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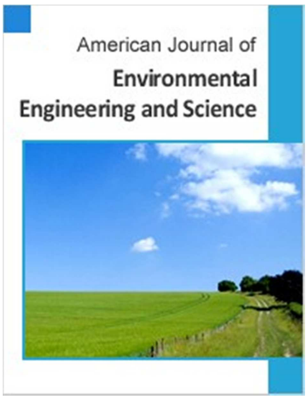

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Potential Use of Asa River Sand as Filter Media in Water Treatment Plants

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Abstract
This study investigated the Potential use of sand from River Asa at Ilorin, kwara State in North- Central Nigeria as filter media in water treatment plants. Sand is mostly widely employed as porous substance (Filter Medium) in filtration plants all over the world and in Nigeria. The sand was subjected to various soil mechanics and hydraulic tests including Particle Size Distribution, Specific Gravity, Acid solubility, Porosity, Permeability and Filterability. The study shows that, sand from river Asa have Effective size (Es) of 0.40 mm; Uniformity coefficient (Uc) of 1.25; Acid solubility (%) of 2.10; Specific Gravity of 3.77; Porosity (%) of 51; Permeability (cm/sec) of 1.06. The maximum head loss obtained from river Asa sand with hydraulic Loading rates of 6.45 m/hr and 9.65 m/hr at 16 and 13 hours of filter run time were 19.014 cm and 24.347 cm of water. The results obtained for filter quality of the Asa river sand with turbidity of 32 NTU and hydraulic loading rates of 6.45 m/hr and 9.65 m/hr at 16 and 13 hours of filter run times were 4.52 NTU and 4.87 NTU, which were well below the recommended value of 5.0 NTU. The Specific objective of the study was achieved and the study shows that, sand from river Asa have potential properties to be used as filter media due to its properties were encouraging.

1. Introduction

The provision of safe and aesthetically acceptable drinking water to the community is of vital importance for the maintenance of public health. The role of public water supplies that are bacteriologically unsafe, as vectors of diseases, a vehicle for the spread of diseases and other water – borne diseases have been established by many incidents and investigators. Realising from such incidents the importance of prevention being better than cure, treatment of water before its consumption was initiated on a wider scale, especially in developed nations [1]. Depending on the prevailing transmission pathways, different intervention in water supply and sanitation are required. More often, most of these diseases are transmitted in drinking water, thus making the quality of drinking water of highest importance. The presence of a safe and reliable source of water is thus an essential pre-requisite for the establishment of a stable community. Filters can be effective in removing iron, manganese and organics, Organics can form carcinogenic by-products when they react with disinfectants [2].

Among the various unit operations of a conventional water treatment plant, filtration occupies a central and important place and perhaps the oldest and most widely used in the water purification treatment [3].

When using sand as a filter medium, composition, size, uniformity and depth of the medium all affect the sand filter performance. Characteristics of the media composition, such as its solubility, acidity, and hardness, must be considered in the filter design. It is extremely important that the medium be washed. The media component should be inspected for cleanliness and suitability by a qualified individual before it is used in the filter. The media grains are sorted and sieved through a series of mechanical sieves. The grains must be relatively uniform in size to prevent clogging. "Effective size" and "uniformity coefficient" are measurements used to express these characteristics. Each sand filter type has its own particle size range requirements. Uniformity coefficient of four or less is recommended for all filter media [4].

Theoretical Background

This section examines the theory guiding the experiments needed to be conducted and their relevance to the study for a better understanding of principles and interpretation of data.

1.1. Particle Size Analysis

The particle size analysis of a soil sample involves determining the percentage by weight of particles within the different size ranges. The particle size distribution of a coarse grained soil can be determined by the method of sieving. A representative sample of the sample of the sand is split systematically down to a convenient sub-sample and then oven-dried. The sample is then passed through a series of standard test sieves arranged in descending order of mesh size.

1.2. Effective Particle Size

The effective size (ES) is defined by the size of screen opening where 90% of a sample of granular media is retained on the screen and 10% passes through the screen, and is referred to as D_{10} [5].

1.3. Uniformity Coefficient

The uniformity coefficient (Uc) is a numeric estimate of how sand is graded, and is a dimensionless number, in other words it has no units. The term "graded" relates to where the concentrations of sand particles are related by size [6]. Sand with all the particles in two size ranges would be defined as narrowly graded sand and would have a low Uc. Sand with near equal proportions in all the fractions would be defined as widely graded sand and would have a high Uc value. The Uc is calculated by dividing D_{60} (the size of screen opening were 60% of sample passes and 40% is retained) by D_{10} (the effective particle size- that size of screen opening where 10% of the sample passes and 90% is retained) [7].

1.4. Specific Gravity

Specific density is mass per unit grain volume, and is important because it affects the backwash flow requirements of the medium. The grain density is measured or determined from the specific gravity following ASTM standard test C128-84 specific gravity and absorption of the fine aggregate, using the displacement technique [8].

The density of granular materials does not directly affect performance of filter media, but it provides vital information that is required for the backwashing behaviour of the filter grains [9]. Specific gravity is the ratio of the mass of a body to the mass of an equal volume of water at a temperature of 23°C [7]. [10] Recommended that filter media should have a specific gravity of not less than 2.5 and a hydrochloric acid solubility of less than 2%.

1.5. Acid Solubility

Acid solubility is used to express the proportion of carbonates or Hydrogen carbonates in the sample (River Sand). Sand cannot be affected to any appreciable (or noticeable) extent by acids because it is mainly SiO_2 compound. When soaked in an acid a change in the weight of the sand is usually noticed in minutes. Any high or noticeable change in the weight of sand raise doubts about its purity as this suggests that the change in the weight is a representation of the impurities which cannot be mechanically removed by washing but are now either dissolved or burnt by the acid. Therefore, a sand sample that has a large solubility value is not good for filter medium as acids are usually formed in water. A method recommended by [11] was adapted in the determination of the acid solubility of the soil sample.

1.6. Porosity

Porosity is defined as the pore volume per unit filter volume. It is a useful measure for its acid test ensures the integrity of the grains. Porosity of soil material is a major factor in determining the flow through such materials. This flow through a porous medium is a common phenomenon occurring in groundwater flow, seepage and infiltration; dewatering of slurries and sludge in industries; clarification of industrial liquids, sewage treatment and water purification. [9] Reported that the practical range of filter porosities lies between 0.35 - 0.50. This however, may vary during the filter run and during the backwash process when it can drop to about 0.1 or rise to about 0.8. He also reported that a typical porosity value for sand media is about 0.45.

1.7. Permeability

Permeability test was determined using the Constant head test of [12]. The permeability was measured by the constant head method, using the I C W laboratory permeameter (Eiji Kelkamp Agrisearch No. 09 02). The permeability concept is a characteristic of both fluid and the porous media. A number of appropriate empherical relationships have been suggested between permeability K and other soil properties.

1.8. Filterability

Deep beds of porous granular media are in widespread use in municipal and industrial practice to filter liquids to improve their clarity. Prominent among these uses is the filtration of drinking water and industrial water, although the filtration of sewage as a tertiary stage of treatment is increasing. Filterability is not a property of just suspension, but is an interactive property between a suspension and some filter media. If the properties of one of these say a standard medium is kept constant then changes in the filterable if it can pass rapidly through a porous medium, giving a clear filtrate with little clogging of filter medium clogging is reflected in the loss of permeability, as seen in the increase in pressure drop. A simple measure of whether the liquid is filterable is useful, to enable assessment of whether filtration is an appropriate process, and if so what type of pre-treatments and filter medium required. Although the normal methods of chemical and physical analysis may with experience indicate whether a suspension may be filtered, they give no direct measures of this property. The early researchers as reported by [13] have proposed a number of measures of filterability.

2. Methods and Materials

2.1. Site Description (Study Area)

Asa River is one of the major rivers in Kwara State with much sand deposits. It lies between latitudes $08^{0}26'00''N - 08^{0}36'00''N$ and longitudes $04^{0}26'00''E - 04^{0}36'00''E$ within Asa and Ilorin West Local Government in Kwara State. The river originated its sources from River Niger from the North of 104 km and flows through Asa Local Government Area of Kwara State as shown in Figure 1. below.

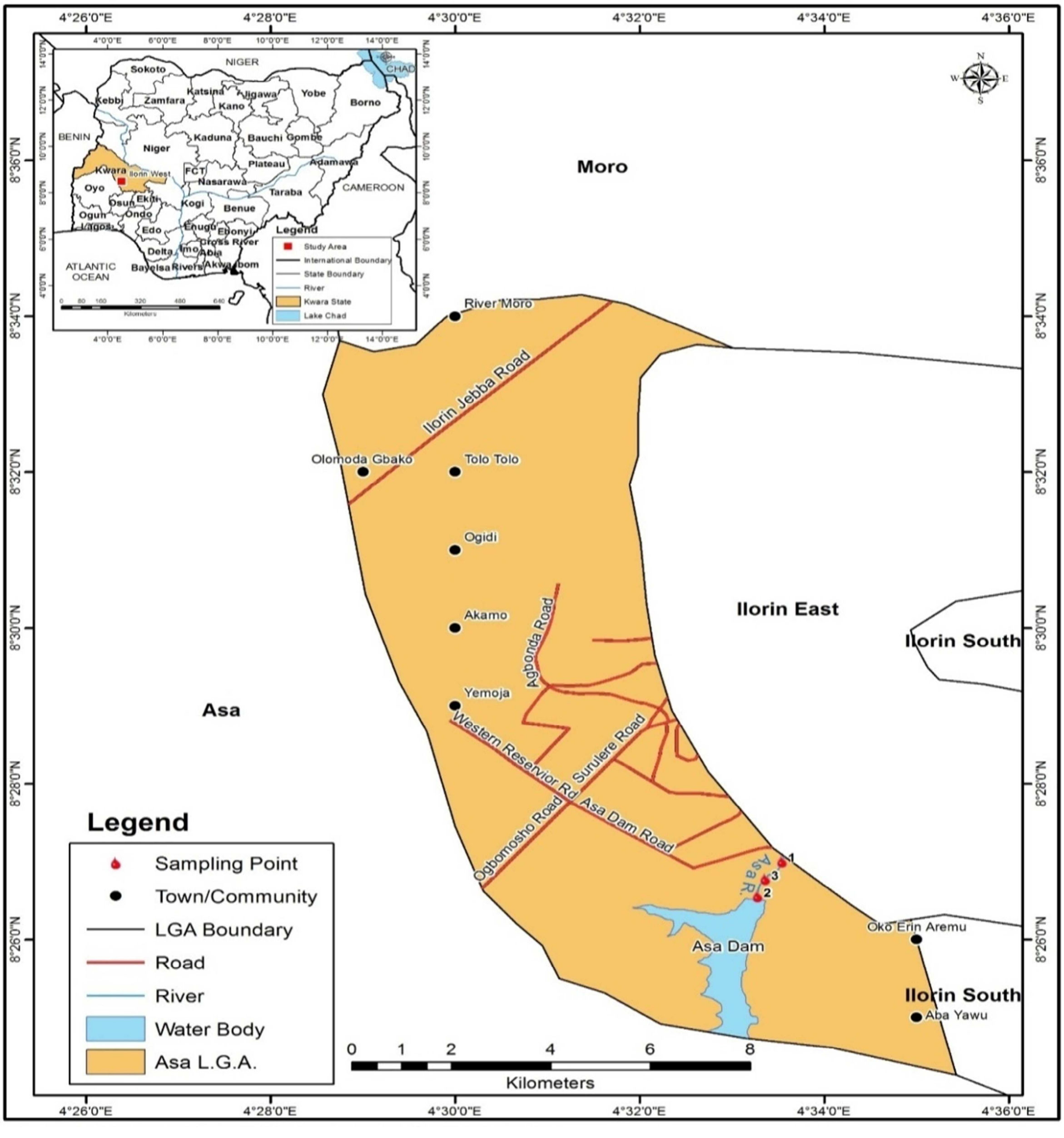

Figure 1. Map of Ilorin West LGA showing River Asa with sample collection points.

2.2. Sample Collection and Preparation

River sand sample for the study were collected from the Asa River in Ilorin West Local Government in Kwara State of Nigeria. Samples were collected at three locations (Sample Points) with their co-ordinates shown in Table 1. from the top of the river bank, the bed of the rivers and at depth of $2\frac{1}{2}$ $meters$ from the river banks with a shovel into porous sacks, so as to allow the water to drain easily. These were mixed together as composite samples (Stocks). The collected sand samples were thoroughly washed to remove all organic materials, dirt and rubbish that may be present in the sand samples.

The sand samples were packed in sacks after washing for dewatering, after which they were removed from the sacks and spread on a clean surface for sun drying. After drying the samples were stored in sacks.

Table 1. *River Sand Showing Sample Collection Points and Co-ordinates.*

River Sand	Sample Points	Co-ordinates	
	1	8° 27' 00.12″ N	8° 26' 46.48″ E
Asa	2	8° 26' 46.56″ N	4° 33' 21.61″ E
	3	8° 26' 33.15″ N	4° 33' 16.70″ E

The following equipment/materials were used in carrying out this study,

(a) Equipment

(1) Complete set of Sieves (Standard British Series)
(2) Hot Air Oven (Gallenkamp, BRIT. No. 882942 ENGLAND)
(3) Electronic weighing balance, G & G, J. J 3000Gallenkamp Ltd
(4) Mettler analytical balance capable of weighing accuracy $\pm$ 0.01gram, Mettler P160N
(5) Stop watch, HF Instrument, New York, USA.
(6) Funnel (100mm), Boro Silicate 24/20 England
(7) Buckets (Plastic), 20liters, OK plastic Nigeria Ltd.
(8) Filter paper, Whatman No 41 Water pump, 1.5hp Peter's pump, Germany
(9) Pipes (PVC), Geepee Nigeria Ltd.
(10) Flow meter and Control valves, Gallenkamp Products, England
(11) Hand glove, C456, Agary Limited, Malaysia
(12) Head pans, John. C, 24/36mm. England
(13) Sacks, Dangote Sacks, 50kg, Nigeria.
(14) Shovel, John. C, Size 14, England
(15) Rubber Gasket and hose (Flexible pipe of 20cm)
(16) Brass Mesh
(17) Stand-pipe glass (Burette, 20cm^3) England
(18) ICW laboratory permeameter (Eiji kelkamp Agrisearch No. 09 02)
(19) Global Positioning System (GPS).
(20) Filter beds
(21) Graded and prepared sand from various sources.
(22) Water pump, 1.5hp Peter's pump, Germany
(23) Pipes (PVC), Geepee Nigeria Ltd.
(24) Flow meter and Control valves, Gallenkamp Products, England

The following glasswares was used in carrying out this study,

(b) Glassware

(1) Measuring cylinder, Kinax USA (100ml, 200ml and 250ml capacity)
(2) Glass beakers, Boro-Slicate England (100ml and 200ml capacity)
(3) Thermometer, 110°C, Gallenkamp England
(4) Crucible dishes, BS 34267, Gallenkamp England.
(5) Specific gravity bottles, Technico-England.

The following reagents was used in carrying out this study,

(c) Reagents

Sulphuric acid (H_2SO_4) and hydrochloric acid (HCL), BDH Pool Limited England and Aluminium Sulphate

2.3. Determination of Particle Size Distribution

These parameters was determined by sieve analysis using the method of the American Society Testing and Materials [7] in which 500 grams of sand sample was sieved using standard sieves series (Apertures 4.760 mm, 2.360 mm, 2.000 mm, 0.600 mm, 0.425 mm, 0.300 mm, 0.212 mm, 0.150 mm and 0.075 mm). The sieves were arranged in decreasing sieve bore size from top to bottom as listed above. The weight of sand retained on each sieve was determined using the electronic weighing balance and the percentage by weight, passing through each sieve was determined and this was plotted against sieve size on a semi-logarithmic paper. The sieve size that permits 10% by weight of the sand sample, to pass through (as interpolated from the plot on the semi-logarithmic paper) gives the Effective size (Es) of the sand sample. Similarly, the sieve that permits 60% of the sand sample by weight, to pass through was obtained. The uniformity coefficient (Uc) of the sand sample was then determined [14] using the relationship below;

$$\text{Uniformity coefficient (Uc)} = \frac{d_{60}}{d_{10}} \quad (1)$$

$$\text{Percentage passing (\%)} = \frac{100(W_1 - W_2)}{W_1} \quad (2)$$

Where

W_1 is the initial weight of the sand
W_2 is the retain weight of the sand
d_{10} is the sieve sizes that pass 10% of the medium
d_{60} is the sieve sizes that pass 60% of the medium [14].

The percentage useable, too fine or too coarse filter media for a given effective size and uniformity coefficient are computed as:

The percentage usable (P_u), from $d_u = 2\ (d_{60} - d_{10})$
The percentage fine (P_f), $d_f = d_{10} - 0.2\ (d_{60} - d_{10})$
The percentage Coarse (P_c), from $d_u = d_{10} + 1.8\ (d_{60} - d_{10})$

2.4. Specific Gravity Determination

Specific gravity is mass per unit volume and is important because it affects the backwash flow requirements for the medium. It is determined using American Society Testing and Materials [15].

The weight (W_1) of specific gravity bottle was determined.

The specific gravity bottle was filled with sand sample and combined weighted (W_2) determined. The specific gravity bottle with the sand sample was then filled with water and weight (W_3). The water in the specific gravity bottle was drained. Water was filled in the specific gravity bottle weighed to give (W_4).

The Specific gravity was then calculated using the formula in equation 3, developed by [16]

$$\text{Specific gravity} = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)} \quad (3)$$

2.5. Acid Solubility

Acid solubility is used to express the proportion of carbonates or Hydrogen carbonates in the sample. A method recommended by [11] was adapted in the determination of the acid solubility of the soil sample. Four hundred (400) grams of sand sample were taken from the washed stock and recorded (W_1). The weighed sample was then immersed in 40% (by volume) of hydrochloric acid (HCL) + 60% distilled water for 24 hours (1 day) in a plastic bucket, to dissolve any organic matter present in the sample. The sample was then filtered with the aid of filter paper and funnel to collect the residue (sand sample). The residue collected were properly rinsed with distilled water, oven dried for 2 hrs at 105 ℃ and weighed (W_2) to determine the loss in weight.

The percentage Solubility was then calculated as follows:

$$\%\ \text{Solubility} = \frac{W_1 - W_2}{W_1} \times 100 \quad (4)$$

Where:
W_1= Initial weight of sand sample
W_2= Final weight of sand sample
$W_1 - W_2$= Loss in weight of sand sample

2.6. Determination of Porosity of Sand

Porosity (n) is the ratio of void volume to the total bed volume, expressed as a decimal, fraction or percentage. It affects the backwash flow required, the fixed bed head loss, and the solid holding capacity of the medium. The porosity was determined in accordance with [14, 12].

A transparent tube of 38 mm and 750 mm was half-filled with water. 150 g of sand sample was weighed and placed in the tube. Air and dirt was removed from the sand sample by shaking the tube. The dirty water in the transparent tube was decanted and the process was repeated until the sand sample is clean as evidenced by the quality of decanted water. The transparent tube was then filled with water and stopper with a cork, which was kept tight. The tube and its contents were supported by means of a clamp on a retort stand. The tube was agitated by inversion and allowed to settle freely in the water with no compaction or undisturbed. After settling, the level of sand in the tube column was then measured immediately, using a scale rule, after the last particles were observed to have settled. The volume **(V)** of the settled sand was then computed from the height of the sand in the column and the diameter of the tube.

Porosity of the sand was calculated as follows:

$$\text{Porosity}\ (\%) = \frac{Volume\ of\ Void}{Total\ Volume} \quad (5a)$$

$$n\ (\%) = \frac{V - {}^{w}/_{\gamma}}{V} \times 100 \quad (5b)$$

Where:
γ is the specific gravity of sand sample.
w is the mass of sand sample used.
V is the volume of the settled sand in the column.

2.7. Permeability Determination

Permeability test was determined using the Constant head test of [12]. The permeability was measured by the constant head method, using the I C W laboratory permeameter (Eiji Kelkamp Agrisearch No. 09 02). The equipment operates on the principle that water is cause to flow through a saturated sand column of know length (L) by the pressure difference on both sides of a well saturated sand sample.

The caps from the ring of known area (A) were removed and the samples were saturated overnight in a basin of water, this was done by covering the blunt end of the ring with a piece of nylon cloth which was held in place by means of a rubber band, to disallow soil loss. A specially meshed container was used to hold the ring which was in turn, placed inside a plastic container. The container containing the sample was then inserted into the permeameter after establishing a constant head. A tube previously filled with water was used as a junction connecting the inside of the ring holder and the water in the permeameter. This ensured flow of water into a burette. The time (T) taken at which a conveniently chosen volume (V) is attainted in the burette is taken using a stop watch. The hydraulic height difference (DH) of water inside the ring holder and outside was measured and the permeability (hydraulic conductivity) (K) was calculated as follows;

$$K = \frac{V.L}{AT(DH)} \quad (6)$$

Where,
K = Permeability (cm/sec)
V = Volume of water collected (cm^3)
L = Length of sand column (cm)
A = Cross sectional area of the sample (equivalent to area of core ring) cm^2
T = Time (Sec).
DH = Hydraulic head difference (cm).

Sand sample were treated as cohesion less soil in the permeameter.

2.8. Filterability Determination

The filtration effectiveness of the sand as filter medium was determined using the filterability test.

(a) Preliminary Treatment of Raw Water

In order to provide various level of initial turbidity for the filter operation and also to reduce the turbidity loading on the filters, preliminary experiments were carried out with jar-test apparatus to determine optimum alum dosage and optimum time for rapid and slow mix [18].

A 20 gram per litre stock solution of coagulant was prepared by dissolving 20 g of coagulant (aluminium sulphate $Al_2(SO_4)$. $18H_2O$ in a litre of distilled water. This solution was added to each of the 1000 ml raw water sample from river Benue by varying the quantities to give different coagulant doses of 0.25, 0.5, 0.75, 1.0, 1.25 and 1.5 g/l [19]. The samples were stirred rapidly (rapid mix) for a period of 1 minute after which the stirring speed was reduced and stirring continued slowly for another 15 minutes. The coagulated water was allowed to settle for 27 minute [11]. Settle water samples were analysed for turbidity reduction and to obtain the optimum coagulant dose.

(b) Filtration experiment

2.8.1. Experimental Method

Preparing the filter bed for the filter run involved filling the column with already graded and prepared sand. The depths of the filter beds inside the column were 120 cm.

Raw water from river Benue, which had be subjected to pre-treatment to attain required constant initial turbidity from the settle water tank was pumped into the overhead plastic bucket from which it was fed in to the filtration column via gravity. The rate of filling up the column was constantly maintained by a control valve and the inflow rate was maintained by flow meter. The primary variables investigated were; inflow rate, effluent flow rate, effluent turbidity as a function of time, bed depth and initial turbidity. The pressure drop across the filter beds was determined using modified Darcy - Wiesbach equations of head loss in pipe to reflect conditions in bed of porous media. The resulting equation, known as the Carmen-Kozeny modified equation [20]

$$h_f = \frac{f' L(1-e)V_s^2}{e^3 g d_p} \tag{7}$$

Where:

h_f = Friction loss through bed of particles of uniform size,

L = depth of the filter, m

e = porosity of bed

V_s = Filtering velocity, i.e the velocity of the water just above the bed

(Total flow Q to the filter divided by the area of the filter), m/s

g = gravitational acceleration, m/s^2

d_p =Diameter of filter media grains

The remaining term f' is a friction factor related to the coefficient of drag around the particle. In the usual range of filter velocities (laminar flow) and can be calculated by

$$f' = 150\frac{(1-e)}{R_e} + 1.75 \tag{8a}$$

Where: Reynolds number

$$(R_e) = \frac{\phi \rho_w V_s d}{\mu} \tag{8b}$$

And ρ_w and μ are the density and dynamic viscosity, respectively, of water. The units of ρ_w are kilograms per cubic meter (kg/m^3), and the units of μ are Newton-seconds per square meter ($N.s/m^2$). The shape factor ϕ ranges from 0.75 – 0.85 for most filter media [20].

Filtrate thus collected was monitored for turbidity until it deteriorated to unacceptable levels when this happened; the filters were taken out of operation and backwashed at a rate of 45.9 m/hr. This rate is near the lowest recommended backwash rate 37 m/hr according to [21].

2.8.2. Experimental Set-up

In setting up the experimental set up as shown in Figure 2 inorder to investigate the filter beds (sand) used, these consist of a column 100 mm in diameter and 2.8 m in height. Sampling points were made across the lower end of the column for a distance of 120 cm at various intervals. Pipes were installed from the sampling point to the sampling containers. Reading of the effluent flow rate and effluent turbidity were measured at various time intervals.

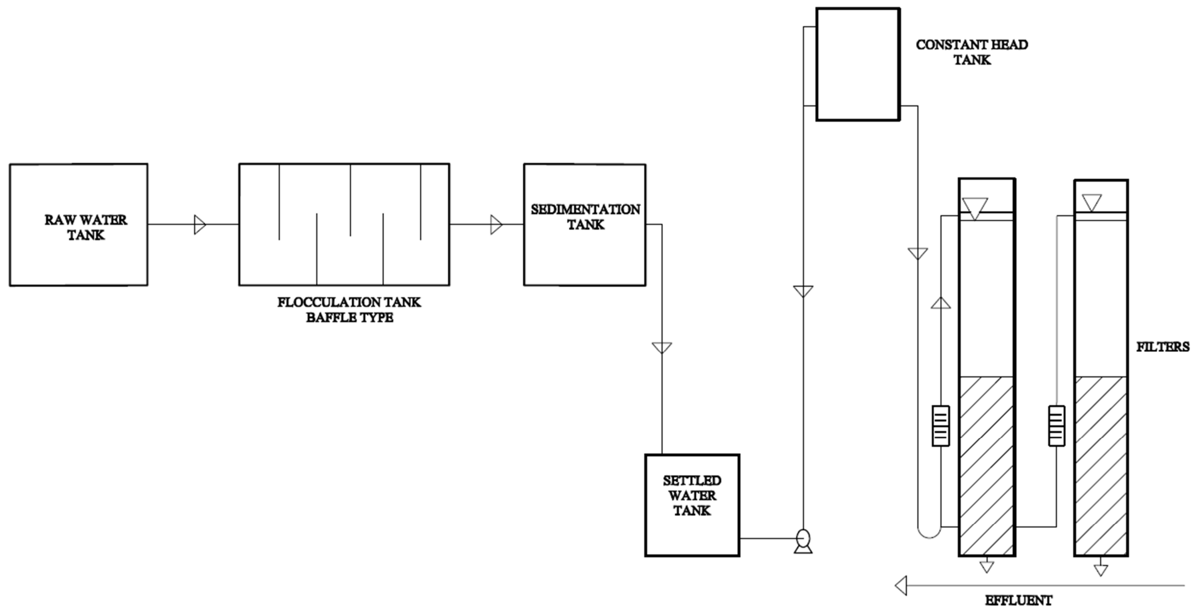

Figure 2. *Schematic Diagram of Filtration Plant.*

2.9. Turbidity Determination

The turbidity of the filtrates was obtained by standardizing the turbidity meter and reading the turbidity values of the water directly from the turbidity meter in accordance with manufacturer's instructions [22]. Turbidity was recorded in Nephelometric Turbidity Unit (NTU) [23].

3. Results and Discussions

3.1. Particle Size Distribution

Details of particle size distribution of Rivers Asa sand is presented in Table 2 and the particle size distribution presented at Appendix A showing the Sand effective size D_{10} of 0.40 mm, while the sieve allowing 60% of the sample to pass through (D_{60}) was 0.50 mm. The Uniformity Coefficients (U_c) which is the ratio of D_{60}/D_{10} are 1.25.

Table 2. *Result of particle size distribution of river Asa sand.*

Sieve sizes (mm)	Mass Retained (g)	% mass Retained	Cumulative mass Retained	% passing
4.760	0.00	0.00	0.00	100.00
2.360	18.20	3.64	3.64	96.36
2.000	14.00	2.80	6.44	93.56
0.600	90.70	18.14	24.58	75.42
0.425	308.90	61.78	86.36	13.64
0.300	37.90	7.58	93.94	6.06
0.212	17.00	3.40	97.34	2.66
0.150	5.10	1.02	98.36	1.64
0.075	1.30	0.26	98.62	1.38

Table 3 shows the portions of stock sand that were too fine (P_F), Useable (P_U) and Coarse P_C as filter medium when graded to the values of uniformity coefficients and effective sizes as presented at appendix A (Figure 3). The table also shows corresponding portion's that would be obtained if sand samples were graded to recommended values of effective sizes of (0.50 mm) and uniformity coefficient (1.50).

Table 3. *Fine, Useable and Coarse portion of stock sand.*

River Asa sand	Effective size (D_{10})	Uniformity Coefficient	Fine Portion P_f (%)	Useable Portion P_U (%)	Coarse portion Pc (%)
Determine values	0.4	1.25	14	40	72
Typical values	0.5	1.5	20	52	84

River Asa sand had a 40% useable portion of stock sample when graded to an effective size of 0.40 mm and uniformity coefficient of 1.25, the corresponding useable portion for the recommended values of effective size and uniformity coefficient is 52%. [24] Also concluded that if sand from river Jewo will have 80% of samples useable as filter media because of the rather higher of uniformity coefficient of 2.41.

3.2. Acid Solubility

Table 4 presents the acid solubility of river Asa sand; the hydraulic acid solubility result shows that river Asa Sand had acid solubility of 2.10%.

Table 4. *Acid Solubility.*

Sand	Description	weight (g)
River Asa Sand	Initial weight of sand sample	400.00
	Final weight of sand sample	381.60
	Loss in weight of sand	8.40
	% Solubility	2.10

3.3. Specific Gravity

The average specific gravity for Asa river sand sample is presented in Table 5 shows the specific gravity of 3.77 Sand imported from Brazil are within the recommended value (> 2.50) to be used as filter media because of the density of the sample is higher than that of water but the river sand from Asa is below the recommended value and is less denser than the density of water.

Table 5. *Specific Gravity of River Asa Sand.*

Bottle No.		2	4	5	Average
Wt. of bottle + water (full)	(W_4)	89.70	96.50	94.40	93.53
Wt. of bottle + Soil + water	(W_3)	95.10	103.00	101.10	99.73
Wt. of bottle + Soil	(W_2)	58.90	57.40	60.80	59.18
Wt. of bottle	(W_1)	48.20	50.10	43.45	47.25
Wt. of Addition of Water	($W_4 - W_1$)	41.50	46.80	44.70	44.33
Wt. of Water added to Soil	($W_3 - W_2$)	36.20	45.15	40.30	40.55

Bottle No.		2	4	5	Average
Wt. of Soil	$(W_2 - W_1)$	10.70	7.75	17.35	11.93
Wt. of Water displaced by Soil	$(W_4 - W_1) - (W_3 - W_2) = W$	5.30	1.65	4.40	3.78
Specific Gravity of Soil Particle	$(W_2 - W_1)/W$				3.77

3.4. Other Physical Properties of the River Sand

Other physical properties of sand from river Asa in North Central Nigeria shown in Table 6 which indicates that sand from river Asa sand had porosity of 51% and Asa sand is slightly above the range recommended value of 35% to 50%, reported by [9].

Table 6. *Other physical properties.*

Sand	Porosity (%)	Permeability (cm/sec)
River Asa sand	51	1.06

3.5. Filtration Tests

The filtration test results are presented in Tables 7 – 8

Table 7. *Head loss development through media with time River Asa Sand (Filtration Rate= 6.45m/hr).*

Depth(cm)/Time(hr)	0	5	15	30	45	60	75	90	105	120
1	0	0.216	0.314	0.461	0.609	0.756	0.903	1.050	1.198	1.345
2	0	0.265	0.461	0.756	1.05	1.345	1.639	1.934	2.228	2.523
3	0	0.314	0.609	1.05	1.492	1.934	2.376	2.817	3.259	3.701
4	0	0.363	0.756	1.345	1.934	2.523	3.112	3.701	4.290	4.879
5	0	0.412	0.903	1.639	2.376	3.112	3.848	4.584	5.320	6.057
6	0	0.461	1.050	1.934	2.817	3.701	4.584	5.468	6.351	7.235
7	0	0.511	1.198	2.228	3.259	4.290	5.320	6.351	7.382	8.413
8	0	0.560	1.345	2.523	3.701	4.879	6.057	7.235	8.413	9.590
9	0	0.609	1.492	2.817	4.143	5.468	6.793	8.118	9.443	10.768
10	0	0.658	1.639	3.112	4.584	6.057	7.529	9.001	10.474	11.946
11	0	0.707	1.787	3.406	5.026	6.646	8.265	9.885	11.505	13.124
12	0	0.756	1.934	3.701	5.468	7.235	9.001	10.768	12.535	14.302
13	0	0.805	2.081	3.995	5.909	7.824	9.738	11.652	13.566	15.481
14	0	0.854	2.228	4.290	6.351	8.413	10.474	12.535	14.597	16.658
15	0	0.903	2.376	4.584	6.793	9.001	11.210	13.419	15.627	17.836
16	0	0.952	2.523	4.879	7.235	9.59	11.946	14.302	16.658	19.014

Table 8. *Head loss development through media with time, River Asa Sand (Filtration rate 9.65m/hr).*

Depth (cm)/Time (hr)	0	5	15	30	45	60	75	90	105	120
1	0	0.245	0.400	0.632	0.865	1.097	1.330	1.562	1.795	2.027
2	0	0.322	0.632	1.097	1.562	2.027	2.492	2.957	3.422	3.887
3	0	0.400	0.865	1.562	2.26	2.957	3.655	4.352	5.050	5.747
4	0	0.477	1.097	2.027	2.957	3.887	4.817	5.747	6.677	7.607
5	0	0.555	1.330	2.492	3.655	4.817	5.980	6.677	8.305	9.467
6	0	0.632	1.562	2.957	4.352	5.747	7.142	8.537	9.932	11.327
7	0	0.710	1.795	3.422	5.05	6.677	8.305	9.932	11.560	13.187
8	0	0.802	2.027	3.887	5.747	7.607	9.467	11.327	13.187	15.047
9	0	0.865	2.260	4.352	6.445	8.537	10.630	12.722	14.815	16.907
10	0	0.942	2.492	4.817	7.142	9.467	11.792	14.117	16.442	18.767
11	0	1.020	2.747	5.282	7.840	10.397	12.955	15.512	18.070	20.627
12	0	1.097	2.957	5.747	8.537	11.327	14.117	16.907	19.697	22.487
13	0	1.175	3.190	6.212	9.235	12.257	15.280	18.302	21.325	24.347

3.6. Filtrate Quality

The filtrate quality results are presented in Table 9 – 10

Table 9. *Filtration turbidity change through media with time, River Asa sand (filtration rate = 6.45 m/hr, inflow turbidity = 32 NTU).*

Depth (cm)/Time (hr)	5	15	30	45	60	75	90	105	120
1	23.50	18.87	15.00	12.03	9.90	8.28	6.89	5.95	5.12
2	22.74	18.28	14.48	11.64	9.54	7.92	6.74	5.83	5.08
3	22.11	17.80	14.13	11.36	9.27	7.76	6.62	5.71	5.06
4	21.50	17.37	13.81	11.12	9.11	7.65	6.50	5.64	5.04
5	20.93	16.93	13.50	10.89	8.95	7.49	6.38	5.59	5.00
6	20.33	16.50	13.18	10.65	8.75	7.37	6.30	5.51	4.98
7	19.62	15.79	12.71	10.37	8.48	7.13	6.14	5.39	4.96
8	19.07	15.39	12.31	10.02	8.28	7.01	6.03	5.31	4.92
9	18.36	14.76	11.88	9.78	8.04	6.82	5.87	5.20	4.88

Depth (cm)/Time (hr)	5	15	30	45	60	75	90	105	120
10	17.72	14.52	11.68	9.54	7.92	6.70	5.83	5.12	4.84
11	17.64	14.56	11.64	9.49	7.84	6.39	5.74	5.04	4.82
12	17.59	14.54	11.59	9.44	7.79	6.34	5.69	4.94	4.80
13	17.54	14.52	11.54	9.39	7.74	6.29	5.62	4.95	4.79
14	18.03	15.05	12.12	9.82	8.16	6.88	5.91	5.18	4.93
15	18.50	15.37	12.32	9.96	8.28	7.00	6.00	5.28	4.67
16	18.99	15.58	12.55	10.12	8.36	7.04	6.07	5.34	4.52

Table 10. *Filtration turbidity change through media with time, River Asa sand (filtration rate = 9.45 m/hr, inflow turbidity = 32 NTU).*

Depth (cm)/Time (hr)	5	15	30	45	60	75	90	105	120
1	23.93	19.46	15.59	12.63	10.49	8.87	7.49	6.72	5.67
2	22.94	18.87	15.08	12.23	10.14	8.59	7.33	6.42	5.59
3	22.47	18.24	14.72	11.95	9.86	8.36	7.21	6.3	5.55
4	21.64	17.96	14.40	11.72	9.54	8.24	7.09	6.22	5.47
5	21.16	17.53	14.05	11.44	9.39	8.04	6.93	6.14	5.39
6	20.49	17.01	13.61	11.24	9.27	7.96	6.82	5.99	5.31
7	19.86	16.34	13.14	10.89	9.07	7.72	6.70	5.87	5.27
8	19.27	15.83	12.78	10.61	8.83	7.57	6.62	5.79	5.23
9	19.69	16.29	13.01	10.67	8.83	7.62	6.64	5.88	4.40
10	20.14	16.78	13.37	10.87	8.95	7.66	6.71	6.00	4.52
11	20.40	16.85	13.40	11.03	9.35	7.98	6.98	6.19	4.67
12	20.86	17.20	13.86	11.12	9.45	8.14	7.03	6.25	4.70
13	20.94	17.55	13.71	11.26	9.49	8.26	7.08	6.33	4.87

4. Discussions

Particle Size Distribution: The effective size and uniformity coefficient of river Asa sand are quite close as indicated by the [4], as shown in Table A (Appendix A), which Asa river sand have the potential to be used as filter media as the values are within the recommended values for filter media [10, 11].

This suggests that the performance of Asa river sand in water treatment will produce results that will be good for filter media. [10, 11], [24] recommended that effective sizes of value greater than 0.75 mm and uniformity coefficient of 1.6 is to be used for river jewo sand in orire local government area of Oyo state. [25] also recommended range of 0.35 – 1.00 for effective sizes and uniformity coefficient of 1.2 – 1.8 for Yola and shelleng sand to be used as filter media. [4] suggested uniformity co-efficient of 1.9 which is differ from the universal Uniformity Co-efficient of 1.3 – 1.8.

Acid Solubility: The low acid solubility results from the acid solubility test carried out from the Asa sand indicate that, the level of hydrogen carbonate or calcium carbonate of the Asa river sand have value slightly above the recommended range value of acid solubility 1 – 2% [11] as show in Table 4. This indicates that Asa River sand have 2.10% slightly above the WHO value but have good filter properties.

Specific Gravity: The specific gravity of individual filter grains is one of several factors important in determining the rate of water flow to achieve a certain bed expansion during backwashing at a given water temperature. It is also one of several factors that determine the rate at which media grains settle after backwashing. In systems where combined air scour and water washing takes place over a weir it determines the size of stilling zone adjacent to the weir necessary to reduce media losses [26].

The average specific gravity for each of the samples is presented in Table 5. The specific gravity of sand from river Asa sand from Kwara has specific gravity of 3.77, which is higher than that of water and is within the recommended value greater than 2.50. The specific gravity parameter is an indication that during backwashing of the filter media, Asa river sand will require more critical fluidization velocity.

Other Physical Properties: The physical properties of river Asa sand fall within the recommended value for sand filter as shown in Table 6 and some properties are slightly above the recommended value. The result presented in Table 6 indicates that river Asa sand have the potential to be used as a filter media due to the values of the porosity, acid solubility, permeability and Uniformity Coefficient that within the recommended values as shown in Appendix B; Table 11. Since porosity is inversely related to sphericity, the river Asa sand may lead to less clogging effect due to regular shape. The porosity and permeability parameters are very important in the choice of a suitable filtering material. This is because if permeability is too high, no meaningful filtration can take place and if too low, the bed gets easily clogged.

Head Loss Development: Filtration rate (hydraulic loading) can influence the performance of a filter bed due to several factors. An increase in volume of flow per unit time gives an increase in weight of the material deposited in the filter pores. The use of higher flow rate produces a greater pressure drop across the clean filters and a greater drop per unit of material deposited, if this is evenly distributed through the filter bed. The change in velocity within the filter bed can alter the removal of the particles and the distribution of deposits in the bed, and hence influence the removal capacity and efficiency.

The shows that an increase in hydraulic loading lead to increase in head loss. It also shows that there is an increase in head loss as well as increase in bed thickness.

At a filtration rate of 6.45 m/hr and run time of 16 hrs, the sand filter media of river Asa sand developed headloss of 19.014 cm, while running the filter for 13 hrs at a rate of 9.65 m/hr, the sand from river Asa sand developed a head loss of 24.347cm as shown in summary Table 12 in Appendix C respectively. [27], recommended head loss of 1.8 m because at head loss of 2 m or more is when floc break through was noticed and [4] also recommended maximum head loss of 2.8 m for Kaduna river.

Filtration Run Time/Quality: The filter run times can be measured either through the attainment of maximum design head loss or by the deterioration of the quality to an unacceptable level as stated by [28]

For the high filtration rates used and for the turbidity loading used, the result obtained for the filter run time are quite significant and very encouraging. 16 hours of operation at a filtration rate of 6.45 m/hr for the river sand with an inflow turbidity loading of 32 NTU. The effluent turbidity is 4.52 NTU for river Asa sand as shown in Table 9 while at 13 hour of operation at a higher rate of 9.65 m/hr, the effluent turbidity were 4.87 NTU as shown in Table 10. These values of sand from river Asa is below the World Health Organization and Nigeria standard of drinking water which is well below the WHO maximum permissible level of 5.00 NTU Filter run times should not be more less than 12 hours and more than 24 hours was recommended by [29] to reduce labour needed to run the plant, also [4] recommended 16 hours at rates of 6.25 m/hr and 22 hours for turbidity load of 10 NTU.

It can be observed that an increase in the hydraulic loading rate resulted to reduction of filter running time. This shows that the hydraulic loading rate is inversely proportional to filter running time.

It can be observed that an increase in hydraulic loading resulted to reduction of filtrate quality. Increase in hydraulic loading increased the rate at which materials were deposited on the filter bed. An increase in filter depth also improved the filtration performance in terms of filtrate quality and output. This suggests that absorption occurs through the filter column in purifying the water.

It was observed that the filtrate quality deteriorated faster at the higher filtration rate of 9.65 m/hr. This is to be expected as increased rate of filtration would cause floc to penetrate the filter at a much faster rate and clog faster, leading to early floc breakthrough into the filtrate.

5. Conclusions and Recommendations

The following conclusion can be drawn from the experimental study:

(a) The porosity, permeability and filterability of the Asa River sand followed the same trend to be used as filter media due to the direct relationship with media sizes (particle size) and density, as established.
(b) A filter depth of 120 cm was found to be adequate for the filtration process.
(c) Sand filter media prepared satisfied specifications relating to physical properties such as appearance/cleanliness, size grading, Specific gravity, Acid solubility, porosity and permeability of filter sand.

In view of the findings and observations in this study and for further research, the following suggestions and recommendations are made:

(a) Acid solubility range of 1-3% be recommended for river sand to be used as filter media
(b) An effective size of 0.45 mm and uniformity coefficient of 1.8 is recommended for the river sand. This will ensure the use of over 65% of the stock samples as filter media. It is therefore recommended that, studies should also be made on the sand size with Uniformity coefficient (U_c) of 1.2 – 1.8
(c) River Asa sand have the potential to be used as filter media in our water treatment plants.

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Appendix

Appendix A

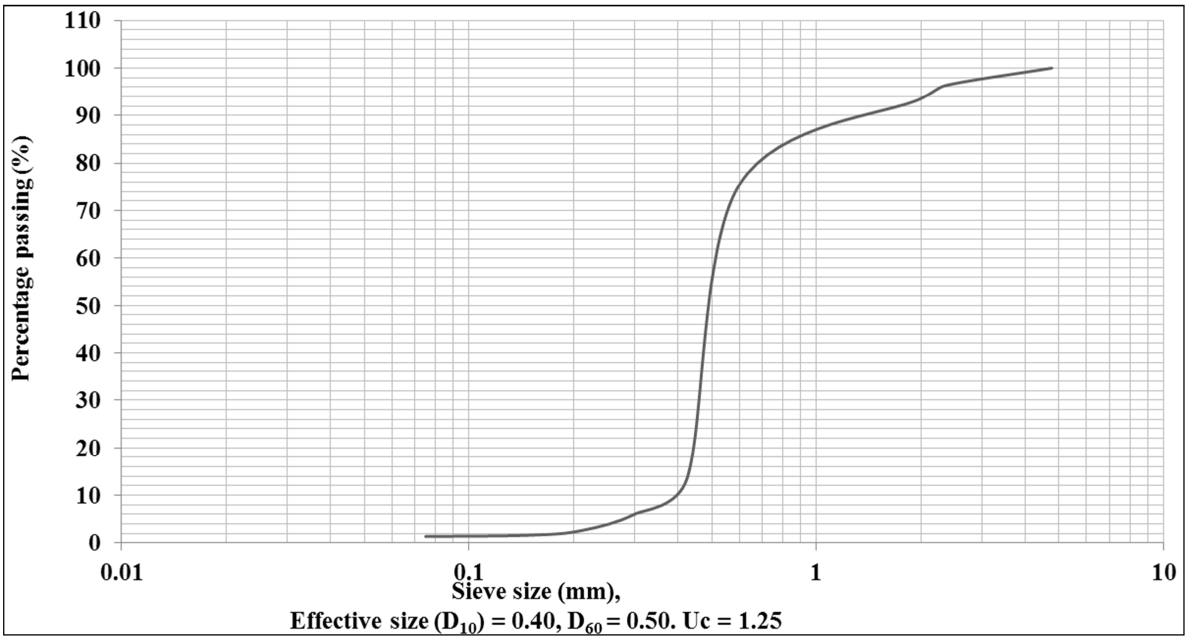

Figure 3. *Particle Size Distribution of River Asa Sand.*

Appendix B

Table 11. *Summary Table, Showing the Physical Properties of Sand Samples.*

River Sands	Effective Sizes (mm)	Uniformity Coefficient (U_c)	Acid Solubility (%)	Specific Gravity	Porosity (%)	Permeability (cm/sec)
River Asa Sand	0.40	1.25	2.10	2.29	51	1.06
Recommended	0.35 -1.00	1.3 - 1.8	< 2	>2.5	35 - 50	$10^{-1} - 10^{-3}$

Appendix C

Table 12. *Summary Table of Filtration Tests (Head Loss Development, (cm))*

River Sands	Rate = 6.45m/hr, Run Time = 16hrs	Rate = 9.65m/hr, Run Time = 13hrs
River Asa Sand	19.014	24.347

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