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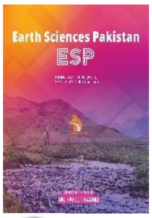

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RESEARCH ARTICLE

ENHANCING BORE-HOLE WATER QUALITY IN COASTAL REGION OF NIGERIA

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ABSTRACT

Water is crucial for human survival, food production, and economic growth. However, many poor nations, including Nigeria, lack access to potable water. Untreated natural sources, such as ponds, rivers, and streams, are the only viable source for domestic use. In Oboguru, a community in Delta State, rainwater harvesting is not possible due to acid rain. The only viable option of water supply is through boreholes which have high iron content. This study is aimed to enhance Borehole water quality in rural areas with simple treatment methods. The treatment plant consists of a multiple-tray aeration tower in a hopper-shaped sedimentation tank constructed to provide a chamber of undisturbed body of water allowing for sedimentation. Draw off of the clear water from the sedimentation tank is by a 100mm diameter pipe that takes the water by gravity to a containerized rapid gravity filter. The filter media consists of graded sand, gravel, and activated carbon for effective iron removal. The filtered water flows by gravity into the 4.5 m3-capacity clear-water/chemical contact ground tank of steel construction. Filter backwashing is accomplished by 45 m3 of treated water in the elevated tank. The results revealed that the removal of iron content of 3.5mg/l was 100%. while the maximum removal of CO2 was 77.4%. The Water Quality Index (WQI) of the treated water improved from 514.74 to 23.28 indicating excellent water quality. With decreases in acidity, hardness, turbidity, alkalinity, and total dissolved solids, there is evidence that aeration, sedimentation, and filtration have greatly enhanced the water's quality. This low-cost treatment method has achieved better water quality that is safe and free from contamination

KEYWORDS

Water quality, Groundwater treatment, Iron Removal. Oxidation, Obuguru.

1. INTRODUCTION

An essential natural resource for humankind's survival and well-being is water. It is also necessary for the production of food and energy, which advance a society's industrial and economic growth. Therefore, a steady and safe supply of water is necessary for both individual well-being and community growth. There is water everywhere but no water to drink is a well-known adage. People are not only dying for water, they are also dying of it (Duru, 2009; Yuri, Adriano and Lutiane, 2022). Primarily, the consequence of the lack of safe water for community consumption is an invitation to various forms of diseases (Sundaravadivel et al., 2009)

The majority of populations in poor nations, including Nigeria, do not have access to potable water. For all domestic requirements, there is complete reliance on untreated natural water sources such as rivers, streams, ponds, and manually dug wells.. This is the situation in Oboguru, a Delta State's Burutu local government area community. Routinely, circumstances compel inhabitants to fetch water from the unprotected community stream. People visit these water sources daily to get drinking and cooking water, wash their clothes, take baths, and for other purposes. These waters are often dangerous to drink because of heavy use and fecal matter pollution. As a result, the populations experience epidemics frequently. (Sundaravadivel et al., 2009).

Boreholes represent a major source of potable water supply for most urban and rural areas in Nigeria (Onyenechere and Osuji 2012; Nwachukwu and Onyenechere, 2023; Ume and Chukwuemeka, 2009; Makonjo and Calford, 2022; Forester et al., 2000). This is the case in the Niger Delta were groundwater is the main source of drinkable water. However, saltwater intrusion poses a significant environmental threat, particularly near the coast where the aquifer system interacts semi-diurnally with seawater. Many dug boreholes, particularly those in Burutu, Obuguru, Akugbene, Okwagbe, Ezebiri, Okwama, Ofrukama, Deghele, etc., have yielded saline water thus far. (Akuaibit, 2020). A significant supply of municipal drinking water for many of Burutu's small and medium-sized towns is from groundwater. Since it is exceptional and of constant quality and it usually requires little to no treatment before consumption, groundwater is preferred by many above surface water. Researchers evaluated the percentage compatibility of the water quality with the standard varied with depths, and observed a strong correlation (r=98) percent) between the depths of boreholes and their water qualities (Obot and Edi, 2012). They recommended that depth be considered if quality compatibility is guaranteed in the coastal plains' sands formation. Regrettably, different ratios of iron and manganese in groundwater supplies can lead to contamination. Researchers in their physiochemical and bacteriological studies of selected borehole water in Uyo metropolis in Akwa Ibom State got results that suggest that the borehole water studies are safe for drinking, laundry, and other application but with some treatment (Asuquo and Etim, 2012). However. the most sensible and realistic option for providing these populations with a secure water supply is groundwater.

Groundwater resources in the Niger Delta are also at risk due to climate change and sea level rise. Sea level rise in this century is estimated in the range of 20 to 88cm. This will result in the migration of the saltwater interface further inland from the coast, making the extraction wells in the freshwater area brackish and saline (Ugbe, 2012).

The amounts of heavy metals in the topsoil of the Niger Delta communities

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of Burutu and Obuguru were measured (Tubotu and Agbaire, 2022). A total of twelve (12) composite soil samples were gathered from both communities. Using an Atomic Absorption Spectrophotometer (AAS) to analyze heavy metals, it was found that of all the soil samples examined, Fe had the greatest concentration. Raw water from boreholes is not suitable for usage due to the presence of iron and other contaminants. Therefore, it is essential to treat the water with a comparatively less expensive method when compared to contemporary methods for treating potable water supplies.

This study is aimed at enhancing Borehole water quality in Obuguru and other rural areas having similar water quality challenges in Nigeria with simple treatment methods. This low-cost treatment method used locally available materials and achieved better water quality that is safe and free of microbial contamination. Hence, the need of this study to enhance the quality of water supply to the community.

2. Materials and Methods

2.1 The Study Area

This research was done in Obuguru. in Ogulagha Kingdom, a riverine izon (Ijaw), and oil-producing kingdom in the Burutu Local Government Council Area (LGA) of Delta State, Nigeria. In 2019, Obuguru sprang up as an autonomous community in Ogulagha Kingdom. The Ogulagha Kingdom is made up of several communities comprising of Obotobo I and II communities, Ogulagha, Sokebolou, Youkiri, Youbebe, Obuguru, Okuntu and others. It is located in the south of the state, on the coast of the Niger Delta. The headquarters of the LGA is Burutu. Burutu has a population of 221,134 people (2006 census. It is located along Nigeria's 850 km long coastline, with the Atlantic Ocean as its border. The majority of the people in Burutu are Ijaw, with a minority of Itsekiri and Urhobo. The economy of Burutu is based on fishing, agriculture, and the oil and gas industry. It is home to several oil and gas companies, including Shell, Chevron, and ExxonMobil. Burutu is a relatively poor LGA, with a high rate of unemployment and poverty. The LGA is also facing some environmental challenges, including oil spills and pollution. Figure 1 is a Satellite Image of Forcados Showing the Obuguru.

Nigeria's Delta State lies in the South-South geopolitical zone (Figure 2). The State is roughly 18,050 square kilometers in size, with more than 60% of the area being made up of land. situated between 5°00' and 6°45' E. and 5°00' and 6°30' N. longitudes. The states of Anambra, Imo, and Rivers States border the east, Edo State borders the west and north, and Bayelsa State borders the southeast. The Bight of Benin spans roughly 160 kilometers of the state's coastline to the south.

Figure 1: Satellite Image of Forcados Showing Obuguru (Source**:** Atakpo, and Akpoborie, 2011).

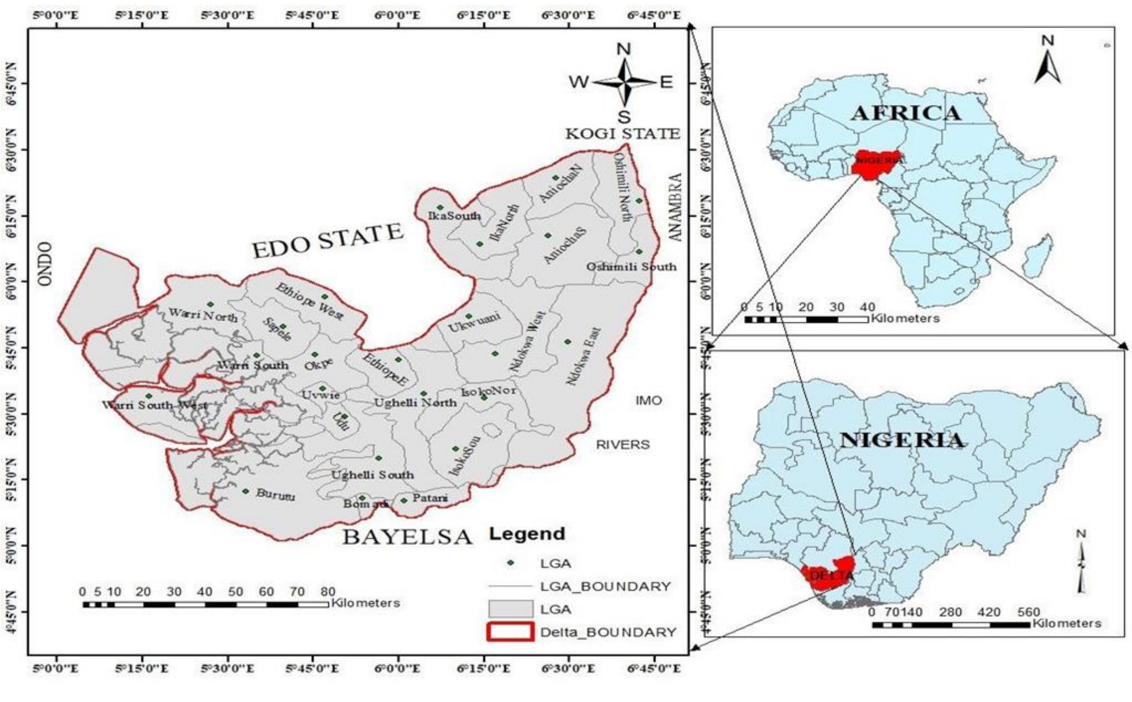

Figure 2: Map of Delta State, Nigeria (Source: Eyeta et al,2023)

As per the World Bank, around 41 million Nigerians reside in regions that are highly susceptible to climate change. Coastal areas such as Delta state is hosting some of the greatest exposure levels.

Due to the waves that strike their homes during high tide, children are frequently ill. There is More than thirty million people who depend on marine resources for their livelihood live there. However, lives, properties, and livelihoods are at risk due to the ongoing ocean encroachment. The distance between the dwellings and the river is only five meters. Sandbags were used to stabilize the houses to keep them from collapsing because the tides had exposed the foundations of numerous homes by carving away soil beneath them. For the protection of their homes and the children, they utilize the wood pile as a preventative measure. Parents are constantly afraid that their children would be carried away by the sea if proper care is not taken.

2.2 Water Treatment Plant Design

The first step in designing a water treatment plant is to assess the water source, the quality and quantity of water required. The water's physical, chemical, and biological properties are taken into account, along with any possible hazards or contaminant

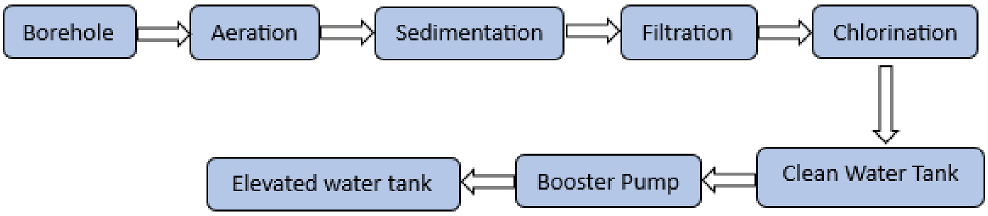

***Figure 3**: Layout of Treatment Plant Adapted for this Study

The layout of the treatment plant adapted for this Study is shown in Figure 3.

2.2.1 Water Borehole as Water Source

The water borehole constructed at Obuguruwas pump tested and its yield was 15m³/hr. A submersible with a discharge (Q) of 12m³/hr. was installed. The result of preliminary assessment of physical, chemical, and biological characteristics of the raw water samples is presented in Table 1. Table 1 shows that the raw water from the Obuguru borehole was characterized by high PH and hardness values. This also gave rise to a high total dissolved solid content. The water is sparkling, haze-free and odor-free.

Table 1: Physicochemical Water Analysis Results. Sources: (NSDWQ, 2007; WHO, 2017).

Parameters (Mg/l)	Raw Water	Maximum Permitted by WHO,2017	Maximum Permitted NSDWQ,2007	Remark
Colour (Hazen units)	800	50	15	Above
pH	7.4	6.5-8.5	6.5-8.5	
Turbidity (NTU)	34	25	5	Above
Acidity (as CaCO3)	40.0	250		
Alkalinity (as CaCO3)	16.0	250		
Sulphate (as CaCO3)	N.D.	200	100	
Free Chlorine	0.0		0.2 - 0.25	
Free Ammonia	0.0			
Total Hardness (as CaCO3)	39.94	100	150	
Calcium (as CaCO3)	7.29	1.0		Above
Magnesium (as CaCO3)	4.43		20	
Chloride	3.55	250	100	
Nitrates	0.0	10	50	
Silica SiO_2	0.0			
PV(COD)	0.40			
Iron as Fe	3.5	0.05-0.3	0.3	Above
Total solids	100			
Total dissolved solids	100	-	500	

Table 1 revealed that colour, turbidity, Calcium (as CaCO3), and Iron as Fe are above the maximum permissible values levels of the Nigerian Standard for Drinking Water Quality NSDWQ (2007) and WHO Guideline for Drinking Water Quality (WHO, 2017). Hence, these impurities would need to be eliminated by the treatment plant

As could be seen on the raw water sample test result, iron is typically found in groundwater as dissolved ferrous complexes. Iron in this form must be removed by oxidizing ferrous iron to insoluble ferric hydroxide, commonly by aeration, and then filtering out the precipitated particles.

The presence of iron in water can cause several major issues, such as: (a) an unpleasant metallic or bitter taste; (b) an unpleasant reddish-brown or black color; (c) deposits that clog plumbing fixtures; (d) stains on clothing when washed; and (e) the growth of microorganisms like clonothrix and crenothrix, especially in the presence of organic matter. These microbes have the potential to worsen deposition issues and to create sulfides, which exacerbate issues with taste, odor, and color; (f) clogging and covering the softening media, which makes water softening procedures for industrial application problematic. Various regulatory bodies have proposed rules to regulate iron and manganese concentrations in order to avoid these problems. For instance, the United States Environmental Protection Agency (USEPA) has mandated that drinking water contain amounts of iron and manganese of no more than 0.3 and 0.05 mg/L, respectively.

Oxidation is a common method for removing iron. The oxidation process may be rendered ineffective if organic materials present in surface waters and groundwaters combine with iron to produce soluble complexes that may not be sufficiently oxidized to an insoluble state. Such waters may need to be treated with strong oxidants. The method chosen for iron removal will depend on the approach taken in the removal of various contaminants. When it comes to groundwater, iron is typically associated with large concentrations of free CO_2. If the iron is removed without addressing the free CO2, pipes and mains may corrode. (g) If lime softening is necessary to remove hardness, it will also work to remove CO2 and iron. (h) Chlorination may be required if organics removal or bacterial disinfection is required; this will help remove iron. The following technologies, out of several available for removing iron and manganese from water supplies, are widely used: (i) Sand filtration (or dual-media filtration) after aeration, frequently combined with chemicals, settling, flotation, and a contact tank. This is how most people in developing nations do it. (j) Water with high iron concentrations (>5.0 mg/L) is treated by chemical oxidation (without pre-aeration) and then filtering.

2.2.2.1 *Treatment Alternatives*

Many water treatment schemes have been developed to remove iron and manganese compounds from water. Systems in use today include aeration followed by filtration, sedimentation, and chlorination; ozone followed by filtration; chlorine dioxide followed by filtration; potassium permanganate followed by filtration, biological filtration; ion exchange etc. The first option was chosen due to its effectiveness, ease of construction, and economy.

Aeration provides the dissolved oxygen needed to convert the iron and manganese from their ferrous and manganous forms to their insoluble oxidized ferric and manganic forms. The produced percipitates of ferric hydroxide and manganic oxide are then removed by sedimentation followed by rapid sand filtration. It takes 0.14mg/L of O_2 to oxide 1 mg/L of iron; and 0.29 mg/L of O2; to oxide 1 mg/L of manganese Aeration oxidizes ferrous hydroxide by first stripping off carbon dioxide and then precipitating ferric hydroxide as follows:

$$4\,Fe(HCO_3)_2 + 2H_2O + O_2 \Rightarrow 4\,Fe(OH)_3 \downarrow + 8CO_2 \quad (1)$$

To change iron from their ferrous forms to their insoluble oxidized ferric and manganic forms, aeration supplies the dissolved oxygen required. Sand filtration is used to quickly remove the ferric hydroxide precipitates that have been generated.

2.2.2 *Multiple Tray Aeration*

Multiple tray aerators were used for this investigation because they are inexpensive and simple to construct. When aggressive carbon dioxide needs to be removed, aeration at atmospheric pressure frequently offers an affordable alternative to costly neutralization treatment.

A set of trays having perforations in the bottom made up a multiple-tray aerator. Coke, ceramic or stone balls, limestone, or other substances that have a catalytic impact on the elimination of iron were placed inside the trays. The materials' main objective is to increase the surface area where air and water come into contact. The water was equally distributed across the upper tray by perforated pipes, from which it drips down, the droplets being scattered and re-collected at each subsequent tray. The design details of Multiple Tray Aerators is as follows:

Normally, three to five trays are often employed at a spacing of 0.3 to 0.7 m. A headroom of 1.5 to 3 m is required. For 40 m^2 of space is needed for every 1,000 m3/hr. Good CO_2 removal and good O_2 rises are features of these aerators (Design Manual, 2009). For a multiple-tray aerator, the design surface loading needed to be around 70 m^3/hour/m^2.

It was assumed that the hardness in the water sample is a result of the presence of bicarbonate. Therefore,using the values in table 1, the amount of carbon dioxide (CO_2) is equivalent to Total Hardness (as $CaCO_3$) – alkalinity (as $CaCO_3$).

Since the values of Total Hardness (as $CaCO_3$) is equal to 39.94 mg/l and alkalinity is equal to 16mg/l, Then,

$$CO_2 = \text{Hardness - alkalinity} = 39.94 - 16 = 23.94 \text{ mg/l} \quad (2)$$

The removal of carbon dioxide by multiple tray aerators is represented by the following equation (AWWA, 1990)

$$\frac{C}{C_o} = e^{-kn} \quad \text{or} \quad C = C_o * e^{-kn} \quad (3)$$

Where:

C =effluent concentration, mg/l; C_o = influent concentration, mg/l; n = number of trays (Three).

The constant of removal rate (k) for CO2 is 0.28–0.37.

Since, C_o = influent concentration, = 23.94mg/l; k=0.33

$$\mathbf{C = C_o} * e^{-0.33*3} = \mathbf{8.96} \text{ mg/l} \quad (4)$$

It was assumed that: (a). Three (3) units of cylindrical tanks (b). Surface loading Rate (SLR) = 10.6 m^3/hr./m^2 (c). Distance between trays 0.6m (d). Yield of borehole = 12m^3/hr.

Surface area of top cylinder $A = \frac{12}{10} = 1.2m^2$

For D which is the diameter of the cylinder, area of tray $A = \frac{\pi D^2}{4}$, $D = \sqrt{\frac{4A}{\pi}}$

$D = \sqrt{\frac{4\times1.2}{3.14}} \approx 1.2m$

Then, D be the diameter of the cylindrical tray one. For the effective collection of water from top tray, D_2 = 1.3m for the second tray and 1.5m for D_3, i.e. top of sedimentation receiving water from tray 2.

2.2.3 *Design of Hopper-Shaped Sedimentation Tank*

Sedimentation tanks with vertical flow which is circular in shape and have vertical flow was used. To get rid of the accumulated sludge, a hoper's bottom was installed at the bottom of the tank. Sludge hoppers have slopes that vary from 1.2:1 to 2:1 (vertical: horizontal). For the solids to slide to the bottom, they ought to be sufficiently steep.

The hopper bottom sedimentation tank allows water to enter by a centrally located intake pipe, and a deflector box acts to deflect the water downward. The water moves through the aperture between the box and the tank wall, rising upward after flowing downhill inside the box. whenever the water begins to rise. The phenomenon of hydraulic subsidence prevents the particles with a specific gravity greater than 1.0 from following the course and eventually settling at the bottom of the tank. When the sludge reaches the bottom of the hopper, it is easily extracted with the use of a sludge pump and sludge pipe.

Because ferrous carbonate is more crystalline than ferric hydroxide, the amount of it in the precipitate generated might vary, affecting the filter media's effective size. Most of the time, filters with a uniform layer of sand work well as long as the bed depth, particle size, and filtration rate are all properly engineered

It was assumed that the discharge-rated water for sediment, Q = 12m^3/hr

It was assumed that a surface loading rate (SLR) of = 10m3/hr/m2

For a hopper-shaped tank, the top diameter of the tank and surface loading Rate (SLR) was used to calculate the surface area requirement of a sedimentation tank.

Detention Time was used in conjunction with the SLR to calculate the volume and side water dept of a sedimentation Basin. For the discharge Q = 12m3/h and the detention time of 15min

Surface area tank $A = \frac{Q}{SLR} \quad A = \frac{12}{10} = 1.2m^2 \quad (5)$

For a hopper shaped tank the top diameter of tank, $D = \sqrt{\frac{4\times1.2}{3.14}} \approx 1.2m$, 1.5m was used.

Surface loading Rate (SLR) was used to calculate the surface area requirement of a sedimentation tank. The required Tank volume = $V_{Tank} = Q + 12 \times 0.25 = 3m^3$

The hopper-shaped sedimentation tank has two parts: a cylindrical and conical. The total volume of the tank (V_{Total}) = Volume cylindrical (V_H) x Volume of cone (V_C)

The total volume of the tank $V_{Tank} = Q + 12 \times 0.25 = 3m^3$

The volume of the cylindrical section V_H is given by:

$$V_H = \frac{1.5^2 \times 3.14 \times 1.55}{4} = 2.73768\ M3$$

$$V_C = Volumeofconc = \frac{\pi}{12} \times D^2 \times \square \quad (6)$$

Where D is the diameter of the upper part and h is the height Vc = $0.262D^2h = 0.262 \times 1.5^2 \times 0.5 = 0.294m^3$

$V = V_H + V_L = 2.737 + 0.294 = 3.031 = Actual\ volume\ of\ Tank$

Since V_T is greater than V_D, The Selected dimensions are adequate

2.2.4 Design Criteria for Rapid Gravity Filter

Some of the general criteria employed in the design of Rapid Gravity Filter are:

i. Filtration rate: Approximately 100 liters per square meter of the sand bed's surface

area per minute

ii Maximum head loss of 2.5 = 3 meters

iii. The Hudson formula provides the minimum sand depth.

$$H_s = \frac{Q \times d_s^3 \times h}{29323 \times B} \qquad (7)$$

Where:Hs = Depth of sand bed in m; Q = Rate of filtration in m3/m2/day

ds = Sand size in mm;h = terminal loss of head in m

B = Break-through index having value in range 4 x 10^{-4} to 6 x 10^{-3} depending on response (poor to good) to coagulation and degree of pretreatment of water being filtered.

vi. Grave depth is obtained from the Empirical formula

Hg = 2.54k (log dg) (8)

Where Hg = Depth of gravel bed in m, dg = Gravel size in mm

k = constant whose value lies in the range 10^{-14}.

By assuming a suitable size gradation from top to bottom, the depth of the gravel bed was computed from empirical formula given by (Duggal, 2013):

vii. Underdrains**,**

a. $\frac{Lengthoflateral}{Diameter} > 60$ (9)

b. Diameter of perforation in laterals 6mm – 13mm at spacing of 7.5cm and 20cm respectively

c. $\frac{Totalareaofperforation}{Totalfilterarea} = 0.2 percent.$ (10)

d. $\frac{Totalareaofperforation}{Totalfilteroflaterals}$= 0.25 to 0.50 (11)

for diameter of perforations as 6mm and 13mm respectively.

e. Maximum lateral spacing of 30 cm

f. Manifold's total size is equal to 1.75 times the sum of the laterals' cross-sectional areas.

i. Washing rate: 15 to 90 cm per minute increase. A 45 cm/mt rate is more than reasonable. This flow rate of 500 lits/m2 of bed area/mt can be used to provide this rate.

ii. Wash-water percentage: 2–4% of the total filtered water.

iii. Washing time: 10 to 15 meters. The intervals between washes are 24 to 48 hours. The pressure at which water is provided for cleaning is 0.4 kg/cm2.The manifold's maximum allowable velocity to supply the necessary amount of wash water is between 1.8 and 2.4 m/sec. In this study**,** a rapid sand filter unit for 4.5 mld with all its principal components was designed:

- Filter size = Design discharge = $12m^3$/hr
- Let rate of filtration be 5,000 lits/m^2/hr (5 m^3/m^2/hr)
- Filter area required = $\frac{12m^3/hr}{10m^3/m^2/hr} = 1.2m^2$
- Providing 1.5m diameter filter
- It was assumed that the depth of sand = 60mm of effective size = 0.65mm

Terminal loss of head = 2.5m

If the Break-through index, B = 4 x 10^{-4} the entering equation is

$$H_s = \frac{2 \times 5 \times 0.65^3 \times 2.5}{29323 \times 4 \times 10^{-4}} = 0.58m = 58mm \qquad (7)$$

58 mm is the minimum depth of sand needed to prevent floc breakthrough. Consequently, the 60 mm assumed sand depth is appropriate.

Depth of Gravel bed:

Assuming gravel size gradation of 3mm at top increasing to 50mm at bottom, the corresponding gravel layer depth is determined by using with *k* = 12. This is presented in Table 2:

Table 2: Sand and Gravel layers

Gravel size (mm)	Gravel depth (cm)
6	0.1
12	0.1
24	0.1
Provide a gravel depth	Total = 0.3cm =30mm

The layout of some elements of the treatment plant is shown in Figure 4. Also presented in Figure 5 is the Filtration unit laterals showing filter bed, wash troughs, and perforated

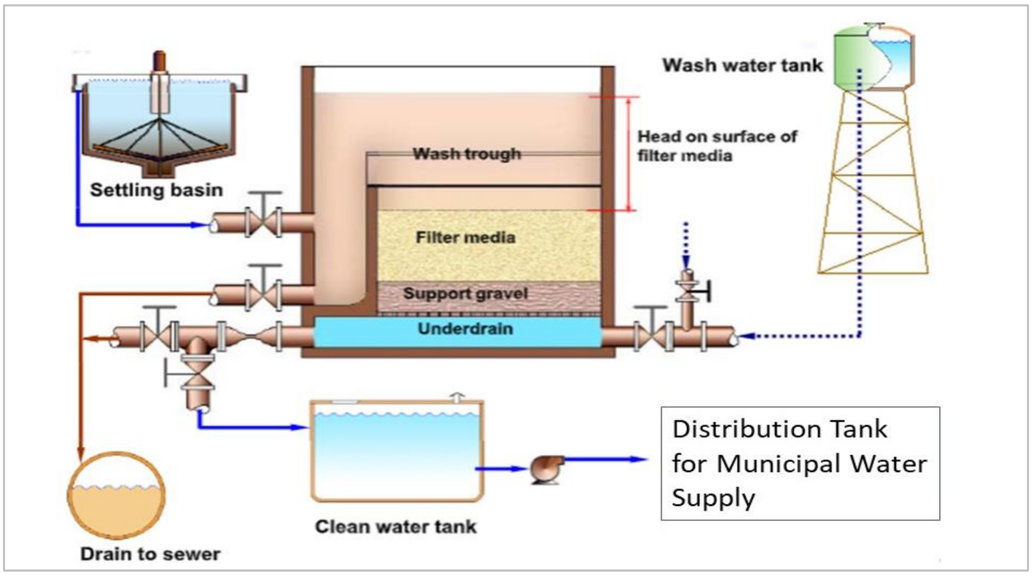

Figure 4: Layout of some elements of the treatment plant (Source: Vigneswaran and Sundaravadivel, 2009).

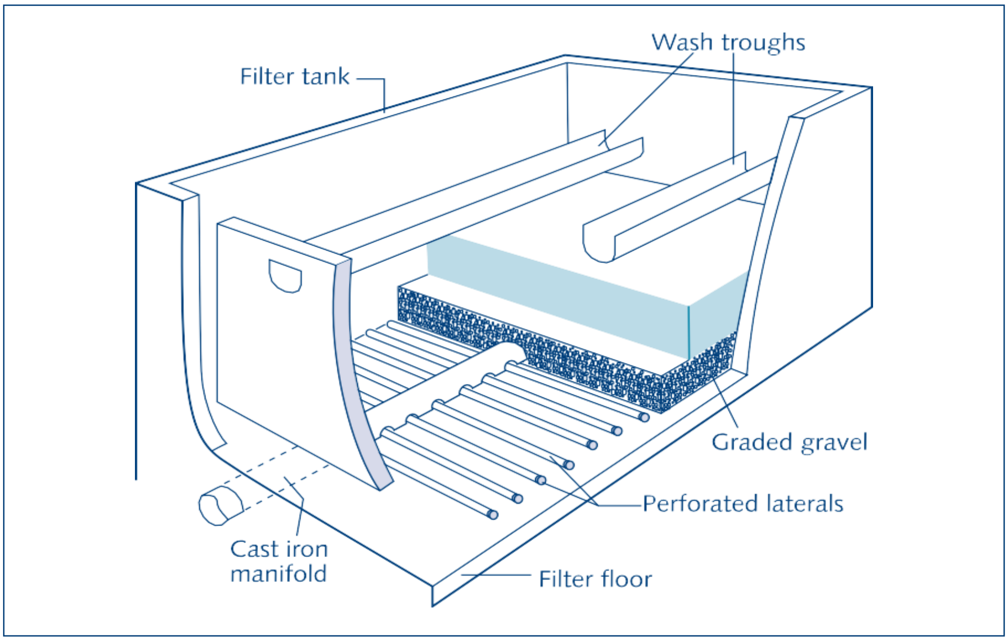

Figure 5: Filtration unit showing filter bed, wash troughs, and perforated laterals (Source: Vigneswaran and Sundaravadivel, 2009).

Underdrains

Total are perforation = 0.2% of total filter area = $\frac{1}{500} \times 1.2 = 0.0024$

The area of a manifold was considered to be twice that of the laterals. The area of the manifold would be four times the total area of perforation, or 4 x 0.0024 = 0.0096 m^2, when the manifold's dia is 100 mm since the latter is typical twice the areas of perforation (of 1.3mm.dia).

It is reasonable to suppose that laterals are spaced 15 cm (maximum 30 cm) apart./Total number of laterals = $\frac{5\times100}{15} = 33.3$, say 34 on either side of the manifold or 68 in a unit.

Length of a lateral = ½ width of filter - ½ dia of a manifold = $4 \times \frac{100}{2} - \frac{45}{2} = 177.5cm = 1.775m$

Let n be of total number of perforations of 13mm, dia, the total area of perforation = 0.04m^2 = 400 cm^2

$n \times \frac{\pi}{4} \times 1.3^2 = 400$ $\quad$ $n \times 1.33 = 400$ $\quad$ $n = 300$

Number of perforation per lateral $= \frac{300}{68} = 4.47$

Area of perforation per lateral = $4.47 \times 1.33 = 5.94cm^2$

Now area of lateral = $2 \times area\ of\ perforation\ per\ lateral = 2 \times 5.94 = 11.88cm^2$

Dia of lateral = 3.89cm

Using equation 9, we have:

$\frac{Length of lateral}{Dia of lateral} = \frac{177.5}{3.89} = 45.6\ which\ is\ less\ than\ 60$ This indicates that the diameter of laterals is adequate.

Let the rate of washing be 45cm/mt

Then wash water discharge = $\frac{45\times5\times4}{100\times60} = 0.15cumecs$

Velocity of flow in lateral = $\frac{0.15\times10,000}{68\times11.88} = 1.86m/sec$

The velocity of flow in manifold = $\frac{0.15}{0.16} = 0.94m/sec.$

This velocity of flow in the manifold is less than 1.8 – 2-4m/sec (maxm. permissible)

Wash water trough

Trough are generally not more than 1.8m apart

Number of trough = $\frac{5}{1.8} say 3$

Discharge per length = $\frac{0.15}{3} = 0.05cumecs = 3{,}0001pm = Q$

For a flat bottom trough

$Q = 0.76\ b\ y^{3/2}$ (8)

Where b = width of trough in cm, y = depth of water at the upper end of trough, in cm

b = 22.5m, y work out as = 24cm.With 5cm free board depth of trough = 29cm

Depth of filter box is made of the following

Depth of underdrains = 0.15. Depth of gravel bed = 0.30 .Depth of sand and activated carbon bed = 0.6 ; Water depth = 0.3 ; Free board = 0.20 ; Depth of filter box = 1.55

2.2.5 Design Details of Chlorination Unit

It´s generally accepted that a dose of 1.5 ppm to 2 ppm of Chlorine is a sufficient dosed for disinfection of water before pumping it into the providing Lines. This was added at the Clear Water tank or else dosed into the pressured lines.

Calcium Hypochlorite (HTH), dozed using an Alldos diaphragm metering pump type M-241-1. A 100-litre capacity plastic tank with a paddle served for mixing the chemical while a mask was provided for use by operators when mixing the chemical. Mixing Concentration instruction was also provided for the available HTH, with 65% chlorine content.

Alldos Diaphragm chemical dozing pump was used in the dosing of HTH. After chlorination with a 1% hypochlorite solution and at a dosage stroke capacity of pump at 100%, the final water had a good pH, residual chlorine, and slightly increased hardness content. The water, however, conforms to the World Health Organization (WHO) acceptable standard for drinking purposes.

2.2.6 Designed and Constructed Water Treatment Plant Drawings

The Plan and the cross-sectional drawing of the treatment plant is presented in Figure 6

2.2.7 Design Details of Clearwater Tank

The filtered water flows by gravity into the 4.5 cub, meter-capacity clear-water/chemical contact ground tank of steel construction 1.525 mm diameter and 2,5 metre long.

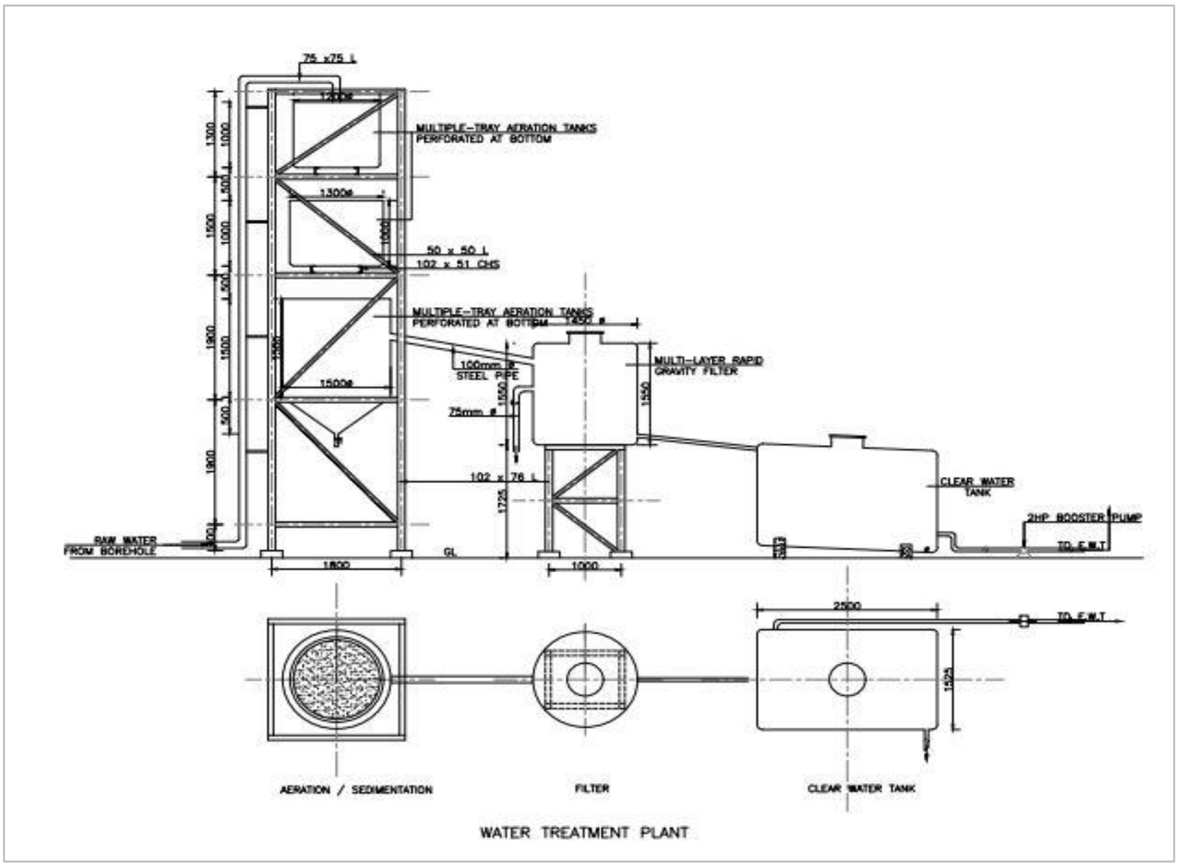

Figure 6: Plan and the cross-sectional drawing of the treatment plan

Figure 7: Picture of 45m³ elevated water tank location in Obuguru (Source: Chime,2023)

3. Results and Discussion

Water is an essential resource that is necessary to sustain life and support ecosystems. Its quality is of the utmost importance for the preservation of human health and the integrity of the environment. This study presents a comprehensive analysis of the water quality test results for the raw water quality tests, Post Aeration and Filtration test, and Post-chlorination (final water) test, conducted on the Obuguru water scheme. The analysis was aimed to evaluate the suitability of the water for various purposes and to identify any potential risks or concerns. The results of the water quality tests analyzed and interpreted using established recommended standards are discussed as follows.:

3.1 Physio-Chemical Analysis

A total of 18 physio-chemical water parameters were analyzed for the collected water sample. These parameters include color, turbidity, acidity (as $CaCO_3$), alkalinity (as $CaCO_3$), sulfate (as $CaCO_3$), free ammonia, total hardness (as $CaCO_3$), calcium (as $CaCO_3$), magnesium (Mg), chloride (Cl), nitrate (NO3), silica (SiO2), PV (COD), iron (Fe), total dissolved solids (TDS), and total solids (TS). The results of the physio-chemical parameters of the collected raw water, the Post Aeration and Filtration test, and the Post-Chlorination (final water) test, samples are presented in Table 2.

3.2 Post-Aeration and Filtration

Post-aeration and filtration treatment process was employed to improve the quality of water before it is distributed for consumption or other uses. The result in Tables 3(a) and (b) revealed a significant difference between the values obtained from the raw water test and the values obtained after the Post Aeration and Filtration process. The results indicate that post-aeration and filtration have significantly improved the quality of the water, with reductions in acidity, hardness, turbidity, alkalinity, iron, and total dissolved solids. This is illustrated in Figure 7.

Table 3: Obuguru water scheme final water quality result

Parameters (mg/l)	Raw water	Post Aeration and Filtration	Post Chlorination (final water)	WHO	NSDWQ
Colour	8	5	5	≤ 15	≤ 15
pH	7.4	7.4	7.4	6.5 – 8.5	6.5 – 8.5
Turbidity,	34	6	4	25	5
Acidity (as CaCo3)	40	8	4	250	
Alkalinity (as CaCo3)	16	10	6	250	
Sulphate (as CaCo3),	ND	0	0	200	100
Free chlorine	0.0	0	0.1		0.2 -0.25
Total hardness (as CaCo3),	39.94	15.42	10.15	100	150
Calcium (as CaCo3),	7.29	5.83	7.29	1.0	
Magnesium (Mg),	4,43	3.55	3.54		20
Chloride (CL),	3.5	4.25	2.13	250	100
Nitrate (NO3),	0	0	0	10	50
Silica (SiO2),	0	2.5	1.5		
PV(COD), .	0.40	0.16	0.0		
Iron (Fe),	3.5	0.1	0.0	0.05 -0.3	0.3
Total Dissolved Solid (TDS),	100	50	50		
Total Solid (TS)	100	50	50		500

Five major parameters taken from Table 3 were plotted of for Raw water, Post Aeration/Filtration and Post Chlorination as presented in Figure 8.

3.3 Post Chlorination (Final Water)

Post-chlorination is the final step in the water treatment process where chlorine is added to the treated water. It occurs after filtration and other treatment stages to ensure the safety and quality of the water. This process effectively disinfects the water and reduces the risk of waterborne diseases for consumption and other uses. This studies has shown that chlorination improves the quality of water by reducing acidity, hardness, chloride, nitrate, turbidity, iron, and total dissolved solids, meeting the guidelines set by the World Health Organization (WHO) and Nigeria Safe Drinking Water Quality (NSDWQ) standard. The free chlorine levels meet the recommended values of WHO and NSDWQ

3.4 Water Quality Index (WQI) Analysis

The Water Quality Index (WQI) is a tool that provides a single number used to represent an overall assessment of water quality at a specific location. It takes into account various water quality parameters to achieve a single number. It's a number that can be easily interpreted by decision-makers. The water quality index was determined using the average weighted index method for the water samples for the raw water, post aeration, and post chlorination, to evaluate the variation of the water quality at the location as shown in Tables 4, 5, and 6 while the rating of the water quality as per weight arithmetic water quality index method is presented in Table 7.

Table 4: Water quality index determination for raw water

S/No	Parameters	(Vi)	(Sn)	1/Sn	K	(Wn = K/Sn)	Lab Results (Vn)	(qn)	[(Wn*qn)]
1	pH	7.4	8.5	0.11765	0.12757	0.0150082	7.4	26.67	0.40022
2	Nitrate	0	50	0.02000		0.0025514	0	0.00	0.00000
3	Acidity	40	250	0.00400		0.0005103	40	16.00	0.00816
4	Turbidity	34	5	0.20000		0.0255140	34	680.00	17.34952
5	Chlorine	0	0.25	4.00000		0.5102800	0	0.00	0.00000
6	TDS	100	500	0.00200		0.0002551	100	20.00	0.00510
7	Colour	11.4	15	0.06667		0.0085047	11.4	76.00	0.64635
8	Sulphate	0	100	0.01000		0.0012757	0	0.00	0.00000
9	Chloride	3.5	100	0.01000		0.0012757	3.5	3.50	0.00446
10	Iron	3.5	0.3	3.33333		0.4252333	3.5	1166.67	496.10556
11	Hardness as CaCO3	39.94	100	0.01000		0.0012757	39.94	39.94	0.05095
12	Total Solid	100	1000	0.00100		0.0001276	100	10.00	0.00128
13	Magnesium	4.43	20	0.05000		0.0063785	4.43	22.15	0.14128
14	Total Alkalinity	16	250	0.00400		0.0005103	16	6.40	0.00327
15	Calcium	7.29	100	0.01000		0.0012757	7.29	7.29	0.00930
						∑ = 0.99998			∑ = **514.72546**
WQI = [∑(Wn*qn)]/[(∑Wn)] = **514.74**									

Table 1 shows a Water Quality Index (WQI) of 514.74 for the raw water sample. this is an indication that the water is unsuitable for drinking without significant treatment.

Table 2 shows a Water Quality Index (WQI) of 18.07 for the post-aeration water sample. This value is significantly lower than that of the raw water, indicating a substantial improvement in water quality. Aeration likely helped to remove volatile organic compounds, dissolved gases, iron, and manganese, contributing to the reduction in the overall quality of the water. This WQI value falls within the range that suggests the water quality is Excellent.

Table 5: Water Quality Index determination for post-aeration and filtration

S/No	Parameters	(Vi)	(Sn)	1/Sn	K	(Wn = K/Sn)	Lab Results (Vn)	(qn)	[(Wn*qn)]
1	pH	7.4	8.5	0.11765	0.12757	0.0150082	7.4	26.67	0.40022
2	Nitrate	0	50	0.02000		0.0025514	0	0.00	0.00000
3	Acidity	40	250	0.00400		0.0005103	8	3.20	0.00163
4	Turbidity	34	5	0.20000		0.0255140	6	120.00	3.06168
5	Chlorine	0	0.25	4.00000		0.5102800	0	0.00	0.00000
6	TDS	100	500	0.00200		0.0002551	50	10.00	0.00255
7	Colour	11.4	15	0.06667		0.0085047	5	33.33	0.28349
8	Sulphate	0	100	0.01000		0.0012757	0	0.00	0.00000
9	Chloride	3.5	100	0.01000		0.0012757	4.25	4.25	0.00542
10	Iron	3.5	0.3	3.33333		0.4252333	0.1	33.33	14.17444
11	Hardness as CaCO3	39.94	100	0.01000		0.0012757	15.42	15.42	0.01967
12	Total Solid	100	1000	0.00100		0.0001276	50	5.00	0.00064
13	Magnesium	4.43	20	0.05000		0.0063785	3.55	17.75	0.11322
14	Total Alkalinity	16	250	0.00400		0.0005103	10	4.00	0.00204
15	Calcium	7.29	100	0.01000		0.0012757	5.83	5.83	0.00744
						∑ = 0.99998			∑ = **18.07244**

WQI = [∑(Wn*qn)]/[(∑Wn)] = **18.07**

Table 6: Water quality index determination for Post Chlorination (final water)

S/No	Parameters	(Vi)	(Sn)	1/Sn	K	(Wn = K/Sn)	Lab Results (Vn)	(qn)	[(Wn*qn)]
1	pH	7	8.5	0.11765	0.12757	0.0150082	7.4	26.67	0.40022
2	Nitrate	0	50	0.02000		0.0025514	0	0.00	0.00000
3	Acidity	0	250	0.00400		0.0005103	4	1.60	0.00082
4	Turbidity	0	5	0.20000		0.0255140	4	80.00	2.04112
5	Chlorine	0	0.25	4.00000		0.5102800	0.1	40.00	20.41120
6	TDS	0	500	0.00200		0.0002551	50	10.00	0.00255
7	Colour	0	15	0.06667		0.0085047	5	33.33	0.28349
8	Sulphate	0	100	0.01000		0.0012757	0	0.00	0.00000
9	Chloride	0	100	0.01000		0.0012757	2.13	2.13	0.00272
10	Iron	0	0.3	3.33333		0.4252333	0	0.00	0.00000
11	Hardness as CaCO3	0	100	0.01000		0.0012757	10.15	10.15	0.01295
12	Total Solid	0	1000	0.00100		0.0001276	50	5.00	0.00064
13	Magnesium	0	20	0.05000		0.0063785	3.54	17.70	0.11290
14	Total Alkalinity	0	250	0.00400		0.0005103	6	2.40	0.00122
15	Calcium	0	100	0.01000		0.0012757	7.29	7.29	0.00930
						∑ = 0.99998			∑ = **23.27912**

WQI = [∑(Wn*qn)]/[(∑Wn)] = **23.28**

Table 6 shows a Water Quality Index (WQI) of 23.28 for the post-chlorination sample. The value of the WQI after chlorination is slightly higher than post-aeration but still in the water quality rating of excellent. The slight increase in WQI could be due to the presence of residual chlorine or chlorination byproducts.

Table 7: Water Quality Rating as per Weight Arithmetic Water Quality Index Method

WQI Value	Rating of Water Quality
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
>100	Unsuitable for drinking

The water treatment process, including aeration and chlorination, has shown an overall water treatment effectiveness. The treatment process effectively transformed highly contaminated raw water into water of good quality, making it safe for consumption.

3.5 Efficiency of The Treatment Plant

The efficiency of the overall treatment plant in the removal of iron E is given by:

$$E = 100(Ferw - Fetw)/Ferw \quad (8)$$

Where Fetrw is the iron content in raw water (mg/l) and Fetw is the iron content in treated water (mg/l).

i e $E = 100(3.5 - 0)/3.5$ =100%

The theoretical efficiency of CO_2 removal by the aeration unit is

$$Et = 100(Co - C)/Co \quad (9)$$

Where Co is the influent CO_2 and C is the effluent CO_2

Using the values in Table 2

Co= 39.94-16 =23.94mg/l and C computed in equation (4) is 8.96mg/l

Hence $Et = 100(23.94 - 8.96)/23.94$ =62.67% (9)

The actual efficiency of CO_2 removal by the aeration, sedimentation, and filtration units,Ea is

$$Ea = 100(Co - C)/Co \qquad (9)$$

Where Co is the influent CO_2 and C is the effluent CO_2

Using the values in Table 2

Co= 39.94-16 =23.94mg/l and C = 15.42-10 is 5.42mg/l

Hence $E = 100(23.94 - 5.42)/23.94$ =77.4% (9)

Understandably, Ea is higher than Et due to the effects of sedimentation and filtration.

4. Conclusions

This study investigated the removal of iron from groundwaters, using aeration (oxidation) followed by, sedimentation, filtration, and chlorination. The results indicated that aeration, sedimentation, and filtration have significantly improved the quality of the water, with reductions in acidity, hardness, turbidity, alkalinity, and total dissolved solids. The raw water contained 3.5 mg/l of iron, while the treated water had 0.0 mg/l of iron after chlorination. The results revealed that a removal of iron was 100% while the maximum removal of CO_2 was 77.4%.. The Water Quality Index (WQI) of the treated water improved from 514.74 to 23.28 indicating excellent water quality. The complete removal of iron by the treatment plant has enhanced the water quality in Obuguru. This treatment plant can be utilized in other rural areas having similar water quality challenges.

Authors Contribution

The authors perform different roles at various stages: data acquisition processing and article writing

Data Availability

The acquired data, other modifications, results, and analysis of this study are in the custody of the corresponding author and will be provided upon reasonable request.

Declarations

Ethical approval: The study presented here does not involve human participants or animal experiments. This article observed all relevant ethical standards.

Informed consent: The consent of all the participants and third-party were adequately sought

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