DESIGN, FABRICATION AND PERFORMANCE EVALUATION OF A SLOW SAND FILTER

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DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

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BY

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BEING A FINAL YEAR PROJECT SUBMITTED IN
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DECLARATION

I hereby declare that this project is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any University or Institution. Information derived from personal communications, Published and unpublished works of others were duly referenced in the text.

.... 13/01/2009

ADEYEMI OLUSEUN BOLARINWA DATE

DEDICATION

This project is dedicated to the glory of the Almighty God, who made me see the completion of my undergraduate study and also to my parents Dr. and Mrs. Stephen Olufemi ADEYEMI for their exemplary lifestyle.

CERTIFICATION

This project entitled "Design, Fabrication and Performance evaluation of a slow sand filter" by ADEYEMI OLUSEUN BOLARINWA meets the regulations governing the award of the degree of Bachelor of Engineering (B.Eng) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

.... 13/10/08

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Acknowledgement

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Abstract

Although slow sand filtration had already been described in ancient times, it is still implemented in major cities around the world. Slow sand filtration is a simple, inexpensive and reliable technique ideally suited for developing countries. Results indicate that it is feasible to use local materials for filters media

The results were satisfactory with significant reductions in natural organic matter and removal of pathogenic organisms.

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CHAPTER ONE

1.0 INTRODUCTION

The dependency of all living creatures on water as one of the major means for Survival is inevitable. Plants depend on water for their growth and survival, since in Plants food is tied to water and it depends on its flow from root foliage. Likewise, animals rely on water, air and food for their survival.

Human beings can virtually do nothing without water. From their daily activities, to farming, to food production and processing e.t.c. Thus, throughout history, sure access to water has been essential to the social and economic development and the stability of cultures and civilization. Since the inception of life or farming activities, agriculture has depended on fortuitous combination of good soils and predictable sources of water and dependable sources of water has played prominent role in the development of all nations in the world.

Unfortunately, the global supply of fresh water is unevenly distributed. Chronic water shortages exist in most African nations and drought is common in so many parts of the world (Mertes, Leal A.K "River" Microsoft R student 2008 [DVD] Redmond, WA :)

An effort to encourage water conservation faces special challenges not encountered with other natural resources. In most parts of the world, water is not controlled by market mechanisms because it is either free to be taking or it is not metered. Water is a global resource that cannot be traded like petroleum or given in aid like food or medicine. If people waste water in one river basin, it is irrelevant to those who live in another.

About one-third of the terrestrial surface area of the planet earth is arid or semi-arid, and about half of the world's nations are situated wholly or partially in dry regions. As the world population densities continue to increase everywhere in the world, demand for water usage is on the increase. .

The African continent is sometimes perceived as being characterised by widespread aridity and a general lack of financial and technological resources. The famine in the Sahel region in about 40 years ago and the current catastrophic food shortages in many parts of Africa show the vulnerability of the prolonged drought. (Akinola, 2005)

The effects of limited availability of natural resources such as water, fertile soils e.t.c are dramatically demonstrated in many parts of the world .In Nigeria, as well as many developing countries, people in the lower income group are severely affected .The interactions of factors such as; limited access to capital and a lack of trained manpower restricts the ability of "the poor" to respond to environmental challenges.

Though, Nigeria on the average receives rainfall, the rainfall is unevenly distributed both geographically and seasonally.

In Conclusion, Water scarcity is a major limiting factor to crop and animal production, Rainfall could therefore be more effectively utilised through the implementation of appropriate water conservation practices, as well as introduction of water recycling process such as sedimentation, filtration e.t.c, which will to a large extent prevent run-off , and encourage water retention and in situ infiltration.

Most rural communities do not have financial and technical means to join the development process. Water conservation methods must therefore be the primary means of securing the resource base, for a healthy livelihood for both human and animal, and increase in crop productivity.

Principal considerations in their development and their acceptance will include technical feasibility, social acceptability economic viability, and practical usefulness within the resources available to the land users. Thus, the present research work is intended to identify the effect of recycling in conserving water as well as in water management, through the use of a slow sand filter. This cross section should go a long way, in support of the area of conservation of fresh water, and maximising available water for its predesigned use.

1.1 Water: Occurrence, Composition and Properties

Water, is the common name applied to the liquid state of the hydrogen-oxygen compound –H_2O .Water, is the only substance that occurs at ordinary temperatures in all three states of matter; as a solid, Liquid and a gas. As a solid (Ice), it is found as glaciers and ice caps, on water surfaces in winter, as snow, hail, and frost and as clouds formed of ice crystals. Water occurs in the liquid state as rain. Clouds formed of water droplets, and on vegetation as dew; So also, it covers three-quarters of the surface of the earth in the form of swamps, lakes, rivers, seas, and oceans. As gas, or water vapour, it occurs as fog, steam, and clouds. Water occurs as moisture in the upper portion of the soil profile, in which it is held by capillary action to the particles of soil.

Pure water rarely occurs in nature because of its capacity to dissolve numerous substances in large amounts. During condensation and precipitation, rain or snow is absorbed from the atmosphere in varying amounts of carbon dioxide and other gases as well as traces of organic and inorganic minerals in the soil and rocks. The principally dissolved constituents of surface and groundwater are sulphates, chlorides, and bicarbonates of sodium and potassium and the oxides of calcium and magnesium. Surface water may also contain domestic sewage and industrial wastes. Ground waters from shallow wells may contain large quantities of nitrogen compounds and chlorides derived from human and animal wastes. Waters from the deep wells generally contain only minerals in solution.

In addition, seawater contains some amounts of sodium chloride, or salt, many other soluble compounds, as the impure waters of rivers and streams are constantly feeding the oceans. Pure water is an odourless, tasteless liquid which has a bluish tint; that can be detected, however, only in layers of considerable depth. Under atmospheric pressure (760mmHg); the freezing point of water is $0^{o}c$ and its boiling point is $100^{o}c$. Water attains maximum density at a temperature of $4^{o}c$ and expands upon freezing. Water is one of the best known ionizing agents because most substances are somewhat soluble in water.

1.1.1 Water: Environment and Population

Water is the major constituent of living matter. About 50 to 90 percent of the weight of living organisms is water. It is fundamental to the biochemistry of all living organisms. The planet's ecosystems are linked and maintained by water and it drives plant growth, provides a permanent habitat for many species i.e. about 25,000 species of fish, and it is a breeding ground or temporary home for others, including most of the world's species of amphibians and reptiles. Water is regarded as a universal solvent which provides pathway for the flow of sediment, nutrients and pollutants, through erosion, transportation and deposition by rivers, glaciers, and ice sheets. Water shapes the landscape and through evaporation, it drives the energy exchange between land and the atmosphere, thus controlling the earth's climate. (Akinola, 2005)

Apart from a few minor chemical processes, water is neither created nor destroyed, but only moves from place to place and changes in quality. Earth has enormous water resources, approximately 1.4 billion cubic kilometers (km^3), and in some regions they are coming under stress. Many rivers also run dry for most parts of the year which includes the Yellow river in China, Indus River in Pakistan, and India's Ganges River.

Furthermore, the renewal rate provided by rainfall varies around the world. Water availability also varies over a longer time scale. However, it is uncertain how this will affect water resources. Evaporation is likely to rise, but changes in rainfall patterns are less predictable. However, it is feared that many areas will become drier, and that floods and droughts may become more frequent and more extreme.

The world is facing the prospect of water shortages caused by population growth, uneven supplies of water, pollution, and other factors. The world has witnessed unprecedented rise in human populations, from about 3.02 billion in 1960 to about 6 billion in July 1999 and it is projected to reach approximately 9 billion people by 2050 (1999 population, Archive article Encarta encyclopedia). Consequently, human demands for water for domestic, Industrial and Agricultural purposes are also increasing rapidly.

The amount of water used by people varies, but tends to rise with living standards.

1.1.2 Water for the People or the Environment

With water crisis facing many countries, it seems an immense task just to manage water so that there is enough water for agricultural, environmental, and Industrial uses. The situation is often presented as a conflict of competing demand as though it was a matter of choice, say, between water for people, or for wildlife, or for the environment.

The immense biological, chemical and physical diversity of the earth form the essential building blocks of the ecosystem. Thus, whilst people need access to water directly to drink, providing water to the environment means using water indirectly for people. This concept is so basic, that it has permeated all aspects of water resource management such as the new water law of South Africa, whose ninth principle states that: "quantity, quality, and reliability of water required to maintain the ecological functions on which humans depend shall be reserved so that the human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems".

More attention needs to be given to the role of natural ecosystems in managing the hydrological cycle and their potential as alternatives to major engineering works.

The water recycling and reservation is essential to meet with its demands. Therefore, for the millions of people all over the world who depend directly and benefit from wet land resources, providing water for the environment and for the people are the same.

1.2 Waste water

Waste water can simply be defined as water that has been used, as for washing, flushing, or in manufacturing processes. Waste water is any water that has been adversely affected in quality by anthropogenic influence. Waste water comprises liquid wastes discharged by domestic residences, Industries and or agriculture and can encompass a wide range of potential contaminants and concentrations.

Sewage is correctly the subset of waste water that is contaminated with faeces or urine. Sewage includes domestic, municipal, or Industrial liquid waste products disposed off, usually via a pipe or sewer or a similar structure.

1.2.1 Waste water -Constituents

The composition of waste water varies widely. The waste water may include water which is often added during flushing to carry waste down the drain. So also included are pathogens such as bacteria, viruses, protozoan and parasitic worms.

Furthermore, organic particles included faeces, hairs, food, fibres, Plant material, humus; Inorganic particles such as sand, grit, metal particles, Ceramics, Soluble inorganic material e.g. ammonia, road-salt, sea-salt, Cyanide, hydrogen sulphide; Macro solids e.g. sanitary napkins, nappies, diapers, condoms, needles; Animals such as protozoa, Insects, Anthropods e.t.c. Likewise, Emulsions e.g. Paints, adhesives, Mayonnaise, hair colourants, as well as Toxins such as pesticides, poisons, herbicides e.t.c add up to form waste water.

1.2.2 Purification of Waste water

The purification of waste water involves mainly the treatment of the waste water either for consumption or for discharge into the environment in an environmentally friendly manner .Therefore, to know the extent to which waste water will be purified; the waste water quality indicator is put into cognisance:

1.2.3 Waste water Quality Indicators

The oxidizable material present in a natural waterway or in industrial waste water will be oxidized both by biochemical or chemical processes. The result is that the oxygen content of the water will be decreased.

Basically, the reaction for biochemical oxidation may be written thus:

Oxidizable material + bacteria + nutrient + $O_2 \rightarrow CO_2 + H_2O$ + Oxidized Inorganic

E.g.NO_3 or SO_4

Thus, the oxygen consumption by reduction:

$$S^- + 20_2 \rightarrow SO_4^-$$

$$NO^-_2 + \frac{1}{2} O_2 \rightarrow NO_3^-$$

All the natural waterways contain bacteria and nutrient. Almost any waste compounds introduced into such waterways will initiate biochemical reactions. The biochemical reactions create what is measured as the Biochemical oxygen demand (BOD). So also, Oxidizable chemicals introduced into natural water will similarly initiate chemical reactions and the chemical reactions results in the laboratory measurement known as Chemical oxygen demand (COD).

Both BOD and COD tests are a measure of the relative oxygen depletion of a waste contaminant. The BOD test measures the oxygen demand of biodegradable pollutants and the COD tests measures the oxygen demand of biodegradable pollutants plus the oxygen demand of non-biodegradable pollutants.

1.2.4 Waste water Treatment

There are various methods that are used to clean up or purify waste water, depending on the type and the extent of the contamination. Most waste water is treated in industrial scale (Waste Water Treatment Plant) which may include physical, chemical and biological treatment processes.

However, the use of septic tanks is widely used in the rural areas.

The most important aerobic treatment system is the activated sludge process based on the maintenance and recirculation of a complex biomass composed of micro-organisms able to absorb the organic matter carried in the waste water. Anaerobic processes are widely applied in the treatment of industrial waste waters and biological sludge. Some waste water may be highly treated and reused as reclaimed water.

Furthermore, ecological approach using reed bed systems such as constructed wetlands may be appropriate. Modern systems include tertiary treatment by micro filtration or synthetic membranes. After membrane filtration, the treated waste water is indistinguishable from waters of natural origin of drinkable quality.

Nitrates can be removed from waste water by microbial denitrification for which a small amount of methanol is typically added to provide the bacteria with a source of carbon. So also, Ozone waste water treatment is used which requires the use of an ozone generator that decontaminates the water as the ozone bubbles percolate through the tank. In conclusion, waste water treatment is essentially classified into Primary treatment and Secondary treatment.

1.3 Objective

The objectives of this project are:

i. To design and fabricate a cottage slow sand filter.

ii. To evaluate the reliability of the fabricated slow sand filter.

1.3 Scope

i. Designing cheap but effective slow sand filter for waste water.

ii. Conducting physical and chemical analysis of the waste water sample.

iii. Collecting samples from different domestic waste water sources.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Background

The increasing demand by growing populations in the twenty first century has created the need for increased efficiency in water management policies. Increasing technology in the wastewater treatment field has allowed researchers to look at the possibilities of recycling water within our water treatment facilities. There are several scientific, economic and political decisions attached with every water management issue, and these must be overcome before policies and solutions can be put in place.

2.2 Waste water Treatment

When residues were built in the past, there were few options available concerning its disposal. A house built in a city, was normally connected to a centralized sewer system. If the house was constructed in a rural area, it usually had an on-site septic system installed in the property. When a conventional septic system is inadequate due to certain site and soil conditions, and the cost of being connected to a centralized sewer system is prohibitive, it may be necessary for property owners to seek alternatives. Alternative system may be necessary when:

1. The volume of water entering the system is too large for the existing system to properly treat.
2. The soil where the drain field has been located does not efficiently filter and treat the effluent.

3. The size drain field required for a conventional system is not possible on the site.

4. The water table underneath the drain field is too close to the surface

5. The system is located in an environmentally sensitive area, such as near a water way.

In choosing an alternative amongst the many available, it thus requires the understanding associated with a particular system.

- Primary treatment is the separation of solids and particulate matter from the waste water. A physical process accomplished in a settling chamber, and is mostly the first stage of a treatment
- Secondary treatment is the reduction of organic compounds in the waste water. It is a biological process that occurs, when bacteria digest these compounds. The secondary stage is important, because it reduces the demand for oxygen in waste water.
- Tertiary treatment is any type stage, where the water is polished through a filtering process, or nutrients are removed through biological or chemical processes.
- Disinfection is the removal of any possible harmful pathogens before the effluent is discharged.

2.3 Sand Filters

Sand filters are defined as structural devices, that treat the volume of run off from the water quality storm (W Q V), and return the flow through an under drain, back to the conveyance system. Sand filters, use physical straining, solids settling, and adsorption processes to reduce pollutant concentrations in storm water. The purpose of the sand filters is to reduce pollutant concentrations in storm water to acceptable levels. They are usually used to treat runoff from impervious areas. The sand filters, can either be:

(a) Granular filters. - Slow sand filter - Rapid sand filter

(b) Pressure filters

(c) Membrane filtration

(d) Cartridge filtration

2.3.1 Slow Sand Filter

Slow sand filter, are gravity filters, and are operated under continuous submerged conditions maintained by adjusting a control valve located on the discharge line from the under drain system. Biological processes and chemical / physical processes common to various types of filters occur at the surface of the filter bed. A biological slime or mat forms on the surface of the bed, which traps the small particles, and degrades organic material present in the raw water. Filtering action is dependent on fine sand and the biological mat. This media also presents a physical barrier to the passage of spores of plant pathogens. Bacteria's such as representatives of the *Genus pseudomonas* and *Trichoderma* have been demonstrated as biological control agents effectively controlling plant pathogens in hydroponics systems. In a slow sand filter, plant pathogens recirculating in the irrigation water are captured in the filter media, and at slow rates of water filtration (100- 200 $ltr/hr/m^2$ surface area of filter), are acted upon by the antagonistic micro organisms that colonized the filter bed.(http : //www. oasisdesign.net/water/treatment/slowsand filter.htm) . The filter consists of a bed of fine sand approximately 3 – 4 feet thick and supported by a 1-foot layer of graded gravel and an underdrain system.

The efficiency of the slow sand filter depends on the particle size distribution of the sand, the ratio of surface area of the filter to depth, and the flow rate of water through the filter. The filter is not backwashed, but is cleaned by scraping about 1 in (2-3 cm) of sand from top. Once the depth is about 2ft (0.6m), new sand is added to bring filter bed back to its original depth

.

2.3.2 Rapid sand Filter

The rapid sand filters, are similar to slow sand filters, but they have a higher filtration rate from the use of more coarse sand in the system. Instead of depending on the biological mat for filtering action, the filters trap suspended matter through several inches or more of depth of filter sand. The rapid sand filters are designed for backwashing for its cleaning. They are cleaned often, usually daily, by reversing the flow of water through the entire filter bed-backwashing.

2.3.3 High-Rate Filters

High rate filters are dual media and multimedia filters, which can operate at rates up to four times higher than the rapid sand filters. The high rate filter makes use of the combination of filter media, not just sand. Dual media filters usually have a bed of sand covered by a layer of granulated anthracite coal. Multimedia (mixed media) filters, use three or more types of media of varying coarseness and specific gravity. Most of the filter bed is used to remove suspended particles.

2.3.4 Direct Filtration

Direct filtration consists of several combinations of water treatment processes. It always includes coagulation and filtration, and it may require flocculation tank or a pressure vessel after water treatment systems, but does not include sedimentation. Nonionic polymers are sometimes added to the filtration step to increase their filter efficiency.

2.3.5 Pressure Filters

Pressure filters, are also known as precoat or diatomite filtration. It relies on a layer of diamatoceous earth of approximately 1/8 inch thick placed on a filter element in pressure vessels or operated under a vacuum in open vessels. Operation and maintenance, of pressure filters require; preparing slurries of filter body feed and dosages for effective turbidity removal; Periodic washing- every 1 to 4 days; disposing of spent filter cake; Periodically inspecting the filter elements for cleanliness and damage; and verifying effluent quality. It uses coagulant to coat the body feed to improve removal rates for viruses, bacteria and turbidity.

2.3.6 Membrane Filtration

A membrane is a thin layer of material capable of separating substances when a driving force is applied across the membrane in the form of a hollow fiber or spiral-wound composite sheets. Organic and other contaminants are retained on the high-pressure side and frequently must be removed by reversing the flow and flushing the waste. Periodic chemical cleaning may be required to remove persistent contaminants. Membrane assemblies are contained in pressure vessels or catridges. The systems require little more than a feed pump, a cleaning pump, the membrane modules, and some holding tanks. Periodic backwashing and occasional chemical cleaning is necessary to maintain the membrane or fibres.

2.3.7 Cartridge Filtration

Cartridge filters are considered an emerging technology suitable for removing microbes and turbidity in small systems. Cartridge filtration uses a physical process which involves straining water through porous media. It can exclude particles 0.2 micrometers or smaller. The pore sizes that is suitable for producing portable water ranges from 0.2 to 1.0 micrometer. Roughing filters, for pretreatment prior to cartridge filtration, are sometimes necessary to remove larger suspended solids and prevent the rapid fouling of the cartridges. Roughing filters can be Rapid sand filter, Multimedia filters, Fine mesh screens, or bag filters. A Cartridge consists ceramic of Or polypropylene filter elements fitted into pressurized housings. A disinfectant is recommended to prevent surface-fouling microbial growth on the cartridge filters, and to reduce microbial pass-through. Except for a disinfectant, no chemical additions are necessary. However, corrosive chemicals may be required for the periodic membrane. (American Water Works Association; 1969)

2.4 Advantages of Slow Sand Filtration

There are several advantages of slow sand filtration over other methods of water disinfestations:

i. It has a low energy consuming process.
ii. It has a low cost of building and running.
iii. It involves simple operation.
iv. It is reliable.
v. System can be built and installed by laymen.
vi. It has a great adaptability and maintenance cost is minimal.
vii. It is able to achieve greater than 99.9 % Giardia cyst removal.

viii. It does not require extensive active control by an operator.

2.4.2 Limitations of Slow Sand Filtration

i. It is not suitable for water with high turbidity

ii. Filter surface requires maintenance

iii. Filters in cold climates develop an ice layer and freeze, which prevents cleaning during winter months.

2.4.1 Limitations of other Filtration Methods

i. The rapid sand filter is a little more complex than the slow sand filter.

ii. Direct filtration is only applicable for systems with high quality and seasonally consistent influent supplies.

iii. Pressure filter is most suitable for water with low bacterial counts and low turbidity < 10 NTU. So also, coagulant and filter aids are required for effective virus removal.

iv. In the membrane filtration, fouling of the membrane is the major problem preventing the wide spread of the application technology.

v. The polypropylene cartridges become fouled relatively quickly, and must be replaced with new units.

vi. The cartridge filter systems are operationally simple, they are not automated and can require relatively large operating budgets

(Filtration processes http://seniordesign.engr.uidaho.edu) fabric may be considered to support the sand as an alternative to some gravel layers. The bottom layer of gravel supports perforated drainage bottom tray, or perforated drainage pipe which may simply bisect the filter or in a large filter from a network of connecting pipes across the base. The use of granulated rock wool as an alternative media to sand can reduce the requirement for the gravel drainage system and thus reduce the depth of the filter. A fine screen over the outlet is recommended to prevent rock wool granules from passing into the outflow.

2.5.4 Flow Control

A regulating tap is connected to the filter outlet to control the flow rate. On large filters, a flow meter is sometimes installed for use in monitoring the flow rate. The flow rate is specified in terms of liters/hr unit area of the surface of the filter (m^2). The flow rate, through the filter is less than gravitational fall keeping the water level above the filter bed constant assists in maintaining an even flow. The flow rate will drop off with the build-up of material on the surface of the filter bed. An open clear fixed to the exterior of the filter can be used to monitor head loss. (http://www.oasisdesign.net/water/treatment/ssf.htm)

2.6 Control of Filtration

It is necessary to control all variables that affect the slow sand filtration in order to obtain optimum results. These factors include the media characteristics; filtration rate; filter run; head loss development, quality of filtrate and depth of filters.

2.6.1 Media Characteristics

Media characteristics are usually defined in terms of the effective size and the uniformity coefficient. However, other characteristics like the durability, porosity, particles shape and specific gravity are equally important.

The effective size of a filter medium is the sum size in millimeters that permits 10% of the medium by weight to pass through it, in a sieve analysis. The uniformity coefficient on the other hand, is the ratio of sieve size that permits 60% of the medium by weight to pass through it, to the effective size (Twort *et al*, 1985)

The effective size of sand in slow sand filter is between 0.15mm to 0.40mm with 0.3mm mostly used, and the uniformity coefficient lies between 1.5mm to 3.6mm with 2.0mm most common and initial bed depths from 0.46m to 1.52m, with 0.9m most common.(Pontius,1990)

According to the America Water works Association (1969), Filter sand usually ranges in size from that, passing a 16-mesh sieve to that retained on a 50-mesh sieve.

The porosity of filter media, or any porous media is the ratio of the void volume to the total volume of the media. It was reported by Ives 1965, that the practical range of filter porosities lies between 0.35 to 0.5.He also reported that a typical porosity value for sand media is about 0.40.It was also observed by Camp, 1964,that porosity is the most important single filter parameter that affect head loss and length of filter run. He stated, that the porosity of filter media varies with depth and that there are no available satisfactory means for measuring the porosity at any depth. So it is usually the average porosity that is reported.

2.6.2 Filtration Rates

The filtration rates ranged from 0.04 to 0.40 m/h with 0.07 to 0.12m/h most common on source water that received no prior pretreatment. Flow rates, higher than 0.3m/h were used following some pretreatment steps to lengthen the filter cycle, such as sedimentation or plain rapid filtration without coagulants.

2.6.3 Head Loss Development

The available head loss for operating the filter ranged from 0.76 to 4.3, but was most commonly from 0.9 to 1.5m (Slezak and.Sims, 1984).

2.6.4 Filtrate Quality

Filtrate quality is the most important parameter in filtration in domestic and other water supply systems. Hudson, Jr, (1981) stated that for good filtrate quality, there should be adequate pretreatment .He added, "If mixing and flocculation are executed poorly, colloids will pass through the best of filters". Thereby producing poor filtrate quality.

The America water works Association stipulated that the turbidity of a properly operating filter should be less than 0.2 NTU. The world health organisation's (WHO) drinking water standard stipulates turbidity less than 5.0 NTU and preferably less than 1.0 NTU.

2.7 Mechanisms of Filtration

Particulate (Microbials, viral and sediment) removal in slow sand filtration is considered a passive process, differing from rapid sand filtration in that chemical pretreatment of inflow is generally not performed and back flushing (pressurized flow reversal) is not used for cleaning the filter media (Haarhoff and Cleasby, 1991).

In rapid sand systems, filtration requires flocculation to coagulate particles contained in the inflow, coupled with back flushing every 1-2 days to dislodge coagulate particles trapped in the media (Haahoff and cleasby, 1991) . In contrast slow sand water purification depends on upon two passive removal mechanisms;

(i) Biological and (ii) physical-chemical; neither of which is well understood (Weber-shirk and Dick, 1997a; Weber-shirk, 1997b).

Removals attributed to biological activity within the filter media are absent in rapid sand filters, due to the aforementioned processes that prevent establishment of biological communities within the filtration media (Haarhoff and Cleasby, 1991)

In slow sand filters, biological processes are considered to dominate the uppermost region of the filter bed (Haarhoff and cleasby, 1991; Ellis 1995). A layer termed schmutzdecke, literally translated as "dirty skin" (Hendricks, 1991), forms on the surface of the sand bed is believed to contribute to the removal of water impurities. (Weber- shirk and Dick, 1997a).

It has been hypothesized that within the schmutzdecke, *algae, plankton, diatoms*, and *bacteria* break down introduced organic matter through biological activity (Weber- shirk and Dick, 1997a)

In addition to the schmutzdecke the sand grains of the filter bed provide additional biological and physical mechanisms that contribute to removal efficiency (Mcmeen and Benjamin, 1997; Ellis 1985). A biofilm develops around the sand grains and it has been hypothesized that such films create sticky surfaces, causing the attachment of organic and inorganic particles (Weber-shirk, 1997b). This surface is thought to biologically be active (consisting of bacteria, protozoa and bacteriophages) and a site for the decomposition of organic matter (Weber-shirk, 1997b)

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

A zeta potential may be described as:

A charged particle suspended in an electrolytic solution attracts ions of the opposite charge to those at its surface, where they form the stem layer. To maintain the electrical balance of the surrounding fluid, ions of opposite charge are attached to the stem layer. The potential at the surface of that part of this diffuse double layer of ions that can move with the particle when subjected to a voltage gradient is the zeta potential. This potential is very dependent upon the ionic concentration, pH, viscosity and dielectric constant of the solution being analyzed.

CHAPTER THREE

1.0 METHODOLOGY

This chapter deals with the methods and materials employed in the fabrication and the performance evaluation of the slow sand filter. Also included, is the necessary experiments carried out to determine the rate of biodegradability present in the waste water.

3.1 Materials for Construction and Fabrication

1. The filter cylinder is made of mild steel gauge 22.
2. Fine grained sand (Beach Sand)
3. Gravel: Loose and rounded gravel (medium), washed and dried before use.

The sand and gravel were collected, soaked and was thoroughly washed to remove impurities which tend to colourise the filtrate.

The standard sized sheet was cut to size in a cylindrical form of 120cm X 40 cm. At the base end of the filter cylinder box are made holes which serves as passage for the filtrate to the underdrain.

The filter chamber is placed on the temporary cylindrical storage of 20cm X 40cm, which serves as the initial storage for the filtrate.

At the base end of the temporary storage is attached a ¾ inch valve which controls the filtrate. (Flow regulator valve).Plates 1-5.

3.1.2 Filter Arrangement

The washed gravel (plate 6) was placed vertically at the bottom of the filter cylinder box, which serves as the support gravel for the fine sand. The gravel was placed vertically to a depth of 20cm with its particle size ranging between

Plate1: Measuring the Diameter

Plate 2: The Underdrain

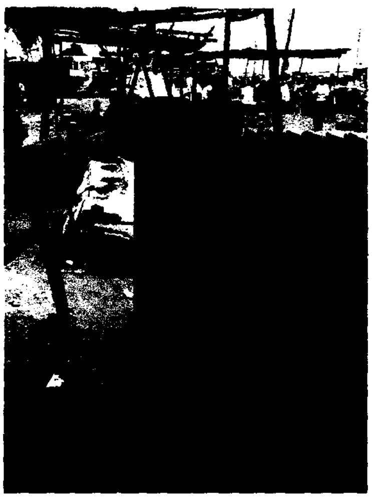

Plate 3: Back view of the Slow Sand Filter

Plate 4: The Filter Bed and the Underdrain

Plate 5: The Filter Cylinder box on its stand

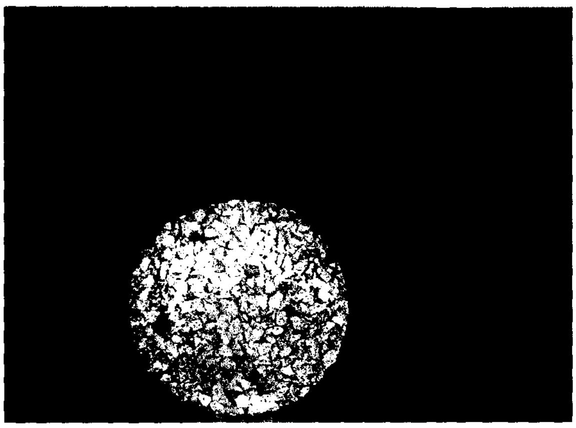

Plate 6: The ¾" Gravel arranged in the Filter Box

2mm-16mm, while the fine sand is placed vertically above the gravel to a depth of 50cm with a particle size of 0.15mm-0.35mm.

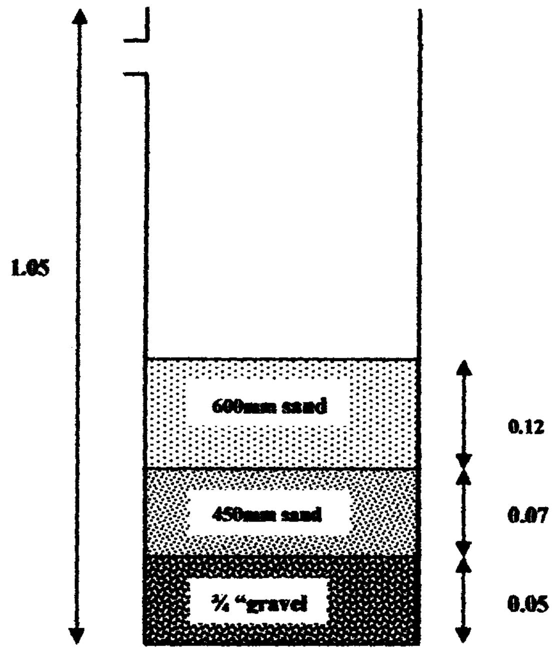

Fig 3.1: Arrangement of the filter bed

3.2 Sampling

The samples were collected from the domestic waste discharge point of the male hostel at the Bosso campus of the Federal University of Technology, Minna, Niger state. The sample was collected in a 150cl bottle.

The sample was tested for the following parameters:

- BOD- Biochemical oxygen demand
- COD- Chemical oxygen demand
- Hydrogen ion concentration
- DO-Dissolved oxygen
- Conductivity

- Turbidity
- Hardness
- Colour
- Alkalinity

3.2.1 Biochemical Oxygen Demand

The Biochemical oxygen demand was determined by determining the dissolved oxygen of the waste water sample on the first day, and same waste water sample was incubated at room temperature for 5days in the dark before the titration for oxygen using the Winkler – azides method.

3.2.2 Chemical Oxygen Demand

50mls of waste water sample was taken; 50mls of sulphuric acid and 1ml of potassium dichromate were added, and was allowed to be digested for 30 minutes after which potassium iodide and starch indicator were added. This was then titrated with thiosulphate.

3.2.3 Turbidity

A spectrophotometer at 450 nanometer was used to check for the turbidity of the sample.

3.2.4 Dissolved Oxygen

The dissolved oxygen was determined by using the Winkler-azide method. Waste water samples should be collected in 250mls BOD stopper bottles and fix them right on the field with 2ml of reagent:

(a) Managanons sulphates and 2ml of reagent (b)(Alkaline-iodide-solution)(KOH+KCl).

2mls of sulphuric acid should then be added to each sample in the laboratory and mix gently. 10mls of the waste water sample should be titrated with 0.025N sodium thiosulphate in starch indicator until it turns colourless. Calculation of the dissolved oxygen should be done based on the formula below:

$$\text{Dissolved Oxygen (mg/l)} = \frac{\text{Volume } (Na_2S_2O_3) \times \text{Normality (acid)} \times 16 \times 1000}{\text{Sample Volume (ml)}}$$

3.2.5 Hydrogen ion concentration

The pH of the waste water sample was being determined with pH meter at room temperature. The meter was initially standardized with buffer solutions of pH 4.0 and 9.0 before taking the reading. The probe of the meter was rinsed thoroughly before inserting it into the water sample whose pH was to be determined.

3.2.6 Conductivity

Conductivity meter was used to measure conductivity of the water samples. The reading is expressed in micro-ohms/cm. The probe of the meter should be rinsed thoroughly before inserting it into the waste water sample whose conductivity is to be determined.

3.2.7 Colour

The colour of the waste water sample was physically observed

3.2.8 Hardness

The total hardness of the waste water sample was determined by adding 1ml of Ammonium chloride buffer solution to 50mls of the waste water sample and follows by addition of 3 drops of Eriochrome black-T indicator. The resultant wine colour should be titrated with 0.01N EDTA (ethylene-diamine-tetraethanoic acid) titrant until a blue end point is observed.

3.2.9 Alkalinity

The alkalinity of the sample was determined, by taking 10mls of the waste water sample in a clean conical flask. 2 drops of methyl orange indicator was added and was uniformly shaken. It was then titrated with 0.02N sulphuric acid until the colour of the solution changed from yellow to orange which determined the end-point. The total alkalinity was calculated using the equation below:

$$\text{Total alkalinity mg/l} = \frac{\text{Vol }(H_2SO_4) \times \text{molarity }(H_2SO_4) \times 100{,}000}{\text{Vol. of sample}}$$

3.3 Grain Size Analysis of the Filtering Material

The proper gradation of soil material, termed filter can be predicted from the grain size analysis. The grain size analysis is in an attempt to determine the relative proportions of the different grain sizes which make up a given mass of soil. The information obtained from the grain-size analysis is represented in the attached appendix.

3.3.1 Materials.

(1) Sand

(2) Gravel

3.3.2 Equipments.

(1) A stack of Sieves

(2) Vibrating machine

(3) Weigh balance

3.3.3 Test Procedure

(1) Washed 500grams of Sand and gravel samples were collected from a field, and separately run through a stack of sieve varying from larger sizes to smaller sizes from top to down.

(2) The vibrating machine carrying the stack of sieves was put on for 15minutes, to allow for uniform particle size distribution on each of the sieve size.

(3) The weight retained on each sieve was measured with the help of a weigh balance.

(4) Percentage weight retained as well as percentage fine was calculated and percentage fine was plotted against the sieve sizes.

3.4 Permeability and Porosity of the Filtering Material.

It is important, to realize the basic difference between the permeability and porosity of a soil sample.

Permeability is a measure of the capacity of a soil to permit the passage of water through a given sample of soil.

Porosity expresses the ratio of void (air or water) space of a soil to the volume (soil inclusive) of the soil. These, were experimentally determined. (Appendix B)

3.4.1 Materials

(1) Sand

(2) Water

3.4.2 Equipment

(1) Sand mould

(2) Stand pipe

(3) Stop watch

(4) Weigh balance

(5) Meter rule

3.4.3 Test Procedure

The falling head method was used.

(1) The mould, dry soil sample was weighed. The mould and wet soil sample weighed

(2) A coarse filter screen is placed at the upper and lower ends of the sample tube. The base of the sample tube is connected to the water reservoir.

(3) To the top of the sample tube, is connected a glass stand pipe known cross section area (4-5mm).The pipe is filled with water as the water seeps down through soil sample, observations were taken of time versus height of water in the sand above base reservoir level.

3.5 Filter Design Criteria

According to Babbith, Donald and Cleas (1962), the actual design of a slow sand filter includes four different dimensions, which is considered in advance: (1) Thickness of the filter bed. (2) The grain size distribution of the filtering material (3) The rate of filtration (4) The depth of the water storage layer, for a given source of raw water. The quality of an effluent depends on the grain size distribution of the filtering materials. The filtration rate, have no influence on its quality but together with the minimum allowable head loss, determines the length the filter run.

3.5.1 Filter Cylinder Box

The filter bed, with the underdrain, and the water storage layer constitute the filter box. They are all enclosed in the box with a depth of 120cm, and known total surface area.

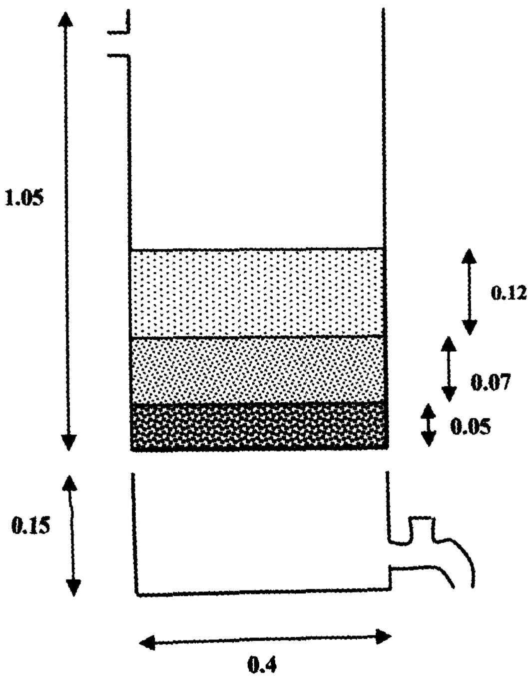

Fig 3.2: The Filter Cylinder Box

3.5.2 Hydraulics of Filtration

The filtration rate V of the slow sand filter is so small, that under all circumstances laminar flow conditions persists. The initial resistance H_0 of a clean filter bed with depth L is consequently given by Darcy's law i.e.

$V = Q/A = (K\Delta H_0)/L$ ...... (i)

$\Delta H_0 = V_L/K$ .... (ii)

K = Coefficient of permeability of filter (m/s)

Hydraulic gradient

L = Height of the sand

3.5.3 Filter Media

For the purpose of this slow sand filter design, the filter bed thickness is 0.24m and from sieve analysis carried out, the following results were obtained:

(i) Effective diameter (d_i) = d_{10} =2.54mm

(ii) 60% = d_{60} = 4.0 mm

(iii) Uniformity Coefficient (U_c)= d_{60} / d_{10}

= 4.0/2.54.0 =1.57mm

(Developing world water 1981-1990)

(iv) The effective diameter (d_s) of the filter material

$d_s = d_{10}\,(1+ 2 \log_{10} U_c)$

d_s = 0.3524 (Lecture manuscript by Mbwette '83)

Table 3.1a: Grain size of gravel / sand used for the slow sand filter

Type of gravel/sand used	Range of size of grains(mm)	Average size of grains (mm)
Medium sand	0.15 - 0.35	0.25
Medium gravel	4.0 - 5.60	4.8

Table 3.1b: Effective diameter (E) and Uniformity coefficient (U_c) derived from the sieve analysis curve

Size range (mm)	Effective diameter E (mm)	Uniformity coefficient (Uc)
Medium sand	2.54	1.77
Medium gravel	4.00	1.33

Source: Vigneswaran, S and C. Visvanathan. (1995)

Velocity = Discharge / Area

CHAPTER FOUR

4.0 Result and discussion.

4.1 Performance Evaluation

This chapter focuses on the laboratory analysis of the results obtained from the sample collected from the project area earlier mentioned in relation to the efficiency of the filter.

4.2 Physical Analysis Result

The physical analysis deals with the determination of turbidity, colour, total dissolved solids, Conductivity and other factors capable of defacing the appearance of the water. These parameters, indicates acceptability or otherwise of water to the consumer as they are widely used to establish its quality.

4.2.1 Determination of Turbidity

The turbidity of the water sample was determined using an instrument called turbid meter. The water sample was poured into culture ensuring that there was no spillage on the side hand stains. Distilled water was used to zero the turbid meter and the turbidity value was 3.20 NTU before filtration.

4.2.2 Determination of the Conductivity

The result of the conductivity was observed to be 277×10^{-6} µS/cm before filtration

4.4 Efficiency value for pH

$$\frac{7.16 - 6.49}{6.49} \times 100 = 10.32\%$$

4.4.1 Efficiency value for Conductivity

$$\frac{(555 \times 10^{-6} - 277 x 10^{-6})}{555 \times 10^{-6}} \times 100 = 50.1\%$$

4.4.2 Efficiency value for COD

$$\frac{2.14 - 1.11}{1.11} \times 100 = 92.8\%$$

4.4.3 Efficiency value for DO

$$\frac{6.00 - 3.00}{6.00} \times 100 = 50\%$$

4.4.4 Efficiency value for BOD

$$\frac{40.00 - 11.00}{40.00} \times 100 = 72.5\%$$

4.4.5 Efficiency value for Hardness

$$\frac{26 - 19}{19} \times 100 = 36.8\%$$

4.4.6 Efficiency value for Turbidity

$$\frac{3.20 - 0.98}{3.20} \times 100 = 71.9\%$$

4.4.7 Efficiency value for Alkalinity

$$\frac{520 - 320}{320} \times 100 = 62.5\%$$

4.5 Operation of the Slow Sand Filter

The water passes through the sand from top to bottom. Any larger suspended particles are left behind in the top layers of sand. Smaller particles of organic sediment left in the sand filter are eaten by microscopic organisms including bacteria and protozoan which 'stick' in the layers of slime that form around the sand particle sand the clean water which passes through the filter is safe to drink. Provided that the grain size is around 0.1mm in diameter, a sand filter can remove all fecal coliforms (bacteria that originate from feces) and virtually all viruses. (Huisman,1974)

4.6 Cost Estimate

The cost estimate, analysis the cost of materials used in the construction / fabrication of the slow sand filter. All the materials used were locally sourced for.

Table 4.2: Cost analysis

S/N	MATERIALS	COST (₦)
1	A mild steel gauge 22mm plate	3,500
2	¾" Tap head	400
3	¾" Socket	200
4	A 450 mg tin of Paint	400
5	50Kg bag of Sand sample	60
6	25Kg ¾" bag of Granite stone	350
7	Labour	1500
	Total	6410

4.7 Maintenance of the Slow Sand Filter

A slow sand filter must be cleaned when the fine sand becomes clogged, which is measured by the head loss. The length of time between cleanings can range from several weeks to a year, depending on the raw water quality. The operator cleans the filter by scraping off the top layer of the filter bed. A ripening period of one to two days is required for scraped sand to produce a functioning biological filter. The filtered water quality is poor during this time and should not be used.

(Vigneswaran, 1995)

- The effective size is the size opening that will pass 10% by weight of the filter material.(Haarhoff)
- The Uniformity coefficient is the ratio of the size openings that pass 60% of filter material to the size openings that pass 10% of filter material.(Haarhoff)

3.5.4 Capacity of the Filter

According to Gail Barth (1991), for a 0.4 m^2 surface area, a 100 litre volume of water, filters at the rate of 1200 ltrs/ hr

Thus,

$$1200\text{ltrs/hr} = \frac{1200 \text{ X } 1000}{3600} \qquad = 333\text{m}^3/\text{s}$$

i.e. 100 ltrs → 333. 33 m^3/s

$$1\text{m}^3 = \frac{3.33}{1000}\ \text{m}^3/\text{s} \qquad = 3.33 \text{ X } 10^{-3}\ \text{m}^3/\text{s}.$$

Volume of slow sand filter tank :

$\Pi r^2 h$

h = 1.2 m; r = 0.2 m

V= 3.142 x 0.2^2x 1.2

V= 0.1508m^3

3.5.5 Filtration Rate

From continuity equation,

$$\text{Velocity} = \frac{\text{Discharge}}{\text{Area}}$$

Surface area of a cylinder = $2\Pi rh$

Surface area of the cylinder = 2 x 3.142 x 0.2 x 1.2

Surface area of the cylinder = $1.5082m^2$

Hence,

$$\text{Velocity} = \frac{3.33 \times 10^{-3}\ m^3/s}{1.1508\ \ m^2}$$

$$\text{Velocity} = 2.8936 \times 10^{-3}\ m/s$$

CHAPTER FIVE

5.0 Conclusion and Recommendations

5.1 Conclusions

In reference to the values of the result of the physical and chemical analysis conducted on the raw water sample, as well as the filtrate, the following conclusions can be deduced:

1) That the aim of the project is achieved by recovering relatively clean water from a sample of waste water.
2) The physio-chemical parameters such as Conductivity, pH, Alkalinity, and hardness of the sample both before filtration and after filtration had differences in value, which implies the slow sand filter performance is average. For instance, the value of the conductivity increased because the waste sample had passed through the filter bed which in turn added some metallic ions to the filtrate.
3) The colour change of the filtrate is obvious, which also attest to the efficiency of the filter.
4) The slow sand filtration, with or without pretreatment reduced the turbidity consistently to a considerable level.

5.2 Recommendation.

The result of this project work should be of particular interest to the Federal University of Technology, Minna community and to the entire Niger state as a whole in the conservation and recycling of water especially in the peak of dry season when drought is being experienced. Therefore, it is recommended, that:

1. Slow sand filtration is well suited for the primary treatment of farm water supply.
2. It is an ideal pretreatment process for surface water containing suspended solids.
3. The filter may be in separate chambers for easy cleaning and replacement of the particles whenever required.

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