·NSTRUCTION AND PERFORMANCE ıON OF A SLOW SAND FILTRATION .LLERY FOR RURAL HOMES

BY

ASHIBI PAUL JOHNSON

MATRIC. NO. 2003/14876EA

BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG.) DEGREE IN AGRICULTURAL AND BIO-RESOURCES ENGINEERING FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

NOVEMBER, 2008

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 of institution. Information derived from personal communications, published and unpublished works of others were duly referenced in the text.

17/Nov/2008

ASHIBI PAUL JOHNSON
(STUDENT)

Date

CERTIFICATION

This project entitled "**Design, Construction and Performance Evaluation of a Slow Sand Filtration Gallery for Rural Homes**" by Paul Ashibi Johnson is an original work and meets the regulations governing the award of the Bachelor degree of Engineering (B. EGN.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

18/11/08

MR. PETER ADEOYE
(Project Supervisor)

DATE

....

ENGR. DR. (MRS) Z.D. OSUNDE
Head of Department

....

DATE

Engr. Prof. E. O. Chukwuma

EXTERNAL EXAMINER

18-11-08

DATE

DEDICATION

This project is dedicated to GOD Almighty, for keeping me from the beginning of this programme to my successful end of study. Next is to my dearly beloved parents **Mr. and Mrs. Johnson Ereshie Egem**, and the entire family for there endless supports both physically, morally, and financially through the period of these programme.

ACKNOWLEDGEMENTS

I thank Almighty GOD for bringing me successfully to the end of my academic programme, may his name be glorified. I also appreciate the effort my parents Mr. and Mrs. Johnson Ereshie Egem for their moral and financial supports.

My special thanks to my Mr. Peter Adeoye for his constructive criticisms of the research manuscripts in spite of his tight schedules.

My greatest regards to my brothers, sisters and cousins, it also gives me a great pleasure to express my gratitude to friends and well wishers who have contributed in one way or the other.

My sincere appreciation goes to the HOD and all the lecturers of this department, I am very grateful.

Other who contributed in diverse ways, I recognize and appreciate all your efforts. May the good Lord Almighty continue to bless and reward you all.

ABSTRACT

This project discusses the various aspects of one particular form of water treatment-the "Slow Sand Filtration" process. This volume also shows objectively the setting up, factors, design consideration of a typical slow sand filter, the testing and results of tests conducted on both raw and treated water.

Dairy waste water discharged from the milk production pallor of Maizube farm in Minna Niger state, was collected and treated by running it through the filter. The raw and filtered water were tested for some parameters such as; the pH, conductivity, hardness, COD, TSS, TS, DO, alkaline and BOD. The results for these parameters indicates; DO 0.8mg/land 28.0mg/l, hardness 230mg/l and 125mg/l, pH 6.12 and 6.04, conductivity 657μ/l and 558μ/l, alkaline 490mg/l and 314mg/l, BOD 64mg/l and 33mg/l, COD 7.9mg/l and 6.4mg/l, TDS 440mg/l and 241.3mg/l, TS 50.13mg/l and 31.21mg/l, TSS 390.19mg/ and 333.2mg/l for raw and treated water respectively. While results from calculation on percentage removal efficiency indicates that from 100% hardness, BOD, TSS, pH, alkaline, conductivity, 45.65% hardness, 48.44% BOD, 15.22% conductivity, 37.74% TS and 35.92% alkaline were removed.

Analysis made from these results shows that the parameters tested for, meets the WHO standard permissible. Showing the effectiveness of the slow sand filtration process as a means of water treatment, and should be recommended for domestic and household use especially in rural area. And also for treatment of water for irrigation purpose in regions such as the Deltaic region, forest zones etc, were there is problem of Sodicity (sodium rich) or Sodic soils and salinity (excess salt).

TABLE OF CONTENTS

List of Figure

List of Tables

List of Symbols and Abbreviations

T.S	Total solids
T.S.S	Total suspended solids
B.O.D	Biological Oxygen Demand
pH	Potential Hydrogen
DO	Dissolve Oxygen
SSF	Slow Sand Filter
COD	Chemical Oxygen Demand
TDS	Total Dissolved Solids
UC	Uniformity Coefficient
NTU	Nephelometric Turbidity Units
Ψ	Ratio between specific diameter and effective diameter
Φ	Shape factor
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Slow sand filtration has been an effective water treatment process for preventing the spread of gastrointestinal disease for over 150 years, having been first used in Great Britain and later in other European countries. Its efficacy was demonstrated during the 1892 cholera epidemic in Hamburg, Germany, when the science of microbiology was in its early years of development.

Slow sand filters do not need constant operator attention, making them an appropriate technology for water systems that are small or that employ part-time operators. During the 1970s through the 1990s, research and field evaluations of slow sand filtration have demonstrated its efficacy for control microbiological contaminants that were unknown in the 1800s. In addition, pretreatment processes such as roughing filters and preozonation have been developed or adapted for use with slow sand filters, increasing the range of source waters that can be treated and the number of contaminants that can be removed in slow sand filters. Inclusion of a layer of granular-activated carbon in a slow sand filter bed has improved capability for control of synthetic organic chemicals. This report views design concepts and process capabilities for slow sand filters and discusses recent innovations in slow sand filters design now enable this technology to be applied more widely than would have been appropriate two decades ago.

The key words here are: slow sand filter, design, operation and maintenance, microbiological contaminants, small systems, pretreatment.

Slow sand filters are used in water purification for treating raw water to produce a potable product. They are typically 1 to 2 metres deep, can be rectangular or cylindrical in cross section and are used primarily to treat surface water. The length and breadth of the tanks are determined by the flow rate desired by the filters, which typically have a loading rate of 0.1 to 0.2 metres per hour (or cubic metres per square metre per hour). Many municipal water treatment works will have 12 or more beds in use at any one time, smaller communities or households may only have one or two filter beds.

Slow sand filtration technology is especially appropriate for small communities that are required to use filtration to comply with new regulations.

1.2 Purpose of Filtration

The purpose of filtration is to remove suspended matter from water. Two types of filters are discussed in this paper, namely Slow Sand Filters, Slow gravity Sand Filters.

1.3 Slow gravity sand filters

Safe drinking water is a high priority for people living without mains facilities. This tip-sheet outlines the necessary testing procedures and tells you how to construct a reliable cleansing filter for small volume of water.

Slow gravity sand filters remove bacteria and other small particles from drinking water, making it safe to drink. This tip-sheet provides a basic introduction to the subject and is for people who wish to maintain a constant supply of clean, running water using simple technology. The sand filter described above (slow sand filters) is designed for domestic use only.

1.4 Theory

i. The action of a slow sand filter is much the same as that of a rapid sand filter. With a filtration rate of 2 to 5 m/d, compared with about 5m/d of a rapid sand filter. The area required to produce the same quantity of water as a rapid sand filter is at least 20 times more.

ii. The slower filtration rate gives the bed a greater efficiency in removal of floc particle or suspended matter than is obtained by a rapid sand filter. Slimes made up of bacteria growths play a larger part in removing organic matter from the water than in case of rapid sand filter.

1.5 How the filter works

The water passes through the sand from top to bottom. Any larger suspended particles are left behind in the top layer of sand. Smaller particles of organic sediment left in the filter are eaten by microscopic organisms including bacteria and protozoans which 'stick' in the layers of slime that form around the sand particles and 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.

1.6 Physical Characteristics

Slow sand filtration is a water purification process in which water is passed through a porous bed of filter medium. Slow sand filters are typically characterized by certain design components: the supernatant (water above the filter sand that provides hydraulic head for the process), filter sand varying in depth, the under drain medium (usually consisting of graded gravel), and a set of control devices (Sims). In a mature sand bed, a thin upper sand layer called a Schmutzedecke forms. The Schmutzedecke consists of biologically active microorganisms that break down organic matter while suspended inorganic matter is removed by straining (Van Duk). Slow sand filters are distinguished from rapid sand filters by the biologically active sand medium (including the Schmutzedecke), and slow detention times. Rapid sand filters utilize primarily a physical removal process, are periodically backwashed for cleaning, and operate with long detention times. Slow sand filters are cleaned by periodically scraping the existing Schmutzedecke (Van Duk). Figure 1.0 is a schematic of a common cross section of a slow sand filter. The supernatant serves two distinct purposes. First, it provides a head of water sufficient to pass the raw water through the filter bed. Second, the supernatant creates a detention time of several hours for the treatment of the raw water. The supernatant should not be considered as a reservoir for sedimentation. If the raw water has a high content of suspended mater, then pretreatment should be considered to prevent rapid clogging of the filter bed. The supernatant depth is typically a meter (Van Duk).

The physical characteristics of a sand bed are important in maintaining the slow sand filter's efficiency. The effective size is the size opening that will pass ten percent by weight of the filter material (Haarhoff). Effective sizes in the range of 0.15 mm to 0.35 mm are used (Van Duk). The uniformity coefficient is the ratio of the size openings that pass sixty percent of filter material to the size openings that pass ten percent of filter material, e.g. the effective size (Haarhoff). Uniformity coefficients range between two and five; most facilities maintain uniformity coefficients less than three (Haarhoff). The filter medium itself should consist of inert and durable grains;

sand should be washed so that it is free of clays, loams, and organic matter. Depth of a filter bed ranges between 1.0 and 1.4 meters (Van Duk).

1.7 Filter media and cleaning

The sand bed may vary in thickness from 300mm to 700mm when the sand bed is blocked, the filter is drained , allowed to dry out and about 6mm of upper sand is removed. Each cleaning, therefore, reduce the thickness until the minimum of 300is reached. The bed is then restored to its original thickness by replacing the newly washed sand. Smaller diameters may cause shorter uneconomical filter runs.

A minimum of three filters is recommended, if one filter is put out of operation and cleaned, water can still be produced in the other filters. I.e. raking the surface of the sand will lengthen the time between scrapings.

1.8 Statement of problem

The increasing population, demand for safe and potable drinking water calls for tremendous expansion and maintenance of water supply sources and also the treatment of water supplied to people for consumption in several countries, particularly in low-and middle–income class, frequently called developing countries.

1.9 Objective to the Study

i. To design and construct a slow sand filter model

ii. To conduct a performance evaluation on constructed slow sand filter in removing undesirable elements such as pathogens, bacteria, odour, sand, taste and other parasitic organisms from water.

1.10 Justification of the Study

On successful completion of this project, records on problems of endemic proportion of millions of people (particularly children) that die annually due to unsanitary water, dearth of water, inadequate hygiene as well as deaths due to waterborne diseases in many rural communities will be properly addressed.

1.11 Scope of Study

This project covers the design and construction of a slow sand filter, the treatment of water using slow sand filter, also it deals with the selected materials of construction and testing of the filters to check its efficiency or otherwise. Though the installation of a slow sand filter requires a large plot of land, for the purpose of this project a small model was constructed to be used in the demonstration of the working principles of a slow sand filter.

CHAPTER TWO

2.0 LITERATURE REVIEW

Slow sand filtration technology is especially appropriate for small communities that are required to use filtration to comply with new regulations; this manual design is intended to serve their special need.

Literatures from various authors have indicated that the first instance of filtration as a means of water treatment dates from 1804, when John Gibb designed and build an experimental slow sand filtration for his bleachery in paisley, Scotland and sold the surplus treated water to the public at a half penny per gallon(Baker, 1949).

John Gibb and others improved on the practical details and in 1829 this method was adopted for "public supply" when James Simpson constructed an installation to treat the water supplied by the Chelsea water company in London. By 1852, the practice had become so established, and its advantages so evident, that the metropolis water Act was passed requiring all water derived from the River Thames within 5 miles of St. Paul's cathedral to be filtered before being supplied to the public (HUISMAN, EWOOD, 1974). At that time, the existence of pathogenic bacteria was unknown, and slow sand filter was regarded as a mechanical means of straining out turbidity and suspended solid/particles.

Although slow sand filtration technology has been widely used in Europe since the early 1800s, its current use in North America has been primarily limited to smaller communities in New England. With the recent insurance of the Surface Water Treatment Rule by United State Environmental Protection Agency and new filter requirements for all surface water systems to ensure removal of Giardia cysts, there is renewed interest in slow sand technology.

2.1 Filtration

Filtration is the process whereby water is purified by passing it through a porous material (or "medium"). In slow sand filtration, a bed of fine sand is used through which the water slowly percolates down ward. Due to the fine grain size the pores of the filter bed are small. The suspended matter present in the raw water is largely retained in the upper filter bed. This allows the filter to be cleaned by scraping away the top layer of sand. As low rates of filtration are used, the interval between two successive cleanings will be fairly long, usually several months (Hoper et el, 1981).

The filtration rate may be determined by a flow meter in one of the lines or by a weir in the outlet tank. Unless the raw water is particularly well treated to about 20 turbidity units or less, this figure should be maintained, unless very reliable post-SSF disinfection is in place. High turbidity levels in the raw will prematurely block SSF, leading to a more shortened time span between cleanings and an overall deterioration of the water quality. High turbidity in the raw water shortens the filter life from several months to a matter of days. The horizontal roughing filter is a very effective means pre-treating the raw water to reduce the turbidity to acceptably levels, from an average of about 200 units, with occasional short-term peaks to around 1000, down to about 20. If the river water turbidity is around 20 units or less, except at certain periods of the year, the HRF could be by-passed most of the year and brought on line during these periods. Other means of turbidity reduction include holding ponds and sedimentation tanks. As with other granular media filtration processes, slow sand filtration performs best when the filtration rate is constant, so frequent rate increases must be avoided. Especially to be avoided is the opening and closing of effluent valves on a frequent basis to maintain a desired water production rate over a day's time. Stopping and starting a slow sand filter may seriously impair filtrate quality, start-stop operation during a filter run is known to be detrimental to filtered water quality in rapid rate filters, and particle attachment is likely to be weaker in slow sand filters because chemical coagulation is not used for slow sand. Likewise, slow sand filters need to be designed for operation on a 24h/d basis, without the need for abrupt filtration rate increases. Provision of filtered water storage sufficient for 1d of use eliminates the need for water production to match system demand and thus allows operators to avoid making frequent rate changes that could deteriorate filtered water quality. Operational flexibility is enhanced when multiple filter beds are provided. So when one bed is removed from service for scraping or sand replacement, others are able to provide a sufficient supply of filtered water without operating at excessively high rate.

2.2 Types of Filters

Basically there are two types of filters. They include:

i. Gravity filters

ii. Pressure filters

The pressure filters consist of closed vessels (steal shells) containing beds of sand or other granular material through water is forced under pressure. Such filters are commonly used in industrial situations; little number of them is install for public water supply.

The gravity filters consist essentially of an open topped box (concrete) drained at the bottom, partially filled with a filtering medium (clean sand). Raw water is admitted to the space above the sand, flows downward under the action of gravity. Purification rates place during this downward passage and the treated water is discharged though the under- drain.

Gravity filters are sub-divided into;

i. Slow gravity filter

ii. Rapid gravity filter

2.3 Features of SSF

Slow sand filters have a number of unique qualities;

Unlike other filtration methods, slow sand filters use biological processes to clean the water, and are non-pressurized systems. Slow sand filters do not require chemicals or electricity to operate.

1. Cleaning is traditionally by use of mechanical scraper, which is usually driven into the filter bed once it has been driven out. However some slow sand filter operators use a method called "wet harrowing" where the sand is scraped while still under water, and the water used for cleaning is drained to waste.
2. For municipal systems there usually is a certain degree of redundancy, it is desirable for the maximum required throughput of water to be achievable with one or more beds out of service.
3. Slow sand filters require relatively low turbidity levels to operate efficiently. In summer conditions and in conditions when the raw water is turbid, blinding of the filters occurs more quickly and pre-treatment is recommended.

4. Unlike other water filtration technologies that produce water on demand, slow sand filters produce water at a slow, constant flow rate and are usually used in conjunction with a storage tank for usage. This slow rate is necessary for healthy development of the biological processes in the filter.

2.4 How SSF works

Slow sand filtration relies on both physical and biological activities in controlling plant pathogens.

In a slow sand filter, the bed is constructed of a medium with high surface area which can be colonized by suppressive micro-organisms. This fine media also present a physical barrier to the passage spores of plant pathogens. Bacteria such as representative of the germs psendomonas and trichoderma have been demonstrated as biological control agents effectively controlling plant pathogens in systems.

In a SSF, plant pathogens recirculation in the irrigation water are captured in the filter media, and at slow rates of water filtration (100-200l/hr/m^2 surface area of filter), are acted upon by the antagonistic micro organisms that colonized the filter bed.

The efficiency of ssf depends on the particle size distribution of the sand, the ratio of surface area of the sand filter to depth and the flow rate of water through the filter. The finest grade sand fractions and granulated rock wool have been shown to be most efficient in controlling diseases such as phytopthora, pythium and fusarium oxysporum, the most widespread nursery diseases. Slow sand filters are usually covered when they are used in cold climates where supernatural water could freeze. In the past, open slow sand filters were used in Denver, Colorado, in spite of freezing conditions, but the operating strategy was to clean the filters in fall before the freeze and then run through the winter, not cleaning the beds again until ice melted in spring. For small systems the cost of a covered filter generally will be worth the investment, as ice formation can be prevented and covered filters can be cleaned whenever needed. Covered filters must provide sufficient headroom for operators to stand erect when performing filter maintenance. Failure to do so will cause very difficult working conditions.

Monitoring needs for slow sand filters are not complicated. Filtered water flow can be monitored using a totalizing meter, and head loss can be monitored by simple water piezometers if the layout of the plant permits this. Turbidity should be monitored continuously, and sample taps should be provided for raw water and filtered water. If sample taps instruments are located so they can easily be accessed, sampling and maintenance activities will be easier to carry out. Generally, filtered water is disinfected at the plant, so a sample tap for finished water is needed also. Most data other than turbidity can be recorded once a day by the operator.

2.5 Advantages of SSF

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

1. it is a low energy consuming process
2. it has great adaptability in components and applications maintenance is minimal

3. systems can be built and installed by laymen

4. Costs of building and running significantly lower than other disinfestations methods.

2.6 Limitations of SSF

1. An important limitation is the need for high quality source water or appropriate pretreatment or filter modification to cope with water quality that is less than ideal.

2. perhaps the most important limitation for using slow sand filtration is the lack of a way to predict a priori the treatability of a source water

3. If treated water quality is not satisfactory, providing a remedy could be very expensive.

2.6.1 Application of SSF for Small Water Systems

Slow Sand filtration is a water treatment process that is well suited for use by small water system (Leland and Dame wood 1990). Visscher (1990) observed that the process was being applied in developing countries and that it was appropriate for small water systems in other counties. The simplicity of the process, especially absence of chemical coagulation for pretreatment, enables these filtration plants to be operated by part-time personnel who have little training in chemistry and microbiology. This was demonstrated in England in the 1800s when slow sand filters were operated successfully in an era before the present understanding of water chemistry and microbiology had been developed. The small amount of operator attention perhaps an hour per day, fits well with the financial capabilities of many small systems that do not sell sufficient water to pay for the salary of a full-time operator. Slow sand filters that are designed for manual operation with a minimum of instruments and electronic controls are less likely than automated package plants employing coagulation and filtration to need service by an electronics technician who may be located hundreds of kilometer away.

Slow sand filter plants some times can be constructed by local population, which may reduce project cost and can be an economic benefit to those in the community who perform the construction. Use of modular, precast concrete boxes as filter beds strengthens the quality control aspect of construction. Providing a structure to house slow sand filter beds is not greatly different from construction of houses or commercial buildings, so this aspect of construction is certainly an appropriate task for the local labor force.

2.7 Effects of Algae on Filters

Although algae do not take part in the filtration mechanism, certain types of algae can have significant effects on the working of a biological filter. These effects may be beneficial or harmful, depending on a variety of conditions.

Practically, all surface water contains algae, their presence contributing to the natural regenerative processes in streams, rivers, and lakes. According to the nature of the water source, its pH, temperature, chemical composition and turbidity, the concentration of nutrients it carries, its depth and velocity of flow, the amount of sunlight it receives, and other factors, different species will predominate. The algae found in a section of a shallow fast flowing stream, for instance, may not be the same as those prevalent in a deep pool or reservoir fed by that stream. For the same reason the algae predominating in the supernatural water of a filter may markedly differ from those in the raw water source from which it is drawn. Both groups, however, will have an influence on the efficiency of subsequent filtration, the algae in the raw water affecting the dissolved oxygen content at the point of entry to the supernatural reservoir, and the algae in the supernatant water itself producing a number of changes in the chemical quality of the water within the reservoir during the waiting period before it passes downward into the sand bed. (Huisman and Wood, 1974)

As autotrophic organisms, algae need light for their photosynthetic processes and are therefore likely to be almost entirely inactive in the supernatant water when the filter structures are covered. Even in uncovered filter reservoirs their growth may be markedly reduced if the raw water is sufficiently turbid, to cut off the essential sunlight. (Huisman and Wood, 1974).

Process is the ability to build up cell material from simple minerals such as water, carbon dioxide, nitrates and phosphates. The carbon cycle may be described by the relationship;

$n(CO_2) + n(H_2O) + \text{energy} \rightarrow (CH_2O)n + n(O_2)$ ....(1)

The energy they required for their metabolism is derived from the oxidation of organic matter. The reverse reaction cell is liberated to be consumed by the bacteria of the filter bed $(CH_2O) + n(O_2)$

$n(CO_2) + n(H_2O) + \text{energy}$ .... (2)

The relative magnitude of these two reactions governs the growth, constancy, and decline of the algae population.

As long as algae are in an active state of growth (in spring and summer in temperature climates and longer in tropical areas), reaction (1) predominates, increasing the oxygen and decreasing the carbon dioxide content. The rise in oxygen content, sometimes to as much as three times the lowering of the carbon dioxide content may cause bicarbonates to dissociate into carbonates and carbon dioxide Ca $(HCO_3)_2 \rightarrow CaCo_3 + CO_3 + H_2O$

The lowering of the bicarbonate content will decrease the temporary hardness, and the insoluble carbonate will precipitate, thus contributing to the clogging of the filter. As the growth of algae continues and their volume increases, the downward movement of the water is hindered, necessitating the periodic removal of the algae from the filter surface.

When the algae are in a state, equation (1) and (2) however, requires sunlight. While the degradation of organic matter according to equation (2) continues at all times. The overall effect is thus an increase in oxygen content during daylight hours and a corresponding decrease at night. The diurnal variation may occur during the dark hours, with the unpleasant consequence already mentioned on the previous section (Taylor, 1961-1962).

In northern climates the temperature of the water will fall during autumn, causing algae to die away as their living conditions come less favorable. This result in the liberation of organic matter, the consumption of oxygen and the production of carbon dioxide content will lower the PH value of the water. Even when the oxygen content of the effluent remains satisfactory, part of the filter may be covered with patches of dead algae below which reduction occurs, producing enteric oils of abhorrent tastes. If the temperature drops suddenly, or if conditions becomes unfavorable in some other way (for instance, through the appearance in the raw water of industrial pollutions of an algicidal nature), a massive mortality algae may ensue. So much degradable organic matter is thereby liberated that decay sets in, and the filter must be taken out of service for cleaning. As the conditions will probably affect more than one filter simultaneously, serious difficulties in maintaining both quantity and the purity of the supply (Huiman and Wood, 1974).

Clearly, unless their members are controlled by periodic harvesting, algae in the supernatant water may give rise to serious operational problems that demand constant supervision. (Brix and Gerlach, 1963). In temperate and cold climates areas, in addition to the foregoing hazards there is the possibility of freezing in winter, the filters are often covered in order to exclude the sunlight and inhibit growth of algae. It must not, however, be thought that the actions of algae are entirely adverse; their presence may have beneficial effects that compensate for the disadvantages, especially in warm climates.

Algae use organic matter from the raw water to build up cell material, and although when they die, an equivalent amount of organic material is liberated. The new material is more easily degradable than the old. There is little difference between a closed and open filter in the average oxygen content of the effluent. But the oxygen consumption of the open filter is about 10 times that of the covered. This is due not only to the carbon cycle shown earlier in equation (1) and (2) above, but also to the conversion of unassailable into degradable organic material. The greater oxidative activity means that the chances of harmful organic substances (both living and dead) being destroyed are corresponding increased.

Further beneficial effects of algae growth may be found in the contribution that filamentous species make to the formation of an active schmutzedeck, the zoogleal content of which forms a medium for the trapping and proliferation of plankton, diatoms, and other forms of life. Thus enhancing straining and adsorption. Less suspended matter reaches the filter medium when the schmutzdecke is well established, and this helps cleanings. In addition, favorable environment is provided for protozoa and other higher organisms, which feed on bacteria and materially reduce the number of E.coli and pathogens that reach the sand bed. The algae themselves, according to some investigations, produce substances harmful to bacteria, thus reducing their chances of survival. The species of predominating algae is important. When they are mainly filamentous a zooglea mat is formed with closely interwoven fibers that give it considerable tensile strength. Which when under the influence of strong sunlight, bubbles off pure oxygen, produced within and upon this mat. Its buoyancy is increased and it may be lifted together with adhering growing from the upper surface of the filter bed. This reduces the filter resistance and the rate of flow correspondingly increases, sometimes very rapidly. On the other hand, when small algae such as diatoms predominate, the matting is poorly formed and the resistance of the filter skin is increased. Blooms of such algae can cause a very rapid clogging of the filter bed, resulting in shortened filter run, operation of algae and lower effluent quality. The whole question of the proliferation of algae and of the species that will predominate is bound up with the composition of the raw water, climate and other conditions. Sufficient light, nutrients, and suitable temperature encourage growth; a clear water of low turbidity containing such mineral constituents such as carbon dioxide, nitrates, and phosphates provides particularly a favorable environment for them. Example have shown that water is likely to be poorer in phosphates than in other constituents, either because the source of water has a low initial content of phosphorus salts which have been precipitated in combination with iron, whether occurring naturally or by human activities (Huiman and Wood, 1974).

The presence of heavy algal growth always carries the potential risk that the filter will have to be cleaned too frequently, so that it will be out of service for a great proportion of time and perhaps requires a larger labor than would otherwise be necessary. In temperate climates, this risk is accentuated during season of rising temperatures, which may cause extensive and sudden algae blooms, and in periods of falling temperature, massive mortality may occur. In tropical climates, other meteorological or seasonal changes may bring about similar phenomena. (Huiman and Wood, 1974)

Covering the filter helps to solve this problem longer and results to more regular filter run, and cleaning may be carried out by day or night and during periods of first or other inclement weather. The absence of algae in the raw water reservoirs of a covered filter may lead to some what reduced filter efficiency; particularly with respect to the reduction intestinal bacteria. But a compensating benefit may accrue from the exclusion of wind borne contamination or bird droppings. (Huiman and Wood, 1974)

Under tropical conditions in which the periods of blooming and drying of algae are less pronounced and ice formation does not occur, filter cleaning normally becomes necessary only at regular and not too frequent intervals, and there is little justification in covering filters. With each filter cleaning, all algal materials are removed, both dead and living. New algal material is brought in by the raw water, and the reaction according to equation (1) predominates. So causing an increase in oxygen content, which in turn allows more organic matter to be degraded. At the same time the carbon dioxide content decreases, rendering the water less corrosive, and the concentration of nutrient salts and organic material is reduced, lessening the load on the filtration processes.

The straining and purifying effects of the schmutzdecke in open filters will contribute to the overall efficiency by maintaining the hygienic quality of the effluent, decreasing filter clogging, and prolonging filter run.

2.8 Application of Slow Sand Filtration in Irrigation Technology

Slow sand filtration apart from being used as a method of water purification for human consumption is currently gaining attention in irrigation technology. Its potential for use in horticulsoture is still under research. At the recent Australian Hydroponics conference in Sydney, Gail Barth from the south Australian plant research centre outlined the technique and its potential role in assisting horticultural produces to meet current and future environmental guidelines [Roger Fox, 1995] Ms Barth first became interested in the technique after visiting at the Geseinhein research centre in Germany, in 1991. There, Dr. Walter Wahonka has over a number of years been exploring the efficiency of sand filters in removing plants pathogens from water.

Gail subsequently applied to the Australian Hydroponics Association and the HRDC for finding to investigate sand filters further and to encourage their trailing by Australian producers. Approved in 1994, these Australian trails have begun in earnest. (Rogers Fox, 1995). According to Barth (1991) the flow rate are in the order of 100 to 300l/hr per square metre (l/hr/m²) of surface area, compared to the rates of 10 to 15c/sec/m² (36000-54000l/hr/m²) used in micro or drip irrigation systems. This flow rate is just slow but their reliability and simplicity is a major recommendation.

2.9 Construction of a Slow Sand Filter

1. **Housing.**

filters can be constructed in tanks with non-reactive surfaces such as plastic or fiber glass, lined galvanized tanks, poly or concrete tanks of various sizes from 44gal drums (205litres) up to 100,000litre tanks. It may be advantageous to construct two smaller SSF units rather than one large unit so one can be shut down periodically for cleaning or repairs. The capacity of the filter is determined by the surface area of the filters top and not the overall volume of the filter. Considerations must be made of the flow rate to be used when determining tank size.

2. Filter bed.

The filter bed consists of a uniform fine particle sand mixture as specified (see sand specifications). The most critical design feature of the SSF is using a correct sand or alternative media. The filter bed is built to a depth of 1.0-1.5m (or more) with a minimum of 0.8m on smaller filters.

This depth of sand will allow for losses which will occur if the top portion of sand is removed when particulate matter and algae is cleaned from the top of the sand.

3. Sand Specifications.

Sand is characterized by the diameter of the individual sand grains (e.g. 0.15-0.35mm) and the effective size of the composite sand, the ES or d_{10}. d_{10} is defined as the sieve size in mm that permits passage of 10% by weight of the sand. The uniformity coefficient (UC) of sand is defined as d_{60}/d_{10}.

Sand needs to be of a fine grade (0.15-0.35mm is recommended), uniform (the Uc should always be less than 3 and preferably less than 2), and be washed free of loam, clay, and organic matter. Fine particles will quickly clog the filters and frequent cleaning will be required. Sand that is not uniform will also settle in volume, reducing the porosity and slowing passage of water. Sand manufacturers should be able to supply or blend sand to these specifications.

4. Water Source

It is important to start off with a fairly clean source of water, so you will need to get a water sample tested at a laboratory, (details of which usually appear in the yellow pages). Sand filters cannot cope with heavy metals or other excessive pollutants. Their prime purpose is to remove bacteria and particles. It is not appropriate to use the technology to cleanup water contaminated by chemical. If your chosen water source does have high level of contamination, ideally you should locate a new one. If this isn't possible, other methods of filtration may be used, depending on the level of contamination. For example, even spring water or very clean river water should be checked for undesirable contaminants. If the water contains sediment, it should be passed through an initial settling tank before it gets to the sand filter

Operating Sequence

When the filter becomes blocked, it may be cleaned by stopping the flow of incoming water, drain the bed to expose the sand. The surface layer of 3-5cm of soiled sand may than be removed with shovels. When this operation has been carried out 3-4 times a fresh layer of clean sand should be put in position to maintain the thickness of the bed.

Slow Sand Filters

The structure of a slow sand filter is similar to a rapid sand filter in that water is supplied to the surface of a bed of sand of some what smaller particle size, about 0.2-0.5mm and about 1.2m (4ft) deep supported on a bed of graded gravel incorporating an under-drain system. An operating depth of about ½-1m (2-3ft) of water must be maintained above the sand level and the rate of flow restricted to about 100litres per m^2 (2gallons per sq:ft) per hour. Initially, the filtering action of a slow sand filter is the same as that of a rapid filter but suspended matter accumulates at the surface of the sand layer and in a short time a layer of hiring organisms forms which adds a significant biological purifying contribution to the mechanical filtering action. This enables colloidal material to be removed and the bacteria / counts of the raw water are reduced considerably.

Dissolved inorganic and organic material is also consumed by the biological film, resulting in some improvement to colour. The slow sand filter cannot be backwashed in the same way as the rapid filters and when cleaning becomes necessary, much less frequently than with rapid filters, the soiled surface of the sand is exposed by draining and must be manually removed to a depth of 1 or 2 inches. A freshly cleaned bed requires a little time to re-establish treatment so that some duplicate equipment must be installed in a slow sand filter plant.

The advantages of slow sand filters lie in their great simplicity. The maintenance of slow sand filters is simple and requires less critical attention than rapid sand filters. No chemical dosing is necessary with slow sand filters. The serious disadvantage of the slow sand filter is that it requires 40-80 times the land area of a rapid sand filter with the same through-put. In rural situations where space and labour are not serious considerations, this type of plant offers many advantages.

2.10 Standards of Performance for SSF

The following standards of performance for slow sand filters have been recommended.

1. The filtrate should be clear with a turbidity of 1NTU or less.
2. The filtrate should be free from colour (3 or less on the cobalt scale).

3. When the raw water turbidity does not exceed 30NTU, the filter runs should normally be not less than 6 to 8weeks. With the filter head not exceeding 0.6m.

4. The initial loss of head should not normally exceed 50mm. a higher head loss will indicate that the entire sand bed needs overhauling.

2.11 Preparation of Filter Sand

The sand to be used in the filter has to be of specified effective size and uniformity coefficient. However, the available sand or stock sand may not meet the required specifications of the size. As such from a sieve analysis of the stock sand, the coarse and fine portion of stock sand that must be removed in order to meet the size specifications can be computed as indicated below.

From the desired or known values of the effective size D10 and the uniformity coefficient Cu, the desired value of D60 of the filter sand may be computed as;

$$D_{60}=Cu \times D_{10} \quad \text{(i)}$$

Let P_{10} be the percentage of stock sand smaller than the desired D_{10} size, and P_{60} be the percentage of stock sand smaller than the desired D_{60} size (as given by equation (i)).

Since the sand lying between D_{60} and D_{10} size will constitute half the specified sand, the percentage of usable stock sand Pusable is

$$Pusable=2(P_{60}-P_{10}) \quad \text{(ii)}$$

To meet the specified composition, the filter sand can contain 1/10 of the usable sand below D_{10} size. Hence the percentage below which the stock sand is too fine for use is;

$$P_{100}\ \text{fine}=P_{10}-0.1\text{Pusable}$$

Or $$P_{100}\ \text{fine}=P_{10}-0.1[2(P_{60}-P_{10})]$$

Or $$P_{100}\ \text{fine}=1.2P_{10}-0.2P_{60}\text{---(iii)}$$

Similarly the percentage above which the stock sand is coarse for use is

$$P_{100}\ \text{coarse}=P_{60}+40\%\ \text{of usable sand}$$

Or $$P_{100}\ \text{coarse}=P_{60}+0.4\times 2(P_{60}-P_{10})$$

Or $$P_{100}\ \text{coarse}=1.8P_{60}-0.8P_{10}\ \text{.................................(iv)}$$

Estimation of thickness of sand bed

The thickness of the sand bed should be such that the flocs do not break through the sand bed. The thickness of the sand bed can be checked against break through of the floc through the sand bed by Hudson formula:

$$Qd^3h/l=Bi\times 29323\ \text{... (v)}$$

Where

Q=rate of filtration in $m^3/hr/m^2$;

d=sand size in mm;

h=terminal loss of head in m;

l=thickness of sand bed in m;

Bi=break through index whose value ranges between

4×10^{-4} to 6×10^{-3} depending on response to coagulation and degree of pretreatment in filter influent.

2.12 Base Material

The sand layer is supported on base material which consists of 45 to 60cm thick gravel bed. The gravel bed is graded and it is laid in layers. The top most layers should be of small size gravel and the bottom most layers should be of big size gravel. A typical section of base material is as indicated below.

Table 1: shows various sizes of layers

Thickness	**Depth**	**Size**
Top layer	15cm	2 to 6mm
Intermediate	15cm	6 to 12mm
Layers	15cm	12 to 20mm
Bottom layer	15cm	20 to 50mm

Total= 60cm

Thus the empirical formula below can be used to estimate gravel size graduation;

L=2.54k (log10d) .... (vi)

Where

K varies from 10 to 14

L=dept

Table: 2 Comparisons of Slow Sand Filters and Rapid Sand Filters

S/No	Items	Slow sand filters	Rapid sand filters
1	Size of filter bed	Varies from $10m^2$ to $2000m^2$ or more	Varies from $10m^2$ to $50m^2$
2	Filter media of sand	Sand grains are finer Effective size: 0.25 to 0.35mm Uniformity coefficient 3 to 5 Thickness: 90 to 11ocm Reduced to not less than 40 cm by scrapping	Sand grains are slightly coarser Effective size: 0.45 to0.70mm Uniformity coefficient: 1.3 to 1.7 Thickness: 60 to 75cm. Not reduced by washing

3	Base material of gravel	Size: 3 to 65mm Thickness : 30 to 75cm	Size: 2 to 50mm Thickness: 45 to 60cm
4	Coagulation	Normally not required	Essential
5	Under drainage	Provided only to receive filtered water It consists of open jointed earthen ware or perforated pipe laterals discharging into a central drain.	Provided to receive filtered water and also to supply water for back washing of filter. It consists of perforated pipe laterals discharging into a central drain.
6	Rate of filtration	100 to 200 litres per hour per m^2	3000 to 6000 litres per hour per m^2
7	Loss of head	15cm initial to 75cm final	30cm initial to 3m final
8	Method of cleaning	Scrapping of top layer of 15 to 30mm thickness	Agitation and back washing with or without compressed air.
9	Amount of wash water	0.2 to 0.6% of filtered water	2 to 5% of filtered water

10	Period of cleaning	1 to 3 months	1 to 3 days
11	Penetration of suspended matter	Superficial	Deep
12	Supplementary treatment of water	Chlorination	Chlorination
13	Efficiency	Very efficient in the removal of bacteria but less efficient in the removal of colour and turbidity.	Less efficient in the removal of bacteria, but more efficient in the removal of colour and turbidity.
14	Economy	High initial cost of both, land and filter material.	Cheap and quite economical.
15	Flexibility	Not flexible for meeting variations in demand.	Quite flexible for reasonable fluctuations in demand.
16	Skilled supervision	Not essential	Essential
17	Construction	Simple	Complicated as under drainage system is to be properly designed and constructed.
18	Cost of operation	Low	High
19	Depreciation cost	Low	High

20	Suitability	The filter can be constructed with local labor and material. It is suitable for small towns where land is cheaply available.	It is suitable for big cities where land cost high and variation in demand of water is considerable

Table 3: Guidelines for Design of Slow Sand Filters

Description	Recommended design value
1. Design period	10 years
2. Filtration rate	
(i) Normal operation	0.1m/hr
(ii) Maximum overload rate	0.2m/hr
3.Number of filter beds	
(i) Minimum	2
(ii) Area upto $20m^2$	2
(iii) Area 20 to $249m^2$	3
(iv) Area 250 to $649m^2$	4
(v) Area 650 to $1200m^2$	5

(vi)	Area 1201 to 2000m^2	6

4. Depth of supernatant water	1.0m
5. Freeboard	0.2m
6. Thickness of filter sand layer	
(i) Initial	1.0m
(ii) Final (Minimum)	0.4m
7. Sand specifications	
(i) Effective size	0.2 to 0.3mm
(ii) Uniformity coefficient	5
8. Gravel (3-4 layers) thickness	0.3m
9. Underdrains (made of bricks or perforated pipes)	0.2m
10. Depth of filter box	2.7m
11. Effluent weir level above sand bed	20-30mm

2.13 Water Treatment

Undesirable tastes and odors are removed from water by aeration, bacteria are destroyed by the addition of a few parts per million of chlorine and the taste of chlorine is then removed with sodium sulfite. Excessive hardness, which renders the water undesirable for many industrial purposes, is reduced by the addition of slaked or hydrated lime or by an ion-exchange process using zeolite as a water softener. Suspended organic matter, which supports bacterial life and suspended mineral matter are removed by the addition of a flocculating and precipitating agent such as Alum, before settling or filtration. Artificial fluoridation of public water is done in some developed communities as a measure for preventing dental caries.

Pre-treatments

1. Pumping and containment: the majority of water must be pumped from its source or directed into pipes or holding tanks. To avoid adding contaminants to the water, this physical infrastructure must be made from appropriate materials and constructed so that accidental contamination does not occur.

2. Screening: the first stem in purifying surface water is to remove large debris such as sticks, leaves, trash and other large particles which may interfere with subsequent purification steps. Most groundwater does not need screening before other purification steps.

3. Storage: water from rivers may also be stored in bank side reservoirs for periods between a few days and many months to allow natural biological purification to take place. This is especially important if treatment is by slow sand filters. Storage reservoirs also provide a buffer against short periods of drought or to allow water supply to be maintained during transitory pollution incidents in the source river.

4. Pre-conditioning: many waters rich in hardness salts are treated with soda-ash (sodium carbonate) to precipitate calcium carbonate out utilizing the common ion effect.

5. Pre-chlorination: in many plants, the incoming water is chlorinated to minimize the growth of fouling organisms on the pipe-work and tanks. Because of the potential adverse equality effects, this has largely been discontinued.

Widely varied techniques are available to remove the fine solid, micro-organisms and some dissolved inorganic and organic materials. The choice of method will depend on the quality of the water being treated, the cost of the treatment process and the quality standards expected of the processed water.

pH Adjustment

Distilled water has an average pH of 7 (neither alkaline nor acidic) and sea water has an average pH of 8.3 (slightly alkaline) if the water is acidic (lower than 7), lime or soda ash is added to raise the PH. Lime is the more common of the two additives because it is cheaper, but it also adds to the resulting water hardness. Making the water slightly alkaline ensures that coagulation and flocculation processes work effectively and also helps to minimize the risk of lead being dissolved from lead pipes and lead solder in pipe fittings.

Flocculation

This is a process which starts with clarifying the water. Clarifying means remover of any turbidity or colour so that the water is clean and colourless. Clarification is done by causing a precipitate forms as very small particles but as the water is gently stirred, these particles sticks together to form bigger particles. This process is some times called flocculation.

Many of the small particles that were originally present in the raw water absorb onto the surface of these small precipitate particles and so get incorporated into the larger particles that coagulation produces. In this way the coagulated precipitate takes most of the suspended matter out of the water and is then filtered or sometimes through a mixture of sand and granulated anthracite (high quality coal). Anthracite, with its high carbon content is able to absorb much of the organic matter present in solution and this can remove odour and taste from the water.

A precipitate that is widely used to clarify water is iron (III) hydroxide. This is formed first by adjusting (if necessary) the pH of the incoming water to about 7 (by adding lime or sodium hydroxide), then by adding a solution of an iron (III) compound such as iron (III) chloride. Iron (III) hydroxide is extremely insoluble and forms even at a pH as low as 7. Aluminum hydroxide is also widely used as the flocculating precipitate.

Sedimentation

Water exiting the flocculation basin may enter the sedimentation basin, also called clarifier or settling basin. It is a large tank with slow flow, allowing floc to settle to the bottom. The sedimentation basin is best located close to the flocculation basin so the transit between does not permit settlement or floc break up. Sedimentation basins can be in the shape of a rectangle, where water flows end to end, or circular where water flow is from the centre outward. Sedimentation basin outflow is typically over a weir so only a thin top layer-furthest from the sediment-exists. The amount of floc that settles out of the water is dependent on the time the water spends in the basin and the depth of the basin. The retention time of the water must therefore be balanced against the cost of a larger basin. The minimum clarifier retention time is normally four hours (4hrs). A deep basin will allow more floc to settle out than a shallow basin. This is because large particles settle faster than smaller once, so large particles bump into and integrate smaller particles as thy settle. In effect, large particles sweep vertically through the basin and clean out smaller particles on their way to the bottom. As particles settle to the bottom of the basin, a layer of sludge is formed on the floor of the tank. This of sludge must be removed and treated. The amount of sludge that is generated is significant, often 3%-5% of the total volume of water that is treated. The cost of treating and disposing of the sludge can be significant part of the operating cost of water treatment plant. The tank may be equipped with mechanical cleaning devices that continually clean the bottom of the tank or the tank can be taken out of service when the bottom needs to be cleaned.

Filtration

After separating most floc, the water is filtered as the final step to remove remaining suspended particles and unsettled floc. The most common type of filter is a rapid sand filter, water moves vertically through sand which often has a layer of activated carbon or anthracite coal above the sand. The top layer removes organic compounds, which contribute to taste and odour. The space between sand particles is larger than the smallest suspended particles. So simple filtration is not enough, most particles pass through surface layers but are trapped in pore spaces or adhere to sand particles. Effective filtration extends in the depth of the property of the filter is key to its operation. If the top layer of sand were to block all the particles, the filter would quickly clog. To clean the filter, water is passed quickly upward through the filter, opposite the normal direction (called back flushing or back washing) to remove embedded particles. Prior to this, compressed air may be blown up through the bottom of the filter to break up the compacted filter media to aid the backwashing process; this is known as air scouring. This contaminated water can be disposed off along with the sludge from the sedimentation basin, or it can be recycled by mixing with the raw water entering the plant.

Some water treatment plants employ pressure filters. These work on the same principle as rapid sand filter (gravity filters), differing in that the filter medium is enclosed in a steel vessel and the water is forced through it under pressure.

Ultra Filtration

Ultra filtration membranes are a relatively new development; they use polymer film with chemically formed microscopic pores that can be used in place of granular media to filter water effectively without coagulant. The type of membrane media determines how much pressure is needed to drive the water through and what sizes of micro-organisms can be filtered out.

Additional Treatment Options

1. Fluoridation: in many areas fluoride is added to water for the purpose of preventing tooth decay. This process is referred to as water fluoridation. Fluoride is usually added after the disinfection process. In developed nations, fluoridation is usually accompanied by the addition of hexafluorosilicic acid, which decomposes in water, yielding fluoride ions.

2. Water conditioning: this is a method of reducing the effects of hard water. Hardness salts are deposited in water systems subjects to heating because the decomposition of bicarbonate ions creates carbonate ions which crystallize out of the saturated solution of calcium or magnesium carbonate. Water with high concentrations of hardness salts can be treated with soda ash (sodium carbonate) which precipitates out the excess salts through the common-ion effect, producing calcium carbonate of very high purity. The precipitated calcium carbonate is traditionally sold to the manufacturers of tooth paste. Several other methods of industrial and residential water treatment are claimed (without general scientific acceptance) to induce the use of magnetic or electrical fields reducing the effects of hard water.

3. Plumbo-solvency reduction: in areas with natural acidic waters of low conductivity (i.e. surface rainfall in upland mountains of igneous rocks), the water may be capable of dissolving lead from any lead pipes that is carried in.

the addition of small quantities of phosphate ion and increasing the PH slightly. Both assist in greatly reducing plumbo-solvency by creating insoluble lead salts on the inner surfaces of the pipes.

4. Radium removal: some groundwater sources contain radium, a radioactive chemical element. Typical sources include many groundwater sources north of Illinois River in Illinois. Radium can be removed by ion exchange, or by water conditioning. The back flush or sludge that is produced is, however, a low level radioactive waste.

5. Fluoride Removal: although fluoride is added to water in many areas, some areas of the world have excessive levels of natural fluoride in the source water. Excessive levels can be toxic or causes undesirable cosmetic effects such as staining of the teeth. One method of reducing fluoride level is through treatment with activated alumina.

2.14 Boiling as Water Purification Technique.

Boiling: water is heated hot enough and long enough to inactivate or kill micro-organisms that normally live in water at room temperature. Near sea level, a vigorous rolling boil for at least one minute is sufficient. At high altitudes (greater than two kilometers or 5000feets) three minutes is recommended. In areas where the water is "hard" (that is, containing significant dissolved calcium salts). Boiling decomposes the bicarbonate ions, resulting in partial precipitation as calcium carbonate. This is the "fur" that builds up on kettle elements etc, in hard water areas. With exception of calcium, boiling does not remove their concentration (dice to some water being lost as vapour).

Boiling does not have a residual disinfectant in the water; therefore, water that has been boiled and then stored for any length of time may have acquired new pathogens.

2.15 Hydraulics of Filtration

Studies have shown that the rate of downward flow conditions may be assumed to prevail throughout the bed in a slow sand filtration, the resistance H offered by a clean filter is in accordance with Darcy's law.

$$H = VF,h/K \quad (3)$$

Where:

h= thickness of the bed

K= coefficient of permeability

VF= filtration rate (the volume passing per hour divided by the surface area of the bed.)

The coefficient k has the dimensions of velocity, and may be expressed in meters per hour. Its value is best determined in a laboratory by actual measurement of the resistance of a representative sample of the filtering medium concerned, but it may also be estimated theoretically by using one of the many formulae available.

For example;

$$K = 150\,(0.72 + 0.028T)\,p^3/\,(1-p)\,\varphi^2 Ds^2 m/h \quad (4)$$

Where

T= temperature in degree Celsius

P= porosity (ratio of volume of pores to total volume of filter medium)

Φ= shape factor

Ds= specific diameter of sand grains in millimeters

The shape factor φ is the ratio of the surface area of a sphere to the surface area of an average grain of the material having the same volume; consequently, it cannot have a value greater than unity and the less spherical the grains, the smaller it will be. The shape factors for various kind of sand grain are as follow;

Table: 4.0 Shape Factors for Various Kinds of Sand Grains

S/N	SHAPES	SHAPE FACTORS
1	Spherical	1.00
2	Nearly spherical	0.95
3	Rounded	0.9
4	Worn	0.85
5	Angular	0.75
6	Broken	0.65

The specific diameter Ds is a means of describing the grain size of an un-graded natural sand, taking into account the variation in size of the individual grain it defined as the size of an imaginary grain from a uniform sand of which a certain weight has the same gross surface area as an equal weight of the filtering medium under consideration.

It is possible to calculate the specific diameter in the following way;

Sample of weight (w) of the material is separated through a series of serve into fractions of weights w1, w2 and wn having liming diameters d1, d2, d3.....dn and dn +1. The value of ds can then be calculated from the relationship below.

$$1/d = \frac{w_1/w}{\sqrt{d_1, d_2}} + \frac{w_2/w}{\sqrt{d_2, d_3}} + \frac{wn/w}{\sqrt{dn+1}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where

d= limiting diameters

w= weight of sample

The use of calculations involving specific diameters is normally restricted to rapid filtration, where grading of the sand must be more accurately controlled than is necessary with slow filtration. In the latter case, the sand is usually characterized by its effective diameter and its coefficient of uniformity. The concept of effective diameter was introduced by A. Hazen as long as 1892; it is defined as the size of the sieve opening through which 10% of the material will just pass and is therefore given the symbol d_{10}. In a similar way, the sieve opening through which 60% of the material will pass is known as d60. The ratio of $d60/d_{10}$ is the coefficient of uniformity (u). Natural sands often have a size/frequency distribution that yields a more or less straight line when plotted on logarithmic probability paper. When this geometric normality is strictly true, the ratio ψ between the specific diameter and the effective diameters (ds/d_{10}) may easily be calculated from the following formulae, with fair accuracy when it is reasonably small (e.g. "between" 1.0 to 2.0).

$$ds = d_{10}\,(1+2\log u) = \psi d_{10} \qquad (6)$$

When the sand is less uniform, ψ may be obtained from the table below;

Table 4: shows the ratio between specific and effective diameter

U	1.0	2.0	3.0	4.0	5.0
Ψ	10.0	1.60	1.93	2.11	2.21

It should also be noted that a sieve with a mesh S will pass grains up to a volumetric diameter d, which may be larger or smaller than S depending on the shape of the sieve opening. For filters with a ratio between d and s varying between 1.05 (rounded grains) and 1.2 (elongated). For ellipsoidal grains, such as are commonly met with in filter sand. A constant ratio of 1.10 is usually assumed, thus: d= 1.10s by substitution of this relationship and of the ratio between specific and effective diameter, the formulae for calculating the coefficient of permeability becomes;

$$K = 150\,(0.72 + 0.028T)\,p^3/(1-p)^2\,\varphi^2\psi\,(1.10s10)^2$$

$$=180\,(0.72 + 0.28T)\,P^3\varphi^2\psi^2\,S10\ 2 \qquad (7)$$

$(1 - p)^2$

Where

K= Coefficient of permeability

P= Porosity

φ= Shape factor

ψ= Ratio between specific diameter and the effective diameter

S10= the clear opening of an imaginary square-woven wire screen that would pass 10% of the filtration material.

T= Temperature in degree Celsius

CHAPTER THREE

3.0 METHODOLOGY AND MATERIALS

3.1 Design Analysis

This chapter provides room for the design considerations of the model. The design considerations are referring to some characteristic which influences the design of this model, quite a number of such characteristic are considered in the design of this model "**Slow Sand Filter**", many of the important once are as follow;

Strength	Live
Corrosion	Shape
Wear	Size
Cost	Stiffness
Safety	Maintenance
Weight	

Some of these have to do directly with dimensions, material selection, sand specification, design calculation and the joining of the model.

Also several factors are put into consideration before embarking on the design of these model, they include;

1. Economy
2. Availability of materials
3. The effectiveness and efficiency of the materials
4. Time available for this project

5. Labour to be used

Based on these considerations and due to financial limitation, the model will be designed as shown figure 0.1.

A slow sand filter consists basically of the following components;

1. Housing
2. Water layer
3. Filter bed
4. Drainage chamber
5. Flow control

The whole length of the water filter is 80cm, the water layer is25cm, to allow for gravity flow down the filter medium through to the drain chamber. The drain chamber is meant to receive the filtered water is made to be 10cm, the diameter of the filter is 30cm, and the shape is cylindrical.

3.2 Material Selection

This is the material science which deals with the selection materials, bearing in mind the need to satisfy service at affordable cost. A number of materials are examined for their ability to be machined, that can withstand the application. The procedures followed in selecting materials are;

1. Analysis of the material requirement in term of service and environment
2. Examinating the material in terms of properties that are relevant to the application
3. Material performance cost, and availability.

3.3 Material and Apparatus

The following materials and apparatus were used in the construction;

1. Mild steel
2. Perforated clear plastic glass sheet
3. Brazing rods
4. Electrode
5. Marker
6. Straight edge
7. Measuring tape
8. manual cutter
9. folding machine (Edward folds)

3.4 Marking Out

This was the first step to be carried out. The mild steel sheet was marked out according to the predetermined dimensions and this was done using marker, measuring tape and a straight edge. The four major parts of the sheet were marked out and a circular shape of radius 15cm was equally made. The perforated clear plastic sheet was also marked out into circular shape with the same radius.

3.5 Cutting Out

The marked out sheets were then cut into the various dimensioned, this was done using the manual cutter. Care was taking to properly set the sheet on the machine before cutting.

3.6 Folding

The mild steel with dimension 80cm×96.8cm was fold into circular shape using the folding machine (Edward folds)

The filter beds were made of a brazing rod (1/4mm) with predetermined dimensions with radius 15cm, then inserting each of the bed into the folded drum in sets, according to range of measurement.

3.7 Welding

All the mentioned parts were then assembled and then weld, the 80cm×96.8cm mild steel, pipes, handle, filter beds of different layer were all welded and assembled. But are made to be removed and replaced in case of any damage or maintenance.

3.8 Coating

The whole filter was then coated with red oil paint in order to prevent or minimize corrosion.

3.9 Determination of grain size and sieve analysis

The apparatus used for the particle size analysis include;

1. Sieve to British Standard test Bs.
2. Mesh of the following sizes 2.0mm, 2.36mm, 850µm, 212µm lip and pan.
3. Weighing balance/machine.
4. Mechanical shaker.

Procedure

1000g of the sample of sand was measured, weighed using the weighing balance pan. The sieves and pan were fitted together to form a nest of sieves, with the sieve having the smallest aperture below just before the pan and that with the largest aperture on top. The weighed sample was then placed in the arranged sieve set and clamped on the mechanical shaker.

The shaker was set on motion for 10 minutes; the volume sand retained on each nest sieve was weighed on the weighing balance and the values.

3.10 Definition of Gram Size and Sieve Analysis.

Apparatus: - the apparatus used for the particle size analysis include:-

1. Sieve to British standard text Bs.
2. Mesh's of the following sizes 2.0mm, 2.36mm, 850μm, 212μm lid, and pan.
3. Weighing balance/machine.
4. Mechanical shaker

Procedure

1000grames of the sample of sand was weighed, using the weighing balance pan.

The sieves and pan were fitted together to form a nest of sieves, with the sieve having the smallest apertures below just before the pan and that with the largest aperture on the top. The weighed sample was the placed in the arranged sieve set and damped on a mechanical shaker.

The shaker was set on motion for 10 minutes, the volume of sound retained on each nest sieve was weighed on the weighing balance and the values were measured and recorded. The retained weight were subsequently added in sequence and the cumulative figures recorded. This was used to plot a summation curve from which the effective size (E) and the coefficient of uniformity (U) were determined.

Table 6: Shows the results of sieve analysis from a total of 1000gramm of sand.

Sieve Diameter	Weight of sand retained
2.00mm	- 340g
2.36mm	- 310g
850μm	- 450g
212μm	- 730g
pan	- 600g

3.11 Grading of the Sand

The washed dry sand was graded using four sieves of 2.36mm, 2.00mm, 850μm, 212μm aperture opening.

The sand was first sieved using the 2.36mm opening, what ever retained on it was thrown away and the percentage that passes through was sieved using the 2.00mm opening and whatever retained on it was also thrown away, the process was done using all the nest (sieves) and the percent retained on the 2.00mm, 2.36mm and 850μm sieve becomes the desired grade of sand used.

3.12 Procedure for Filling Filter Beds/Justification

After sieving the sand using sieves of various apparatus, the model was then empty the first layer if the bed contain gravel and drain chamber was fitted in cylinder and gravel pored to 5cm from the bottom of the cylinder leaving 5cm for drain then plastic glass which separates the fitter bed from the second layer. Then a light textile material (popularly known as china yard) was used to cover the perforated plastic glass. This textile material helps to trap fine sand particles that are mixed with the water which comes from the upper layers.

Next, the second filter bed 10cm of height was then filters into the cylinder so that it lay on the first filter bed. These buyers contain finer sand 0.1mm in diameter. Perforated plastic glass 2mm thick was also used to cover the top of the second lay. These processes was repeated up to the fourth layer 25cm of height, which contain water layer 25cm height at the top of the cylinder, there is a feel inn top which water released into the cylinder.

3.13 Justification

The often layer because water flow in sand through gravity. So the higher & wider the water layers the faster water flow through the sand.

SSF relies on both physical and biological activity in controlling plant pottages.

- **Water layer: -**

The water layer above the filter bed provides the head to push water through the filter bed on gravity. It is convenient as a water storage zone and provides an effective temperature buffer to stabilize the filter and protect the biological activity occurring in the top buyers of the filter bed. A minimum depth of

0.5m up to 1.5m is not commonly used, but for experimental/practical purpose, a depth of 25cm (0.25m) was used for these projects. Research suggests that this water layer should be maintained at a constant depth by the use of a small pump from an overflow tank or from the filtered water reservoir this is particularly important if nutrient solution or recycled water is introduced into the filter in pulse or not continuously.

- **Filter Bed:-**

The filter bed consists of a uniform fine particle sand mixture, the first layer consist of coarse sand or also known as the hypogeal layer, it allow for rapid flow of water, trap plant stucks and consists of bacteria, fungi, protozoa, rotifera and a range of aquatic insect larval. More algae tend to develop and larger aquatic organisms may be present including some bryotoa, snails and Annelid worms. This layer provides the effective purification in potable water treatment, the underlying sand that is the second and third layer provides the support medium for the biological treatment layer. As water passes through the first layer (coarse sand layer), particles of foreign matter are trapped in the mucilaginous matrix and dissolved organic material is adsorbed, absorbed and metabolized by the bacteria, fungi and protozoa. The water produced from a well – managed slow sand filter can be exceptionally good quality with no detectable bacterial content.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents and discusses the calculation made before and after the model was constructed.

- The test carried out
- The results
- Discussion and cost analysis.

4.2 Calculation

Volume of water layer = $\pi r^2 \times h$

r = radius

h = height

$= 3.142 \times (15)^2 \times 25$

$= 17673.75cm^3$

Volume of fitter bed = $\pi r^2 \times h$

First layer=

r = 15cm

h = 20cm

$= 3.142 \times (15)^2 \times 20$

$= 14139cm^3$

Second layer = $\pi r^2 h$

r = 15cm

h = 15cm

$= 3.142 \times (15)^2 \times 15$

$= 10604.25\ cm^3$

Third layer =

$3.142 \times (15)^2 \times 10$

$7069.5cm^3$

Total volume of filter bed = $31812.75cm^3$

Volume of Drain = $\pi\ (15)^2 \times 10$

$= 7069.5cm^3$

Total volume of SSF

$= \pi r^2 h$

$r = 15$

$h = 80$

$= 3.142 \times (15)^2 \times 80$

$= 56556cm^3$

4.3 Sieve Analysis Results

This analysis is necessary to discard the too fine and too coarse sand. For a fitter to be efficient and standard, preliminary analysis such as these is conducted in order to determine the most suitable grade of sand.

Table 7: shows the result of the sieve analysis.

Sieve dia.	Weight retained	Percentage retained	Cumulative (%)	Percentage passing
2.36mm	340g	14	14	86
2.00mm	310g	75	26.75	73.25
850μm	450g	52	45.27	54.73
212μm	730	04	75.31	24.69
pan	600	24.69	100	0.00
	Total = 2430			

4.4 Tests

The following parameters were tested both for the raw water and for the filtered water

1. pH
2. BOD
3. TS,
4. DO
5. Hardness
6. TSS
7. Conductivity
8. Alkaline
9. COD
10. TDS

4.5 Discussions

Due to the nature of the sample analyzed, which is found to be very weak in dissolve oxygen, 20ml of the sample was taken and diluted with into 400mls of distilled water. The first BOD was analysed and multiplied by the factor, while the second BOD was repeated 5days later and was treated as same before the subtraction.

Table 8: Show Analysis Test Results

Variables	DO mg/l	Hardness mg/l	pH	Conductivity µs	Alkaline mg/l	BOD mg/l	COD mg/l	TDS mg/l	TS mg/l	TS mg
Before treatment	0.8	230	6.12	657	490	64	7.9	440.19	50.13	39
After treatment	28.0	125	6.04	558	314	33	6.4	241.3	31.2	33.

Calculations

S/No	Variable	Raw Water	Treated Water
1.	Hardness	230	125

230-125=105

Percentage hardness removal efficiency

$=105/230\times 100=45.65\%$

2.	BOD	64	33

64-33=31

Percentage BOD removal efficiency

$31/64\times 100=48.44\%$

3.	Conductivity	657	558

657-557=100

Percentage conductivity removal efficiency

$100/657\times 100=15.22\%$

4.	TS	50.13	31.21

50.13-31.21=18.92

Percentage total solid removal efficiency

18.92/50.13×100=37.74%

5. Alkaline 490 314

490-314=174

Percentage alkaline removal efficiency

174/490×100=35.92%

4.6 Cost Analysis

In carryout this project, certain cost was incurred, this includes:-

i. Cost of materials used

ii. Labour

iii. Transport and miscellaneous Expenses.

Table 9: Cost Analysis

S/No	Item & Description	Amount ₦
1	1/3 sheet of mild steel	₦1, 300
2	½ length brazing rod	₦850
3	½ plastic glass galvanized sheets.	₦750
4	Sand	₦1000
5	Labour	₦2000
6	Test	₦2000
7	Tape head	₦300
8	Transport	₦1400
	Total	₦9600

10% contingencies

= 10/100 x 9600 = ₦960

Total cost = total amount + 10% contingencies

= 9600 + 960

= ₦10, 560.

CHAPTER FIVE

5.0 CONCLUSION

The major aim of this project is to make available safe and portable drinking water for consumption to people in rural areas.

Slow sand filters have a long history of successful. Water treatment, when applied to appropriate source waters and when designed and operated properly, failures have happened and will continue to occur, however, if the process is used when source water is not treatable by slow sand or if the design is flawed or basic operating principles are ignored. Design engineers who are aware of the capabilities and limitations of slow sand filtration can in many instances provide for successful use of slow sand filtration by small communities.

5.1 Recommendation

1. The filter should never stand with an exposed dry top layer, or stagnant water which would accumulate only if the filter outlet was closed at the bottom. Continuous filtering assists in development and maintenance of a healthy filter.

2. The depth of water layer should be between 0.5m to 1.5m.

3. Sand needs to be of a fine grade (0.15 to 0.35mm is recommended), uniform (the Uc should always be less than 3 and preferably less than 2).

4. The most critical design feature of the SSF is using a correct sound or alternative media, the filter bed is built to a depth of 1.00 to 1.5m (or more) with a minimum of 0.8m on smaller filters.

5. Filters can be constructed in tanks with non – reactive surface such as stainless steel, plastic or fiberglass lined galvanized tanks, poly or concrete tanks of various sizes from 44gal drums (205 litres) up to 100,000 litre tanks. But it is advantageous to construct 2 smaller SSF units rather than one large unit so one can be shut down periodically for cleaning or repairs.

6. Sand should be thoroughly washed to the absent of turbidity before they are used as filter.

7. The stock sand should be regraded to required design and operation specifications before use in filters.

8. At least two filters are required so that water supply can always be constant even when one is out for maintenance.

REFERENCES

Berkelman et al (1993) in slow sand filtration Rogex fox (1995) Childers, L. and F. Claasen, 'Unicef's upward-flow waterfilter', Waterlines, Vol. 5, No. 4, IT Publications, London, 1987.

Dian Desa, 'Water Purification with Moringa seeds', Waterlines, Vol.3, No.4, IT publications, London, 1985.

Heber, G., Simple methods for the treatment of drinking water, GATE, F. Vieweg, Braunschweig, 1985. IRC, Community Self-Improvements in Water Supply and Sanitation: A training and reference manual for community health workers, community development workers and other community-based workers, Training Series No. 5, International Water and Sanitation Centre (IRC), The Hague,1988.

Hofkes E.H. (ed.), L.Huisman, B.B.Sundaresan, J.M. De Azevedo Netto and J.N. Lanoix, 'Small Community Water Supplies', Technical Paper Series No. 18, International Reference Centre for Community Water Supply and Sanitation (IRC), Wiley, Chichester, 1983.

Holfkes E.H., Husman L., sundarsesan B.B., Netto J.M, and lanoix J.N, (1981) ; Small community water supplies, Technology of small water supply systems in developing countries; 1983 Edition; John Wiley and sons.

Haarhoff, Johannes, and John L. Cleasby. "Biological and Physical

http://www.biosandfilter.org

http://www.manzwaterinfo.ca

Jahn, Samia Al Azharia, Proper use of Natural Coagulants for Rural Water Supplies: Research in the Sudan and a guide for new projects, GTZ, Eschborn, 1986.

Letterman, Raymond D. "Operation and Maintenance." *Slow Sand Filtration.*

Manual of design for slow sand filtration (1991); htt://www.photometer com/en/abc/abc 095.htm

Mechanisms in Slow Sand Filtration." Slow Sand Filtration. New York: American Society of Civil Engineers, 1991.

Modelling slow sand filters:- PhD Thesis, Luiza Campos, Imperial College, 2002.

Mustafa. S. and Yusuf M.I (1999); A textbook of Hydrology and Water Resources; Fist Edition; craft techniques publishers.

Nokomoto, N(2002); Slow Sand Filtration makes a come back Business News Publishing Company New York: American Society of Civil Engineers, 1991.

Pyper, Gordon R., and Gary S. Logsdon. "Slow Sand Filter Design." Slow Sand Filtration. New York: American Society of Civil Engineers, 1991.

Slow san filtration", World Health Organization, 1974 ISBN92 – 4 – 154037 – 0

Slow sand filtration, Huisman L. and Wood, W.E., WHO 1974

Sims, Ronald C., and Lloyd A. Slezak. "Slow Sand Filtration: Present Practice in the

Timms, S., J.S. Slade, and C.R. Fricker. "Removal of Cryptosporidium by Slow Sand Filtration." *Water Science and Technology* 31.5-6 (1994): 81-84.

Sutherland, J.P., G.K.Folkard and W.D.Grant, 'Natural coagulants for appropriate water treatment: A novel approach', Waterlines, Vol. 8, No. 4 , IT Publications, London, 1990.

Singh,V.P. and M. Chaudhuri, 'A perfomance evaluation and modification of the UNICEF upward-flow water filter', Waterlines, Vol.12, No.2, IT Publications, London, 1993.

UN High Commissioner for Refugees (UNHCR) Water Manual for Refugee

Situations", Geneva, November 1992. slow sand filters recommendations listed on page 38

United States." *Slow Sand Filtration*. New York: American Society of Civil Engineers, 1991.

Van Dk .C. and J.H.C.M. Oomer, "Slow Sand Filtration for Community Water Supply in Developing Countries," *Technical Paper No. 2*, WHO International Reference Centre for Community Water Supply, Voorburg (The Hague), The Netherlands, 1978.

APPENDIX

Conversion of volume of water from centimeter cube to liters

1. Volume of water layer

$$=\frac{17673.75}{1000}=17.67\text{liters}$$

2. Volume of filter bed

$$=\frac{14139}{1000}=14.14\text{liters}$$

3. Second layer

$$=\frac{10604.25}{1000}=10.60\text{liters}$$

4. Third layer

$$=\frac{7069.5}{1000}=7.07\text{liters}$$

5. Total volume of filter bed

$$=\frac{31812.75}{1000}=31.81\text{liters}$$

6. Volume of drain

$$=\frac{7069.5}{1000}=7.07\text{liters}$$

7. Total volume of SSF

$$=\frac{56556}{1000}=56.56\text{liters}$$

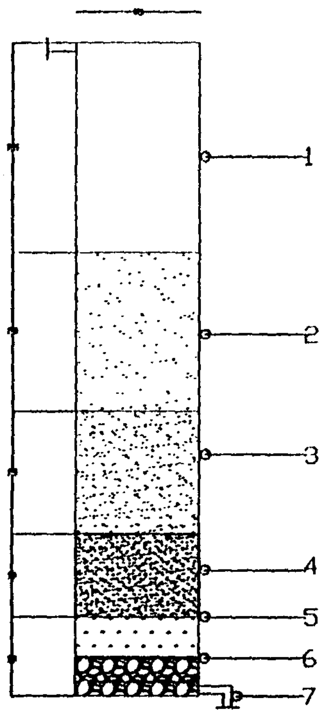

FIGURE 1: SCHEMMATIC DAIGRAM OF A SLOW SAND FILTER

S/NO	KEY
1	WATER LAYER
2	0.25mm DAIMETER SAND
3	0.2mm DAIMETER SAND
4	0.1mm DAIMETER SAND
5	PAFORATED PLASTIC GLASS SHEET
6	DRAIN AND SUPPORTED GRAVEL CHAMBER
7	WATER RELEASE VALVE