Grey Water Reuse for Irrigation

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Abstract

Although, there are various reuses of grey water but this study is limited to one type of reuse- irrigation. The objective of this project is to design and construct a filter for grey water reuse for irrigation of not less than one hundred (100) household. To achieve this objective, samples were collected from one hundred households within the University of Nigeria, Nsukka campus and its environs. Laboratory tests were conducted on these samples and they revealed the presence of BOD, TSS, nitrate, PH, Coliform etc, whose values varies when compared with that of the parameters for standard irrigation water. This gave me insight to the kind of treatment and filtration medium that would be required. From the results obtained a slow sand filter bed for not more than one hundred households was designed and constructed. It is hoped that this project would be of great help to developing countries of the world most especially, countries affected by drought, to ameliorate their water resources need.

Keywords: Grey water, irrigation water, sand filter, household and drought.

Introduction

1.1 Back Ground of Study

Wastewater generally is made of black water and gray water. Grey water, sometimes spelled gray water, grey water or grey water and also known as **sullage**, is non-industrial wastewater generated from domestic processes such as washing dishes, laundry and bathing. Grey water comprises 50-80% of residential wastewater. Grey water is distinct from black water in the amount and composition of its chemical and biological contaminants (from feces or toxic chemicals).

Grey water gets its name from its cloudy appearance and from its status as being neither fresh (white water from ground water or portable water) nor heavily polluted (black water). Essentially, any water, other than toilet wastes, draining from a household is grey water. Although this used water may contain grease, food particles, hair, and any number of other impurities, it may still be suitable for reuse. Reusing grey water serves two purposes: it reduces the amount of freshwater needed to supply a household, and reduces the amount of waste water entering sewer or septic systems, (Agunwamba, 2001).

Grey water is a domestic waste water that is collected from dwelling units, commercial building and institutions of the community. It may include process wastewater of industry (food, laundries etc) as well as ground infiltration and miscellaneous waste liquids. It is primarily spent water from building water supply to which have been added to the waste effluent of bathrooms, kitchens and laundry (Crook, 1991).

Domestic wastewater is the spent water from the kitchen, bathrooms and laundry. Many of the minerals and organic matters in the water serve as food for saprophytic micro-organisms and hence the wastewater is unstable biodegrable. (Fair, Geyer and Okun, 1971).

Reduction of relative dependence on portable water usage is becoming a necessary facet of good water management. Many new or modified treatment processes are being investigated in an attempt to solve the serious water supply and waste water disposal problems of the growing population and its industries. Even with the application of the water reducing scheme, a large amount of water is still required and eventually, reuse of water may have to be practice. Therefore, several possible re-use of water schemes such as distillation and membrane techniques for complete reuse and biological oxidation, filtration and disinfection schemes for partial reuse have been considered (Crook, 1991).

1.2 Problems

There has not being any record of illness caused by grey water to man. Grey water skyrockets in value during drought emergency and anywhere that other water sources are not available especially for irrigation. (www.oasisdesign.net) but due to the particles found in grey water as well as its chemical and biological properties it may be suggested that grey water could contain some properties which could cause dilapidation to plant growth and, or the soil. It was suggested that grey water from kitchen sink and dish washer should not be reused as these can contain heavy loads of organic materials, fats and caustic additives in high concentrations that are not readily broken down by soil organisms (Estrey and Morgan, 1991) Soaps and detergents are components in grey water which could adversely affect plants the most. (www.sahra.arizona.edu). Relating to these facts, we decided to test for it's properties(physical, chemical and biological) and then purify it to meet up to the standard for irrigation.

1.3 Objectives of Study

Grey water as it is today in Nigeria, is either allowed to flow either in open streets channels (gutter) or through sewers connected to soak away tanks. The objective of this study is

(1) To determine the quantity of water used and the amount of grey water generated by one hundred house holds.
(2) To determine the characteristics of the grey water
(3) To design and construct a filter for gray water to meet up to the standard of the characteristics of irrigation water.

1.4 Scope of Study

The fact remains that grey water can be used for many purposes but this project anchored it's base on its reuse for irrigation; and samples were collected from 100 house holds which comprised of: male hostels, female hostels, junior staff quarters, senior staff quarters, campus and the houses of both the high and low income earners in Nsukka metropolis.

2.1 Characteristics of Grey Water

Analysis of water and wastewater is aimed at determination of the level of impurity and the type of treatment units required for effective purification before intended use. The analysis involves determining the physical, chemical and biological characteristics of water and waste water. (Agunwamba, 2000)

Fresh domestic wastewaters have little odour, are grey and contain dissolved oxygen, their solids retain most of their original bulk. They are generally about 99.9% of water with the remaining 0.1% comprising various solids in dissolved or suspended form and fluctuate with size of family, family habits, farm family versus suburban family and a multitude of other reasons. Different types of waste materials are discharged into a variety of plumbing fixtures that are used at different times of the day and week. The duration of use and the amount and brand of materials used will affect the characteristics and quantity of wastewater. The characteristics of household wastewater change according to the type and amount of food and water intake (Agbogu *et al*, 2005).

Table 2.1:The general characterization of grey water is shown below:

Parameters	Ranges of value mg/l	Average value mg/l
BOD5	22.1 – 358.8	128.9
TSS	8 – 200	53.O
NITRATE	0.8 – 17.5	1.5
PH	5.3 – 10.8	7.0
COLIFORM	0 - 500 – 10,000Cu/100ml	500Cu/100ml

Source: (Kreissl, 1994)

2.2 Standard Characteristics for Irrigation Water

Laboratory determinations and calculations are needed to use the guidelines given in Table 2.2 along with the symbols.

Table 2.2: Laboratory Determinations Needed To Evaluate Common Irrigation Water Quality Problems

Water parameter	**Symbol**	**Unit**[1]	**Usual range in irrigation water**	
SALINITY				
Salt Content				
Electrical Conductivity	EC_w	dS/m	0 – 3	dS/m
(or)				
Total suspended Solids	TSS	mg/l	0 – 2000	mg/l
Cations and Anions				
Calcium	Ca^{++}	me/l	0 – 20	me/l
Magnesium	Mg^{++}	me/l	0 – 5	me/l
Sodium	Na^{+}	me/l	0 – 40	me/l
Carbonate	CO^{--}_3	me/l	0 – 10	me/l
Bicarbonate	HCO_3^-	me/l	0 – 20	me/l
Chloride	Cl^-	me/l	0 – 30	me/l
Sulphate	SO_4^{--}	me/l	0 – 20	me/l
NUTRIENTS[2]				
Nitrate-Nitrogen	NO_3-N	mg/l	0 – 10	mg/l
Ammonium-Nitrogen	NH_4-N	mg/l	0 – 5	mg/l
Phosphate-Phosphorus	PO_4-P	mg/l	0 – 2	mg/l
Potassium	K^+	mg/l	0 – 2	mg/l
MISCELLANEOUS				
Boron	B	mg/l	0 – 2	mg/l
Acid/Basicity	Ph	1–14	6.0 – 8.5	
Sodium Adsorption Ratio[3]	SAR	(me/l)[1], [2]	0 – 15	
Coliform		Cu/100ml	0 – 5000	Cu/100ml

Source: ALPHA, 1996

1. ds/m = decisiemen/metre in S.I. units (equivalent to 1 mmho/cm = 1 millimmho/centi-metre)

   mg/l = milligram per litre ≃ parts per million (ppm).
   me/l = milliequivalent per litre (mg/l ÷ equivalent weight = me/l); in SI units, 1 me/l= 1 millimol/litre adjusted for electron charge.

2. NO_3 -N means the laboratory will analyse for NO_3 but will report the NO_3 in terms of chemically equivalent nitrogen. Similarly, for NH_4-N, the laboratory will analyse for NH_4 but report in terms of chemically equivalent elemental nitrogen. The total nitrogen available to the plant will be the sum of the equivalent elemental nitrogen.The same reporting method is used for phosphorus.

3. SAR is calculated from the Na, Ca and Mg reported in me/l

2.3 Generation of Grey Water

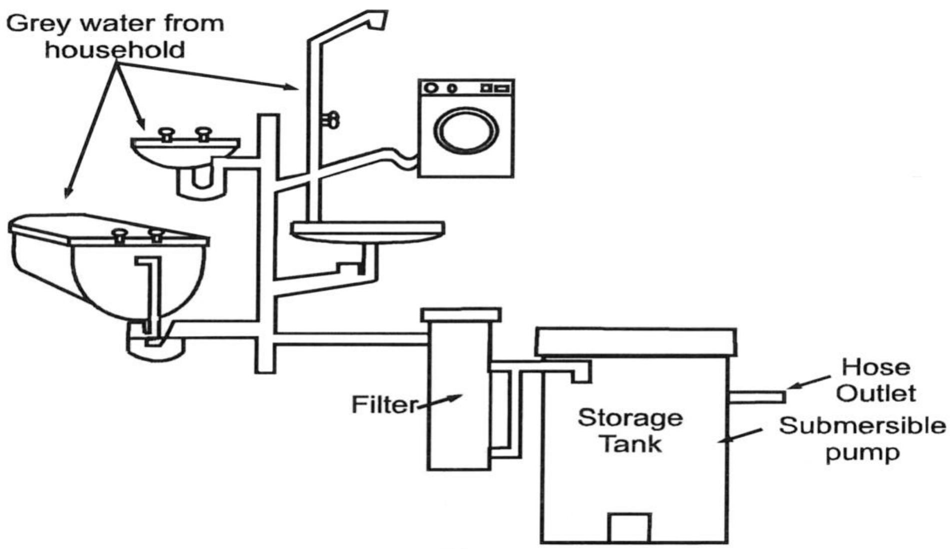

Fig 2.1 Diagrammatic representation of household grey water generation

Fig 2.1 above shows the various sources from which grey water is generated. Grey water also known as **sullage**, is non-industrial wastewater generated from domestic processes such as dish washing, laundry and bathing. Grey water comprises 50-80% of residential wastewater (Amoah *et al*, 2003).

2.4 Various Filter for Grey Water

Filters for gray water are generally of three types- rapid sand, slow sand and membrane filters (Ernest: 1960). Filtration removes microorganism and suspended matter from water not receiving sedimentation treatment or it illuminate percolated particles flocs remaining after sedimentation. (Bill: 1995). As the wastewater flows through the filter adsorption occurs and most of the organic material removed by contact with the coating. The organisms decompose organic nitrogen compound and destroy carbohydrates. (Meritt: 1986).

Filtration plays a very important role in grey water treatment. A filter usually consists of a layer of sand or crushed coal supported on a bed of gravel. The sand used in the filters must be hard and resistant to chemical attack and free from dirt such as clay or dust. The sand could be coarse (0.4-2.0mm), medium (0.3-1.8) or fine (0.25-1.50mm).

Fine sand is used when:

1. The level of pretreatment is poor.
2. High bacteria and turbidity removal efficiency is desired.
3. Saving of wash water is not an important factor.

The coarse sand is used when;

1. The level of treatment is good.
2. Water to be treated is not highly polluted.
3. Small amount of wash water is possible.

There are mainly pressure and gravity filters. The gravity filters are grouped into slow and rapid sand filter.

2.4.1 Slow Sand Filter

Slow sand filter are widely used in water treatment, especially in the UK. Twenty percent of drinking water in the UK and 80% of that in London are still treated by slow sand filtration. Oxidized or oxidizing iron and manganese and about 30% of the natural color in water are effectively removed by slow sand filter. They can also achieve 99.99% removal of cryptosporidium and more than 90% removal of total coli form bacteria in water (Agunwamba: 2000).

A slow sand filter is usually a reinforced concrete box consisting of the following components:

a. Raw water inlet valve
b. Valve for drainage of supernatant water layer
c. Valve for bed filling the filter bed with clean water
d. Valve for drainage of filter bed and outlet chamber
f. Valve of regulation of the filtration rate
g. Valve for delivery of treated water
h. Valve for delivery of treated water to the clear-water reservoir
i. Outlet weir
h. Calibrated flow indicator

A **slow sand filter** removes the tiniest particles from water - even smaller than the gap between the very fine grains of sand in the filter. A slow and constant flow of water through the filter to **biological activity** as the top layer of sand traps micro-organisms (e.g. bacteria and viruses). These micro-organisms digest disease-causing **pathogens** when they too get trapped in the sand. In time a bio-film builds up on top of the sand through which few pathogens can cross (www.sciencedirect.com).

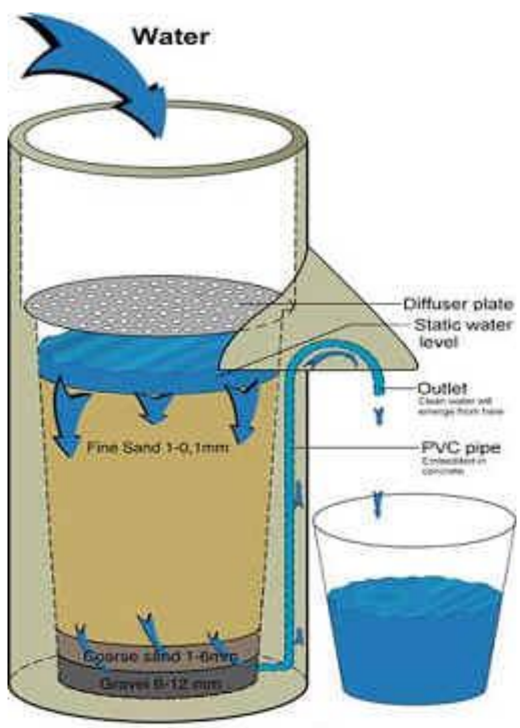

Figure 2.3 Slow sand filter
Source: Agunwamba (2000)

For a **slow sand filter** to work, the flow of water through it must be pretty much constant. A few hours without grey water and biological activity can cease as the biological layer become stagnant. Cleaning a slow sand filter is usually achieved by simple scraping off the top few centimetres of sand from the container.

However, there are three zones of purification that occurs in the bed: surface coating (schumzdecke), autotrophic zone and heterotrophic zone. During the first two weeks of operation of a new filter, the upper layer of sand grain, become coated with iron, manganese, aluminum and silica. The coating being positively charged absorbs anions in solution and organic matter existing in colloidal state. After two to three weeks, the uppermost layer of the sand contain a concentration of inorganic salt, mainly phosphates .In the presence of light these phosphates enhance the growth of algae. Consequently, there is the formation of thin film of algae, bacteria and protozoa on the surface of sand. As the water flows finely divided suspended material, plankton and other organic matter are deposited. The thin film is called schmutzdecke and it act as an extremely fine straining mat.

Below the film is an autotrophic zone. The growing plant breaks down organic matter and decomposes plankton. Available nutrient and carbon dioxide are utilized while oxygen is released.

Another zone, the heterotrophic zone, exists below the autotrophic zone, extending some 300mm into the bed. In this zone bacteria multiply in great number. The bacteria break down the organic matter and later destroy themselves. After several weeks or months the filter skin gets clogged. The filter is cleaned by scraping off top few centimeters of the filter bed including the filter skin. (Agunwamba, 2000).

3.1 Sources of Sample

In order to ensure that an effective and qualitative characteristics of grey water from one hundred (100) household within and outside the community of the university of Nigeria, Nsukka campus, the area was divided into zones and samples collected from each of the zones. The zones are the senior staff quarters (zone 1), Junior Staff quarters (zone 2), male hostels (zone 3) and female hostels (zone 4) within the school community and the high class (zone 5) and low class (zone 6) income earners outside the school community. The samples collected from each household were ensured contained wastewater from dish watching, water used for washing food items, bathing and laundry.

3.2 Sample Collection

Samples were collected with the aid of sixteen (16) 2.0 litres rubber containers from each zone to ensure enough volume that were conveniently transported to and effectively handled in the laboratory for initial analysis. The sample that was passed through the filter bed was collected with the aid of 25 litres plastic container knowing well that the filter bed container which is made of a circular plastic material whose capacities is 40 litres; while still accurately obtaining a representative sample of the initial sample for the final analysis and for this reason, care was taken to obtain a thorough representation of the existing conditions.

As grey water varies in both magnitude of flow and strength throughout the day, samples were collected in the morning and worked upon within twenty four hours of collection to ensure a balance composition. All samples were labelled as soon as collection was done showing date and time of collection as well as the zone. Private transport (okada) was used in conveying the samples to the laboratory for analysis in the morning.

3.3 Construction of the Filter for Greywater

The filter is made of a circular plastic container whose capacity is 40 litres, the depth of the container is 65cm and the diameter is 45cm. A circular hole was constructed at the base to which $3^1/_4$ in thread socket with bushing can be fitted into which serve as the opening through which influent goes into the filter bed through a plastic hoist of length 1.6m and diameter 3cm. Another opening was constructed at 50cm from the bottom circumference of the base opening but at the reverse position with same $3^1/_4$ in thread socket with bushing as the float pipe or spillway which served as the opening through which effluent comes out the filter bed.

The filter media was made of two medium which are fine and coarse gravel and with both filling the entire 50cm. The bed started with the coarse gravel occupying 15cm of the depth in the ranges from coarse particles (0.4mm – 2.0mm) to fine sand(0.25mm – 1.50mm) occupying 35cm of the depth of the filter as specified for slow sand filter.

3.4 Experimental Set Up

Total Suspended Solid (TSS)

1. Filter papers were cut to fit into the diameter of the funnel of the vacuum filter apparatus already set up.
2. The filter papers were then placed inside clean beakers, labelled to match each samples and placed in the oven.
3. The filter paper and the beaker were then weighed with an electrical weighing machine. And then placed the filter paper inside the funnel
4. 30ml of each sample were measured with a measuring cylinder and poured into the funnel gently after the initial wetting of the filter while the vacuum pump switched on.
5. After the filter was then placed back inside the corresponding labelled beaker and replaced back in the oven to dry
6. After drying the final weight of the beaker and the filter and the sample were taken in order to get the weight of the sample.

CHLORIDE (Cl^-)

1. 100ml of the sample was measured with a measuring cylinder into a 250ml conical flask.
2. 1ml of potassium chromate indicator was then added.
3. 0.0141N of silver nitrate solution was then titrated into the sample
4. The end point gotten was pinkish yellow.

ALKALINITY

1. 50ml of the sample was measured into a 250ml conical flask using a measuring cylinder.
2. 2 or 3 drops of phenolphthalein was added into the sample.
3. When pink colour appeared, concentrated H_2SO_4 of 0.02 normality was titrated into the sample and the volume recorded as endpoint turns to orange.
4. 2 or 3 drops of methyl orange was added and then finally titrated with the concentrated H_2SO_4 of 0.02 normality and the volume recorded as the endpoint is reached.

MAGNESSIUM (Mg^+)

1. 100ml of sample was pipette into a 250ml conical flask.
2. 0.2g of erichrome black tea (BT) was added.
3. The sample was then titrated with 0.1 morality of EDTA
4. The volume used was recorded as the endpoint turns to red sky blue.

CALCIUM (Ca^{2+})

1. 50ml of sample was pipette into 250ml conical flask.
2. 2ml of 1 normality of sodium hydroxide was added to the sample
3. 0.4g of murexzide indicator was then added
4. 0.01 morality of EDTA was titrated with the sample to endpoint purple and the volume recorded.

SULPHATE (SO_4)

1. 100ml of sample was measured with a measuring cylinder into 250ml conical flask.
2. 5ml of condition reagent was pipette into sample and stirred thoroughly.
3. Barium chloride about 1g was added and stirred for about one minute at a constant speed
4. The solution was taken to the spectrophotometer and measured the transmittance and the absorbance with turbidimeter with the wave length of 420.

NITRATE (NO_3)

1. 5ml of sample was measured into a beaker and placed in oven for 24hrs.
2. 2ml of di-sulphuric acid was added into the sample and rub with a stirring rod thoroughly.
3. 20ml of distilled water was then added.
4. The sample was then placed in fumes cupboard for sometimes while adding 7ml of ammonia solution and stirred.
5. The beaker was then emptied into a 50ml of volumetric flask and filled up to the brim with distilled water to make up.
6. Taken to the spectrophotometer to measure the transmittance and absorbance after the wavelength has being set to 410

COLIFORM

1. After the preparation of the mackonky broth 10ml of double strength was pipette into test tubes and 5ml of single strength pipette into test tubes.
2. A Durham tube was then placed inverted in each of the tubes.
3. Each tube covered with cotton wool and placed in the auto clave at 120^{o}c for 15 minutes.
4. After it has cooled inoculation of sample was done on each test tube with the 1ml for the double strength and 0.1ml for single strength test tubes.
5. All the test tube arranged in racks and then placed in water bath for 48hrs and then taken readings.

PHOSPHATE (PO_3)

1. 5ml of sample was pipette and dilute to 50ml if turbid using distilled water into 250ml conical flask.
2. A drop of phenolphthalein indicator was added into the sample in the conical flask.
3. Whenever red colour appears, put a drop of strong acid solution to discharge the colour.
4. 15ml of potassium per sulphate or 0.4g ammonium per sulphate was then added to the sample in the conical flask.
5. The sample was then auto clave for 30 minutes at 120^{o}c.
6. After cooling, the sample was neutralized to faint pink colour with sodium hydroxide of 1.0 normality.
7. The sample was then transferred to 100ml volumetric flasks and 4ml molybdate reagent and 0.5ml stainous chloride reagent and mixed thoroughly.
8. The sample was allowed to develop colour and then taken to the spectrophotometer whose wave length was set to 690.
9. The transmittance and absorbance value was measured.

BIOLOGICAL OXYGEN DEMAND (BOD)

1. The preparation of dilution water by the adding of $cacl_2$(BOD), ferric chloride solution, magnesium sulphate(BOD) and buffer solution (BOD) to distilled water and then aerated with the vacuum pump for about 1 hour was done.
2. 3ml of sample was pipette into each BOD bottle of two set of A and B filled to the brim with dilution water.
3. Set B of the BOD bottle with sample was placed in the incubator for five days.
4. Set A of the BOD bottle with sample was pipette with 2ml of alkali-iodide azide and manganese sulphate each. After coagulation which took place in the process has settled down, the top of effluent was tip off.
5. 2ml of concentrated H_2SO_4 was added to the BOD bottle of set A and the colour changed to deep yellow.
6. 0.025 normality of sodium theosulphate was titrated into the BOD bottle of set A to pale yellow colour.
7. The volume of titrate used was then recorded and starch added and colour turns to deep blue and finally titrate to colourless and the final volume recorded.

3.5 Parameters

* BIOCHEMICAL OXYGEN DEMAND (BOD)

This is the amount of oxygen required by bacteria to stabilize decomposable organic matter under aerobic conditions. It is used to determine the relative oxygen requirement of wastewaters, effluents and polluted waters.

* TOTAL SUSPENDED SOLIDS (TSS)

This is called the non filterable residue which is obtained by filtering wastewater through a filter paper and measuring the dry weight of the material left on the filter. This is used to determine the turbidity efficiency treatment in wastewater.

* COLIFORM

Coliforms are organisms comprises of all the aerobic, anaerobic, facultative, gram-negative, non-spore forming rod shaped bacteria which ferment lactose with gas formation within 48 hours at 35^{o}c.

* NITRATE (NO_3)

  This is among one of the major nutrients in wastewater which stimulate plant growth.

* PHOSPHATE (PO_3)

  This is among one of the major nutrients in wastewater which stimulate plant growth.

* SULPHATE (SO_4)

This plays a measure role in the formation of hydrogen sulphide that gives corrosion of concrete and possible gastrointestinal irritation.

* ALKALINITY (BICARBONATE AND CARBONATE)

The alkalinity presence in a solution is its acid neutralizing capacity or the amount of acid required to lower the pH to 4.3. The alkalinity is principally due to salts of weak acids or strong bases.

* MAGNESSIUM (Mg^+)

This produces salty taste in water in combination with other chemical such as chloride etc. Equally, it contributes to the hardness, scale formation and gastrointestinal irritation.

* POTASSIUM (K^+)

This produces salty taste in water in combination with other chemical such as chloride etc.

* SODIUM (Na^+)

This produces salty taste in water in combination with other chemicals such as chloride etc.

* CHLORIDE (Cl^-)

This produces salty taste in water which varies with the quantities of sodium ions, magnesium ion.

* CALCIUM (Ca^{2+})

This produces hardness, scale formation and salty taste in wastewater in combination with other chemical.

* PH VALUES

This measures the intensity acidity or alkalinity of wastewater.

3.6 Laboratory Analysis

In the course of carrying out these experiments, it was found that the grey water samples from the sites visited do not contain some of the parameters as required in grey water requirement for irrigation. The grey water samples do not have magnesium and calcium presence but do have phosphate, sulphate, nitrate, potassium, sodium, PH values, alkalinity, suspended solids, BOD and coliform.

Each of the containers labelled (1-16) were collected samples from zones (1-6) and were tested for all parameters one after the other by measuring out the desired quantities, adding the necessary reagent and titrating as required in the experimental analysis for each of the parameters already discussed above.

3.6.1 Filterdesign

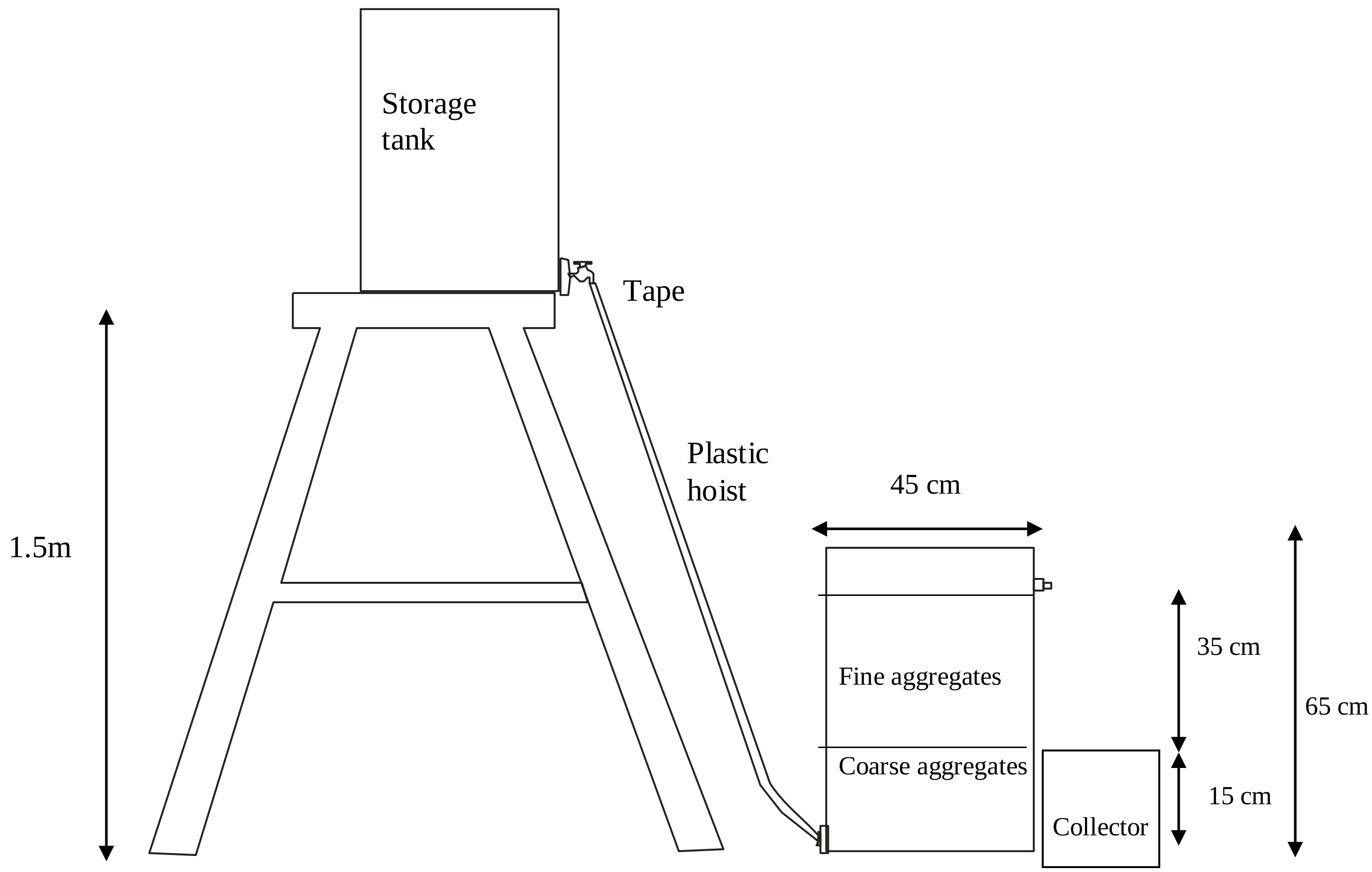

Figure 3.1: filtration set up

The grey water was screened to remove larger particles before allowed into a tank which served as skimming tank where oil was removed by the principle of floatation and finally allowed to pass through the filter unit where the bulk of the pollutants were removed.

The set up shown in figure 3.1 above represents the model of the filter, the already skimmed grey water was poured into the storage tank of height 50cm and a tap attached 2cm from it base. The flow is varied at a slow rate with the tap through the plastic hoist into the filter bed in order to avoid boiling. Initially, the time taken for the grey water to flow through the media of depth 50cm was three (3) hours. This interval was accounted for the fact that all the materials of the filter media were oven dried when placed in the filter bed and hence had to absorb water up to saturation point before allowing the flow of water through them. Eventually, a constant discharge (Q) through the medium was gotten as 0.5litre/min.

The flow rate (V) in litre/m/m^2 was obtained as follows:

Inner diameter of filter unit Di = 0.45m

Surface area (A) $= \frac{\pi D^2}{4} = \frac{3.142 \times 0.45^2}{4} = 0.159m^2$

But discharge (Q) =0.5litre/min = 0.0005m^3/min = 0.030m^3/hr = AV

The Velocity (V) $= \frac{0.030}{0.159} = 0.189$m/hr

Neglecting minor losses,

The head loss,

$H = h + \frac{4flv2}{2gD}$ (Rajput, 2004)

Where,
H= Head loss
h= difference in height = 1.35
l= Length of plastic hoist = 1.6m
f= coefficient of friction = 0.01
A= area of hoist = $\frac{\pi D^2}{4}$ = 7.07x10-4m2
Q= 0.030m3/hr
V= velocity through hoist = Q/A = 0.012m/sec
By substitution, head loss => H= 1.35m

In designing the filter for the one hundred (100) household, the following were done.

The average population per household used as designed population was taken to be 13 with allowances for house help, those in boy's quarters and visitors. The average discharge of grey water in litre per capita per day as gotten from the table as shown above was 79 LPCD but a design discharged value of 85 LPCD was used to take care of loss due to leakage and other unforeseen losses giving the total discharge of 85x13 = 1105litre/day per a household, actual slow sand filter for the one hundred (100) household unit:
Discharge through the filter bed = 100x1105 = 110500l/day = 110.5m^3/d
= 4.60m^3/hr
Filtration through the filter bed = 0.189m/hr

The required area of bed = $\frac{4.60}{0.189}$ = 24.34m^2

The area for a single unit = 12.17m^2
Length/Width ratio = (2 – 4): 1, (Van Dijk and Oomen, 1982)
Let Length/Width = 3 => Length = 3W
Assuming a rectangular bed area,
Area = length x width = 3WxW
$3W^2 = 12.17 \Rightarrow W = \left(\frac{12.17}{3}\right)^{1/2} = 2.014m$
Length of bed = 3x2.014 = 6.042m
Since the filter bed will be working for 24hr per day, the entire discharged into the filter by day is 110.5m^3/day

Therefore volume = depth x Area = 110.5m^3
Depth = $\frac{Volume}{Area} = \frac{110.5}{12.17}$ = 9.08m
The provided dimension of the filter bed = LxWxD = 6.042mx2.014mx9.08m

3.7 Statistical Analysis

In the course of this project, it was discovered that there are three basic sources through which grey water was generated; they are the kitchen, during laundry and bathing. The quantity of water supplied and the quantity of grey water generated from each zones for each days of the week were gotten orally and tabulated in litre per capita per day (LPCD) are shown in table 3.1 – 3.6.

Table 3.1: Rate of water consumption and grey water generation senior Staff quarters

ZONE	SENIOR STAFF QUARTERS, UNN				
DAYS OF THE WEEK	WATER SUPPLIED (LPCD)	KITCHEN GRAYWATER (LPCD)	LAUNDARY GRAYWATER (LPCD)	BATHING GRAYWATER (LPCD)	TOTAL GRAY WATER GENERATED
SUN	140	40	50	30	120
MON	110	30	25	30	85
TUE	120	30	30	30	90
WED	110	30	33	32	95
THUR	100	25	30	30	85
FRI	130	30	40	32	102
SAT	150	35	60	30	125
Average	123				100.29

Table 3.2: Rate of water consumption and grey water generation from Junior staff Quarters.

ZONE	JUNIOR STAFF QUARTERS UNN				
DAYS OF THE WEEK	WATER SUPPLIED (LPCD)	KITCHEN WATER (LPCD)	LAUNDARY WATER (LPCD)	BATHING WATER (LPCD)	TOTAL GRAY WATER GENERATED
SUN	120	25	35	30	90
MON	98	20	20	30	70
TUE	100	25	25	30	80
WED	120	24	30	30	84
THUR	100	20	30	30	80
FRI	110	25	35	30	90
SAT	120	25	40	30	95
Average	110				84.14

Table 3.3: Rate of water consumption and grey water generation from male hostels, UNN.

ZONE	MALE HOSTELS UNN				
DAYS OF THE WEEK	WATER SUPPLIED (LPCD)	KITCHEN WATER (LPCD)	LAUNDARY WATER (LPCD)	BATHING WATER (LPCD)	TOTAL GRAY WATER GENERATED
DAYS OF THE WEEK	WATER SUPPLIED (LPCD)	KITCHEN WATER (LPCD)	LAUNDARY WATER (LPCD)	BATHING WATER (LPCD)	TOTAL GRAY WATER GENERATED
SUN	80	8	20	20	48
MON	75	6	15	20	41
TUE	60	8	17	20	45
WED	70	6	18	22	46
THUR	75	8	15	22	45
FRI	80	9	20	22	51
SAT	100	10	40	25	75
Average	77				50.14

Table 3.4: Rate of water consumption and grey water generation from female hostels, UNN

ZONE	FEMALE HOSTELS				
DAYS OF THE WEEK	WATER SUPPLIED (LPCD)	KITCHEN WATER (LPCD)	LAUNDARY WATER (LPCD)	BATHING WATER (LPCD)	TOTAL GRAY WATER GENERATED
SUN	100	15	40	30	85
MON	95	10	20	30	60
TUE	98	13	22	28	63
WED	100	15	30	30	75
THUR	98	14	22	30	66
FRI	100	15	28	30	73
SAT	120	15	40	32	87
Average	102				72.71

Table 3.5: Rate of water consumption and grey water generation from High income earners.

ZONE	HIGH INCOME EARNERS, OUTSIDE UNN				
DAYS OF THE WEEK	WATER SUPPLIED (LPCD)	KITCHEN WATER (LPCD)	LAUNDARY WATER (LPCD)	BATHING WATER (LPCD)	TOTAL GRAY WATER GENERATED
SUN	150	35	50	30	125
MON	120	22	30	30	82
TUE	125	25	30	30	85
WED	128	28	35	30	93
THUR	120	20	30	30	80
FRI	130	32	40	30	102
SAT	155	40	60	30	130
Average	133				99.57

Table 3.6: Rate of water consumption and grey water generation from Low income earners

ZONE	LOW INCOME EARNER, OUTSIDE UNN				
DAYS OF THE WEEK	WATER SUPPLIED (LPCD)	KITCHEN WATER (LPCD)	LAUNDARY WATER (LPCD)	BATHING WATER (LPCD)	TOTAL GRAY WATER GENERATED
SUN	110	20	30	25	75
MON	95	15	15	20	50
TUE	98	18	20	20	58
WED	97	20	28	20	68
THUR	95	18	20	20	58
FRI	100	22	30	22	74
SAT	120	25	35	25	85
Average	103				66.86

To determine the average value of grey water generation is by using

$$\frac{\sum X}{n}$$

Where

n = total number of zone

X = average value of grey water generation from each zone

=>

The overall average grey water generation for the entire zones

$$= \frac{100.29+84.14+50.14+72.71+99.57+66.86}{6} = 78.95 \text{ lpcd}$$

Approximately = 79lpcd.

The accuracy of our filtered effluent parameter from the standard parameter for irrigation water is tested using biasness and precision of our data. Biasness measures systematic errors. This can be removed by careful checks on experimental techniques and equipments. Precision has to do with the scatter between repeated measurements. This scattered is caused by random errors. This random error can be minimize by making repeated measurements and averaging them. If biasness is zero, and the precision value is small, the accuracy of the experimental result is good (APHA, 1995).

Biasness = X – n

Where,

X= average value of parameter

n = standard value of parameter for irrigation standard.

Precision = Standard deviation (SD) = $\frac{(\sum(x-x)^2)}{N-1}$ when N<30

X= value of parameter

N= number of zones

N-1= degree of freedom.

From table 3.7, it was discovered that the biasness values are all negative (i.e. not greater than one (1)). This implies that experiment is accurate.

From table 3.8, it was also observed that the precision values are high this account for random error.

4.0 Results and Discussions

4.1 Data Presentation

The samples obtained from each zones were analyzed in duplicate. The results of the analysis of the unfiltered grey water from the households of each zone (senior staff quarters, junior staff quarters, male hostels, female hostels, high income earners and low income earners) were analysed. The average of each unfiltered parameter from the zones is shown in table 4.1 while that of the filtered parameter is shown in table 4.2 respectively.

Bar charts (fig 4.1-4.11) show the variations of each parameter between the unfiltered and filtered grey water qualities and standard irrigation water quality. Table 3.1-3.6 show the daily variation of water supply and grey water generation for the six zones under study.

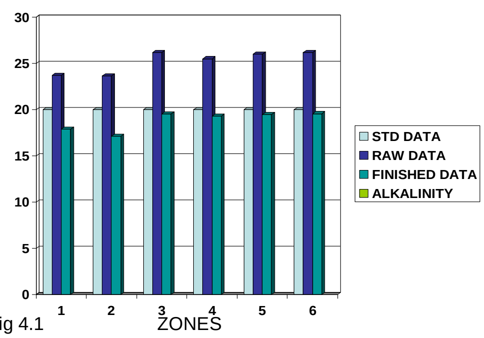

Fig 4.1

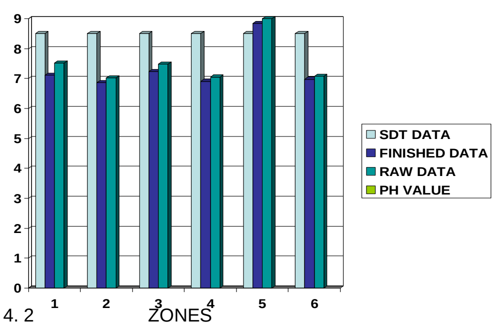

Fig 4. 2

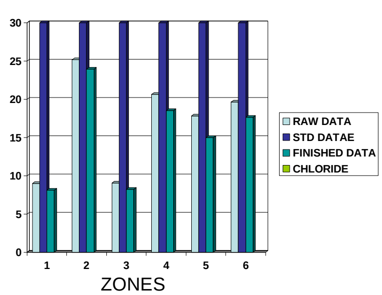

Fig 4.3

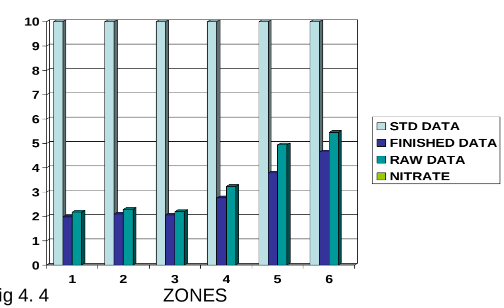

Fig 4. 4

BAR CHARTS RELATING PARAMETERS FOR STD, RAW AND FINISHED DATA AT THE VARIOUS ZONES

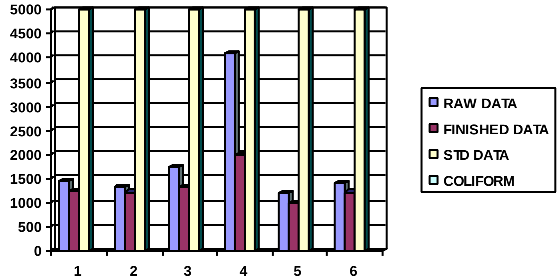

Fig 4.5 ZONES

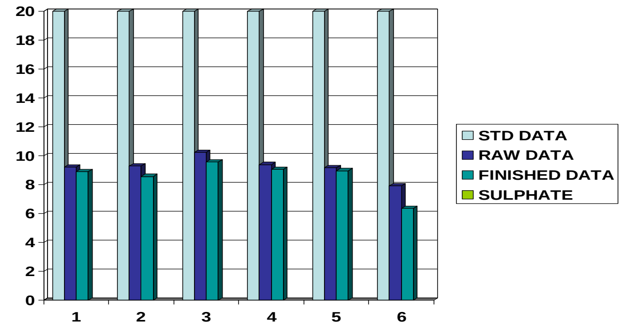

Fig 4.6 ZONES

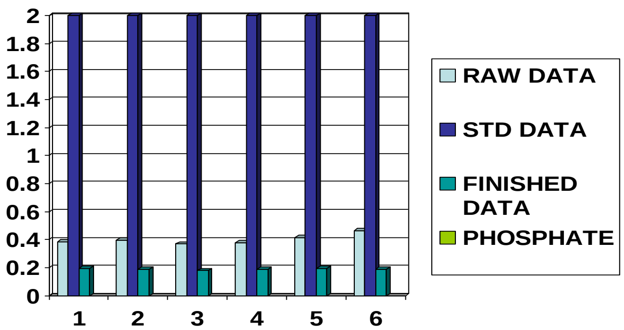

Fig 4.7 ZONES

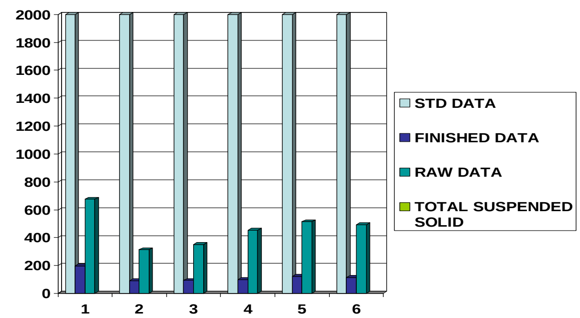

Fig 4.8 ZONES

BAR CHARTS RELATING PARAMETERS FOR STD, RAW AND FINISHED DATA AT THE VARIOUS ZONES

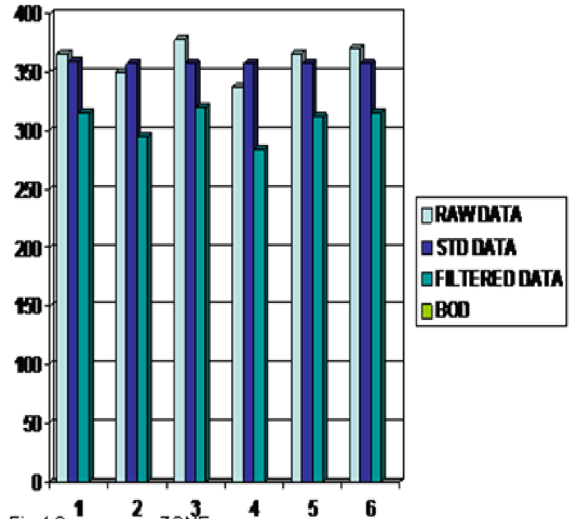

Fig 4.9

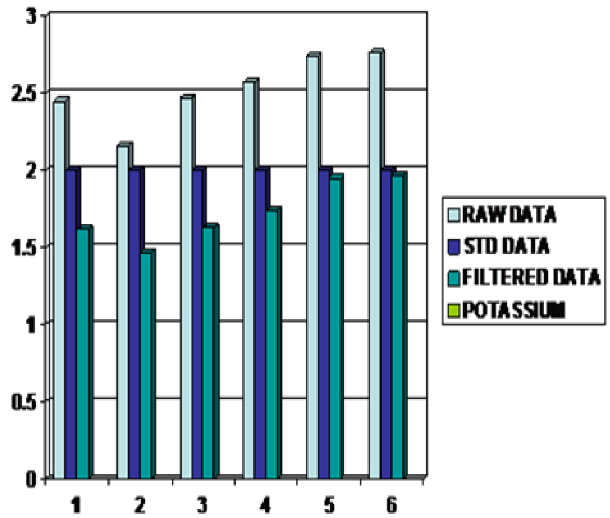

Fig 4.10

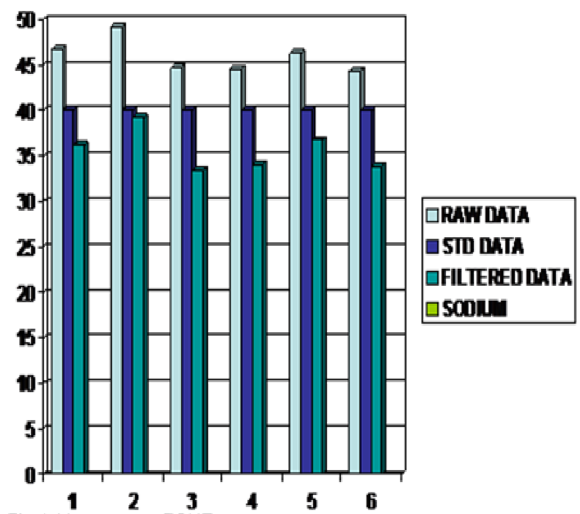

Fig 4.11

BAR CHAT RELATING PARAMETERS FOR STD, FILTERED AND RAW DATA AT THE VARIOUS ZONES

4.2 Quality of Grey Water

Analysis carried out on the unfiltered effluent as shown in table 4.1 shows the absence of some of the parameters stated in the standard for irrigation water such as magnesium and calcium after several trials. The presence of phosphorus and nitrogen in grey water is useful, as they are major nutrients for plant growth, found in grey water.

The presence of alkalinity is on the high side in male, female and low income earners, as compared to junior and senior staff quarters. This may be attributed to the kind of laundry powders and soaps they use. The chloride content was very high and obviously due to the general use of common salts (sodium chloride) in food preparation. Coliform is so much on the high side and this is attributed to the bacteria growth due to food particle found in kitchen water, and in bathing and laundry water due the oil used in soap making. It is very obvious that the total suspended solids obtained should be high due to the activities in which individuals in these zones engage themselves in, such as recreation, occupation etc.

4.3 Performance of Filter

Comparing table 4.1 and table 4.2, it was found that there was a significant reduction in the strength of the grey water and hence the quality of each parameters in the filtration process.

The efficiency of the filter in the reduction of all the parameters was high due to their tangible nature which enable them to succumb surface forces of the filter media; among which are the van dar waals forces that binds the particles to the surface even though, they may bear the same electrical charge as the filter grains. For this reason, even for highly turbid grey water, the filtrate was so clear, that the bottom of the containing vessel can be seen (i.e. high reduction of turbidity). The relatively large surface area of the filter media or the interface in contact with the water and its impurities are also contributing factors.

5.0 Conclusion and Recommendation

Aggregates generally are good filters. It is therefore required to have relatively large depth and surface area of aggregate (comprising of both fine and coarse, most especially the fine aggregate) for effective filter.

However, it is becoming increasingly obvious that this might prove to be a major method of conservation of portable water for irrigation use in the future most especially in areas where drought is evident.

In addition the results' obtained by this method of grey water filtration is opened to further research and improvement by any one that wishes to work on grey water and its related uses.

The efficiency of the filter could be improved by varying the sizes, ranges and proportions of the materials of the media and also, depth of the media.

Furthermore I recommended that effluents from the filter designed can be used for general irrigation process such as irrigating lawns, gardens, cash crops, vegetative crops, roads etc using any of its method.

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