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Utilization of Agricultural Biomass Materials for Treatment of Minna Underground Water for Human Consumption

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Abstract Minna, capital of Niger State, is a town located in central part of Nigeria which experiences acute water shortage during dry season of every year due to inadequate supply of treated water from State Water Board. This has made many low income citizens of the state to sink shallow wells that they can financially afford to source water for their daily needs. Despite low yields from these wells, the water had been found to be polluted with organic/inorganic matter and micro-organisms that make it unsuitable for human consumption as compared with world Health Organization guidelines on safe drinking water. In order to control the diseases that continuous consumption of this type of infected water might unconsciously been causing to people that drink it, this project developed an affordable water filtration plant using locally available materials that included the ash of biomass of rice husk wasted away after harvest of rice, sand and gravel as filtration media for its treatment. The plant was designed, constructed and test run with water sample sourced from 11 wells located in different parts of Minna. Physico-chemical tests on the treated water samples showed that the compositional characteristics including PH, turbidity, alkalinity, temperature, hardness and chloride ion contents that were above WHO acceptable values before treatment were all modified by treatment plant and brought to within WHO standard for safe drinking water. The micro-organic constituents of raw well water samples got reduced from the heavy presences of enterobacter, aerogen and Escherichia-coli bacteria to concentrations of Nill/70ml to Nill/100ml which was better and safer than or equal to the Nill/100ml recommended by WHO for safe drinking water.

Keywords: *well water, filtration plant, rice husk ash, sand, gravel, WHO safe drinking water*

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1. Introduction

The accessibility of all living things to safe water from any available source is a universally accepted phenomenon for life sustainability of all living species. Water is considered as a most critical natural resource that is desperately needed for survival of creatures as substantial percentage of body mass of all living things is made of moisture. For humans water is needed for drinking, cooking of food, cleaning, growing his food crops, tendering his domesticated animals and other uses in commerce and industry. However, right from prehistoric time safe drinking water has always been unrealizable for large majorities of people especially the rural and sub-urban dwellers in developing countries that don’t have ready accessibility to treated water. This problem coupled with ever growing population and staggering demand for portable water prompted United Nations and World Health Organization to declare provision of portable water for every citizen as one of the key agenda of the Millennium Development Goals (MDG) pronounced before the end of the twentieth century as a developmental strategy to get safe water for all on or before the year 2015 that we have already into.

Despite this universal effort and strategic achievements by many nations of the world, potable water is still not sufficiently available to many people. The shortage has forced a lot of all over the world to still continue to depend on untreated water from any natural source close to their habitats. Although the world we live in consists of over 70% of surface and underground water, most of it has minerals, gases, harmful bacteria/virus, solid/liquid contaminants, industrial wastes, undesired taste and odour. These must be removed or minimized by appropriate treatments to make such natural water suitable for human consumption (Brock T. D., 1991). Undesired organic and inorganic matter constituents of water cause many life threatening diseases like dysentery, cholera, gastroenteritis, typhoid, river blindness e. t. c. Common sources of natural water which those not opportuned to public or privately treated water resort to include rain water (seasonal), underground water (accessed through sunk shallow and deep wells) and surface water (from rivers and streams). Of all these water resources, only that from the seasonal rains does not require conditioning treatment. Nigeria, as a developing nation has its own share of this global portable water non-availability problem.

In Minna, capital of Niger State located in central Nigeria, the general water shortage afflicting the town particularly during dry seasons of the year when average daily temperatures could rise above 40°C and most surface water is dried up; has made people resort to underground and subsurface untreated water from sunk shallow, intermediate and deep wells to alleviate their problems. Low income earners amongst citizens who cannot afford deep sunk wells that produce safe drinking water and packaged water popularly known as pure water to source water from shallow wells; the water of which they can't also financially afford to treat before usage. Moreover state departments responsible for sampling/testing such water for suitability or otherwise for humans and advice users accordingly are not forthcoming with the vital services. Those that use packaged water are still not free of water borne diseases because most packaged water producers in the town source their raw water from these same infested wells and lack appropriate treatment plants to make pure water absolutely safe for humans (Dada, 2009) as regulated by the National Agency for Food and Drug Administration and Control in Nigeria. This makes treatment of well water before its consumption inevitable to avoid disease outbreak (Arbelot A, 1994). The study conducted by Ademoh (2014); a summary of which is presented in Table 1 showed that the shallow wells contain several organic and inorganic compounds originating from decaying organic matters, agricultural runoffs, domestic/industrial wastes, synthetic inorganic materials like detergents, pesticides, herbicides, solvents from use of processed products and other sources. The contaminants are what the study raised as being responsible for well water not complying with requirements spelt out by the World Health Organization on safe drinking water.

Table 1. Result of physico-chemical tests on the raw well water samples by Ademoh (2014)

Water Sample	Turbidity (NUT)	PH	Tem (°C)	Total Alkalinity	Total Hardness (mg/l)	Colour (TCU)	Chloride ion (mg/l)	Bacteria Present
Well A (Central Minna)	10.5	6.6	31.6	230.0	196.0	151	63.9	Enterobacter/Aerogen
Well B (Central Minna)	15.7	6.3	31.5	160.0	176.0	169	45.4	Enterobacter/Aerogen
Well C (Central Minna)	15.8	6.3	31.3	200.0	280.0	119	44.0	Enterobacter/Aerogen
Well D (Central Minna)	23.7	7.5	31.6	100.0	252.0	0ver range	56.8	E.Coli/Enterobacter/Aerogen
Dutse kura well	3.7	7.7	32.0	210	356	32	120.7	Enterobacter/Aerogen
Fadipe well	10.5	7.8	31.8	204	166	3	18.5	Enterobacter /Aerogen
Sauka-kahuta well	4.8	7.1	31.8	228	132	53	42.6	Enterobacter /Aerogen
Maikunkele well	10.9	7.6	31.8	120	300	68	12.8	E.Coli/Enterobacter/Aerogen
FQS well	1.4	7.1	31.7	200	234	1	49.7	E.Coli/Enterobacter/Aerogen
Chanchanga well	26.6	7.0	31.5	142	210	174	17.2	Enterobacter /Aerogen
Tunga-maje well	4.9	6.9	31.8	200.0	384.0	33	213.0	Enterobacter /Aerogen

Table 2. Some selection World Health Organization Guidelines for safe drinking water

Parameters	Permissible Limits (by WHO)
Temperature	30°C
Odour	Unobjectionable/odorless
PH	6.5-8.5
Hardness	500mg/l
Total Dissolved Solids	1500mg/l
Turbidity	5NUT
Conductivity	120YS/cm^3
Chloride Ion	250mg/l
Alkalinity	100mg/l
Colour	15TCU
Appearance	Clear
Bacteriological	
Coliform	Nil/100ml
E.Coli	Nil/100ml

The aim of this work is to develop a cheap plant that uses agro biomass waste filtration materials with a daily capacity to treat well water for a standard family size water need. The main objectives of the work are to adopt result of well water analyses conducted by Ademoh (2014) showing disparities between sampled Minna wells and WHO standard in respect of the biological and chemical balances (Table 2); develop an affordable local treatment plant using agro-based biomass filtration materials; treat water samples from selected wells; analyse the filtered water using standard test methods and to compare results with WHO guidelines for safe drinking water to ascertain its performance efficiency. The significance of the study is that low income citizen of Minna in particular and Nigeria in general would be provided with low cost affordable treatment plant to provide them safe drinking water and reduce incidences of water borne diseases associated with consumption of contaminated well water.

2. Research Materials and Methods

2.1. Materials

The major materials used in construction of the localized filtration plant included the following; agro-biomass from rice husks, granite stone gravel, plastic pvc pipe, polymer mesh, stainless/copper/steel clips, ABRO pvc gum, steel rods, 20L capacity plastic buckets, tiger back nut, gate valve, tiger nut socket,oil paint, 20cm X

20cm angle irons for structural frame work and tiger bushings. The rice husks were sourced from rice farm centres at out skirt of Minna town. Some other vital materials used in this work are as described and presented in the relevant sections.

2.2. Methods

The filtration plant fabrication was preceded by a comprehensive stress analysis to determine the design parameters as follows:

2.2.1. Uses of Water in Domestic Home

By reference to WHO standard the following holds:

Daily per capita waer consumption = 5 ×20 =100L

That is an individual will use 20L in 5 aspects of needs in a day as a member of family home.

Classified main uses of water by a person include drinking, cooking, washing linens, bathing and other sundary uses. Based on these, lets assume 20% for backwashing of filter,10% as waste and 20% for variation/tolerance during filtration process; totaling 50% extra allowance.

Population of people in an average Minna family as an estimated assumed design size = 15 members (consisting a father, two mothers of polygamy, 10 children and 2 dometic servants/extended family members). So in a day, a family home needs 15 people X 100L = 1500L.

2.2.2. Estimation of Water Demand in a Family Home Per 28 Days of a Month

Assuming that water treatment is done and stored once per month for family use, then;

Per month water need = 15 people per family X 100L/day X 28 days a month = 42,000L.

Monthly water considered with 50% allowance for waste, backwash of filter and variation/tolerance: Raw water demand 42, 000L X 1.5 = 63,000L

Assume that the filter works 12hours in a dedicated filtration and a built in redundancy time so that the desired capacity = 63000/12h = 5,250L per period and 12 hours down time for refreshing of filter bed to idle the plant after filtration untill the next month. Also, for purpose of affordability of water storage facility and space requirent problem for large storage tank; provide for water treatment frequency of 12 times in a 28 days month.

Required

$$size\ of\ \ facility\ required = \frac{63000}{12} = \frac{5250 litres}{day}$$

$$cross\ sectional\ area\ of\ the\ pipe$$
$$= \frac{\pi d^2}{4} = \frac{\pi\left(D^2 - d^2\right)}{4}$$
$$= \pi \frac{\left(33^2 - 30^2\right)}{4} = 148.46 mm^2$$

Velocity = discharge/cross sectionl area $= \frac{5250}{148.46}$ = 35.36m/s

Headloss across filter sand during filtration mode (clean filter);

$$\frac{\Delta h}{L} = \frac{K \times \mu}{\rho \times g} \times \frac{(1-\varepsilon)^2}{\varepsilon^3} \times \left(\frac{6}{\varphi \times d}\right)^2 \times \mu \quad (1)$$

where Δh headloss across the bed of filter sand (m)

L= depth of filter sand in the filter = 1.0m

K =dimensionless kozeny constant = 5

μ = dynamic viscosity of water = 0.89 $\times 10^{-3} N_S / m^2$

ρ =density of water = 1000kg/m^3 at 25^{0}C

ε = porosity of sand = 0.455 (sand); 0.42 (gravels)

φ = sphericity of sand = 0.75

d= mean effective size of filter sand

v = maximum filtration rate = 5.0m^3/m^2 filter area per hour; and $\Delta h = 9.62 \times 10^{-12} m$.

Headloss across supporting filter gravel during filtration mode (Ergun equation)

$$\frac{\Delta h}{L} = \frac{4.17 \times \mu}{\rho \times g} \times \frac{(1-\varepsilon)^2}{\varepsilon^3} \times \left(\frac{6}{\varphi \times d}\right)^2 \times \mu + 0.48 \times \frac{(1-\varepsilon)}{\varepsilon^3} \times \left(\frac{6}{\varphi \times d}\right) \times \frac{V^2}{g} \quad (2)$$

$$\Delta h = 0.0833 m$$

Velocity of backwash water across filter (colebrook – white equation)

$$V = {}^{-2}\sqrt{(2gDi)} \log_{10}\left[\frac{K_s}{3.7D} + \frac{2.51\vartheta}{{}^{D}\sqrt{(2gDi)}}\right] \quad (3)$$

Where, v =velocity of flow (m/s)

g = acceleration due to gravity (9.81m/s^2)

D= pipe internal diameter (m)

i = hydraulic gradient (m/m)

K_S = linear measure effective roughness of pipe (m) = 0.5m

ϑ =kinetic viscosity =$1.14 \times 10^{-6} m^2 s^{-1}$.

V = -0.014m/s.

2.3. Design Analysis

2.3.1. Design of Sand Filter Bed

Maximum load on sand filter bed = weight of wet sand + weight of sieve

2.3.2. Design of Rice Husks Filter Bed

Maximum load on rice husk filter bed = weight of wet rice + weight of sieve

Minimum load on filter bed = weight of dry rice husk + weight of sieve

2.3.3. Work Done on Fluid (Water) Flow

Consider the connecting pipe linking filtration tank to storage tank;

Mass flow rate through pipe; m = ρ_1 A1V1 = $\rho_2 A_2 V_2$;

Where $p_{1=}p_2$ = density of fluid

$A_{1,}$ A_2 = Cross- sectional area of sections; $V_{1,}$ V_2 = Velocities of moving fluid

Therefore, velocities of water flowing through the horizontal pipe;

$$V = \frac{m}{\rho_1 A_1} \quad (4)$$

Where; m = mass flow rate.

Rate of flow of fluid through a section of the pipe Q may be determined by

$$Q = AV. \quad (5)$$

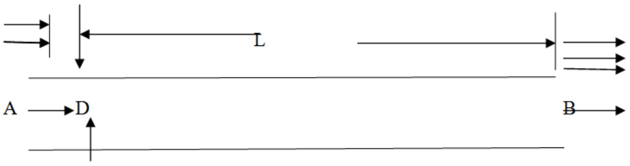


Figure 1. flow through a pipe

Work done in moving liquid from A to B = Force x distance $= P_1 \times A \times L$

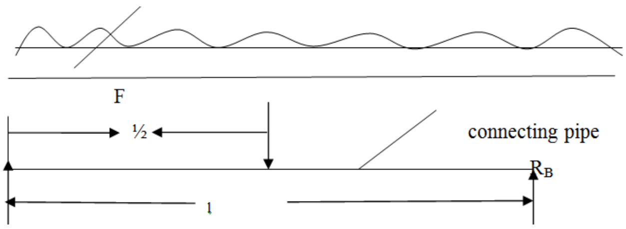
Where, P = Pressure of the fluid; A = cross sectional area of pipe = πr^2; L = length of the pipe

2.3.4. Design of Pipe Diameter

To determine diameter of pipe

Maximum weight of water W_{10} = mg; Where; m = mass of water (kg); g = gravitational acceleration

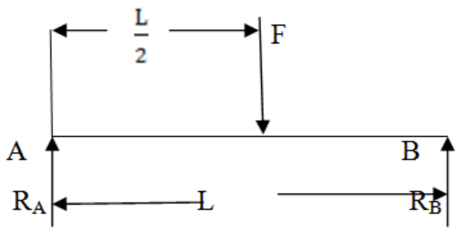
For the pipe, considering the flowing fluid as an evenly distributed load for mass of water;



Force, F exerted on pipe would be acting at mid-span of pipe,

F= weight of water + weight of pipe

$$F = W_W + W_P \quad (6)$$



Taking all vertical forces; $EF_V = 0$

$$F = R_A + R_B$$
$$R_A = F - R_B.$$

Taking moments about support A; $EM_A = 0$

$$R_B \times l = F \times \frac{l}{2}$$
$$F = 2R_B$$
$$R_B = \frac{F}{2}$$

From equation R_A = F- R_B = $2R_B$ - R_B = R_B

But; $R_A = R_B$

Considering bending moment;

$$M = \frac{Fl^2}{2El} \quad (7)$$

Bending stress;

$$\delta = \frac{My}{l} \quad (8)$$

To determine the Pipe diameter, d;

$$d = \left\{ \frac{16 f_s}{\delta} \left[M + \sqrt{M^2 + T^2} \right] \right\} \quad (9)$$

Where; f_s = factor of safety and δ = bending stress

Cross sectional area of pipe A; $A = \pi \frac{d^2}{4}$; $A = \frac{\pi\left(D^2 - d^2\right)}{4} = \pi \frac{\left(33^2 - 30^2\right)}{4} = 148.46mm^2.$

2.3.5. Weight of Water Required to Completely Fill the Pipe

$$Radius\ of\ \ pipe = \frac{D}{2} = \frac{33}{2} = 16.5mm$$
$$V = \pi r^2 l = \pi 16.5^2 \times 615 = 526076.84mm^3$$

Recall that density = mass × volume = 1000kg/m^3× 526076.84 = 526.08 × 10^6 kg/mm^3

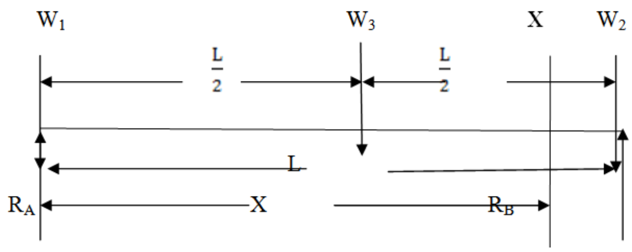
Weight = mg = 526.08 × 10^6 kg/mm^3= 5160.8 × 10^6N.

2.3.6. Total Weight of the Pipe and Water in the Pipe

Where, W_{System} = weight of the system; W_{water} = weight of water; W_{pipe} = weight of pipe

W_{System} = W_{water} + W_{pipe} = 2.5 + 1.2 = 3.7N

2.4. Dsign of the Structural Members



$$R_A + R_B = W_1 + W_2 + W_3; R_A = W_1 + W_2 + W_3 - R_B$$

Using Macaulay's method;

$$EI \frac{d^2 y}{dx^2} = -M \quad (10)$$

In this case,

$$M = R_a x - W_1 x - W_3 \left(x - \frac{l}{2} \right) \quad (11)$$

For slope,

$$EI \frac{dy}{dx} = \frac{R_a x^2}{2} - \frac{W_1 x^2}{2} - \frac{W_3 \left(x - \frac{l}{2} \right)^2}{2} + C_1 \quad (12)$$

Deflection;

$$EIy = \frac{R_a x^3}{6} - \frac{W_1 x^3}{6} - \frac{W_3\left(x-\frac{l}{2}\right)^3}{6} + C_1 x + C_1 \quad (13)$$

$$y = \frac{1}{6EI}\left(R_a x^3 - W_1 x^3 - W_3\left(x-\frac{l}{2}\right)^3 + 6C_1 x + 6C_2\right) \quad (14)$$

2.4.1. Design of Filtration Sieves

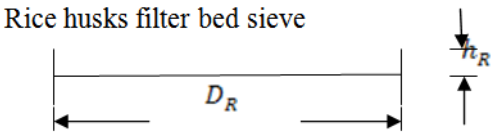


Figure 2. Rice husk filter bed

Where D_R = diameter of the sieve

Surface area of sieve, $A_R = \pi R^2$

Since cross- sectional area of sieve is circular.

$A_R = \pi R^2 = \pi(236)^2 = 174996.83\text{mm}^2$

Volume of rice husk filter bed, $V = \pi R^2 h_R$

Since the sieve can be taken as a small cylinder

V = 174996.83 ✕ 55 = 9624825.65mm^3

2.4.2. Maximum Weight of Rice Husk Expected on the Sieve

Maximun weight = $W_{\text{wet rice husk}}$ + W_{sieve}; Minimum weight = $W_{\text{dry rice husk}}$ + W_{sieve}

Weight of dry rice husks was measured to be = 23.1kg

Weight of wet rice husks was measured to be = 23.43kg

Weight of the rice husk sieve was measuresd to be = 3.55kg

Min weight = $W_{\text{dry rice husks}}$ + W_{sieve} = 23.1 + 3.55 = 26.65kg

Max weight = $W_{\text{wet rice husk}}$ + W_{sieve} = 23.43 + 3.55

M = 26.98kg

Force = mass × acceleration due to gravity; = 26.98 × 9.81 = 264.67N

Moment for rice husks; M = force × perpendicular distance

$$perpendicular\ dis\tan ce = \frac{20}{2};$$

$$and\ moment = 246.67 \times \frac{20}{2} = 2646.74N/mm.$$

2.4.3. Stresses on the Rice Husks Sieve

$$\delta = \frac{My}{l}; y = \frac{2.5}{2} = 1.25;$$

$$I = \frac{bd^3}{12} = 465 \times \frac{2.5^3}{12} = 605.47mm^4$$

$$\delta b = \frac{My}{l} = \frac{2646.74 \times 1.25}{605.47} = 54.64 \times 10^3 N/mm^2$$

a) Rapid sand filter bed

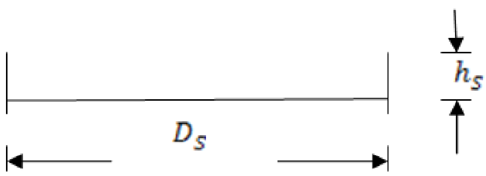


Figure 3. Rapid sand filter bed

Where, D_S = diameter of the sieve

Surface area of sieve, $A_S = \pi S^2$

Since cross- sectional area of sieve is circular; $A_S = \pi S^2 = \pi(211.5)^2$ = 140548.73mm^2

Volume of the rice husk filter bed; $V = \pi S^2 h_S$

Since sieve can be taken as a small cylinder; = 140548.73 × 50 = 7027436.50mm^3.

2.4.4. Maximum Weight of Rapid Sand Expected on the Sieve

Maximun weight = $W_{\text{wet sand}}$ + W_{sieve}; Minimum weight = $W_{\text{dry sand}}$ + W_{sieve}

Weight of the dry rapid sand was measured to be = 21kg

Weight of wet rapid sand was measured to be = 21.55kg

Weight of the rapid sand sieve was measured to be = 3.50kg

Min weight = $W_{\text{dry sand}}$ + W_{sieve} = 21 + 3.50 = 24.50kg

Max weight = $W_{\text{wet sand}}$ + W_{sieve} = 21.55 + 3.50 = 25.05kg

Force = mass × acceleration due to gravity = 25.05 × 9.81 = 245.74N

Moment for rapid sand; m = force × perpendicular distance

$$perpendicular\ dis\tan ce = \frac{20}{2};$$

$$moment = 245.747 \times \frac{20}{2} = 2457.41N/mm.$$

2.4.5. Stresses on the Rapid Sand Filter Bed

$$\delta = \frac{My}{l}; y = \frac{2.5}{2} = 1.25;$$

$$I = \frac{bd^3}{12} = 432 \times \frac{2.5^3}{12} = 562.50mm^4$$

$$\delta s = \frac{My}{l} = \frac{2457.42 \times 1.25}{560.50} = 54.61 \times 10^3 N/mm^2$$

2.5. Design of Filtration Tank and Storage Tank

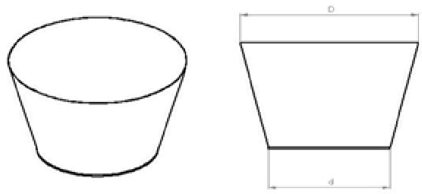


Figure 4. Sketch of the filtration tank

Taking the bucket to be a truncated cone

Volume = $\frac{1}{3}\pi r^2 h$; Where;

$D = upper\ \ diamater\ of\ \ the\ tank$

$d = lower\ diamater\ of\ \ the\ tank$

$H = height\ of\ \ the\ tank.$

2.6. Bill of Materials

The materials used for the construction and the quantities are as presented in Table 3

Table 3. Break down of material and quantities

S/No	Material	Size /quantity
1	Plastic filtration bucket	1 capacity
2	Plastic storage tank	1 capacity
3	Tiger back nut	5
4	Pvc pipe	1
5	ABRO pvc gum	1 quantity
6	Stainless clip	8
7	Steel rod	1
8	$1\times\frac{3}{4}$ tiger bushing	5
9	$\frac{1}{2}\times\frac{3}{4}$ tiger bushing	5
10	$\frac{1}{2}\times$ gate valve	2
11	Tiger nut socket	1
12	Polymer(mesh)	11yards
13	Miscellenous	

2.7. Treatment of Filter Materials

2.7.1. Rice Husk as Biomass Filter Material

Some carefully selected agro-waste from rice husk was collected from a known rice farm in centres close to Maikun-kele out skirts of Minna town. The husks were sorted out to clean off the leaves from the needed stalks. The rice stalk biomass was washed to remove all soil contaminants that came along with husk. Cleaned and washed stalks were then thoroughly sun dried to rid it of almost all moisture content. The dried husk was then subjected to controlled and supervised burning in clay pot to convert it to ash. The ash was classified to remove un-burnt stalks and charcoal and stored until needed.

2.7.2. Filtration Gravel and Sand Classification

Sharp stone gravels were required to be used as the filter bed. The granite gravel was purchased from a building materials dealer in Minna. Gravel was classified with vibrated sieve categorized in accordance with BS standard to obtain the different aggregate sizes needed as A, B, C and D standard grain sizes and then stored separately. The sharp sand for filtration bed was classified with the vibrated sieve and required grain sizes were separated, collected and stored waiting when needed for use.

2.8. Fabrication of the Plant

The fabrication was carried out in the central workshop of the department of mechanical engineering Federal University of Technology, Minna using tools that included: welding machine, meter rule, Vernier calliper, scriber and weighing balance. Welding machine was used to join members of the filtration stand together. Meter rule was used to measure linear distances. Vernier caliper was used to measure inner and outer diameters of the pipe; while the scriber was used to mark lines on in metal work pieces. Weighing balance was used to determine the weight or mass of filter media used.

2.8.1. Methods/Operations

Localized heating was done on predetermined sections of the filtration plant and the storage to make cutting holes into sections easier. The holes permitted PVC pipe to pass through to storage tank from the filtration plant, entering of raw water from source, backwash drain inlet and air vent outlet. Hacksaw was used to cut PVC pipes into required sections and a larger hacksaw was used to cut rod for water tank stand. Rivets were used for permanent and temporary fastenings on filter bed and in making filtration mesh sieve. Drilling was done to create round hole into the work part. Boring was then done to enlarge and finish holes accurately. Threaded fastener inserted and screwed into material to hold fabricated part together. Filter bed was assembled by use of screws to join the metallic parts to mesh sieve. Adhesive bonding (ABRO gum) was used to provide a permanent bond between the PVC pipes and the tanks together. Electrical arc welding was used to weld members of steel rods to form structural stand.

2.8.2. Fabricated Components

The parts fabricated from the processes above included: the steel stand, filter bed (mesh), plastic filtration plant, plastic storage tank. The PVC pipes, $\frac{1}{2}\times$ tiger nipple, PVC gum, $\frac{3}{4}\times$, $\frac{1}{2}$ tiger bushings, $\frac{1}{2}$ brass tap, gate valves, $1\times\frac{3}{4}$ tiger bush, plastic buckets (50L capacity each), back nuts, stainless clip and gate valves were purchased from equipment vendors.

2.8.3. Assembly of the Plastic Filtration Plant and Storage Tank

The fabrication/assembly was done using materials that included plastic bucket 100litres, PVC pipe, stainless copper steel clips, mesh, plastic bucket 50L and PVC gum. Polymer plastic buckets of 100L and 50L were heated to their plastic state and bored round to diameter 33mm and 30mm using hacksaw. Heat was applied to the bucket to bore four round holes that bring water into the filtration tank, back-wash the plant, connection link to the storage tank, outlet to give off dissolved and gaseous composition (air vent outlet). Back nuts were screwed into PVC pipe and gate valve was placed in between pipe to regulate water flow by PVC gum. The gum was applied round pipe at entrance point of pipe into the filtration tank and storage tank to avoid leakage. Tiger nipple to reduce pipe diameter was attached opposite to pipe inlet from filtration tank to storage tank. A pipe and brass tap were coupled together to the tiger nut as tap for water collection for use. Inside filtration tank are two filter beds constructed by cutting aluminum to size and bending to desired shape to hold mesh by screwing mesh to aluminum to hold them tight. The aluminum plate for rice husks was dimensioned as 461 × 57mm and mesh was rolled into five yards for efficiency. Aluminium plate for sand was dimensioned as 135 × 75mm and mesh was rolled into six yards. Plates were paint coated to prevent corrosion. Beds were held up by four stainless copper steel clips for a filter bed and alternate to each other to prevent bending/deformation.

2.8.4. Filtration Plant Stand Assembly

A steel rod of 615mm was cut and stretched and then reduced to 612mm height to make support members for the filtration tank. Steel rod of 340mm was made circular by welding it to both ends to support the lower diameter of filtration plant. A steel rod of 325mm to serve as a connecting rod was used as support members and welded to both ends of the lower filtration plant stand. The height of storage tank measured as 303mm and support member, 315mm. Three connecting rods of 860mmm were constructed to connect filtration plant with storage tank welded to both ends. Steel rods of 312mm were welded as supports to the storage tank. The total length of the stand measured as 1555mm from filtration plant to the end of storage tank.

2.8.5. Description of the Plant

The filtration plant consists of filtration tank and a storage tank. The filtration tank has three filter beds, rice husk, rapid sand and sharp gravel. The first layer of filter bed was made with rice husk as it has capacity of removing tiny particles in water, works on bacteria contents like E-coli and conditions the physical parameters like colour and turbidity. The water flows to the rapid sand bed for further purification and then to the gravel. The gravels trap micro particles that were able to pass through the filter beds and get water purified. The purified water is then passed to the storage tank and kept as treated water that is safe for human consumption. Appropriate dosage of chlorine or other of disinfectant could then be added to the water in the storage tank to take care of bacteria that survived the filtration process up to this terminal point.

2.9. Testing of the Developed Water Treatment Plant

The entire water filtration plant having being successfully assembled was test run for evaluation and optimization to treat water; sample of which was analyzed to ascertain efficiency of plant. Raw water from each well sample characterized by Ademoh (2014) was fed through it by gravity through the receiver. Alum was added to the raw well water to aid sedimentation before filtration through the plant. As the water was passed through the sharp gravel beds, the larger particulate contaminants and coagulants were removed. From here further filtration took place in the rapid sand media that trapped smaller contaminants that escaped from the gravel beds. The water then drips through the rice husk ash media, at where its turbidity got reduced due to presence of potash in ash as usual with biomass ashes. Unwanted iron and Escherichia-coli bacterial contaminants were also removed. Filtered water then flowed to the storage tank for collection and use. The overall filtrate was clean sparkling water that can be chlorinated to disinfect it of traces of harmful micro-organism that was possibly present. Physico-chemical and biological analysis were conducted on the treated un-chlorinated water sample to determine its portability.

2.10. Filtered Water Compositional Analysis

Samples of the filtered water were taken to water quality laboratories of Niger State water Board, Chemistry and Chemical engineering Departments of the Federal University of Technology, Minna, Nigeria for comprehensive quality analysis. The same methods of tests adopted byAdemoh (2014) were used for the physic-chemical, bacteriological analyses, presumptive and confirmatory tests of the specimens to ascertain purity of the treated water as compared with WHO guidelines.

3. Results and Discussion

Engineering drawings developed for fabricating the plant are as presented in Figure 5-Figure 8. Figure 5 presents the orthographic plan and front view showing necessary dimensions; Figure 6 shows vertical sectional view; Figure 7 shows the assembly drawings and Figure 8 shows isometric view of the plant.

Engineering drawings of the filtration plant presented without the external water storage facility is very handy and can easily be accommodated within the family compounds of users. It can be situated close to well from where raw water is fetched. The plant can be made mobile by introducing wheeled rollers for manual movement from place to place. Treated water can be piped directly to an external overhead, surface or underground storage facility. Result of filter sand sieve analysis is as in Table 4. Required filter bed sand of appropriate size range was selected and administered on the plant.

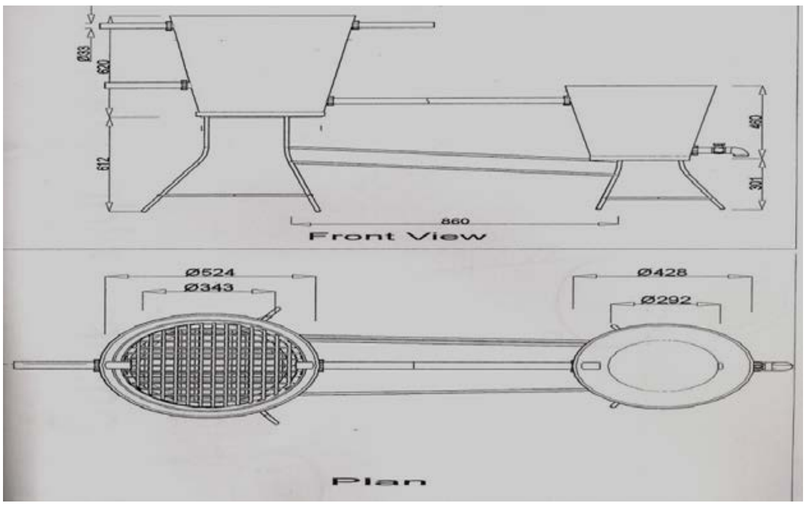


Figure 5. Orthographic plan and front views of the filtration plant

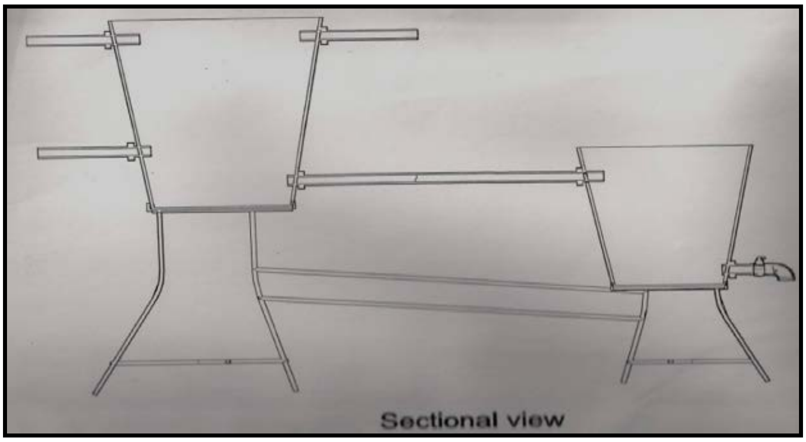


Figure 6. Sectional view of the filtration plant

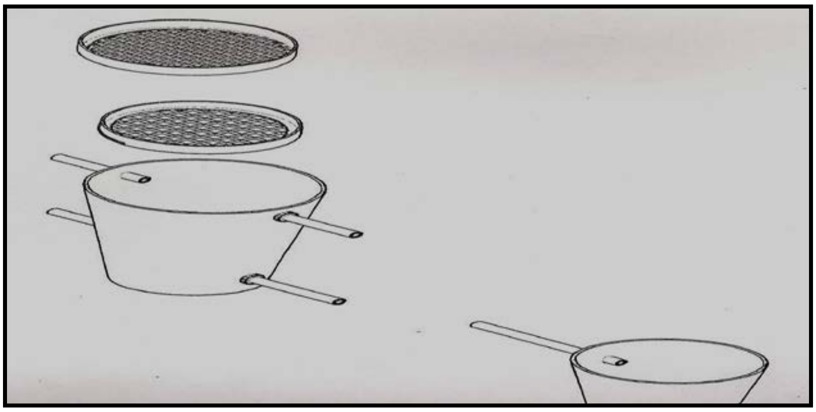


Figure 7. Assembly drawing showing the arrangement of filter elements of the plant

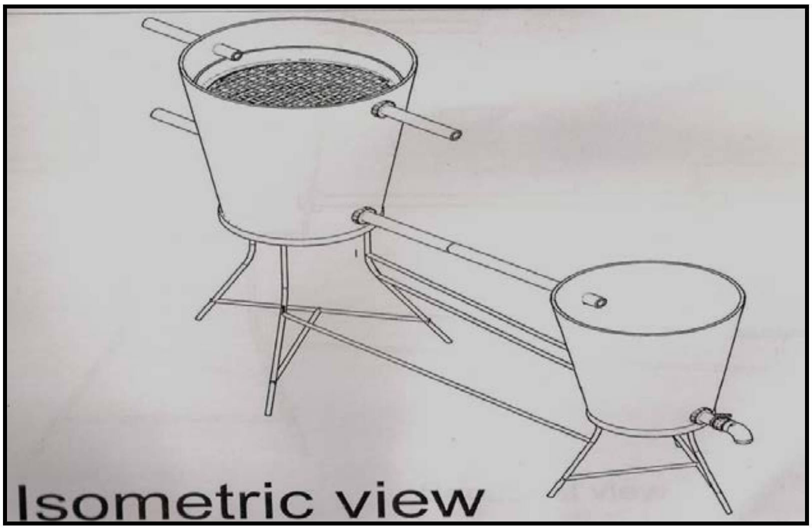


Figure 8. Isometric view of the filtration plant

Table 4. Filter Sand Sieve Analysis

Sieve size(mm)	Weight retained (Kg)	% Retained	% Passing
2.8 mm	2	0.1	99.9
2.36 mm	2	0.1	99.8
2.0 mm	32	2.2	97.6
1.70 mm	79	5.4	92.2
1.40 mm	222	15.1	77.1
1.18 mm	286	19.5	57.6
1.0 mm	563	38.4	19.2
0.858mic	222	15.1	4.1
0.710mic	23	1.6	2.5
0.600mic	22	1.5	1.0
Passing 0.600mic	15	1.0	-
TOTAL	1468	100.0	

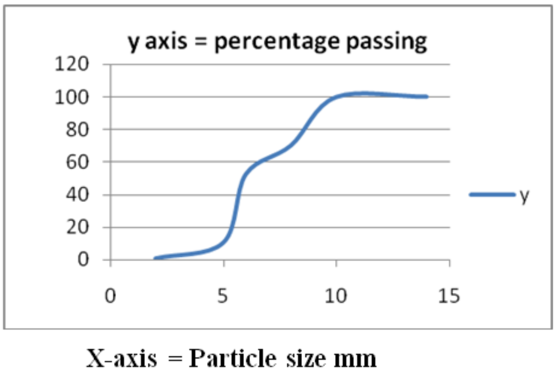
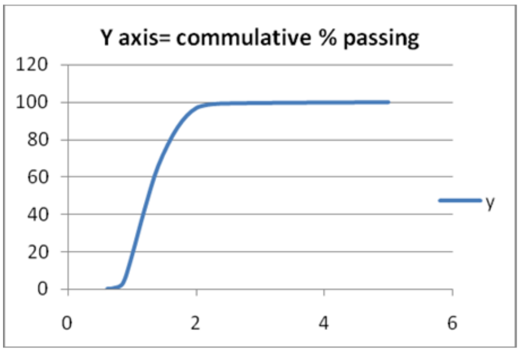


Figure 9. Specification for filter gravel 6-10 mm sieve analysis graph

Figure 9-Figure 13 presents the geotechnical test results for the sand and gravel grain size classification.

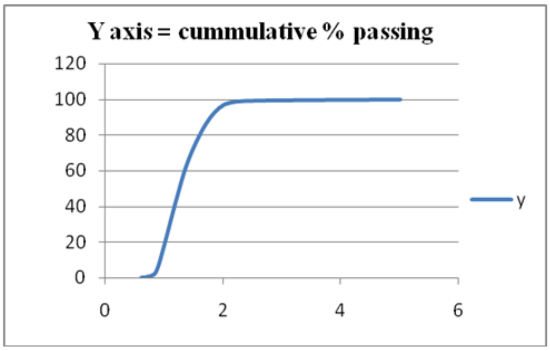
The result when compared with that used by Niger State Water Board was confirmed to agree with standard sharp sand used for water filtration. Sand grains retained by sieve size 1.18mm-0.710micron was used to enable sand properly trap minute contaminants and still allow sufficient water flow rate.



Effective Size D10 =0.92mm
D30 = 1.20mm
D60 = 1.40mm
Coefficient Of Uniformity = 1.52

X-axis = Particle size (mm)

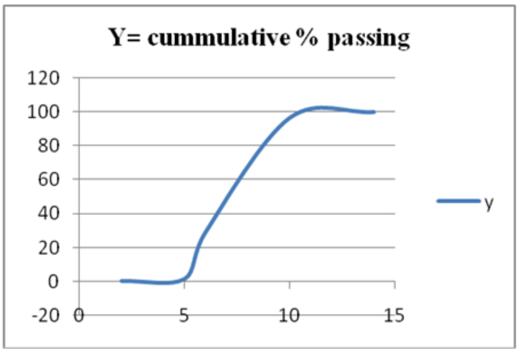
Figure 10. Particle size distribution of filter sand sample A



Effective Size (D10) = 0.91mm
D30 =1.20mm
D60 =1.40mm
Coefficient Of Uniformity = 1.54

X-axis = Particle size (mm)

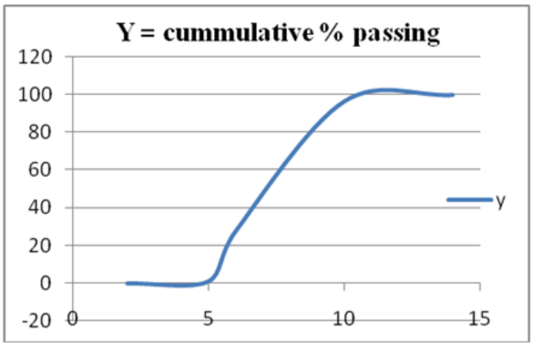
Figure 11. Particle size distribution of filter sand sample B



Effective Size (D10) =5.8mm
D30 =6.0mm
D60 =7.50mm
Coefficient Of Uniformity = 1.29

X-axis = Particle size (mm)

Figure 12. Particle size distribution of filter gravel sample C



Effective Size (D10) = 5.5mm
D30 =6.0mm
D60 =7.50mm
Coefficient Of Uniformity = 1.36

X-axis = Particle size (mm)

Figure 13. Particle size distribution of filter gravel sample D

Figures 9-Figure 13 present the sieve analysis of the filter sand and the granite gravels used for constructing the filter bed of the treatment plants. Four grades of gravel designated as A, B, C and D were used; each had a table of analysis showing the aggregate sand/gravel size with its coefficient of uniformity.

The result showed that coefficient of uniformity of sand/gravel used were 1.52, 1.54, 1.29 and 1.36 for sand gravel grades A, B, C and D respectively. By water filtration bed standard, classes A and B are referred to as fine sharp sands that trapped the minute particulate contaminants while classes C and d are gravels that trapped the higher size particle contaminants. The layered placement of these graded sand enabled decontamination of water flowing by gravity as it meanders and drips through the pores created at irregular patterns in filtration bed.

Table 5. Result of physico-chemical and biological analysis after running the filtration plant

Water Sample	Turbidity (NUT)	PH	Temp. (°C)	Total Alkalinity	Total Hardness (mg/l)	Colour (TCU)	Chloride ion (mg/l)	Bacteria Present
Well A (Central Minna)	5.1	6.3	30.2	99.9	188.0	13	102.4	Coliform-Nill/90ml
Well B (Central Minna)	5.3	6.1	30.5	102.0	157.0	11	144.5	Coliform- Nill/70ml
Well C (Central Minna)	5.0	6.2	30.3	99.5	198.0	15	98.7	Coliform-Nill/80ml
Well D (Central Minna)	5.2	6.8	31.0	93.1	210.0	12	102.2	Coliform-Nill/100ml
Dutse kura well	1.1	6.7	31.0	92.0	247.0	4	175.4	Coliform-Nill/70ml
Fadipe well	4.0	7.0	30.9	99.7	104.0	2	75.9	Coliform-Nill/70ml
Sauka-kahuta well	2.3	6.5	30.7	103.4	100	8	83.4	Coliform-Nill/80ml
Maikunkele well	4.2	6.6	31.1	95.5	210	13	80.5	Coliform-Nill/70ml
FQS well	0.8	6.3	31.0	99.2	198.0	1	160.3	Coliform-Nill/70ml
Chanchanga well	7.6	6.5	30.7	97.4	143.0	14	88.5	Coliform-Nill/100ml
Tunga-maje well	2.5	6.2	30.6	98.9	248.0	7	247.0	Coliform-Nill/100ml

After filtration plant treatment of sample from each of the wells the result of the analysis presented in Table 5 showed that in comparison with analysis on the raw water, all the characteristics analysed got substantially improved. The data in Table 4 when compared with World Health Organization (WHO) standard in Table 1 showed that out of the 11 wells, only samples taken from Chanchanga well had turbidity (7.6NUT) that was clearly above WHO standard of 5.0 NUT. Dutse kura well (3.7NUT), Sauka-kahuta well (4.8NUT), FQS well (1.4NUT) and Tunga-maje well (with 4.9NUT) that satisfied the requirements before treatment further improved in quality to better values of turbidity. Wells A, B and D in central Minna had values marginally above WHO standard that could be tolerated. PH of treated well water generally got reduced because of the neutralizing nature of potash contained in rice husk ash that formed the bottom layer of filter bed that released acidic siliceous and potassium oxides. PH fell to the range 6.1-7.0 after treatment whereas WHO species 6.5-8.5.

There were slight reductions in water temperatures after treatment though most samples were still marginally above 30°C of WHO. This is acceptable considering the nearness of Minna to the tropical Capricorn and the regular high daily temperature throughout the year. Before treatment, it was only water from Well D in Minna central that satisfied total alkalinity of 100mg/l of WHO. The treatment conditioned all the samples except sauka-Kahuta and well B in Minna central that had slightly higher alkalinity. The maximum water hardness of 500mg/l of WHO was satisfied by 11 well water samples tested before filtration treatment. After treatment water hardness reduced with the highest being 247 and 248 for Dutse kura and Tunga-maje wells respectively. These were still below 50% of WHO maximum. Only Fadipe and FQS wells met 15TCU colour specification of WHO before treatment. After treatment all the sample improved in colour quality to be in compliance with WHO guidelines on drinking water showing reasonable reduction in water colouration contaminants like organic and inorganic pollutants. This actually confirmed the safe status of water samples due drastic reductions in the health threatening constituents which Arbelot (1994) advised must be minimized to tolerable levels before water is declared safe for human consumption. Even if a well was not sunk to sufficient depth to prevent product of human and organic activities on earth surface from water contaminations adequately articulated treatment can purify and make suitable it for drinking. Chloride ion content of samples before and after the treatment was below 250mg/l of the WHO guidelines. However increases were observed generally in chloride concentration after water treatment as a result of dosing with chemical during processing for disinfection. The levels are acceptable and even make water safer from bacterial infestation. The bacteriological analyses on samples after treatment presented with Table 5 showed that concentration of microorganisms consisting enterobacter, aerogen and Escherichia-coli in raw water samples were reduced to below and at parity with Nill/100ml recommended by WHO; thereby further confirming water as safe for drinking without risk of water borne disease infections.

4. Conclusion

This work developed through the system design, fabrication, testing, evaluation and optimization of well water filtration treatment plant for low income class of Minna, Nigeria who find it financially very difficult to source underground water from deep boreholes that directly yield drinkable water. The plant was fabricated completely from locally available materials to make it affordable to the category of people for whom it was developed. The filtration plant was tested and found capable of purifying contaminated raw well water to the level of acceptability of the World Health Organization standard for potable water. Chlorine chemical dosing of the filtered water was done during testing to ensure that traces of microorganisms not removed by the process was biologically taken care of for assured purity. The design was made robust to facilitate easy operation and maintenance by both skilled and unskilled users.

Acknowledgement

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