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Effectiveness and Risk Assessment of Bio Sand Filters (BSF) technique in Rural Water Purification

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Abstract Every human deserves the right to consume safe water as it is the basic necessity for their existence and sustenance. The study was aimed with the view of ascertaining the effectiveness of carbon and gravel-based biosand filters in treating rural waters and evaluating the risk of consumption using the water consumption risk assessment matrix (W-CRAM). The treatment using the carbon-based biosand filter (BSF) at Falcorp Mangrove Park increased the pH from 5.46 ± 0.05 to 7.5±0.3while gravel-based biosand filter at Otsoron community increased minimally from 4.43 ± 0.2 to 5.86 ± 0.4. For all the locations, there was 100% eradication of *E. coli*. Using the W-CRAM, the untreated waters had a 62% - 69% conformance and was rated medium risk and since it will affect people (P), the risk level could be classified as 3 E or 15 (P). However, after treatment, there was an increase between 77% and 100% conformance, with above 80% classified as excellent water quality with low risk rated as 1E or 5 (P). The study concluded that no water should be consumed if the non-conformance was contributed by microbial entities as severe health risk may set in.

Capsule summary
The use of carbon-based biosand filter was more effective than gravel-based biosand filter in water purification and the W-CRAM used to evaluate contaminated water could ensure potability.

Keywords point-of-use technique; purification; risk assessment matrix; water consumption

Introduction

The essence of water to human and living entities is very crucial and without this valuable resource, life on earth would cease to exist. Worldwide statistics has shown that there are over 844 million people who lacks access to safe water and about 2.3 billion people do not have basic sanitation services which have led to several water related diseases and death, a menace ravaging the world's population today [1]. For a healthy life, humans must consume safe water, which provides countless health benefits and free them from harmful pollutants and disease causing organisms (bacteria, viruses and parasites). Water is important for certain purposes and functions which include drinking, cooking, bathing and washing. Other applications of water include: agricultural, industrial, manufacturing and electricity generation amongst others [2].

Water could be obtained from different sources, some of which include; surface, ground, rain and spring. Untreated water may contain bacteria, viruses, heavy metals, pesticides, dissolved solids, human and animal wastes as a result of anthropogenic activities [3]. If consumed, the contaminants in untreated waters could cause a myriad of illness including gastrointestinal abnormalities, diarrhea, cholera, dysentery and typhoid. Also, there is a huge imbalance between demand and availability of water due to population growth, and the quest for water continues to increase and intensifies pressure on the finite water sources [4].

Most regions of the world especially developing nations have given up on water purification because they do not have the relevant technology to improve the untreated water they consume. Simple methods such as boiling and filtration are not adequate for the treatment of all possible contaminants that may be present in water. Dating back to the 19th century, natural spring water, which was considered safe for all practical purposes must now be tested before use because of the introduction of impurities from the atmosphere and environmental matrices. The old water purification technologies are being modified daily and new technologies are being invented, in a bid to curb water contamination and sustain lives. Some traditional treatment methods include: filtration through winnowing sieve, cloth, clay vessels, plant parts, Jempeng stone filter method and so on. These traditional methods could only eliminate some pollutants in the water, but would not provide safe drinking water. Modern ways of water purification which include: ultrafiltration (UF), ultraviolet (UV), electrochemical activation (ECA), portable reverse osmosis water purifiers, activated carbon filter, candle filter purifier and efficient adsorbent filters are expensive and not usually within the reach of the local populace [5].

In a bid to eliminate water contamination and enhance water purification, David Manz in the 1990s' came up with a water purification technology known as the biosand filter. The biosand filter is a simple household water treatment and water storage device, which is an innovation from the traditional slow sand filters specifically constructed and patterned for intermittent use. The biosand filter is an appropriate technology enable development (ATED) for water treatment. After several researches the centre for affordable water and sanitation technology, CAWST, [6], concluded that the biosand filter was able to remove up to 100% helminths (worms), 98.5% of bacteria, 70-99% of viruses and 95 % of turbidity and iron.

Governments in many developed countries have advance technologies to carry out water purification and distribution to its citizens at no cost. In Nigeria, most towns, cities and rural communities rely mainly on surface water and privately dug borehole water which is consumed untreated. The Niger Delta region and its environs has very low water table and suffer lots of challenges and is currently threatened with water pollution, environmental degradation and poor water quality.

This study evaluated the effectiveness of carbon and gravel-based biosand filter in purifying rural waters. Thus, in other to evaluate the risk associated with consuming such waters, the water consumption risk assessment matrix (W-CRAM) was applied. This was due to the fact that the water is not treated and used extensively for drinking and other domestic purposes.

Materials and Methods

Sampling Location

The study area was in Warri metropolis, an oil hub city located in Delta State, Nigeria. It shares boundary with Agbarho/ Ughelli, Sapele, Okpe, Udu and Uvwie, although most of these places, notably Udu, Okpe and Uvwie have been integrated to the larger cosmopolitan Warri. Delta State has twenty-one (21) Local Government Areas (LGA) with a 17,698km^2 land mass at a coordinate of 5.5325^{o}N and 5.8987^{o}E. The state hasan annual average rainfall above 300mm from the month April to October but less than 50mm from the month of December to March. However, there is hardly a month without rain in the Niger Delta coastline.

States surrounding Delta state includes Edo State, Anambra State, Bayelsa State. Warri South local government area as a centre of focus has a land mass of 1,520 square kilometers, the local government is made up of several communities including Ogunu, Ode-Itsekiri, Edjeba, Ijala, Ubeji, Ifie-kporo, Agbasa, Omadino, Orugbu, Igbudu, Obodo, Ikpisan, Ajamimogha, Ekurede, Okere and Alders town (Figure 1). The state habours many industrial establishment including major oil companies and is also a home to three different ethnic groups namely Ijaws, Urhobos and Itsekiri. The means of livelihood include farming, trading, fishing and extraction of fossil fuels (petroleum and natural gas) [7].

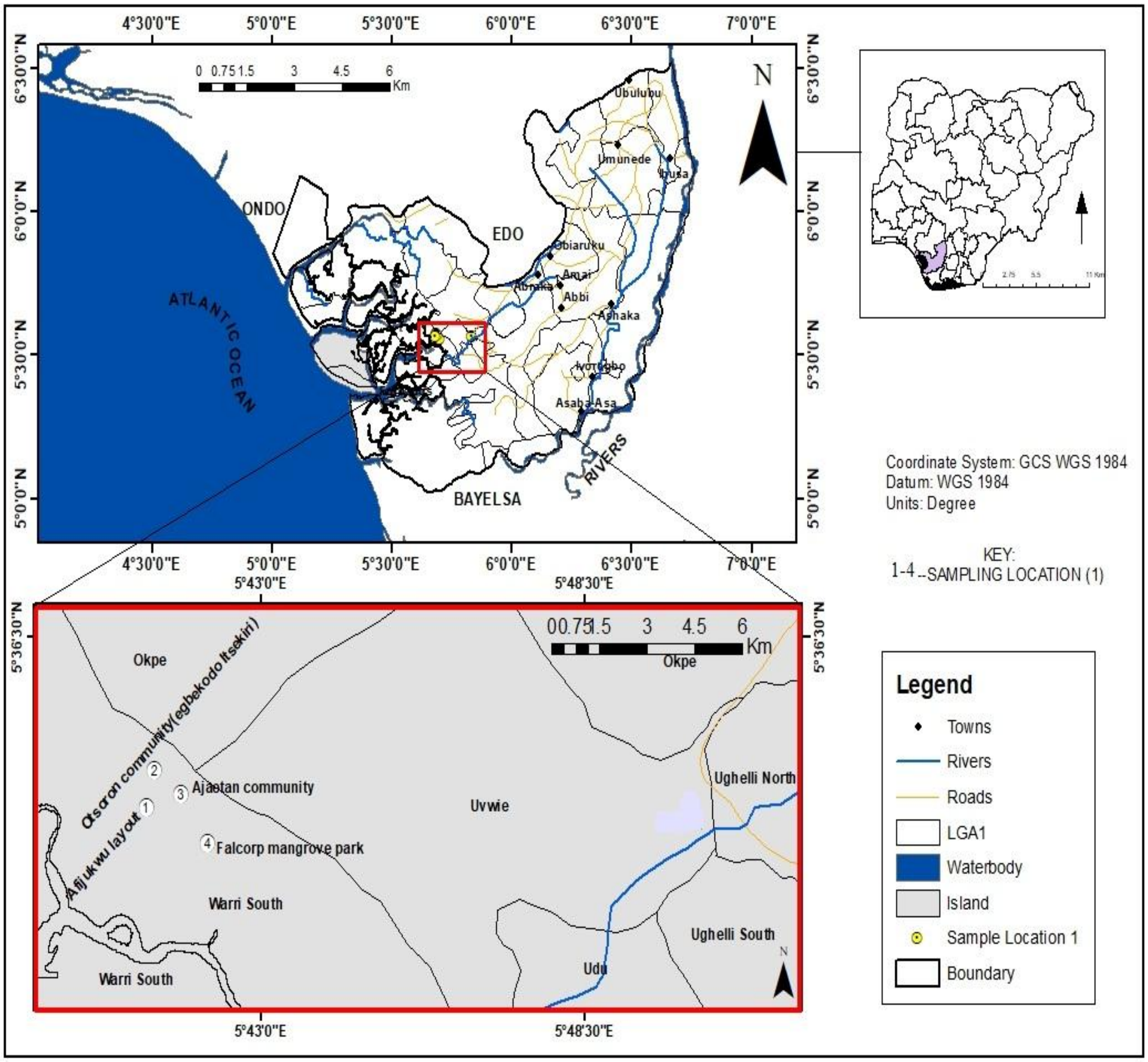


Figure 1: Geological map of Delta State showing the sampling locations

Water Sampling

The sampling locations include: Otsoron community at Egbokodo, Itsekiri, Falcorp Mangrove Park and Ajaetan community at Ifiekporo and Afijukwu layout in Warri, South Local Government Area of Delta State. A total of forty eight (48) samples were collected in triplicate from the sampling locations after one yearof active use of the biosand filters by the residents. During sampling, the pre-conditioned sample containers were rinsed three (3) times with the samples to be collected. Samples were collected after 2 minutes of consistent flow of water from the outlet tap of the water source. For the analysis of physico-chemical parameters, the samples were collected inpolyethylene sampling containers and were duly preserved by cooling in an ice chest at 4^{o}C. While samples for metals were preserved with 2 mL of 1:1 nitric acid (HNO_3). At the point of collection, parameters such as temperature, pH, electrical conductivity, total dissolved solids (TDS) and turbidity were determined in-situ while the other parameters including total hardness, salinity, total suspended solids (TSS) and microbial analysis were determined ex-situ in the laboratory [8].

Table 1: Coordinates for the sampling locations

Sampling Location	Latitude	Longitude
Otsoron community	N5^{0}34’36”	E5^{0}41’12”
Falcorp Mangrove park	N5^{0}33’34”	E5^{0}42’06”
Ajaetan community	N5^{0}34’16”	E5^{0}41’39”
Afijukwu layout	N5^{0}34’04”	E5^{0}41’04”

Determination of some physico-chemical and microbial properties

Table 2: Analytical methods for some parameters assessed in this study

Parameters	Analytical methods
pH	pH, (APHA 4500 H^+
Temperature, ^oC	Thermometer (APHA, 2550-B)
Total dissolved solids (TDS), mg/L	TDS (APHA 2540-C)
Salinity (Cl^-), mg/L	Mohr's Argentometric method (APHA 4500 Cl-B)
Conductivity, µS/cm	Conductivity (APHA 2510 B)
Total hardness	EDTA complexometric method (APHA 2340 C)
Turbidity	Nephelometric method: (APHA – 2130-B)
Feacal coliform bacteria	Multiple tube test (APHA 9222A)

Determination of metals in samples

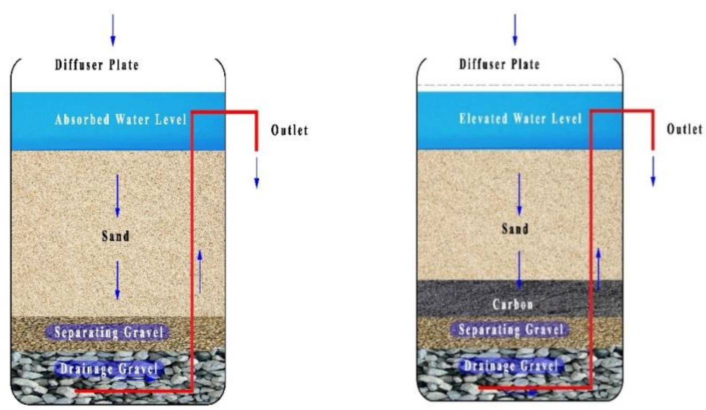
Two hundred and fifty (250) mL of water sample was accurately measured into a beaker, each labelled with the sample identity. Five (5) mL of nitric acid was accurately measured and added to the beaker containing the sample. The samples were digested on a hot plate at a temperature range of 90^{o}C to 95^{o}C until the volume was reduced to 15-20 mL, upon which they were allowed to cool and filtered. The filtrate was poured into a 25 mL volumetric flask and made up to the mark with double distilled water. The desired metals in the samples were analyzed using the atomic absorption spectrophotometer, Shimadzu AA-7000.

Determination of Feacal Coliform (*Esherichia coli* count)

Feacal coliform (*E. coli* count) was determined using multiple tube fermentation technique (#9222A) expressed as most probable number (MPN)/ml [8].

The biosand filter

The biosand filter is a simple ATED household water purification device that provides clean water to the developing world by using locally available low cost materials. In this study, the biosand filter employed comprised of different layers of well selected gravel / carbon and sand, all contained in a plastic container (Figure 2).



(a) Gravel-based biosand filter (b) Carbon-based biosand filter

Figure 2: Biosand filter

In the biosand filter, the top is fitted with a tight lid which prevents contaminants and unwanted pests from entering the filter. Below the lid, there is the diffuser plate, which protects the sand layer and prevents disturbance of the biolayer when water is poured into the filter. The biolayer is a community of micro-organisms that live on the top of the sand between 1 and 2 cm. This is a zone of biological activities where the micro-organisms formed consumes the pathogens in the contaminated water and in the process enables the filter treat the water. By keeping the contents wet, a biofilm develops, which is expected to remove 99% of impurities from the water, however, the water should not be consumed until after a 21-daycuring period.
The filtration sand removes pathogens and suspended solids while the separation gravel supports the filtration sand and prevents it from going into the drainage layer and clogging the outlet tube. Below the separation layer is the drainage gravel consisting of a coarser gravel that provides support to the separating gravel layer, which helps the water flow into the outlet tube. Gravity pushes the water up the tube, which then flows out into the safe water storage container. The water storage container must have a lid and a tap that protects the water from being re-contaminated (Figure 3).

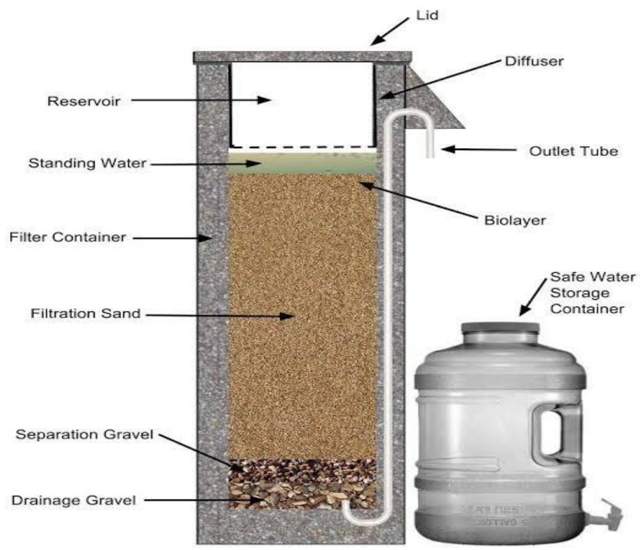


Figure 3: Components of a biosand filter

The mechanism of the removal of pathogens and suspended solids involves a combination of biological and physical processes that takes place in the biolayer and within the sand layer. These processes include: mechanical trapping, predation, adsorption and natural death (Figure 4).The biosand filter can be regarded as cost effective, provides safe and affordable potable water to rural households in developing countries [6].

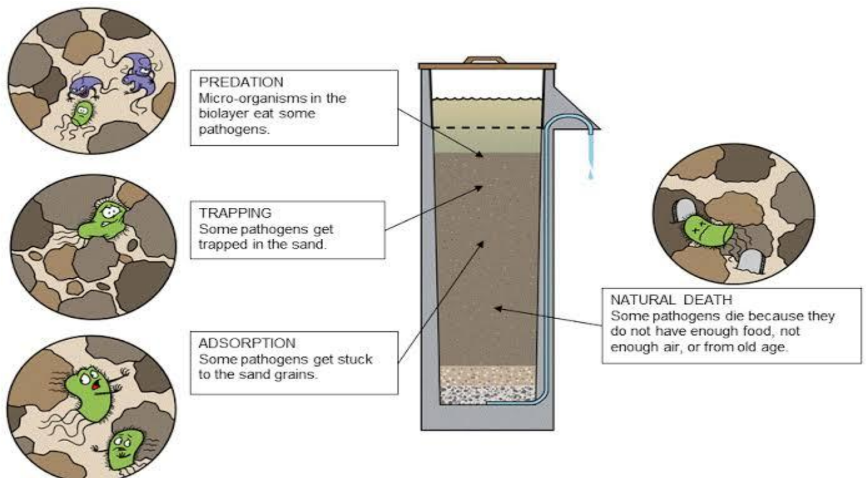


Figure 4: The biosand filter mechanism: Source: CAWST, [6]

Risk assessment for water consumption

On the water consumption risk assessment matrix (W-CRAM), risk levels can be classified as low, moderate, medium, high or very high (Table 3). A person consuming the water may be affected depending on the water quality, frequency / duration of consumption and if the water is treated or untreated. Factors considered for classification include: consumption frequency, safety consideration, indicator for water consumption, risk level and water quality amongst others. The risk levels are categorized in a numbered format [9,10]. Each hazard is given a rating, and this was multiplied by the probability that these hazards would occur using the relationship:

Risk level = hazard severity x likelihood (probability) of consumption (Table 3).

Hazard severity are rated as 1 (no harm), 2 (slightly harmful), 3 (minor harm), 4 (very harmful) and 5 (major harm/fatality).Similarly, the likelihood or probability of consumption are rated as 1 (seldom – A - yearly), 2 (frequent – B - quarterly), 3 (very likely – C - monthly). 4 (near certain – D - weekly) and 5 (certain – E – daily) (Table 3) [9,10].

For example rated on a scale of 10, if 7 parameters analyzed complied with the regulatory limits means that:

Percentage conformance = 7/10*100 = 70%,

From the rating on conformance it would be classified as moderate risk. Thus, if the water is consumed daily which is a probability of 5 or E and the conformance is 70% having a hazard severity of 2 (Table 3), then the,

Risk level = hazard severity (2) x likelihood (5) (probability of consumption) = 2 x 5 (E) = 10 or 2E and the risk level is moderate (i.e. intermediate).

Similarly, it also implied that for a 0% conformance and daily consumption, the risk level would be high, which is

Risk level = hazard severity (5) x (probability of consumption) 5 (E) = 25 or 5E

However, since it is affecting people it would be classified as 5E (P). Relevant researches have indicated that very high (extreme) risk could likely affect humans with severe impact on certain organs and resultant ailments [11, 12].

Table 3: Water Consumption Risk Assessment Matrix (W-CRAM)

Severity	**Consequences**						**Increasing Probability**				
	% conformance with tested parameters	**Indicator for water consumption**	**People**	**Safety consideration**	**Risk level**	**Water Quality**	**A**	**B**	**C**	**D**	**E**
							Seldom /yearly	Frequent/quarterly	Very likely/ Monthly	Near certain/weekly	Certain / daily
1	80 - 100%	Suitable	No harm	Safe	Low	Excellent	Low				
2	70 - 79%	Suitable	Slightly harmful	Moderate	Moderate	Good					

3	50 - 69%	Unsuitable	Minor harm	Medium	Medium	Medium		
4	20 - 49%	Unsuitable	Very harmful	Not safe	High	Bad		
5	0 - 19%	Unsuitable	Major harm/fatality	Not safe	Very high	Very bad	Medium	High

Data extracted from Ogeleka *et al*., [10] (modified)

The following is a guide for precautions to be taken when consuming water having the following risk levels:

1 x 5 = 5 = Low - adjudged potable and fit for consumption

2 x 5 = 10 = Moderate – should be considered fit for consumption

3 x 5 = 15 = Medium - should not be consumed without treatment

4 x 5 = 20 = High - consumption should be discontinued until at least 80 - 100% conformance is ascertained

5 x 5 = 25 = Very high (extreme) - consumption should be discontinued until at least 80 - 100% conformance is ascertained.

Results

Table 4 showed the mean results of water samples from Otsoron community and Afijukwu layout which had gravel-based biosand filter while the mean results displayed in Table 5were from Ajaetan and Falcorp Mangrove Park communities, having carbon-based biosand filter. Other data are displayed in Tables 6 and Figures 5-7.

The pH analysis carried out on the water samples before filtration using the gravel biosand filter indicated that the waters were acidic in Otsoron community (4.43 ± 0.2)and Afijukwu layout(4.40 ± 0.05). The pH values after filtration showed minimal increase with the gravel biosand filter in Otsoron community (5.86 ± 0.4) and Afijukwu layout (4.88 ± 0.3), which did not comply with the World Health Organization (WHO), Department of Petroleum Resources (DPR) and Federal Ministry of Environment (FMEnv) range of 6.5-8.5.However, after filtration using the carbon-based biosand filter, the pH results increased from 4.57 ± 0.02 to 6.26 ±0.4 for Ajaetan location, and 5.46 ± 0.05 to 7.5 ± 0.3 for Falcorp Mangrove Park (Table 5).

Electrical conductivity determines the concentration of conductive ions from dissolved salts and inorganic materials such as chlorides, sulphides and carbonate compounds. A higher conductivity value indicates that there are more salts dissolved in the water. The conductivity values ranges from a minimum of 59 ± 0.1µS/cm of the filtered water at Afijukwu layout to 67.46 ± 0.1µS/cm of the untreated water at Otsoron community (gravel BSF), and 40± 0.3µS/cm to 203 ± 10µS/cmin Falcorp mangrove park (carbon BSF). The recommended standard by WHO is 250µS/cm. All water samples were within the acceptable regulatory standards (Table 4 and 5).

Total dissolved solids (TDS), a measure of the combined content of all inorganic and organic substances contained in the water ranged from a minimum of 29 ± 0.4mg/L in Afijukwu layout to a maximum of 34 ± 1.0mg/L inOtsoron community while in Falcorp Mangrove Park, a range from 20 ± 0.02 mg/L to 106 ± 7.0mg/L was reported (Table 5).

Total suspended solids (TSS) of 18 ± 1 mg/L in the untreated water at Otsoron community was completely removed after treatment. Similarly, there was 100% suspended particle removal upon treatment of the water at Ajaetan community which initially had 1.0 ± 0.02 mg/L suspended particles present. The samples from Falcorp Mangrove Park was free of suspended solids.

When water is cloudy with particles, it is said to be turbid. Turbidity measures the degree to which water loses its transparency due to the presence of suspended particles. The standard for turbidity according to WHO is 5 NTU. Untreated water samples from Otsoron community with a turbidity value of9 ±1NTU was reduced to 1 ± 0 NTU after filtration with the gravel biosand filter (Table 4).

The average salinity as chloride content ranged from 11.1 ± 0.4 mg/L to 14.1 ± 0.1 mg/L (Afijukwu layout)and 7.04 ± 0.02 mg/L to 8.1 ± 0.07mg/L (Falcorp mangrove park).The mean values for total hardness lies between 10 ± 0.05mg $CaCO_3$/L and 18 ± 0.1 mg $CaCO_3$/L in compliance with the WHO standard of 500 $CaCO_3$ mg/L. The range for calcium hardness varied between 1.6 ± 0.04 mg/L (Otsoron community) and 2 ± 0.05 mg/L (Ajaetan community).

Table 4: Mean results of treated and untreated water using gravel-based biosand filter

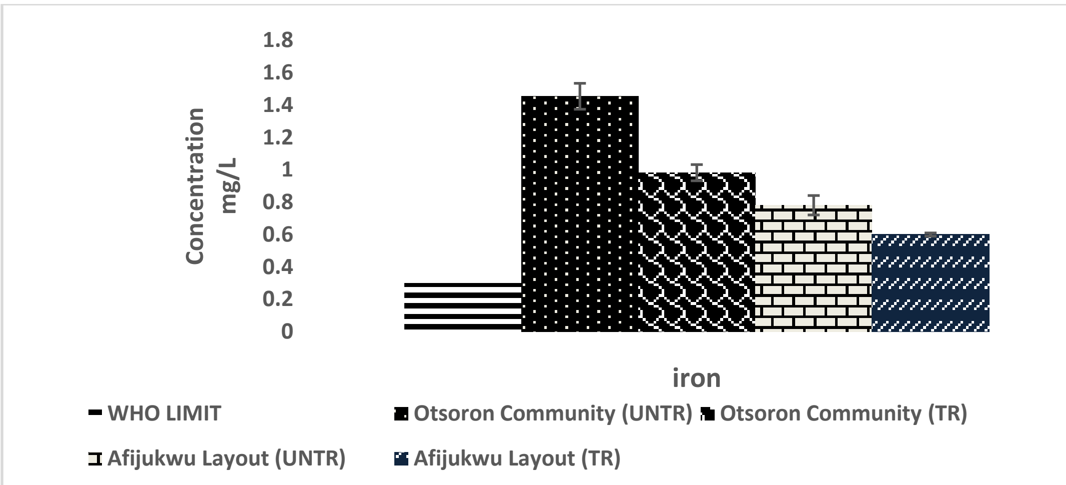
Parameters	WHO Limit	DPR Standard	FME Standard	Otosoron Community		Afijukwu layout	
				Untreated	**Treated**	**Untreated**	**Treated**
pH	6.5-8.5	6.5-8.5	6.5-8.5	4.43±0.2	5.86 ±0.4	4.4±0.05	4.88±0.3
Temperature °C	N/A	25	25	29.2 ± 0.15	29.3 ± 0.55	29.4 ± 0.35	29.5 ± 0.5
Electrical Conductivity µS/cm	250	N/A	N/A	67.46 ± 0.1	60.4 ± 0.1	60 ± 0.1	59 ± 0.1
Total Dissolved Solids mg/L	1500	N/A	2000	34 ± 1	30 ± 0.1	30 ± 0.51	29 ± 0.4
Total Suspended Solids mg/L	N/A	N/A	N/A	18 ± 1	0 ± 0	2 ± 0	0 ± 0
Turbidity NTU	5	N/A	10	9 ±1	1 ± 0	5 ± 1	1 ± 0
Salinity mg/L	200	N/A	600	12.1 ± 0.1	12.1 ± 0.1	14.1 ± 0.1	11.1 ± 0.4
Total Hardness mg $CaCO_3$/L	500	500	500	14 ± 0.08	10 ± 0.05	16 ± 0.05	12 ± 0.05
Calcium Hardness mg/L	75	200	200	1.6 ± 0.04	1.6 ± 0.04	1.6 ± 0.04	1.6 ± 0.04
E coli count (MPN/mL)	0	N/A	N/A	20 ± 0	0± 0.0	20 ± 0	0± 0.0
Metals (mg/L)							
Copper	2	1.5	1.5	0.042 ± 0.001	0.03± 0.002	0.062± 0.003	0.024± 0.001
Cadmium	0.005	N/A	N/A	0.048± 0.003	0.012± 0.001	0.006± 0.00	0.003± 0.00
Lead	0.01	N/A	N/A	<0.001	<0.001	<0.001	<0.001
Nickel	0.007	N/A	N/A	<0.001	<0.001	<0.001	<0.001

Table 5: Mean results of treated and untreated water using carbon-based biosand filter

Parameters	WHO Limit	DPR Standard	FME Standard	Ajaetan community		Falcorp mangrove park	
				Untreated	**Treated**	**Untreated**	**Treated**
pH	6.5-8.5	6.5-8.5	6.5-8.5	4.57± 0.02	6.26± 0.4	5.46± 0.05	7.5± 0.3
Temperature^{0}C	N/A	25	25	32.4 ± 0.5	32 ± 0.6	30 ± 0.8	30 ± 0.6
Electrical Conductivity µS/cm	250	N/A	N/A	86 ± 0.2	78 ± 1	203 ± 10	40 ± 0.3
Total Dissolved Solids mg/L	1500	N/A	2000	43 ± 0.4	39 ± 0.5	106 ± 7	20 ± 0.02
Total Suspended Solids mg/L	N/A	N/A	N/A	1 ± 0.02	0 ± 0	0 ± 0	0 ± 0
Turbidity NTU	5	N/A	10	3 ± 0.2	0 ± 0	2 ± 0.4	0 ± 0
Salinity mg/L	200	N/A	600	14.1 ± 0.1	10.1 ± 0.3	8.1 ± 0.07	7.04 ± 0.02
Total Hardness mg $CaCO_3$/L	500	N/A	N/A	18 ± 0.04	16 ± 0.02	14 ± 0.02	10 ± 0.03
Calcium Hardness mg/L	75	N/A	NA	2 ± 0.05	1.6 ± 0.05	1.6 ± 0.05	1.22 ± 0.02

E coli count (MPN/mL)	0	N/A	N/A	15 ± 0	0± 0.0	7 ± 0	0± 0.0
Metals							
Copper	2.0	1.5	1.5	0.068± 0.002	0.024± 0.001	0.062± 0.003	0.036± 0.002
Cadmium	0.005	N/A	N/A	0.008± 0.001	0.003± 0.00	0.009± 0.001	0.002± 0.00
Lead	0.01	N/A	N/A	<0.001	<0.001	<0.001	<0.001
Nickel	0.007	N/A	N/A	<0.001	<0.001	<0.001	<0.001

The results of heavy metals water samples in the gravel and carbon filter indicated that iron, copper and cadmium content were reduced after filtration (Table 4 & 5; Figures 5&6).However, lead and nickel concentrations in all the samples was below the detection limit of the measuring instrument – atomic absorption spectrophotometer (AAS).



UNTR= untreated, TR= treated

Figure 5: Average concentrations of iron using gravel-based biosand filter

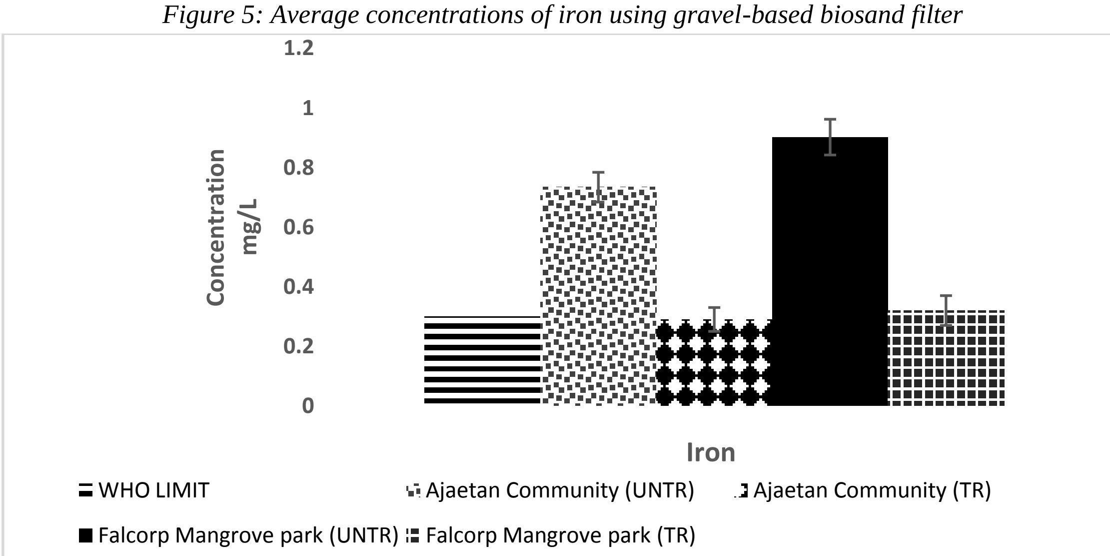


Figure 6: Average concentrations of iron using carbon-based biosand filter

Percentage efficiency of the biosand filter

Percentage efficacy can be regarded as a measure of the effectiveness of the biosand filter in water purification based on a scale of 100. This was achieved by considering some determinants of water quality which include some physico-chemical and microbiological parameters tested in this study. The two filter types were effective in reducing the turbidity of the untreated coloured cloudy waters. The biosand filter attained a percentage efficiency of 80% at Afijukwu layoutand 89% at Otsoron community while 100% was achieved in both Ajaetan community and Falcorp mangrove park.

Total suspended solid (TSS) which includes all particles suspended in water had 100% removal in the affected locations. Iron precipitated as ferric iron (Fe^{3+}) causes a reddish brown colouration in water, which makes it cloudy. The biosand filter reduced iron by 61% at Ajaetan community, 66% at Falcorp Mangrove Park, 33% at Otsoron community and 23% at Afijukwu Layout. In addition, the biosand filters eradicated microbial contamination by 100% (Figure 7).

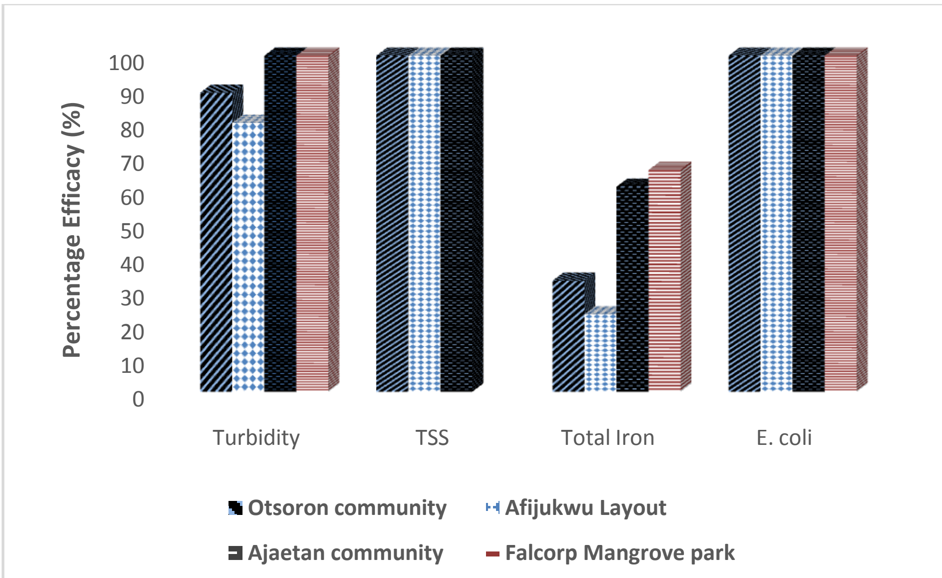


Figure 7: Percentage efficacy of gravel and carbon–based biosand filter

Risk evaluation using the water consumption risk assessment matrix

The risk associated with drinking water was evaluated using the water consumption risk assessment matrix (W-CRAM),This was achieved by using some water quality parameters, which include pH, electrical conductivity, TDS, Turbidity, total hardness, calcium hardness, salinity, *E coli,* iron, copper, cadmium, lead and nickel to adjudge the percentage compliance with the WHO standard.

Table 6: Risk assessment of water using the water consumption risk assessment matrix

	Otosoron Community		**Afijukwu layout**		**Ajaetan community**		**Falcorp mangrove park**	
	Untreated	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**	**Untreated**	**Treated**
Parameters analyzed	13	13	13	13	13	13	13	13
Parameters with conformance	8	10	9	11	9	12	9	13
% conformance	62	77	69	85	69	92	69	100
Water quality	Medium	Good	Medium	Excellent	Medium	Excelle	Medium	Excellent

rating						nt		
Risk level	Medium	Moderate	Medium	Low	Medium	Low	Medium	Low
Risk level for daily consumption	3E or 15 (P)	2E or 10(P)	3E or 15 (P)	1E or 5 (P)	3E or 15 (P)	1E or 5 (P)	3E or 15 (P)	1E or 5 (P)

The WHO limits was used for rating the risk level for the parameters with limits.

The untreated waters recorded a percentage conformance of 62% in Otsoron community while 69% was attained in Afijukwu Layout, Ajaetan community and Falcorp Mangrove park (Table 6). This may imply that people consuming suchuntreated waters daily could be at medium risk with a calculated risk value of3 E or 15 (P) based on the W-CRAM, which could lead to some health risk. With non-conformance in pH, total iron, cadmium and *E coli* one cannot adjudge the safety of these waters as ideal quality since the untreated waters were acidic, contained considerable amount of heavy metals and disease causing organisms. Although the World Health Organization stated that these parameters may not pose serious health concern at levels found in drinking water, they however concluded that humans may reject such waters based on their non-conformance [2].

After filtration, the treated waters at Otsoron Community and Afijukwu layouthad a percentage conformance of 77% and 85% respectively, while 92% and 100% were recorded for Ajaetan community and Falcorp Mangrove Park, which showed good to excellent water quality. It should be noted that daily consumption of the treated (filtered) water at Otsoron Community is at a moderate risk. Afijukwu Layout, Ajaetan community and Falcorp Mangrove Park would be at low risk since the water quality had a calculated risk value of1 E or 5 (P) based on the W-CRAM (Table 6).

However, a non-conformance in feacal coliform (*E. coli* count) could be detrimental to human since such waters could likely contain disease carrying organisms that can cause severe health implications, including cholera, dysentery, diarrheal, typhoid and gastro-intestinal disorders, hence such waters should not be consumed without treatment to acceptable compliance.

Discussion

Potable (drinking) water should have acceptable quality in terms of its physical, chemical and biological parameters so that it can be safely used for drinking, cooking and other domestic purposes. World Health Organization (WHO) considers drinking water to be safe only if significant health risk during its lifespan when it is consumed is low and poses no health challenges. The risk associated with human consuming polluted water are listless and could result in several water related diseases such as cholera, typhoid, diarrheal, dysentery and gastrointestinal disorders [13]. The rate of mortality as a result of consuming untreated waters is higher in rural areas than urban areas since certain urban communities can still have access to treated water. However, most rural populace do not have facilities for water treatment, hence consumes such waters untreated. Most rural dwellers are daily at the risk as a result of poor hygiene, improper sanitation and lack of treated water [14,15].

The biosand filter have the capability to eradicate microbial contamination in addition to eradicating some physical and chemical impurities. Humans can physically identify when water is turbid, coloured, taste bad and smell awful with their sensory organs. Once this is identified, they take caution whether to drink the water or not depending on whether it appear / taste unpleasant. However, there are waters consumed today, which may appear clean by physical observation but may contain unseen pathogens, which may be responsible for most of the water related diseases suffered today. Thus, any water containing specific coliform like *E. coli* or other forms of coliform may likely result in severe health risks and such waters should not be consumed until treated to achieve a high level of conformance with relatively low risk applying the W-CRAM.

Several studies reported a decrease in organic substances and turbidity in groundwater using the biosand filter with a percentage efficiency between 71.28% and 76.82%for organic substance while turbidity recorded an efficiency range of 94.08% to 96.56% [16]. A similar study also showed that these filters effectively removed up to 90%

viruses, >99.9% of protozoa and helminthes, 90-100% of *Escherichia coli,* and up to 85% turbidity [17]. The results from these researches corroborates the data obtained from this study.

Similarly, the use of biosand filters as a point-of-use water purification technique in rural communities would help in solving the problems associated with ground and surface water pollution posing threat to human lives and in turn grant access to many lacking potable water [18]. However, some studies have previously reported contamination in drinking water occurring during transport, storage and serving. In other words, filtered waters could still be contaminated if not properly handled as noted in studies by Clasen and Bastable, [19]; Copeland *et al*., [20] and Wright *et al*., [21].

Consequently, the risk of consuming untreated waters cannot be underestimated as illustrated using the W-CRAM. Drinking safewater has lots of benefit to the human body and the use of an improved biosand filter with carbon would help to achieve the good health we all earnestly yearn for, which includes relieving fatigue due to dehydration, flushing out toxins and saving lives.

Conclusion

We conclude that the biosand filter could be considered an appropriate technology in water purification because of its efficacy in eliminating most pollutants and reducing the inherent risk in untreated waters with the carbon-based filter having better efficiency than the gravel-based filter. Using the water consumption risk assessment matrix (W-CRAM) to appraise the quality of water would further assist in adjudging the quality of drinking water since most untreated waters cannot be considered safe or fit for consumption without assessment. Thus, the use of the W-CRAM indicated that the risks associated with consuming untreated waters can be prevented if known and this could help to safeguard human from the deleterious effects of water related diseases.

Competing Interests

Authors have declared that no competing interests exist.

Authors' Contributions

This work was carried out in collaboration between both authors. Doris Fovwe Ogeleka designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Mildred Chukwuedum Emegha managed the analysis and literature searches. Both authors read and approved the final manuscript.

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Biography

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