IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 12, Issue 3, March. 2022, || Series -I || PP 41-53

Sand Filtration Technique for Improving Drinking Water Quality in Rural Areas of Akwa Ibom State

[1]Udeme Hanson Iron, [2]Udechukwu John Abaraogu and [3]Dr. Christopher Brownson Afangideh
1& 2 Department of Civil Engineering, Faculty of Engineering University of Uyo, Nigeria.
3 Civil Engineering department, Akwa Ibom State University, Ikot Akpaden.
Received 25 March 2022; Accepted 06 April 2022

ABSTRACT

Slow sand filtration is a long-established technique for improving the biological and physical quality of water. In its standard form, water is passed at about 200mm/hours down through a bed of sand about one meter deep. For use in rural communities in Akwa Ibom State, a much cheaper and therefore shallower filter is required and one must accommodate the intermittent flow corresponding to water being drawn off for a few minutes several times a day. Sand used in slow sand filters should have an effective size of 0.15 - 0.35mm and a uniformity coefficient of 1.5 - 3, however less than 2 is desirable. This paper examines how slow-sand filtration could actually be used to improve drinking water qualities in rural areas. Site visitation was carried out and samples of sand and gravel were obtained. Sieve analysis was performed on the sand and gravel samples and a physio-chemical analysis of the raw water and filtered water was performed. Results showed reductions in faecal coliform count of about 95% in the filtered water. Recommendations on appropriate filter operation and maintenance were made.

KEYWORDS: **biological, coliform, filtration, physio-chemical, Sieve.**

I. INTRODUCTION

The limited amount of money invested in the treatment of water in the rural areas is partly caused by the high cost of water treatment systems. Consequently, the majority of rural communities are still drinking superficial water that does not meet the required standard of quality, thereby causing serious health problems. In many cases, the high cost of water treatment systems and the poor quality of water deter investment in even the simplest systems of untreated water conveyance by gravity, further aggravating the health situation and forcing the population – particularly women and children – to walk long distances to fetch water of a worse quality than that which they could have obtained by conveyance from the head waters of nearby rivers. Water treatment at the different rural water works station has been a thing of concern.

Sand filtration system is a technically viable water treatment solution. Nevertheless, there are still a number of difficulties involved in the implementation and operation of the system. In addition, the direct cost of the construction is relatively low so that the system can actually achieve its purpose to supply drinking water to rural dwellers. In this study, the focus was on sand filtration techniques for improving drinking water qualities for Idu Uruan rural community in Akwa Ibom State. Fig. 1 is a map showing the different Local Governments Areas of the state including Uruan L.G.

1.1 Aims and Objectives of the Study

This study aimed at investigating the various aspects involved in the “biological filtration” process with a view to evaluating the possibility of adopting this system of water purification in the rural communities.

The specific objectives are to determine the need for treatment of surface waters and ground waters for drinking purposes and to demonstrate the sand filtration approach to water treatment before supply for consumption. Moreover comparison will be made between the sand filtered water and the untreated water to determine which one meets the WHO standards for quality.

II. INTRODUCTION TO SLOW SAND FILTERS

Safe drinking water is of great importance for the health and well being of people. Water quality is determined by the level of various factors for water quality control. Cancer, arthritis, skin irritation and eruption, heart disease, central system pathology, kidney problems, skin rashes etc are the diseases associated with drinking untreated water. Sickness results depending on the concentration of the contaminant chemicals. The “biological filtration” or “slow sand” process is an age long process of water treatment. The system has been in continuous use since the beginning of the nineteenth century, and has proved effective under widely differing circumstances. It is simple, inexpensive, and reliable and is still a chosen method of purifying water supplies for some of the major cities of the world (WHO, 1974), (WHO, 1992) and (WHO, 2002).

Originating in Europe, slow sand filtration is classified as the first, modern water-treatment technology (Elis, 1985). This filtration process removes water through a porous sand media. Unlike rapid sand filtration, conventional slow sand technology does not involve chemical or physical pre-treatment applications (Collins et al, 1992). The origin of slow sand filtration technology dates back to 1790, in Lanchashire, England. It was there that rudimentary sand filters were first constructed to purify water used in the bleaching process. In 1804, John Gibb of Paisley Scotland constructed a sand filter used primarily for his bleachery, however, he also sold excess filtered water to the public (Ellis, 1985). In 1827 Robert Thom improved upon Gibb's design (Ellis, 1985). Two years later, James Simpson used this modified design in his plans for a one acre sand filter for the Chelsea water company of London (Ellis, 1985). The health benefits attributed to London's first sand filter led to the construction of additional filters. By 1852, the city of London required filtration of all drinking water sold to the public. To ensure fulfillment of this requirement, the Thames Conservancy Board was established to regulate drinking water quality (Hendricks, 1991).

Adoption of slow sand filter technology spread throughout Europe in the mid-to late 1800's and by 1872, the technology had reached the United States. Poughkeepsie, New York was the first American town to build a slow sand filter (Hendricks, 1991). Additional installations followed, and by 1899, twenty such filters were in use in the United States (Hendricks, 1991).

America's preference for this technology, however, was not forthcoming. By 1940, the United States had approximately 100 slow sand filters with an aggregate capacity of 52.6 million gallons per day (mg/d), in contrast to roughly 2,275 rapid sand filters with a production capacity of 237 mg/d (Hendricks, 1991). Problems associated with highly turbid waters made conventional slow sand treatment impractical for communities plagued with such sources of water. Conventional slow filters clogged under such conditions, and the technology of choice became rapid sand filtration, due to its ability to produce large quantities of acceptable finished water from highly turbid water source (Ellis, 1985). An additional factor influencing the move to rapid sand filtration was public support for the newest technology available, regardless of community size (Logsdon, 1991).

Fig. 1 Map of Akwa Ibom State showing the different L.G.A including Uruan L.G.A.

The effectiveness, affordability and ease of operation available with slow sand filtration systems is appealing to small communities (those under 10,000 people) that lack significant capital for constructing, operating and maintaining rapid sand filtration facilities (Riesenberg, Walters, Steele, and Ryder, 1995). Brink and Parks (1996) stated that a preliminary report compiled for the American Slow Sand Association indicated that 225 such facilities were in use in the United States. It is anticipated that additional facilities will be built by small communities needing affordable, effective water treatment technology to comply with the surface water requirements established in 1989 (Logsdon, 1991; Brink and Parks, 1996).

2.2 Sand Filtration Technology and Mechanism

Particulate (microbial, viral and sediment) removal in slow sand filtration is considered a passive process, differing from rapid sand filtration in that chemical pretreatment of inflow is generally not performed and back flushing (pressurized flow reversal) is not used for cleaning the filter media (Haarhoff and Cleasby, 1991). In slow sand filters, biological processes are considered to dominate the uppermost region of the filter bed (Haarhoff and Cleasby, 1991; Ellis 1995). A layer termed the schmutzdecke, literally translated as “dirty skin” (as cited in Hendricks, 1991), forms on the surface of the sand bed and is believed to contribute to the removal of water impurities.

Collins et al (1992) showed that bacterial concentrations in the schmutzdecke were a function of elapsed time and potential for cell growth, rather than the filtration of free-living bacteria from source water. This suggests that biological communities grow and develop within this layer. In addition to the schmutzdecke, the sand grains of the filter bed provide additional biological and physical mechanisms that contribute to removal efficiency (Ellis 1985). A biofin develops around the sand grains and it has been hypothesized that such films create sticky surface, causing the attachment of organic and inorganic particles. This surface is thought to be biologically active (consisting of bacteria, protozoa and bacteriophages) and a site for the decomposition of organic matter. Hendricks (1991) presents a thorough review of the potential pathways that particles (organic and inorganic) follow through the filter media and the theoretical collisions such particles experience within the media.

Physical mechanisms such as straining and adsorption are also considered to contribute to the removal effectiveness of slow sand filters Adsorption of suspended material is influenced by zeta potentials (Hendricks, 1991).

2.3 Design Elements

Slow sand filter consists of essentially three components: Sand, Gravel and an under drainage (Ellis, 1985). A container (circular, square or rectangular) is used to hold a column of water (the supernatant or headwater) on a bed of sand (filtration media) supported by gravel medium. The column of water provides a pressure head for driving the flow of raw water through the filter media. The gravel supports the sand bed in addition to the under drains, a network of perforated pipes that collect filtered water and channel it out of the filter container (Ellis, 1985), which it covers. The gravel is arranged with the finest grade directly beneath the sand bed and successively coarser grades leading to and surrounding the under drain pipes.

2.4 Types of Sand Filters

The use of sand and gravel as filter media for water supplies can be split into three basic filter types: slow sand filters, rapid filters and roughing filters.

Slow sand filters use sand with effective sizes of 0.15 – 0.35 mm to remove a large percentage of coliforms, cryptospridum and Giardia cysts. They operate most effectively at a flow rate of 0.1 – 0.3 m/h (or $m^3/h/m^2$), which equates to 100 – 300 l/h per m^2 of filter area. Apart from desalination and reserve osmosis, slow sand filters are perhaps the most effective single treatment for purifying drinking water supplies. They are used on a large scale as part of the water supply for large cities, as part of systems for small villages and on a much smaller scale they can be adapted for use in individual households.

These filters use physical processes such as sedimentation, adsorption and straining to remove fine particles as well as microbiological processes to remove organic material and bacteria. Because of the slow filter rates, the raw water sits above the sand for several hours before passing through it. Various oxidation reactions break down organic material during this time. Algae, that grows on the sand surface consumes this oxidizing organic material and releases oxygen back into the water.

The flow of raw water through the filter should be continuous, however small scale filters for use in individual households have been designed to work intermittently (i.e. a few hours a day). These have been widely used in several countries around the world.

Rapid sand filters use coarser sand than slow sand filters and the effective size of the filter media is usually greater than 0.55 mm. The flow rates are normally between 4 and 21 m/h equating to 400 to 2100 l/h per m^2 of filter. Rapid sand filters do not remove disease causing entities as efficiently as slow sand filters and usually need a post filtration chlorination process hence they are of less use for small village supplies unless the raw (untreated) water supply is of a reliable high quality. Flocculation and coagulation are sometimes used as pre-treatment.

Roughing filters are used to remove suspended solids by passing the water through material that is much coarser than that used in slow sand filtration or rapid sand filters. They are used to reduce the turbidity of water supplied and often used as a pre-treatment before slow sand filtration. The filter material is usually graded so that the water passes through coarser (25mm) medium and then fine (5mm) sand. Flow rates are often in the region of 0.3 – 0.6 m/h (i.e. 300 – 600 l/h per m^2 of filter surface area).

2.5 Drinking Water Quality Standard Used in Nigeria

In 2005, the National Council on Water Resources (NCWR) recognized the need to urgently establish acceptable Nigerian Standard for Drinking Water Quality because it was observed that the "Nigerian Industrial Standard for Potable Water" developed by Standards Organisation of Nigeria and the "National Guidelines and Standards for Water Quality in Nigeria" developed by Federal Ministry of Environment did not receive a wide acceptance by all stakeholders in the country.

2.6 Advantages of Slow Sand Filters

1. Quality of Treated water: No other single process can effect such an improvement in the physical, chemical, and bacteriology quality or normal surface waters as that accomplished by biological filtration. The water delivered does not support after growth in the distribution system, and no chemicals are added, thus obviating one cause of taste and odour problems.
2. Cost and Ease of Construction: The simple design of slow sand filters make it easy to use local materials and skills in their construction. The cost of imported materials and equipment may be kept to almost negligible proportions, and it is possible to reduce the use of mechanized plant to the minimum and to economize on skilled supervision. Design is easier, little special pipe work or equipment is required, instrumentation can be almost completely eliminated, and a greater latitude in the screening of media and the selection of construction materials can be permitted. Only when a high price has to be paid for land and when expensive super-structures are necessary for protection against low temperatures is the capital cost of slow sand filters likely to equal or exceed that of comparable rapid filters.
3. Cost and Ease of Operation: The cost of operation lies almost wholly in the cleaning of the filter-beds, which may be carried out either mechanically or manually. In developing countries and elsewhere where labour is readily available, the latter method will be used, in which case virtually the whole of the operating cost will be returned to the local economy in the form of wages. No imported chemicals or other materials are needed for the process, though in many cases chlorination is practiced as an additional safeguard. However, chlorination would be equally necessary with any other form of treatment, and, in general, the dosage required to disinfect biologically treated water are less than those needed to disinfect water treated by other methods. No compressed air, mechanical stirring, or high-pressure water is needed for backwashing, thus there is a saving not only in the provision of plant but also in the cost of fuel or electricity. The operator of a biological filter requires far less training and skill that does his colleagues in charge of a rapid gravity filter, and less supervision and support. Slow sand filters automatically accommodate minor fluctuations in raw water quality, temperature, and climatic conditions and can short period of excessive turbidity or demand without breaking down.
4. Conservation of Water: In water-short areas, biological filters have the additional advantage of not requiring the regular flushing as in the case of pressure or rapid gravity filters, which need cleaning every few days. Such wastage represents some 2-3% of the total amount treated. Reclamation may be practiced in some places but represents an additional expense. The water that is passed through a slow sand filter immediately after cleaning and before the biological function has been restored (a process known as "ripening") can either be returned to source or diverted to another filter since it does not carry impurities additional to those in the raw water.

2.7 Disadvantages of Slow Sand Filters

1. In countries where construction methods are largely mechanized and where the importation of such materials as steel and cast-iron pipe work presents no problems, the reinforced concrete construction and metal fitting of rapid filters may be cheaper to construct than the more extensive (though simpler) non-reinforced construction of slow filters.
2. Where unskilled labour for cleaning is in short supply it may be easier and cheaper to recruit the skilled staff required to operate and maintain rapid filters (especially when these are fitted with automatic control equipment) than to retain the necessary labour force. However, recent developments in mechanical cleaning of slow sand filters make this condition of less consequence than formerly.

3. Where the water to be treated is liable to reverse and sudden changes in quality or where certain types of toxic industrial wastes or heavy concentrations of colloids may be present, the working of biological filters can be upset.

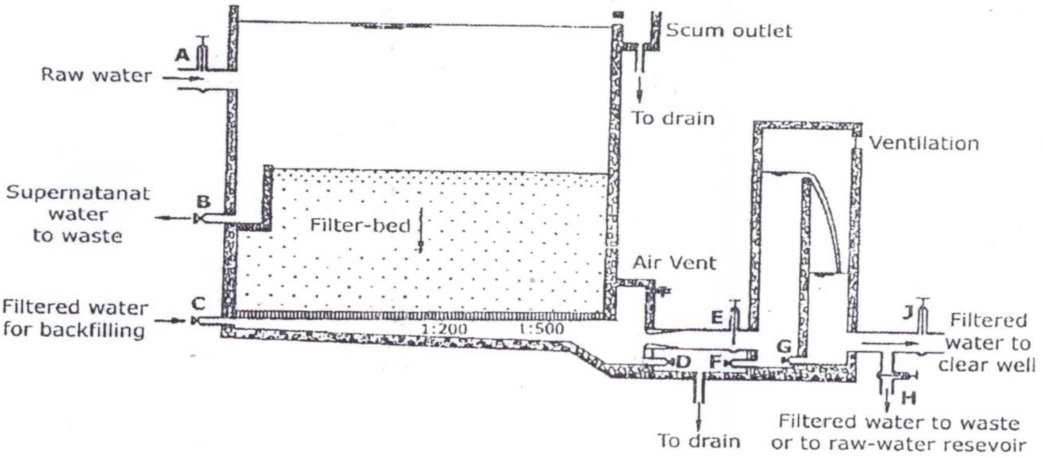

Fig 2a Diagram or Sketch of Slow Sand Filter

III. MATERIALS AND METHODOLOGY

The project objectives were accomplished by site visitation, collection of sand and gravel samples, and sieve analysis was carried out on the samples. Moreover, a physio-chemical analysis of the raw and filtered water was carried out in order to provide recommendations on filter operation and maintenance.

3.1 Sieve Analysis: Sieve analysis involves separation of sample of aggregate into various fractions of the same size. This was done by arranging the stacks of sieves in a descending order, with the largest sieve at the top and the receiving pan at the bottom of the pack. The dry sand was well mixed and approximately 200g of it was scooped onto the topmost sieve. With the lid covered, the whole stack was manually shaken for 10 minutes. After shaking, the weight of the sand retained on each sieve was determined as accurately as possible and the percentage passing each sieve was calculated and the grading curve was finally determined.

3.1.1 Characterizing Sand Samples: The sand and gravel samples were taken from the stream and river respectively and were sieved analyzed. Their effective sizes and coefficients of uniformity were determined for comparison with available standards. Sand used in slow sand filters should have an effective size of 0.5 – 0.35 mm and a uniformity coefficient of 1.5 – 3, however < 2 is desirable. Preferably the sand should have rounded, rather than jagged grains and be free from clay hence; sand from streams or rivers is normally suitable for slow sand filters than sand from pits.

3.2 Laboratory Analysis

3.2.1 Turbidity: Turbidity measurement was done using Hach turbidimeter and reading was taken directly from the instrument after the reading had stabilized.

3.2.2 Temperature: The water temperature was taken at insitu using mercury in-glass thermometer.

3.2.3 Alkalinity: Titrimetric analysis employing sulphuric acid titrant, methyl orange indicator solution, burette, pipette and conical apparatus were used to determine the alkalinity of the water.

Calculation:

$$\text{Alkalinity} = \frac{(\text{Total ml of } 0.01NH_2SO_4) \times 1000}{\text{MI of sample}}$$

$$= \frac{\text{Titre} \times 0.01N \times 60 \times 1000}{50}$$

3.2.4 Nitrate Content: Nitrate was determined by using spectrophotometer DR 2010 and the reading was taken when the instrument was set.

3.2.5 Conductivity: Conductivity measurement was measured in the water samples using Hach sension 5 conductivity meter and reading was taken directly from the instrument.

3.2.6 Acidity: Titrimetric analysis employing Sodium hydroxide as titrant, Methyl Orange indicator solution, burette, pipette, conical flask and screen was carried out to determine the acidity of the water.

Calculation:

$$\text{Acidity as mg/l} = \frac{(\text{total ml of } 0.02 NAOH) \times 1000}{\text{MI of sample}}$$

All the analysis was done at Akwa Ibom State Water Company Limited Laboratory, Uyo.

IV. RESULT AND DISCUSSION

4.1 **Sieve Analysis Result:** The results of the sieve analysis of aggregate were used to estimate the quantity or amount of particle size of sand present in the filter. The particle size distribution of the gravel and sand used are shown in Tables 4.1 and 4.2 respectively. They are also shown in Figures 4.1, and 4.2 for gravel and Figures 4.3 and 4.4 for sand.

Table 4.1: Grain Size Analysis Result for Gravel

Sieve Size (mm)	Weight retained retained (kg)	Cumulative weight retained (kg)	Percentage retained (%)	Percentage passing (%)
19.00	-	-	-	100.00
14.00	1.40	1.40	56.90	43.10
9.50	0.48	1.88	76.40	23.60
6.30	0.23	2.11	85.80	14.20
4.75	0.10	2.21	89.84	10.16
2.36	0.10	2.31	93.90	6.10
2.00	0.08	2.39	97.20	2.80
1.18	0.05	2.44	99.20	0.80
Pan	0.02	2.46		

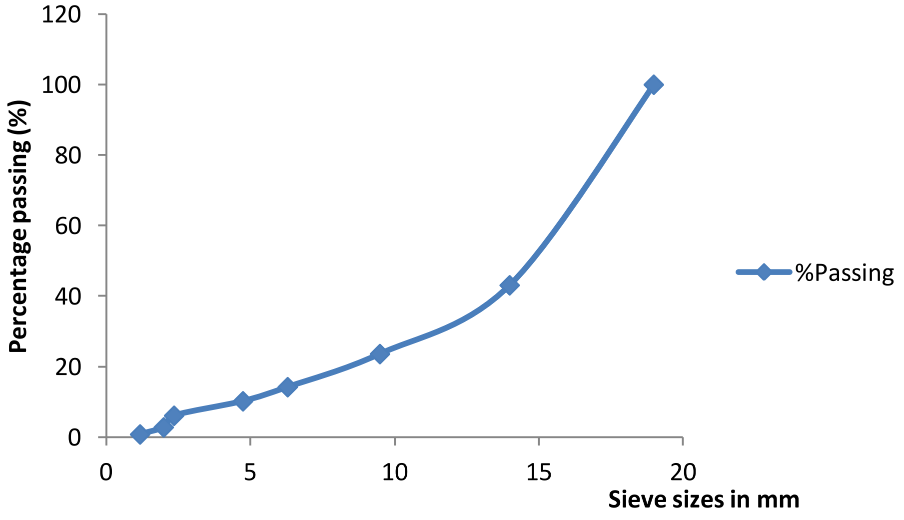

Fig. 4.1: Particle size distribution for gravel used

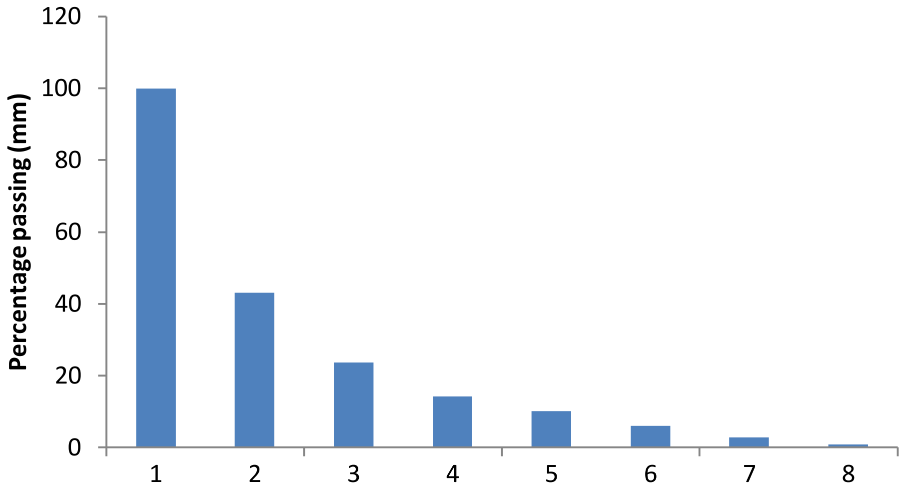

Fig. 4.2: Particle size distribution for gravel used

Table 4.2: Grain Size Analysis Result for Sand

Sieve size (mm)	Weight retained (kg)	Cumulative retained (kg)	Percentage Retained	Percentage passing
4.75	0.15	0.15	8.36	94.60
2.36	0.10	0.25	8.93	91.10
2.00	0.05	0.30	10.71	89.30
1.18	0.15	0.45	16.10	83.90
0.43	1.80	2.25	80.40	19.60
0.30	0.15	2.40	85.70	14.30
0.15	0.30	2.70	96.40	3.60
0.06	1.10	2.80	100.00	0.00

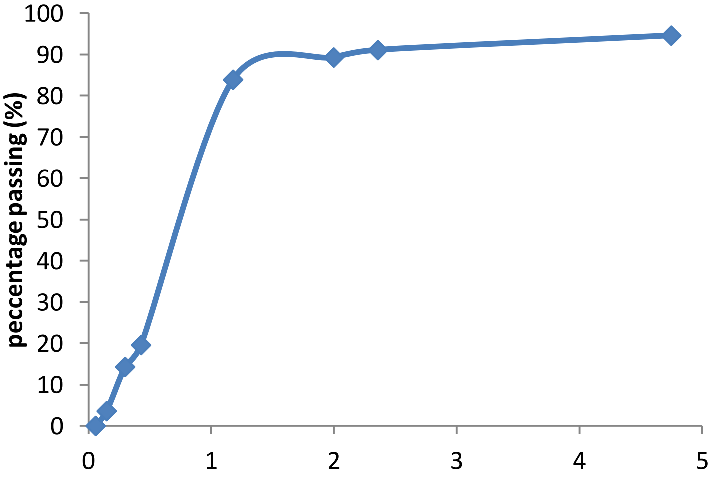

Fig. 4.3: Particle size distribution for sand used

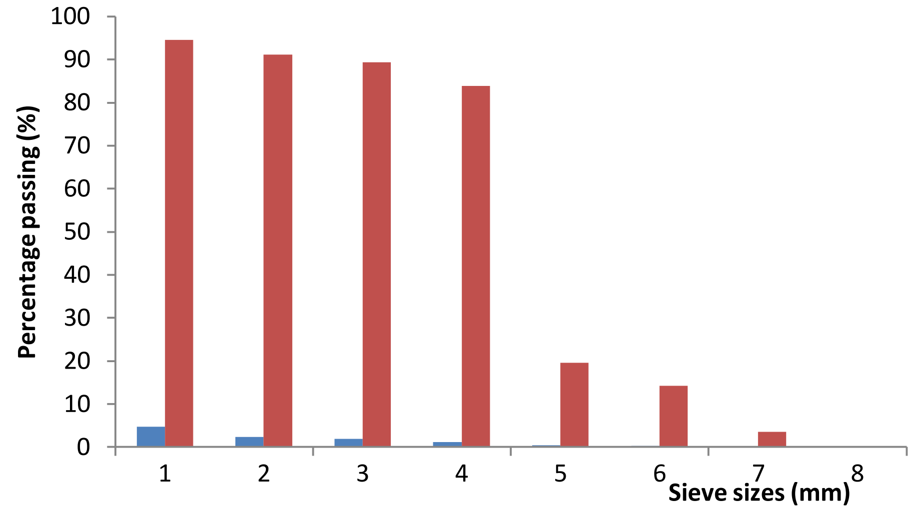

Fig. 4.4: Particle size distribution for the sand used

Coefficient of Uniformity, $Cu = \frac{D60}{D30} = \frac{20}{30} = 0.667$

Coefficient of Curvature, $Cc = \frac{(D30)2}{D10D60} = \frac{(17)2}{(12)(20)} = 1.204$

Table 4.2: Laboratory Report for Physio-chemical Examination of Water

S/No.	Parameters	Raw Water	Filtered Water	NSDWQ	WHO
1	Temperature			Ambient	
2	Salinity	0.2	0.0	0.4	0.5
3	Electricity Conductivity	678	18.71	1000	1000
4	Dissolved Solid	298	5.3	600	500
5	Iron	0.3	0.06	0.3	0.3
6	PH	7.2	4.09	6.5 – 7	6.5 – 8.5
7	Nitrate	0.14	0.1	50	50
8	Nitrate	0.4	0.006	0.2	0.2
9	Manganese	0.2	0.2	< 0.1	< 1
10	Turbidity	2.5	1.56	5	5
11	Suspended Solids	11	3	15	< 10
12	Sulphate	77.3	100	100	3
13	Phosphate	3.7	0.9	3.5	3.5
14	Total Hardness	78	38	500	500
15	Acidity	0.1	3.4	4.5 – 8.5	4.5 – 8.2
16	Total Alkanlinity	98	71	100 – 200	100 – 200
17	Copper	0.06	0.01	1	0.05
18	Lead	0.3	0.01	0.01	7
19	Zinc	0.5	3	3	0.01
20	Mercury	0.5	0.001	0.001	0.2
21	Floride	0.2	1.5	1.5	0.06
22	Dissolved oxygen	1	0.5	1.0 – 5.0	1.0 – 5.0
23	Barium	0.2	0.01	0.6	3
24	Cadium	0.01	1	0.003	0.003
25	Total Coliform	60	10	100	100
26	Feacal Coliform	< 10	10	100	100
27	E. Coli	< 10	0	100	100
28	Total Solid	380			
29	Total Suspended	82			

4.2 Physio-chemical Characteristics

4.2.1 Salinity: The test result showed that the filtered water was saline free having no salt.

4.2.2 Dissolved Solid: The result met the required specification of WHO being 500mg/l.

4.2.3 Turbidity: The result of the analysis showed that the filtered water had turbidity level within the specification of WHO being a maximum of 5. The result is plotted in Fig. 4.2.A

4.2.4 Total Alkalinity: The result showed that the alkalinity of the filtered water was within limits specified by WHO and NSDWQ being 500mg/l.

4.2.5 Total Hardness: The result from the test showed that the water met the required standard of WHO and NSDWQ

4.2.6 Acidity (P^H): From the result of the test; it was found out that the P^H value of the filtered water was very low compared to WHO standard. The result is shown in Fig 4.2C.

4.2.7 Phosphate: The test result showed that phosphate was low in the filtered water as it was 0.21mg/l.

Some Graphical Representations of the Results of the Physico-Chemical Parameters Analysis are presented in Figures 4.5 to 4.11.

Parameter	RW	FW	NSDWQ	WHO
Turbidity	2.6	1.56	5	5

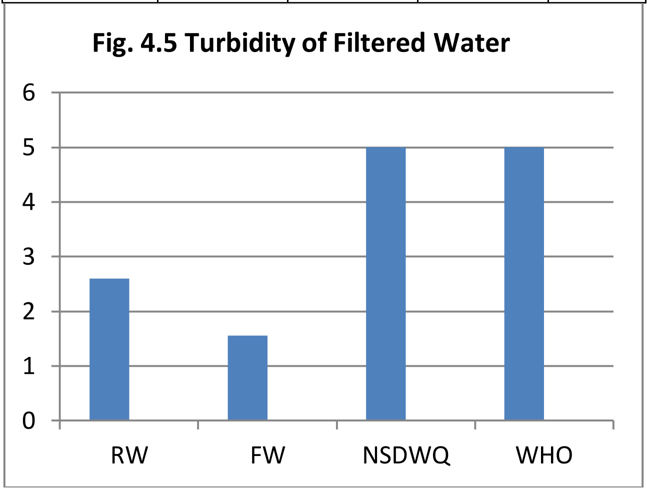
Fig. 4.5 Turbidity of Filtered Water

Parameter	RW	FW	NSDWQ	WHO
Acidity	4.1	3.4	8.5	8.5

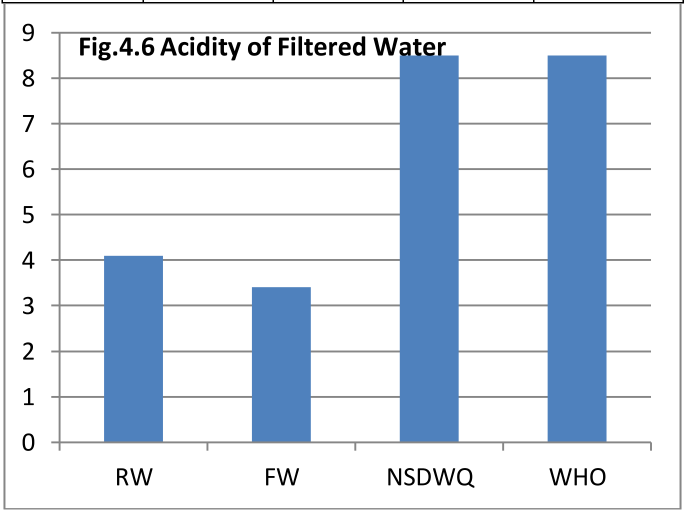
Fig.4.6 Acidity of Filtered Water

Parameter	RW	FW	NSDWQ	WHO
P^H	7.2	4.09	7	7

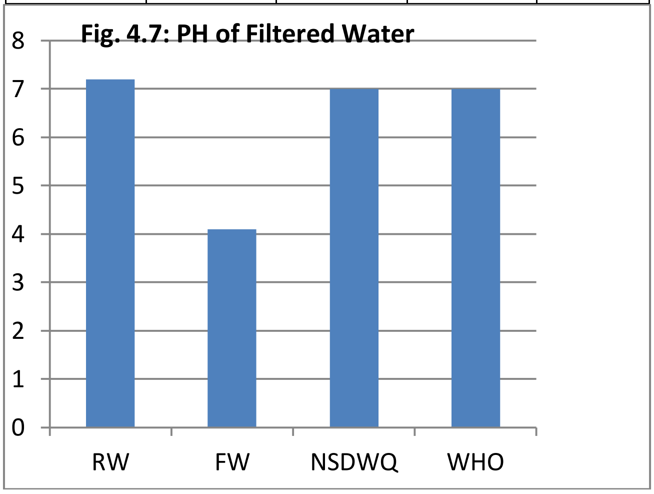
Fig. 4.7: PH of Filtered Water

Parameter	RW	FW	NSDWQ	WHO
Total Alkalinity	98	71	100	100

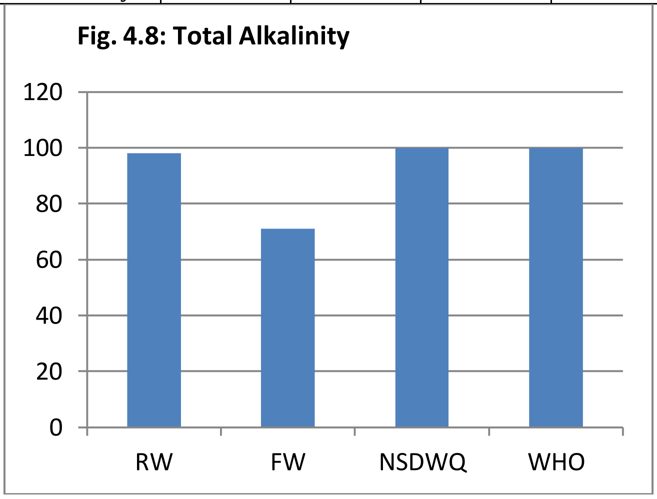
Fig. 4.8: Total Alkalinity

Parameter	RW	FW	NSDWQ	WHO
Mercury content	0.5	0.001	0.2	0.2

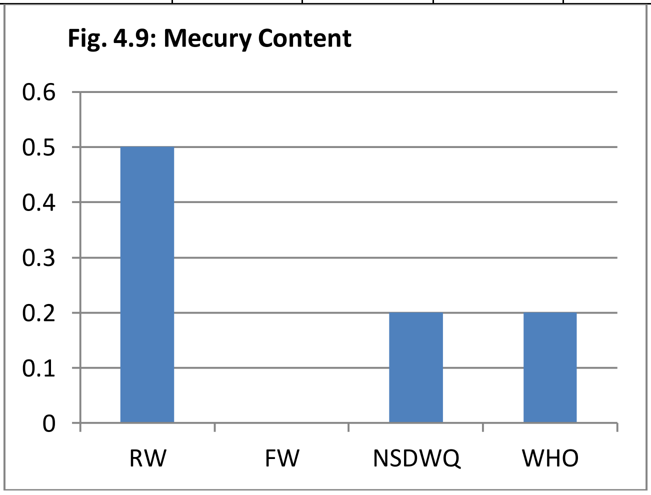
Fig. 4.9: Mecury Content

4.4 BACTERIOLOGICAL ANALYSIS

The result of the analysis shows that the filtered water was free from bacteria and was fit for drinking and domestic use. The result showed a reduction of 95% in feacal coliform count, indicating that slow sand filtration can improve drinking water quality in rural areas. The results of bacteriological Analysis at 72 hrs Nutrient AGAR are presented in Figs. 4.10 and 4.11.

SAMPLE	Dilution Factor	E. Coli per 100ml	Total Coliform per 100ml
NSDWQ	101	0	10
FILTERED		0	1 x 101 - 10

Parameter	RW	FW	NSDWQ	WHO
Total Coliform	80	10	100	100

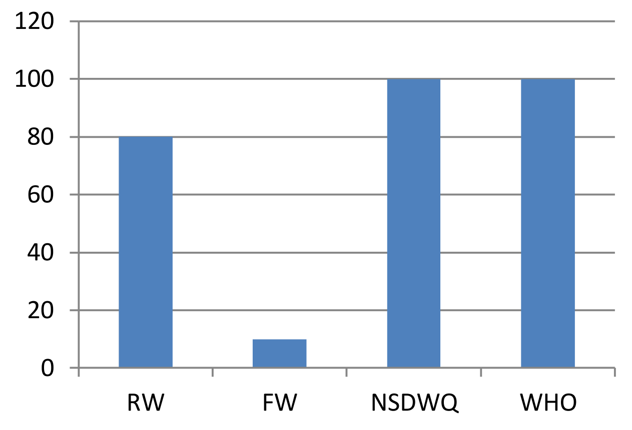

Fig. 4.10: Total Coliform per 100 ml

Parameter	RW	FW	NSDWQ	WHO
E-Coli	7.2	0	100	100

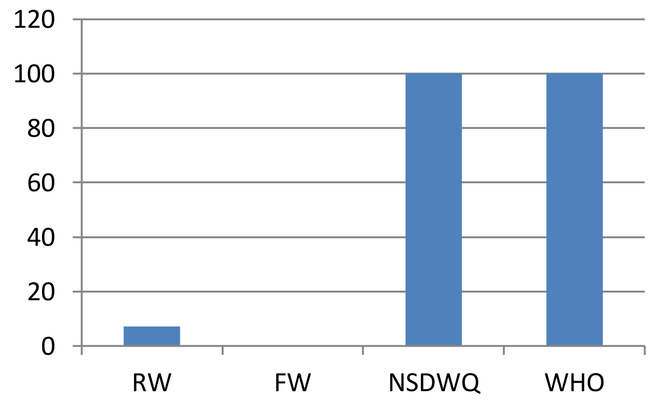

Fig. 4.11: E-Coli per 100ml

TABLE 4.3 Design Criteria and Recommendations for Slow Sand Filter

DESIGN PARAMETER	RECOMMENDATION
Depth of filter bed:	
Initial Bed Depth	0.8m-0.9m (2.63ft – 2.95ft)
	*modified 1.0 – 1.3m (3.28ft – 4.27ft)
Minimum Bed Depth:	
(requires re-sanding at this depth)	0.5m – 0.5m (1.64ft – 1.97ft)

Maximum Bed Area	200m^2 (2153ft2) minimum of 2 beds
Sand size:	
Effective size (D_{10})	0.15mm – 0.30mm (0.006 in -0.012in)
Uniformity Coefficient (C_u)	< 5 (preferably < 3)
Dept h_f gravel support	0.3m – 0.5m (0.984ft – 1.64 ft)
Dept of supernatant (headwater)	1m (3.28 ft)
Filtration Rate	0.2m/h

V. CONCLUSION

This research shows that slow sand filtration is a low-cost process for improving water quality in rural households. Reductions in faecal coliform count of about 95% were obtained. These mechanisms need a systematic study. Slow sand filters have a long history of successful water treatment, when applied to appropriate source waters and when designed and operated properly. Failures have happened and will continue to occur, however, if the process is used when source water is not treatable by slow sand or if the design is flawed or basic operating principles are ignored. Design engineers who are aware of the capabilities and limitations of slow sand filtration can in many instances provide for successful use of slow sand filtration by small communities. Slow sand filter must be cleaned when the fine sand becomes clogged, which is measured by the head loss. The length of time between cleanings can range from several weeks to a year, depending on the raw water quality.

VI. RECOMMENDATION

i) Since viruses are far smaller than bacteria and protozoan cysts, they can travel further into the sand bed of the slow sand filter, thus making slow sand filter less effective in removing viruses. Further research under well controlled conditions is needed to characterize viral removal by the improved slow sand filter.

ii) The management, operation and maintenance of slow sand filters require skilled personnel. Skilled, trained people who understand how slow sand filters function should be assigned at states/localities as well as at each location of a slow sand filter. The choice of durable materials and proper supervision is necessary for construction avoid early malfunctioning of the slow sand filter. Slow sand filters have no mechanisms to indicate when the filters need cleaning. This should be considered in the design. The application of slow sand filter for raw water from Idu Uruan needs to be looked at critically, since the turbidity of water from this source is too high for a slow sand filter to be effective as a standalone treatment system. Raw water from Idu Uruan River should be treated differently depending on its quality.

REFERENCES

[1]. Brink, D. R. and Parks, S. (1996). Update on Slow Sand/Advanced Biological Filtration Research. In N. Graham and R. Collins (Eds.), Advances in Slow Sand and Biological Filtration (pp. 11-18). England: John Wiley & Sons Ltd.
[2]. Collins, M.R., Eighmy, T. T., Fenstermacher J. M., Spanos, S. (1992). Removing Natural Organic Matter by Conventional Slow Sand Filtration. *Journal of the America Water Works Association* May 1992, 80 – 90.
[3]. Ellis, K. V. (1985). Slow Sand Filtration. CRC Critical Reviews in Environmental control, 14 (4) pp315 – 354.
[4]. Haarhoff, J., and Cleasby, J. L., (1991). "Biological and Physical Mechanisms in Slow Sand Filtration", in G. S. (Ed), Slow Sand Filtration. New York: American Society of Civil Engineers
[5]. Hendricks, D. (Ed.). (1991). Manual of Design for slow Sand Filtration. Denver: American Water Works Association (AWWA).
[6]. Hendricks, D. W. and Bellamy, W. D. (1991). "Microorganism Removals by Slow Sand Filtration", In G. S. Logsdon (Ed), Slow Sand Filtration: a report prepared by the Task Committee on Slow Sand Filtration.
[7]. Logsdon (Ed), Slow Sand Filtration: A report prepared by the Task Committee on Slow Sand Filtration. New York: American Society of Civil Engineers. Filtration, Huisman L. and Wood, W. E., WHO 1974.
[8]. Logsdon, G. S. (Ed). (1991). Slow Sand Filtration, A report published by the Task Committee on Slow Sand Filtration. New York: American Society of Civil Engineers.
[9]. Man, J.T., and D. Williamson, 1986. Water Treatment and Sanitation: Simple Methods for Rural Areas. London, Intermedia Technology Publications.
[10]. Managing Water in the Home: Accelerating Health Gains from improved Water Supply, by M. Sobsey, WHO 2002. Available at www.catas1.org.
[11]. National Guidelines and Standards for Water Quality in Nigeria.
[12]. Nigerian Industrial Standards for Potable Water and Natural Mineral Water (1992).

[13]. Reid, G., and K. Coffey. 1978. Appropriate Methods of Treating Water and Wastewater in Developing Countries. Stillwater, Oklahoma, University of Oklahoma, Bureau of Water and Environmental Resources Research.
[14]. Riesenberg, F., Walters, B. B., Steele, A., and Ryder, A. R. (1995). Slow sand filters for small Water system. Journal of the American Waterworks Association, 87 (11), 48-56.
[15]. Slow Sand Filtration, by L. Huisman and W. E. Weed. WHO 1974. Available at www.catas1.org.
[16]. Tropical Research and Development, Inc. 1992. Intensive Survey of Rural and Urban Activities Impacting Water and Coastal Resources. USAID.
[17]. WHO Guidelines for Drinking-Water Quality, 3rd edition. Available at http://www.who.int/water sanitation health/dwg/gdwq3/en/.

Udeme Hanson Iron, et. al. "Sand Filtration Technique for Improving Drinking Water Quality in Rural Areas of Akwa Ibom State." *IOSR Journal of Engineering (IOSRJEN)*, 12(03), 2022, pp. 41-53.