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

J. K. Kirui, K. Kotut and P. O. Okemo

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

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 adverse interactions 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 sur-
face 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 (Wilhelm, 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 tra-
ditional 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 speci-
mens 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 work-
ing 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 $1.0 \times 10^8$ 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 pro-
cedure was repeated after 1 hour in order to determine the
optimum time for maximum antibacterial action. The ef-
cicacy 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

<table>
<thead>
<tr>
<th>Water source</th>
<th>Median pH</th>
<th>Total alkalinity (mg L$^{-1}$)</th>
<th>Conductivity ($\mu$S cm$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lodungokwe Dam</td>
<td>7.6</td>
<td>103.33</td>
<td>232.67</td>
</tr>
<tr>
<td>Ewaso Nyiro River</td>
<td>7.5</td>
<td>65.83</td>
<td>155.00</td>
</tr>
<tr>
<td>Serewamba River</td>
<td>7.5</td>
<td>47.50</td>
<td>188.00</td>
</tr>
<tr>
<td>Namunyak Dam</td>
<td>8.2</td>
<td>132.50</td>
<td>619.33</td>
</tr>
<tr>
<td>Mugur Omuny</td>
<td>7.6</td>
<td>411.66</td>
<td>530.66</td>
</tr>
<tr>
<td>Enyangainito</td>
<td>7.5</td>
<td>117.50</td>
<td>306.00</td>
</tr>
<tr>
<td>Naibilibeli Dam</td>
<td>7.5</td>
<td>63.75</td>
<td>551.00</td>
</tr>
<tr>
<td>Ndikir</td>
<td>7.5</td>
<td>137.50</td>
<td>442.00</td>
</tr>
<tr>
<td>Nagoruworu wells</td>
<td>7.4</td>
<td>210.66</td>
<td>551.67</td>
</tr>
<tr>
<td>Nkwaas</td>
<td>8.4</td>
<td>71.57</td>
<td>196.57</td>
</tr>
</tbody>
</table>

**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-
The 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 2010). 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 2012). It has also been shown that their seeds possess coagulation properties (Jahn 2009).

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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