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Full Length Research Paper

Harvesting surface rainwater – purification using *Moringa oleifera* seed extracts and aluminum sulfate

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Ground water harvesting is a method of collecting surface runoff from a catchment's area and storing it in surface reservoirs. The water harvested is usually contaminated and turbid. Methods used to purify water include filtration, sedimentation, boiling and chlorination. This project was carried out in Nyatike district, Western Kenya where water is scarce and water-borne diseases such as cholera, typhoid and dysentery are prevalent. The main objectives of the research were to disseminate water harvesting technology using hand-dug water pans and to evaluate the effect of *Moringa oleifera* seed extract as water purifier. Sites were identified for construction of demonstration water pans. Moringa seeds were milled after which methanol was used to extract water soluble components.. Representative water samples from Victoria Lake, Kuja River and Otho pond were collected and subjected to purification studies using *M. oleifera* seed extract and aluminum sulfate. *M. oleifera* was also tested for antibacterial activity against *Escherichia coli* (ATCC 25922) *Salmonella typhii* and *Vibrio cholerae* (ref. Romel Cary Blair Lot. 452610). A total of 452 farmers were trained in water harvesting and purification technologies. Studies on water purification indicated that Alum lowered the water p*H* from 7.4 to 4.4 while samples treated with *Moringa* extract did not affect water pH. Alum was the better water purifier whereby application of 0.25 g/L decreased water turbidity from 310.7 to 1.1 NTU while *M. oleifera* decreased turbidity to 45.6 NTU. *M. oleifera* extract showed antibacterial activity. *S. typhii* was the most sensitive while *V. cholera* was the least sensitive.

Key words: Aluminum sulfate, antibacterial activity, *Moringa oleifera*, water harvesting, water purification.

INTRODUCTION

Kenya has an average annual rainfall of 630 mm with a variation from less than 200 mm in Northern Kenya to over 1800 mm on the slopes of Mt. Kenya. The rainfall distribution pattern is bimodal with long rains falling from March to June and short rains from October to November for most parts of the country.

In the water cycle, there are several ways by which the earth looses water. One of the ways by which water comes back to earth is through rainfall. At this stage, the water is relatively clean and can be collected for use with minimal capital investment. It is paradoxical however, to allow rainwater to flow over the surface of the earth and cause environmental disasters in the form of flooding, landslides, soil erosion etc, while it is possible to harness it for use in households, agriculture, as well as for livestock and environmental improvement. Kenya is among the water scarce countries of Africa and has also seen her water storage per capita deteriorate with time to critical levels of 8 m^3 (Kenya, 2008). It is for this reason that Kenya is promoting rain water harvesting and utilization (MoA, 2007).

Rainwater harvesting is not new, as communities in Kenya have practiced it for a long time. Most rainwater harvesting technologies are simple, acceptable and replicable across many cultural and economic settings.

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Unlike big dams, which collect and store water over large areas, small-scale water harvesting project lose less water to evaporation because the rain or run-off is collected locally and can be stored in a variety of ways (UN, 2006). A report presented by UNEP and World Agro-forestry Center (UN, 2006) showed that Kenya with a population of about 40 million is capable of meeting the water needs of six to seven times its current population. The rainwater harvesting potential in Kenya is estimated at over 12,300 m^3/person compared with the current annual renewable water availability of just over 600 m^3/person (KRA, 2006). Most areas in Lake Victoria basin experience intense rainfall event, which result in a lot of runoff generation. However, most of this runoff ends up causing soil erosion and going to waste. Use of runoff harvesting for growing crops can make a big contribution to increasing yields and food security.

Surface runoff water taken for household use carries silt particles, solids, bacteria and other microorganisms (some of which are pathogenic). It is therefore necessary to remove all these impurities before this water is used for drinking purpose. Since over 80% of the Kenyan population lives in the rural areas where conventional water purification using alum and chlorine is rarely practiced, recurrent diseases like cholera, dysentery and typhoid are prevalent.

Water purification interventions include boiling, chlorination, coagulation-flocculation mud pot filtering system (TWAS, 2005) and use of certain plants as flocculants (Gottsch, 1992; KEFRI, 1997). In large-scale treatment plants, aluminum sulfate (Alum) is used as a conventional chemical coagulant. As an alternative to conventional coagulants, *Moringa oleifera* seeds can be used as a natural coagulant in household water treatment. The seed kernels of *M. oleifera* contain significant quantities of low molecular-weight (water-soluble proteins) that carry a positive charge. When the crushed seeds are added to raw water, the proteins produce positive charges acting like magnets and attracting the predominantly negatively charged particles (such as clay, silt, bacteria, and other toxic particles in water) (Sutherland et al., 1990). Since bacteria in water are generally attached to solid particles, treatment with *Moringa* powder can leave water clear with 90 to 99% of the bacteria removed (Scwarz, 2000; Oloduro and Aderiye, 2007; Amagloh and Benang, 2009; Bukar et al., 2010). Additional treatment of the water by boiling or adding chlorine is needed to render it completely safe to drink. Studies carried out to determine the potential risks associated with the use of *Moringa* seeds in water treatment has to date not shown any evidence that the seeds cause secondary effects in humans (Sutherland et al., 1990). There is a dual advantage in using *Moringa* for household water purification: (1) It can be used as a locally produced substitute for imported flocculant, thus reducing expenditure by poor population; (2) *Moringa* flocculant, unlike aluminum sulfate, is completely biodegradable.

MATERIALS AND METHODS

The study area

This project was carried out in Nyatike district (Figures 1 and 2), Nyanza province in Kenya. The project location was west Kadem location within an area of 20 km radius, east of Muhoro (marked as rainfall recording station +9) (Figure 2). Nyatike district lies within agro-ecological zones lower midlands 4 and 5 (LM 4 & 5) (Jaetzold et al., 2009). Subzone LM 4 (typified by Muhoro sub-locations) is the marginal cotton zone with a medium to short cropping season followed by intermediate rains, and a (weak) very short to short one (Jaetzold et al., 2009). The predominant soil type in this subzone is poorly drained dystric planosols, partly lithic or paralithic phase. The rainfall amount is highly variable and hence reliability is a restricting factor. The first rainy season can expect an amount of more than 350 mm in 10 out of 15 seasons; the second rainy season more than 150 mm only. The 60% reliability of the growing periods during the first and second seasons is more than 115 to 135 and 65 to 70 days, respectively. Subzone LM 5 (typified by Macalder town) (Figure 2) is the livestock-millet Zone with a (weak) short to medium cropping season and very uncertain. The predominant soil type in this subzone is the well to moderately well drained verto-luvic and haplic phaeozems, with calcic cambisols and chromic vertisols. The rainfall amount is variable and hence reliability is a problem. The first rainy season can expect an amount of more than 300 mm in 10 out of 15 seasons; the second rainy season > 100 mm only. The 66% reliability of the growing periods during the first rainy season is more than 105 to 115 days in 6 out of 10 years. The second rainy season is weak, very short and not reliable for growing crops. The average land acreage is 3.26 ha/household (MoA, 2006). The project was carried out between April 2008 and July 2010.

Farmers' training and dissemination of water harvesting technologies

Training sessions were conducted for the farmers at the beginning of the project (between April and August 2009). The venues selected were: Agape Vocational Training Center, Nyangere Secondary School, Moi Nyatike Secondary School, Amoyo Chief's Camp, Amoyo Legio Maria Center, Koweru Health Center and Olando Secondary School. The following topics were discussed:

1. Project objectives and the role of the community in its implementation.
2. Water borne diseases and sanitation.
3. Water harvesting technologies (surface runoff water and roof water).
4. Water budgeting - household water demand.
5. Water purification methods (using Alum, chlorine and *Moringa* seed powder).
6. Demonstrations on how to plant *Moringa* seedlings (farmers in attendance were also given 10 to 15 *Moringa* seedlings for planting).

Farmers were provided with the brochure entitled "Water, the Real Thing: Collect it All" (Tuitoek et al., 1999). The brochure contains information on: Site selection for water pan construction, calculation for capacity for water pan, construction of water pan, construction of silt traps and reduction of evaporation of water using agro-forestry techniques.

Construction of demonstration pans (d*ago/silanga)*

After consultations with the Provincial administration and the community leaders, the following sites were selected for the

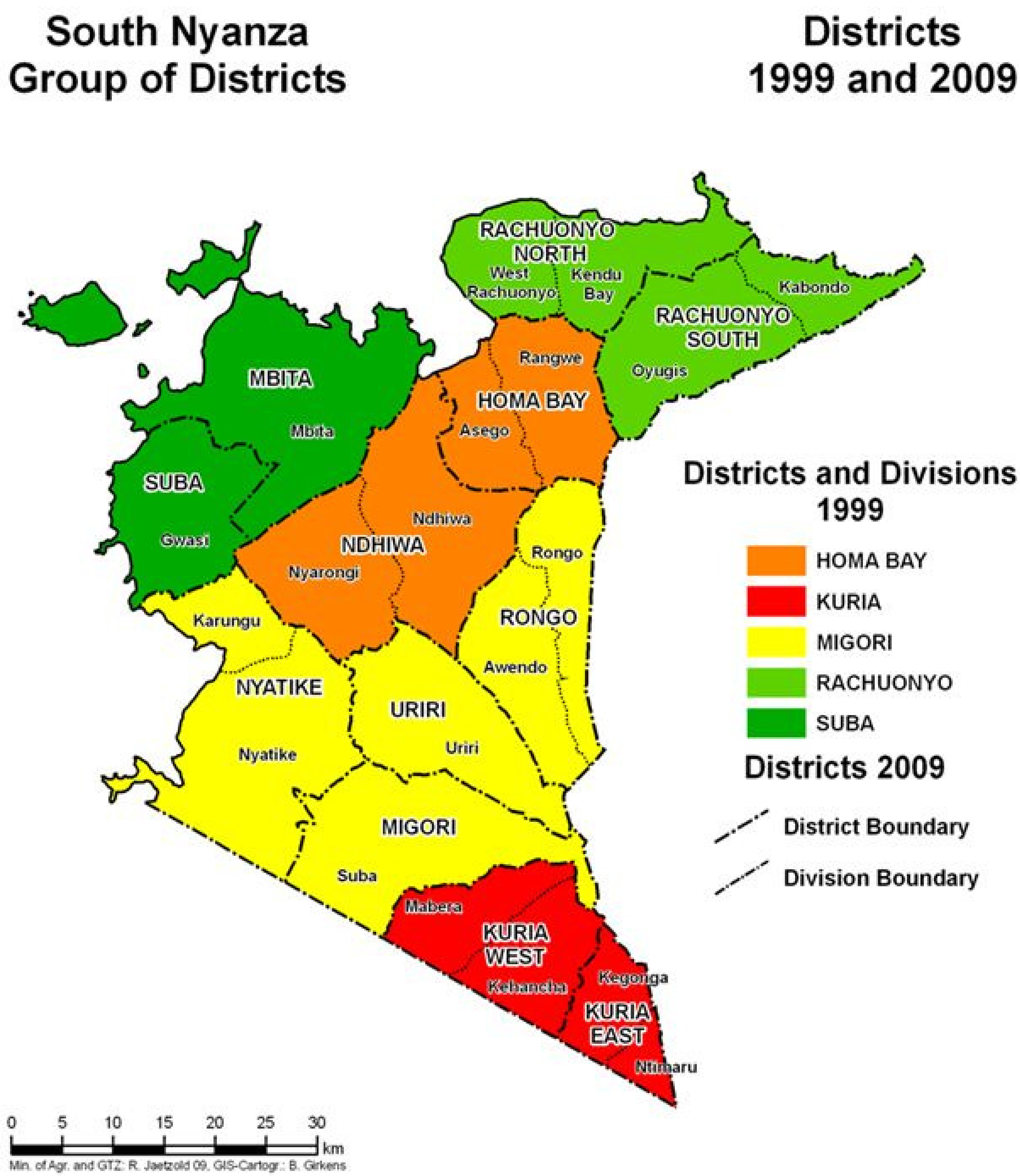

Figure 1. South Nyanza group of districts (Jaetzold et al., 2009).

construction of demonstration water pans: Nyangere Secondary School, Otho, Danya Women's Group, Moi Nyatike High School and Bande Girls Secondary School.

The water pan capacity was determined based on the catchment area, and the amount required for irrigation and domestic use. Evaporation losses and seepage was also taken into account. The recommended pan depth at any location of interest was calculated according to the following equation:

$$D = 1 + E - R + S$$

where (D) is recommended pan depth (m), (E) the evaporation, (R) the rainfall, and (S) the seepage (Tuitoek et al., 1999).

The required catchment area to collect the required volume of the water pan was determined by the equation given by Senay and Verdin (2004):

$$WA = D \times \frac{WV}{RF} \times 0.0001$$

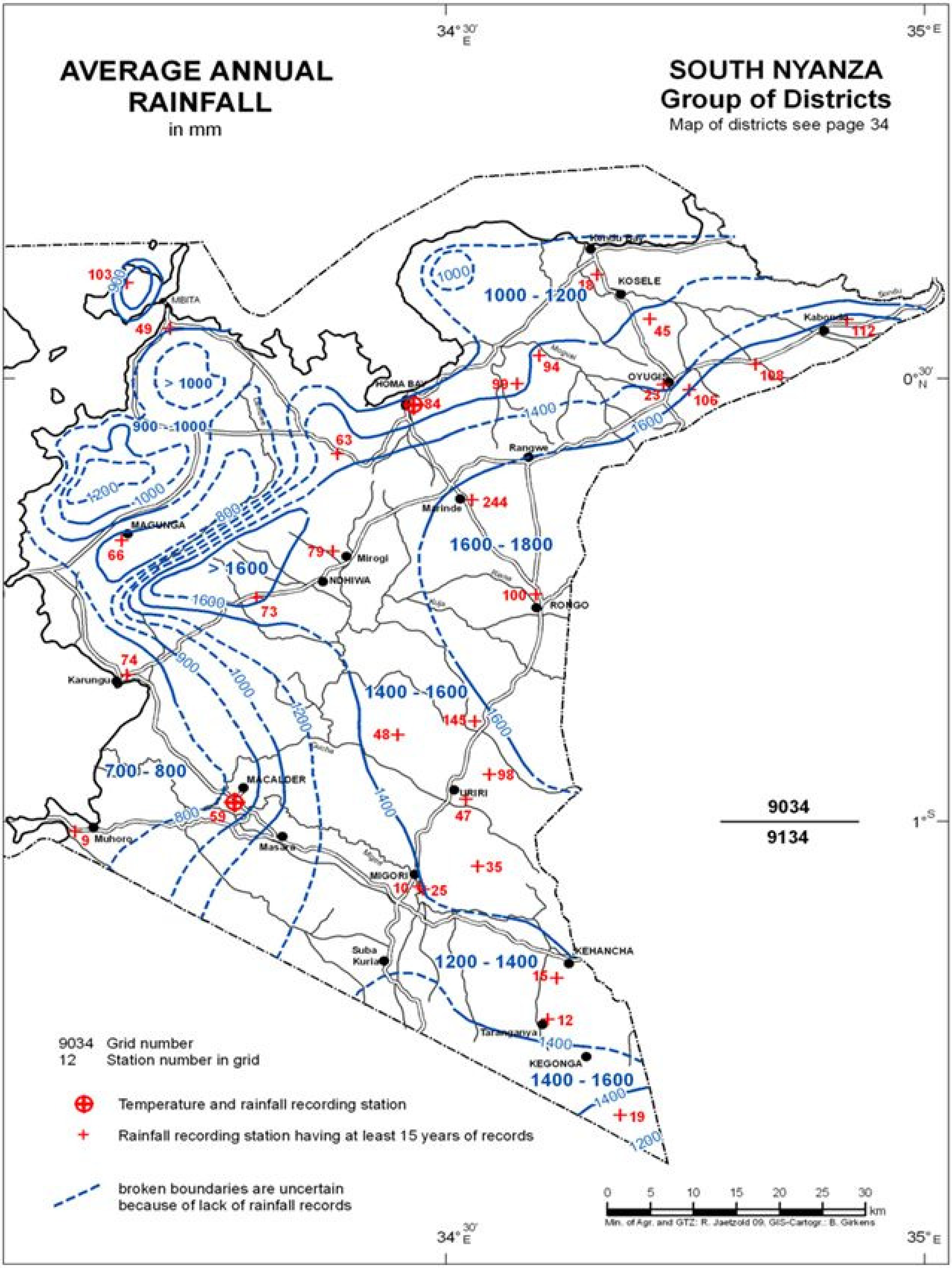

Figure 2. Average annual rainfall in South Nyanza group of districts (Jaetzold et al., 2009

Figure 3. Shelled *Moringa* seeds.

where WA is the required watershed area (ha) per pan; D is the recommended pan depth (m), WV is the expected volume of water in the water pan (m^3) and RF is the average runoff depth in a watershed.

Once the dimensions of the water pans were determined, the water pans were constructed and protected from sedimentation by methods recommended by Tuitoek et al. (1999).

Collection and preparation of seeds

Seeds of *M. oleifera* were collected from a single tree grown by a farmer at Sota in Kadem West location. The seeds were de-shelled to remove the kernels. Seed kernels (Figure 3) were further dried at ambient temperatures for a period of five days. The white kernels were milled into a fine powder using a mill (Model 4E Quaker Grinding Mill) at 8000 rpm.

Extraction of water soluble polysaccharides

Extraction of oil using n-hexane

Using a balance, 1000 g of *Moringa* seed powder was weighed and placed in a 5 L Erlenmeyer flask after which 2000 ml *n*-hexane was added. The flask was continuously shaken for 4 h and then allowed to stay overnight. The oil was decanted into a conical flask. The remnant extract was then vacuum filtered through Whatman filter paper No.1. The filtrate was concentrated using a rotary evaporator placed in a water bath set at 40°C until the condensation of the solvent stopped.

Extraction of water soluble compounds using methanol

The solid residue from the *n*-hexane extraction was placed into 5 L conical flask containing 2000 ml methanol and shaken continuously for 4 h on a laboratory shaker (Stuart Orbital Shaker SOI) at 150 rpm. The flask was then allowed to stay overnight in order to settle down for decantation into a Buchner flask. The extract was vacuum filtered through Whatman filter paper No.1. The filtrate was concentrated using a rotary evaporator (KRvrTD 65/45) at 40°C.

Water samples

Water samples were collected into 10-L sterile plastic vessels from Lake Victoria, River Kuja and Otho Constituency Development Fund pond. Using measuring cylinder, 500 ml of each water sample was measured and placed in a 1000 ml sterile beaker. The p*H* and turbidity of each water sample was recorded. The water soluble methanol extract from (b) above and aluminum sulfate treatments were then added into the beakers. The treatments consisted of the following concentrations: (1) 0 (control) (2) 0.25 g/L (3) 0.5 g/L (4) 1.0 g/L (v) 2.0 g/L and (5) 4.0 g/L. The water was stirred for 15 min and then left undisturbed for 30 min. The p*H* of the treated water samples was taken. The water was decanted into turbidity measuring bottles and turbidity recorded in nephelometric turbidity units (NTU) using a portable turbidimeter (Hach 2100P IS). The experimental design was completely randomized (CRD) with four replicates.

Antibacterial studies

Peptone bacteriological agar and MacConkey agar were prepared according to the manufacturers' instructions. The antibacterial studies were performed as per the method given by Barry and Brown (1996). The media were poured into 90 mm Pyrex Petri dishes. Test organisms used were; *Escherichia coli* (ATCC 25922) *Salmonella typhii* and *Vibrio cholerae* (ref. Romel Cary Blair Lot. 452610) were obtained from Kenya Medical Research Institute (KEMRI), Kisian-Kisumu Centre.

A swab of each specimen was streaked over the entire surface of the agar plate. Immediately after inoculation of the media, sterilized Whatman No. 1 paper discs of 5 mm diameter were impregnated with the test extract and placed onto the surface of the inoculated media. Treatments for *Moringa* seed extract were: (a) Control [dimethyl sulphoxide (DMSO)] (b) 2.5% (c) 5% (d) 10% (e) 20% and (f) 40%. The experimental design was completely randomized with four replicates. The plates were incubated at 37°C for 24 h. The diameter of the zones of complete inhibition was then measured. Area of inhibition zones were calculated and analyzed using SAS statistical package.

RESULTS

Farmers' training and dissemination of water harvesting technologies

A total of 452 farmers (356 women and 96 men) were trained during the project period (Table 1). Training was conducted mainly during the first and second quarter periods of the project. During the first half of the project period (April to October 2009), the following brochures were developed and issued to the farmers during the training sessions:

1. Drink clean pond/river water: Use Moringa
2. Surface water is free: Collect it all! Water pans
3. Small scale irrigation

The poster titled *"How do you estimate the water you need?"* was developed and used as a teaching aid.

Construction of demonstration water pans

A total of six demonstration circular water pans (Table 2) were constructed in Kadem East, West and Central locations. Four water pans were constructed in Kadem

Table 1. Participants trained in water harvesting and purification technologies.

Venue	Location	Training provided	
		Men	Women
Serena market center	Kadem West	24	121
Sota Primary School	Kadem West	3	5
Otho Chief's camp	Kadem West	7	34
Agape Christian Vocational Training Center	Kadem West	19	7
Nyangere Secondary School	Kadem West	10	5
Amoyo Legio Maria Center	Kadem West	6	57
Bande Girls Secondary School	Kadem East	4	5
Olando Secondary School	Kadem East	6	6
Koweru Health Center	Kadem East	8	36
Moi Nyatike High School	Kadem Central	9	80
Total number of trainees		96	356

Table 2. Site locations and dimensions of demonstration water pans constructed in Nyatike district.

Pan	Site	Location	Dimensions (width × depth) (m)
A	Nyangere Secondary School	Kadem West	4.2 × 1.8
B	Otho	Kadem West	4.2 × 1.8
C	Danya Women's Group	Kadem West	6.0 × 2.0
D	Otho	Kadem West	6.8 × 2.5
E	Moi Nyatike High School	Kadem Central	7.0 × 2.5
F	Bande Girls Secondary School	Kadem East	8.7 × 2.7

West and one each in Kadem East and Central locations. The pan in Nyangere Secondary School was lined with yellow polyethylene material (Figure 4) while the others were not (Figure 5). *Lucaenia sp.* was planted around the two pans at Otho. The pans at Otho were located in an individual farmer's farm. Danya Women's' group pan was constructed in the group's farm. The other pans were located in learning institutions.

The labor cost for constructing a small pan (A and B) was between US$ 100 to 150 as compared to US$ 200 to 300 required to construct the larger pans (C, D, E and F). The costs depended on the soil type and whether there were underlying rocks near the surface. The most expensive pan was that constructed at Bande Girls Secondary School because of hard underlying rocks near the surface. The pan cost US$ 320 to construct.

During the third quarter of our project four farmers in Kadem West location had adopted the technology and constructed pans in their homesteads. The family water pans ranged from the smallest of 5.3 × 2.1 m to the largest 8.2 × 3.1 m. family labor was used for the construction.

Water purification using *M. oleifera* seed extracts

Water pH

The pH of raw water samples were 6.3 for Otho CDF pond, 7.1 for River Kuja and 7.4 for L. Victoria. Results presented in Table 3 showed that addition of 0.25 g/L of aluminum sulfate resulted in a sharp decrease of water pH to 4.4 for Otho CDF pond water and 4.4 for L. Victoria water. Addition of 4.0 g/L of aluminum sulfate resulted in further reduction of pH to 3.8 for L. Victoria sample and 3.6 for Otho CDF pond water (Table 3). The same trend was observed on water obtained from River Kuja. Addition of 0.25 g/L of *M. oleifera* extract resulted in no change in pH of L. Victoria water. Addition of 4.0 g/L of *M. oleifera* extract resulted in slight reduction of pH from pH 6.3 to 6.1 for Otho CDF pond water and a reduction from pH 7.1 to 7.0 for River Kuja water (Table 3).

Water purification

The turbidity of the raw water from Otho CDF pond (Figure 6), Kuja River and L. Victoria were 310.7, 145.3 and 33.1, respectively (Table 3). Treating Otho CDF pond water with 0.25 g/L of aluminum sulfate, gave a turbidity of 1.1 NTU, while for L. Victoria the turbidity was 2.4 NTU. Addition of 4.0 g/L of aluminum sulfate resulted in turbidity of 2.3 NTU for Otho CDF pond water, 2.6 for Kuja River water and 2.1 for L. Victoria water. With respect to *M. oleifera,* the lowest NTU was obtained at the concentration of 0.25 g/L. For instance, at that concentration, *M. oleifera* extract reduced turbidity from

Figure 4. Completed water pan (A) at Nyangere Secondary School lined with yellow polyethylene material.

Figure 5. Water pan (B) at Otho with water during dry season.

Table 3. The pH and turbidities of three water samples treated with aluminum sulfate and *M. oleifera.*

Water source	Treatment (g/L)	Concentration	pH	Turbidity (NTU)
Otho pond	Aluminum sulfate	0.0	6.3	310.7
		0.25	4.4	1.1
		0.5	3.7	1.4
		1.0	3.6	1.4
		2.0	3.6	2.5
		4.0	3.6	2.3
	M. oleifera	0.0	6.3	310.7
		0.25	6.0	45.6
		0.5	6.5	53.4
		1.0	6.2	60.3
		2.0	6.3	58.7
		4.0	6.1	57.5
River Kuja	Aluminum sulfate	0.0	7.1	145.3
		0.25	4.2	2.1
		0.5	3.7	2.2
		1.0	3.7	1.4
		2.0	3.8	1.2
		4.0	3.6	2.6
	M. oleifera	0.0	7.1	145.3
		0.25	7.1	14.3
		0.5	6.9	29.3
		1.0	6.9	26.2
		2.0	6.9	21.8
		4.0	7.0	25.0
Lake Victoria	Aluminum sulfate	0.0	7.4	33.1
		0.25	4.4	2.4
		0.5	4.1	0.74
		1.0	4.0	0.8
		2.0	3.8	1.4
		4.0	3.8	2.1
	M. oleifera	0.0	7.4	33.1
		0.25	7.4	12.4
		0.5	7.4	17.4
		1.0	7.4	22.2
		2.0	7.4	20.0
		4.0	7.4	24.0

310.7 NTU for Otho CDF pond water to 45.6 NTU. It was observed that higher concentrations of *M. oleifera* applied resulted in increase of water turbidity. This trend was observed in all the three water samples tested (Table 3).

Antibacterial activity

The mean for zone inhibitions against the test organisms indicated that *V. cholerae* had the lowest mean inhibition zone of 13.8 mm^2 while *S. typhii* had the largest mean inhibition zone of 44.4 mm^2 (Table 4). *Moringa* extract concentrations that gave the largest inhibition zones were 40, 20 and 5% for *V. cholerae, E. coli* and *S. typhii* respectively. The highest concentration used of 40% produced the smallest inhibition zone of 12.4 mm^2 on *S. typhii*.

Table 4. Culture inhibition zones (mm²) exhibited by three test organisms treated with methanol extract of *M. oleifera*

Concentration (%)	Bacteria species		
	V. cholera	*E. coli*	*S. typhii*
40	24.5[c]	18.2[b]	12.4[a]
20	14.9[b]	36.4[c]	41.9[b]
10	11.7[a]	19.5[b]	44.7[b]
5	9.2[a]	11.2[a]	67.0[d]
2.5	8.6[a]	10.4[a]	56.0[c]
0 (control)	0	0	0
Mean (excluding control)	13.8	19.1	44.4

Means followed by the same letter in a column, are not significantly different at p = 0.05, using LSD.

Figure 6. Turbid water (left) and water purified with *Moringa* extract (right).

DISCUSSION

During our entire training sessions, it was observed that large number of women attended as compared to men (Table 1) indicating that water problem is mainly related to women thereby confirming the statement made by the community of N'atipkong/Ngendui (Roy et al., 2005). During discussions with the communities, it was observed that though one gets relatively clean water from roof water catchment, the costs are prohibitive. This involves the cost of gutters and a water tank. A plastic water tank with a capacity of 2300 L costs US$ 200 while that of 5000 L capacity costs US$ 300. These costs are exclusive of transport costs which would cost US$ 50. Another prohibitive factor is that house tops are grass thatched that limited the capacities of the community to harvest roof water. Therefore the viable alternative was in surface runoff.

Water harvesting

Water and waterborne diseases have remained a big problem in Nyatike area over a very long period of time. Water collection is an activity that is mainly undertaken by women and takes almost two hours per day. Improved water access promises significant progress in the life of many. Unsafe and insufficient water means sick children, unhealthy food, and infrequent cloth washing, less production of milk, vegetables and fruit. The water fetched by women from hills is very cumbersome. The brunt of this burden and heavy labor is borne by women (Roy et al., 2005). In the report published by the World Agro-forestry center (UN, 2006) it was observed that some countries are already successfully exploiting their rainwater. In South Australia, over 40% of households use rainwater stored in tanks as their main source of drinking water. Germany has over half a million rainwater harvesting schemes. In our studies, the cost of construction for the largest pan with a capacity of 80 to 85 m^3 at Bande Girls Secondary School was US$ 320 as compared to a plastic water tank with a capacity of 25 m^3 at a cost of US$ 2500. During a water harvesting project carried out in Nakuru district of Lare Division, between 1999 and 2002 (Seth Owido, personal communication) there was a dramatic increase in the adoption of run-off water harvesting technology from 409 water pans in 1998 to 2,400 water pans in 2002. As a result of this, less water borne diseases, less soil erosion, improved reforestation and agricultural productivity was observed. The adoption rate in Nyatike so far is too low as compared to Lare. This could be explained by the prolonged dry spell that followed immediately after the demonstration of pans was completed. The soil was dry and hard that discouraged farmers from constructing the pans. Due to the prolonged drought, only three of the pans D, E and F retained water whereas the Pans A, B and C had dried up. The best solution to solve this problem is to construct larger and deeper water pans of approximately 7.0 m diameter by 3.0 m deep as compared to our demonstration pans of 4.2 m wide × 1.8 m depth. The larger pans will reserve sufficient water for longer use.

Water purification

The three water sources selected represented the diverse sources of surface water to the communities living in Nyatike district. The water samples also represented the diversity in turbidity status with Otho CDF pond water (310.7 NTU) and River Kuja (145.3 NTU) representing the turbidity of water source from the constructed water pans. The recommended acceptable range of pH for drinking water specified by WHO (2008) is between 6.0 and 8.0. Both L. Victoria and Kuja River had raw p*H* within the acceptable standards. The pH for Otho CDF pond water was lower than the acceptable limits. Results obtained indicated that addition of 0.25 g/L Alum to the water samples greatly reduced the water pH to between 4.2 and 4.4. In Municipal water treatment plants, it is common practice to add lime or soda ash to raise the pH to acceptable levels. In Kadem West and East locations, aluminum sulfate is bought from the market from vendors. These vendors do not have application rates for prescription to the buyers. Through trial and error, the users estimate the quantities sufficient to clarify a specific amount of water. This results in water hardiness (low pH). The people are forced to drink the acidic water because in most cases it is fetched from long distance sources. Such acidic water may be a health hazard for humans as it may lead to or even accelerate development of stomach ulcers. *M. oleifera* extract did not significantly lower or raise the water pH. Pal et al. (1995) reported that the *Moringa* seed powder and leaves extracts have anti-ulcer and anti-gastritis activity. *Moringa* also has antibiotic activities against *Helicobacter pylori* which cause gastritis, gastric and duodenal ulcers (Harristoy et al., 2005). This makes *Moringa* a better alternative for water clarification since it is cheap and reduces chances of developing or accelerating ulcers in humans.

The declared WHO guideline for conductivity provided for safe drinking water is 5 NTU (log100.700NTU) (WHO, 2008). Aluminum sulfate was the better water purifier as compared to *M. oleifera*. An interesting observation was that as the concentration of *Moringa* was increased from 0.25 to 4.0 g/L, there was an increase in turbidity (Table 3). This could be explained by the presence of free positively charged molecules of the flocculants repelling, leading to the flocs floating or suspended in the water (Sutherland et al., 1990; Sutherland et al., 1994). Such floating flocs could be filtered to achieve lower turbidity. In this study, *Moringa* seed extract was used instead of seed powder. This was an attempt to concentrate the active ingredients of *Moringa*. In future, it is proposed to formulate the extract through lyophilization and use in sachets whose quantities are known. In real practice, the local communities will not use water soluble methanol seed extracts of *M. oleifera* as reported in our studies.

Antimicrobial activity of *Moringa* seeds extract

A study carried out in India, in which crude ethanol extract of *M. oleifera* were tested against *E. coli*, *S. typhii*, *V. cholera, Shigella dysentriae* and *Pseudomonas aeruginosa,* showed activity against *E. coli* only (Shekhar et al., 2000). This study had shown that water soluble extracts of *M. oleifera* had antibacterial activity against *E. coli.*

In humans, *Salmonella* are the cause of two diseases called salmonellosis: enteric fever (typhoid), resulting from bacterial invasion of the bloodstream, and acute gastroenteritis, resulting from a food borne infection/ intoxication. In this study, it was shown that methanol extracts of *M. oleifera* had antimicrobial properties against *S. typhii*. It was observed that *S. typhii* was the most sensitive to *Moringa* extracts as compared to *V. cholerae* and *E. coli.* This is an indication that the extracts can be effectively used to treat water contaminated with *S. typhii*.

Cholera is potentially epidemic and life-threatening and transmission of *V. cholera* in humans occurs through contaminated water and food. To prevent it from spreading, water and food must therefore be kept clean and the domestic water can be treated using *M. oleifera* extracts. In this study, inhibition activity against *V. cholera* for *Moringa* extract was observed at the highest concentrations of 0.4 mg/ml. This indicated that *V. cholerae* was the most tolerant bacteria species to *Moringa* extract as compared to *E. coli* and *S. typhii*.

CONCLUSIONS AND RECOMMENDATIONS

Surface water harvesting is a simple and cost effective technology that can be used for household water supply particularly in Nyatike district. This would be achieved through construction of suitable water pans within the homestead. Given the prolonged drought periods in the district, farmers should plant trees such as *Lucaenia* sp. around the water pans to reduce evaporation. Once the farmers have collected sufficient water to meet human and livestock consumptions, we recommend that small scale irrigations should be introduced. It is recommended that the use of *M. oleifera* for water purification should be promoted in the region. Apart from the water purifying qualities, *Moringa* leaves are also of high vegetable value. *Moringa* seeds contain up to 40% high value cooking oil that can be extracted before using the cake for water purification. In view of the fact that most pathogenic organisms are becoming resistant to antibiotics (Chandarana et al., 2005), wide application of greatly under-utilized trees like *M. oleifera* would be most desirable to use as safe, inexpensive and readily available water clarifier and disinfectant. More research needs to be carried out on the bactericidal effects of the seed extracts. The dosage rates for the seed extracts need to be precisely determined as it was realized in this study that the rates used were on the higher side.

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