



Research Article

Evaluation of the Effectiveness of Some Local Plants in Purification of Water Samples from Selected Sources

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Abstract

This study evaluates the effectiveness of local plants such as banana peel, watermelon seed, neem leaf and orange peel in treating borehole and well water around Kontagora in Nigeria. Chemical coagulants such as alums present hazard and economic shortcomings in water treatment. They reduce water pH due to their acidic nature, against the pH 6.5 – 8.5 standard recommended for potable water. It is therefore, desirable to replace these chemical coagulants with plant-based ones, which are economic and environmental friendly. This study analysed some physicochemical parameters such as temperature, conductivity, and others, and heavy metals such as Cu, Fe and Pb before and after treatment with plant-based coagulants and alum. From the results, irrespective of water sample type and coagulant, the conductivities measurement before treatment was 28.8 – 30.6 $\mu\text{S}/\text{cm}$, and increased to 34.8 – 48.0 $\mu\text{S}/\text{cm}$ for alum. The range was 37.6 – 48.8 $\mu\text{S}/\text{cm}$ for plant-based. Turbidity before treatment ranged 0.96 – 6.50 NTU and decreased to the range 0.1 – 0.36 NTU for alum and 0.05 – 0.09 for plant-based. Total Dissolved Solid (TDS) before treatment ranged 4.00 – 7.00 mg/L and reduced to 2.15 – 4.00 mg/L for alum, 1.00 – 4.32 mg/L for plant-based. Total Hardness (TH) before treatment showed 28.00 – 32.00 mg/L range, which reduced to 28.00 – 30.00 mg/L for alum, 19.00 – 28.50 mg/L for plant-based. Most parameters, including alkalinity, acidity, BOD, DO, chloride, sulphate, colour and TSS showed improved performance with plant-based coagulants better than alum with values within the WHO standards for drinking water. Heavy metals analysed recorded varied concentrations: Fe in raw borehole water was 0.85 mg/L and reduced to 0.10 mg/L with alum, and 0.1 – 0.27 mg/L range with plant-based coagulants. Fe concentration in well water increased with all treatments, including alum. Cu, Fe and Pb concentrations in raw well water were 0.30 mg/L, 0.05 mg/L and 0.2 mg/L respectively, where Pb concentration was higher than the WHO limit of 0.01 mg/L set for drinking water. Pb was found below detection limit in borehole water. While alum reduced the levels of Cu to 0.07 mg/L, all the plant-based treatments increased its concentration within 0.1 – 0.87 mg/L range, which were below the 1.0 mg/L, WHO limits for Cu in drinking water. From these findings, in no particular order, the plant-based coagulants of banana peel, watermelon leaf and orange peel displayed greater potency for water treatment than neem leaf. Conclusively, all plant-based coagulants used in this study showcased better alternatives than alum.

Keywords

Alum, Banana Peel, Neem Leave, Orange Peels, Purification, Watermelon Seed, Water

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1. Introduction

Water is an essential resource that sustains life. It requires an adequate supply for all lives [1, 2]. It is a multi-purpose agent used by humans for drinking, washing, recreation and in industrial and manufacturing processes [3]. In Africa, boreholes, groundwater- wells, springs, rivers and other local reserves serve as popular sources of drinking water but access to clean, safe and properly treated piped water is low [4]. Urbanisation and anthropogenic practices such as industrialisation and agricultural activities discharge more than 80 percent of wastewater into the environment untreated [2, 5]. These waters go into different natural water bodies while some percolates into the soil and contaminate underground waters. Hence, many people around the world, say one of three persons globally has no access to clean and safe potable water. In Sub-Sahara Africa such as Nigeria, a quarter of the population is denied access to safe drinking water [4].

Consumption of unclean and unsafe water is capable of causing serious challenges to human health and the ecosystems. Wide range of infectious and parasitic water-borne diseases such as diarrhoea, cholera, trachoma, schistosomiasis, elminthiasis, typhoid and dysentery can result from using contaminated water [2, 3]. Several conventional techniques such as coagulation/flocculation which use inorganic/synthetic chemicals have been reportedly employed in water treatment but with shortcomings varying from high costs to the health hazards they impact [3, 6-8]. This prompts the search for sustainable, affordable and eco-friendly alternatives.

Reports have shown that parts of plants are of great importance and good replacements for the synthetic coagulants [3, 4, 8, 9]. Plants are bio-coagulants and are capable of phytoextraction, rhizofiltration, phytostabilization and phyto-transformation/phytodegradation processes [9]. They are biodegradable coagulants that produce less amount (20–30 %) of sludge than the alum treated counterparts [8]. Many plants find their use in water treatments due to their coagulant, disinfectant/antimicrobial and purification properties which are accountable to the presence of different phytochemicals such as phenols, quinones, flavonols, tannins, coumarins and alkaloids in their tissues [3, 10]. It is against this backdrop that in this work, the researchers delve into evaluating the effectiveness of plant parts seeds, peels and leaves of watermelon, banana, orange and neem respectively in the purification of samples of selected well and borehole water around Kontagora town in Niger State.

Water from well and borehole is not 100 percent clean and safe for drinking or for special purposes requiring high level of purity such as pharmaceuticals and clinics [11]. Water from contaminated sources can result in serious health problems for humans and animals especially in areas where access to clean water is limited. In addition, a long term sustainability of clean, pure and safe water supply has been a serious challenge globally at these times when growth in population, agricultural and

economic developments have triggered urbanisation, industrialisation and applications of irrigation water, which have led to pollution and scarcity of clean fresh water [12]. Contaminations by microbes, heavy metals and sediments are major causes of impurity in water and one of the greatest problems faced with humans is lack of cheap and adequate water treatment methods.

Treatment of water by conventional techniques using synthetic chemicals is expensive in terms of infrastructure and energy consumption and is chemically hazardous to lives [13]. These disadvantages make them a problem which needs alternative replacement. Hence, the need to use locally and ubiquitously available plant based resources which are cheap, biodegradable and eco-friendly for water treatment.

This study investigates the effectiveness of some local plant parts: banana peel, watermelon seed, neem leaf and orange peel in purification of water samples from borehole and well water around Kontagora town in Niger State to evaluate their efficacies in removing contaminants from the water samples, assess the impact of plant treatment technique on the physico-chemical properties of water samples and compare the results/performance of plant based treatment with conventional alum water treatment.

2. Materials and Methods

All chemicals and reagents were of analytical grades (Analar) and distilled water was used throughout the research. All glassware and plastic containers were washed with detergent and 10 % trioxonitrate (V) acid, rinsed with tap water and finally with distilled water, then allowed to dry for 24 hours.

2.1. Collection of Samples

2.1.1. Collection of Plants' Parts

Neem leaves were collected freshly raw at their natural habitats around Federal University of Education, Kontagora Botanical Garden and watermelon seeds, orange and banana peels were collected from their fruits purchased in substantial quantities from vendors at Old Market in Kontagora town, Niger State, Nigeria. All the samples were taken to the laboratory for further pre-treatments.

2.1.2. Collection of Water Samples

Water samples were collected from different locations around Kontagora town separately in a cleaned and sterilized two litre plastic bottle. The water samples were then transported to the laboratory for further treatments. The samples are coded as:

WTA = Well water treated with alum

RBW = Raw borehole water

RWW = Raw well water

BHTBP = Borehole water treated with Banana Peel
 WTBP = Well water treated with Banana Peel
 BHTA = Borehole water treated with alum
 BHTWMS = Borehole Water treated with watermelon seed
 WTWMS = Well water treated with watermelon seed
 BHTNL = Borehole water treated with Neem leaf
 WTNL = Well water treated with Neem leaf
 BHTOP = Borehole water treated with Orange peel
 WTOP = Well water treated with Orange peel

2.2. Samples Preparation

With slight modification, the methods employed by Danta *et al* [14] was adopted. The collected fruity plants and neem leaves were cleaned and rinsed with clean water, followed by distilled water, to remove any traces of sand and other dirt that accompanied them. They were sun-dried for 1 h and the fruity plants were peeled to obtain the peels and seeds. The neem leaves, peels and seeds were further dried for 48 h to a constant weight. The dried samples were separately pulverised, carefully transferred into labelled airtight containers and stored in a refrigerator at 4 °C prior to experimental analysis. Collected water samples were also stored in the refrigerator, prior to experimental procedure.

2.3. Experimental Procedure

2.3.1. Determination of Physicochemical Parameters

Exactly, 0.5 g of each of the plant samples was added to 250 cm³ of the water samples contained in 1000 cm³ beakers. The mixture was stirred continuously for 25 minutes and was left undisturbed for 2 h for sedimentation to take place and then filtered. Each filtrate was analysed for its physicochemical properties: temperature, pH, conductivity, turbidity, total hardness, total dissolved solids, alkalinity, chlorides, sulphates, Biological Oxygen Demand (BOD), Dissolved Oxygen (DO) and Total Suspended Solids (TSS) using different modified analytical methods.

1) Temperature

Temperature was measured using a mercury thermometer. The thermometer was dipped into the samples for 1 minute. Readings for each sample was taken and recorded.

2) pH and Conductivity

With slight modification of Owamah *et al.* [15] for pH measurement, cell electrode of pH meter was calibrated with buffers 4, 7 and 9. The electrode was cleaned and rinsed with distilled water before immersing it in the sample. pH for each sample was read and recorded. Same procedure was repeated for the electrical conductivities of each sample, using conductivity meter [16].

3) Turbidity

With slight modification, Hadadi *et al.* [17] method was adopted. Sample cells were filled with the samples and capped, placed into the cell holder of the turbidimeter and covered

tightly with the instruments cap. Turbidity levels were read and recorded.

4) Total Hardness (TH)

With slight modification, TH was determined using the methods of Michael-Igolima *et al.* [16]. Exactly 100 cm³ of each sample was measured and transferred into conical flask. 3 drops of Erichrome black T indicator was added to give purple colour and titrated against 0.10 mol/dm³ EDTA contained in the burette until colour changed to blue.

5) Total Dissolved Solids (TDS) (Gravimetric Method)

With slight modification, Khettaf *et al.* [18] method was adopted. Evaporating dishes were oven-dried to constant weight and recorded. Exactly, 100 cm³ of each treated samples was measured and transferred into the evaporating dishes. The dishes with the contents were dried further in an oven and then allowed to cool. After cooling, the weights were taken and recorded.

6) Alkalinity

A modified method of Shailesh [19] was used. A known volume, 50 cm³ of each treated water sample was measured and transferred into conical flask. 2 drops of methyl orange was added and titrated against 0.02 mol /dm³ HCl contained in the burette until orange end point was observed.

7) Chloride

By modifying the method used by Dragana *et al.* [20], exactly, 100.00 cm³ of each sample was measured and transferred into 250 cm³ conical flask and 2 cm³ of K₂CrO₄ indicator was added and titrated against 0.02 mol/dm³ AgNO₃ contained in the burette until a colour change was observed.

8) Sulphate (Gravimetric Method)

Using the method of Ismail *et al.* [21] with modification, exactly 50.00 cm³ of each sample was measured and transferred into 250 cm³ beaker and 1: 1 HCl was added into the sample and stirred. 3.00 cm³ of BaCl₂ solution was added and mixed thoroughly. The mixture was left undisturbed for 10 minutes for precipitation formation. The precipitate was filtered off, washed with distilled water, oven dried and weighed. Value was taken and recorded.

9) Biological Oxygen Demand

Combined methods of Adelodun *et al.* [22] and Aziz *et al.* [23] were modified for BOD determination. Exactly, 200 cm³ of each sample was measured and transferred into five (5) different conical flasks. Exact volumes, 1.00 cm³ of MnSO₄ and 1.00 cm³ of alkali-ioded-azide solution were transferred into BOD bottles and the caps closed. These were incubated for 120 h prior to decantation. 2.00 cm³ of ortho-phosphoric acid was added and titrated against 0.025 mol/dm³ sodium thiosulphate until the color turned colorless.

10) Dissolved Oxygen

Methods described by Aziz *et al.* [23] was adopted with slight modifications, to determine the DO. Exact volume, 200 cm³ of treated water sample was transferred into conical flask and 1.00 cm³ of MnSO₄ and 1.00 cm³ of alkali-ioded-azide solution were added and shaken. The mixture was kept undisturbed for 5 minutes within which there was emergence of

brownish colour. Each solution was decanted and 2.00 cm³ of orthophosphoric acid was added and titrated against 0.025 mol/dm³ sodium thiosulphate until the color turned colorless.

11) Total Suspended Solids (TSS)

Using the method employed by Patdu *et al.* [24], exactly 20 cm³ of treated water sample was transferred onto a pre-weighed glass fiber filter before starting the vacuum filtration process. The filter was removed after filtration process was completed and placed in an aluminum dish in an oven at 100 °C for 3 hours to completely dry off the remaining water. The filter was then weighed and the gain in filter weight was recorded as the TSS contents expressed in mass per volume of sample filtered (mg/L).

2.3.2. Determination of Heavy Metals

Heavy metals were analysed using Atomic Absorption Spectrophotometer (AAS) – AAnalyst 2. The treated and untreated water samples were digested with 16 cm³ concentrated

HNO₃. Exactly 50 cm³ of each sample was measured and transferred into a 25 cm³ conical flask. Each sample mixture was then subjected to heating on a hot water bath for 30 minutes. The various samples were removed and allowed to cool and then further digested with distil water and made up to level mark in 100 cm³ sample bottle, and then subjected to AAS Analysis where different hollow cathode lamps were used for metal determinations. The standard solution for each element under investigations were equally prepared and used in calibration [25, 26].

3. Results and Discussion

3.1. Physicochemical Parameters Measurement

The results of the physicochemical parameters determined are represented in Tables 1 to 5.

Table 1. Physicochemical Analysis of Raw and Alum Treated Borehole and Well Water Samples.

Parameters	RBHW	BHTA	RWW	WTA	PL
Temperature (°C)	27	25	30	27	Ambient
Conductivity (µs/cm)	28.8	48	30.6	34.8	100
Turbidity (NTU)	0.96	0.10	6.50	0.36	5.0
TDS (mg/L)	4.00	2.15	7.00	4.00	500
pH	6.9	3.54	6.6	3.44	6.5 - 8.5
Acidity	40.00	20.00	62.00	26.00	
Alkalinity	30.00	26.18	38.00	29.45	600
Total Hardness (mg/L)	28.0	28.0	32.0	30	150
BOD (mg/L)	4.6	3.24	4.23	4.00	5.0
DO (mg/L)	4.1	4.0	6.5	4.6	5.0
TSS (mg/L)	30.00	4.00	45.00	5.00	25.00
Chloride (mg/L)	72.4	89.9	107.92	147.68	250
Sulphate (mg/L)	27.98	29.63	32.92	37.04	100
Appearance	Clear	Clear	Clear	Clear	Clear
Odour	Odourless	Odourless	Odourless	Odourless	Odourless
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Colour (PLCO)	22	16	35	18	50

PL = Permissible Limits, Source: [27].

Table 2. *Physicochemical Analysis of Borehole and Well Water Samples Treated with Banana Peels.*

Parameters	BHTBP	WTBP
Temperature (°C)	28.0	30.0
Conductivity (µs/cm)	38.20	48.41
Turbidity (NTU)	0.05	0.07
TDS (mg/L)	2.4	3.0
pH	7.9	6.8
Acidity	29.12	30.00
Alkalinity	22.00	35.00
Total Hardness (mg/L)	22.50	27.14
BOD (mg/L)	4.2	3.0
DO (mg/L)	3.1	5.0
TSS (mg/L)	4.0	4.7
Chloride (mg/L)	78.11	113.60
Sulphate (mg/L)	21.48	24.27
Appearance	Clear	Clear
Odour	Odourless	Odourless
Taste	Tasteless	Tasteless
Colour (PLCO)	25	39

Table 3. *Physicochemical Analysis of Borehole and Well Water Sample Treated with Watermelon Seed.*

Parameters	BHTWMS	WTWMS
Temperature (°C)	26	28
Conductivity (µs/cm)	37.6	39.00
Turbidity (NTU)	0.09	0.08
TDS (mg/L)	1.00	1.20
pH	7.6	7.1
Acidity	45.00	50.00
Alkalinity	20.00	29.00
Total Hardness (mg/L)	19.00	27.00
BOD (mg/L)	3.4	4.6
DO (mg/L)	3.2	5.1
TSS (mg/L)	3.0	4.0
Chloride (mg/L)	74.32	114.7
Sulphate (mg/L)	16.50	23.78
Appearance	Clear	Clear
Odour	Odorless	Odorless
Taste	Tasteless	Tasteless

Parameters	BHTWMS	WTWMS
Colour (PLCO)	27	36

Table 4. *Physicochemical Analysis of Borehole and Well Water Samples Treated with Neem Leaf.*

Parameters	BHTNL	WTNL
Temperature (°C)	28.4	30.0
Conductivity (µs/cm)	48.2	48.8
Turbidity (NTU)	0.47	1.08
TDS (mg/L)	1.04	4.32
pH	7.5	7.1
Acidity	28.30	42.34
Alkalinity	20.00	25.80
Total Hardness (mg/L)	20.00	30.25
BOD (mg/L)	3.4	5.0
DO (mg/L)	3.1	4.5
TSS (mg/L)	3.0	4.0
Chloride (mg/L)	79.63	115.62
Sulphate (mg/L)	18.50	27.60
Appearance	Clear	Clear
Odour	Odourless	Odourless
Taste	Tasteless	Tasteless
Colour (PLCO)	29	39

Table 5. *Physicochemical Analysis of Borehole and Well Water Samples Treated with Orange Peel.*

Parameters	BHTOP	WTOP
Temperature (°C)	29.4	30.7
Conductivity (µs/cm)	41.3	38.8
Turbidity (NTU)	0.08	0.09
TDS (mg/L)	2.00	4.00
pH	7.4	6.8
Acidity	24.00	27.10
Alkalinity	20.00	25.00
Total Hardness (mg/L)	23.80	28.50
BOD (mg/L)	2.05	4.10
DO (mg/L)	4.40	5.02
TSS (mg/L)	3.00	5.01
Chloride (mg/L)	73.50	109.82

Parameters	BHTOP	WTOP
Sulphate (mg/L)	16.46	24.69
Appearance	Clear	Clear
Odour	Odourless	Odourless
Taste	Tasteless	Tasteless
Colour (PLCO)	26	39

3.1.1, Temperature Levels

From Table 1, temperature of water samples ranged from 25 °C for BHTA to 30 °C for RWW. Alum-treated borehole and well water samples showed lower temperatures 25 °C and 27 °C respectively than their corresponding raw samples with temperatures 27 °C and 30 °C respectively. RWW with higher temperature of 30 °C than 27 °C RBHW could be due to difference in depth of the sources of sampled water. Table 2 showed BHTBP with a degree unit temperature, 28 °C higher than RBHW 27 °C. WTOP maintains the same temperature with RWW, which implied no significant effect of addition of the plant coagulant on water. Table 3, showed 1 °C and 2 °C reduction in the temperatures of BHTWMS and WTWMS respectively than their corresponding RBHW and RWW samples. Tables 4 and 5 revealed slightly higher temperature difference in the neem leaf and orange peel-treated water samples than their corresponding raw water samples. Generally, this study revealed that alum-treated water samples had lower temperatures than the plant coagulants treatments. This observation could be attributed to endothermic reaction associated with alum hydrolysis, which takes place during water purification processes.

3.1.2. Conductivity Values

Table 1 shows conductivities 48.0 µs/cm and 34.8 µs/cm for BHTA and WTA respectively higher than their respective 28.8 µs/cm and 30.6 µs/cm for RBHW and RWW. Tables 2, 3, 4 and 5 revealed conductivities of plants-treated borehole water samples with a range 37.6 to 48.2 µs/cm irrespective of plant type, lower than the BHTA 48.0 µs/cm. This could be due to the biosorbent nature of the plants, that possess certain functional groups such as -COOH, -OH and -NH₂, which are responsible for ion exchange of metal ions in water for H⁺ ions, thereby removing the cations by sticking to the surface and pull out of water. However, BHTNL showed conductivity 48.2 µs/cm slightly higher than BHTA. On the contrary, all plant-treated well water samples showed higher conductivities ranging 38.8 – 48.8 µs/cm, irrespective of plants than the alum-treated well water, 34.8 µs/cm. This could be due to the ability of alum to hydrolyse to form Al(OH)₃, which has a positive surface charge and adsorbs negative ions like phosphates and sulphates to form fluffy flocs with huge surface area. This

drops the total ions load and decreases the conductivity. However, conductivity results obtained in this study are lower than the 100.0 µs/cm value recommended by the World Health Organisation (WHO) for potable water.

3.1.3. Turbidity Levels

The turbidity results of this study showed reduction for both alum-treated borehole and well water samples from 0.96 NTU in RBHW and 6.50 NTU in RWW to 0.10 NTU and 0.36 NTU respectively (Table 1). All plants treated borehole and well water samples showed further reduction in turbidity ranging from 0.05 to 0.09 NTU for the former and 0.07 to 0.09 NTU for the later (Tables 2, 3 and 5). In Table 4, BHTNL and WTNL however, showed contrary results of 0.47 NTU and 1.08 NTU respectively, which were higher than the corresponding BHTA (0.10 NTU) and WTA (0.36 NTU). This implied that banana peel, watermelon seed and orange peel are more efficient in removing tiny suspended particles from the water samples than neem leaf. In other words, the order of efficiency purifiers of the water samples with respect to treatment is banana peel > orange peel > watermelon seed > alum > neem leaf for borehole water, and banana peel > watermelon seed > orange peel > alum > neem leaf. The turbidity results obtained in this study are however; lower than the WHO recommended value of 5.0 NTU, except for the raw well water (6.50 NTU).

3.1.4. Total Dissolved Solids (TDS) Levels

In Table 1, the TDS in RBHW, 4.00 mg/L is lower than in RWW, 7.00 mg/L, and alum reduced the TDS in both to 2.15 mg/L and 4.00 mg/L respectively. Except banana peel, with slightly higher TDS value of 2.4 mg/L than obtained for alum, 2.15 mg/L (Table 2), all other plant types reduced TDS further in borehole water samples within the range 1.00 to 2.00 mg/L with effectiveness of the order watermelon seed > neem leaf > orange peel > banana peel (Tables 2, 3, 4 and 5). This implied that the plants are effective for removing solid particles from the water. Well water samples also reflected similar results, but with neem leaf (4.32 mg/L) showing slightly less effectiveness than alum (4.00 mg/L) with respect to TDS reduction. The order of effectiveness of plant types for TDS reduction in well water was watermelon seed (1.20 mg/L) > banana peel (3.00 mg/L) > orange peel (4.00 mg/L) > neem leaf (4.32

mg/L). TDS values obtained in this study are however significantly much less than 500 mg/L recommended by the WHO for potable water.

3.1.5. pH Values

The pH values obtained in this study were within the neutral range 6.6 to 7.9 (slightly acidic /alkaline) for all water samples, treated with plants and the untreated raw water as shown in Tables 1 to 5. However, alum-treated borehole and well water samples tended towards increased acidity in the range 3.44 to 3.54 from the later to the former. The reason for this may be that, for every Al^{3+} in alum, three H^+ ions are released. Thus, this suggests that plants are more appropriate in water treatment than alum, having recorded pH values around the recommended range 6.5 to 8.5 set by the WHO for drinking water.

3.1.6. Total Hardness (TH) Values

Total hardness (TH) of the raw water samples ranged from 28.0 mg/L in borehole water to 32.0 mg/L in well water (Table 1). These values however, decreased with treatments, which showed better results for plants (19.0 to 23.8 mg/L) than alum (28.0 mg/L) for borehole water samples (Tables 2 to 5). Same results were obtained for plants-treated well water samples having TH reduced in the range 27 to 28.5 mg/L, but not significantly better than 30 mg/L alum (Tables 2 to 5). These observations yet suggest better performance of plants as water purifiers than alum in terms TH reduction, asides their toxicological friendliness. TH concentrations obtained in this study are lower than the 150.0 mg/L recommended by WHO.

3.1.7. Biochemical Oxygen Demand (BOD) Levels

BOD is a measure of the amount of dissolved oxygen needed by aerobic water microbes to stay alive to degrade biodegradable organics at certain temperature over a specific period of time [28]. In Table 1, the BOD measurement of raw borehole and well water samples were 4.6 and 4.23 respectively. These values were brought down in alum treatment to 3.24 and 4.00 respectively. This implied that alum reduced the organic pollutant in the water samples. Nonetheless, in Tables 2 to 5, borehole water showed higher BOD values ranging 3.40 – 4.20 irrespective of type of plants treatments than alum. Orange peel recorded lowest BOD of 2.05 for borehole water. This implies that orange peel cleans the water better than other plant types and alum. On the other hand, banana peel recorded the lowest BOD value 3.0 for well water (Table 2) and highest of 5.0 against neem leaf (Table 4). Generally, with the exception of orange peel in borehole water and banana peel in well water, alum showed better performance for BOD reduction than other plant types for both samples of water. As revealed in Table 4, neem leaf may not be suitable for purification of well water in terms BOD because the plant recorded the same BOD value as that of WHO recommended value of 5.00 for potable water.

3.1.8. Dissolved Oxygen (DO) Levels

DO values indicate the degree of pollution in the water bodies. Dissolved Oxygen in this study as in Table 1 is 4.1 mg/L in RBHW and 6.5 mg/L in RWW. These values were slightly reduced by alum to 4.0 mg/L in BHTA and significantly to 4.6 mg/L in WTA. Drop in DO as observed for plants-treated borehole water samples indicates poor water treatment by banana peel, watermelon seed and neem leaf (3.1 to 3.2 mg/L). Good treatment of water was however offered by orange peel (4.4 mg/L). DO values of 5.0 to 5.02 mg/L for plant-treated well water showed better water treatment but slightly higher than the WHO recommended limits of 5.0 mg/L. Generally, banana peel, watermelon seed and orange peel generally showed prospect for well water treatment better than alum and other plants.

3.1.9. Total Suspended Solids (TSS) Levels

The TSS values in this study were 30 mg/L in raw borehole water and 45 mg/L in raw well water (Table 1). After successive treatments with plants and alum, there was huge decrease in TSS values 3.00 to 5.01 mg/L irrespective plant type, treated water samples and treatment method (Tables 2 to 4). These values were fairly lower than the 4.0 mg/L shown for alum-treated borehole water and 5.0 mg/L for alum-treated well water samples. This implied that the plants have better performance than alum, in terms of suspended solids removal for potable water. The values of all treated samples were much lower than the TSS value of 25 mg/L recommended by WHO for drinking water.

3.1.10. Chloride and Sulphate Levels

Chloride levels ranged from 72.40 mg/L in raw borehole water to 147 mg/L in alum-treated well water (Table 1). Chloride ions in alum-treated borehole water was higher (89.90 mg/L) than the raw value 72.40 mg/L, and it was lower in plants-treated borehole water in the range 73.5 to 89.90 mg/L, irrespective of plant type (Tables 1 to 5). In the same vein, Cl^- ions in alum-treated well water was higher (147.68 mg/L) than the raw value 107.92 mg/L, and it was lower in plants-treated borehole water in the range 109.82 to 115.62 mg/L, irrespective of plant type than alum-treated water (Tables 1 to 5). This observation could be traced to the release of Cl^- ions from alum itself: – since some commercial alum grades have Cl^- ions in them. All chloride values obtained in this study were below the recommended specification of 250 mg/L set by the WHO.

Sulphates levels in Table 1 in RBHW and RWW were 27.98 mg/L and 32.92 mg/L respectively. These concentrations increased with the alum-treated samples to 29.63 mg/L and 37.04 mg/L respectively. This could be due to release of SO_4^{2-} ions from alum into the samples. However, sulphates concentrations decreased with all the plants-treated borehole (16.46 to 21.48 mg/L) and well (23.78 to 27.60 mg/L) waters studied

(Tables 2 to 5). This could be attributed to the biosorbent nature of the plant materials, adsorbing sulphate ions onto their surfaces thereby, removing the ions from water. All these concentration levels are however; lower than the acceptable limit of 100 mg/ L sulphate recommended by the WHO.

3.2. Heavy Metals Determination

Heavy metals analysis of the water samples was carried out. Result of analysis is presented in Table 6.

Table 6. Heavy Metal Analysis of Water Samples.

Heavy Metal (mg/L)	RBH W	BHTA	RWW	WTA	BHTBP	WTBP	BHTW M	WTWMS	BHTNL	WTNL	BHTOP	WTOP	PL
Cu	ND	ND	0.30	0.07	ND	0.10	ND	0.15	ND	0.10	0.60	0.87	1.00
Fe	0.85	0.10	0.05	0.30	0.10	0.20	0.20	0.18	0.10	0.30	0.27	0.29	0.30
Pb	ND	ND	0.20	ND	ND	ND	ND	ND	ND	ND	ND	0.0042	0.01

PL = Permissible Limit, Source: [27]. ND = Not Detected

Copper (Cu) and lead (Pb) were not detected in the borehole water but iron (Fe) was detected at 0.85 mg/L level. Fe level was lower in water treatment with alum with a value of 0.10 mg/L. It was observed that all plants-treated borehole water retained/increased Fe levels within the range 0.1 to 0.27 mg/L from banana peel/neem leaf to orange peel treatments. This observation could be as a result of leaching of Fe originally contained in the plants into the water. Therefore, the needs for lower dosage application of these plant materials for treatment is required, as higher dosage could increase the Fe levels above the WHO permissible level of 0.30 mg/L recommended for Fe in potable water.

Cu, Fe and Pb were discovered in raw well water at concentrations 0.30 mg/L, 0.05 mg/L and 0.2 mg/L respectively. Here, Pb recorded a concentration higher than the WHO set limit of 0.01 mg/L recommended for drinking water. While alum reduced the levels of Cu to 0.07 mg/L, all the plants treatments increased its concentration within the range 0.1 to 0.87 mg/L, which were lower than the WHO permissible limits of 1.0 mg/L recommended for Cu in drinking water.

Fe concentration in well water increased with all treatments, including alum. Although, the reason Fe increased with alum is not clear, it may however, be due to pH drop triggered by the alum.

Reports have it that Pb in drinking water is unsafe, especially for children. However, all treatments were observed to significantly reduce its levels, even with some, below detection. Nevertheless, Pb concentration in raw well water was 0.2 mg/L, a concentration which is higher than the WHO recommended limits of 0.01 mg/L.

In Tables 1-5, all the water samples reflected no objectionable appearances: They were all odourless and tasteless. They all displayed colour (PLCO) in the range 36 – 39, which is within the WHO recommended allowable limits of 50 set for potable/drinking and clean water.

4. Conclusion

The quality of the water consumed is essential to human wellbeing and development. Unfortunately, raw underground or surface water does not always meet the required criteria in terms of chemical and microbiological quality. Therefore, water must be treated before it is consumed. Coagulation-flocculation is one of the most widely used processes for the treatment of raw water, as it is efficient and simple to implement. Its implementation requires coagulants. Chemical coagulants present a danger for humans and the environment; hence the need to find an alternative. Plant-based coagulants: seeds, peels and leaves promise to be human, economy and environment friendly.

In this study, for different physicochemical parameters and heavy metals analysed, banana peels, watermelon seeds, neem leaf and orange peels have shown great potential for water treatment for human consumption. Some of the plants understudied are better for different properties associated with safe drinking water than the conventional alum, which have been proven to be harmful to humans and animals at certain concentrations. However, use of plant parts may not be too palatable for metals removal from waters, since they naturally contain some of the metals, which get leached into water. This may increase their concentrations and surpass the recommended permissible limits set for drinking water, if care is not taken.

Finally, it is recommended that plants parts such as the ones used in this study, be harnessed, for their characteristics bio-friendliness, ubiquitousness and cheapness, at scalable levels

in water plants for municipal water treatment and purification, especially in Kontagora town where wells and boreholes serve as their main sources of water.

Abbreviations

RBHW	Raw Borehole Water
WTA	Well Water Treated with Alum
BHTBP	Borehole Water Treated with Banana Peel
BHTWMS	Borehole Water Treated with Watermelon Seed
WTNL	Well Water Treated with Neem Leaf
BOD	Biological Oxygen Demand
DO	Dissolved Oxygen
TH	Total Hardness
AAS	Atomic Absorption Spectrophotometer
NTU	Nephelometric Turbidity Unit
RWW	Raw Well Water
BHTA	Borehole Water Treated with Alum
WTBP	Well Water Treated with Banana Peel
WTWMS	Well Water Treated with Watermelon Seed
BHTNL	Borehole Water treated With Neem Leaf
BHTOP	Borehole Water treated With Orange Peel
WTOP	Well Water Treated with Orange Peel
COD	Chemical Oxygen Demand
TSS	Total Suspended Solids
TDS	Total Dissolved Solids
PL	Permissible Limits
WHO	World Health Organisation

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Conflicts of Interest

The authors declare no conflicts of interest.

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