Efficacy of aqueous plant extract in disinfecting water of different physicochemical properties

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ABSTRACT

This study explored the possibility of disinfecting water using aqueous extracts of medicinal plants. Seven medicinal plants used by Samburu herbalists for the treatment of stomach illnesses were investigated for water disinfection. Aqueous extracts of the dried powdered plant material were directly used to treat the water samples collected. Efficacy of water treatment with medicinal plants expressed as percentage reduction in bacterial colonies revealed that *Acacia nilotica* extract with a mean percentage reduction of 99.86% was the most effective at reducing the number of bacterial colonies. *Albizia anthelmintica* extract with a mean of 9.47% was the least effective at reducing the number of bacterial colonies. The study also revealed a possible interaction between plant extracts and water source ($P < 0.05$, df $= 54$). The results obtained in this study point out a possibility of using aqueous extracts from *A. nilotica* in disinfecting water of different physicochemical properties.

Key words | aqueous extract, bacterial colonies, disinfection, medicinal plants

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INTRODUCTION

Samburu district is one of the most remote regions of Kenya. The area lacks proper infrastructure such as roads and conventional medical facilities. The area is semi-arid savannah grassland with an annual rainfall of 250–500 mm. Because of the low and erratic rainfall, this region experiences frequent shortages of water. During periods of low water availability, competition for water between humans, livestock and wildlife is common. The pressure for use combined with a diversity of users may result in contamination of water in various sources. Human and animal wastes that may get into water sources through surface runoff may contain pathogenic bacteria that cause diarrhea.

The World Health Organization estimated that around 1.1 billion people in low income countries lack access to improved water sources (United Nations Report 2005) and that diarrheal diseases cause 2.2 million deaths a year (World Health Organization 1999). Studies have shown that water treated with flocculent-disinfectant reduces diarrhea (Crump et al. 2004). The methods for treatment of drinking water that have been proved to reduce waterborne diarrheal diseases include the addition of sodium hypochlorite solution (Quick et al. 2002) and solar disinfection

(Conroy et al. 1999), combined with safe storage of water in narrow-mouthed containers (Mintz et al. 1995).

Reller et al. (2003) found that while high doses of sodium hypochlorite render water microbiologically safe, such levels adversely affect the taste of water and therefore decrease the willingness of people to treat the water. In addition to the mentioned limitation, the commercial disinfectants are not readily available in remote settings, and if availed, the Samburu community, which is marginalized, may not be able to afford to buy them. In response to these limitations, an alternative local technology for water disinfection was explored. We hypothesized that this treatment could be useful to treat water in remote areas where the commercial water treatment methodologies are not readily available.

Through interviews with herbal medicine practitioners, seven medicinal plants commonly used by the Samburu community were identified. The Samburu community uses these plants to manage diarrhea related to consumption of contaminated water. Aqueous extracts of these plants were used to treat model contaminated water of different physicochemical properties. This study focused mainly on the efficacy of the

selected plants as disinfectants. However, there is a need for a systematic evaluation of the quality of the water treated with the plant extracts that have been shown to be highly effective in water disinfection.

MATERIALS AND METHODS

Water sampling

Water samples were collected from 10 groundwater and surface water sources. Water was collected in sterile plastic bottles fitted with screw caps. Where possible, each probe was in turn lowered directly into a suitable portion of the water body and readings were taken after the meter had been stabilized (American Public Health Association 2002). Where this was not possible, samples were carefully collected with a water scooper and readings were taken immediately after lowering each probe into the water sample.

Field measurements

Electrical conductivity and pH were measured on site using a Universal Multiline P4 WTW (Wilheim, Germany) meter.

Chemical analysis

Total alkalinity was determined by the standard procedure (American Public Health Association 2002).

Plant collection and identification

The plant identification was conducted by interviewing traditional healers using the local language. Seven plants were successfully identified using the questionnaire and they included *Acacia nilotica, Acacia seyal, Acacia tortilis, Acacia etbaica, Albizia anthelmintica, Euclea divinorum* and *Plumbago zeylanica.* Local scouts were used to translate the interview and to collect identified plants from the field with bio-conservation aspects in mind. Since the plants were identified using vernacular names, it was therefore easy to assign them botanical names because the collected medicinal plants had already been described. Voucher specimens were deposited at Kenyatta University Herbarium.

Preparation of plant extract

The fresh plant materials were washed with plenty of tap water followed by distilled water. The washed plant parts were cut into small pieces, air dried under shade and then crushed to powder using a crushing machine (Model 8 Lab., Mill Christy and Norris, England). The plants were extracted using a maceration extraction procedure employed by the Samburu community to obtain the crude plant extract. Briefly, 15 g of the powdered plant material was soaked in 100 mL of distilled water for 30 minutes. After 30 minutes, the mixture was sieved using a tea strainer into a clean and sterile container as ground material was squeezed for maximum liquid extraction. The sieved extract was further filtered using Whatman filter paper. The extract filtrate was stored in a refrigerator at 4 °C.

Water treatment

Model contaminated water from different water sources was prepared by autoclaving at 121 °C for 15 minutes. The working concentration of the plant extract and the volume ratio of the plant extract to sample water were optimized during preliminary treatment. The sterile water sample (15 mL) was spiked with 1 mL of fecal coliform cultures containing approximately 1.0×10^8 colony-forming units (cfu)/mL, then treated with 5 mL of freshly prepared plant extract. The number of cfu was determined at zero time by plating 0.1 mL of serially diluted treated water sample in duplicate on nutrient agar and incubating at 35 °C for 48 hours, after which all the bacterial colonies were counted. The same procedure was repeated after 1 hour in order to determine the optimum time for maximum antibacterial action. The efficacy of the plant extract was expressed as a percentage.

RESULTS

Medicinal plants used by Samburu people to treat diarrhea

Seven plants were identified using the questionnaire. The plants identified were *Acacia nilotica, Acacia seyal,*

Acacia tortilis, *Acacia etbaica*, *Albizia anthelmintica*, *Euclea divinorum* and *Plumbago zeylanica*.

Physico-chemical properties of water

Water from 10 sources from the Samburu District, Wamba Division was sampled and the physico-chemical properties (electrical conductivity, pH, total alkalinity, orthophosphate phosphorus and total phosphorus) were determined. One-way analysis of variance (ANOVA) revealed that there was no significant difference in electrical conductivity ($P = 0.1146$, df = 27) and total alkalinity ($P = 0.44$, df = 13) among the sites investigated. Median pH values varied between 7.4 at Nagoruworu to 8.4 at Nkwaas (Table 1).

Table 1 | Physico-chemical properties of the selected water sources in Wamba Division, Samburu District, Kenya

Water source	Median pH	Total alkalinity (mg L^{-1})	Conductivity (µS cm^{-1})
Lodungokwe Dam	7.6	103.33	232.67
Ewaso Nyiro River	7.5	65.83	155.00
Serewamba River	7.5	47.50	188.00
Namunyak Dam	8.2	132.50	619.33
Mugur Omuny	7.6	411.66	530.66
Enyangainito	7.5	117.50	306.00
Naibelibeli Dam	7.5	63.75	551.00
Ndikir	7.5	137.50	442.00
Nagoruworu wells	7.4	210.66	551.67
Nkwaas	8.4	71.57	196.57

Efficacy of medicinal plants in water treatment

The efficacy of water treatment with medicinal plants expressed as percentage reduction in bacterial colonies revealed that *A. nilotica* extract with a mean percentage reduction of 99.86% was the most effective at reducing the number of bacterial colonies (Figure 1, Table 2). *A. anthelmintica* extract with a mean of 9.47% was least effective at reducing the number of bacterial colonies. Control treatments resulted in an increase in colony-forming units (mean percentage increase of 2.37) clearly demonstrating that the bacteria continued to grow in the absence of medicinal plant extract. Based on all plant extracts, water from the Serewamba river registered the highest reduction in bacterial colonies (mean percentage reduction 33.84), while Lodungokwe (mean percentage reduction 25.22) had the lowest reduction in bacterial colonies with the same plant extracts. Using the ANOVA test, it was established that the difference in percentage reduction of bacterial colonies by the different plant extracts was significant ($P < 0.05$, df = 6). The study revealed a significant interaction between the type of plant extract and the water source ($P < 0.05$, df = 54).

DISCUSSION

The commercial methods for the treatment of drinking water commonly used include chlorination, solar disinfection and slow sand filtration (Acra *et al.* 1990). Despite the efficacy of these methods, they are out of reach for the majority of people, particularly those in remote regions like Samburu. Commercial water disinfectants are affected by the physico-
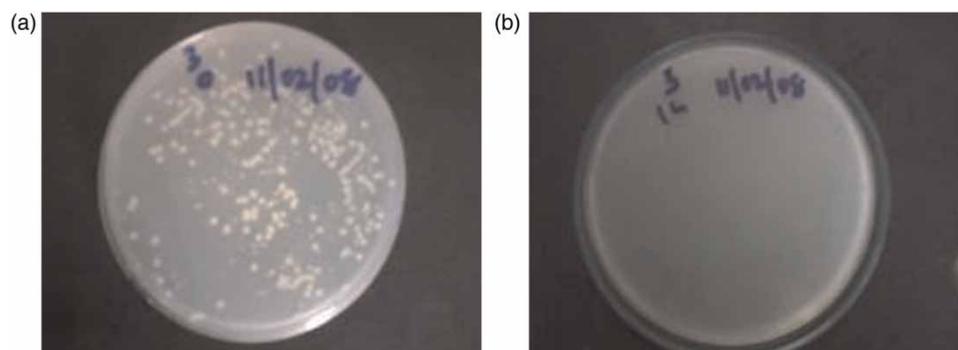

Figure 1 | Colony-forming units (cfu) in water treated with *Acacia nilotica* plated at the beginning of treatment (a) and after 1 hour (b).

Table 2 | Mean percentage reduction in the number of bacterial colonies in water sources after treatment with medicinal plants

Water source	Plt 1 Mean	SD	Plt 2 Mean	SD	Plt 3 Mean	SD	Plt 4 Mean	SD	Plt 5 Mean	SD	Plt 6 Mean	SD	Plt 7 Mean	SD
Lodungokwe Dam	12.1	1.07	22	3.54	100	0	11.2	1.78	36.72	0.92	6.74	2.43	18.54	0.53
Ewaso Nyiro River	7.31	3.23	25.5	5.46	100	0	24.2	4.63	36.4	2	15.23	2.82	23.01	0.12
Serewamba River	5.91	2.13	19.8	2.73	99.64	0.31	16.1	1.60	49.86	2.27	34.15	2.39	46.41	2.68
Namunyak Dam	3.92	1.43	26.6	5.6	100	0	16.9	5.03	25.85	0.93	14.09	3.61	44.39	0.48
Mugur Omuny	15	1.64	38.1	1.15	99.7	0.25	15.1	3.74	19.25	1.47	19.09	6.19	27.23	7.95
Enyangainito	11.2	2.41	23.6	1.43	100	0	11.6	2.78	37.52	4.61	14.78	1.63	23.03	5.26
Naibelibeli Dam	7.51	1.28	28.3	1.92	100	0	17.9	0.77	26.74	0.52	13.3	2.54	22.68	2.75
Ndikir	12.1	2.99	26.5	1.88	99.49	0.43	31.7	4.53	26.44	2.22	13.74	0.55	18.19	2.18
Nagoruworu wells	12	0.88	21.3	1.61	99.7	0.25	16.5	1.10	35.39	2.02	24.48	1.07	19.99	0.71
Nkwaas	11.6	1.45	21.4	0.93	100	0	23.2	3.19	42.24	1.84	10.61	1.64	40.1	1.10
Mean per plant	9.87		25.3		99.86		18.4		33.64		18.66		28.35	

1: *A. anthelmintica*, 2: *P. zeylanica*, 3: *A. nilotica*, 4: *A. etbaica*, 5: *A. seyal*, 6: *A. tortilis*, 7: *E. divinorum*.

chemical properties of water such as turbidity, alkalinity and concentration of organic matter (Crump *et al.* 2004). An increase in pH improves the antimicrobial activity of some disinfectants but decreases the antimicrobial efficacy of phenols, hypochlorite and iodine by either altering the structure of the disinfectant molecule or the cell surface (Rutala & Weber 2008). Studies on water treatment with plant extracts have been conducted using an extract from *Moringa oleifera*, which demonstrated its ability to clarify water and reduce total coliforms in raw water by 65% (Ndabigengesere & Narasiah 1998). It has also been shown that their seeds possess coagulation properties (Jahn 1986). The results obtained in this study indicate that *A. nilotica* could be an alternative to *Moringa oleifera*, as its extract registered a high percentage reduction of bacterial load in water (Figure 1). *A. nilotica* extract was also consistently effective in all the different water samples treated suggesting that its efficacy is not significantly affected by the physico-chemical properties of the water.

High doses of sodium hypochlorite have been shown to render water microbiologically safe. However, such levels adversely affect the taste of water and therefore decrease the willingness of people to treat the water (Reller *et al.* 2003). Likewise, the treatment of water with crude plant extracts is also known to add color, taste and odor problems (Ndabigengesere & Narasiah 1998). These problems can be further amplified by the storage of treated water for longer periods. Water treated with crude aqueous extract should

therefore be stored for periods not longer than 24 hours (Jahn 1986) to prevent it from developing a bad taste that may result from microbial decomposition of its organic compounds (Ndabigengesere & Narasiah 1998). Extracts from plants such as *Acacia nilotica* and *Acacia seyal* do not have a discouraging taste like the bitter taste of *A. anthelmintica*. Hence, potential users may not shy away from using them.

CONCLUSIONS AND RECOMMENDATIONS

Aqueous extracts of *A. nilotica* demonstrated higher efficacy in water disinfection. Hence the plant has the potential of being used as an alternative water disinfectant that is cheap and readily available. Using this plant in water treatment may avoid the dangers that people are exposed to in water chlorination. Further studies are required to standardize the method of water disinfection using medicinal plants. More research needs to be carried out on *A. nilotica* on aspects such as its effect on water properties and its toxicity.

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