.02	1	2	1.3
Fluoride (mg/L as F-)	1.72	2.01	0.05	2.59	1.65	1.5	1.5	2
Hardness (mg/L as CaCO3)	82.4	146.8	9.6	25.6	222.4	N/A	100 300	100 300
Iodine (mg/L as I2)	7.9	0.08	0.13	1.98	0.05			
Iron (mg/L as Fe)	0.08	0.01	0	0.12	0.1	0.05	N/A	N/A
Maganese (mg/L as Mn)	0.7	1.6	0	0	0.9	N/A	0.4	0.05
Nitrite LR (mg/L as NO2-N)	0.085	0.005	0.01	0.094	0	N/A	1	1
Phosphate Reactive (mg/L as PO43-)	5.23	1.06	0.09	0.23	0.33			
Silica HR			2.8		80.6			
Sulfate	7	7		0	13 17	400	N/A	250
Sulfide (ug/L as S2-)	5	6		8	3			

*In NTU

Key to Violation:
ALL
Kenya & WHO
US EPA
WHO
Kenya
WHO & EPA

Table 9. Results from probes and spectrophotometer tests: All other samples

Parameter	Awuor Dam	Majengo Dam					Mabinju Dispensary	Lake Victoria WTP				Yawo Shallow Well	Kenya MCL (mg/L)	WHO Guideline (mg/L)	US EPA Guideline MCL (mg/L)
Name															
Site Number	1.2	2.2	2.3	2.4	2.5	2.6	3.2	4.2	4.3	4.4	4.5	5.2			
pH (pH unit)	7	6.3	7	8	8	8	6	7					N/A	N/A	6.5 8.5
pHmV (mV)															
Conductivity (mS/cm)															
Temperature (°C)															
DO (% DO)															
DO (mg/L O2)															
Ammonium (mg/L NH4-N)								0.08					N/A	35	35
Nitrate (mg/L NO3-N)													10	11	10
Chloride (mg/L Cl)													250	N/A	250
ORP (mV)															
Turbidity (NTU)	95.4	8.96	19	28	12.4	160	0.58	3.11	14.9	5.13	1.21		5*	1*	0.3* 5*
TDS (g/L)													N/A	N/A	0.5
SSG (σt)															
Alkalinity (mg/L as CaCO3)	60														
Ammonia (mg/L as NH3)	0.07														
Bromine (mg/L as Br2)															
Chlorine, Free (mg/L as Cl2)							0.2	0.4				0.01			
Chlorine, Total (mg/L as Cl2)							0	0.57				0.01			
Chromium 6+ (mg/L as Cr6+)															
Copper (mg/L as Cu)													1	2	1.3
Fluoride (mg/L as F-)	0.94							0.36					1.5	1.5	2
Hardness (mg/L as CaCO3)	31.6												N/A	100 300	100 300
Iodine (mg/L as I2)															
Iron (mg/L as Fe)		0.19			0.28								0.05	N/A	N/A
Maganese (mg/L as Mn)	0												N/A	0.4	0.05
Nitrite LR (mg/L as NO2-N)													N/A	1	1
Phosphate Reactive (mg/L as PO43-)															
Silica HR															
Sulfate													400	N/A	250
Sulfide (ug/L as S2-)															

*In NTU

Key to Violation:	
(orange)	ALL
(purple)	Kenya & WHO
(red)	US EPA
(blue)	WHO
(green)	Kenya
(dark red)	WHO & EPA

Appendix B. Microbiology Testing Results

Table 10. Raw data from microbiological plate testing

Sample	Dilution Factor	Fecal Coliforms (CFU)	Other Coliforms (CFU)	Other Colonies	Sample	Dilution Factor	Fecal Coliforms (CFU)	Other Coliforms (CFU)	Other Colonies
1.1	1	155	55	present	3.1	1	19	34	TNTC
1.1	1	120	72	present	3.1	1	14	51	TNTC
1.1	1	127	42	present	3.1	1	15	50	TNTC
1.1	5	33	15	present	3.2	1	0	0	present
1.1	5	42	22	present	3.2	1	0	0	49
1.1	5	42	26	present	3.2	1	0	0	54
1.1	10	17	14	present	4.1	1	3	17	TNTC
1.1	10	16	12	present	4.1	1	7	16	TNTC
1.1	10	20	24	present	4.1	1	2	15	TNTC
1.2	1	0	0	present	4.2	1	0	0	0
1.2	1	0	0	present	4.2	1	0	0	0
1.2	1	0	2	present	4.2	1	0	0	0
2.1	1	32	45	present	4.3	1	0	1	TNTC
2.1	1	29	37	present	4.3	1	2	14	TNTC
2.1	1	28	28	present	4.3	1	0	8	TNTC
2.1	10	3	12	present	4.4	1	0	12	TNTC
2.1	10	10	10	present	4.4	1	0	14	TNTC
2.1	10	1	7	present	4.4	1	6	9	TNTC
2.2	1	1	18	present	4.5	1	0	0	2
2.2	1	0	18	present	4.5	1	0	0	5
2.2	1	0	30	present	4.5	1	0	0	0
2.3	1	0	12	present	5.1	1	0	1	present
2.3	1	0	25	present	5.1	1	0	2	present
2.3	1	0	22	present	5.1	1	0	1	present
2.4	1	0	68	present	5.2	1	0	24	present
2.4	1	0	43	present	5.2	1	0	28	present
2.4	1	0	48	present	5.2	1	0	21	present
2.5	1	88	TNTC	present	5.3	1	0	TNTC	present
2.5	1	98	TNTC	present	5.3	1	1	TNTC	present
2.5	1	110	TNTC	present	5.3	1	1	TNTC	present
2.6	1	6	153	present	5.4	1	0	TNTC	present
2.6	1	7	155	present	5.4	1	0	TNTC	present
2.6	1	4	161	present	5.4	1	0	TNTC	present
2.6	10	1	22	present	5.5	1	0	30	present
2.6	10	2	25	present	5.5	1	1	33	present
2.6	10	0	30	present	5.5	1	0	37	present
					hotel	1	1	35	present
					hotel	1	4	32	present

Table 11. *E. coli* and Total Coliform counts from microbiological plate testing

Sample	E. coli (CFU/mL)	Total Coliforms (CFU/mL)	Sample	E. coli (CFU/mL)	Total Coliforms (CFU/mL)
1.1	155	210	3.1	19	53
1.1	120	192	3.1	14	65
1.1	127	169	3.1	15	65
1.1	165	240	3.2	0	0
1.1	210	320	3.2	0	0
1.1	210	340	3.2	0	0
1.1	170	310	4.1	3	20
1.1	160	280	4.1	7	23
1.1	200	440	4.1	2	17
1.2	0	0	4.2	0	0
1.2	0	0	4.2	0	0
1.2	0	2	4.2	0	0
2.1	32	77	4.3	0	1
2.1	29	66	4.3	2	16
2.1	28	56	4.3	0	8
2.1	30	150	4.4	0	12
2.1	100	200	4.4	0	14
2.1	10	80	4.4	6	15
2.2	1	19	4.5	0	0
2.2	0	18	4.5	0	0
2.2	0	30	4.5	0	0
2.3	0	12	5.1	0	1
2.3	0	25	5.1	0	2
2.3	0	22	5.1	0	1
2.4	0	68	5.2	0	24
2.4	0	43	5.2	0	28
2.4	0	48	5.2	0	21
2.5	88	TNTC	5.3	0	TNTC
2.5	98	TNTC	5.3	1	TNTC
2.5	110	TNTC	5.3	1	TNTC
2.6	6	159	5.4	0	TNTC
2.6	7	162	5.4	0	TNTC
2.6	4	165	5.4	0	TNTC
2.6	10	230	5.5	0	30
2.6	20	270	5.5	1	34
2.6	0	300	5.5	0	37
			hotel	1	36
			hotel	4	36

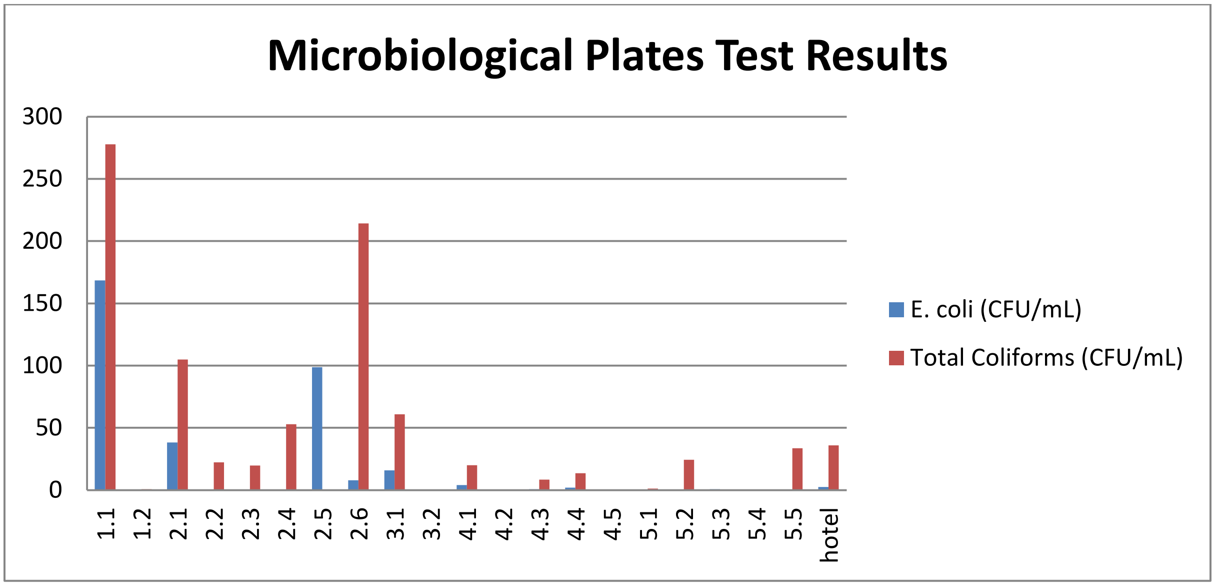

Figure 50. Summary of results from microbiological plate testing (Note: Samples 2.5, 5.3, and 5.4 contained too many Total Coliforms to count.)

Table 12. Results from microbiological jar testing

Sample	Total Coliforms	Fecal Coliforms
1.1	Present	Present
1.1	Present	Present
1.2	Present	Present
2.1	Present	Present
2.1	Present	Present
2.2	Absent	Absent
5.1	Absent	Absent
5.2	Present	Present
5.3	Present	Present
5.4	Present	Present
5.5	Present	Present

Appendix C. Water Contaminants, Regulations, Health Effects, and Sources

Table 13. Microbiological contaminants and regulations

Contaminant	Kenya MCL (mg/L)	WHO guideline (mg/L)	US EPA		Human Health Effects	Source in Drinking Water
			MCL (mg/L)	MCLG (mg/L)		
Cryptosporidium	n/a	10 organisms/L	TT* must disinfect and filter water so that 99% is removed/killed. Unfiltered systems are required to include Cryptosporidium in their existing watershed control systems	0	gastrointestinal illness (diarrhea, vomiting, cramps)	Human and animal fecal waste
Giardia lamblia	n/a	n/a	TT* (99.9% removal)	0	gastrointestinal illness (diarrhea, vomiting, cramps), headaches	Human and animal fecal waste
Heterotropic plate count	n/a	n/a	TT* (no more than 500 bacterial colonies per mm)	n/a	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is. Commonly indicates Acinetobacter, Aeromonas, Flavobacterium, Klebsiella, Moraxella, Serratia, Psuedomonas, and Xanthomonas	HPC measures a range of bacteria that are naturally present in the environment. HPCs reduce in coagulation, sedimentation, chlorinization, ozonation, and UV disinfection but proliferate in activated carbon and sand filtration
Legionella	n/a	n/a	TT*	zero	Legionnaire's Disease (a type of pneumonia), pontiac fever, symptoms include: fever, chills, headache, myalgia, malaise	Found naturally in water; multiplies in heating systems
Total coliforms	30 counts/100 mL	n/a	0.05	zero	Use as an indicator whether other potentially harmful bacteria may be present	Coliforms are naturally present in the environment; as well as feces; fecal coliforms and E. coli only come from human and animal fecal waste.
Fecal coliforms including E.coli	n/a	Must not be detectable in any 100mL; must not be present in 95% of large samples in 12 month period	A positive test for fecal coliform or E. coli leads to repeat test in which any one shows positive for total coliform, the system has an acute MCL violation. 5% of samples can be coliform-positive in a month	0	Food poisoning, ear infections, dysentery, typhoid fever, viral and bacterial gastroenteritis, and hepatitis A	Naturally present in environment, come from human and animal fecal waste
Turbidity	5 NTU	Below 5 NTU, and if possible below 1 NTU	The turbidity level must never be above 1 NTU, and the plant must operate at 0.3 NTU for 95% of the time	n/a	Despite the fact that turbidity itself does not harm human health, it can be indicative of the presence of other chemical and microbial contaminants due to insufficient filtering. In fact, high turbidity concentration have been linked to gastrointestinal infections, diarrhea, headaches, cramps, and nausea.	Turbidity is comprised of organic matter, inorganic and inorganics, such as minerals and soil, which arise in water from erosion, sewage, urban runoff, and industrial wastewater. Turbidity can also include inert particles from clay in groundwdater.
Viruses (enteric)	n/a	n/a	Surface water must be disinfected and filtered so that 99.99% of viruses are removed or inactivated	zero	infect human gastrointestinal tract; meningitis; various other diseases and illnesses	human and animal fecal waste

Table 14. Inorganic contaminants and regulations

Contaminant	Kenya MCL (mg/L)	WHO guideline (mg/L)	US EPA MCL (mg/L)	US EPA MCLG (mg/L)	Human Health Effects	Source in Drinking Water
Antimony	n/a	0.02	0.006	0.006	Leads to increased blood cholesterol, decreased blood sugar, and increased blood pressure	Discharge from petroleum refineries, also exists in fire retardants, ceramics, electronics and solder of pipes and fittings
Arsenic	0.05	0.01	0.01	0	Skin damage or problems with circulatory systems. Possible increased risk of cancer	Erosion from natural deposits; runoff from orchards, runoff from glass and electronics production wastes
Asbestos	n/a	n/a *no consistent evidence of hazards to health	7 Million fibers/Liter	7 Million fibers/Liter	increased risk of developing benign intestinal polyps	decay of asbestos cement in water mains; erosion of natural deposits
Barium	1	0.7	2	2	increase in blood pressure	discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium	n/a	n/a	0.004	0.004	intestinal lesions	discharge from metal refineries, coal-burning factories, and from electrical, aerospace, and defense industries
Cadmium	0.01	0.003	0.005	0.005	Kidney Damage; Carcinogenic by inhalation however no clear evidence that carcinogentic if consumed orally	Corrosion of galvanized pipes; erosion of natural deposits; discharges from metal refineries; runoff from waste batteries and paints; waste/runoff from steel and plastic industries; Fertilizers; Food
Chromium	0.05	0.05	0.1	0.1	Kidney damage	Discharge from industrial sites sucha as steel and pulp mills; erosion of natural deposits
Copper	1	2	1.3	1.3	Short term exposure: Gastrointestinal distress, Long term exposure: Liver or kidney damage, People with Wilson's Disease should consult their doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits
Cyanide	0.01	0.07	0.2	0.2	Possible nerve damagePoisonous. Central nervous system and cardiovascular disturbances	Nature, discharge from industrial chemical factories
Fluoride	1.5	1.5	*Secondary standard: Flouride has a recommended, but not enforceable, guideline of 2.0 mg/L		dental fluorosis, alzheimer's, skeletal fluorosis, and thyroid issues	Naturally in the environment and added in some water systems
Lead	0.05	0.01	0.015	zero	neurodevelopmental effects, cardiovascular diseases, impaired renal function, hypertenstion, impaired fertility, and advers pregnancy outcomes. In children potential delays in physical or mental development, slight deficits in attention span, and learning disabilities.	Primary source is from corrosion of service connections and plumbing which contain lead. Erosion of natural deposits.
Mercury	0.001	0.006	0.002	0.002	Longterm: may affect kidneys	Erosion from natural deposits; Discharges from industrial sources like refineries and factories; Runoff from landfills and croplands
Nitrate	10 (as NO3)	11 (as nitrogen)	10 (as nitrogen)	10 (as nitrogen)	Could cause illness and possible death in infants below the age of six months. Shortness of breath and blue-baby syndrome	Fertilizer; Septic Tank Leakage; Sewers; Natural Deposits
Nitrite	n/a	3 mg/L as nitrite ion; 0.9 mg/L as nitrite-nitrogen; the sum of the rations of nitrite and nitrate cannot exceed 1	1	1	Methaemoglobinaemi in bottle-fed infants; Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome; Could form N-nitroso compounds, which of some are found cancerous to humans	Runoff from fertilizer use; leaking from septic tanks; sewage; erosion from natural deposits; Occurs in higher doses in distribution systems where chloramination is used; Ingested from vegetables
Selenium	0.01	0.04	0.05	0.05	hair or fingernail loss; numbness in fingers or toes; circulatory problems	discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium	N/A	N/A	0.0005	0.002	hair loss; changes in blood; kidney, intestine, or liver problems	leaching from ore-processing sites; discharge from electronics, glass, & drug factories

Table 15. Organic contaminants and regulations

Contaminant	Kenya MCL (mg/L)	WHO guideline (mg/L)	US EPA MCL (mg/L)	US EPA MCLG (mg/L)	Human Health Effects	Source in Drinking Water
Atrazine	n/a	0.1	0.003	0.003	Cardiovascular system or reproductive problems; Modulation of the immune system; Kidney toxicity as caused by Hydroxyatrazine	Runoff from pre-emergent or early post-emergent herbicide used on row crops, generally the control of annual broadleaf and grassy weeds
Benzene	0.01	0.01	0.005	zero	Increased risk of cancer; red blood cell deficiency (Amenia); decrease in blood platelets	Discharge from industrial factories; leaching from gas storage tanks and landfills
Benzo(a)pyrene (PAHs)	0.00001	0.0007	0.002	zero	Reproductive difficulties;risk of cancer	Leaching from linings of water storage tanks and distribution lines
Polychlorinated biphenyls (PCBs)	30 ppm	n/a	0.0005	0	Acute poisonings; irritation of nose, throat and gastrointestinal tracts; changes in liver function; cancer	Transformers, capacitors, and electric motors
Toluene	n/a	0.7	1	1	Toluene is capable of producing negative fetotoxic and embryotoxic effects, however, it is not a carcinogen. It has also been linked with kidney, nervous system, and liver complications.	Toluene is used in the chemical production processes as a raw material and solvent, generally in petroleum factories.
Vinyl chloride	n/a	0.0003	0.002	zero	Increased risk of cancer	PVC pipe leaching; plastic factory discharge
Xylenes	n/a	0.5	10	10	Nervous system damage	Discharges from industrial sources like petroleum and chemical factories

Table 16. Radionuclide contaminants and regulations

Contaminant	Kenya MCL (mg/L)	WHO guideline (mg/L)	US EPA		Human Health Effects	Source in Drinking Water
			MCL (mg/L)	MCLG (mg/L)		
Alpha particles	1 Bq/l	.5 Bq/l	4 millirems/year	0	Alpha particles are known as carcinogens due to their radioactive nature.	Caused by the eroding radioactive mineral deposits, which inturn can emit alpha radiation.
Beta particles and photon emitters	1 Bq/l	1 Bq/l	4 millirems per year	0	Increased risk of cancer	decay of natural and man-made deposits of radioactive materials
Radium 226 and 228	n/a	1 Bq/L (*37 Bq/m3=1pCi/L)	5 (pCi/L)	0	Increased risk of cancer	erosion of natural deposits
Uranium	n/a	0.03	0.03	0	Increased risk of cancer, kidney toxicity	erosion of natural deposits

Table 17. Disinfection byproducts and regulations

Contaminant	Kenya MCL (mg/L)	WHO guideline (mg/L)	US EPA		Human Health Effects	Source in Drinking Water
			MCL (mg/L)	MCLG (mg/L)		
Bromate	n/a	0.01	0.01	zero	Increased risk of cancer	Byproduct of drinking water disinfection
Chlorite	n/a	0.7	1	0.8	Effects nervous system in infants & young children; Also resutls in Anemia	Drinking water disinfection by-products
Haloacetic acids	n/a	0.0005	0.06	n/a	Increased risk of cancer	By-product of drinking water disinfection
Total Trihalomethanes	0.03(Chloroform)	0.3 (Chloroform); 0.1 (Bromoform); 0.1 (Dibromochloromethane); 0.06 (Bromodichloromethane)	0.08	0 (Bromodichloromethane); 0 (Bromoform); 0.06 (Dibromochloromethane); 0.07 (Chloroform)	Carcinogen, reproductive effects	Byproduct of drinking water disinfection

Table 18. EPA secondary contaminants and regulations

Contaminant	Kenya MCL (mg/L)	WHO guideline (mg/L)	US EPA		Human Health Effects	Source in Drinking Water
			MCL (mg/L)	MCLG (mg/L)		
Aluminum	0.1	0.1	n/a	0.05 to 0.2	kidney problems, skeletal and neuromuscular problems, brain degeneration, Alzheimer's disease	Water treatment facilities, discharge from packaging plants
Chloride	1000	n/a	250	n/a	There are no known health concerns at levels found in drinking water--above the MCL a detectable taste is noticed	Natrual sources, sewage, industrial effluents, urban unoff from de-icing salt and saline intrusion.
Color	15TCU	Non health-based value 15TCU	15CU	n/a	Affects acceptability and palatability of water	May indicate metal, natural organic matter (humics) and DBPs
Copper	0.1	2	1	n/a	metallic taste; blue-green staining	corrosion in pipes; erosion of natural deposits
Corrosivity	n/a	n/a	noncorrosive	n/a	metallic taste; corroded pipes (which can reduce water flow)/ fixtures staining	a low pH can cause the water to corrode pipes
Fluoride	1.5	1.5	4	4	bone disease; children may get mottled teeth; dental fluorosis; Alzheimer's disease; skeletal fluorosis; depress activity of the thyroid gland; disrupts hormones	water additive which promotes strong teeth; erosion of natural deposits; discharge from plastic and fertilizer factories
Foaming Agents	n/a	n/a	0.5	n/a	None; levels above MCL cause frothiness, cloudiness, bitter taste, and odor	detergents and similar substances in agitated water (such as in faucets)
Iron	0.3	Non health-based 0.3	0.3	n/a	taste and appearance of water affected before the quantity of iron becomes a health hazard	where various iron salts are used as coagulating agents in water-treatment plants and where cast iron, steel, and galvanized iron pipes are used for water distribution. Naturally present in minerals.
Manganese	0.1	0.04	n/a	0.05	ingestion of manganese-contaminated water is extremely rare	natural deposits; land disposal of manganese-containing wastes
Odor	n/a	n/a	3 threshold odor number	n/a	Hydrogen Sulfide is toxic	result from H2S normally found in well water
pH	n/a	6.5–8	6.5 - 8.5	n/a	usually dilute in water	chemical disposal, acid rain
Silver	n/a	0.1	0.01	n/a	Kidney, liver, and brain damage; cardiac abnormalities Excessive silver ingestion can lead to discoloring of the hair and skin.	Can occur in groundwater due to levels in soil (not very common),
Sulfate	400	n/a	250	n/a	salty taste	mineral deposits
Total Dissolved Solids	1500	Non health-based value 600	500	n/a	Affects acceptability and palatability of water; possibly provides transportation of viruses, bacteria etc.	salty taste, hardness, color, staining, deposits
Zinc	5	n/a	5	n/a	Short term: stomach cramps, nausea and vomiting. Long term: anemia, nervous system disorders, damage to the pancreas and lowered levels of "good" cholesterol	Mining, smelting metals (like zinc, lead and cadmium) and steel production, as well as burning coal and certain wastes can release zinc into the environment

Appendix D. Community Surveys (Raw Data)

AWUOR PAN **FEB 20, 2012**

GPS S 0° 6.643°
E 34° 15.217°

Dug by Swiss in 1992
Approximate size: 46 x 27 m
Serves 21 villages, each approximately 600-700 people
The village we visited was the largest with a population of about 945

Weather Pattern: March-May: Rain; June: Transitional; July-September: Dry; October-December: Rain; January-February: Dry

Interview #1: Jane

GENERAL INFORMATION

- Middle aged woman from the Awuor Pan community
- 10 dependent kids; 3 attend school
- Husband: Deceased
- Income:
  - Agriculture (Maize): 18-30 bags of maize which are 90 kg/year. 10 required for family consumption, remainder used for livestock/additional income/additional food source
  - Side Business (4000 Shillings/mo)
  - Pension: Late husband's teaching career (5000 Shillings/mo)

TAP WATER

Water Source: Bondo University College
- Distance: 2 km
- Price: 10 Shillings/20L Jerrycan
- Cleaner, Tastes Better, Smells Better

Collection
- Water purchased on weekends by children
- 2 km travel to source
- During dry season tap runs dry & are too crowded

Consumption
- 20 Jerrycans/Week
- Drinking
- Tea

Water Treatment: None, assumed water from tap was clean to drink
Water Storage: Water was stored in the container it was collected in
Health: No Diarrhea

POND WATER

Water Source: Awuor Pan

- Pond dries up every 3-4 years
- Poor odor & Taste, particularly in the dry season due to cattle

Collection

- Distance: 5 minute walk from home
- When dry, walks 4 km to Yala River or pays an upcharge from those who deliver water to community

Consumption

- 20 Jerrycans/Day
- Used for laundry, bathing, cooking & cleaning
  - Used for cooking because "boiling killed all the germs"

Water Treatment

- "Why would you spend time or effort"
- WaterGuard
  - Dry Season: Not readily available
  - Wet Season: Available
  - Occasional (rare) use
    - Expensive
    - Sold in central Bondo
- Too time consuming; would spend no more than 10 min treating water
- Cloth Filtration
  - No Knowledge
  - Uninterested

Water Storage

- Jerrycans used for collection & storage
- Got impression that the same jerrycans for both pond and tap water

Health: Acknowledged that the water was dirty and caused typhoid but there were no other feasible options

General Comments

HEALTH

- "Water can make you sick, but when you have no other choice, what can you do?"
- Majority of bad odor and taste come from the animals
- Thought the water had a stronger odor when it rained, recognized that there were more contaminants in the water due to runoff containing feces but did not adjust water habits because of it
- No diarrhea lately

PRIORITIES

- Did not seem willing to spend time or effort for clean water
- Was concerned that during the dry season too many people used the pond
- Concerned about the quality of the pond during the dry season (condensed contaminants)

EDUCATION

- Does not used pretreated water for cooking because boiling kills all the germs
- Recognized that germs lead to illness, and were present in untreated water
- Did not receive any water education
- Never heard of cloth filtration
- Does not wash hands regularly, but thought doing laundry washed your hands, which she did every 2 weeks

- Boiled water was reused

Interview 2: Group of Women

GENERAL INFORMATION:

- Interview was conducted with a large group of middle-aged women sitting under a tree but most questions were directed to one woman and others would agree or comment as necessary
- Spokeswoman specifics
    - 15 family members; 8 children required school fees
    - Income: Farming and Charcoal sales during dry season (800 shillings/mo)
- Translated through Rehema (Nairobi University social science grad student)

TAP WATER

Water Source: Bondo University College

- Dry Season: Mostly available; at times access would be cut for 3+ days at a time
- Expensive
- Unpleasant chlorine odor

Collection

- Distance: 2 km
- 5 Shillings/20 L Jerrycan
- Retrieve water by foot or children would retrieve water by bike

Consumption

- 28 Jerrycans/Week
- Drinking only

Water Storage

- Jerrycans: Collection & storage
- Clay Pot: Keeps water cold
- Mug: Water transfer

Health: Confident water was safe to drink/cleanest available source

POND WATER

Water Source: Awuora Pan

- Dries up annually

Collection:

- Distance: 10 minute walk
- Travel to Yala River when pond dries up or purchase water for 50 shillings/20 L

Consumption: Bathing, Laundry, Cooking

Treatment

- Cloth Filtration (very few)
- WaterGuard (several)
- No Treatment (most)

Water Storage: N/A

Health: N/A

GENERAL COMMENTS

Health

- Understand germs are in water and cause sickness
- Water causes pneumonia, malaria, stomach pains, and diarrhea
- Sickness is generally attributed to the pond's water quality
- Health problems increased when tap wasn't functioning or when they didn't have money to buy water

Priorities

- Reduce water treatment time (WaterGuard takes up to 7 hours to complete treatment)
- Feel trapped by treating water, that it consumed too much of their time, and they wanted an instant improved water quality system
- Willing to spend 1000 shillings/month but only when money is available to them (which is highly irregular)

Education

- Biannual visits from health sector give presenations
  - Airing of dishes and utensils
  - Digging holes to bury trash
  - Building pit latrines
- Women were well informed but rarely followed these practices
  - Few aired dishes
  - Trash: Some buried & burned, some only burned, others just tossed
  - Pit Latrines: Shared by a single household (up to 15 people); Many could not afford to build them
- Identified water contaminants as direct animal contact with water, animal feces, and feces that are washed into pond during rains

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Interview #3: Margaret

GENERAL INFORMATION

- Observational interview while visiting her home
- 8 Dependents; 5 Children requiring school fees
- Occupation: Basket Weaving & Farming (500 shillings per week)

TAP WATER

Water Source: Bondo University College **did not provide additional treatment**

Water Appearance

- Clear with very small amount of sediment
- No apparent odor

Water Storage

- Same jerrycans used to collect water or dumped into uncovered plastic garbage can used specifically for a tap water storage facility
- The plastic garbage can is scrubbed with dawa before each use
- Jerrycans used for collecting tap water are separate from those used for collecting the pond water
- Dips cup in water to drink, cleans the cup with soap and water 3x per day
- Chickens kept loose in storage room

Health

- Knows the importance of keeping tap water and pond water containers separate
- Germs in the water cause illness

POND

Water Source: Awuor Pan

- Collects the water and carries it on her head in a jerrycan
- Water stored up to 1 week

Water Treatment

- Boiling occurs during cooking but otherwise not used
- Containers treated with dawa to coagulate

Water Appearance

- Water appears very turbid, with high levels of sediment.
- Brown in color
- Odorous

Water Storage

- Water stored in the cans as used for collection, top left open
- Kept separate from tap water
- Jerrycans washed with pond water and scrubbed with dawa for cleaning in between uses

Health

- Knows pond water causes diarrhea and other serious illness
- Knows importance of washing hands after handling pond water and before eating
- Knows the importance of fencing off the water source, but it conflicted because animals still need water and cannot be denied
- Was aware that drying your dishes outside after washing was important but did not have a drying rack since it was hard to maintain

GENERAL COMMENTS

HEALTH

- Wash hands after using the latrines, and before and after eating
- Family used soap but she noted that not everyone in the community used soap
- Hands were air dried

EDUCATION

- Knew she should dry her dishes with a clean towel but is not able to wash her towels often enough to do so
- Participated in community health events

PRIORITY

- Wanted rainwater catchment or storage facility to collect water
- Said using tap is time consuming and required a lot of effort to carry home
- Said there was plenty of water to collect during wet season for use in dry season
- This would allow her to avoid the poorest quality water in the pond during dry season
- Willing to pay weekly fee for community storage facility

Interview #4: George Oketch

GENERAL INFORMATION

- Born: 1965
- Occupation: Water Commissioner

TAP WATER

Water Source: Bondo University College

Collection

- Price: 20 Shillings/ Jerrycan
- Distance: 10-15 Minutes

Consumption: Drinking Water

Treatment: Untreated

Water Storage: N/A

Health: N/A

POND WATER:

Water Source: Awuor Pan
- 21 Communities
- 18,000 People
- Sept-November: Rain Season; Pond Fills
- Pond dries in 1.5 months, pending rain
- No irrigation (enforced)

- Don't clean bikes with water (not enforced)

Collection

- Women & Children
- Bicycles, Donkeys, Pickups
- Center of pond believed to contain cleaner water; people wade to collect
- Price: 20 Shillings/ Jerrycan
- Distance: 10-15 Minutes
- Some travel 10 km during drought

Consumption:

- Construction, domestic animals, food, washing, drinking; management prohibits irrigation
    - **Muddy water used for irrigation during dry season
- Price: 10-20 shillings, pending on distance from pond & depending on availability of tap water

Treatment:

- WaterGuard
    - Price: 10 shillings
    - Too expensive for the minority
    - Procedure: Add to water, let sit for 20-30 minutes
    - Believes that most follow these instructions
    - Storage: Inside in cupboards
- Dawa Treatment by *Margarit Abongo*:
    - Dawa: Calcium Carbonate Rocks; "Chlorine", used for dilution
    - Procedure: Mix in water for 30-60 seconds, Let settle for 5-10 minutes, Leave sediment in bottom of container & scoop water off top as needed
    - Doesn't work in Sun
    - Faster in cold weather
    - Uses: Cleaning & Cooking Water
    - Price: 20 shillings/2 weeks –dependent on water consumption
    - Smuggled from water treatment plants & sold illegally in open market
    - Tastes like salt
    - Is used for tooth aches
    - Affects taste of water
- **Cloth Filtration**
    - Clean, Cotton Cloth
    - Used after addition of WaterGuard

Water Storage: N/A

Health: N/A

Politics:

- In the past there were disagreements about water rights, particularly with people from outside the community.
- Now, all are welcome to use the water.

RAINWATER

Water Source: Rain

Collection: Metal Drums, Plastic Cans, Jerrycans off roof

Consumption: Drinking Water; Considered Fresh

Water Treatment: No Treatment

Water Storage: Same containers as pond water

Health: N/A

General Information:

HEALTH:

- Increased disease due to population growth; houses used to be spaced 3 km, now neighbors in site
- Open defecation
- Had typhoid 4 yrs. Ago

EDUCATION:

- Radio
- Hospitals/Dispensaries
- Chief Assembly (NGO, CBO, Clinics outreach & demonstrate)

DUTCH NGO:

- 1997: Built second smaller pond at higher elevation for filtration
- Designated areas for domestics & washing
- Erosion & clogging

FUTURE:

- Multiple sources: Pond, Boreholes & Tap
- Tap water a lone isn't feasible due to unreliability; need workers, electricity, etc.
- Boreholes: Too Salty
- Pond: Dries Up

Interview #5: Vincent Omolo Ogutu

GENERAL INFORMATION

- Age: 63
- Title: Village Elder
- Village: Bar-Kuogo

- Occupation: Craftsman to get money, Subsistence farmer to get food
- Craft: Rope & Baskets
- Lives: 1.7 km from pond

WATER SOURCES:

- Primary Source: Pond
- Rain Water
- Tap; Bondo University
- Gets water twice in the morning and twice at night (160 L /day, two trips in the morning and two trips at night). This water serves 10 people and t heir animals
- When dry he collects tap water but only up to 40 L / day.
- He will drink pond water untreated only when he is forced to (compelled) due to thrist.
- Most make clean water as a priority unless forced by thirst to act otherwise
- Personally, he has not limit on water quality treatment.

POND WATER:

- Primary Source
- Treatment: Dawa, WaterGuard, Pur
- Dawa: Cooking & Cleaning; weekend use, heard it was unhealthy to drink dawa water
- WaterGuard: Lasts 2 weeks, uses before cloth filtration, 30 minutes, Expiration: if at store they are allowed to return bottle but once they leave the store and go home they cannot return the bottle to the store and they are forced to use expired bottle.
- Water Pur – Rare
- Boils: Occasional
- Stored in ceramic pots with loose tops
- Extremely important for the village
- Supports agro-business activities
- Believes leachate to ponds from humans is a big contributor to water pollution

RAINWATER:

- 100 L metal pot used to collect rainwater
- Roof is dustu
- Boils rainwater but most people don't
- Stores in jerrycans
- Attempts to consume before mosquito larvae form

BOREHOLES:

- He prefers more boreholes
- Saltier so cant make milk tea, cant make foamy soap, and is believed to not quench thirst but he believes it does (personally)
- Need to be 40 to 50 ft deep with pump
- He believes boiling saltwater will make it less salty!
- Borehole water is good for animals

THE TAP – BONDO UNIVERSITY:

- Stored in ceramic pots with loose top
- Yala River is source and it never runs out

EDUCATION:

- Younger people do not go to informational meetings by HBC or practitioners that show them how to use watergaurd, etc.. Younger people also do not care enough about water quality.
- But – elder people do go and care more about cleaning.

POLITICS:

- People used to fight over water when people not in community used water
- Now management said the water is hear for everyone to use without restriction on person
- Most employed people in Bondo use tapwater and not pond BUT their animals do use pond.

DISEASE:

- No diarrhea
- Stomach pains
- Him and wife had malaria in 2010 but now it is better

THE DUTCH:

- Initially worked but lots of mud built up in basins.
- People are more reactive that proactive so people get lazy, don't dredge mud out, and go to orginal pond. Also management didn't fix it.
- They could make anyone do it because the society has changed.

FUTURE:

- He wants more boreholes with a pump.
- Then animals could use pond
- Tap wont do it because it is too many people to supply
- Build second pan
- Pond is irreplaceable because of the business is surrounding it. It will always be important.

Interview #4: George Oket ch

GENERAL INFORMATION

- Born: 1965
- Occupation: Water Commissioner

POND WATER:

Water Source: Awuor Pan
- Extremely Important to village
- Supports Agro-Business Activities
- Believes leachate to ponds from humans is a big contributor to water pollution

Collection

- 2x Morning & 2X Evening
- 160 L/Day
- When dry, collects water from tap (40 L/Day)

Consumption: 160 L/Day

Treatment

- Dawa:
  - Water used for cooking & cleaning
  - Weekend Use
  - Unhealthy for consumption
- WaterGuard
  - Lasts 2 weeks
  - Used before cloth filtration
  - 30 minutes
  - Expiration dates checked sometimes; if expired will still use
- Water Pur**:** Rarely used
- Boiling**:** Occasional

Water Storage:

- Ceramic Pots with loose tops
- Jerrycans

Health: N/A

RAINWATER

Water Source: Rain

Collection: 100 L metal drums

Consumption: Drinking Water

Water Treatment: Boiling, but most don't

Water Storage: Jerrycans

Health: Attempts to assume before mosquito larvae form

BOREHOLES:

- He prefers more boreholes
- Saltier so cant make milk tea, cant make foamy soap, and is believed to not quench thirst but he believes it does (personally)
- Need to be 40 to 50 ft deep with pump
- He believes boiling saltwater will make it less salty!
- Borehole water is good for animals

THE TAP – BONDO UNIVERSITY:

- Stored in ceramic pots with loose top
- Yala River is source and it never runs out

General Information:

HEALTH:

- No diarrhea
- Stomach Pains
- He and his wife had malaria in 2010, treated at hospital

EDUCATION:

- Younger people do not go to informational meetings by HBC or practitioners that show them how to use watergaurd, etc.. Younger people also do not care enough about water quality.
- But – elder people do go and care more about cleaning.

THE DUTCH:

- Initially worked but lots of mud built up in basins.
- People are more reactive that proactive so people get lazy, don't dredge mud out, and go to orginal pond. Also management didn't fix it.
- They could make anyone do it because the society has changed.

FUTURE:

- He wants more boreholes with a pump.
- Then animals could use pond
- Tap wont do it because it is too many people to supply
- Build second pan
- Pond is irreplaceable because of the business is surrounding it. It will always be important.

MAJENGO PAN **FEB 21, 2012**

- Pan serves approximately 4,000 people in the area
- It was suspected to run dry in the coming weeks
- Alternative sources of water in the areas include kiosk (the nearest of which was unrealiable) and other pans
- A borehole had been dug in the area, but it was too salty for continued use

Interview #1: Wikista Okoth

GENERAL INFORMATION

- 9 total people in family
  - 7 children; 4 attend school
- Occupation: sells water (est. 800 shillings/week)

TAP WATER

Water Source: Akoko Primary School tapstand

- Distance: ~5 km

- 5 shillings per jerrycan

Collection

- Walking: once per day
- Bike: twice per day (takes less time)

Consumption

- Not regular drinking source; only collected once per week/month

Water Treatment

- None

POND WATER

Water Source: Majengo Pan

- 30-minute walk to get to pan
- Dislikes odor caused by cattle
- Dries up 2-3 times per year; uses tapstand instead

Collection

- Uses 3 donkeys; each carry 4 jerrycans; travels 2x per day = total 24 jerrycans per day
- Usually collected only by Wikista

Consumption

- For all uses (drinking, cooking, washing)
- For livestock (3 cows, 6 goats)
  - Doesn't bring livestock to pond because can't spend time taking another trip
- 9 people total in family (7 children)

Water Treatment

- Boiling
  - Always boils before drinking
  - Specified that water boils thoroughly, but no specification on time left boiling
  - Cost: 100 shillings to boil 2 jerrycans of water (~40 L)
  - Water still cloudy after boiling
- Chlorine
  - NOT used by Wikista
  - Sometimes used to reduce cloudiness

Water Storage

- Clay pot used, but now broken; currently uses jerrycan
- Has a jerrycan only for drinking water
- Water lasts about 3 days
- Cleans storage containers 2x per week with soap and sponge
- Prepares 1 jerrycan at a time for drinking

Health

- Pours waste wash water on ground
- Lives 20 minutes from dispensary "hospital"

(At this point in the interview, two more residents joined the conversation; data recorded at this point can be viewed in interview 2)

Interview #2: 3 Residents

GENERAL INFORMATION

- Wikista Okoth (see general information in previous interview)
- John Okelo
  - 5 family members
  - Occupation: garage business (500 shillings/week)
- Rebeka Achieng Opany
  - Widow with 5 children
  - Occupation: sells maize (200 shillings/week)

General Comments

HEALTH

- Dispensary "hospital" located 5 min - 2 hr from residents
  - Sometimes doesn't have correct drug and must travel farther into Bondo to other location
- Diarrhea and typhoid are present
  - Both children & adults
  - Boiling reduces frequency, but still present
  - Recognize water as source of problem (told at "hospital")
- All interviewees have pit latrines

PRIORITIES

- Willing to spend time on treatment, but recognize not everyone would do this
- Willing to spend 100 shillings/day on water
  - Calculated based on 10 shillings/jerrycan and 10 jerrycans/day

EDUCATION

- Ministry of Health
  - Come to community 1-2x per year
  - Educate on boiling or just adding WaterGuard
    - Wash hands before eating or after bathroom
    - Dry utensils outside
    - Use pit latrines
  - Good representation of community is present (adults & children)

Interview #3: Group of ~10 Women

GENERAL INFORMATION

- Mostly middle aged women with a few young adults and elderly women.
- Primary sources
  - Pan
  - Wagusu Beach, Lake Victoria
  - Piped water

TAP WATER

Water Source: NONE NOW

POND WATER

Water Source: Majengo Pan

- Odor was the most disliked characteristic of the water. They blame the poor odor on cattle urination and dead dogs and cats being dumped in the pan.

Collection

- Methods of transporting water from the pan are using donkeys, bicycles and carrying the jerrycans on their head
- Elderly who do not have money have someone fetch them water. Therefore the closest source, the pan, is used.
- When there is a lot of water both the men and women collect water but when water is scarce, the women are the only ones that collect

Consumption

- Used for bathing, laundry, cooking and drinking

Water Treatment

- Allow water to settle in storage tank and sometimes use cloth filtration
  - Most use a white cotton cloth but others use whatever they have
- Other forms of treatment are not used based on affordability
- Many people do not use WaterGuard because it is unfamiliar and they have not been educated on its use
- If water could be treated at home to a point where it is safe to drink, the women would not put a limit on the amount of time they are willing to spend treating it.

Water Storage

- Use buckets, jerrycans, super drums and ceramic pots

Health

- A lot of instances of diarrhea and stomach pains because of the water

General Comments

PRIORITIES

- Main priority is having safe drinking water as soon as possible
- In order for everyone to be able to afford piped water it should cost 2 shillings/jerrycan but it is currently 5-10

EDUCATION

- Ministry of Health come to community meetings once a month
  - Teach about boiling water
  - No WaterGuard education
  - Adults who attend try to teach their children
    - A minority attend, so many children are uninformed about safe drinking water practices

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Interview #4: Boniface Okumu

GENERAL INFORMATION

- Chairman of Pan Management Committee (unpaid position)
- Age: 70
- Married

- In 1931, his grandparents dug the pan by hand

TAP WATER

Water Source 1: Majengo Kiosk

- Distance: 0.5 km
- Price: 5 Shillings/20L Jerrycan
- Cleaner water with better taste and smell
- Typically only used for drinking water

Collection (for water source 1)

- Kiosk has been down for about one month
- Regularly stops working to the point where people no longer trust it
- Lacks a storage tank so anytime the pump feeding it stops working, it also stops working

Water Source 2: Akoko Kiosk

- Distance: 10 km
- Price: 10 Shillings/20L Jerrycan, 10 shillings to pay for transport or jerrycan
- Cleaner water with better taste and smell
- Typically only used for drinking water

Collection (for water source 2)

- Kiosk has a storage tank and is more reliable than water source 1
- Has better pressure because of the storage tank
- Still runs dry

Water Source 3: Bondo Kiosk

- Distance: 10 km
- Price: 5 shilling/ 20L Jerrycan
- Most reliable source of treated water

Water Treatment: None, assumed water from tap was clean to drink

Water Storage: Water was transported in a jerrycan and stored in a super drum inside his house. Cup used to collect water was washed before use

Health: No issue were reported

PAN WATER

Water Source: Majengo Pan

- Pond was suspected to dry up in 1-3 weeks
- Serves approximately 900 people
- Large amounts of cattle use pond
- Dead animals (donkeys, cats, and dogs) sometimes end up in the pond leading to increases in sickness
- During the dry season when water levels are low, cattle are restricted from accessing the water. This requires 5 people guarding the pond.
- Bicycles and cloths are not allowed to be washed in the pond, but people sometimes break the rules if no one is around to regulate

History

- Made by his grandfather and opened to everyone in 2007

- In 2007, the Ministry of Water began construction the pan to make it larger. Construction stopped after 6 months before work was completed.
- The elevation was not correct where water was designed to enter the pond so water flowed around it.
- A ditch leading to the pond is dug continually by volunteer work
- A tank was intended to be put on the hill above the pond, but it was never made because of lack of funds

Collection

- Distance: 5 minute walk from house
- Collected in jerrycans
- When dry, they are required to dig to access water before collecting
- People come from 20 miles away to collect water
- People with bicycles and donkeys collect large quantities of water and sell it for 20 shillings/jerrycan no matter distance

Consumption

- Boniface and family consume 120 L/day. Other homesteads consume up to 200 L/day
- Used for laundry, bathing, cooking, cleaning, and drinking

Water Treatment

- People were not willing to put time into treating water.
- When asked if he would treat the pond water if it would result in the same quality of the kiosk he said he would not be willing
- Does not treat water because of cost
- Let settle for water for 1 hour because "there are insects in the water and we don't want to ingest them"
- WaterGuard
    - Occasional (rare) use
        - Expensive
        - Unappealing taste and odor to a majority of the community
- Cloth Filtration
    - Used but not by many people
    - Think it is not effective because still comes out turbid
- Dawa Stone
    - Used to remove turbidity in laundry water so whites remain white.

Water Storage

- Water stored in super drum with lid
- Use cup to retrieve water from super drum.
- Super drum used for both pond and kiosk water but cleaned in between

Health: The water can make us sick. Have had stomach pains and headaches from drinking. Higher instances of diahrreah when animals were found. Have to drink because we do not have another option.

PAN WATER

Water Source: Majengo Pan

- Pond was suspected to dry up in 1-3 weeks
- Serves approximately 900 people
- Large amounts of cattle use pond
- Dead animals (donkeys, cats, and dogs) sometimes end up in the pond leading to increases in sickness

- During the dry season when water levels are low, cattle are restricted from accessing the water. This requires 5 people guarding the pond.
- Bicycles and cloths are not allowed to be washed in the pond, but people sometimes break the rules if no one is around to regulate

History

- Made by his grandfather and opened to everyone in 2007
- In 2007, the Ministry of Water began construction the pan to make it larger. Construction stopped after 6 months before work was completed.
- The elevation was not correct where water was designed to enter the pond so water flowed around it.
- A ditch leading to the pond is dug continually by volunteer work
- A tank was intended to be put on the hill above the pond, but it was never made because of lack of funds
- Fertilizers not used in surrounding area. Use compost manure.

Collection

- Distance: 5 minute walk from house
- Collected in jerrycans
- When dry, they are required to dig to access water before collecting
- People come from 20 miles away to collect water
- People with bicycles and donkeys collect large quantities of water and sell it for 20 shillings/jerrycan no matter distance

Consumption

- Boniface and family consume 120 L/day. Other homesteads consume up to 200 L/day
- Used for laundry, bathing, cooking, cleaning, and drinking

Water Treatment

- People were not willing to put time into treating water.
- When asked if he would treat the pond water if it would result in the same quality of the kiosk he said he would not be willing
- Does not treat water because of cost
- Let settle for water for 1 hour because "there are insects in the water and we don't want to ingest them"
- WaterGuard
  - Occasional (rare) use
    - Expensive
    - Unappealing taste and odor to a majority of the community
- Cloth Filtration
  - Used but not by many people
  - Think it is not effective because still comes out turbid
- Dawa Stone
  - Used to remove turbidity in laundry water so whites remain white.

Water Storage

- Water stored in super drum with lid
- Use cup to retrieve water from super drum.
- Super drum used for both pond and kiosk water but cleaned in between

Health: The water can make us sick. Have had stomach pains and headaches from drinking. Higher instances of diahrreah when animals were found. Have to drink because we do not have another option.

BOREHOLE

- One borehole was dug by Lake Victoria Commission
- Depth: 80 ft. Water table is very deep so no other boreholes have been dug
- Too salty. Does not quench thirst

General Comments

HEALTH

- "The water doesn't taste good but water is life."
- Water makes them sick and have stomach pains
- Boniface thinks "insects" in water makes them sick

PRIORITIES

- Boniface's biggest priority was expanding the pond so it could have more water year round. Preferred the pond because it had water for the animals.
- The kiosks are not a priority because the pumps do not consistently work.
- Young people do not treat water and think it is safe to drink if their wives go and collect it and it is in the storage tank.
- Get together once a year to maintain public structures (ponds, roads, ditch) but attendance has been on the decline because it is volunteer
- Quantity and not quality is the priority

EDUCATION

- NGOs
    - K International
    - Plan International
    - Ministry of Health
- Hold chief assembly weekly
- Hold meetings at church so more people come.
- Information includes safe drinking water, latrine, and sanitation
- People listen to educational radio broadcasts
- In Boniface's opinion, young people do not come to assembly and are not keen to learn.
- Rule enacted that every homestead should have a pit latrine. Majority of people have them but sometimes it is just a formality and use bush.

Interview #5: Man with bike

GENERAL INFORMATION

- ~25 years old
- Carrying two jerrycans on a bike
- Uses 60 L per day for 3 people
- Lives 5 minutes away from pond
- Has a zinc roof and collects rain water in a 15 L cooking pot
- Went to Bondo 3 days ago to get tap water 5 shillings/Jerrycan
- Every Monday they have chief meetings
    - Attend once a month because he is a family man so he has to fend for his family

WATER TREATMENT

- Uses WaterGuard to treat pond water and when he has money goes to kiosk

PRIORITIES

- Priority is pond water and wants to expand it because with the pond he is sure that the water is there.
    - Kiosk is not reliable
- Try to encourage having a fund but the people are not willing to contribute.

Interview #3: Group of ~10 Women

GENERAL INFORMATION

- Mostly middle aged women with a few young adults and elderly women.
- Primary sources
    - Pan
    - Wagusu Beach, Lake Victoria
    - Piped water

TAP WATER

Water Source: NONE NOW

POND WATER

Water Source: Majengo Pan

- Odor was the most disliked characteristic of the water. They blame the poor odor on cattle urination and dead dogs and cats being dumped in the pan.

Collection

- Methods of transporting water from the pan are using donkeys, bicycles and carrying the jerrycans on their head
- Elderly who do not have money have someone fetch them water. Therefore the closest source, the pan, is used.
- When there is a lot of water both the men and women collect water but when water is scarce, the women are the only ones that collect

Consumption

- Used for bathing, laundry, cooking and drinking

Water Treatment

- Allow water to settle in storage tank and sometimes use cloth filtration
    - Most use a white cotton cloth but others use whatever they have
- Other forms of treatment are not used based on affordability
- Many people do not use WaterGuard because it is unfamiliar and they have not been educated on its use
- If water could be treated at home to a point where it is safe to drink, the women would not put a limit on the amount of time they are willing to spend treating it.

Water Storage

- Use buckets, jerrycans, super drums and ceramic pots

Health

- A lot of instances of diarrhea and stomach pains because of the water

General Comments

PRIORITIES

- Main priority is having safe drinking water as soon as possible
- In order for everyone to be able to afford piped water it should cost 2 shillings/jerrycan but it is currently 5-10

EDUCATION

- Ministry of Health come to community meetings once a month
  - Teach about boiling water
  - No WaterGuard education
  - Adults who attend try to teach their children
    - A minority attend, so many children are uninformed about safe drinking water practices

WAYE COMMUNITY DEVELOPMENT WATER KIOSK FEB 22, 2012

- Constructed two NGOs three years ago:
  - Western Flood Mitigation
  - World Bank
- Community offered land to construct it
- The area consists of
  - Kiosk with a 10m3 tank
  - 2 troughs for animals
  - A latrine center
  - The start to a possible community garden
- 11 person committee is in charge of running the kiosk
- 5 shillings/ 20L jerrycan
- Alternative sources of water in the area
  - Lake Victoria
  - Other kiosks
  - Private homes with water connections

Interview #1: Monica Dola (Treasurer)

GENERAL INFORMATION

- Treasurer of Waye Community Development Kiosk
- Uyawi Anglican Church is what she refers to the community as
- Has been treasurer of kiosk for the past 3 years
- Lives in sight of the Kiosk (wealthier from the look of the house)
- Previous treasurer lived in Nairobi and could no longer commute to the kiosk due to health reasons
- Positions is volunteer (not paid)

HISTORY OF KIOSK

- Constructed two NGOs:
  - Western Flood Mitigation
  - World Bank
- The NGOs offered the plan of the kiosk, the community accepted and offered land
- The kiosk with a 10 m3 tank, latrines, and two troughs were constructed.

    - The troughs were meant to be used to people could pay to let their animals drink. Nobody uses them since they can just take the animals to the lake.
- NGOs gave some education before construction but more focused on water related education after the kiosk was built
- The community formed an 11 person committee with the main roles being chairman, secretary, and treasurer to manage the kiosk
- A bank account was also opened when the kiosk started, but no money has been put into it

KIOSK BANK ACCOUNT

- Treasurer stated that money has not gone into account because all excess money has gone towards payment of the person running the kiosk (this statement was later contradicted)
- In the past three years, no money has been added to the account
- The cost of water ranges from 1,600-3,000 shillings per month
- The person running the kiosk is paid 700 shilling per month. This is regarded as a meager wage and she is offered use of the kiosk water for washing in exchange.
- Usually 100-1,000 shilling is leftover after paying the water bill and person running the kiosk. So far, this money has been used to start planting a vegetable garden. The treasurer hopes this will make more money for the community account.
- Reasons for issues making money with the kiosk according to the treasurer:
    - They pay for the water entering the tank rather than the water that people are buying
    - People pay for water in IOUs but never fulfill their obligation
    - Increased water fees have led less people to come to the kiosk (explained below)

WATER FEES

- When they kiosk was initially constructed, they charged 3 shillings per 20L jerrycan. This was considered a reasonable rate for those buying.
- The water company raised the prices of water and the kiosk needed to start charging more per jerrycan in order to cut a profit. This was when the price went to its current rate of 5 shilling per 20L jerrycan
- Many people went to households or other water kiosk which still charged 3 shillings per 20L jerrycan. The kiosk lost a lot of business.
- Even though everyone has been forced to raise the price to 5 shillings per 20L jerrycan business is still low at the kiosk.

MISCELLANEOUS

- Problems with the water lines are usually repaired within a day if there is pipe available and people are notified. If not, it takes 2-3 days to buy pipe and fix the problem.
- If electricity is out and the tank cannot be filled, it usually takes about 2 days for the tank to be drained.
- The tank is also used at the local high school

IDEAS FOR IMPROVEMENT

- Bigger tank that can serve everyone and doesn't run dry when water is not being pumped
- Install irrigation pipes to help irrigate the community garden
- Find better ways to advertise the health benefits of the kiosk. According to the treasurer, the amount they pay for water at the kiosk is very small compared to what it would cold for treatment if people get sick. She is hesitant to tell people this because they might call her corrupt.

Interview 2: Atieno Ogula

GENERAL INFORMATION:

Atieno typically buys 6-8 jerrycans a day to care for a family of 8 people (5 children). She uses the water for drinking, cleaning, washing, and bathing. About 30% of the time her family cannot afford to purchase water and must resort to using water directly from the lake. She brings her cattle to the lake for drinking. She was very confident in the kiosk's water quality and said her family only experienced problems when they reverted to drinking lake water. Even though she treats the lake water with WaterGuard she still reported health problems. She said that she typically bought WaterGuard every two weeks and checked the expiration date.

Interview #3: Group of Women

GENERAL INFORMATION

We then talked to a group of women who use the tap for their primary water source. They all agreed the water was of high quality and none had health complaints after consuming it. They wanted the price of water to be reduced from 5 to 3 shillings per jerrycan because it would allow them to use water more freely and feed their cattle more conveniently. They thought if they started a community garden they could subsidize the price of water.

YAWO SHALLOW WELL **FEB 23, 2012**

Interview #1: 6 Members of the Nyandiek Women's Group

GENERAL INFORMATION

- The funds collected by the women's group are put into an account and used to pay the repairman when the well breaks.
  - The last time the well needed repairs was about a year ago and breaks or leaks are rare.
- The people rely on rain water for irrigation and do not use the well water for that purpose.
- The well is padlocked ta night and the caretaker keeps the key to prevent people from stealing water.
- Animals go to the pond to drink and the community does not give the well water to them.
- The community decided on the forming the Nyandiek Women's Group and how much tariffs would be.
  - Price set so that the members of the village can afford the water.
- Community seems to be of a higher socioeconomic status than other villages we have visited.

Water Source

Yawo Shallow Well

- 70 feet deep well that never runs out, but takes longer to pump during the dry season.
- Dug by hand by the community with free labor and an engineer overseeing, so the community accepts it as their own.
- Serves less than 70 people/day because there is another borehole, pond and stream nearby.
- Cost
  - Membership = 70 shillings plus 30 shillings/month (women only)
  - Non-members: 3 shillings/jerrycan
- Well was originally run by a Dutch company and Unicef came to replace the top which was stolen. Then it was handed over to the women.
- Water quality is clear consistently

Collection

- The women collect water from the well using a funnel and a jerrycan. They pump the water into the funnel using the hand pump.

Consumption

- Complain that the water is saltier than they would prefer.

Water Treatment

- Only half of the community treats their water and when they do use WaterGuard.
- One woman, Florence, said that she prefers to take precaution by using WaterGuard from learning about how it helps.

Water Storage

- One woman stores her water in a ceramic pot with a cover.

HEALTH

- No stomach complaints or sickness reported
- Before the well was constructed the people would drink the pond water and there was a higher frequency of disease.
- General health has improved since the well was installed.

PRIORITIES

- First priority: Want well to be fenced in with a gat that can be locked so stealing will not happen as frequently.
    - People cut off the padlock and steal the water.
- Second priority: Get the well treated with chlorine like was done when Unicef came.

EDUCATION

- Get most of their information from radio broadcasts and chief assembly meetings.
- Some people will boil the well water that they plan on drinking.

Interview #2: Risper Atieno

GENERAL INFORMATION

- Chairwoman for Yawo Shallow Well
- Household of 13
- Nice, Brick house

Shallow Well

Water Source:

- Yawo Shallow Well
- Built 1996 by Catholic Missionaries from the Netherlands
- Pump broke in 2005
- Unicef repaired pump by 2006
- 3 weeks of training on pump usage at instillation for men and women
- Slight salty taste
- Generally happy with water quality; slightly hard

- Nyandiek Womans' Group: 41 members at inception; 20 current members due addition of shallow wells in the area
- Only women can be members; anyone can use the pump
- Payment given to caretaker at pump
- Some default on payments, but most pay on time
- Well used to dry up, but it doesn't anymore, per the addition of new wells
- 3 Care-Takers who collect payments
- Locked from 12:00-3:00

Collection

- Price
  - Members
    - 50 Shilling Registratin Fee
    - 30 Shillings/Month
  - Non-Members: 3 Shillings/Jerrycan
- Services 60 people/day
- Distance: 0.5 Kilometers from home

Consumption

- Drinking Water
- Animals: In troughs away from well
- Wash Water: In basins away from well
- 5-6 Jerrycans/Day

Water Treatment

- Generally treats raw water with WaterGuard
- Many people in her community don't treat water at all
- Dosage: 1 cap/20 liters; Waits 8 hours
- WaterGuard Price: 45 shillings/bottle

Water Storage:

- Treats water in collection basin
- Stores drinking water in clay pot with lid
- Uses cup to scoop water for consumption

Health:

- Sickness do to water is uncommon

RAIN WATER:

- Secondary source for drinking water
- Small collection tank
- Intermitant WaterGuard treatment

General Comments

HEALTH: Sickness uncommon

PRIORITIES: N/A

EDUCATION

- 3 Weeks of education when pump was first built

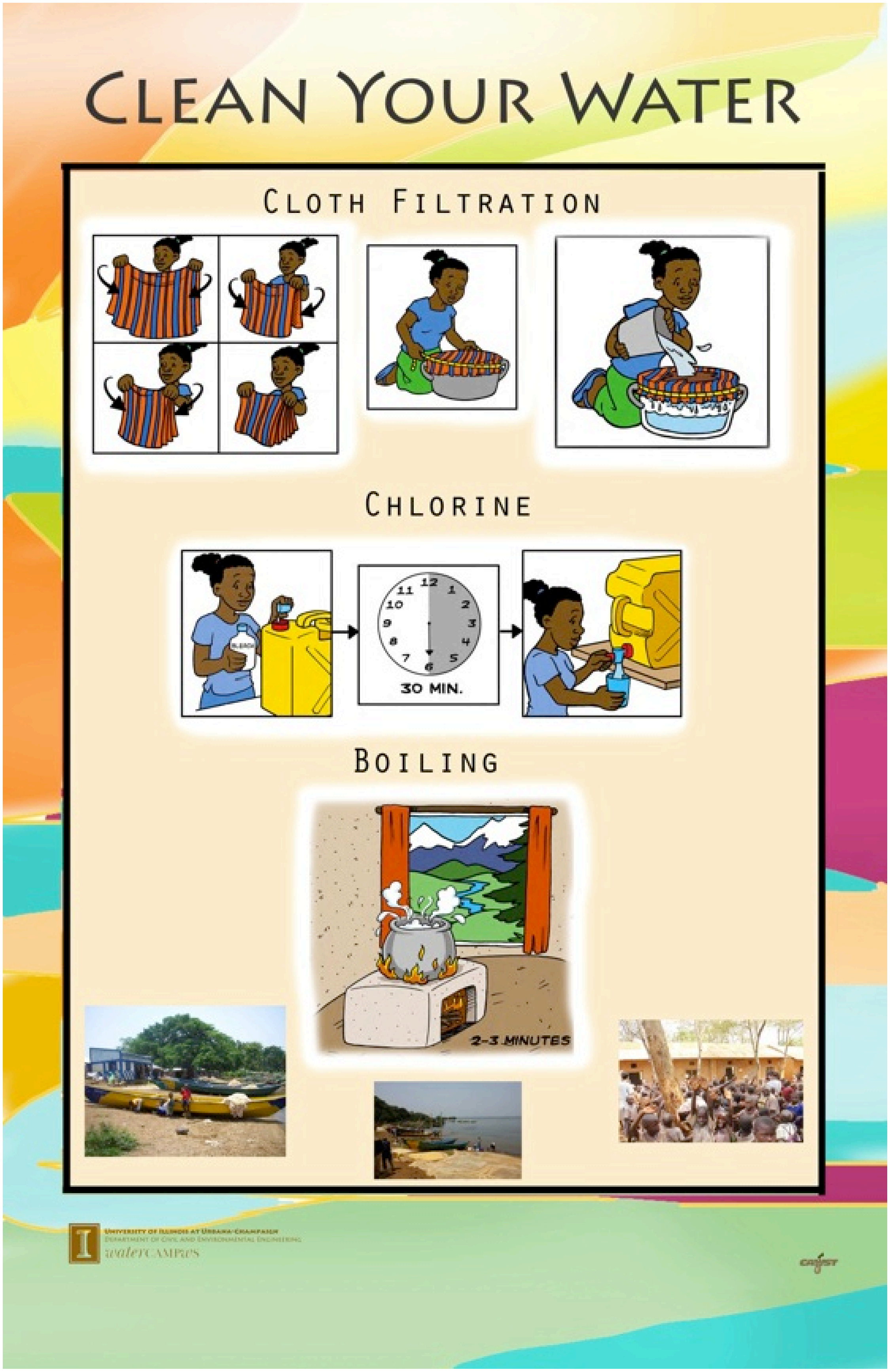
- No regular education
- Sometimes knowledge is disseminated within community; rare

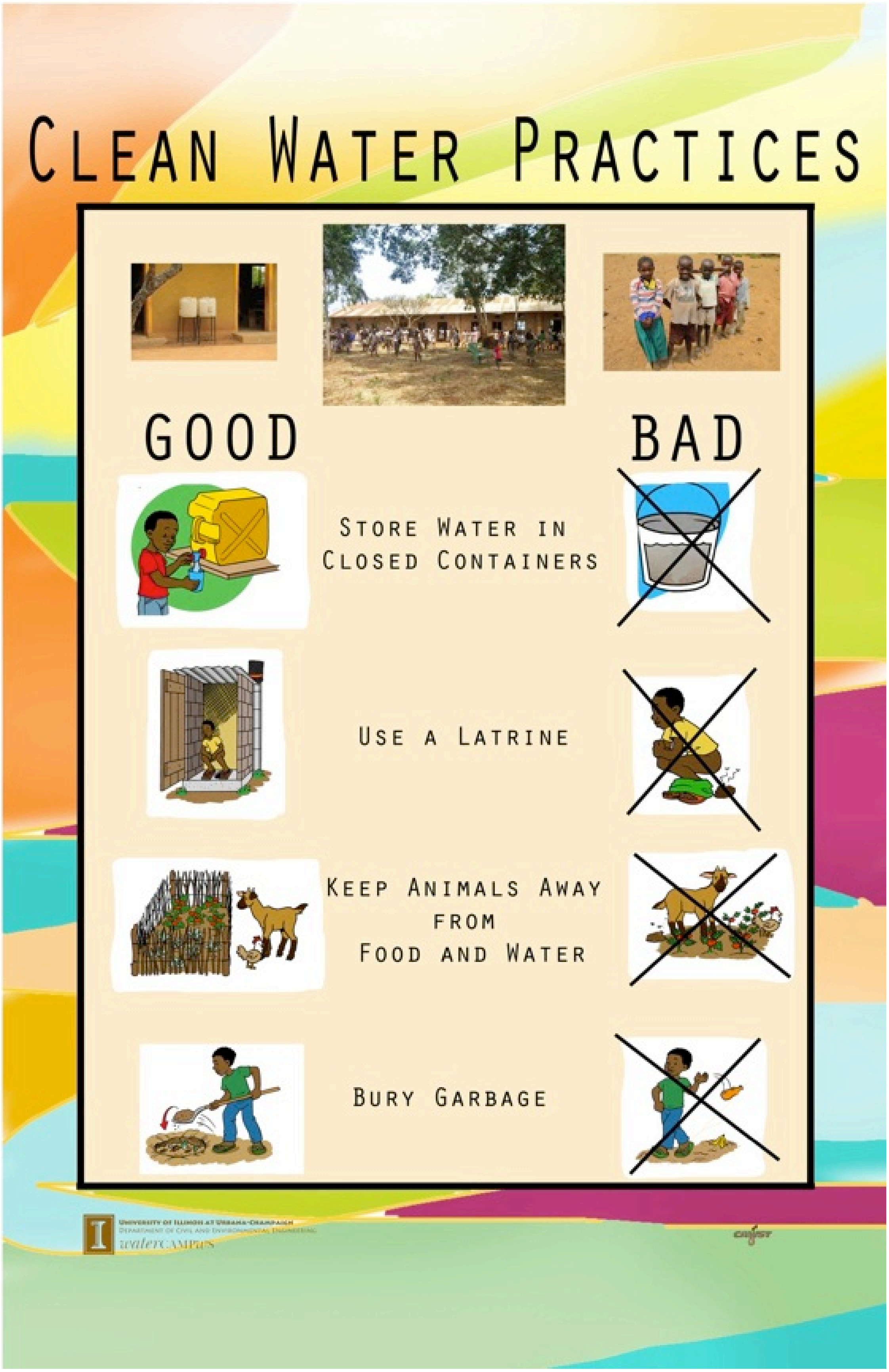
Appendix E. Educational Posters and handouts

Educational Items consisted of:

- 4 posters (3 copies of each were printed out)
- Double sided half-page handout (50 copies printed)
- 12 page book (one copy printed)

Posters were given to the Bondo Water District Office, St. Lazarus Primary School, and the Mabinju Dispensary. Handouts were left at the school and the dispensary. The book was left at the school.


CLEAN YOUR WATER
CLOTH FILTRATION
CHLORINE
30 MIN.
BOILING
2-3 MINUTES



Clean Water Practices
Good
Bad
Store Water in Closed Containers
Use a Latrine
Keep Animals Away from Food and Water
Bury Garbage

WASH YOUR HANDS WITH SOAP AND WATER
Wash your hands after pooping
Wash your hands before eating.
University of Illinois at Urbana-Champaign
Department of Civil and Environmental Engineering
waterCAMPWS


GERMS


STOP GERMS
30 MIN.
2-3 MIN


GOOD
BAD
STORE WATER IN CLOSED CONTAINERS
USE A LATRINE
KEEP ANIMALS AWAY FROM FOOD AND WATER
BURY GARBAGE
Wash Your Hands with Soap and Water
Wash your hands after pooping
Wash your hands before eating.
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
waterCAMPWS
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