Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Effect of Different Filtration Methods on Drinking Water Quality Parameters in Parts of Onitsha, Anambra State, Nigeria

N.G. Ezekoye*, N.H. Okoye*, U.E. Ekpunobi*, I.O. Eboh -Ajoku**, C.T. Umeh*

*Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.

**Department of Chemistry, Kingsley Ozumba Mbadiwe University, Ogboko, Imo State, Nigeria.

Author to whom correspondence should be addressed; E-mail: ogechi.eboh@komu.edu.ng

ABSTRACT

This work studied the effect of three filtration processes on some water quality parameters of selected boreholes and sachets of water sold in Onitsha North LGA. A total of ten water samples were collected each month for a period of six months. Five samples were collected from five different boreholes while another five samples were sachet water from five water companies. The samples collected were treated with different water filtration processes, namely Carbon filtration (CF), Ceramic Candle filtration (CCF) and Step Filtration System (SFS). Sample analysis was conducted using Atomic Absorption Spectrophotometer (AAS) for calcium and magnesium ion and standard test methods for pH and TDS. The Water Quality Index (WQI) was also calculated. The results obtained were compared with World Health Organization (WHO) standards. It is evident from this study that some of the selected water samples (borehole and sachet water) in Onitsha North, Anambra State met the recommended standards for physicochemical qualities. The TDS of the samples during the period of study were all below the threshold limit (1000 mg/L) allowed. For the months of December, 2016, and January, 2017, 40% of sampled water was below the recommended pH value range of 6.5 to 8.5. In the months of February, March, and April, 2017, 70 % of sampled water was below the WHO pH range, while in May, 2017, only 30 % of sampled water was below the WHO range. The acidic samples were neutralized on treatment with the different filtration processes. The WQI analysis of the sampled water showed that the water were suitable for human consumption as the values fell within 0-25 (Excellent) and 26-50 (good). The overall trend of filtration efficiency was SFS > CCF > CF. It is highly recommended that regular monitoring be conducted and municipal filtration processes be used to augment the water purification.

Keywords - Filtration method, Water quality index, Borehole, Phyisicochemical parameter, Sachet water

INTRODUCTION

Water is an essential requirement of life for drinking, domestic, industrial and agricultural purposes. Its quality and quantity which vary over space and time are important components in the integral development of any area. There is possible contamination of these sources by surface runoff or leachate from sewage systems [13].The production of sachet water has increased tremendously in Nigeria with outrageous registered and unregistered producers [10]. Besides, sachet water has long been implicated in the outbreak of water-borne diseases in United Kingdom [6]. Due to the increased consumption of borehole and sachet water, it is necessary to study the water quality.

There are lots of information on water qualities of packaged waters, popular surface waters, borehole waters and drinking water sold in the market.. Onitsha is an urban area located in Anambra state. The inhabitants rely on few boreholes and sachet water for drinking. The location and management of some of these boreholes and sachet water producers raise suspicion of possible contamination. Onitsha is an industrial city with several industrial activities that may lead to environmental pollution. The city records high rate of poor hygienic environment. Several studies on the microbial quality of bottled and sachet water have reported violations of national and international quality standards [15],[11]. Adherence to production and analytical standards are doubtful as most of the factories are observed to lack the appropriate technology and expertise for achieving these. It is also reported that some producers just bag and seal pipe-borne or well water without any form of treatment [12]. Many packaged water manufacturers initially comply with the standard processes of drinking water treatment outlined by the National Agency for Food and Drug Administration and

Control (NAFDAC), but later revert to ineffective treatment processes because of lack of monitoring. Thus, the consumers are vulnerable to water related diseases. In view of this, there is the need to assess drinking water quality of these sources as well as to ascertain the effect of different filtration method on its water quality.

MATERIALS AND METHODS

Sample Collection

The samples were collected in two sets of 1Liter pre-wash polyethylene bottles.The number of water samples was 10 (5 borehole water and 5 sachet water). Each sample was further subjected to three different filtration methods using carbon filter (CF), ceramic candle filter (CCF) and step filtration system (SFS). Thus we have 10 unfiltered samples, 10 from carbon filtration, 10 from CCF and 10 from SFS. This brought the sample to a total of forty. The samples were collected between December, 2016 and May, 2017. Samples were collected once every month from all designated sampling point. 2 replicate samples measuring 10.0 L each were collected at each sampling site. Samples a – e are sachet water while f – j are borehole water.

Methods

Determination of physicochemical parameters:

The pH values were determined using the calibrated pen-type pH meter (pH-02), while total dissolved solid was measured using TDS meter - 4-HMD. Ca and Mg ion were determined using Atomic Absorption Spectrophotometry (AAS) according to the methods of AOAC (2003).

Water quality index (WQI).

Water quality index is a single number used to characterize the overall quality of water [8]. In this study, four water quality parameters, pH, TDS, Ca^{2+} and Mg^{2+}, were used to calculate the WQI. The equation (1.0) was used to calculate the WQI:

$$\text{WQI} = \frac{\sum_{i=1}^{4} q_i W_i}{\sum_{i=1}^{4} W_i} \qquad (1.0)$$

Where: W_i is weightage factor calculated by using equation (2.0), while $w_i$is the weight assigned to the i^{th} water quality parameter. Taking 5 as a maximum weight, the water quality was assigned weight values based on their importance in water quality assessment. pH was assigned 0.3333, TDS was assigned 0.3333, Ca was assigned 0.1667 and Mg was assigned 0.1667 [8]; n is the total number of water quality parameters; q_i is the quality rating for the i^{th} water quality parameter and it is calculated using equation (3.0)

$$W_i = \frac{w_i}{\sum_i^n w_i} \qquad (2.0)$$

$$q_i = \sum_{i=1}^{n} \frac{A_i - I_i}{S_i - I_i} \qquad (3.0)$$

Where A_i is the average values of the parameters determinedunder laboratory condition

S_i is the standard permissible values obtained from recognized organizations/bodies and

I_i is the ideal values for the parameters

(All ideal values (I_i) are taken to be zero except that of pH =7, DO=14.6 and fluorides=1)[5].

RESULT AND DISCUSSION

Result of Physicochemical parameters

Table 1. Result for Physicochemical Analysis for the month of December, 2016

Parameter i		A	B	C	D	E	F	G	H	I	J	WHO
pH	N	7.43 ±0.01	4.06 ±5.73	7.07 ±0.07	5.50 ±0.14	4.28 ±0.03	6.94 ±0.2	7.44 ±0.08	7.10 ±0.07	4.01 ±0.27	7.65 ±0.01	6.5-8.5
	CF	7.42 ±0.01	4.06 ±0.04	7.06 ±0.07	5.50 ±0.14	4.27 ±0.04	6.94 ±0.2	7.42 ±0.03	7.09 ±0.1	6.01 ±0.13	7.65 ±0.01	
	CCF	7.10 ±0.07	4.05 ±0.01	6.90 ±0.11	5.48 ±0.03	4.27 ±0.04	6.46 ±0.57	7.02 ±0.04	6.89 ±0.17	6.01 ±0.13	7.65 ±0.01	
	SFS	7.08 ±0.06	4.05 ±0.01	6.80 ±0.13	5.50 ±0.06	4.28 ±0.03	6.45 ±0.57	7.06 ±0.07	6.9 ±0.03	6.94 ±0.06	7.60 ±0.03	
TDS (mg/L)	N	179.00 ±4.24	172.00 ±1.41	190.00 ±7.07	58.00 ±2.83	265.00 ±7.07	6.00 ±1.41	83.00 ±2.83	99.00 ±1.41	185.00 ±4.24	49.00 ±1.41	1000
	CF	178.00 ±2.83	170.00 ±2.83	189.00 ±4.24	58.00 ±2.83	264.00 ±7.07	6.00 ±1.41	83.00 ±2.83	98.00 ±1.41	185.00 ±4.24	48.00 ±1.41	
	CCF	179.00 ±1.41	169.00 ±1.41	190.00 ±5.66	57.00 ±2.83	264.00 ±5.66	6.00 ±0.00	82.00 ±1.41	97.00 ±2.83	186.00 ±4.24	49.00 ±1.41	
	SFS	178.00 ±1.41	169.00 ±1.41	190.00 ±5.66	57.00 ±2.83	264.00 ±4.24	6.00 ±0.00	82.00 ±1.41	99.00 ±1.41	185.00 ±4.24	48.00 ±2.83	
Ca (mg/L)	N	8.00±0.02	4.67±0.38	5.33±0.05	0.67±0.09	9.33±0.19	0	1.33±0.15	4.00±0.28	2.00±0.14	1.33±0.19	200
	CF	6.67±0.14	4.00±0.28	4.00±0.14	0	8.00±0.14	0	0.67±0.02	3.33±0.19	1.33±0.24	0.67±0.00	
	CCF	5.33±0.16	2.67±0.13	3.33±0.19	0	5.33±0.09	0	0	1.33±0.02	0	0.67±0.05	
	SFS	2.00±0.28	0.67±0.04	1.33±0.02	0	2.67±0.13	0	0	0.67±0.07	0.67±0.05	0	
Mg (mg/L)	N	0.74±0.01	0.9±0.03	0.42±0.02	1.21±0.02	0.96±0.02	1.92±0.11	0.50±0.03	0.66±0.08	0.89±0.01	0.27±0.04	150
	CF	0.67±0.02	0.81±0.00	0.34±0.04	1.17±0.02	0.80±0.01	1.85±0.21	0.46±0.09	0.59±0.13	0.79±0.02	0.22±0.03	
	CCF	0.60±0.00	0.73±0.01	0.34±0.03	1.12±0.01	0.83±0.08	1.77±0.18	0.44±0.06	0.51±0.03	0.70±0.02	0.18±0.02	
	SFS	0.63±0.03	0.70±0.01	0.38±0.03	1.15±0.02	0.82±0.01	1.75±0.22	0.40±0.01	0.47±0.04	0.67±0.05	0.14±0.06	

N = Non-filtered water samples, CF = Carbon filter water samples,CCF = Ceramics candle filtered water samples andSFS = Step filtration system water samples.

Table2. Result for Physicochemical Analysis for the month of January, 2017

Parameter J		A	B	C	D	E	F	G	H	I	J	WHO
pH	N	4.20 ±0.01	6.76 ±0.06	5.86 ±0.06	6.50 ±0.07	7.10 ±0.14	6.21 ±0.13	7.31 ±0.01	6.71 ±0.13	4.01 ±0.10	5.82 ±0.11	6.5-8.5
	CF	4.20 ±0.01	6.67 ±0.04	5.79 ±0.01	6.10 ±0.42	6.50 ±0.07	6.20 ±0.07	7.30 ±0.03	6.52 ±0.04	6.00 ±0.07	6.22 ±0.18	
	CCF	4.00 ±0.01	6.50 ±0.13	5.70 ±0.08	5.98 ±0.04	6.30 ±0.14	6.87 ±0.33	7.02 ±0.01	6.43 ±0.17	5.90 ±0.21	6.34 ±0.01	
	SFS	3.90 ±0.00	6.56 ±0.23	5.60 ±0.11	5.40 ±0.71	6.30 ±0.14	6.9 ±0.42	7.01 ±0.01	6.53 ±0.08	6.00 ±0.14	6.80 ±0.21	
TDS (mg/L)	N	147.00 ±5.66	172.00 ±7.07	228.00 ±2.83	231.00 ±1.41	299.00 ±1.41	8.00 ±1.41	62.00 ±2.83	74.00 ±1.41	184.00 ±1.41	56.00 ±2.83	1000
	CF	145.00 ±5.66	171.00 ±5.66	228.00 ±2.83	230.00 ±2.83	297.00 ±1.41	8.00 ±1.41	62.00 ±2.83	72.00 ±2.83	183.00 ±1.41	56.00 ±2.83	
	CCF	147.00 ±2.83	172.00 ±2.83	228.00 ±2.83	231.00 ±1.41	298.00 ±4.24	7.00 ±1.41	60.00 ±2.83	74.00 ±1.41	184.00 ±1.41	56.00 ±2.83	
	SFS	146.00 ±0.00	172.00 ±2.83	227.00 ±4.24	231.00 ±1.41	299.00 ±5.66	8.00 ±1.41	62.00 ±2.83	74.00 ±1.41	184.00 ±1.41	56.00 ±2.83	
Ca (mg/L)	N	8.00±0.02	4.67±0.38	5.33±0.05	0.67±0.09	9.33±0.19	0	1.33±0.15	4.00±0.28	2.00±0.14	1.33±019	200
	CF	6.67±0.14	4.00±0.28	4.00±0.14	0	8.00±0.14	0	0.67±0.02	3.33±0.19	1.33±0.24	0.67±0.00	
	CCF	5.33±0.16	2.67±0.13	3.33±0.19	0	5.33±0.09	0	0	1.33±0.02	0	0.67±0.05	
	SFS	2.00±0.28	0.67±0.04	1.33±0.02	0	2.67±0.13	0	0	0.67±0.07	0.67±0.05	0	
Mg (mg/L)	N	0.74±0.01	0.90±0.03	0.42±0.02	1.21±0.02	0.96±0.02	1.92±0.11	0.50±0.03	0.66±0.08	0.89±0.01	0.27±0.04	150
	CF	0.67±0.02	0.81±0.00	0.34±0.04	1.17±0.02	0.80±0.01	1.85±0.21	0.46±0.09	0.59±0.13	0.79±0.02	0.22±0.03	
	CCF	0.60±0.00	0.73±0.01	0.34±0.03	1.12±0.01	0.83±0.08	1.77±0.18	0.44±0.06	0.51±0.03	0.70±0.02	0.18±0.02	
	SFS	0.63±0.03	0.7±0.01	0.38±0.03	1.15±0.02	0.82±0.01	1.75±0.22	0.40±0.01	0.47±0.04	0.67±0.05	0.14±0.06	

N = Non-filtered water samples, CF = Carbon filter water samples,CCF = Ceramics candle filtered water samples andSFS = Step filtration system water samples.

Table 3. Result for Physicochemical Analysis for the month of February, 2017

Parameter	F	A	B	C	D	E	F	G	H	I	J	WHO
pH	N	4.05 ±0.06	3.95 ±0.07	7.01 ±0.01	4.75 ±0.07	4.27 ±0.04	6.34 ±0.23	4.23 ±0.04	6.98 ±0.04	3.93 ±0.11	4.33 ±0.28	6.5-8.5
	CF	6.90 ±0.07	6.90 ±0.14	7.01 ±0.01	6.61 ±0.11	6.42 ±0.11	7.29 ±0.01	6.22 ±0.11	6.96 ±0.07	6.90 ±0.07	6.30 ±0.21	
	CCF	7.04 ±0.06	6.91 ±0.14	6.93 ±0.14	6.68 ±0.01	6.56 ±0.06	7.26 ±0.03	7.12 ±0.14	6.92 ±0.08	6.89 ±0.01	7.18 ±0.10	
	SFS	7.06 ±0.04	6.94 ±0.13	6.91 ±0.14	6.72 ±0.08	6.59 ±0.03	7.21 ±0.01	7.1 ±0.13	6.90 ±0.11	6.91 ±0.06	7.19 ±0.14	
TDS (mg/L)	N	177.00 ±4.24	171.00 ±2.83	213.00 ±2.83	259.00 ±1.41	324.00 ±5.66	9.00 ±1.41	58.00 ±2.83	88.00 ±2.83	183.00 ±2.83	53.00 ±1.41	1000
	CF	176.00 ±1.41	171.00 ±2.83	213.00 ±2.83	256.00 ±8.49	324.00 ±5.66	9.00 ±0.00	56.00 ±2.83	87.00 ±2.83	181.00 ±1.41	53.00 ±1.41	
	CCF	176.00 ±2.83	171.00 ±2.83	212.00 ±4.24	255.00 ±7.07	324.00 ±5.66	8.00 ±0.00	58.00 ±2.83	88.00 ±2.83	183.00 ±2.83	53.00 ±4.24	
	SFS	176.00 ±1.41	171.00 ±2.83	210.00 ±5.66	259.00 ±1.41	322.00 ±2.83	8.00 ±1.41	58.00 ±2.83	88.00 ±2.83	181.00 ±1.41	51.00 ±1.41	
Ca (mg/L)	N	10.00±1.70	6.00±2.26	4.67±0.24	1.33±1.04	10.67±1.23	0.67±0.94	1.33±0.15	4.00±0.28	2.67±2.22	1.33±0.90	200
	CF	9.33±0.47	5.33±2.17	4.00±0.14	0.67±0.94	9.33±0.47	0	0.67±0.02	3.33±1.18	2.00±1.84	0.67±0.94	
	CCF	6.67±0.33	2.67±0.47	2.00±0.71	0	6.67±0.66	0	0	1.33±0.66	0.67±0.94	0	
	SFS	5.33±0.80	2.00±0.14	1.33±0.80	0	6.00±0.28	0	0	0.67±0.07	0.67±0.94	0	
Mg (mg/L)	N	0.76±0.04	0.93±0.06	0.39±0.01	1.17±1.59	0.98±0.11	1.89±0.15	0.52±0.31	0.7±0.15	0.91±0.02	0.25±0.07	150
	CF	0.72±0.06	0.88±0.10	0.38±0.10	1.14±1.57	0.95±0.06	1.84±0.23	0.48±0.40	0.66±0.22	0.85±0.08	0.20±0.01	
	CCF	0.66±0.04	0.82±0.14	0.27±0.07	1.06±1.48	0.86±0.06	1.77±0.19	0.44±0.34	0.61±0.03	0.82±0.19	0.18±0.12	
	SFS	0.63±0.02	0.80±0.12	0.25±0.16	1.03±1.45	0.83±0.09	1.74±0.23	0.43±0.33	0.57±0.04	0.8±0.13	0.18±0.11	

N = Non-filtered water samples, CF = Carbon filter water samples,CCF = Ceramics candle filtered water samples andSFS = Step filtration system water samples.

Table 4. Result for Physicochemical Analysis for the month of March, 2017

Parameter M1		A	B	C	D	E	F	G	H	I	J	WHO
pH	N	7.50 ±0.42	4.30 ±0.08	7.06 ±0.03	6 ±0.07	4.8 ±0.07	6.01 ±0.27	4.30 ±0.07	7.30 ±0.07	4.93 ±0.21	4.60 ±0.07	6.5-8.5
	CF	7.40 ±0.14	6.30 ±0.04	7.05 ±0.06	6.1 ±0.14	6.46 ±0.08	6.9 ±0.07	6.29 ±0.04	7.29 ±0.01	6.80 ±0.07	6.58 ±0.06	
	CCF	7.01 ±0.01	6.40 ±0.14	6.89 ±0.08	7.98 ±0.04	6.5 ±0.07	6.92 ±0.04	6.15 ±0.08	7.12 ±0.03	6.90 ±0.11	6.54 ±0.06	
	SFS	6.90 ±0.14	7.10 ±0.07	6.85 ±0.10	7.97 ±0.1	6.7 ±0.04	7.05 ±0.06	6.10 ±0.03	7.10 ±0.03	6.94 ±0.06	6.50 ±0.11	
TDS (mg/L)	N	46.00 ±4.24	181.00 ±5.66	157.00 ±4.24	14.00 ±1.41	328.00 ±2.83	7.00 ±0.00	60.00 ±2.83	98.00 ±2.83	196.00 ±2.83	50.00 ±1.41	1000
	CF	46.00 ±4.24	180.00 ±7.07	155.00 ±5.66	13.00 ±2.83	328.00 ±2.83	7.00 ±0.00	58.00 ±1.41	98.00 ±2.83	194.00 ±2.83	49.00 ±1.41	
	CCF	45.00 ±4.24	181.00 ±5.66	157.00 ±4.24	14.00 ±1.41	327.00 ±4.24	7.00 ±0.00	49.00 ±1.41	97.00 ±2.83	196.00 ±2.83	50.00 ±1.41	
	SFS	46.00 ±2.83	180.00 ±5.66	157.00 ±4.24	14.00 ±1.41	328.00 ±2.83	7.00 ±0.00	48.00 ±1.41	97.00 ±2.83	195.00 ±4.24	49.00 ±1.41	
Ca (mg/L)	N	10.00±1.27	5.33±1.32	5.33±1.18	0.67±0.09	10.00±0.28	0	0.67±0.05	3.33±1.23	2.00±0.14	0.67±0.05	200
	CF	9.33±0.47	4.67±0.80	4.67±0.80	0	8.00±1.41	0	0	2.67±0.24	1.33±0.61	0	
	CCF	8.00±0.99	4.00±0.71	3.33±1.18	0	6.67±0.66	0	0	2.00±0.28	0.67±0.05	0	
	SFS	7.33±0.90	2.67±0.94	2.67±1.08	0	6.00±0.28	0	0	0.67±0.07	0.67±0.05	0	
Mg (mg/L)	N	0.77±0.05	0.98±0.11	1.83±0.10	0.04±0.00	1.60±0.01	0.04±0.00	0.20±0.00	0.83±0.18	0.68±0.02	0.23±0.04	150
	CF	0.69±0.02	0.93±0.16	1.76±0.06	0.01±0.00	1.51±0.16	0	0.19±0.02	0.77±0.04	0.63±0.04	0.21±0.01	
	CCF	0.64±0.07	0.90±0.00	1.75±0.07	0	1.42±0.03	0	0.14±0.05	0.73±0.04	0.57±0.04	0.19±0.06	
	SFS	0.60±0.07	0.86±0.09	1.71±0.01	0	1.38±0.12	0	0.08±0.02	0.69±0.01	0.53±0.05	0.16±0.05	

N = Non-filtered water samples, CF = Carbon filter water samples,CCF = Ceramics candle filtered water samples andSFS = Step filtration system water samples.

Table 5. Result for Physicochemical Analysis for the month of April, 2017

Parameter A		A	B	C	D	E	F	G	H	I	J	WHO
pH	N	6.30 ±0.06	4.03 ±0.04	7.22 ±0.01	6.45 ±0.01	4.45 ±0.03	6.91 ±0.01	4.17 ±0.04	7.04 ±0.03	4.11 ±0.06	4.45 ±0.07	6.5-8.5
	CF	6.30 ±0.06	6.00 ±0.01	7.20 ±0.16	6.55 ±0.01	6.40 ±0.00	6.89 ±0.01	7.06 ±0.62	6.79 ±0.01	6.97 ±0.03	6.32 ±0.14	
	CCF	7.62 ±0.03	6.60 ±0.03	6.90 ±0.06	6.58 ±0.03	7.10 ±0.03	6.90 ±0.01	7.15 ±0.04	6.89 ±0.01	6.99 ±0.04	6.44 ±0.08	
	SFS	7.90 ±0.07	6.80 ±0.03	7.05 ±0.04	6.88 ±0.03	7.21 ±0.01	6.97 ±0.03	7.99 ±0.01	6.89 ±0.01	7.09 ±0.06	6.54 ±0.07	
TDS (mg/L)	N	44.00 ±1.41	172.00 ±1.41	158.00 ±2.83	13.00 ±1.41	340.00 ±7.07	9.00 ±1.41	62.00 ±2.83	93.00 ±2.83	186.00 ±5.66	57.00 ±4.24	1000
	CF	43.00 ±2.83	172.00 ±1.41	157.00 ±4.24	13.00 ±2.83	337.00 ±4.24	8.00 ±1.41	62.00 ±2.83	92.00 ±2.83	184.00 ±5.66	57.00 ±4.24	
	CCF	44.00 ±0.00	171.00 ±0	149.00 ±1.41	13.00 ±1.41	339.00 ±1.41	8.00 ±1.41	60.00 ±2.83	93.00 ±1.41	186.00 ±2.83	55.00 ±5.66	
	SFS	45.00 ±1.41	172.00 ±2.83	158.00 ±1.41	12.00 ±1.41	338.00 ±2.83	9.00 ±1.41	61.00 ±1.41	93.00 ±0.00	185.00 ±4.24	57.00 ±4.24	
Ca (mg/L)	N	11.33±0.19	6.00±0.28	6.67±0.47	2.00±0.14	10.67±0.94	0.67±0.05	0.67±0.05	3.33±0.47	2.00±0.71	0.67±0.05	200
	CF	10.00±0.28	5.33±0.47	0	1.33±0.05	9.33±0.47	0	0	2.67±0.47	1.33±0.47	0	
	CCF	6.67±0.33	3.33±0.47	0	0	6.00±0.28	0	0	2.00±0.00	0	0	
	SFS	6.67±0.94	2.67±0.94	0	0	5.33±0.66	0	0	0.67±0.47	0	0	
Mg (mg/L)	N	0.78±0.07	0.99±0.01	1.86±0.22	0.05±0.01	1.63±0.04	0.03±0.00	0.20±0.01	0.85±0.07	0.66±0.34	0.24±0.06	150
	CF	0.07±0.06	0.97±0.23	1.83±0.32	0.04±0.01	1.62±0.02	0.03±0.01	0.01±0.00	0.83±0.05	0.65±0.22	0.23±0.04	
	CCF	0.05±0.00	0.91±0.15	1.76±0.37	0.03±0.01	1.56±0.08	0.02±0.00	0	0.78±0.12	0.58±0.16	0.16±0.08	
	SFS	0.05±0.01	0.91±0.15	1.75±0.49	0.02±0.00	1.55±0.06	0.01±0.00	0	0.77±0.24	0.57±0.10	0.14±0.06	

N = Non-filtered water samples, CF = Carbon filter water samples,CCF = Ceramics candle filtered water samples andSFS = Step filtration system water samples.

Table 6. Result for Physicochemical Analysis for the month of May, 2017

Parameter M2		A	B	C	D	E	F	G	H	I	J	WHO
pH	N	4.80 ±0.14	7.01 ±0.06	6.01 ±0.03	6.10 ±0.06	7.30 ±0.28	6.80 ±0.14	4.68 ±0.03	7.03 ±0.03	4.31 ±0.01	5.56 ±0.06	6.5-8.5
	CF	6.67 ±0.04	7.00 ±0.28	6.46 ±0.06	6.06 ±0.01	7.29 ±0.01	6.80 ±0.14	6.54 ±0.06	7.01 ±0.00	6.69 ±0.01	7.20 ±0.21	
	CCF	6.68 ±0.03	6.95 ±0.07	6.90 ±0.14	7.98 ±0.03	7.12 ±0.11	6.67 ±0.04	6.84 ±0.06	6.54 ±0.06	7.12 ±0.11	7.43 ±0.03	
	SFS	6.78 ±0.03	6.97 ±0.10	6.92 ±0.03	7.97 ±0.04	7.10 ±0.03	6.85 ±0.07	6.89 ±0.01	6.52 ±0.03	7.29 ±0.01	7.52 ±0.04	
TDS (mg/L)	N	89.00 ±1.41	196.00 ±5.66	233.00 ±2.83	25.00 ±1.41	314.00 ±1.41	8.00 ±1.41	60.00 ±2.83	101.00 ±1.41	187.00 ±4.24	49.00 ±1.41	1000
	CF	87.00 ±1.41	196.00 ±5.66	231.00 ±5.66	24.00 ±1.41	312.00 ±4.24	8.00 ±1.41	58.00 ±2.83	101.00 ±1.41	187.00 ±4.24	49.00 ±1.41	
	CCF	89.00 ±1.41	195.00 ±5.66	232.00 ±4.24	25.00 ±1.41	315.00 ±4.24	7.00 ±1.41	69.00 ±1.41	98.00 ±1.41	186.00 ±4.24	49.00 ±1.41	
	SFS	89.00 ±1.41	196.00 ±2.83	231.00 ±4.24	24.00 ±1.41	313.00 ±2.83	8.00 ±1.41	59.00 ±1.41	100.00 ±1.41	188.00 ±4.24	48.00 ±1.41	
Ca (mg/L)	N	12.00±0.71	6.67±0.66	7.33±0.47	2.67±0.47	11.33±0.47	1.33±0.47	0.67±0.05	2.67±0.05	2.67±0.05	0.67±0.05	200
	CF	10.67±1.23	5.33±0.47	6.00±0.57	2.00±0.42	10.00±1.41	0.67±0.05	0	2.00±0.42	2.00±0.42	0	
	CCF	9.33±0.19	4.67±0.47	5.33±0.47	1.33±0.47	9.33±0.47	0.67±0.05	0	1.33±0.47	1.33±0.47	0	
	SFS	5.33±0.33	4.00±0.00	4.00±0.28	0.67±0.05	8.67±2.36	0	0	0.67±0.05	0.67±0.05	0	
Mg (mg/L)	N	0.80±0.01	1.00±0.00	1.88±0.02	0.05±0.02	1.64±0.06	0.03±0.01	0.20±0.00	0.84±0.06	0.65±0.07	0.25±0.07	150
	CF	0.77±0.10	0.96±0.09	1.83±0.04	0.05±0.01	1.59±0.13	0.01±0.00	0.18±0.02	0.78±0.02	0.64±0.06	0.21±0.01	
	CCF	0.74±0.06	0.93±0.29	1.79±0.12	0.04±0.00	1.55±0.07	0.01±0.00	0.17±0.10	0.77±0.10	0.59±0.02	0.16±0.06	
	SFS	0.72±0.02	0.91±0.28	1.76±0.09	0.03±0.00	1.54±0.05	0	0.14±0.05	1.01±0.16	0.57±0.10	0.13±0.04	

N = Non-filtered water samples, CF = Carbon filter water samples,CCF = Ceramics candle filtered water samples andSFS = Step filtration system water samples.

DISCUSSION

From Table 1., it was observed that the values for the pH in the water samples ranged from 4.01 to 7.65. In the month of December, samples **B, D, E,** and **I** (40% of sampled water) were below the WHO recommend value range of 6.5 to 8.5. It was observed from Table1 that the values for the TDS range from 7 to 315mg/L. These values were within WHO acceptable limit of 1000mg/L for drinking water. It was observed that the TDS values for samples **A, B, C, D** and **E** (borehole water samples) were relatively higher than the samples **F, G, H, I** and **J** (sachet water samples). This may be attributed to the treatment process the sachet water may have undergone prior to packaging. According to WHO (1984), there has not been any deleterious physiological reactions occurring in persons consuming drinking water that has TDS values in excess of 1000 mg/L, but the lower level of 1000 mg/L as a guideline value for TDS was recommended. (Ca) levels for the month of December ranged from Nil to 9.33±0.19 mg/L as presented in Table1. They were all within the WHO acceptable standard (200 mg/L). It was not detected in sample **F** . The highest level was observed in sample e (9.33±0.19 mg/L) for the month of May. This is similar to the report of [18] where they reported that the calcium level of all the sampled sachet water was within the permissible limit set by WHO. Calcium plays an important role in bone structure, muscle contraction, nerve impulse transmission, blood clotting and cell signaling[9][4].From Table 1, the concentration of Mg^{2+} ranged from 0.14 mg/L to 1.92 mg/L. These values were all below the WHO recommended value (150 mg/L) for drinking water. The low values of the magnesium is a possible indication that the water samples have undergone softening by cation exchange either naturally as in the case of borehole water sample or through treatment as in the case of sachet water samples [1]..

From Tables2. it was observed that the values for the pH in the water samples ranged from 3.90 to 7.31. Samples a, c, f, i and j (50% of sampled water) were below the WHO recommended value ranged from 6.5 to 8.5. It was observed from Table 2 that the values for the TDS ranged from 7 to 299 mg/L. These values were within WHO acceptable limit of 1000mg/L for drinking water. The Calcium (Ca) levels for the month of January ranged from Nil to8.00±0.02 mg/L as presented in Table 2. They were all within the WHO acceptable standard (200 mg/L). It was not detected in sample F. The highest level was found in sample A (8.00±0.02 mg/L).The concentration of Mg ranged from 0.14 mg/L to 1.92 mg/L. The values were all below the WHO recommended value (150 mg/L) for drinking water. Sample J recorded the lowest level of Mg (0.14 mg/L) while sample F recorded the highest level (1.92 mg/l)

From Table3, it was observed that the values for the pH in the water samples ranged from 3.93 to 7.01. Samples A, B, D, E, G, I and J (70% of sampled water) were below the WHO recommended value range of 6.5 to 8.5. Upon filtration, it was observed that the pH values were adjusted within the WHO guideline values. SFS gave the best pH adjustment followed by CCF and then CF. The adjustment of the pH could be attributed that the water samples contained some acidic metal that upon filtration balanced the pH of the water samples [2]. The values for the TDS ranged from 8.00±1.41 to 324±5.66 mg/L. These values were within WHO acceptable limit of 1000mg/L for drinking water. The Calcium (Ca) levels for the month of February ranged from 0.67±0.94mg/L in sample F to 10.67±1.23 mg/L in sample E. It was observed that upon filtration, Ca contents of the water samples reduced. The concentration of Mg ranged from 0.25 mg/L to 1.89 mg/L. The values were all below the WHO recommended value (150 mg/L) for drinking water. Sample J recorded the lowest level of Mg (0.25 mg/L) while sample F recorded the highest level (1.89 mg/L).

Table 4. showed the values for the pH in the water samples ranged from 4.30±0.07 to 7.50±0.42. Samples B, D, E, F, G, I and J (70% of sampled water) were below the WHO recommended value range of 6.5 to 8.5. Upon filtration, it was observed that the pH values were adjusted within the WHO guideline values. SFS gave the best pH adjustment followed by CCF and then CF. The adjustment of the pH could be attributed that the water samples contained some acidic metal that upon filtration balanced the pH of the water samples [2]. The values for the TDS ranged from 7.00±0.00 to 328.00±2.83 mg/L. These values were within WHO acceptable limit of 1000mg/L for drinking water. The Calcium (Ca) levels for the month of February ranged from Nil in sample F to 10.00±1.27 mg/L in sample A. It was observed that upon filtration, Ca contents of the water samples reduced. The values of the Ca contents were all below the WHO guideline values of 200 mg/L for drinking water.The concentration of Mg ranged

from 0.04±0.00 mg/L to 1.83±0.10 mg/L. The values were all below the WHO recommended value (150 mg/L) for drinking water.

Table 5. showed the values for the pH in the water samples ranged from 4.03±0.04 to 7.22±0.01. Samples A, B, D, E, G, I and J (70% of sampled water) were below the WHO recommended value range of 6.5 to 8.5. After filtration,it was observed that the pH values were adjusted within the WHO guideline values. SFS gave the best pH adjustment followed by CCF and then CF. The values for the TDS ranged from 8.00 ± 1.41 to 340.00 ± 7.07 mg/L. These values were within WHO acceptable limit of 1000mg/L for drinking water. The Calcium (Ca) levels for the month of April ranged from Nil to 11.33±0.19 mg/L. It was observed that upon filtration, Ca contents of the water samples reduced. The values of the Ca contents were all below the WHO guideline values of 200 mg/L for potable drinking water.The concentration of Mg ranged from Nil to 1.86±0.22 mg/L. The values were all below the WHO recommended value (150 mg/L) for drinking water.

Table 6. showed the values for the pH in the water samples ranged from 4.31±0.01 to 7.98±0.03. Samples A, C, D, G, I and J (60% of sampled water) were below the WHO recommended value range of 6.5 to 8.5. 40% of the samples had pH values above WHO limit. Upon filtration, it was observed that the pH values were adjusted within the WHO guideline values. SFS gave the best pH adjustment followed by CCF and then CF. The values for the TDS ranged from 7.00±1.41 to 315.00±4.24 mg/L. These values were within WHO acceptable limit of 1000mg/L for drinking water. The Calcium (Ca) levels for the month of April ranged from Nil to 12.00±0.71 mg/L. It was observed that upon filtration, Ca contents of the water samples reduced. The values of the Ca contents were all below the WHO guideline values of 200 mg/L for potable drinking water.The concentration of Mg ranged from Nil to 1.88±0.02 mg/L. The values were all below the WHO recommended value (150 mg/L) for drinking water.

It was observed that most of the water samples that had pH values outside the WHO's guideline were acidic. This results recorded is agreeable to the fact that Onitsha is a fast growing industrial location, of which such area are characterized by high presence of CO_2 and SO_2. These compounds when mixed with rain results to acid rain. The acidic rain can leach into the underground water and thus affect the pH of the borehole water [14]. The high presence of these greenhouse gases in supplied potable water can cause scale build up in water pipes and often lead to bitter taste in water causing a laxative effect on humans and young livestock [14]. Acid water can also lead to corrosion of copper pipes which could in turn lead to copper poisoning.pH is generally considered to have no direct impact on humans. However, long-term intake of acidic water can invariably lead to mineral deficiencies [7]. More so,low water pH can cause gastro-intestinal irritation in sensitive individuals [16].

On filtration using CF, CCF, and SFS, It wasobserved that the pH of the water samples were adjusted by the filtration methods employed. SFS gave the best pH adjustment followed by CCF and then CF. The adjustment of the pH could be attributed to the fact that the water samples contained some acidic metal that upon filtration balanced the pH of the water sample [2]. The results were in line with the report of [2]. The authors subjected some water samples to activated carbon filtration. They observed that the filtration balanced the pH of the water samples from acidic condition to within the WHO's guideline of 6.5 to 8.0. The difference in pH observed for six months may be due to the characteristics of the source waters influenced by both natural and anthropogenic factors [4].

The values for TDS in this study were within the WHO acceptable limit of 1000 mg/L for drinking water. It is observed that the TDS values for samples A, B, C, D and E (borehole water samples) were relatively higher than the samples F, G, H, I and J (sachet water samples). This may be attributed to the treatment process the sachet water may have undergone prior to packaging. WHO, however recommends the lower level of 1000 mg/L as a guideline value for TDS. However, it was observed that the three filtration methods (CF, CCF and SFS) had little or no significant effect on the values of the TDS as their values remained relatively the same after each filtration.The Calcium (Ca) levels from this study were found to be similar to the report of [18].They reported that the calcium level of all the sampled sachet water were within the permissible limit set by WHO. Calcium plays an important role in bone structure, muscle contraction, nerve impulse transmission, blood clotting and cell signaling [9],[4].
Generally in this study, Magnesium was found to be below the WHO guideline value. The low values of the magnesium is a possible indication that the water sample have undergone softening by cation exchange either naturally as in the case of borehole water sample or through treatment as in the case of sachet water samples [1].

Result of Water Quality Index

The WQI value ranges are presented in Table 7: by [3].The Water quality index (WQI) values and the water quality status (WQS) for each sample are presented in Table 8

Table 7: WQI value ranges (Brown *et al.,* 1970)

WQI Range (%)	Water quality status
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor

Table 8: WQI values of the water samples

	Dec. 2016		Jan. 2017		Feb. 2017		Mar. 2017		Apr. 2017		May, 2017	
	WQI	**WQS**	**WQI**	**WQS**	**WQI**	**WQS**	**WQI**	**WQS**	**WQI**	**WQS**	**WQI**	**WQS**
A	35.85	Good	22.12	Excellent	31.86	Good	31.86	Good	27.20	Good	22.88	Excellent
B	22.14	Excellent	32.73	Good	23.45	Excellent	23.45	Excellent	22.15	Excellent	34.69	Good
C	34.55	Good	31.07	Good	33.57	Good	33.57	Good	34.34	Good	32.15	Good
D	23.69	Excellent	33.38	Good	24.06	Excellent	24.06	Excellent	25.90	Good	24.98	Excellent
E	26.50	Good	38.69	Good	30.77	Good	30.77	Good	29.85	Good	40.22	Good
F	27.63	Good	24.83	Excellent	23.81	Excellent	23.81	Excellent	27.46	Good	27.05	Good
G	32.11	Good	30.90	Good	18.94	Excellent	18.94	Excellent	18.50	Excellent	20.43	Excellent
H	31.55	Good	29.19	Good	32.26	Good	32.26	Good	31.08	Good	31.25	Good
I	22.16	Excellent	22.12	Excellent	26.11	Good	26.11	Good	22.56	Excellent	23.43	Excellent
J	31.77	Good	24.83	Excellent	19.79	Excellent	19.79	Excellent	19.43	Excellent	23.52	Excellent

Table 7 shows the different ranges of Water Quality Index while Table 8 shows the result of calculated Water Quality Index for the samples studied. The results showed that majority of the water samples fall under excellent (0-25) and good (26-50). This shows that the water samples are safe for drinking. It was observed that the WQI was not influenced by the different time of the year the water were sampled.

CONCLUSION

This study has been able to demonstrate the quality of borehole and sachet water within Onitsha metropolis and the effectiveness of three filtration methods on improving the water quality.It is evident from this study that the selected water samples (borehole and sachet water) in Onitsha north, Anambra state, except for pH and Pb in some cases, met the recommended standards for physical, chemical and microbiological qualities.

The TDS of the samples during the period of study were all below the threshold limit (1000 mg/L) allowed by WHO. For the month of December, 2016, 40% of sampled water were below the WHO recommended pH value range of 6.5 to 8.5. For the month of January, 2017, 40 % of sampled water were below the WHO recommended pH value range for drinking water. In the month of February, 2017, 70 % of sampled waterwas below the WHO pH range. In March, 2017, 70 % of sampled waterwas below the WHO range. In April, 2017, 70 % of sampled water was below the WHO pH range. In May, 2017, 30 % of sampled water was below the WHO range. From the values, they are observed to be acidic but upon filtration treatments, the acidic samples were neutralized giving samples within the WHO standard.Among the filtration processes used, step filtration system(SFS)gave the best result. The Water Quality Index (WQI) analysis of the sampled water showed that the water were suitable for human consumption as the values fell within 0-25 (Excellent) and 26-50 (good). SFS and CCF recorded a 100% removal of Pb where it was detected.Since the study was conducted using randomly selected borehole and sachet water samples produced in some areas of Onitsha, Nigeria,it is advised that further study should be carried out on more borehole and sachet water brands in order to ascertain strictcompliance with WHO standards. This would help to avert public health hazards associated with theconsumption of contaminated sachet water.

DECLARATIONS

Funding Statement: This research was funded by five of us that did the research. We do not have any support from any other person or organization.

Conflict of Interest: The authors have no relevant financial or non-financial interest to disclose.

REFERENCES

1. Adediji, A and Ajibade, I.T.(2005). Quality of Well Water in Ede Area, South Western Nigeria. *Journal of Human Ecology.* 17(3): 223-228

2. Atabaki, M.M., Idris, J. and Siong, Y.K. (2014). Performance of Activated Carbon in Water Filters. Water Resources. 3(4): 21-35

3. Brown, R.M., Meclellan, N.I., Deininger, R.A. and Tozer, R.G. (1970). A Water Quality Index- do we care? *Water Sewage Work*s. 117: 339-343

4. Daiwo, F. (2011). Water Supply of Accra, With Emphasis on Sachet Water. Masters Thesis. *Royal Institute of Technology (KTH)*. Pp 38-51.

5. Dhakad, N.K., Deepak, S. and Choudhary, P. (2008). Water Quality Index of Ground Water (GWQI) of Jhabua Town. M.P. (India). *Journal of Environmental Research And Development*. 2(3):443-446.

6. Dufour, A., Snozzi, M., Koster, W., Bartram, J., Ronch, E. and Fawtrell, I. (2002). Assessing Microbial Safety of Drinking Water, Improving Approaches and Methods. *WHO/OLCD,* Pp, 47-55.

7. Fairweather-Tait, S. and Hurrel, R.F. (1996). Bio Availability of Minerals and Trace Elements. *Nutrition Research Reviews.* 9(1): 295-324.

8. Gajendra, C. (2013). Water Quality Assessment and Prediction Modelling of Nambiyar River Basin, Tamil, India. Doctoral Dissertation. Retrieved from http://shodhganga.inflibnet.ac.in/handle/10603/9477. 138-151.

9. Institute of Medicine [I.O.M] (1997). Dietary Reference Intakes for Calcium, Phosphorous, Magnesium, Vitamin D and Fluoride . Prepared by the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition Board. *National Academy Press Washington, DC*. Pp 1-100.

10. Lindsay, M. (2005). My Work At Enterprise Works, Ghana, Travelblog.org/Africa/Ghana. www.travelblog.org/Africa/Ghana/Greater-Accra/Accra/blog-155055. (accessed february 15^{th}).

11. Mberekpe, P. and Eze, N. (2014). Effect of Preservation on the Quality of Sachet Water Consumed by Households In Nsukka Zone. *Civil And Environmental Research.* 6(7): 25-30.

12. Nwosu, J.N. and Ogueke, C.C. (2004). Evaluation of Sachet Water Samples in Owerri Metropolis. *Nigerian Food Journal.* 22: 164-170.

13. Obiri-Danso, K., Okore-Hanson, A. and Jones, K. (2003). The Microbiological Quality of Drinking Water Sold on the Streets of Kumasi, Ghana. *Letters in Applied Microbiology.* 37: 334-339.

14. Orewole, M.O., Mkainde, O.W., Adekalu, K. and Shittu, K.A. (2007). Chemical Examination of Pipped Water Supply of Ile-Ife in South West Nigeria. Iran. *Journal of Environmental Health Science and Engineering*. 4(1): 51-56.

15. Oyedeji, O., Olutiola, P.O. and Moninuola, M.A. (2009). Microbial Quality of Packed Drinking Water Brands Marketed in Ibadan Metropolis an Ile-Ife City in South Western Nigeria. *African Journal Of Microbial Research.* 4: 96--102.

16. Uduma, A.U. (2004). Physicochemical Analysis of the Quality of Sachet Water Consumed in Kano Metropolis. *American Journal of Environment, Energy and Power Research.* 2(1): 1-10.

17. WHO (1984). Guildlines For Drinking Water Quality. Vol 2. Health Criteria and Other Supporting Information. Geneva. Pp 145-155.

18. Yusuf, Y.O., Iguisi, E.O. and Bello, A.L. (2007). A Comparative Analysis of the use of the Velocity Area Method and their Technique in Assessing the Discharge of River Kubanni, Zaria. *Journal of Geography, Environment and Planning.* 3(1): 37-45.