Purification of Water using Local Plants: An Effective Innovation Method for Water Treatment

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Abstract

This study evaluated the effectiveness of locally available plants and Aluminium sulphate (Alum) in the treatment of borehole water and well water within Kontagora, Niger State. Analysis of the physicochemical parameters such as temperature, conductivity, turbidity, colour pH, TDS, TSS, BOD, DO, Chloride, Sulphate, Hardness, Alkalinity and Acidity were carried out. Heavy metals such as Cu, Fe and Pd were also analysed before and after purification of two water samples with two different coagulants of plants origin (Moringa Oleifera and Hibiscus seed). The electrometric, gravimetric, and titrimetric methods were used for the analysis of physicochemical parameters while, the concentrations of heavy metals were determined using Atomic Absorption Spectrophotometer (AAS). The conductivity and TDS values for both raw water samples ranges from 28.8 us/cm to 30.6 us/cm and 4.00 mg/l to 7.00 mg/l respectively. The hardness, alkalinity and acidity ranges from 28.0 mg/l to 32.0 m/l, 30.0 mg/l to 38.0 mg/l and 26.0 mg/l to 62.0 mg/l respectively. The BOD, DO, chloride, sulphate, TSS and colour ranges from 40 mg/l to 4.2 mg/l, 4.0 mg/l to 4.5 mg/l, 72 mg/l to 107.0 mg/l, 27.92 mg/l to 32.46 mg/l, 22 mg/l to 35 mg/l and 30 mg/l to 45 mg/l respectively. The pH ranges from 6.9 to 6.6 respectively. The turbidity ranges from 0.96 to 6.50 respectively. The value of copper in raw Well water sample was 0.3 mg/l, copper was not detected in borehole raw water sample, and iron content ranges from 0.85 mg/l to 0.05 mg/l, which showed that iron content in raw water is higher than the recommended value by WHO, 0.3 mg/l, while lead in raw well water sample was 0.02 mg/l, was not detected in borehole raw water sample. Hence, the findings showed that natural coagulants plants were capable, effective, faster and easier than synthetic coagulants (e.g Alum) in water treatment, thus, creating an alternative means for water purification.

Keywords: Alum, Hibiscus, Moringa, Purification and Water

Introduction

Developing countries and third world countries are facing portable water supply problems because of inadequate financial resources. The cost of water treatment is increasing and quality of borehole and shallow well water is not stable due to suspended and colloidal particles caused by land development and effluents material released by different human activities and industries into the environment or by some domestic activities or high run off, which leads to high cost of treatment in which the purification of water companies cannot sustain (Mohammed *et al.,* 2017). As a result, the drinking water that reaches the consumer is not properly treated. Therefore, it is of great importance to find a natural alternative for water coagulant to purify drinking water. It has been found that *Moringa Oleifera*, Banana Peel, Mango leaf, Neem leaf, Water-melon seed and so on and natural coagulant discovered yet, that can replace aluminum sulphate (Alum) that are used widely around the world (Mc Comachie *et al.*, 2004).

Portable drinking water is the most precious of all natural resources. Portable water as defined in advanced learner's dictionary 7th edition, as water that is safe to drink. Another edition of the advanced learner's dictionary defined clean water as water that is fit to drink. Water is next to air, it is the most need of man, and in spite of the considerable investment of Governments in Nigeria over the years in this essential human requirements a large population still does not have access to water in adequate quality and quantity (Mohammed *et al*., 2017). Water-borne diseases are one of the major problems in developing countries; about 1.6 million people are compelled to use contaminated water (Mohammed *et al.,* 2017). This is due to the level of pollutants in surface and underground water, since a large proportion of rural and urban dwellers in Nigeria obtain domestic water and sometimes drinking water from ponds, boreholes, well water (Adekunle *et al.*, 2015). The discharge of wastewater onto surface water and the resultant deleterious change in water ecology have been reported be several researchers (Olayemi, 2011). World Health Organization (WHO) also expressed concern over human health and pathogenic micro-organism by aquatic organisms. Some of these diseases have been traced to the use of water grossly polluted by waste. The consequences of which include 4.6 million deaths of people by diarrhea diseases and sizeable number of casualties from *ascariasis* (APHAs, 2012). Hospitals records have confirmed high incidence of typhoid, cholera, dysentery, infectious hepatitis and guinea worm in both rural and urban settlements in Nigeria (Kajogbola, 2014). This is because many communities of this country do not use water purification methods like coagulation, flocculation and sedimentation due to high cost or low availability of chemical coagulants such as aluminium sulphate and ferric salts. The natural coagulant found in *Moringa oleifera* seed, Banana peel, Neem leaf and water melon seed is present of the 14 species of above local plants in many parts of Africa, India and Arab nations. For example, the people of Sudan have used the seed of *moringa oleifera* for water purification since the beginning of the 20th century by surling the seeds in cloths, bags with water for a few minutes and allowing it to settle for an hour. Scientifically, the coagulant properties of *Moringa oleifera* seeds were first confirmed by a German scientist Samia Al-azharia John (Muyibi *et al*., 2003). The active component, a protein, acts as a Cationic Polyelectrolyte, which attaches to the soluble particles and creates bindings between them, leading to large flocs in the water Muyibi *et al*., 2003). Stirring and mixing was found to accelerate the electrostatic flocculation, and the flocs condense the contaminants (Muyibi, *et al.,* 2012). So far, there has not been much use of these natural coagulants such as the seeds of water melon, *Moringa oleifera* , banana peel in Nigeria for purification of raw water (Ndabigengesere, and Narasiah, 2017).

Materials and Methods

Apparatus/Equipment

Beakers, spatula, filter papers, siever, measuring cylinder, analytical weighing balance, mortar and pestle, electric blender, pH meter, thermometer, electric hot plate, cloth and whatman filter paper, plastic bottles, stop watch, turbidity meter, conical flask, stirring rod, burette, dried oven,

Pipette, conductivity meter, tripod stand, water Bath, AAS Machine were used.

Reagents/Materials

Distilled water, Aluminium sulphate, Tetraoxosulphate (vi) acid, Sodium hydroxide, Calcium hydroxide, Natural local plants, Borehole water, Well water, Buffer pH, Methyl orange, Phenolphthalein indicator, Barium chloride ($BaCl_2$), Ammonium chloride (NH_4Cl), Ammonium hydroxyl (NH_4OH), Sodium thiosulphate ($Na_2S_2O_3$), Sliver Nitrates ($AgNO_3$), Nitric acid (HNO_3), Potassium dichromate (K_2CrO_4), Ethylene diammine tetracetate (EDTA) $C_{10}H_{16}N_2O_8$, Lead salt ($PbCl_2$), Copper salt ($CuCl_2$) were used.

Collection of Water Samples

Samples were collected from a well located at life-camp, state lowcost along FCE Kontagora in two plastic bottles of two litres each and, borehole water at FCE. Kontagora Campus were collected in two plastic bottles of two litres, and transported to the laboratory for further analysis.

Collection of Plants Materials

The *Moringa oleifera* seed and *Hibiscus seeds* were bought at old market Kontagora.

Preparation /Treatment of Local Plants Powders.

The collected plants were cleaned and rinsed with distilled water to remove any traces of sand and other dirts that may accomplish the plants. It was then sun-dried for two days and grounded into a fine powder using a pestle and mortar to obtain a coagulant powder.

Experimental Procedure

Exactly, 0.5 g of each of the local plant fine powder was added to 250 ml of the water samples contained in 1000 ml of beakers. This was stirred continuously for 25 minutes for the purification to take place. It was then left undisturbed to settle for 2 hours. After the settlement of the water treatment, the water was then filtered and measured. The physicochemical parameters and Alkalinity and Acidity were carried out as contained in Ademorati (1996) and APHA (2012), and the heavy metals of each treated water sample were determined using Atomic Absorption Spectroscopy.

Temperature

The temperature was measured using a mercury thermometer. The thermometer was dipped into the sample and allowed to stay for 1minutes and, the readings were recorded for each sample.

pH and Conductivity

This was done by instrumental analysis. The pH electrode conductivity machine was switched on, each tested sample was taken into the beaker, and the cell electrode was then calibrated with buffer 4, 7, and 9 in other to sensitize it with acid, neutral and basic condition. The cell was wiped with tissue paper and rinsed with distilled water. The electrode was immersed in the sample and the pH value was read from the pH meter screen. The test sample was also taken in to the beaker and the electrode was immersed in the sample and readings of pH and conductivity were recorded respectively, for each sample.

Turbidity

The sample cell was filled with the sample and was capped. The sample cells was placed into the cell holder of the turbid meter and covered tightly with the instruments cap. Therefore, the value was read and recorded.

Total Hardness

100 ml of sample was measured and transferred into conical flask and 3 drops of Erichrome black T indicator was added to give purple color. 0.1M of EDTA was poured into the burette and titrated against the water sample until the color change to blue at the end point and the readings were recorded.

Total Dissolved Solids (Gravimetric method)

The evaporation dishes were cleaned and dried inside the oven for about 30 minutes and weighed, they were then removed and 100 ml of each sample was measured and poured into each of the evaporation dishes. These were taken to the oven for drying. After total dryness, they were removed and allowed to cool and then weighed and readings were recorded.

Alkalinity

50 ml of each water samples was measured and poured into conical flask and 2 drops of methyl orange were added and the color change was observed. 0.02 M of HCl was poured into the burette and titrated against the sample which changes to orange end point and readings were recorded.

Chloride

Exactly 100 ml of each sample were measured and poured into 250 ml conical flask and 2 ml of K_2CrO_4 indicator was added into water samples. The color changes to yellow, 0.02 M of silver nitrate ($AgNO_3$) was titrated against the each sample and the color changes to brick red at end point.

Sulphate (Gravimetric Method)

50 ml of each sample was measured into measuring cylinder and poured into the beaker and 1:1 HCl was added into the sample and stirred. Three (3) ml of Barium chloride solution was added and mixed thoroughly. This was allowed for 5-10 minutes for precipitation formation. The precipitate was filtered off and washed with distilled water and then oven dried and weighed.

Biological Oxygen Demand and Dissolve Oxygen

Five (5) conical flasks were washed and 200 ml of each water sample was measured in measuring cylinder and transferred into the flasks and 1 ml of $MnSO_4$ and 1 ml of alkali-ioded-azide solution was then poured into the BOD bottles and the cap was closed. It was incubated for 5 days. Then it was decanted and 2 ml of orthophosphuric acid was added and titrated against 0.025 M sodium thiosulphate until the color changed to colorless. For Dissolve Oxygen (DO) 200 ml of sample was poured in each flask and 1 ml of $MnSO_4$ and 1 ml of alkali-ioded-azide solution were added and shaken also allowed to settle for 5 minutes a brownish color formed. Then , each solution were decanted and 2 ml of orthophosphuric acid was added and titrated against 0.025 M sodium thiosulphate at end point when the color changed to colorless and the readings were taken.

Total Suspended Solids

The measurement of TSS in water samples was carried out according to the standard methods of (APHA and Sawyer *et al.*, 2017) by the filtration process. Therefore, the accuracy and precision of the following methods are well approved and cited in the scientific literature. A fixed volume of water samples was poured on a pre-weighed glass fiber filter of a specified pore size before starting the vacuum filtration process. The filter was removed after the completion of the filtration process and placed in an aluminum dish in an oven at 100 ^{o}C for about 2-3 hours to completely dry off the remaining water. The filter was then weighed and the gain in filter weight represented the TSS contents, finally was expressed in mass per volume of sample filtered (mg/l).

Heavy Metals

Heavy metals were analyzed using atomic absorption spectrophotometer. The treated and untreated water samples were first of all prepared for the analysis by digesting the sample with concentrated nitric acid (HNO_3). 50 cm^3 of each sample was measured using measuring cylinder and poured in to a 250 cm^3 conical flask. The each sample mixture was then subjected to heat using a hot water bath where they were allowed to stay for 30 minutes. The various sample was removed and allowed to cool and made up to level mark in 100 cm^3 sample bottle with distil water, and then subjected to AAS Analysis where different hallow cathode lamps were used to determine different metals. The standard solution for each element under investigation was equally prepared and used in calibration (Nkansah and Amoaka, 2010).

Results

The Tables 1and 2 below shows the results of the analysed physicochemical parameters and the detected heavy metals in Borehole and Well water samples before and after treated with the local plants *Moringa oleifera* seed, *Hisbicus seeds* and synthetic chemical(Alum). The samples are coded as:

WTA = Well water treated with alum

RBW = Raw borehole water

RW = Raw water

BHTMO = Borehole water treated with *Moringa Olifera*

WTMO = Well water treated with *Moringa Olifera*

BHTA = Borhole water treated with alum

WTHS = Well water treated with *Hibiscus Seeds*

BTHS = Borhole water treated with *Hibiscus Seeds*

WHO = World Health Organization

Table1: Physicochemical analysis of Borehole and Well water sample treated with *moringa oleifera* seed and alum.

Parameters	WTA	BHR	RW	BHTMOS	WTMO	BHTA	WHO Standard
Temperature (°c)	27	27	30	28	30	25	Ambient
Conductivity (µs/cm)	34.8	28.8	30.6	48.8	46.7	48.8	100
Turbidity (NTU)	0.36	0.96	6.50	0.04	0.09	0.10	5.0
TDS (mg/l)	4	4	7.00	1.00	2	2.00	500
Ph	3.44	6.9	6.6	7.9	7.4	3.54	6.5-8.5
Acidity (NTU)	26.00	40.00	62.00	30.00	52.00	20.00	-
Alkalinity (mg/l)	29.45	30.00	38.00	20.00	26.00	26.18	600
Hardness (mg/l)	230.0	28.0	32.0	20.10	28.00	28.0	150
BOD	4.00	4.6	4.23	3.0	4.00	3.24	5.0
DO	4.6	4.0	4.5	3.1	5.0	4.00	5.0
TSS (mg/l)	5	30	45	3	4	4	25
Chloride (mg/l)	147.68	72.4	107.92	79.52	110.96	97.98	250
Sulphate (mg/l)	37.04	27.98	32.92	16.46	24.69	29.63	100
Appearanc	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Odor	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Color (PLCO)	18	22	35	24	37	16	50
Cu (mg/l)	0.20	ND	0.30	ND	0.10	ND	1.0
Fe (mg/l)	0.3	0.85	0.05	0.15	0.11	0.10	0.3
Pb (mg/l)	ND	ND	0.20	ND	ND	ND	0.01

ND= Not Detected

Table 2. Physicochemical analysis of Borehole and Well water sample treated with *Hibiscus Seeds.*

Parameters	WTA	BHR	RW	BHTHS	WTHS	BHTA	WHO
Temperature (^{0}c)	27	27	30	28.00	30.00	25	
Conductivity (µs/cm)	34.8	28.8	30.7	32.4	48.8	38.0	100
Turbidity (NTU)	0.36	0.96	6.50	0.12	0.15	0.10	5.0
TDS (mg/L)	4	4.00	7.00	2.00	5.00	2.00	500
Acidity (mg/l)	26.00	40.00	62.00	26.00	34.00	20.00	
Alkalinity (mg/l)	29.45	30.00	38.00	20.52	28.9	26.18	600
Total hardness (mg/l)	30.00	28.0	32.0	19.00	25.11	28.00	150
BOD	4.00	4.6	4.23	4.3	4.04	3.24	5.0
DO	4.6	4.0	4.5	3.4	4.8	4.00	5.0
TSS (mg/l)	5	30	45	3	6	4	25
Chloride (mg/l)	147.68	72.4	107.0	72.91	110.2	97.98	250
Sulphate (mg/l)	37.04	27.98	32.92	17.48	21.30	29.63	100
Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Odor	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Color (PLCO)	18	22	35	29	38	16	50
Cu (mg/l)	0.02	ND	0.35	ND	0.2	ND	1.0
Fe (mg/l)	0.25	0.85	0.05	0.003	0.04	0.2	0.3
Pb (mg/l)	0.008	ND	0.2	ND	0.006	0.008	0.01

ND= Not Detected

Discussion

From the results of the analysis none of the water samples had any objectionable appearance, odor, color or taste. Also, from the results the measured conductivities of the two water samples ranged from 28µs/cm to 48µs/cm, and the average values was 38 µs/cm. The lowest and highest conductivity values was below recommended values set by the WHO and NDWQS for drinking purposes and also within the criteria limit set by FAO, this indicates a high amount of dissolved inorganic substances of water caused by a variety of particles and is another key parameter in drinking water analysis. It was also related to the content of diseases causing organisms in water, which may come from soil or bodies of water. The turbidity result for borehole water samples before treatment was 0.96 NTU, for well water sample was 6.50 NTU. The raw water sample obtained from Shallow Well exhibited turbidity level of 6.5 NTU which was slightly above the acceptable values assigned by (WHO, 2013). But, after treatment of both water samples with each coagulant, the turbidity values were below the standard recommended maximum turbidity limit set by WHO and FAO for drinking water, which is a 5 nephelometric turbidity unit (NTU). The pH is classed as one of the most important water quality parameters. Measurement of pH also relates to the acidity or alkalinity of the water. The pH values of the two raw water samples and after addition of local coagulants were found to be in the range between 6.6 to 7.4. However, purification of water with alum in this study shows that, the values of both water samples were out of range recommended by WHO. This implies that the pH was more acidic with addition of alum as a coagulant, during water treatment process alum produces acid which in turn lowers the pH. In the tests of the remaining parameters of both raw water samples was not altered and after the treatment they were also within the stipulated values set by WHO (2016).

There have been many efforts conducted by scientists to reduce the concentration of dissolved metals in the environment. One of them is coagulation process. The observed metals in this study were Cu, Fe and Pd. The determination of heavy metal in this study was carried out by using Atomic Absorption Spectroscopy. The result was presented in Tables 1 to 2 above. The Table 1 and 2 shows that the addition of coagulants can reduce the level of metals in borehole and raw well water sample significantly. The borehole water sample was found not to contain copper and lead before and after the treatment. The addition of *Moringa* as a coagulant decreased the copper content in well raw water sample from 0.3 ppm to 0.1 ppm except *Hibiscus* and Alum that exhibited reduction from 0.3 ppm to 0.2 ppm. This implies that, *Moringa* seed and *Hibiscus seeds* were more efficiency than Alum in treatment concentration of copper present in water. The addition of each coagulant in water sample increased iron content from 0.05 to 0.29; this is because each of these coagulants contains organic matter which can increase the content of iron. But the concentration of the iron was still within a range provided by World Health Organisation (WHO) and Food Agricultural Organisation (FAO).

The concentration of the iron in well raw water samples was beyond acceptable value which was 0.8 ppm and after the addition of each coagulant, the iron content was lowered from 0.01 ppm to 0.08 ppm. The lead content in well raw water sample was 0.02 and after addition of all coagulants the lead content was not detected in the raw well water sample.

Conclusion

Considering the results obtained from physic-chemical analysis of borehole and well water samples before and after purification of water by locally available natural *coagulants Moringa Oleifera* seed, *Hibiscus seeds* and Alum. It revealed that the two local plants used in this study were better than Alum in water purification because, as the plants coagulate well in the water treatment due to the positively charge ion in them. The positive charge of the coagulants neutralizes the negative charge of dissolved and suspended particles in the water soluble proteins, which allows the resulting flocs to settle to the bottom or be removed by filtration. This finding revealed that proteins can remove micro-organisms by coagulation as well as acting directly as growth inhibitors of the microorganisms. It was found that these coagulants reduced about 90 - 96% of the impurities in water samples, they are highly effective in removal of not only physical contaminants but also chemical contaminants as seen in the sharp drop in the values of sulphate, iron and so on. Another good remark that could be said about the present study is that, the coagulants performed best at 0.5 g dosage. This means that each coagulant can be considered to be more economical to be used because of the small quantities that will be required to treat a given volume of water.

However, in all the tests, the initial values for all parameters of both samples were not altered, after the treatment; the values were within the WHO accepted values. But, the turbidity in raw well water was above the limit. After addition of Alum to the both water samples, the pH value was decreased from 6.9 - 3.54 and 6.6 - 3.44 respectively. The pH was more acidic after treatment with alum, during water treatment process, alum produced acid which in turn lower the pH value. Hence, the results shows that the locally available natural coagulants, purifies the water and reduce the level of heavy metals content in both Borehole and well water, as the coagulant forms flocs and pull those metals into the flocs.

Recommendations

Based on the research findings, the following recommendations were made:

i. Application of plant flocculants such as *Moringa Oleifera* is highly recommended for water purification where people are used to drink unsafe water.

ii. This study also recommended the use of natural coagulants of plants origin in water purification instead of synthetic coagulants such as, chlorine, Alum because natural coagulants are more economical and less environmental hazard to use, and more effective than synthetic coagulant.

iii. Further research should be carried out using banana peels and neem leaves in water purification.

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