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ORIGINAL ARTICLE

Purification efficacy of different parts of *Mangifera indica* on water samples from contaminated drinking water sources in chanchaga local government area of Niger State, Nigeria

Mary Banke Okunlola[1] · Udeme Josiah Joshua Ijah[1] · Jonathan Yisa[2] · Peter Olabisi Abioye[1] · Damola Stephen Ariyeloye[3] · Julius Ndayaman Ibrahim[4]

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Abstract

The use of natural coagulant in water purification has gain popularities owing to the public health consequences of consuming untreated water and the carcinogenic properties of synthetic coagulant. In the present study, the leaf, stem, seed and bark powdered samples *Mangifera indica* were used to treat contaminated river, stream and pond water at concentrations of 0.1, 0.2, 0.3, 0.4 and 0.5 g/L. Microbial quality and physicochemical properties of the water samples were investigated after 0, 12 and 24 h of treatment. The results showed that the addition of *M. indica* considerably decreases or even eliminated (in most cases) the aerobic heterotrophic bacteria, coliforms, salmonella and shigella in the water samples. All parts of *M. indica* tested decreased the pH, dissolve oxygen, total dissolved solid, calcium, nitrate, turbidity and chemical oxygen demand contents of the water samples when compared with untreated water. The activities of the plant materials increase with increase treatment time and concentrations. In conclusion, the raw surface water (stream, river and pond) used for the study fall short of standard. *Mangifera indica* leaf, stem, seed and bark materials improved the quality of the raw surface water based on the maximum permissible limit of microbial load and physicochemical parameters. This could serve as a cheaper and safer alternative to the synthetic coagulant.

Keywords Phytochemicals · *Mangifera indica* · Antimicrobial · Physicochemical · River · Stream · Pond

Introduction

Water is a basic human necessity for well-being and a healthy life. However, the level of water purity being consumed is very essential since it has a direct effect on health. About 75% of the world population lives in developing countries, out of which 1.2 billion people particularly in East Asia, South Asia and sub-Saharan Africa are still lacking safe drinking water (Megersa et al. 2014; UNICEF 2010). Pollution of these waters can occur via natural and human sources including industrial effluent, agricultural runoff, human and animal faeces. In addition, unhygienic transport, and domestic handling of water within the home can contaminate previously safe water (WHO 2006). These contaminated waters harboured thousands of pathogenic and diseases causing microorganisms, such as bacteria, viruses, protozoa and helminths), resulting in varieties of water born-diseases such as diarrhoea, cholera, typhoid and dysentery (Pritcharda et al. 2009). Consumption of these contaminated water has caused a serious public health challenge, accounting for 4 billion annual cases of diarrhoea and 1.8 million mortalities, mostly in children under the age of five (UNESCO 2007). In Nigeria, the most common source of drinking water for the rural population are from ponds, well, rivers stream and borehole water. This groundwater is usually consumed without any treatment whatsoever (Megersa et al. 2014).

✉ Mary Banke Okunlola
bankeokunlolla@gmail.com

1 Department of Microbiology, Federal University of Technology, Minna, Niger State, Nigeria

2 Department of Chemistry, Federal University of Technology, Minna, Niger State, Nigeria

3 Department of Biochemistry, Federal University of Technology, Akure, Ondo State, Nigeria

4 Department of Biological Sciences, Federal Polytechnic, Bida, Niger State, Nigeria

Imported chemicals used for conventional water purification to ensure potable water quality are expensive for developing countries including Nigeria (Abatneh et al. 2014). In addition to the high cost of importing chemicals for water treatment, the most available and affordable chemicals coagulant like alum (aluminium sulphate), have been associated with carcinogenic effect (Tröltzsch and Otto 2017). Consequently, these threatened the well-being of the consumers, while those who chose to avoid such chemical treatment end up taking the untreated water which also poses a threat to their health.

The uses of natural plant materials including seeds, sap, bark leaves, fruits and roots of trees and plants for water purification has been well practiced for many centuries (Anwar and Rashid 2007). These plant materials offered several advantages of cost-effectiveness, biodegradability and safe to human health (Yusuf et al. 2018a), as opposed to synthetic chemicals such as Alum (Aho and Lagasi 2012).

Mangifera indica has been reportedly used as water coagulant in traditional water purification system. In addition to the well-documented antimicrobial activities of *M. indica* (Oluduro et al. 2010; Singh et al. 2010), it also possessed numerous health benefits including anti-ulcer, anti-diarrhoea, diuretic, anti-hypertensive, anti-cancer activities and antiparasitic activities (Meran et al. 2017). Thus, as a solution to the aforementioned, *M. indica* could serve an alternative natural coagulant to replace synthetic aluminum thus increasing the safety and suitability of water for human consumption. The present study therefore aimed at evaluating the effect of seed, leaves, bark and stem materials of *M. indica* on the microbial quality and physicochemical properties of river, stream, pond and well water samples from Chanchaga Local Government area, Niger State, Nigeria.

Materials and methods

Sample collection

Seeds, roots, bark and leaves of *Mangifera indica* were collected from Bosso Local Government Area of Niger State. The plant materials were identified at and authenticated at National Institute for Pharmaceutical Research and Development (NIPRID) Abuja where the vouchers number (NIPRD/H/7023) was deposited.

Processing of plant materials

The plant materials were air-dried under ambient temperature at Microbiology Laboratory Federal University of Technology, Minna, Nigeria. The dried plant materials were pulverized into fine powder, filtered using sieve of mesh size 0.8 mm. The powder samples were stored in an air tight container at ambient temperature until required for use.

Qualitative phytochemical screening of the plant materials

Preliminary qualitative phytochemical screening which involved performing simple chemical tests to detect the presence of secondary metabolites, including tannins, flavonoids, phenols, alkaloids, saponins and glycosides, was carried out in accordance with the method described by Harborne (1998), and Trease and Evans (1983).

Collection of water samples

The sampling sites selected for the purpose of this study were Chanchaga River, Angwakopini Stream and Rugakafi Pond in Niger State Nigeria. The samples were collected where people commonly collect water for their domestic activities. Standard sampling methods of APHA (1999) were adopted in the collection of the water samples. Water samples for physicochemical analyses were collected using transparent sterile containers of 2.0 L capacity. The plastic containers were thoroughly washed with 5% nitric acid (HNO_3) and rinsed with tap water (WHO 2011). They were later rinsed thoroughly with deionized water and allowed to dry before use.

Screening of plant materials for potential to purify water

In each treatment case, a solution was prepared by dissolving 0.1 g, 0.2 g, 0.3 g, 0.4 g and 0.5 g of each powder sample in 100 mL of sterile distilled water. The solution was shaken for five minutes and poured into 900 mL of water sample, made up to 1 litre and allowed to stand for 30 min to allow the coagulated particles to settle to the bottom. The supernatant was poured through a filter paper to ensure that any suspended coagulant is trapped (McConnachie et al. 1999). The supernatant was then subjected to microbial and physicochemical analysis. Based on the volume of water, appropriate different concentration of alum and calcium hypochlorite was introduced into water sample and allowed to stand for some hour, after which the water was subjected to both microbiological and physiological analysis to compare its efficiency of water treatment with the plant materials.

Bacteriological analysis of water

Membrane filtration technique was employed to determine microbial quality of the water samples in accordance with American Public Health Association (APHA 1999). Analyses were carried out to determine total viable counts (TVC),

total coliform counts (TCC) and faecal coliform counts (FCC). TVC, TCC and FCC were determined by using lauryl sulphate broth (MLSB) medium, *Salmonella shigella* counts using *Salmonella Shigella* agar (SSA).

Identification of Bacterial Isolates

Isolates from the plates were identified further by biochemical tests, using the method of Vandepitte et al. (2003) and Cheesbrough (2008). Morphological and biochemical tests carried out included Gram staining, catalase, oxidase, indole tests, urease production, methyl red, Voges–Proskauer, H_2S production, coagulase, starch hydrolysis, lactose and citrate utilization, mannitol, sucrose and glucose tests.

Physicochemical Analyses of the Water Samples

The physicochemical parameters of the water were analyzed using the standard procedures outlined in the Standard Method for the Examination of Water and Wastewater (APHA 1999) to check the pH, conductivity, hardness, turbidity, total dissolved solid (TDS), biological oxygen demand (BOD), chemical oxygen demand (COD), nitrate, chloride, calcium and magnesium.

Statistical analysis

Data collected were subjected to statistical analysis using the Statistical Package For Social Science (SPSS) version 21.0 and expressed as mean ± standard error of mean (SEM). Differences between groups were compared using analysis of variance, ANOVA ($P < 0.05$) followed by Duncan's multiple range test. Differences in mean were considered to be significant 5% level of significance.

Results

Phytochemicals

The qualitative phytochemical composition of the seed, leaf, bark and stem of *Mangifera indica* is presented in Table 1. Results revealed the presence of alkaloids, steroids, cardiac glycosides, phenol, flavonoids, saponins, tannins, cardiac glycosides and anthraquinone and terpenes.

Table 1 Phytochemical composition of *Mangifera indica* used for water purification

	Leaf	Seed	Stem	Bark
Phenol	+	+	+	+
Flavonoids	+	+	+	+
Saponins	+	+	+	+
Tannin	+	+	+	+
Alkaloids	+	+	+	+
Cardiac glycoside	+	+	+	+
Anthraquinone	+	+	+	+
Terpenes	+	+	+	+
Steroids	+	+	+	+

Key: + (Present)

Effect of *Mangifera indica* leaf, seed, stem and bark powder on bacterial quality of water samples

Stream water

The leaf and bark materials of *Mangifera indica* at concentrations of 0.2, 0.3, 0.4 and 0.5 g/L completely eliminated the coliforms, *Salmonella* and *Shigella* in the stream water after 12 h of treatment. The stem material at concentrations of 0.3, 0.4 and 0.5 g/L completely eliminated the bacteria of the stream water after 12 h of treatment. However, the seed material was less active, eliminating bacteria after 24 h only at 0.4 and 0.5 g/L (Table 2). Treatment of stream water with alum and calcium hypochlorite completely eliminated the bacteria after 24 h.

Pond water

The leaf and bark materials of *Mangifera indica* at concentrations of 0.2, 0.3, 0.4 and 0.5 g/L completely eliminated the various bacteria from the pond water after 12 h of treatment. The stem material was least active and caused complete elimination of total viable bacteria, coliforms, *Salmonella* and *Shigella* only after 24 h of treatment. However, the seed material was able to eliminate the organisms only at 0.5 g/L concentrations after 24 h treatment (Table 3).

River water

Treatment of river water with alum and calcium hypochlorite completely eliminated the bacteria after 24 h. The powdered leaf material of *Mangifera indica* at concentrations of 0.3, 0.4 and 0.5 g/l completely eliminated the coliforms from the river water after 12 h of treatment, while all concentrations tested caused complete elimination of faecal coliforms, *Salmonella* and *Shigella* after 12 h of treatment. The bark and the stem materials at all concentrations tested caused complete elimination of the various bacteria after 24 h. However, the seed material was less active causing elimination of the bacteria only at 0.4 and 0.5 concentrations after 24 h treatment (Table 4).

Table 2 Effect of leaf, stem, seed and bark of *Mangifera indica* on bacterial counts stream water

Sample (g/L)	TVC × 10^5 cfu/mL			TCC × 10^3 cfu/mL			FCC mpn/100 ml			SSC × 10^3 cfu/mL		
	0	12	24	0	12	24	0	12	24	0	12	24
Stream water	6.60 ± 0.03	6.60 ± 0.03	6.60 ± 0.03	2.96 ± 0.03	2.96 ± 0.03	2.96 ± 0.03	300.45 ± 0.87	300.05 ± 0.45	300	1.56 ± 0.03	1.56 ± 0.03	1.56 ± 0.03
Calcium hypochlorite	5.78 ± 0.03	2.63 ± 0.03	Nil	2.02 ± 0.03	1.53 ± 0.02	Nil	295.45 ± 4.57	20.13 ± 1.24	Nil	1.63 ± 0.04	1.42 ± 0.02	Nil
Alum	5.52 ± 0.03	3.23 ± 0.03	Nil	2.01 ± 0.02	1.24 ± 0.01	Nil	284.24 ± 2.90	23.67 ± 2.34	Nil	1.62 ± 0.04	1.20 ± 0.02	Nil
Leaf of M. indica												Nil
0.1	6.60 ± 0.03	0.91 ± 0.01	Nil	2.96 ± 0.03	0.21 ± 0.01	Nil	2780.95 ± 0.67	Nil	Nil	1.56 ± 0.03	Nil	Nil
0.2	6.60 ± 0.03	Nil	Nil	2.96 ± 0.03	Nil	Nil	298.78 ± 0.78	Nil	Nil	1.56 ± 0.03	Nil	Nil
0.3	6.60 ± 0.03	Nil	Nil	2.96 ± 0.03	Nil	Nil	296.05 ± 0.27	Nil	Nil	1.56 ± 0.03	Nil	Nil
0.4	6.60 ± 0.03	Nil	Nil	2.96 ± 0.03	Nil	Nil	296.22 ± 0.78	Nil	Nil	1.56 ± 0.03	Nil	Nil
0.5	6.60 ± 0.03	Nil	Nil	2.96 ± 0.03	Nil	Nil	294.10 ± 0.26	Nil	Nil	1.56 ± 0.03	Nil	Nil
Stem of M. indica												
0.1	6.60 ± 0.03	1.88 ± 0.02	Nil	2.96 ± 0.03	0.84 ± 0.02	Nil	289.05 ± 0.78	13.56 ± 0.26	Nil	1.56 ± 0.03	0.90 ± 0.03	Nil
0.2	6.60 ± 0.03	1.32 ± 0.02	Nil	2.96 ± 0.03	0.45 ± 0.02	Nil	289.04 ± 0.78	9.56 ± 0.67	Nil	1.56 ± 0.03	0.52 ± 0.03	Nil
0.3	6.60 ± 0.03	0.099 ± 0.02	Nil	2.96 ± 0.03	Nil	Nil	299.05 ± 0.23	Nil	Nil	1.56 ± 0.03		Nil
0.4	6.60 ± 0.03	Nil	Nil	2.96 ± 0.03	Nil	Nil	297.02 ± 0.09	Nil	Nil	1.56 ± 0.03	Nil	Nil
0.5	6.60 ± 0.03	Nil	Nil	2.96 ± 0.03	Nil	Nil	298.45 ± 56	Nil	Nil	1.56 ± 0.03	Nil	Nil
Seed of M. indica												
0.1	6.60 ± 0.03	1.72 ± 0.02	1.01 ± 0.02	2.96 ± 0.03	0.98 ± 0.02	0.98 ± 0.02	298.45 ± 3.45	15.56 ± 0.67	8.45 ± 0.56	1.56 ± 0.03	0.91 ± 0.02	0.52 ± 0.02
0.2	6.60 ± 0.03	1.39 ± 0.02	0.59 ± 0.02	2.96 ± 0.03	0.92 ± 0.02	0.92 ± 0.02	299.35 ± 3.89	8.67 ± 0.43	5.67 ± 0.34	1.56 ± 0.03	0.60 ± 0.02	0.24 ± 0.02
0.3	6.60 ± 0.03	1.19 ± 0.02	Nil	2.96 ± 0.03	0.45 ± 0.02	0.45 ± 0.02	298.45 ± 3.09	4.34 ± 0.35	1.45 ± 0.01	1.56 ± 0.03	0.10 ± 0.02	Nil
0.4	6.60 ± 0.03	0.93 ± 0.02	Nil	2.96 ± 0.03	0.27 ± 0.02	Nil	298.56 ± 4.45	1.56 ± 0.32	Nil	1.56 ± 0.03	Nil	Nil
0.5	6.60 ± 0.03	0.32 ± 0.02	Nil	2.96 ± 0.03	Nil	Nil	296.34 ± 5.46	Nil	Nil	1.56 ± 0.03	Nil	Nil
Bark of M. indica												
0.1	6.60 ± 0.03	Nil	Nil	2.96 ± 0.03	Nil	Nil	299.43 ± 3.56	Nil	Nil	1.56 ± 0.03	Nil	Nil
0.2	6.60 ± 0.03	Nil	Nil	2.96 ± 0.03	Nil	Nil	299.56 ± 4.54	Nil	Nil	1.56 ± 0.03	Nil	Nil
0.3	6.60 ± 0.03	Nil	Nil	2.96 ± 0.03	Nil	Nil	296.56 ± 3.46	Nil	Nil	1.56 ± 0.03	Nil	Nil
0.4	6.60 ± 0.03	Nil	Nil	2.96 ± 0.03	Nil	Nil	295.54 ± 2.45	Nil	Nil	1.56 ± 0.03	Nil	Nil
0.5	6.60 ± 0.03	Nil	Nil	2.96 ± 0.03	Nil	Nil	293.90 ± 3.56	Nil	Nil	1.56 ± 0.03	Nil	Nil

Data are MEAN ± SEM of triplicate determinations

TVC total viable counts, *TCC* total coliforms counts, *FCC* faecal coliforms counts, *SCC Salmonella-Shigella* counts, *g/L* gram per litre

Table 3 Effect of leaf, stem, seed and bark of *Mangifera indica* on bacterial counts pond water

Sample (g/L)	TVC × 10^5 cfu/mL			TCC × 10^3 cfu/mL			FCC mpn/100 ml			SSC × 10^3 cfu/mL		
	0	12	24	0	12	24	0	12	24	0	12	24
Pond water	6.10 ± 0.03	6.10 ± 0.03	6.10 ± 0.03	3.30 ± 0.03	3.30 ± 0.03	3.30 ± 0.03	250.00 ± 0.00	250.00 ± 0.00	250.00 ± 0.00	1.68 ± 0.03	1.42 ± 0.02	Nil
Calcium hypochlorite	5.78 ± 0.03	2.63 ± 0.03	Nil	2.02 ± 0.03	1.53 ± 0.03	Nil	250.00 ± 0.00	20.03 ± 0.52	Nil	1.63 ± 0.03	1.20 ± 0.02	Nil
Alum	5.52 ± 0.03	3.23 ± 0.03	Nil	2.01 ± 0.02	1.24 ± 0.03	Nil	240.00 ± 0.00	23.50 ± 0.05	Nil	1.62 ± 0.03	Nil	Nil
Leaf of M. indica												
0.1	6.10 ± 0.03	0.29 ± 0.01	Nil	3.30 ± 0.03	0.11 ± 0.01	Nil	250.00 ± 0.00	3	Nil	1.68 ± 0.03	Nil	Nil
0.2	6.10 ± 0.03	Nil	Nil	3.30 ± 0.03	Nil	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03	Nil	Nil
0.3	6.10 ± 0.03	Nil	Nil	3.30 ± 0.03	Nil	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03	Nil	Nil
0.4	6.10 ± 0.03	Nil	Nil	3.30 ± 0.03	Nil	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03	Nil	Nil
0.5	6.10 ± 0.03	Nil	Nil	3.30 ± 0.03	Nil	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03		
Stem of *M. indica*											0.58 ± 0.02	Nil
0.1	6.10 ± 0.03	1.66 ± 0.02	Nil	3.30 ± 0.03	0.88 ± 0.02	Nil	250.00 ± 0.00	14.50 ± 0.05	Nil	1.68 ± 0.03	0.39 ± 0.02	Nil
0.2	6.10 ± 0.03	1.39 ± 0.02	Nil	3.30 ± 0.03	0.82 ± 0.02	Nil	250.00 ± 0.00	6.00 ± 0.00	Nil	1.68 ± 0.03	0.21 ± 0.02	Nil
0.3	6.10 ± 0.03	0.94 ± 0.02	Nil	3.30 ± 0.03	0.37 ± 0.02	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03	Nil	Nil
0.4	6.10 ± 0.03	0.73 ± 0.02	Nil	3.30 ± 0.03	Nil	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03	Nil	Nil
0.5	6.10 ± 0.03	Nil	Nil	3.30 ± 0.03	Nil	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03	0.84 ± 0.02	0.42 ± 0.02
Seed of M. indica												
0.1	6.10 ± 0.03	1.76 ± 0.02	1.02 ± 0.02	3.30 ± 0.03	0.92 ± 0.02	0.51 ± 0.02	250.00 ± 0.00	29.45 ± 0.50	12.00 ± 0.05	1.68 ± 0.03	0.60 ± 0.02	0.23 ± 0.02
0.2	6.10 ± 0.03	1.29 ± 0.02	0.90 ± 0.02	3.30 ± 0.03	0.66 ± 0.02	0.25 ± 0.02	250.00 ± 0.00	19.09 ± 0.43	5.00 ± 0.00	1.68 ± 0.03	0.39 ± 0.02	Nil
0.3	6.10 ± 0.03	1.00 ± 0.02	0.52 ± 0.02	3.30 ± 0.03	0.62 ± 0.02	0.01 ± 0.02	250.00 ± 0.00	11.55 ± 0.50	Nil	1.68 ± 0.03	Nil	Nil
0.4	6.10 ± 0.03	0.69 ± 0.02	Nil	3.30 ± 0.03	0.43 ± 0.02	Nil	250.00 ± 0.00	9.55 ± 0.05	Nil	1.68 ± 0.03	Nil	Nil
0.5	6.10 ± 0.03	0.33 ± 0.02	Nil	3.30 ± 0.03	Nil	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03		
Bark of M. indica											Nil	Nil
0.1	6.10 ± 0.03	0.10 ± 0.01	Nil	3.30 ± 0.03	0.02 ± 0.01	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03	Nil	Nil
0.2	6.10 ± 0.03	Nil	Nil	3.30 ± 0.03	Nil	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03	Nil	Nil
0.3	6.10 ± 0.03	Nil	Nil	3.30 ± 0.03	Nil	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03	Nil	Nil
0.4	6.10 ± 0.03	Nil	Nil	3.30 ± 0.03	Nil	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03	Nil	Nil
0.5	6.10 ± 0.03	Nil	Nil	3.30 ± 0.03	Nil	Nil	250.00 ± 0.00	Nil	Nil	1.68 ± 0.03		

Data are MEAN ± SEM of triplicate determinations

TVC total viable counts, *TCC* total coliforms counts, *FCC* faecal coliforms counts, *SCC Salmonella-Shigella* counts, *g/L* gram per litre

Table 4 Effect of leaf, stem, seed and bark of *Mangifera indica* on bacterial counts river water

Sample(g/L)	TVC × 10^5 cfu/mL			TCC × 10^3 cfu/mL			FCC mpn/100 ml			SSC × 10^3 cfu/mL		
	0	12	24	0	12	24	0	12	24	0	12	24
River water	8.62 ± 0.03	.8.62 ± 0.54	8.62 ± 0.03	4.32 ± 0.03	4.32 ± 0.03	4.32 ± 0.03	360.45 ± 0.03	360.89 ± 0.45	360.89 ± 0.45	1.63 ± 0.03	1.63 ± 0.03	1.63 ± 0.03
Calcium hypochlorite	8.56 ± 0.03	0.26 ± 0.34	Nil	4.0 2 ± 0.03	0.15 ± 0.03	Nil	350.43 ± 0.03	20.32 ± 0.52	Nil	1.63 ± 0.03	1.42 ± 0.02	Nil
Alum	8. 52 ± 0.03	0.32 ± 0.04	Nil	4.1 1 ± 0.03	0.12 ± 0.03	Nil	340.43 ± 0.03	23.23 ± 0.67	Nil	1.62 ± 0.03	1.20 ± 0.02	Nil
Leaf of M. indica												
0.1	8.62 ± 0.03	0.84 ± 0.01	Nil	4.32 ± 0.03	0.36 ± 0.01	Nil	358.00 ± 0.89	Nil	Nil	1.63 ± 0.03	0.30 ± 0.03	Nil
0.2	8.62 ± 0.03	0.62 ± 0.01	Nil	4.32 ± 0.03	0.02 ± 0.01	Nil	356.00 ± 0.87	Nil	Nil	1.63 ± 0.03	Nil	Nil
0.3	8.62 ± 0.03	Nil	Nil	4.32 ± 0.03	Nil	Nil	355.00 ± 0.55	Nil	Nil	1.63 ± 0.03	Nil	Nil
0.4	8.62 ± 0.03	Nil	Nil	4.32 ± 0.03	Nil	Nil	352.00 ± 0.34	Nil	Nil	1.63 ± 0.03	Nil	Nil
0.5	8.62 ± 0.03	Nil	Nil	4.32 ± 0.03	Nil	Nil	350.00 ± 0.56	Nil	Nil	1.63 ± 0.03	Nil	Nil
Stem of M. indica												
0.1	8.62 ± 0.03	1.83 ± 0.02	Nil	4.32 ± 0.03	0.89 ± 0.02	Nil	357.00 ± 0.56	17.45 ± 0.89	Nil	1.63 ± 0.03	0.68 ± 0.02	Nil
0.2	8.62 ± 0.03	1.69 ± 0.02	Nil	4.32 ± 0.03	0.62 ± 0.02	Nil	354.00 ± 0.78	6.45 ± 0.45	Nil	1.63 ± 0.03	0.39 ± 0.02	Nil
0.3	8.62 ± 0.03	1.10 ± 0.02	Nil	4.32 ± 0.03	0.30 ± 0.02	Nil	351.00 ± 0.89	Nil	Nil	1.63 ± 0.03	0.39 ± 0.02	Nil
0.4	8.62 ± 0.03	0.69 ± 0.02	Nil	4.32 ± 0.03	Nil	Nil	350.00 ± 0.59	Nil	Nil	1.63 ± 0.03	Nil	Nil
0.5	8.62 ± 0.03	Nil	Nil	4.32 ± 0.03	Nil	Nil	348.00 ± 0.78	Nil	Nil	1.63 ± 0.03	Nil	Nil
Seed of M. indica												
0.1	8.62 ± 0.03	1.69 ± 0.02	0.69 ± 0.02	4.32 ± 0.03	0.92 ± 0.02	0.52 ± 0.02	356.00 ± 0.78	7.45 ± 0.48	4.34 ± 0.32	1.63 ± 0.03	0.70 ± 0.02	0.70 ± 0.02
0.2	8.62 ± 0.03	1.31 ± 0.02	0.31 ± 0.02	4.32 ± 0.03	0.74 ± 0.02	0.44 ± 0.02	352.00 ± 0.46	3.78 ± 0.21	Nil	1.63 ± 0.03	0.31 ± 0.02	0.31 ± 0.02
0.3	8.62 ± 0.03	1.10 ± 0.02	0.10 ± 0.02	4.32 ± 0.03	0.36 ± 0.02	0.21 ± 0.02	351.00 ± 0.78	1.54 ± 0.89	Nil	1.63 ± 0.03	0.26 ± 0.02	Nil
0.4	8.62 ± 0.03	0.39 ± 0.02	Nil	4.32 ± 0.03	0.10 ± 0.02	Nil	350.00 ± 0.57	Nil	Nil	1.63 ± 0.03	Nil	Nil
0.5	8.62 ± 0.03	0.16 ± 0.02	Nil	4.32 ± 0.03	0.06 ± 0.02	Nil	350.00 ± 0.67	Nil	Nil	1.63 ± 0.03	Nil	Nil
Bark of M. indica												
0.1	8.62 ± 0.03	0.52 ± 0.03	Nil	4.32 ± 0.03	0.35 ± 0.01	Nil	358.05 ± 0.45	Nil	Nil	1.63 ± 0.03	Nil	Nil
0.2	8.62 ± 0.03	Nil	Nil	4.32 ± 0.03	Nil	Nil	355.06 ± 0.78	Nil	Nil	1.63 ± 0.03	Nil	Nil
0.3	8.62 ± 0.03	Nil	Nil	4.32 ± 0.03	Nil	Nil	353.05 ± 0.27	Nil	Nil	1.63 ± 0.03	Nil	Nil
0.4	8.62 ± 0.03	Nil	Nil	4.32 ± 0.03	Nil	Nil	341.06 ± 0.89	Nil	Nil	1.63 ± 0.03	Nil	Nil
0.5	8.62 ± 0.03	Nil	Nil	4.32 ± 0.03	Nil	Nil	337.03 ± 0.35	Nil	Nil	1.63 ± 0.03	Nil	Nil

Data are MEAN ± SEM of triplicate determinations

TVC total viable counts, *TCC* total coliforms counts, *FCC* faecal coliforms counts, *SCC Salmonella-Shigella* counts, *g/L* gram per litre

Effect of *Mangifera indica* treatment on Physicochemical qualities of Water Samples

Physicochemical properties of water samples treated with leaf, stem, seed and bark materials of *Mangifera indica*

Pond water The leaf, stem, seed and bark materials of *Mangifera indica* had no effect on temperature, COD, chloride, nitrate and magnesium but decreased the turbidity, calcium and water hardness of the pond water. However, leaf material increased the conductivity from 184.90 ± 2.34 to 327.43 ± 4.78 µS/cm and decreased the TDS of the pond water sample from 134.78 ± 2.34 to 105.32 ± 2.89 mg/l (Table 5).

River water Treatment of river water with *Mangifera indica* showed no significant effect ($p > 0.05$) on the temperature, DO, calcium, nitrate, COD and turbidity when compared with the untreated river water. All part of *Mangifera indica* used significantly ($p < 0.05$) reduced the pH (except for the seed material), hardness and chloride but increased the conductivity of the river water sample. Treatment with alum significantly ($p < 0.05$) decreased the pH but increased the conductivity and chloride content of the water, while calcium hypochlorite significantly ($p < 0.05$) increased the TDS, calcium and chloride when compared with the untreated river water (Table 6).

Stream water Treatment of the stream water with stem, seed, leaf and bark powder material of *Mangifera indica* decreased the pH, DO, TDS, calcium, nitrate, turbidity and COD contents of the stream water when compared with untreated stream water (Table 7). Treatment of stream water with alum significantly ($p < 0.05$) decreased pH (6.25 ± 3.50), DO (6.25 ± 3.50 mg/l), nitrate (12.53 ± 2.56 mg/l) and turbidity (5.38 ± 2.58 NTU) but increased the conductivity (365.50 ± 3.80 µS/cm), calcium (97.50 ± 3.80 mg/l) and magnesium (78.25 ± 1.75 mg/l) content when compared with the untreated stream water. Calcium hypochlorite, on the other hand, decreased the DO (6.73 ± 0.56 mg/l), nitrate and increased conductivity (365.50 ± 3.80 µS/cm) and calcium (85.41 ± 3.41 mg/l) of stream water when compared with untreated water.

Minimum inhibitory concentrations (MIC) and minimum bactericidal concentrations MBC)

The minimum inhibitory concentrations (MIC) and minimum bactericidal concentrations of the plant materials against *Escherichia coli, Bacillus megaterium, Shigella dysenteriae, Brenner iaquercina, Pseudomonas aeruginasa, Enterobacter aerogenes, Salmonella spp, Proteus myxofaciens, Klebsiella oxytoca, Klebsiella pneumonia, Kluyvera ascorbata, Proteus mirabilis* and *Staphylococcus aureus* isolated from river, stream and ponds water samples (Table 8). The minimum inhibitory concentrations (MIC) of the powdered seed, leaf, bark and stem materials of *Mangifera indica* range between 8 and 32 mg/mL against all the isolates tested. The minimum bactericidal concentrations (MBC) ranged from 8–64 mg/mL against all organism tested (Table 8).

Table 5 Physicochemical properties of pond water sample treated with powdered leaf, stem, seed and bark of *Mangifera indica*

Parameters	Untreated	Alum	Calcium hypochlorite	Stem	Seed	Leaf	Bark
pH	9.30 ± 0.02^{b}	8.20 ± 1.30^{a}	9.10 ± 0.46^{b}	7.62 ± 1.53^{a}	9.42 ± 1.65^{b}	8.92 ± 0.54^{ab}	9.53 ± 0.65^{b}
DO (mg/l)	8.67 ± 0.45^{b}	6.73 ± 2.50^{a}	6.73 ± 0.56^{a}	7.52 ± 1.63^{ab}	8.22 ± 2.52^{b}	7.52 ± 1.07^{ab}	8.32 ± 2.01^{b}
TDS (mg/l)	134.78 ± 2.34^{b}	113.20 ± 2.50^{a}	113.24 ± 4.97^{a}	135.06 ± 2.76^{b}	135.21 ± 2.44^{b}	105.32 ± 2.89^{a}	155.21 ± 2.60^{b}
Conductivity (µS/cm)	184.90 ± 2.34^{b}	187.90 ± 2.50^{b}	187.21 ± 4.32^{b}	107.07 ± 2.54^{a}	167.09 ± 1.45^{b}	327.43 ± 4.78^{c}	167.21 ± 4.55^{b}
Temp. (°C)	33.96 ± 2.45^{a}	32.25 ± 2.70^{a}	32.62 ± 2.32^{a}	32.22 ± 2.52^{a}	32.52 ± 2.89^{a}	32.42 ± 2.65^{a}	32.52 ± 2.70^{a}
Hardness (mg/l)	694.97 ± 8.34^{b}	342.50 ± 2.60^{a}	654.32 ± 5.43^{b}	438.4 ± 2.56^{a}	318.3 ± 2.45^{a}	408.54 ± 2.32^{a}	302.32 ± 2.52^{a}
Calcium (mg/l)	89.24 ± 2.45^{a}	184.30 ± 1.65^{b}	85.41 ± 3.43^{b}	79.43 ± 4.65^{b}	89.32 ± 2.90^{b}	69.43 ± 1.89^{a}	79.21 ± 2.45^{b}
Chloride (mg/l)	20.01 ± 2.34^{a}	19.55 ± 2.50^{a}	20.54 ± 2.35^{a}	20.32 ± 0.56^{a}	25.52 ± 0.70^{b}	20.42 ± 0.78^{a}	20.52 ± 0.65^{a}
Nitrate (mg/l)	13.53 ± 1.45^{b}	12.50 ± 2.40^{b}	12.53 ± 3.45^{b}	10.32 ± 0.87^{a}	13.52 ± 0.87^{b}	12.32 ± 0.74^{b}	11.22 ± 0.89^{ab}
Magnesium (mg/l)	65.78 ± 1.78^{ab}	73.43 ± 1.60^{b}	64.21 ± 1.56^{a}	56.43 ± 2.43^{a}	66.32 ± 1.54^{ab}	66.21 ± 2.98^{ab}	56.54 ± 2.62^{a}
Turbidity (NTU)	9.61 ± 0.45^{b}	7.78 ± 1.58^{a}	9.61 ± 0.32^{b}	8.53 ± 0.43^{a}	9.12 ± 0.76^{a}	9.52 ± 0.87^{a}	9.32 ± 0.96^{a}
COD (mg/l)	88.90 ± 1.56^{b}	86.09 ± 0.80^{b}	84.02 ± 2.45^{b}	9.42 ± 0.74^{a}	61.42 ± 2.52^{b}	61.42 ± 4.99^{b}	55.44 ± 4.87^{b}

Data are MEAN ± SEM of triplicate determinations

COD chemical oxygen demand, *TDS* total dissolved solid, *DO* dissolved oxygen, *NTU* nephelometric *turbidity* units, *µS/cm* micro-Siemens per centimeter, *mg/L* milligram per litre

Values followed by different superscript are significantly different ($p < 0.05$)

Table 6 Physicochemical properties of river water sample treated with powdered leaf, stem, seed and bark of *Mangifera indica*

Parameters	River	Alum	Calcium hypochlorite	Stem	Seed	Leaf	Bark
pH	9.57 ± 1.75^{b}	7.45 ± 0.58^{a}	9.10 ± 0.46^{b}	8.33 ± 0.65^{ab}	9.33 ± 0.45^{b}	7.32 ± 0.65^{a}	8.24 ± 0.56^{ab}
DO (mg/l)	6.38 ± 2.17^{a}	6.75 ± 0.55^{a}	6.73 ± 0.56^{a}	9.42 ± 0.88^{a}	8.33 ± 0.65^{a}	8.43 ± 0.99^{a}	8.43 ± 0.65^{a}
TDS (mg/l)	115.21 ± 1.02^{a}	113.07 ± 0.77^{a}	113.24 ± 4.97^{b}	132.43 ± 3.78^{a}	135.21 ± 3.78^{a}	152.32 ± 2.69^{b}	144.21 ± 2.87^{ab}
Conductivity (µS/cm)	169.55 ± 2.83^{a}	262.06 ± 0.57^{b}	187.21 ± 4.32^{ab}	187.32 ± 1.87^{b}	197.32 ± 4.88^{b}	187.21 ± 2.76^{b}	187.21 ± 3.88^{b}
Temp. (°C)	33.42 ± 2.45^{a}	32.24 ± 1.57^{a}	32.62 ± 2.32^{a}	33.77 ± 0.80^{a}	33.22 ± 0.89^{a}	33.34 ± 0.54^{a}	32.34 ± 0.76^{a}
Hardness (mg/l)	652.23 ± 2.56^{b}	312.30 ± 2.58^{a}	654.32 ± 5.43^{b}	312.21 ± 0.56^{a}	312.21 ± 2.90^{a}	312.21 ± 3.54^{a}	362.21 ± 1.89^{a}
Calcium (mg/l)	85.40 ± 2.89^{a}	85.05 ± 0.78^{a}	120.41 ± 3.43^{b}	84.32 ± 3.89^{a}	78.43 ± 1.65^{a}	84.21 ± 1.69^{a}	84.46 ± 3.86^{a}
Chloride (mg/l)	19.52 ± 1.74^{a}	87.08 ± 3.87^{b}	86.54 ± 2.35^{b}	20.52 ± 1.54^{b}	21.52 ± 3.65^{b}	17.52 ± 3.89^{a}	19.53 ± 4.90^{b}
Nitrate (mg/l)	10.61 ± 1.45^{a}	12.53 ± 0.54^{a}	12.53 ± 3.45^{a}	13.42 ± 2.56^{a}	13.22 ± 1.87^{a}	13.23 ± 4.65^{a}	13.24 ± 4.76^{a}
Magnesium (mg/l)	63.12 ± 1.20^{a}	64.47 ± 0.59^{a}	64.21 ± 1.56^{a}	56.32 ± 1.77^{a}	73.34 ± 3.88^{b}	74.23 ± 2.80^{b}	56.33 ± 1.98^{a}
Turbidity (NTU)	9.14 ± 2.30^{b}	4.38 ± 0.87^{a}	9.61 ± 0.32^{b}	9.05 ± 2.90^{a}	9.04 ± 2.89^{a}	10.22 ± 3.55^{a}	8.54 ± 0.55^{a}
COD (mg/l)	81.23 ± 2.50^{b}	64.08 ± 0.76^{a}	84.02 ± 2.45^{b}	61.33 ± 2.65^{a}	63.35 ± 2.70^{a}	63.33 ± 4.76^{a}	61.33 ± 2.45^{a}

Data are MEAN ± SEM of triplicate determinations

COD chemical oxygen demand, *TDS* total dissolved solid, *DO* dissolved oxygen, *NTU* Nephelometric *Turbidity* Units, *µS/cm* micro-Siemens per centimeter, *mg/L* milligram per litre

Values followed by different superscript are significantly different ($p < 0.05$)

Table 7 Physicochemical properties of stream water sample treated with powdered leaf, stem, seed and bark of *Mangifera indica*

Parameters	Stream	Alum	Calcium hypochlorite	Stem	Seed	Leaf	Bark
pH	9.26 ± 1.98^{b}	6.25 ± 3.50^{a}	9.10 ± 0.46^{b}	7.54 ± 0.54^{a}	8.33 ± 0.55^{a}	8.54 ± 0.56^{a}	8.34 ± 0.56^{a}
DO (mg/l)	8.36 ± 1.19^{b}	6.25 ± 3.50^{a}	6.73 ± 0.56^{a}	8.34 ± 0.66^{a}	9.34 ± 1.54^{a}	8.34 ± 0.66^{a}	8.34 ± 0.55^{a}
TDS (mg/l)	140.35 ± 2.87^{b}	328.35 ± 2.36^{b}	113.24 ± 4.97^{a}	145.43 ± 2.67^{a}	145.32 ± 2.76^{a}	145.54 ± 3.77^{a}	140.32 ± 4.67^{a}
Conductivity (µS/cm)	185.73 ± 2.76^{a}	365.50 ± 3.80^{b}	187.21 ± 4.32^{a}	178.43 ± 3.66^{a}	184.43 ± 7.55^{a}	178.54 ± 3.78^{a}	182.43 ± 5.76^{a}
Temp. (°C)	33.45 ± 1.98^{a}	32.27 ± 3.59^{a}	32.62 ± 2.32^{a}	32.44 ± 3.67^{a}	33.23 ± 3.67^{a}	32.43 ± 4.65^{a}	33.44 ± 1.89^{a}
Hardness (mg/l)	351.46 ± 2.12^{a}	256.55 ± 3.50^{a}	654.32 ± 5.43^{b}	316.34 ± 4.89^{a}	336.43 ± 3.66^{a}	336.43 ± 2.77^{a}	386.34 ± 3.67^{a}
Calcium (mg/l)	86.31 ± 2.24^{b}	97.50 ± 3.80^{b}	85.41 ± 3.43^{b}	66.54 ± 3.55^{a}	63.54 ± 3.87^{a}	68.63 ± 4.53^{a}	63.54 ± 3.66^{a}
Chloride (mg/l)	20.51 ± 1.72^{a}	19.55 ± 3.77^{a}	20.54 ± 2.35^{a}	20.34 ± 2.54^{a}	20.33 ± 4.53^{a}	20.43 ± 3.99^{a}	20.44 ± 3.67^{a}
Nitrate (mg/l)	18.58 ± 0.70^{b}	12.53 ± 2.56^{a}	12.53 ± 3.45^{a}	13.42 ± 2.87^{a}	12.53 ± 2.67^{a}	13.43 ± 3.90^{a}	13.54 ± 4.79^{a}
Magnesium (mg/l)	66.11 ± 2.01^{a}	78.25 ± 1.75^{b}	64.21 ± 1.56^{a}	64.44 ± 1.78^{a}	$66.32 \pm .46^{a}$	67.54 ± 4.56^{a}	66.67 ± 3.59^{a}
Turbidity (NTU)	9.53 ± 1.09^{b}	5.38 ± 2.58^{a}	9.61 ± 0.32^{b}	9.53 ± 2.89^{a}	8.53 ± 2.43^{a}	9.54 ± 3.32^{a}	9.34 ± 3.78^{a}
COD (mg/l)	84.09 ± 29^{b}	86.07 ± 3.87^{b}	84.02 ± 2.45^{b}	68.54 ± 3.80^{a}	64.54 ± 3.54^{a}	62.54 ± 3.32^{a}	64.33 ± 2.76^{a}

Data are MEAN ± SEM of triplicate determinations

COD chemical oxygen demand, *TDS* total dissolved solid, *DO* dissolved oxygen, *NTU* Nephelometric *Turbidity* Units, *µS/cm* micro-Siemens per centimeter, *mg/L* milligram per litre

Values followed by different superscript are significantly different ($p < 0.05$)

Discussion

It was reported that crude material of medicinal plant contains significant amount of phytochemical with antimicrobial properties (Tsado et al. 2016; Ibrahim et al. 2017; Yusuf et al. 2018b); these phytochemicals have also been reported to enhance surface water purification. The medicinal properties of these plants particularly the antimicrobial properties will enhance microbial decontamination of water, thus making it fit for drinking and for other domestic or industrial application (Okunlola et al. 2020).

Interestingly, all the phytochemical investigated in this study were present in all parts of *Mangifera indica.* The result of phytochemical screening from this study shows similarities to several studies conducted in an attempt to determine phytochemical constituents of different part of *M. indica* (Aiyelaagbe and Osamudiamen 2009; Sanwaral and Susish 2013). The result was in conformity with study of Doughari and Manzara (2008) on in vitro antibacterial

Table 8 Minimum inhibitory concentrations (MIC) and minimum bactericidal concentrations (MBC) of the powdered seed, leaf, bark and stem materials of *Mangifera indica* against the isolated organism

Plant (mg/mL)	Part	*E. coli*	*B. megaterium*	*S. dysenteriae*	*B. aquercina*	*P. aeruginasa*	*E. aerogenes*	*Salmonella spp*	*P. myxofaciens*	*K. oxytoca*	*K. pneumonia*	*K. ascorbata*	*P mirabilis*	*S. aureus*
Minimum inhibitory concentrations														
Mangifera indica	Seed	32	8	16	16	32	32	16	32	32	16	32	16	16
	Leaf	16	32	16	16	16	8	8	16	16	16	16	16	16
	Bark	32	16	16	16	8	8	16	16	16	16	8	16	32
	Stem	32	32	8	32	16s	8	16	16	16	32	16	32	16
Minimum bactericidal concentrations														
Mangifera indica	Seed	32	8	16	16	32	32	16	32	32	16	32	16	16
	Leaf	16	32	16	32	16	8	32	16	32	16	32	32	16
	Bark	32	16	32	16	8	16	16	32	32	32	8	64	64
	Stem	32	32	8	32	32	8	32	16	16	32	16	64	16

mg/mL milligram per milliliter

activity of crude leaf extract of *M. indica,* in which preliminary phytochemical analysis revealed the presence of tannins, glycosides, saponins and phenols. Other experiments conducted to determine the phytochemical constituents in *Mangifera indica* by Aiyelaagbe and Osamudiamen (2009), and Sanwaral and Susish (2013), showed the presence of alkaloid, flavonoids, tannins, saponins, glycosides and anthraquinones. These components are known to be biologically active because they protect the plant against infections and predation by animals.

Similarly, Pintu and Arna (2014) reported that aqueous extract of *Mangifera indica* young leaves contained tannins, alkaloids, steroid, carbohydrate, glycoside and flavonoid that may be responsible for the anti-diarrhoeal properties of the plant material. Pritesh and Dash (2015) reported that saponins may help to prevent colon cancer. Therefore, the microbial decontamination of stream, river and well water by *M. indica* observed in this study material may be attributable to the presence of the above phytochemicals.

However, on a contrary note Olasehinde et al. (2018) reported the absence of alkaloid and cardiac glycoside in aqueous leaf material of *M. indica*. This may be attributed to the differences in the method used in the extraction of the phytochemicals from the leaf of *M. indica*, i.e. Olasehinde et al. (2018) use hot extraction method, while cold aqueous extraction was employed in this study. Lawal et al. (2014) argued that the variations in the presence or absence of phytochemical constituents of plants could be attributed to the difference in polarity of the solvents used, method of extraction, duration of extraction or the period of the year the plant was obtained.

The mean viable counts, coliform counts for the river, stream and pond water samples recorded in this study were generally higher than the set standard for water meant for drinking purposes by WHO (2011). The presence of these high bacterial species in the water samples suggests that the water bodies in the study area have been contaminated with wastes either from human or animal origin (Megersa et al. 2014).

Interestingly, the leaf and bark materials of *Mangifera indica* at concentrations of 0.2, 0.3, 0.4 and 0.5 g/L completely eliminated the aerobic heterotrophic bacteria, coliforms, salmonella and shigella in the stream and pond water after 12 h of treatment. Similarly, for river water, the powdered leaf sample *Mangifera indica* at concentrations of 0.3, 0.4 and 0.5 g/l eliminated the TVC and TCC of the river water after 12 h, while all concentration tested caused complete elimination of FCC and SSC after 12 h of treatment.

The high antimicrobial activity of *M. indica* is an indication that the leaf, stem, seed and bark of this plant are effective in decontamination of microbes in surface water, thus making the water safe for consumption as recommended by WHO 2011). This significant activity of *M indica* could be

attributed to its phytochemical composition particularly the alkaloid, flavonoid and tannins (Table 1) which have been reported to have antimicrobial activity. However, the seed material was less active as the bacteria were eliminated only at higher doses (0.4 and 0.5 g/L) after 24 h of treatment. This could be attributed to the earlier mentioned findings that the quality and quantity of antimicrobial agent in the plants varies according to the part of the plant (leaf, stem seed or root).

The activity of *Mangifera indica* could also be due to fact that the bioactive agents in *M. indica* are mainly positively charged amino acids that attract the negatively charged component such as bacteria thus reducing the bacterial load of the water samples. This is supported by previous studies by Oluduro et al (2010), where treatment with *M. oleifera a*nd *M. indica* showed bactericidal activity.

The MIC of the *Mangifera indica* material (seed, leaf, bark and stem) ranged between 8–32 mg/mL against all the isolates, whereas in previous study MIC range of mango leaf against the bacteria was 12.5–100 mg/ml (Doughari and Manzara, 2008). This variation may be due to the dependent of mango leaf composition on several factors including origin, age, storage conditions and type of processing methods. Singh et al. (2010) reported that stem bark of M. indica exhibited excellent antibacterial and anti-fungal activities (MIC = 0.08 mg/mL) against *Streptococcus pneumonia, Enterobacter aerogenes, Klebsiella pneumonia* and *Candida albicans.* The potent activity of *Mangifera indica* might be due to the presence of a strong bioactive agent mangiferin that shows multiple mode of action against microorganism (Navarro et al. 2003).

Hydrogen ion concentrations of the untreated water samples in this study exceeded the maximum permissible limit for drinking water. The slight tendency towards acidic pH values observed when *Mangifera indica* powdered materials were used could be attributed to the presence of H^+ group in the acidic amino acid composition of *Mangifera indica* materials which is donated, thus making the solution acidic (Doer 2005).

The untreated river, stream and pond water evaluated in this study are very hard according to USEPA (2009) classification. The use of this water for laundry purpose will not be adequate as it will not lather with soap. However, the observed significant reductions in the level of water hardness following treatment with *M. indica* powdered materials reflect the water remediation quality of the plant. This reduction in water hardness may improve the usefulness of the water for laundry purposes; it may also reduce the cost of laundry as lesser amount of soap will be required for lather formation.

Nitrates ranged between 13.53 ± 1.45 (pond) and 10.61 ± 1.45 (river). This value exceeded the maximum permissible limit of the standards (WHO 2006). The high nitrate content of untreated water sample could cause hypoxic condition in infant due to interference with the ability of red blood cells to transport oxygen (Orlov and Karkouti 2015). The significant reduction in nitrate contents of the water samples after treatment with *Mangifera indica* therefore reduced the threat of nitrate intoxication thus making the water safe for human consumptions.

Highly mineralized waters are unsuitable for many industrialized applications (APHA 1999). However, the total dissolved solids ranged between 115.21 ± 1.02 mg/l and 140.35 ± 2.87 mg/l. This value fell within the permissible limit of the standards suitable for drinking purpose. The significantly higher TDS in stream and pond water when compared with the river water is an indication that the stream and pond water are polluted or unhealthy (WHO 2011). Hence, removal of TDS is a primary factor. Fortunately, all parts of *Mangifera indica* tested significantly decreased TDS, thus improving the quality of the water.

Conclusion

The raw surface water (stream, river and pond) used for the study fall short of standard in terms of microbial load and the physicochemical properties. *Mangifera indica* leaf, stem, seed and bark materials contained bioactive compounds and improved the quality of the raw surface water based on the maximum permissible limit of microbial load and physicochemical parameters. This could serve as a cheaper and safer alternative to the synthetic coagulant.

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Compliance with ethical standards

Conflict of interest The authors declared that they have no conflict of interest.

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