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Qualitative Effects of Sand Filter Media in Water Treatment

Oyewo Ayobami Solomon*

University of Agriculture, Abeokuta, Ogun State Nigeria
*Corresponding author: ayobamioyewo@gmail.com

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Abstract Water samples were taken from three different shallow wells in Abeokuta, Ogun state Nigeria (West Africa). These wells are represented by as raw water A, B and C and were filtered using sand as filter media, sand grains of different sizes was used. The raw water was filtered with fine sand (column 1), coarse sand (Column 2) and very coarse sand (column 3), these loadings are homogenous and the fourth column contains there three sand layers. The filtered water was subjected to laboratory analysis which includes the following: pH value, TDS (Total dissolved solids), EC (Electrical conductivity), TS (Total Suspended Solid), Calcium, Magnesium, Potassium, Hardness and Sodium. The obtained laboratory test results were compared with W.H.O standard for highest desirable and maximum permissible. One way ANOVA and bar Chart are the statistical tools employed in analyzing the data. The fine sand homogenous filter gives the best output, and then followed by the coarse sand, and then the mixture of the sand also gives preferable outputs. The homogenous fine sand media flow rate was slower but give the best output. In situation where sand particles is very small, bed depth is very high, minimal or no chemical treatment will be required after filtration.

Keywords: *water, filtration, sustainable development, water resources management, sand filter media*

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1. Introduction

Water is an essential resource for human sustenance and existence, scarcity of safe water in terms of quality and quantity has a vital impact on sustainable development [1,2]. Water, unlike most other natural resources is essential to the survival of life. In the past few decades many developing countries such as Nigeria have experienced a phenomenal growth in population resulting in the demand for increased quantities of fresh portable water

The shortage of drinking water in many urban and most especially in the rural area of Nigeria calls for a greater responsibility from all and sundry more than ever before, in putting resources together for the provision of adequate water, death cases and illness have been traceable to water borne diseases.

Water is therefore life necessity and not luxury. Water is an indispensable element (2007 WHO Report) 1.1 billion people lack access to an improved drinking water supply 88% of the 4 billion annual cases of diarrhea diseases are attributed to unsafe water, inadequate sanitation and hygiene, 1.8 million people die of diarrhea disease each year. The WHO estimated the 94% of these diarrhea are prevented through modification to the environment.

Safe water for human consumption and other activities in necessary in poverty alleviation and socio-economic development, there has been increasing attention overtime for good water in term of quality and quantity that is in abundance.

However, abnormally low levels of access to clean water by large population of human have been reported worldwide about 2 billion people struggle daily for access to clean and sufficient water, about 35 countries in the world whose domestic water use below 50 litres per capita per day in Africa, In Nigeria 52% of the population does not have access to safe drinking water [3]. Improved access to safe drinking water is a prerequisite for poverty reduction, access to safe water in terms of quality and quantity prevents the spread of water borne and sanitation related diseases.

The essentiality of water cannot be over emphasized, the problem of availability of safe water is a global issue, and the problem becomes intense as human population increases. The pollution of water resources is traceable to anthropogenic pressure on the environment, water is vital driver of public health, and the effect of scarcity has a markedly effect on social, economy and environmental sector [4]. In other to solve the issues of increasing demands on the use of water resources in required quantity and suitable quality with aim to achieve its sustainable use, water resources management requires conservative and sustainable practices.

This paper aims at evaluating the effect of filter media in water treatment, to check the efficacy and efficiency of sand filter as water treatment media and to determine output of using different sand grain on water quality and quantity yield.

2. Methodology and Data

2.1. Study Area

Abeokuta is the capital city of Ogun state in Southwest Nigeria; it is located at 7.15° North latitude, 3.35° East longitude and 67 meters elevation above the sea level, having about 593,100 inhabitants. Water samples were taken from three different shallow wells in Abeokuta, Ogun state Nigeria (West Africa). These wells are represented by as raw water A, B and C and were filtered using sand as filter media, sand grains of different sizes was used. The raw water was taken from Adigbe, Olomore and Ago Ika, which was represented respectively as A, B and C and shown on the map of the area [Figure 1].

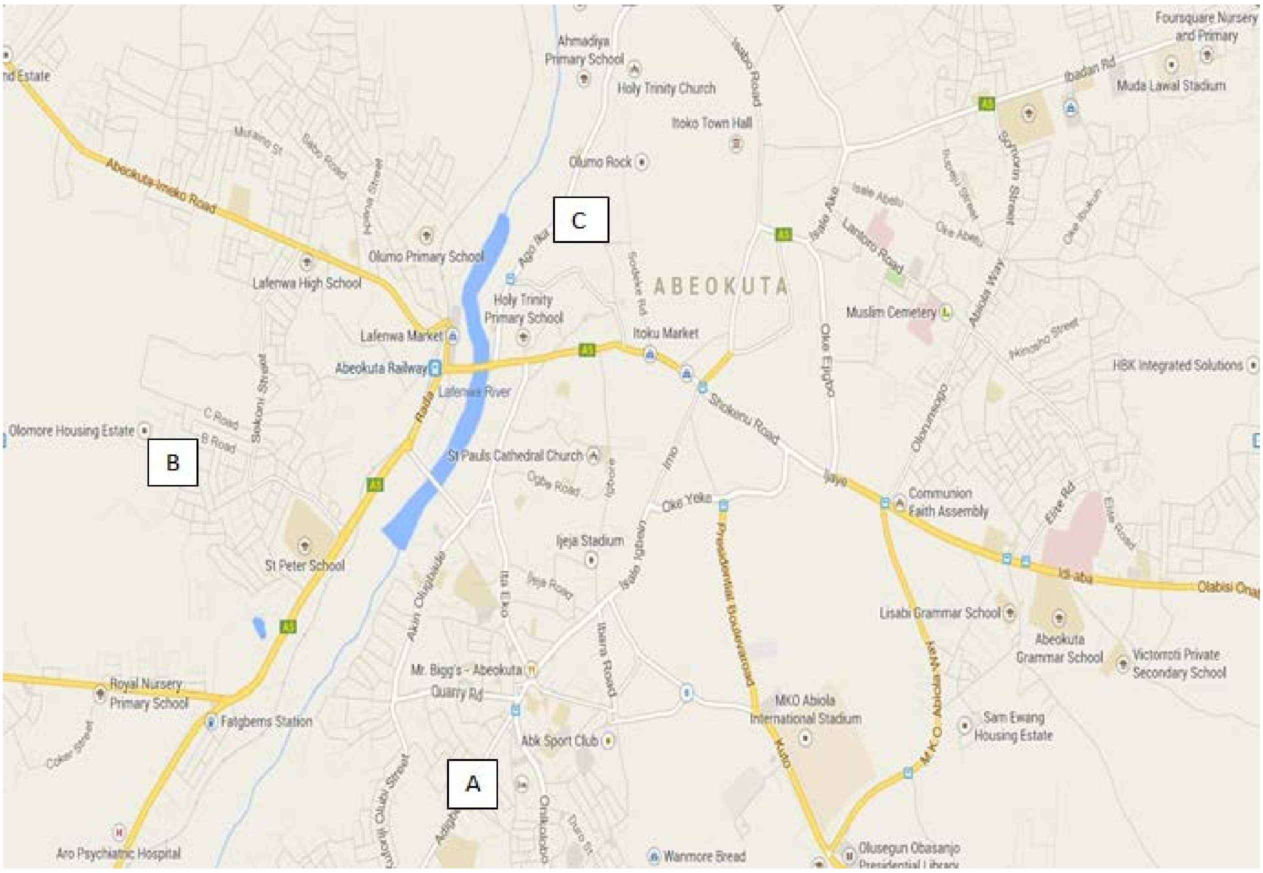

Figure 1. Map of Abeokuta showing the site where water samples were collected

2.2. Experimental

The raw water was collected from the sites and stored in three different vessels (50 litres each), and transport immediately to the laboratory for storage. The experimental setup was carried out in the department of Civil engineering, a big column made of PVC, was constructed to supply raw water under gravity to the different column containing the sand filters, after the raw water was supplied in to the columns the main valve was turn off, while the valve from each column containing the sand filters remains off. Afterwards each column valve was opened and timed using a stop watch; the filtered water was collected using 10 litre vessel from each column, prior laboratory analysis. The raw water was filtered in the three different columns containing sand filters, the first column contain fine sand, the second coarse sand, third very coarse sand and the fourth column was filled with the three different sand size to make a three layer in the column in this order fine sand first, followed by coarse sand and the very coarse sand at the base. The flow rate from each column varies due to the difference in sand particle size, the flow from the fine sand column was very slow, while the coarse sand was high and the very coarse sand was the highest, the difference in flow rate is due to the size particles, the particles of the fine sand are smaller and well packed together and result in slow flow rate, while the particle size of the coarse and very coarse are large and which results in loose packing and allow fast flow rates.

2.3. Laboratory Analysis

The filtered water collected from the experiment and the raw water was subjected to laboratory analysis which includes the following pH value, TDS (Total dissolved solids), EC (Electrical conductivity), TS (Total Suspended Solid), Calcium, Magnesium, Potassium, Hardness and Sodium. The laboratory analysis was carried out in the Laboratory of department of Environmental Management and Toxicology, University of Agriculture, Abeokuta.

2.4. Determination of pH

The pH meter was cleansed with distilled prior usage to test the filtered waters samples; the pH meter was switched on and allowed to reach room temperature. Thereafter the water samples were filled into beakers after rinsing with distilled water and filtered water to be tested in the different beakers. The pH meter was then probe into each beaker containing the water samples and the readings were recorded after getting a stable value. The procedure was used to measure the pH of the entire samples.

2.5. Determination of Electrical conductivity

A beaker was rinsed with distilled water and with water sample prior to measurement, the cleansed beaker was filled with water sample then the conductivity meter was dipped into the water the value of the conductivity was read from the meter screen after obtaining a stable value. This procedure was applied to all the water samples.

2.6. Determination of Total Dissolved Solid (TDS)

The procedure of measurement was the same as in the case of the determination of the electrical conductivity of the samples.

2.7. Determination of Total Solid(TS)

The initial weight of the beaker was recorder (Y), 50 ml of samples measured into the beaker and weighed (Z). The content was allowed to evaporate to dryness on the hot plate. It was thereafter transferred into a dish for complete dryness and allowed to cool. The final weight of the beaker was taken(X). The difference in weight per volume of sample was calculated to get the value of total solid in grams per liter.

2.8. Calculation

$$Total\ Solids = \frac{X - Y}{Z} \times 1000 = X\ "g \setminus l$$

$$X\ "g \setminus l \times 100 = Y\ "g \setminus l$$

Where:
X = Final weight of the beaker after dryness
Y = Initial weight of beaker
Z = Volume of sample

2.9. Determination of Total Suspended Solids (TSS)

The value of the TSS was determined by subtracting the value of the TDS from the TS. Since the TDS and TSS make up the TS. This procedure was repeated for all the samples analyzed.

2.10. Determination of Hardness

A conical flask was cleansed with distilled water, and then with sample a measuring cylinder of 25 ml was also rinsed with distilled water and sample, 25 ml of the sample was measured into the conical flask with the measuring cylinder, 1 ml of ammonium buffer ($NH_4CL \setminus OH$) and 4 drops of eriochrome Black T indicator was added to the samples respectively. The sample color changed to wine. The solution was titrated with 0.02 M Ethylene-diamine-tetra-acetic acid (EDTA) on a white surface. Titration continues slowly while shaking until wine color changes from deep purple to blue color at end point.

$$Total\ Hardness\ as\ CaCO_3 = \frac{Volume\ of\ 0.02\ EDTA\ (ml)}{Volume\ of\ sample\ (ml)} \times 1000\ in\ mg \setminus l$$

2.11. Determination of Calcium Hardness

A conical flask was rinsed with distilled water and samples twice and measuring cylinder was rinsed with sample, 25 ml of sample was measures into the flask and 1 ml of 4 M NaOH, 0.4 g of Murexide was added respectively to the water sample. The solution changes to wine red. The solution was titrated with 0.02 M EDTA the color changes to purple at the end.

2.12. Determination of Magnesium Hardness

The determination of magnesium hardness was calculated, since the total hardness is defined as the sum of calcium and magnesium concentration both expressed as calcium carbonate in milligram per liter the value of the calcium hardness was subtracted from the total hardness to give the value of the magnesium hardness.

2.13. Determination of Potassium and Sodium

The samples were digested for 20 minutes, 100 ml of sample was used and the initial color when the acid was added is colorless. 10 ml of HCl was added on heating, it was colorless and also colorless at the end.

3. Results

The results obtained from the laboratory were all subjected to statistical analysis. This includes the one-way ANOVA and Bar chart to show the level of significance in the value obtained and then compared with the WHO standard for the highest desirable and maximum permissible.

3.1. Result of Laboratory Analysis

KEY
Arw: Raw water A
A_1: Filtered water A with filter media 1
A_2: Filtered water A with filter media 2
A_3: Filtered water A with filter media 3
A_4: Filtered water A with filter media 4
Brw: Raw water B
B_1: Filtered water B with filter media 1
B_2: Filtered water B with filter media 2
B_3: Filtered water B with filter media 3
B_4: Filtered water B with filter media
Crw: Raw water C
C_1: Filtered water C with filter media 1
C_2: Filtered water C with filter media 2
C_3: Filtered water C with filter media 3
C_4: Filtered water C with filter media 4
Filter media 1 (Column 1): Fine sand load
Filter media 2 (Column 2): coarse sand loading
Filter media 3 (Column 3): very coarse sand loading
Filter media 4 (Column 4): consist of three filter media layer in the order Fine sand at the base, followed by the coarse sand and the very coarse sand the top.

Each sample was subjected to the treatment majorly to check difference in quality if the water from each sand loading in each column and that of the raw water sample. Then the samples filtered were analyzed at the laboratory and the values were compared with the W.H.O standard. The following laboratory analysis was done: pH value, TDS (Total dissolved solids), EC (Electrical conductivity), TS (Total Suspended Solid), Calcium, Magnesium, Potassium, Hardness and Sodium. The data obtained are analyzed using one-way ANOVA to indicate the level of significance of the result from the laboratory with the W.H.O standards and also with a bar chart.

Table 1. Laboratory analysis for each sample

samples	pH	TDS	EC	TSS	TS	CALCIUM	MAGNESIUM	POTASSIUM	HARDNESS	SODIUM
A1	6.28	183	365	37	220	172	68	4	240	22
A2	6.75	188	395	112	300	176	88	5	264	23
A3	7.48	268	428	132	400	216	160	6	376	22
A4	6.9	254	500	146	400	132	144	4	276	32
Arw	7.93	279	557	161	440	296	268	10	564	25
B1	7.1	90	180	110	200	132	0	2	132	11
B2	7.29	158	316	157	315	168	124	5	292	18
B3	7.42	183	366	180	363	184	124	5	308	18
B4	7.33	220	440	189	409	168	132	5	300	28
Brw	7.88	291	582	200	491	104	52	11	156	28
C1	6.97	162	381	58	220	108	124	2	232	25
C2	7.22	267	474	73	340	172	76	3	248	34
C3	7.3	236	471	79	315	160	80	3	240	28
C4	7.1	239	477	81	320	220	80	6	300	29
Crw	7.94	288	576	532	820	200	240	12	440	24
WHO STANDARD HIGHEST DESIRABLE	8.9	0	900	0	500	0	20	10	100	0
WHO STANDARD MAXIMUM PERMISIBLE	9.5	0	1200	0	1500	0	20	10	500	0

SAMPLES (MEAN±STANDARD DEVIATION)

Table 2. Shows the descriptive analysis of the samples

	A	B	C
pH	7.0680±0.6448	7.4040±0.2906	7.3060±0.3757
TDS	234.4000±45.5445	188.4000±74.4332	238.4000±47.7525
EC	499.0000±78.5462	376.8000±148.8664	475.8000±69.0196
TSS	117.6000±48.5417	167.2000±35.6749	164.6000±205.5804
TS	352.0000±90.1110	355.6000±108.5118	403.0000±237.6868
Calcium	198.4000±62.1353	151.2000±32.5454	172.0000±42.8019
Magnesium	145.6000±78.3122	86.4000±58.2134	120.0000±69.9142
Potassium	5.8000±2.4900	5.6000±3.2863	5.2000±4.0866
Hardness	344.0000±133.4766	237.6000±86.0511	292.0000±86.9022
Sodium	24.8000±4.2071	20.6000±7.3348	28.0000±3.9370

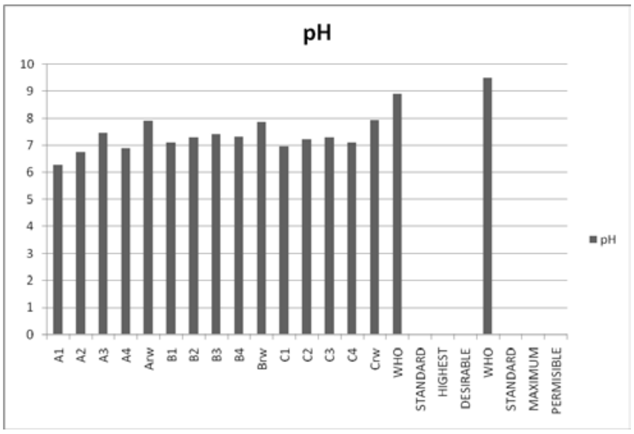

Figure 2. Represent the chart of the pH of the samples and the W.H.O standards

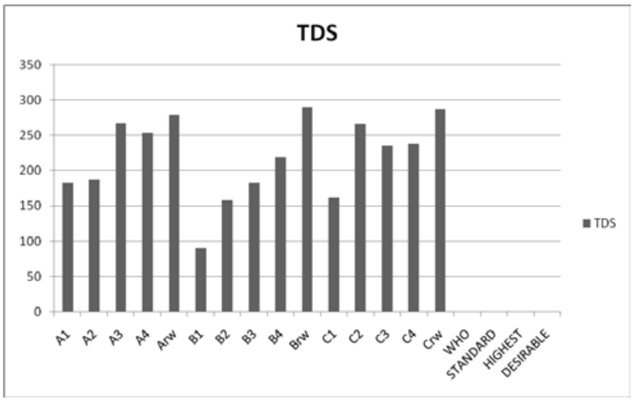

Figure 3. Represent the chart of the Total dissolved solid (TDS) of the samples and the W.H.O standards

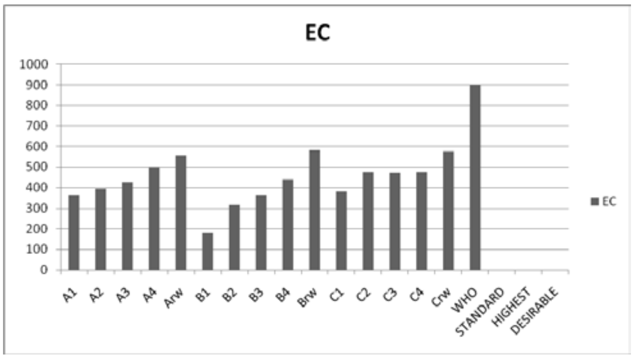

Figure 4. Represent the chart of the Electrical Conductivity (EC) of the samples and the W.H.O standards

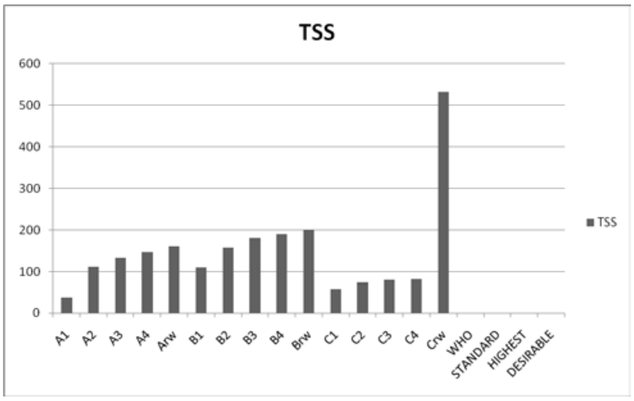

Figure 5. Represent the chart of the Total Suspended solid (TSS) of the samples and the W.H.O standards

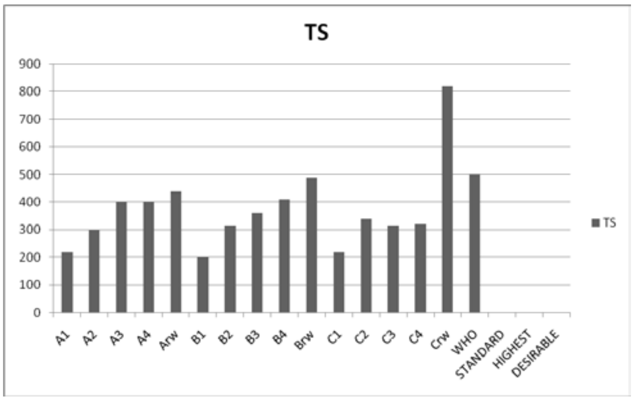

Figure 6. Represent the chart of the Total Solid (TS) of the samples and the W.H.O standards

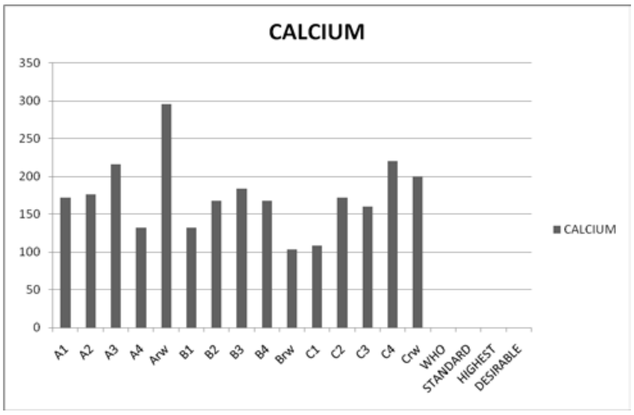

Figure 7. Represent the chart of the Calcium of the samples and the W.H.O standards

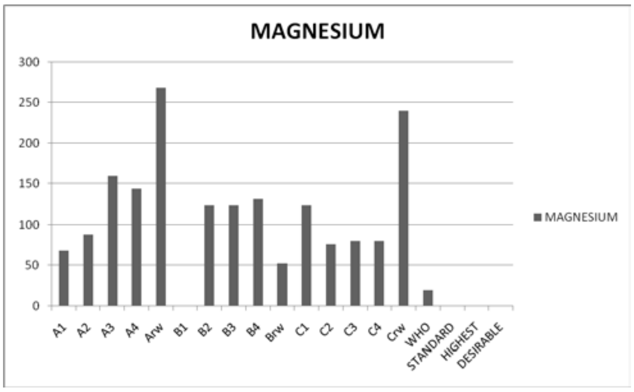

Figure 8. Represent the chart of the Magnesium of the samples and the W.H.O standards

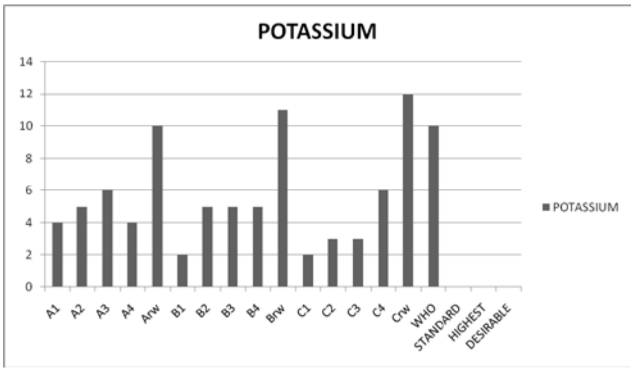

Figure 9. Represent the chart of the Potassium of the samples and the W.H.O standards

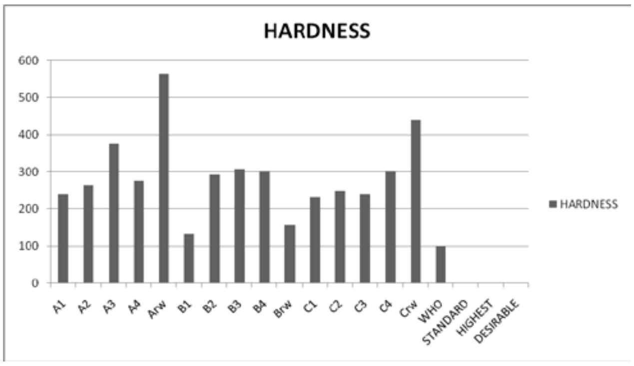

Figure 10. Represent the chart of the Hardness of the samples and the W.H.O standards

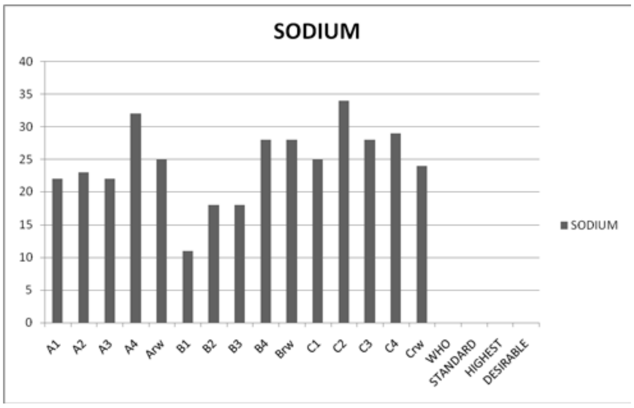

Figure 11. Represent the chart of the Sodium of the samples and the W.H.O standards

4. Discussion

The result obtained from the laboratory was also compared with the WHO standards in each of the bar chart in Figure 2 - Figure 11.

The pH values of the sample in compares with the WHO standards (in Figure 2) indicates that filter media one which yield samples A_1 B_1 and C_1 are preferable when compared with the WHO standard, then followed by samples with subscript 2, 3, and 4 while the pH of the raw water is found to be higher compared to the filtered samples, obtained results of all sample falls within the W.H.O standard limit for the highest desirable.

The Total Dissolve Solid (TDS) of the samples compared with the WHO standard in Figure 3, reveals that A_1 B_1 and C_1 have low TDS content then followed by samples with subscript 2, 3 and 4, while the raw water is high compared with the filtered water samples.

The electrical conductivity of the samples in compared with W.H.O standard in Figure 4, reveals that A_1 B_1 and C_1 have low TDS content then followed by samples with subscript 2, 3 and 4, while the raw water is high compared with the filtered water samples, while the raw water sample is high, this shows the effect of filtration. But all samples fall with the W.H.O limit.

The Total suspended solid of the samples in compared with W.H.O standard in Figure 5, reveals that A_1 B_1 and C_1 have low TSS content then followed by samples with subscript 2, 3 and 4, while the raw water is high compared with the filtered water samples, while the raw water sample is high, the W.H.O standard for TSS in not stated.

Total solid (TS) of the samples in compared with W.H.O standard in Figure 6, reveals that A_1 B_1 and C_1 have low TS content then followed by samples with subscript 2, 3 and 4, while the raw water is high compared with the filtered water samples, the raw water C has higher TS than the W.H.O standard for highest desirable. But all the samples value falls below the W.H.O standard for maximum permissible.

The calcium content of the samples A_1 B_1 and C_1 have low calcium content compared with samples with subscript 2, 3 and 4, while the raw water calcium content for the raw water is high, especially for raw water A (in Figure 7).

The magnesium of the samples compared with the WHO standard in Figure 8, reveals that A_1 B_1 and C_1 preferred followed by samples with subscript 2, 3 and 4, the magnesium content of the raw water is high especially that of raw water A and C with an exception of raw water B.

The potassium content of the samples compared with the W.H.O standard in Figure 9 reveals that samples A_1 B_1 and C_1 preferred followed by samples with subscript 2, 3 and 4, while the raw water samples value are higher compared with the W.H.O standard limit. The sodium content as revealed in Figure 9 reveals that samples A_1 B_1 and C_1 have low sodium content compared with other samples.

The result of the samples level of hardness as in Figure 11 compared to the W.H.O standard, reveals that reveals that A_1 B_1 and C_1 preferred followed by samples with subscript 2, 3 and 4. The raw water samples are high with exception of raw water B, all other sample values is above the W.H.O standard for the highest desirable.

5. Conclusion

Good water quality is very crucial for communal economic development, in improving the health of an environment availability of good water in terms on quality and quantity in important. Therefore access to safe water is needful in poverty reduction schemes.

The filtration process in water treatment is necessary so as to obtain better water quality, slow sand filtration with considerable depth might not require further chemical treatment if need be it will be minimal.

Recommendation

Slow sand filtration has been proven to be very effective in water treatment for good water quality. Therefore, homogenous sand filtration is very effective from this work, for its effectiveness sand grain size should be small and the bed loading should be very high, so as to obtain a natural groundwater filtration process. In case of larger particles flow rate is high and there might be need for further treatment.

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