Determination of Effectiveness of Traditional Drinking Water Treatment Methods

Okwadha G.D.O.[1*] & Ahmed A. A.[2]

[1]Senior Lecturer, Department of Civil & Construction Engineering, The Technical University of Kenya, P.O. Box 52428-00200 Nairobi, Kenya

[*]E-mail: *george.okwadha@tukenya.ac.ke*

[2]B. Tech. Civil Engineering Student, Department of Civil & Construction Engineering, The Technical University of Kenya, P.O. Box 52428-00200 Nairobi, Kenya

E-mail: *ahmed.dwo10@yahoo.com*

Abstract: This study surveyed the effectiveness of Green gram seed (GGS) powder, Moringa seed (MS) powder, Bean pod (BP) ash, Pea nut stalk (PNS) ash, Ceramic filter (CF), Sand filter (SF), boiling and cloth filtration treatment methods as alternatives to conventional water treatment for households. GGS and MS were grounded to obtain fine powder. BP and PNS were burnt to obtain the ash. Two (2) grams of grounded powder and ashes was mixed with 500ml of sample water in a bottle, shaken for about 15 seconds and allowed to settle for 2 hours before testing. Raw water filtrate from a CF and a clean sterile cotton cloth was collected separately and tested. Boiling was done for 1hr at 100^{0}C, and allowed to cool before testing. The SF was made from graded sand. Raw water was passed through it, and the filtrate collected and stored in a refrigerator. The pH, colour, conductivity, Turbidity, TDS, Total and Fecal coliform parameters were used to monitor the efficiency of the treatment methods. The results show that GGS powder, MS powder, PNS ash and CF removed colour and turbidity effectively from highly turbid water. Boiling and CF removed total and fecal coliform 100% from all types of raw water. BP ash, CF, boiling, and cloth filter were quite effective in removing fecal coliform in water samples with low turbidity. BP ash, CF, and boiling were very effective in removing total and fecal coliform from borehole and tap water. BP ash treatment was not effective in Pond water and Tana River water samples. The most effective treatment method was Ceramic Filter (CF) when used in low turbidity water. The order of effectiveness in descending order therefore is, CF, Boiling, MS powder, GGS powder, Cloth filter, SF, BP ash and PNS ash.

Keywords: Water treatment; Green Gram seeds, Moringa seeds, Bean pod, Ceramic filter, boiling, Cloth filtration

I. INTRODUCTION

Water as a human right is essential for public health and well being of the society, and should be sufficient, safe, acceptable, physically acceptable, and affordable to households. However, one of the most pervasive problems affecting people worldwide is inadequate access to clean water and sanitation. Access to safe drinking water is estimated by the percentage of the population using improved drinking water sources. An improved drinking water source is one that by the nature of its construction adequately protects the source from outside contamination, in particular with fecal matter [1,2,3]. An improved sanitation facility is one that hygienically separates human excreta from human contact. In assessing the adequacy of the drinking-water supply, basic service parameters such as quality; whether the supply has an approved water safety plans (WSP) that has been validated and is subject to periodic audit to demonstrate compliance, quantity; the proportion of the population using water from different levels of drinking-water supply, (for example, no access, basic access, intermediate access and optimal access), accessibility; the percentage of the population that has reasonable access to an improved drinking-water supply, affordability; the tariff paid by domestic consumers, and continuity; the percentage of the time during which drinking-water is available (daily, weekly and seasonally) should normally be taken into consideration [4]. Problems associated with scarcity of safe drinking water are expected to grow worse especially in developing countries. Statistics provided by the World Health Organization (WHO) show that 1.2 billion people lack access to safe drinking water, 2.6 billion have little or no sanitation, millions of people die annually, about 3900 children die daily from waterborne diseases, which can be avoided or reduced if clean water and sanitation were provided, and countless more are ailing from waterborne diseases and contamination [3,5]. In particular, intestinal parasitic infections and diarrheal diseases caused by waterborne bacteria and enteric viruses have become a leading cause of malnutrition owing to poor digestion of the food eaten by the sick due to consumption of contaminated water [6,7,8]. However, some improvement has been made in the provision of safe drinking water to both urban and rural communities since the last progress report. The WHO/UNICEF Joint monitoring programme (JMP) reported that about 96% of the urban population now uses improved drinking water sources, compared with 84% of the rural population [9]. To mitigate this problem, all water from all sources should be treated. This is because all available water sources including groundwater aquifers are contaminated by industrial and agricultural wastes.

Water treatment is purifying water to a level safe for drinking, free of all pathogens and toxic substances, having pleasant appearance and being tasteless and odourless [10]. There are numerous conventional water treatment technologies available which include physical methods such as coagulation, flocculation, sedimentation, filtration and activated carbon adsorption, pressurized filtration technologies such as microfiltration, ultrafiltration, nanofiltration and reverse osmosis, and chemical processes such as hardness removal such as lime softening, ion exchange softening; disinfection methods such as chlorination, ozonation and ultraviolet radiation. These conventional water treatment methods have been used to treat water to supply mainly urban communities with very little rural coverage. Consequently, all over the world, rural communities have adopted some simple and rudimentary water treatment techniques that can serve either a community or individual households [11]. The aim of such techniques was to remove visible impurities such as leaves, twigs, or large suspended particles including insects, tadpoles collected from unprotected local water sources. Recently, solar radiation of water in glass bottles was discovered by UNICEF to be able to kill 99.9% of e. coli bacteria if exposed for 24 hours on sunny roofs [4]. Therefore, building on the traditionally known and used water treatment practices is expected to have the potential of reducing morbidity and mortality of waterborne diseases. Some of the traditional water treatment methods include; Filtration through winnowing sieve [11]; Filtration through cloth [10,11]; Filtration through clay vessels [11]; Jempeng Stone Filter Method [11]; Clarification and filtration of turbid water using plant parts such as Moringa seeds, legume plant seeds and plant ashes [10,12,13]; Boiling [10]; Coagulants such as seeds of Moringa oleifera, potash alum (dawa) [10,12]; and Long Storage [10].

These traditional water treatment methods are widely used in rural communities in developing countries, and are what can now be referred to as appropriate technology which combines traditional knowhow to current practice to satisfy an immediate need [14]. However, these methods can as well be used by urban communities depending on availability and convenience whenever a conventional water treatment system breaks down. This is because initiatives to manage safety of water do not only support public health, but often promote socioeconomic development and well-being as well [15,16]. In addition, contacting water borne diseases and malnutrition due to consumption of contaminated water depletes a country's merger resources which could have been used for preventative measures instead of curative measures of disease control. It is therefore prudent to employ any available and viable method to purify water, and provide safe drinking water to communities.

The main objective of this study is to evaluate and prescribe the most effective traditional water treatment method which can augment convention drinking water treatment method when a need arise. This will be done by carrying out a drinking water treatment process using some of the traditional methods outlined above, assessing their performance in reducing turbidity and water pathogens especially E. coli by comparing them with results from a conventional water treatment method, and finally prescribing a traditional drinking water treatment method, which may be used when the drinking water treatment plant breaks down. The parameters to be evaluated will include pH, Colour, Conductivity, Turbidity, Total dissolved solids (TDS), Total Coliform, and Fecal Coliform.

II. METHODOLOGY

Raw water samples were collected from a Pond (Sample No. 125), Tana River (Sample No. 126), Ziwani Borehole (Sample No. 127), and Garissa Water Supply tap water (Sample No. S128), preserved in glass bottles in accordance with WHO guidelines and Kenya Bureau (KEB) of standards, and delivered to the Kenya Water Institute (KEWI) laboratory within 24 hours for safe storage and testing to determine pH, Colour, Conductivity, Turbidity, Total dissolved solids (TDS), Total Coliform, and Fecal Coliform after purification through Green Gram seeds (GGS) powder, Moringa seeds (MS) powder, Bean pods (BP) ash, pea nuts stalk (PNS) ash, Ceramic filter (CF), sand filter (SF), boiling and cloth filtration.

A. GREEN GRAM SEEDS AND MORINGA SEEDS

Green Gram and Moringa seeds were grounded using a pestle and mortar to obtain fine powder (Figs 1a, 1b, 2a, and 2b). Two (2) grams of grounded powder was mixed with 500ml of sample water in a bottle, shaken for 15 seconds, and the mixture allowed to settle for 2 hours before testing.

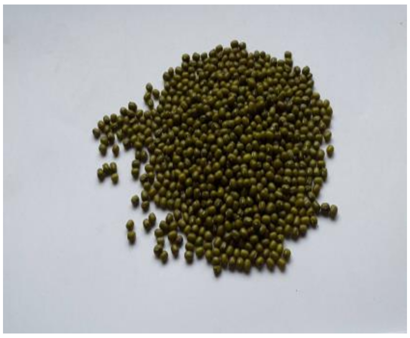

Fig. 1a Green Gram seeds

Fig. 1b Making of Green Gram powder using a Pestle and mortar

B. BEAN PODS AND PEA NUT STALKS

Bean pods and Pea nut stalks were burnt to obtain the ash. Two (2) grams of grounded powder was mixed with 500ml of sample water in a bottle, shaken for 15 seconds, and the mixture allowed to settle for 2 hours before testing.

Fig. 2a Moringa seeds

Fig. 2b Moringa seeds powder

C *CERAMIC FILTER AND SAND FILTER*

Water sample was poured into the Ceramic filter (Fig. 3) and allowed to accumulate in a container before testing. The Sand filter (Fig. 4) was made from graded sand in a container. A layer of gravel size particles was overlaid with coarse sand which was in turn overlaid with fine sand. Water samples were passed through it, and the filtrate collected and stored in a refrigerator.

Fig. 3 Ceramic filter

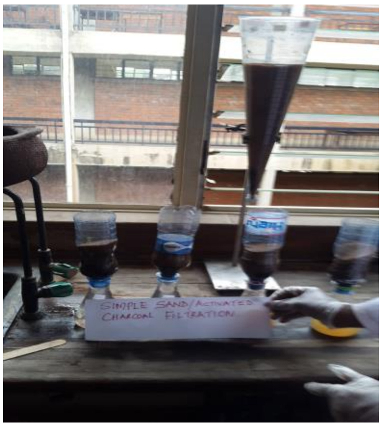

Fig. 4 Sand filter

D. *BOILING*

Boiling was done in a 100ml beaker at 100^0C using a hot plate (Fig. 5) for 1hr, allowed to cool, and then stored in a sterile refrigerator before testing.

E. CLOTH FILTER

A clean sterile 1 m^2 cotton cloth (Fig. 6) was used to filter samples. The filtrate was collected and then stored in a refrigerator for testing.

Fig. 5 The boiling process

Fig. 6 A $1m^2$ cotton cloth

III. RESULTS AND DISCUSSION

A. WATER QUALITY ANALYSIS BEFORE TREATMENT

The results of water quality before treatment for all samples are shown in Table 1.

Table 1. Water analysis before testing

Sample no	pH (scale)	Colour (Hazen)	Conductivity (µS/cm)	TDS (mg/L)	Turbidity (NTU)	Total Coliform/100ml	Fecal coliform/100ml
125	6.73	65	700	434	689	>2400	1100
126	7.56	400	1150	713	5830	>2400	210
127	7.74	0	2220	1376.4	0.06	>2400	3
128	6.88	25	1600	992	221	1100	7
KEBS	6.5 -8.5	<15	<2000	<1200	5	<10	Nil
WHO	6.5-8.5	<15	1000	500	≤ 5	Nil	Nil

pH

Table 1 shows the results for the control sample. The results of analysis indicate that the pH values range between 6.73 and 7.74. This shows that the values are within the desirable limits of WHO guidelines and KEB standards.

Colour

The results of the analysis indicate that the colour values for sample 125, 126 & 128 are 65, 400 and 25 respectively (Table 1). This shows that the values are above the desirable limit of WHO guidelines and KEB standards. Sample number 127 had zero hazen. This means that it is colourless.

Conductivity

Conductivity values for sample 125, 126, 127, &128 are 700, 1150, 2220 and 1600 μscm^{-1} respectively (Table 1). These values are within the WHO guidelines and KEB standards except sample 127 which has a value of 2220 which is above the desirable limit of WHO guidelines and KEB standards.

Total Dissolved Solids (TDS)

The TDS results for sample 125, 126, 127 & 128 were 434, 713, 1376.6 and 992 respectively Table 1). This shows that the values are within the WHO guidelines and KEB standards, except sample 127 which is above the desirable limit of WHO guidelines and KEB standards.

Turbidity

The Turbidity value for sample 127 is 0.06 NTU, which is within the desirable limit of WHO guidelines and KEB standards (Table 1). Sample 125, 126, and 128 values are 689, 5830 & 221 respectively. These values are above the desirable limits of WHO guidelines and KEB standards.

Total Coliform

The results of the analysis indicates that the values of coliform are >2400 for sample 125, 126, and 127 (Table 1). Sample 128 has a value of 128. These values are above the desirable limits of WHO guidelines and KEB standards.

Fecal Coliform

The result of the analysis indicates that the values of E.coli for sample 125, 126, 127 & 128 are 1100, 210, 3 and 7 respectively (Table 1). These values are above desirable limit of WHO guidelines and KEB standards.

B. WATER QUALITY ANALYSIS AFTER TREATMENT

i. Pond Water (Sample No. 125)

The results of the performance of GGS powder, MS powder, BP ash, PNS ash, CF, SF, boiling and cloth filtration for water sample no. 125 is presented in Table 2.

pH

The results of the analysis indicate that the pH value reduced from 6.73 to 5.88 and 6.73 to 6.14 for GGS powder and MS powder water treatment respectively. However, treatment using BP ash, PNS ash, CF, SF, boiling and cloth filter raised the pH value from 6.73 to 9.98, 10.20, 8.14, 7.37, 8.76, and 7.76 respectively. This shows that the chemical composition of some of these materials is alkaline in nature, and might have affected their pH values. However, all other materials except BP ash and PNS ash fell within the desirable limits of both WHO guidelines and KEB standards.

Colour

The results of the analysis indicate the colour for GGS powder, MS powder, PNS ash and CF are 3, 0, 2.5 and 0 respectively. This indicates that these materials remove colour up to the desirable value of WHO guidelines and KEB standards. The values for BP ash, SF, boiling, and cloth filter were 60, 35, 70 and 45 respectively, and are above the desirable limits of WHO guidelines and KEB standards. All treatment methods significantly reduced the colour except boiling which raised the value.

Conductivity

Conductivity level increased for all treatment methods from 700 to 1304, 1663, 4380, 5960, 783, 1251, 920, and 950 for GGS powder, MS powder, BP ash, PNS ash, CF, SF, boiling, and cloth filtration respectively. This shows that BP and PNS ashes have more mineral content. However, GGS powder, MS powder, CF, SF, boiling and cloth filtration values were within the limits of WHO guidelines and KEB standards.

Table 2. Results for Pond Water, Sample No. 125

Parameter/ Unit	Raw Water	GGS Powder	MS Powder	BP ash	PNS ash	CF	SF	Boiling	Cloth Filter	KEB Std
Ph (scale}	6.73	5.88	6.14	9.89	10.20	8.14	7.37	8.76	7.76	6.5-8.5
Colour (Hazens)	65	3	0	60	2.5	0	35	70	45	<15
Conductivity (µS/cm)	700	1304	1663	4380	5960	783	1251	920	950	<2000
TDS (mg/L)	434	808.5	1031.06	2716	3695.2	485.5	775.6	570.4	589	<1200
Turbidity (NTU)	689	1.82	2.85	324	5.35	4.8	238	600	411	<5NTU
Total coliform /100mls	>2400	>2400	>2400	>2400	1100	Nil	>2400	Nil	>2400	<10/100mls
Fecal coliform /100mls	1100	1100	1100	1100	1100	Nil	1100	Nil	>2400	Nil

TDS

All treatment methods except BP and PNS ashes had values falling within WHO guidelines and KEB standards (Table 2).

Turbidity

The Turbidity decreased from 689 NTU for raw water to 1.82, 2.85, 3.24, 5.35, 4.8, 2.38, 600, and 411 NTU for GGS powder, MS powder, BP ash, PNS ash, CF, SF, boiling, and cloth filter respectively. All treatment methods except PNS ash, boiling and cloth filter fell within the desirable limit of WHO guidelines and KEB standards.

Total Coliform

Total coliform values for PNS ash, CF and boiling reduced from greater than 2400 to 1100, 0, and 0 respectively. All other treatment methods remained the same as ram water value. These results were above the desirable limits of WHO guidelines and KEB standards.

Fecal Coliform

The fecal coliform values as measured by the amount of E. Coli range were 1100 for raw water, GGS powder, MS powder, BP ash, PNS ash, and SF respectively, and greater than 2400 for cloth filter. CF and boiling methods had no E. Coli detected. This shows that only CF and boiling methods can destroy fecal coliforms to the required WHO guidelines and KEB standards.

ii. Tana River Water (Sample No. 126)

The results of Tana River water sample no. 126 are tabulated in Table 3 below.

pH

The results of the analysis indicate that the pH value reduced from 7.56 for raw water to 6.45 and 6.56 for GGS powder and MS powder treatment respectively (Table 3). These values were within the WHO guidelines and KEB standards. However, the pH value for BP ash, PNS ash, CF, SF, boiling, and cloth filter increased from 7.56 for raw water to 9.76, 10.06, 7.73, 8.01, 9.02, and 7.70 respectively. The pH values for BP ash, PNS ash and boiling were above the limits set by WHO guidelines and KEB standards. The BP and PNS ashes might have added the carbonate ions into the water which made the treated water more alkaline. The increase in pH from the boiling process could have been from contaminants in the water.

Colour

The results of the analysis indicate that the colour value reduced from 400 for raw water to 5, 0, 140, 2.5, 0, 80, 140, and 140 for GGS powder, MS powder, BP ash, PNS ash, CF, SF, boiling, and cloth filter respectively. This result shows that GGS powder, MS powder, PNS ash and CF treatment methods removed colour up to the desirable value of WHO guidelines and KEB standards. However, BP ash, SF, boiling, and cloth filter were above the desirable limits of WHO guidelines and KEB standards but significantly removed colour.

Conductivity

The Conductivity results are shown in Table 3. These results indicate that all treatment methods except BP and PNS ashes had conductivity values less than 2000 µS/cm, which falls within WHO guidelines and KEB standards, a manifestation of more mineral content in the ashes.

TDS

The result of the analysis indicates that the TDS values all treatment methods except BP and PNS ashes fell within desirable limits of KEB standards and WHO guidelines.

Turbidity

The result of the analysis indicates that the Turbidity values reduced from 5830 NTU for raw sample to 5, 2.86, 884, 14.6, 0.12, 597, 400, and 1560 for GGS powder, MS powder, BP ash, PNS ash, CF, SF, boiling, and cloth filter respectively. All treatment methods except GGS powder, MS powder, and CF had turbidity of less than 5NTU which falls within WHO guideline limit and KEB standards.

Total Coliform

The result of the analysis indicates that all treatment methods except CF and boiling had total coliform values greater than 2400/100 ml which is above WHO guidelines and KEB standards.

Fecal Coliform

All treatment methods except CF and boiling had E. coli counts more than 0 count, the threshold set by WHO and KEB standards. E. coli count reduced from 210 for raw sample to 150 and 120 for MS powder and SF treatment methods respectively. All other treatment methods did not E. coli count in water.

iii. Ziwani Borehole, Sample no. 127

The Ziwani Borehole water test results are shown in Table 4.

pH

The results of the analysis indicate that the pH value reduced from 7.74 for raw water to 6.74, 6.93, and 7.05 for GGS powder, MS powder and CF treatment respectively (Table 4). However, SF and Cloth filter pH values were 8.45 and 8.01 respectively which fell within the WHO guidelines and KEB standards. In addition, the pH values for BP ash, PNS ash, and boiling increased from 7.74 for raw sample to 9.73, 10.01, and 9.95 for BP ash, PNS ash, and boiling respectively. These pH values were above the limits set by WHO guidelines and KEB standards of 6.5-8.5. The BP and PNS ashes might have added the carbonate ions into the water which made the treated water more alkaline. The increase in pH from the boiling process could have been from contaminants in the water.

Colour

The results of the analysis indicate that all treatment methods attained the colour value set by WHO guidelines and KEB standards.

Conductivity

Conductivity level increased for all treatment methods from 2220 µS/cm to 2560, 2980, 6320, 7400, 2560, 2950, 2540, and 2330 for GGS powder, MS powder, BP ash, PNS ash, CF, SF, boiling, and cloth filtration respectively. This shows that BP ash and PNS ash have more mineral content. All treatment methods gave conductivity values above the WHO guidelines and KEB standards.

Table 3 Tana River Water (Sample No. 126)

Parameter /Unit	Raw Water	GGS Powder	MS powder	BP ash	PNS ash	CF	SF	Boiling	Cloth Filter	KEB Std
pH (scale}	7.56	6.45	6.56	9.76	10.06	7.73	8.01	9.02	7.70	6.5-8.5
Colour (Hazens)	400	5	0	140	2.5	0	80	140	140	<15
Conductivity (µS/cm)	1150	1595	1936	4540	5850	1765	1790	1080	1220	<2000
TDS (mg/L	713	989	1200	2815	3627	1094	1110	670	757	<1200
Turbidity (NTU)	5830	5	2.86	884	14.6	0.12	597	400	1560	<5
Total coliform/100ml	>2400	>2400	>2400	>2400	>2400	Nil	>2400	Nil	>2400	<10
Fecal coliform /100ml	210	200	150	200	210	Nil	120	Nil	210	Nil

TDS

The result of the analysis indicates that the TDS values of all treatment methods were above the desirable limits of KEB standards and WHO guidelines of less than 1200 mg/L. In addition, all treatment methods increase the amount of TDS in water.

Turbidity

The result of the analysis indicates that the Turbidity values reduced from 0.06 NTU for raw sample to 0 for SF, boiling, and cloth filter respectively. However, turbidity values for GGS powder, PNS ash, and CF increased from 0.06 for raw sample to 4, 2.18, and 0.32 respectively but still fell within WHO guidelines and KEB standards.

Total Coliform

The result of the analysis indicates that all treatment methods except BP ash, CF, boiling and cloth filter had Coliform count of 0 count/100 ml which is within WHO guidelines and KEB standard. However, PNS ash had Total coliform count of 1100/100 ml which is less than the count in raw sample.

Fecal Coliform

All treatment methods except BP ash, CF, boiling and cloth filter had E. coli count of 0, which is the threshold set by WHO guidelines and KEB standards. All other treatment methods had E. coli count of 3 which marginally fell above the WHO guidelines and KEB standards.

Table 4 Ziwani Borehle (Sample No. 127)

Parameter /Unit	Raw Water	GGS Powder	MS powder	BP ash	PNS ash	CF	SF	Boiling	Cloth Filter	KEB Std
pH (scale}	7.74	6.74	6.93	9.73	10.01	7.05	8.45	9.95	8.01	6.5-8.5
Colour (Hazens)	0	0	0	5	0	0	0	0	0	<15
Conductivity (µS/cm)	2220	2560	2980	6320	7400	2560	2950	2540	2330	<2000
TDS (mg/L)	1376.4	1587.2	1847.6	3918	4588	1587	1829	1575	1445	<1200
Turbidity (NTU)	0.06	4	10.9	5.82	2.18	0.32	0	0	0	<5
Total coliform /100mls	>2400	>2400	>2400	Nil	1100	Nil	>2400	Nil	Nil	<10
Fecal coliform /100mls	3	3	3	Nil	3	Nil	3	Nil	Nil	Nil

Garissa Water Supply Tap Water, Sample No. 128

The Garissa Water Supply tap water test results are shown in Table 5, Sample number 128.

pH

The results of the analysis indicate that the pH value reduced from 6.88 for raw water to 5.87 and 6.45 for GGS and MS powder treatment respectively (Table 5). However, all other treatment methods had increased pH value from 6.88 for raw sample to 9.88, 10.2, 7.16, 8.75, 8.65, and 7.52 for BP ash, PNS ash, SF, boiling, and cloth filter respectively. The pH values of all treatment methods fell within the WHO guidelines and KEB standards of 6.5-8.5 except BP ash, PNS ash, SF and boiling. The BP and PNS ashes might have added the carbonate ions into the water which made the treated water more alkaline. The increase in pH from the boiling process could have been from contaminants in the water.

Colour

The results of the analysis indicate that all treatment methods attained the colour value set by WHO guidelines and KEB standards of less than 15 hazens. All treatment methods reduced colour far below the value in raw sample.

Conductivity

Conductivity level increased for all treatment methods except CF and cloth filter. BP and PNS ashes had the highest conductivity values of 5300 and 6330 µS/cm. This shows that BP ash and PNS ash have more mineral content. All treatment methods gave conductivity values above the WHO guidelines and KEB standards of less than 2000 µS/cm except ceramics and cloth filters.

Table 5 Garissa Water Supply Tap, (Sample No. 128)

Parameter /Unit	Raw Water	GGS Powder	MS powder	BP ash	PNS ash	CF	SF	Boiling	Cloth Filter	KEB Std
PH (scale}	6.88	5.87	6.45	9.88	10.20	7.16	8.75	8.65	7.52	6.5-8.5
Colour (Hazens)	25	0	0	15	0	0	0	0	15	<15
Conductivity (µS/cm)	1600	2050	2450	5300	6330	1372	3750	2650	1790	<2000
TDS (mg/L)	992	1271	1519	3286	3925	851	2350	1643	1110	<1200
Turbidity (NTU)	221	3	3.74	58.8	1.06	4.1	0	4.47	156	<5
Total coliform /100mls	1100	1100	Nil	Nil	1100	Nil	>2400	Nil	>2400	<10
Fecal coliform /100mls	7	3	Nil	Nil	3	Nil	4	Nil	>2400	Nil

TDS

The result of the analysis indicates that the TDS values of all treatment methods were above the desirable limits of KEB standards and WHO guidelines of less than 1200 mg/L except CF and cloth filter. In addition, all treatment methods increase the amount of TDS in water except CF. This means that organic materials used in treatment might be partially dissolving in water with a subsequent addition of TDS.

Turbidity

The result of the analysis indicates that the Turbidity values reduced from 221 NTU for raw sample to 3, 3.74, 58.8, 1.06, 4.1, 0, 4.47, and 156 for GGS powder, MS powder, BP ash, PNS ash, CF, SF, boiling, and cloth filter respectively. However, all treatment methods reduced turbidity to within WHO guidelines and KEB standards of less than 5NTU except BP ash and cloth filter.

Total Coliform

The result of the analysis indicates that all treatment methods except GGS powder, PNS ash, SF, and cloth filter had total coliform count of 0 count/100 ml which is within WHO guidelines and KEB standard of 10/100 ml. However, GGS powder and PNS ash had Total coliform count of 1100/100 ml which is the same as the count in raw sample.

Fecal Coliform

All treatment methods except GGS powder, PNS ash, SF, and cloth filter had E. coli count 0 /100 mls, which is the threshold set by WHO guidelines and KEB standards. All other treatment methods had E. coli count of 3, 3, 4, and greater than 2400/100 ml for GGS powder, PNS ash, SF, and Cloth filter respectively which are above the WHO guidelines and KEB standards. However, E. coli count for GGS powder, PNS ash, and SF were below the count in raw sample.

Table 6. Number of parameters passing or within WHO guidelines and KEB Standards after treatment

	Number of parameters passing or within WHO guidelines and KEB Standards							
SampleNo/ Treatment Method	GGS powder	MS powder	BP ash	PNS ash	CF	SF	Boiling	Cloth filter
125-Pond Water	5	5	0	1	7	3	4	3
126-Tana River Water	5	5	0	1	7	3	4	3
127-Ziwani Borehole Water	3	2	3	2	5	3	4	5
128-Garissa Water Supply Tap Water	3	5	3	2	7	2	5	4
TOTAL	16	17	6	6	26	11	17	15

IV. CONCLUSIONS

1. Green gram powder, MS powder, and Pea nut ash have high coagulation properties and removes colour and turbidity effectively. Maximum turbidity reduction was obtained from highly turbid water.
2. Pea nut stalk ash was not effective in removing Total and fecal coliform.
3. Boiling and Ceramic filter were highly effective in removing total coliform and fecal coliform (E.coli) from all types of contaminated water, and can effectively be applied to water with both high and low turbidity with 100% pathogens removal efficiency.
4. Bean pod ash, Ceramic filter, boiling, and cloth filter were very effective in removing total and fecal coliform in water with low turbidity.
5. Bean pod ash treatment was not effective in Pond water and Tana River water samples because their results did not meet WHO guidelines and KEB standards.
6. Ceramic filter water treatment is the simplest, cheapest and most effective technique since it does not require a coagulant and removes most parameters to the required standard.
7. Although each treatment method is effective in different types of water samples, the best treatment method is Ceramic Filter (CF) when used in low turbidity water, and the general order of effectiveness in descending order of effectiveness is Ceramic filter (CF), Boiling, Moringa Seed (MS) powder, Green gram seed (GGS) powder, Cloth filter, Sand filter (SF), Bean Pod (BP)ash and Pea nut stalk (PNS)ash.

ACKNOWLEDGEMENT

The authors would like to thank the Kenya Water Institute for allowing them use their water quality laboratory for this research.

Conflict of Interest: The authors declare no competing interests in relation to the work.

Ethical Statement: The authors declare that they have followed ethical responsibilities.

REFERENCES

[1] G.K. Khadse, M.D. Kalita and P.K. Labhsetwar (2012). Change in drinking water quality from source to point-of-use and storage, Environ. Monit. Assess. Vol.184 (9). pp. 5343-5361.

[2] G.K. Khadse, P.M. Patni, A.V. Talkhande and P.K. Labhasetwar (2015). Surveillance of drinking water quality for safe water supply in urban areas. Int. j. curr. Res. Aca. Rev. Vol. 3(8). pp. 45-50.

[3] WHO/UNICEF JMP (2010). Progress on Sanitation and Drinking water, 2010 Update. Geneva: World Health Organisation (WHO) / New York: UNICEF.

[4] WHO/UNICEF JMP (2008). MDG assessment report: Progress in drinking water and Sanitation. Geneva: World Health Organisation (WHO) / New York: UNICEF.

[5] M. A. Montgomery and M. Elimelech (2007). Water and sanitation in developing countries. Environ. Sci. Technol. Vol. 41 (1), pp. 17–24.

[6] M. A. Shannon, P.W. Bohn, M. Elimelech, J.G. Georgiadis, B.J. Marinas and A.M. Mayes (2008). Science and technology for water purification in the coming decades. Nature. Vol. 452, pp. 301-310.

[7] A. A. M. Lima S. R. Moore, M.S.Jr. Barboza, A.M. Soars, M.A. Schleupner, R.D. Newman, C.L. Sears, J.P. Nataro, D.P. Fedorko, T. Wuhib, J.B. Schorling and R.L. Guerrant (2000). Persistent diarrhea signals a critical period of increased diarrhea burdens and nutritional shortfalls. J. Infect. Dis. Vol. 181(5). Pp. 1643–1651.

[8] J.R. Behrman, H. Alderman and J. Hoddinott (2004). Hunger and malnutrition. In Copenhagen Consensus. Global Crises, Global solutions Ed.1 Cambridge University press.

[9] WHO/UNICEF JMP (2015). Progress on Sanitation and Drinking-Water, 2015 Update. Geneva: World Health Organisation (WHO) / New York: UNICEF.

[10] N. Idika, T. Odugbemi, and F.T. Ogunsola (2002). An assessment of existing common traditional methods of water purification. Afr. J. Clin. Exp. Microbiol., Vol. 3 (1). pp. 41-44.

[11] S. Vigneswaran and M. Sandaravadivel (2004). Traditional and Household water purification methods of rural communities in developing countries. In: EOLSS. Wastewater Recycle, Reuse, and Reclamation, Vol. II, 2004.

[12] O.B. Olayemi and R.O. Olabi (1994). Studies on traditional water purification using Moringa oleifera seeds. Afr. Stud. Monogr. Vol. 15(3). pp. 135-142.

[13] N.J. Marobhe, G. Renman, and G. Jacks (2007). The study of water supply and traditional water purification knowledge in selected rural villages in Tanzania. Tribes and Tribals, Special Volume No. 1. Pp. 111-120.

[14] E.K. Boon and L. Hens (2007). Indigenous knowledge systems and sustainable development: Relevance for Africa. In Tribes and Tribals, Special Volume No. 1**.** Kamala-Raj Enterprises, India.

[15] P.H. Gleick (2002). Dirty Water: Estimated Deaths from Water-Related Diseases 2000-2020. Pacific Institute Research Report.

[16] WHO (2013). Water Quality and Health Strategy 2013-2020. http://www.who. int/water_sanitation_health/publications/2013/water_quality_strategy/en/index.html

