

Original Research Article

Evaluation of Slow Sand Filter with **Filter Aid for Rural Water Treatment: a case study of Girei, Adamawa State, Nigeria**

ABSTRACT

Treatment of water has a great influence on the use of water for domestic use both in rural and urban areas. Slow sand filtration involves the use of beds of sand for the filtration of water. The reason for designing and constructing slow sand filter for rural water treatment is to make treatment of water easy and qualitative. This research involves the use of three tanks, filter beds, filter media and filtrate tanks. Raw water is filtered by the layers of different sand particles, and conveyed by pipe after filtration to the filter media that has diatomite as the sieving agent which filters the water before been conveyed into the filtrate tank. From test carried out, the result shows that slow sand filter with filter aid is moderately **efficient** for water treatment. The **design and construction** applied **appropriate technology**; hence the ease of filtering raw water as well as improvement in taste and odor of water being treated was achieved.

Keywords: Sand, Filter Aid, Water treatment, Tanks, Diatomite, Rural area, Technology

1. INTRODUCTION

1.1 Background Information

Water is necessary for many purposes ranging from domestic uses, industrial water supply and irrigation [1]. Slow sand filter was proven to be sustainable and reliable drinking water treatment alternative for a small communities like Sabon Gari Girei community, which can be beneficial for addressing the small systems challenges [2]. Slow sand filtration has been an effective water treatment process for preventing the spread of gastrointestinal disease for over 150 years, having been first used in Great Britain and later in other European countries. Slow sand filters were built to serve communities in North America both before and after 1900, but the advent of effective coagulation, sedimentation, and rapid rate filtration resulted in a declining interest in slow sand filtration in North America in the early part of the twentieth century [3]. **A driving force for the reevaluation of slow sand filtration** in the United States was the need for simple effective water treatment processes for small water systems located in rural areas. A similar reevaluation has occurred in China. Slow sand filtration was used in China in the 1930s and 1940s, but later, rapid gravity filtration found favor due to the land requirements for slow sand filters in the urban areas since the 1980s [4]. Slow sand filtration has been applied in rural areas in China for small-scale water treatment facilities [5].

The efficiency of slow sand filtration depends on the particle size distribution of the sand, the ratio of the surface area of the filter depth and the flow rate of water through the filter [6]. The finest grade sand fractions and granulated Rockwool have been shown to be most efficient in **controlling disease such as phytophthora, pythium** and furacium oxosporum, the most wide spread nursery disease.

Slow sand filters have traditionally been designed with a bed of sand initially about 1m in depth with about 1m of super-natural water. The effective size of the filter sand ranges from about 0.15 – 0.35 mm [7] recommended that the uniformity co-efficient should be less than 5 and preferably less than 3. Filtration rates are typically in the range of 0.1 – 0.3m/h [8, 9] or 1 – 2% of this rate control. In a slow sand filter, the filter bed is constructed of a medium with

high surface area which can be colonized by suppressive microorganisms. This fine media also presents a physical barrier to the passage of spores of plant pathogens. Bacteria, such as representative of the genus *Pseudomonas* and *Trichoderma* have been demonstrated as biological control agents effectively controlling plant pathogens in hydroponics systems. In a slow sand filtration, plant pathogen recirculating in the irrigation water are captured in the filter media, and at slow rates of water filtration (100 – 200 l/hr/m² surface area of filter), are acted upon by the antagonistic micro-organism that colonized this filter bed.

Treatment of water for rural community has been a very major problem culminating against the utilization of water for domestic and drinking purpose for entire rural community. The existing method use in treatment of water for rural community seem very expensive and sometimes the chemical use of water obtained directly from stream is very harmful and deadly to the community. Secondly the water treatment process use in supply of water to urban area seems very cumbersome and cannot be used in small community. Then, the need arises to construct a slow sand filtration unit that is very efficient and cost effective for rural area. This research is aimed at constructing a slow sand filter with a filter aid filtration unit for rural water treatment using locally available materials.

2. MATERIALS AND METHODS

2.1 Design theories

The design of slow sand filter unit with filter aid involves the study of decision making processes which was used in the formulation of plans for the physical realization of the unit. Certain criteria are taken into consideration.

- i) Selection of material: for example, factor governing the choice of material, which include strength, durability, flexibility, weight, corrosion resistance.
- ii) Safety of operation cost of production and finally assembly

Tank is required to carry the sizes of sand alongside the raw water that is to filter. It is necessary to consider the material that was used in the design of the tank. This material should be a ductile material of high resistance to corrosion thus mild steel is selected based on the fact that those properties listed above were fulfilled by it. In determination of the height of the tank it was considered that the length is known by assuming a value [10]. The area of the tank was computed from equation 1 below.

$$A = L \times B \quad 1$$

where A is area of the tank (m²), L is length of the tank (meter), B is breath of the tank (meter).

$$Q = A \times V \quad 2$$

where Q is quantity of fluid carried per minute, A is area of the tank (m²), V is velocity of the fluid flowing per minute (m/s) [10].

$$\text{Since } Q = \frac{V}{t} \quad [10] \quad 3$$

where V is volume of the tank (m³), t is time taken (seconds)

The inside diameter of the pipe depends upon the quantity of the fluid to be delivered and it was computed from equation below.

$$Q = \frac{\pi x D^2 x V}{4} \quad 4$$

After deciding upon the inside diameter of the pipe, the thickness of the wall (t) in order to withstand the internal fluid pressure (p) was obtained by using thin cylinder formula.

$$t = \frac{PD}{2\delta} \quad 5$$

where t is thickness, D is diameter of pipe, δ is stress in pipe. Thus;

$$\delta = \frac{\delta_t}{P} \quad 6$$

For cast Iron material the allowable tensile stress (δ_t) for commercial purpose is 14N/mm² [11].

It is expected that the smaller tank be half the volume of the bigger tank in the sense that virtually half of the water is being absorb by the layers of sand and some of the impurities that as added to the volume as being remove by this slow sand filter and also by the filter aid. Thus,

$$V_s = \frac{V_L}{2} \quad 7$$

where Vs is volume of large tank (m³), VL is volume of the smaller tank (m³).

The kind of valve to be selected to control the inflow and discharge of water is based on the kind of fluid into be carried it expected that for water with little impurities or raw water a gate valve and globe valve was selected. For the purpose of the design gate valve is selected because of availability and ease of opening and closing. The essence is to hold the work together the stress due to the weight on weld is assumed to be equally distributed.

A fillet form of welding is choosing for the design of frame and weld. Thus the effective weld force or strength of fillet P is given as.

$$P = L x t x \delta \quad 8$$

where δ is the permissible stress for axial compression or tension and is usually given as 140 Mpa [12], L is the total length of weld or welded length, t is the effective throat thickness and it is usually.

$$t = Kx \quad 9$$

where x = is the size of the weld which is 6 mm, K = is a constant (for welding angle between 60° to 90° C and K = 0.7) [12, 13]. Production cost of this equipment is shown in Table 1.

Table 1: Material Costing

S/NO	Material Description	Quantity	Unit cost (₦)	Total Cost (₦)
1.	Sheet metal (unprotected) gauge	5/9	500	2500
2	Sheet metal (unprotected) gauge	1/9	500	500

3	Sheet metal (unprotected) 3/9	3/9	500	1500
4	¾ round pipe (galvanized)	36" Long (3ft)	150 per feet	450.00
5	Gate valve made of brass	1	450	450.00
6	Metal tap head made of copper	1	500	500.00
7	Socket made of galvanized	5	100	500.00
8	Auto base paint	1 medium size tin	900	900.00
9	Elbow joint made of galvanized pipe	1	60	60.00
10	Electrode (gauge) mild steel	30 pieces		250.00
11	1" square pipe black (mild steel)	3	800	2400.00
12	Diesel for gem	4 liters	116	425.00
Total				10,435.00

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116 In making the selection of materials for use in the construction the choice of materials is
 117 paramount factor. The choice of material was guided by the stages of design. At the
 118 beginning of the design it was non directional and the options are wide, at this stage all
 119 material was considered. As the design become more focused and took shape, the selection
 120 criteria shaped and the list of material which can satisfy them become more stringent. The
 121 choice of precise by which the materials is to be formed, framed joined and finish or
 122 otherwise treated and formed, framed joined and finish or otherwise treated and cost on the
 123 other hand enter both in the choice of materials and the way the materials was processed [14].

124 There are two main steps for selection of materiel for the design and construction of this
 125 machine which includes; 1. Screening and ranking, 2. Supporting information. Unbiased
 126 selection required that all materials are considered to be candidates until proven otherwise.
 127 The first of step is screening which involve elimination of candidate which cannot do this job
 128 at all because one or more of its properties or attribute lies outside the limits imposed by this
 129 designer thus this requirement was referred to as property limit. Further selection was done
 130 by applying material indices to find the candidate that can do the job better by ranking the
 131 candidate.

132 The outcome of result of screening and ranking steps was a shortlist of candidate which
 133 satisfies the requirement of the design; to proceed a detail profiled of the supporting
 134 information on each candidate was seek. The final choice between competing candidates
 135 depend on the local conditions, that is, the weather and climate conditions of where they will
 136 be used.

137 From the specifications already given, the materials used were based on their known
 138 information as presented below. In the design and fabrication of most Engineering equipment

model, it is advisable and more economical to use Aluminum and Mild Steel because of their resistance to corrosion and relatively cheap cost. Steel was used for the design of the equipment. For the fact that components are produced by varying methods depending on the availability of material relative weight, technological know-how and other unforeseen circumstances, all items have different cost attached to them.

3. RESULTS AND DISCUSSION

Construction involves the fabrication of the various part that make up the equipment and putting them together to operate as a composite member that is to say the fabricated parts were assembled to form a single product (slow sand filtering unit).The construction started with marking out, cutting bending of the bank, welding, assembling, finishing and testing. Some of these component uses were standard e.g. vale and tap head were selected and purchased from the local market. The square pipe was marked out with a scribe according to the dimensional requirement specified on my working drawing for frame they were them cut and welded into the shape of the main frame. The metal steel sheet [15] was measured according to the dimensional requirement on the working drawing and thereafter it is marked out with a scribe and folded with a perfect tank and it thus welded together such that it will not leak.

The metal steel sheet was measured according to the dimensional required on the working drawing and thereafter it is marked out with a scribe and bended with a folding machine in such a way that it gives the perfect shape of a tank and it thus welded together such that it will not lake [11].The metal sheet was measure and marked out with the aid of scribe to the dimensional requirement specified thereafter it is cut and bended with a bending machine to get the required shape after with it welded together.

The cylindrical pipe of diameter 23 mm was marked out to the required dimension thereafter it was then cut with hawk saw to the required length. The mainframe was formed by welding together the part making up the frame. The big tank was welded tighter and a small hole of equal diameter to the pipe is to derived at the bottom of the tank thus welded on it is a small treaded pipe joint A which the treaded pipe is to be joined, and connected to it is a Ball value that is thus link to the filter aid media. A pipe form filter aid media is link or connected to the smaller tank (filtrate tank). The pipe which is also treaded to be joined at elbow joint through fastening to the smaller tank. The entire unit is thus molted on the main frame wheel act a support to the filtering unit.

The evaluation of slow sand filter (Figure 1) was carried out by using the standard parameter. Table 2 below shows the test result in comparison with standard parameter from [16, 17]. The result shown below gives a clear indication that slow sand filter with filter aid is partially efficient for treating raw material for rural area. Since there is little or no difference between the standard values obtained from WHO and the result obtained in the course of the test. Thus slow sand filtering is moderately better than other method of treating water for rural water treatment.

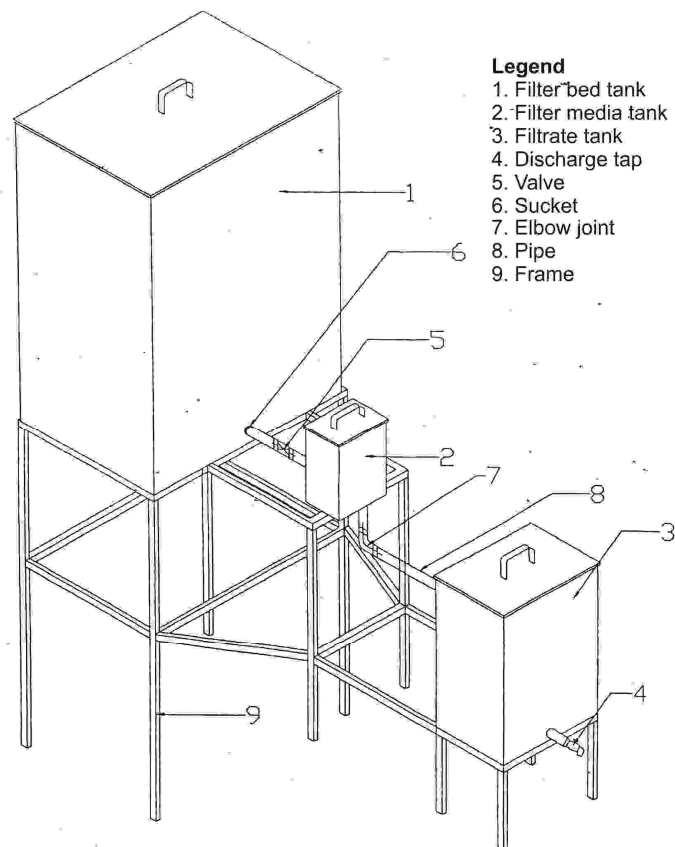
Table 2: Test Result

S/N	Test	Result	WHO (2010) Standards
1	pH test	6.5	7-9

2.	Membrane filtration test	Partially colourless	Colorless mesh
3.	Total dissolved solid test.	≥ 3	≥ 5
4.	Taste and odour test	Tasteless and odourless	Tasteless, odourless
5	Sludge test	50%	30% - 40%
6	Iron test	0.3ppm	0.1ppm
7	Macro biological	Absent	Absent
8	Algar	0	0
9	Protozoan	1	0
10	Micro biological factors	0	0
11	Total Califorms	1	0

179 3.1 Principle of Operation

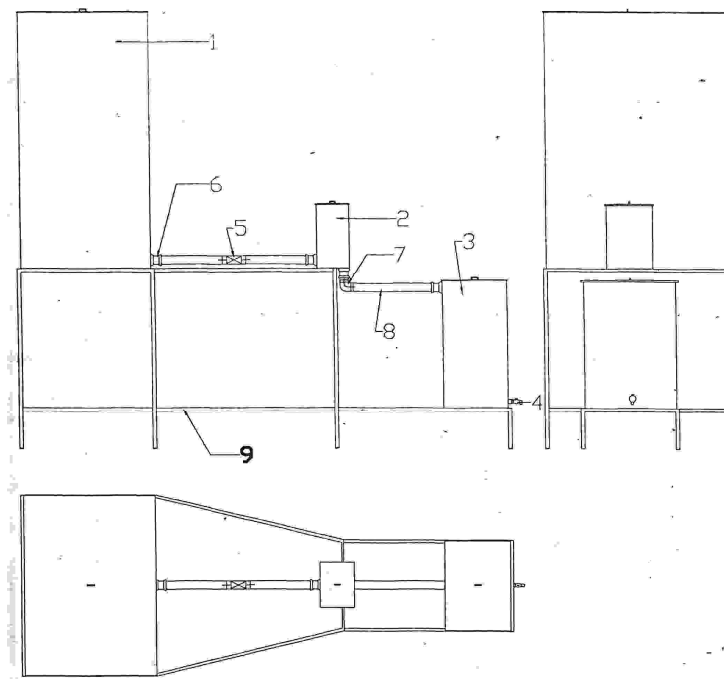
180 Raw water was introduced through the inlet (the upper part) of the big tank (filter bed
181 tank) (Figure 1). The big tank comprises of various soil size ranging from the gravel that
182 form the bed to the smallest size of the sandy soil as the water gradually flow through the
183 layer of soil size particle that are unwanted are being tapped by microbial action. Thus the
184 raw water is gradually been filter by the layer or bed of soil. The discharge at the lower part
185 of the tank is open to allow the filter water to further pass through a filter aid container where
186 it further been filter by the “diatomite” which serve the purpose of sieve to further purify the
187 water thereafter the water is collected through gravitational mean into the smaller tank where
188 the water can be collected for domestic use [18].



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Figure 1: Assembly Drawing of the Slow Sand Filter



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Figure 2: Orthographic View of the Slow Sand Filter

4. CONCLUSION

The design of the slow and filter with filter aid (diatomite) has a simple operation and should have high filtration efficiency, however the result obtained actually shows that there is a little deviation in the performance of the slow sand filtering unit that is designed and constructed thus there is still need for improvement on the performance of the slow sand filter especially in carrying out proper research on suitable sand that can be used to achieved proper filtration. With the result obtained, a moderately efficient slow sand filtering unit for rural water treatment was achieved. Thus, the slow sand filter if made available to the rural area will help solve the problem encountered with treatment of water.

REFERENCES

1. Saladi JA and Salehe FS. Assessment of Water Supply and Its Implications on Household Income in Kabuku Ndani Ward, Handeni District, Tanzania. *Asian Journal of Environment & Ecology*, 2017; 2(1): 1 – 26.
2. Cleary SA. Sustainable drinking water treatment for small communities using multistage slow sand filtration. Published M.Sc. Thesis, *Waterloo, Ontario, Canada*, 2005; 1 – 288.
3. Baker DL& Duke F. Intermittent Slow Sand Filters for Household Use - A Field Study in Haiti. *IWA Publishing, London, UK*, 2006; 1 – 4.
4. Nkwonta O & Ochieng G. Roughing filter for water pre-treatment technology in developing countries: A review. *International Journal of Physical Sciences*, 2009; 4(9): 455 – 463.
5. Saravanan SP & Gobinath R. Drinking Water Safety through Bio Sand Filter - A Case Study of Kovilambakkam Village, Chennai. *International Journal of Applied Engineering Research*, 2015; 10(53): 254 – 262.
6. Clark PA, Pinedo CA, Fadus M & Capuzzi S. Slow-sand water filter: Design, implementation, accessibility and sustainability in developing countries. *Med Sci Monit*, 2012; 18(7): 105-117.
7. Zaman S, Yeasmin S, Inatsu Y, Ananchaipattana C & Bari ML. Low-Cost Sustainable Technologies for the Production of Clean Drinking Water—A Review. *Journal of Environmental Protection*, 2014; 5: 42 – 53.
8. Sims RC & Slezak LA. Slow sand filtration: Present practice in the United State. In slow sand filtration. *American Society of Civil Engineers, New York*, Edited by G. Logsdon, 1991.
9. Seger A & Rothman M. Slow sand filtration with and without ozonation in Nordic climate. In Advances in slow sand and alternative Biological filtration. Graham, N., Collins, R., *John Willey & Sons Ltd., England*, 1996/
10. Hunter P. Household water treatment in developing countries: Comparing different intervention types using meta-regression. *Environ. Sci. Technol.*, 2009; 43: 8991–8997.
11. Burleson GE. Water Treatment Technologies for the Developing World. Published B. SC in Mechanical Engineering Thesis, Oregon University, 2016; 63.
12. Rabbani KS. Low Cost Domestic Scale Technologies for Safe Drinking Water. *Appropriate Healthcare Technologies for Developing Countries*, 2012.

- 236 13. Sission AJ, Wampler PJ, Rediske RR & Molla AR. An assessment of long-term bio
237 sand filters use and sustainability in the Artibonite Valley near Deschapelles, Haiti.
238 *Journal of Water, Sanitation and Hygiene*, 2013; 3(1): 51 – 60.
- 239 14. Taghizadeh MM, Torabian A, Borghei M & Hassani AH. Feasibility study of water
240 purification using vertical porous concrete filter. *Int. J. Environ. Sci. Tech.*, 2007; 4(4):
241 505-512.
- 242 15. Collins MR, Cole JO, Westersund CM & Paris DB. Assessing Roughing Filtration
243 Design Variables. *Water supply*, 1994; 12:1 – 2.
- 244 16. World Health Organization. Guidelines for drinking water quality, *World Health*
245 *Organization, Geneva*, 2010.
- 246 17. APHA. Standard methods for examination of water and waste water 15th Ed. American
247 pub. Health Asso., Washington D.C., 1995
- 248 18. Jones SA, Anya A, Stacey N & Weir L. A Life-cycle Approach to Improve the
249 Sustainability of Rural Water Systems in Resource-Limited Countries. *Challenges*,
250 2012; 3: 233-260.