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Effect of *Moringa oliefera* Seed cake on Microbial Contamination of Drinking Water of Some Darfur's Displaced People's Camps

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Abstract

Uses of natural coagulating materials - such as *Moringa* seeds -as a drinking water treatment method is indigenous in most developing countries. This study was undertaken to evaluate efficacy of *Moringa oliefera* seeds cake on the reduction of microbial contamination in drinking water in some camps for displaced people in Darfur states in the Sudan, and compare the effectiveness against the conventional coagulum , alum (aluminium sulfate).Drinking water was treated with doses of 4, 6, 8, 10, and 12 g/L of the *Moringa* seeds cake, and aluminium sulfate (alum) as coagulant. A control (untreated water) was included. Treated samples were kept on the shaker for 45 min at 110 rpm. A settling time of 1 hour was allowed,After which the supernatant treated water was used for microbiological analyses . A significant antimicrobial activity. Use of the seed cake succeeded into reducing the total viable bacterial count and *Salmonella* sp. than aluminum sulphate, and also reduced the total coliform and *E.coli* counts at doses of 10 and12g/ L.

keywords: *Moringa oleifera* ,Drinking Water , camps, alum

1.Introduction:

In the Sudan, *Moringa oleifera* was originally an ornamental tree, planted during the British rule in the alleys along the Nile, in public parks, and in the gardens of foreigners. It seems likely that the Arab women of Sudan discovered this remarkable clarifier tree. Samia Jahn (a German scientist) carried out preliminary laboratory tests which confirmed the presence of a very efficient coagulant in seeds from *Moringaoleifera*,(Gidde and Bhalerao 2006.) And later, seeds from another *Moringa* species from Kenya *(Moringastenopetala)* revealed similar flocculating properties. Moringaceae is a single genus family with 14 known species thus far, which are indigenous to Africa (DishnaSchwarz2000), Madagascar (Ndabigengesere1998), Arabia (Ndabigengesere1995), and India (Ndabigengesere 1998).Half of them are relatively common and already sporadically cultivated, yet only *Moringa oleifera*, because of its many uses, is planted in the whole tropical belt.

Water is essential to sustain life; therefore a satisfactory supply must be made available to consumers. Every effort should be made to maintain drinking- water quality as high as practicable. Protection of water supplies from contamination is the first line of defense. Source protection is almost invariably the best method of ensuring safe drinking water, and is to be preferred to treating a contaminated water supply to render it suitable for consumption. Once a potentially hazardous situation has been recognized, the availability of alternatively hazardous situation remedial measures must be considered.

As far as possible, water sources must be protected from contamination by human and animal waste, which may contain a variety of bacterial, viral, and protozoon pathogens and helminthes parasites. Failure to provide adequate protection and treatment will expose the community to the risk of water–borne diseases.

The acceptable quality of water is defined by the World Health Organization (WHO) as that which is suitable for all usual domestic purposes, including personal hygiene (WHO 1993). It should be palatable, wholesome, attractive to sense of sight and hygienically safe. There is an urgent need for simple, effective low-cost methods for the protection of water from pathogenic and harmful chemical substances (John 1977).

For many years, the Sudanese community did not pay much attention to water contamination problems, but today the community is aware of the importance of good water quality and its relation to diseases. Diseases that can be transmitted by water include: Typhoid fever (caused by *Salmonella typhi*), Cholera (*Vibrio cholerae)*, Dysentery, shigellosis (*Shigella* spp.), viral diseases such as those caused by poliovirus or hepatitis A virus, and protozoal diseases such as Giardiasis *(Giardia lamblia*) or Cryptosporidiosis (*Cryptosporidium parvum)* [http//www.cdc..gov/epa/mmwr/wr.html].

More than a billion people are affected by water-borne diseases which cause death of 2-4 million children annually (Mcfarland *et al.* 1998). Worldwide, the lack of sanitary waste disposal and of clean water for drinking, cooking and washing is to blame for over 12 million deaths a year. The recent breakout of *E.coli* poisoning in Europe will lay heavy emphasis on the issue.

The contamination of drinking water in camps of displaced people could be due to the social behavior, low educational standards of displaced people and their crowded conditions (Omer 2003).According to the World Health Organization, microbial resistance to conventional water treatment mechanisms is on the rise, and medicinal plants offer a good source of alternatives. Preparations from *Moringa* species can be used as a cheaper alternative to the conventional disinfectants (Gassenschmidt*et al.* 1995). Use of the seeds of this tree in water clarification and disinfection in the displaced people´s camps could prove worthwhile.A water treatment method indigenous to many African, Asian and South American communities uses *Moringa oleifera* seeds in the form of a water-soluble extract in suspension, resulting in an effective natural clarification agent for highly turbid and untreated surface water (Lea, 2010). Efficient reduction (80.0% to 99.5%) of high turbidity produces an aesthetically clear supernatant, concurrently accompanied by 90.00% to 99.99% (1 to 4 log) bacterial reduction. Application of this low-cost *Moringa oleifera* protocol is recommended for simplified, point-of-use, low- risk water treatment where rural and peri-urban people living in extreme poverty are presently drinking highly turbid and microbiologically contaminated water. One of the sad outcomes of the civil war in Darfur provinces has been the displacement of many people in refugee camps. These displaced people are in higher risk of unhygienic water supplies.

1.1 Site of the study: Nyala town

Nyala is the capital city of South Darfur state, Western Sudan. Nyala is a fast growing town which extends over an area of approximately 8x6 kilometers. The number of inhabitants was estimated in 2009 to be approximately one million according to Central Bureau of Statistics. Currently Nyala is surrounded by almost more than 300000 internally displaced people (IDPs). They are settled in camps inside and around the town. These camps are Otash, Derige, Kalma, Mossai, Sacalee, Eelsalam and Elserif camps.There is continuous movement of people from the rural areas of Darfur to Nyala town, thus placing increased pressure on the public utilities (Water Resources Assessment Program in the Sudan 1985).Water sources in IDPs camps.The water sources in IDPs camps include boreholes equipped with submersible pumps connected with pipe line to the water tanks and bladders (water point) where disinfection with chlorine takes place and IDPs take water to their houses. In addition, hand pumps are also drilled inside the camps and consumers take their water directly from the hand pump in household containers (WHO 2002).

The objective of the current study was:

To investigate the microbial quality of the drinking water for the displaced people in camps in Darfur and to use seed cake of *Moringa oliefera* as a safe and natural clarifying agents and study of their possible effects on microbial contamination.

2.MATERIALS AND METHODS

2.1 Location of the study

This work was carried out to study the effect of seed and leaf extracts of the horse radish (drumstick) tree *Moringa oleifera* Lam. (family Moringacae) on water clarification and alleviation of microbial contamination of drinking water of somecamps for displaced people in Darfur, Western Sudan. Two camps were chosen for the study, specifically the Mossai camp, east of Nyala city, and Otash camp to the north- west of Nyala. Nyala town is the capital of South Darfur State, in Western Sudan. It lies at longitude 24^0 53 east, and it is divided by latitude 12^0 04 into two halves. It is about 900 kilometerssouth west of Khartoum and 250 kilometers east of the borders with the Republic of Chad.

Mossai and Otash camps receive drinking water from three sources:

Boreholes equipped with submersible pumps,Hand pumps,andWater points (bladders and water tanks)

2.2 Collection of water samples

To determine the chemical and microbiological parameters of drinking waterin Mossai and Otash camps and suggest corrective measures, water samples were collected from boreholes equipped with submersible pumps, from hand pumps, water points (water tanks) and from household storages containers (zeers, and plastic containers) and from donkey-pulled carts.

Water samples were collected from camps of Darfur's displaced people as follows:

Otash camp: Water samples were obtained from household earthen containers (zeers), from hand pumps, and from boreholes**.**

Mossai camp: Water samples were obtained from donkey-pulled carts, from zeers, and from hand pumps.

The collection of samples was carried following APHA Standard Methods of Examination of Water and Wastewater (2000). Samples were collected for 18-months over the period from January 2012 to July 2013. A total of 132 samples of drinking water were collected.Water samples for microbiological examination were collected in sterile screw-cap bottles (capacity 1 liter) under aseptic conditions. The time of collection was between seven and eight o'clock in the morning. All samples were examined in the Microbiology Laboratory, Veterinary Research Laboratory, Nyala city, South Darfur State.

2.3 Preparation of the seed cake of *Moringa oliefera*

Mature brown fruit pods were picked from *M. oliefera* trees growing in southern Blue Nile in the season 2010 - 2011. The fruits were cracked along the seam and the seeds were plucked out, then the seed coat and the wings were removed from the white/yellowish seed kernels as described by Jahn(1988) (plate 1). The seed kernels were roasted in a skillet; they were thoroughly mashed using a mortar for crushing. The seed cake was placed in boiling water for a total of 5 min. After boiling, the liquid was strained through a cotton filter cloth into a clean container, and the seed cake was retained from the cotton cloth. Finally, the seed cake (presscake) was dried for 2 days in direct sunlight (Plate 2) following the method described in Current Protocols in Microbiology (2010).

Plate 1: Left side *Moringa Oliefera* seeds with seed coating and right side seeds without seed coating

Plate 2: *Moringa Oleifera* **seed cake (presscake) dried for 2 days in direct sunlight**

2.4 Assay of the microbiological parameters before and after treatment with *Moringa* seed cake and alum

Total viable bacterial counts (TVBC), Most probable number (MPN) and *Salmonella spp*. techniques were done according described by Harrigan (1998).

3. Statistical analysis

Data were statistically analyzed using the M-STAT software was used for statistical analysis. Means were separated by Duncan Multiple Range test (Steel and Torrie, 1980).

4.RESULTS

4.1.Microbiological parameters of the drinking water in Darfur camps

4.1.1Mossai camp

4.1.1.1. Total viable bacterial counts

The total viable bacterial counts (TVC) in the Mossai camp (zeer, hand pump and borehole water) are shown in Table 1. In the untreated samples, zeer water harboured the highest viable bacterial count, followed by the hand pump water, then the borehole water. When these waters were treated with *Moringa* seedcake, however, the counts were significantly decreased, and the decrease was greater with increase in the seed cake dose. On the other side, a similar pattern of reduction was obtained with treatment with alum, but the effectiveness of the latter was far lower than that of the *Moringa* seed cake.

4.1.1.2. The most probable number (MPN) of total coliforms

Table (2) shows the most probable number (MPN) of total coliforms in the three water sources in Mossai camp. It can be seen that in the untreated samples, the hand pump water harboured the highest number of total coliforms, followed by the zeer water, then the borehole water. Treatment of samples from these water sources with *Moringa* seed extract significantly reduced the total coliform loads, and the effect increased with increase in the extract dose. This was particularly evident in the borehole water where coliforms were completely abolished by a dose of 10 or 12 g/L *Moringa* seed extract. However, alum appeared to be more effective than the *Moringa* seed extract in getting rid of coliforms, whereby no coliforms were reported even with the lowest alum dose (4 g/L).

4.1.1.3. **Presence/absence of *Escherichia coli* in water**

Escherichia coli was reported as present in all three untreated drinking water sources of the Mossai camp, as well as in the samples treated with up to 8 g/L *Moringa* seed extract or 8 g/L alum. However, with increase in the dose to 10g/L *Moringa* seed extract or alum, no *E. coli* was reported in any of the three water samples (Table 3).

4.1.1.4 **Presence/absence of *Salmonella* spp. in water**

Salmonella spp. werefound in all three untreated drinking water samples in Mossai camp. However, unlike *E. coli*, treatment with the least applied dose (4 g/L) of *Moringa* seed extract or alum succeeded in ridding the water from this bacterium (Table 4).

Table 1. Total viable bacterial counts(cfu/mL) in three water samplesfrom Darfur displaced people's Mossai campbefore and after treatment with *Moringa oleifera*seed extract and aluminum sulfate

Treatment	Source of watersample		
	Zeer water	Hand pump	Borehole
Untreated	291.60^{a}	210.00^{a}	155.00^{a}
M_1(4 g/L)	28.33^{de}	30.00^{cd}	20.00^{e}
M_2(6 g/L)	24.33^{f}	23.33^{cde}	18.50^{e}

M_3(8 g/L)	14.67^{g}	20.67^{de}	16.67^{e}
M_4(10 g/L)	14.00^{g}	17.33^{de}	11.00^{f}
M_5(12 g/L)	6.33^{h}	5.00^{e}	7.67^{f}
A_1(4 g/L)	56.00^{b}	136.00^{b}	60.00^{b}
A_2(6 g/L)	30.00^{d}	43.33^{c}	24.67^{d}
A_3(8 g/L)	43.33^{c}	30.00	38.67^{c}
A_4(10 g/L)	26.67^{def}	25.33^{cd}	20.00^{e}
A_5(12 g/L)	25.33^{ef}	25.33^{cde}	18.00^{e}
SE±	1.206	6.45	1.351

Values are mean±SD.

Any two means sharing same superscript are not significantly different($P \leq 0.05$).

MC= Mossai Camp; OC= Otash Camp

M_1….M_5= *Moringa oleifera* seed powder concentrations

A_1….A_5= Alum (Aluminum sulfate) concentrations

Table 2. Total coliforms (MPN/mL) in water samples from three different sources from Darfur displaced people's Mossai campbefore and after treatment with *Moringa oleifera* seed extract and aluminum sulfate

Treatment	**Source of watersample**		
	Zeer water	**Hand pump**	**Boreholes**
Untreated	42.00^{a}	93.00^{a}	23.00^{a}
M_1(4 g/L)	9.10^{b}	13.30^{b}	13.30^{c}
M_2(6 g/L)	7.30^{c}	11.70^{b}	16.70^{b}
M_3(8 g/L)	3.60^{d}	8.70^{c}	18.30^{b}
M_4(10 g/L)	0.40^{e}	0.60^{d}	0.00^{d}
M_5(12 g/L)	0.30^{e}	0.33^{d}	0.00^{d}
A_1(4 g/L)	0.00^{e}	0.00^{d}	0.00^{d}
A_2(6 g/L)	0.00^{e}	0.00^{d}	0.00^{d}
A_3(8 g/L)	0.00^{e}	0.00^{d}	0.00^{d}
A_4(10 g/L)	0.00^{e}	0.00^{d}	0.00^{d}
A_5(12 g/L)	0.00^{e}	0.00^{d}	0.00^{d}
SE±	0.4274	0.7979	1.059

Abbreviations as in Table 1

Table 3. Presence (or absence) of *E.coli* in water samples from three different sources from Darfur displaced people's Mossai camp before and after treatment with *Moringa oleifera* seed extract and aluminum sulfate

Treatment	Source of watersample		
	Zeer water	Hand pump	Borehole
Untreated	+	+	+
M_1(4 g/L)	+	+	+
M_2(6 g/L)	+	+	+
M_3(8 g/L)	+	+	+
M_4(10 g/L)	–	–	–
M_5(12 g/L)	–	–	–
A_1(4 g/L)	–	–	–
A_2(6 g/L)	–	–	–
A_3(8 g/L)	–	–	–
A_4(10 g/L)	–	–	–
A_5(12 g/L)	–	–	–

Abbreviations as in Table 1

Table 4. Presence (or absence) of *Salmonella* spp. in water samples from three sources in Darfur displaced people's Mossai camp before and after treatment with *Moringa oleifera* seed powder and aluminum sulfate

Treatment	Source of water sample		
	Zeer water	Hand pump	Borehole
Untreated	+	+	+
M_1(4 g/L)	–	–	–
M_2(6 g/L)	–	–	–
M_3(8 g/L)	–	–	–
M_4(10 g/L)	–	–	–
M_5(12 g/L)	–	–	–
A_1(4 g/L)	–	–	–

A_2(6 g/L)	_	_	_
A_3(8 g/L)	_	_	_
A_4(10 g/L)	_	_	_
A_5(12 g/L)	_	_	_

Abbreviations as in Table 1

4.1.2. Otash camp

4.1.2.1. Total viable bacterial counts (CFU/ml)

Table 5.shows the total viable bacterial counts (TVBC) in the three drinking water sources in Otash camp. In the untreated water samples, the total viable bacterial load was highest in the donkey-pulled carts water, followed by zeer water, then borehole water. However, on treatment with the least applied dose of *Moringa* seed extract or alum (2 mg/L), the load was significantly reduced. The reduction in both cases linearly increased with increase in the size of applied dose, but was more pronounced with application of *Moringa* seed extract than with alum.

4.1.2.2. Total coliforms(MPN/mL)

The most probable numbers of total coliforms in the untreated water samples were highest in donkey-pulled cart water (37.67 MPN/mL), followed by zeer water (22.3 MPN/mL), then borehole water (8.77 MPN/mL). On treatment with the dose (12 g/L) of either *Moringa* seed extract or alum, no coliforms were reported in all three water samples.(Table 6).

4.1.2.3. Presence/absence of *E.coli*

Escherichia coli was present in all three untreated water samples, and its presence was recorded in these samples even after treatment with 4, 6 or 8 g/L *Moringa* seed extract (Table 7). However, it disappeared from all three sources due to treatment with 10 or 12 g/L. On the other hand, no E. coli could be observed in samples treated with alum which appeared to be more effective in this respect.

4.1.2.4. Presence/absence of *Salmonella* spp.

Table 14 records presence/absence of *Salmonella* spp. in water samples from the three sources in Otash camp.*Salmonella* was present in the untreated drinking water samples from all three sources. However,treatment with the least dose of either Moringa seed extract or alum succeeded in complete abolishment of this bacterium.

Table 5.Total viable count of bacteria (cfu/mL) in water samples from three different sources in Otash Camp before and after treatment with *Moringa oleifera* seed cake and aluminum sulfate

Treatment	Source of watersample		
	Zeer water	Cart water	Borehole
Untreated	206.00[a]	304.30[a]	94.33[a]

M_1(4 g/L)	26.67^{f}	35.00^{e}	25.67^{f}
M_2(6 g/L)	17.67^{g}	29.33^{ef}	18.33^{g}
M_3(8 g/L)	15.67^{gh}	17.67^{g}	14.67^{gh}
M_4(10 g/L)	10.67^{h}	12.67^{g}	10.00^{h}
M_5(12 g/L)	2.67^{i}	6.33^{h}	1.00^{i}
A_1(4 g/L)	68.33^{b}	62.67^{b}	65.00^{b}
A_2(6 g/L)	54.00^{c}	55.00^{c}	47.00^{c}
A_3(8 g/L)	47.67^{d}	45.00^{d}	43.33^{cd}
A_4(10 g/L)	44.00^{d}	31.67^{ef}	39.67^{de}
A_5(12 g/L)	37.67^{e}	27.33^{f}	36.33^{e}
SE±	1.798	1.904	2.197

Values are mean±SD.

Any two mean values having different superscript letter in a column are significantly different ($P \leq 0.05$).

Table 6. Total coliforms (MPN/mL) in water samples from three different sources in Otash campbefore and after treatment with *Moringa oleifera* seed extract and aluminum sulfate

Doses	**Source of water**		
(g/L)	**Zeer water**	**Cart water**	**Boreholes**
Untreated	22.33^{a}	37.67^{a}	8.77^{b}
M_1(4 g/L)	0.53^{e}	0.53^{b}	0.00^{c}
M_2(6 g/L)	0.47^{e}	0.53^{b}	0.00^{c}
M_3(8 g/L)	0.27^{e}	0.27^{b}	0.00^{c}
M_4(10 g/L)	0.00^{e}	0.00^{b}	0.00^{c}
M_5(12 g/L)	0.00^{e}	0.00^{b}	0.00^{c}
A_1(4 g/L)	13.00^{b}	0.53^{b}	13.30^{a}
A_2(6 g/L)	8.93^{c}	0.40^{b}	10.37^{b}
A_3(8 g/L)	7.63^{c}	0.20^{b}	10.37^{b}
A_4(10 g/L)	4.27^{d}	0.13^{b}	9.37^{b}
A_5(12 g/L)	0.00^{e}	0.00^{b}	0.00^{c}
SE±	1.077	2.643	0.7508

Values are mean±SD.

Any two mean values having different superscript letter in a column are significantly different (P≤0.05).

Table 7. Presence (or absence) of *E.coli* in water samples from three different sources in Otash camp before and after treatment with *Moringa oleifera* seed powder and aluminum sulfate

Doses (g/L)	**Source of water**		
	Zeer water	**Cart water**	**Borehole**
Control(0)	+	+	+
M_1(4 g/L)	+	+	+
M_2(6 g/L)	+	+	+
M_3(8 g/L)	+	+	+
M_4(10 g/L)	–	–	–
M_5(12 g/L)	–	–	–
A_1(4 g/L)	–	–	–
A_2(6 g/L)	–	–	–
A_3(8 g/L)	–	–	–
A_4(10 g/L)	–	–	–
A_5(12 g/L)	–	–	–

Table 8. Presence (or absence) of *Salmonella* spp. in water samples from three different sources in Otash camp before and after treatment with *Moringa oleifera* seed extract and aluminum sulfate

Doses (g/L)	**Source of water**		
	Zeer water	**cart water**	**Borehole**
Control(0)	+	+	+
M_1(4 g/L)	–	–	–
M_2(6 g/L)	–	–	–
M_3(8 g/L)	–	–	–
M_4(10 g/L)	–	–	–
M_5(12 g/L)	–	–	–
A_1(4 g/L)	–	–	–
A_2(6 g/L)	–	–	–

A_3(8 g/L)	_	_	_
A_4(10 g/L)	_	_	_
A_5(12 g/L)	_	_	_

5.DISCUSSION

On the bacterial load of the examined raw waters in the two camps, the results have shown that the total viable bacterial counts ranged from 155 to 291.6 cfu/mL in Mossai camp and 304.4 to 94.33 cfu/mL in Otash camp. These values are not much alarming for heterotrophic plate counts, and have been significantly reduced in presence of *Moringa* seed cake. The total coliforms, on the other hand, were present in numbers between 93 and 23 MPN/mL in Mossai camp and between37.67 and 8.77 MPN/mL in Otash camp. In both cases, they were either completely wiped out (Otash camp) or reduced to decimal values (Mossai camp) in presence of *Moringa* seed cake. More importantly, both *Escherichiacoli* and *Salmonella* spp. were present in the untreated raw water in both camps, but were completely removed in the presence of *Moringa* seed extracts, particularly by the high doses used (10 and 12 g/L).

According to Shekhar *et al.* (2000) crude ethanol extract of *M. oleifera* tested against *E. coli*, *S. typhii, V.cholerae, Shigella dysentriae* and *Pseudomonas pyocyaneus* showed activity against these bacteria at reduced extract concentrations. Swanson *et al.* (2007) indicated that salmonellosis can be cured by use of plant extracts such as *Moringa* species. Folkard and Sutherland (2005) proposed utilization of *Moringa* seeds as food since it sterilizes the food and destroys *Salmonella typhi* which lives in the intestinal tracts of man. Walter *et al*. (2011) investigated the anti-bacterial activity of methanol and n-hexane extracts of *Moringa oleifera* and *Moringa stenopetala* seeds on three bacterial species (*Salmonella typhi, Vibrio cholerae* and *Escherichia coli*) which normally cause water-borne diseases. Their results showed that *M. oleifera* and *M. stenopetala* had a good degree of antibacterial properties especially in low doses, and they suggested that the methanol extract of *Moringa oleifera* can be used at low concentrations to prevent the spread of typhoid. It has also been reported that crushed seed extract of *Moringa oleifera* had bactericidal activity against *Staphylococcus pyogenus* and *Pseudomonas aerogenosa* (Suarez *et al.,* 2005). Harvey (2005) also reported that Pterygospermin, a bactericidal and fungicidal compound contained in an aqueous extract made from seed of *Moringa oleifera* was as effective against *Staphylococcus aureus* as the antibiotic neomycin. However, a research conducted by Vaghasiya and Chanda (2007) showed that *M. oleifera* crude extracts had no activity against *E. coli,* showing variance with the present findings.

Some scientific evidence for the antibiotic activity of *Moringa* extracts has been available for over 50 years, although much of it is completely unknown to many people. In the late 1940's and early 1950's a team from the University of Bombay (BR Das), Travancore Unsity (PA Kurup), and the Department of Biochemistry at the Indian Institute of Science in Bangalore (PLN Rao), identified a compound they called pterygospermin which they reported readily dissociated into two molecules ofbenzyl isothiocyanate (Das *et al*. 1954; 1957a,b,c; Kurup and Narasimha Rao 1952; 1954a,b,c; Kurup *et al.* 1954; Narasimha Rao and Kurup 1953). Benzyl isothiocyanate was already understood at that time to have antimicrobial properties. Subsequent elegant and very thorough workBadgett (1964)identified a number of glyosylated derivatives of benzyl isothiocyanate. The identity of these compounds was not available in the refereed scientific literature until "re-discovered" 15 years later by Kjaer *et al.* (1979).

CONCLUSION

This study was conducted to evaluate the use of *Moringa oliefera* seed and leaf extracts on the reduction of microbial contamination in drinking water and compare it to the effectiveness of comparable loads of the conventional coagulum aluminium sulphate (alum).

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