# 5TH ANNUAL ENGINEERING CONFERENCE

## SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

## FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

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**Theme:** ENGINEERING AND TECHNOLOGY IN A PRIVATISED ECONOMY

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# FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA

## PROCEEDINGS OF THE 5TH ANNUAL ENGINEERING CONFERENCE HELD ON THE 16TH – 18TH JUNE 2004 AT THE NEW LECTURE HALL I

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## THEME: ENGINEERING AND TECHNOLOGY IN A PRIVATIZED ECONOMY

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# DESIGN AND PRODUCTION OF PROTOTYPE DOMESTIC WATER TREATMENT UNIT FOR RURAL COMMUNITY

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## ABSTRACT

This paper presents the results obtained from experimental design and production of prototype domestic water treatment unit for a rural populace. Details of materials used for the construction of the unit have been given, including laboratory experimental analysis. Design parameters guiding the design of the filter bed have been given, finally, a portable water treatment unit have been designed and constructed to provide drinking water, laboratory results obtained from the performance of the prototype unit shows that it's capable of providing safe drinking water according to WHO drinking water standards.

## INTRODUCTION

The aim of filtration is to purify the water by passing it through a porous medium.
During this passage, water quality improves by:-

a. Removal of floating and colloidal mater
b. Reduction of bacteria and other pathogenic micro organisms
c. Removal of suspended and dissolved solids contents
d. Improvement in its chemical constituents

Water Borne Diseases are diseases caused by water pollution, water being the Source of life (primary host). The source of pathogenic organisms found in water is often from human beings who are infected with disease or who are carriers of a particular disease (Garg, 1988).

The usual pathogenic organisms that may be excreted by man course diseases of the gastro intestinal tract, such as typhoid and paratyphoid fever, dysentery, diarrhoea and cholera. Because these organisms are highly infections, they are responsible for many thousands of death each year in areas with poor sanitation, especially in the tropics. Water contains some impurities, which directly or indirectly relates to their source. Sources of contamination of water supplies are shown in fig. 1. Based on this afore-mentioned knowledge, it was deduced that, turbidity, colour, Taste/odour, and presence of bacteria shall be investigated and treated for, taking a typical local populace as a case study.

The International Drinking Water Supply And Sanitation Decade targeted 1990 as the year for supplying safe water and sanitation to all. It is very clear that at least from Africa and other third World countries, this has not been achieved.

Experience has shown that there has to be an orientation away from expensive, sophisticated techniques towards appropriate, low-cost and socially acceptable techniques that are adapted to or suitable for local conditions. Hence, the idea for proposing the production of domestic water treatment unit for rural populace. The quality of water can be completely defined and estimated by studying it's physical, chemical, bacterial and microscopic characteristics. The quality depends on the previous history of the water. Water collects impurities from the moment of its formation in the clouds. Some impurities are harmless, others may be offensive aesthetically or even dangerous to health (Salvato, 1992)

The constructed proto-type has been subjected to analytical cost evaluation so as to determine the economic benefit of the work. As it is Common in the production sector, the more you produce the cheaper each item would be in the open market. It is therefore hoped, with necessary support from investors, government agencies or philanthropist who will be willing to

promote knowledge that very soon mass production of the unit would be embarked upon.
The operation of the unit for treating water for consumption is very simple, it does not require much skill knowledge and the maintenance can easily be done by back washing.

## METHODS AND MATERIALS

The World health Organisation (WHO) Drinking water standard is the guiding objective for water treatment in Nigeria. Another International Standard is the U.S.A. Environmental Protection Agency (EPA) which is a result of the safe Drinking Water Act of 1974 and subsequent amendments. It is in line, with the requirements of the WHO standards that this work has been carried out.
Federal University of Technology, Bosso environs has been used to carry out investigative studies, the outcome of the research work is applicable to the generality of Nigeria and other developing countries. Having completed the design process and laboratory experimental analysis for materials used for water treatment, a proto-type unit was constructed.
Samples of raw water were collected from Bosso water works, underground wells within Bosso area, public water supply within the School premises and the School's bore-hole (near the male Hostel Mosque) water supply. These water samples were tested are given.

### *Sieve Analysis*

The main experimental design relating to this work is sieve analysis of gravel and sand used in the treatment unit. The system of operation of the filter is down flow, the bed is graded fine-to-coarse, with the smallest pore sizes at the top of the bed. As a result, solids removal occurs primarily at or very near the bed surface. This type of operation if characteristics of rapid sand filter.

Natural run-off-bank sand may be too coarse, too fine, or too non-uniform for a projected filter within economic limits, specified sizing and uniformity can be obtained by screening out coarse grains and washing out fines. Similar exercise is also required for the gravel. It is when this screening have been done for these materials before they were put into the filtering bed.
In view of the above, samples of gravel and sand were collected at a run-off-bank of Shiroro River. Sieve analysis was carried out on the collected samples. (See result of sieve analysis).

### *Design Parameters*

- ***Detention Time (DT)***

The phenomena responsible for the purification of water react rather slowly, because of this, one of the most important parameters used in the analysis and design of the water treatment unit is the detention time, (Linsley, 1992). Detention time (DT) can be expressed as:

$$(DT) = V/Q \text{ -------} \quad (1)$$

Where V = Volume of compartment in $m^3$ and;

Q = Design discharge ($m^3/hr$)

Assume a family of 8 people each drinking an average of 5 litres of water per day, and allowing for extra 10 litres. It is also assumed that one hour in a day would be devoted to preparing the water.

Assume Q = 50 Litres/hr
$= 0.05 m^3/hr$

Volume of treatment compartment V

$$V = \pi r^2 \times \text{depth}$$
$$= \pi(0.09)^2 \times 0.14$$
$$= 0.00356 m^3$$

Therefore from equation 1, DT = V / Q,

$$t = 0.00356 m^3 / 0.05 m^3/hr$$
$$= 0.0712 hr$$
$$= 4.3 \text{ minutes}$$

- ***Filtration Rate ($R_F$)***

Filtration rate is a measure of the height of water fall in the filter per hour

$$R_F = \frac{Q}{A} \text{ ------------- (2)}$$

Where Q = Design discharge= 0.05m$^3$/hr.

A= plan area of filter bed

$= \pi r^2 = \pi(0.09)^2$

= 0.0254469m2

Therefore from equation 2, $R_F$ = 0.05m$^3$/hr / 0.0254469m$^2$

= 1.9649m/hr

= 2.0m/hr (with the unit being continuously fed from the bowl)

- ***Filter Materials***

Materials for treatment inside the filter are activated carbon (charcoal), sand and gravel.

Grain size for sand is within the range of 0.4mm → 0.55m

Grain size for gravel shall be 6mm → 19mm

Uniformity coefficient for sand is specified lying between 1.2 and 2.0.

- ***Filter depth***

Layer of sand/Activated carbon = 35mm

Layer of gravel = 25mm

***Hydraulics of filter Unit***

Flow through filter is predominantly laminar, thus Head loss is proportional to approach velocity according to Darcy's law.

v = ki

i = $h_f$ / L = v / K

Therefore, $h_f$ = VL / K ----------(3)

Where,

$h_f$ = Headloss (m)

v = Approach velocity or filtration rate (see equation 2).

= 2m/hr

Therefore, L = Filter media depth

= 0.06m

K = permeability coefficient usually, k > 6m/hr

$h_f$ = 2 x 0.06 / 6

= 0.02m

## MATERIALS FOR THE WATER TREATMENT UNIT

Materials used in constructing the drinking water treatment unit consist of high pressure PVC pipe (Ø200mm), a plastic tap, a plastic cover and a gauze. All these form the construction components of the unit. Materials used for treatment in the unit are activated carbon (charcoal), gravel and sand.

***High Pressure PVC Pipe.***

The High pressures PVC pipe, 20mm diameter and having a thickness of 5mm, is a polymer material belonging to the thermophotic group. The thermophotics are those polymer materials, which are composed of independent linear polymer chains melt to form liquid which, although highly viscous, may normally be extruded and injection moulded to fabricate polymeric products. Melting and solidifying occur reversibly according to temperature.

The pressure PVC pipe is Notch brittle, because it does not break, unless when sharp-notched. The pipe is durable and therefore can withstand environmental degradation in polymers such as ultraviolet radiation from sunlight, heat, oxygen, ozone and water.

The PVC pipe does not aid corrosion and is also non-toxic, since it has been subjected to tight control, for pipes meant to supply portable water.

Biological attack caused by fungi and bacteria on plastics can be avoided mainly by periodic maintenance especially when backwashing.

## RESULTS AND DISCUSSION

***Sieve Analysis of filter Material***

The appropriate sizes of filtering materials used were determined by carrying out sieve analysis on the gravel and sand materials. The results of the analysis are shown in Fig. 2 and Fig. 3. From Fig. 2, the uniformity coefficient (U.C.) for sand,

U.C = Size of aperture through which 60% sand pass / Size of aperture through which 10% sand pass

$= D_{60} / D_{10}$ = 0.83 / 0.45 = <u>1.8</u>

From fig. 3, UC, for gravel,

UC. = $D_{60} / D_{10}$ = 16.5 / 11 = <u>1.5</u>

The result shows that both the sand and gravel material used in the filter medium are well graded.

*Water Quality after Treatment*

The raw water samples were treated by passing them through the prototype water treatment unit. Results obtained were compared with those of the raw water as shown in Table 1and 2.

## CONCLUSIONS

From the results of the test carried out on the treated water, it was found out that the proto-type drinking water treatment unit, is capable of providing portable drinking water to the required standard.

It can also be said that, no sophisticated technology is required for constructing the prototype unit, because the mode of construction is simple and much can be produced, once sufficient materials are available. Fairly experienced skill labours are required for production.

Problem of non-availability of production materials is not foreseen because, materials used for water treatment and for constructing the prototype unit are locally available.

The filtering unit will treat water mainly by physical method, although it is also capable of removing chemical and biological impurities.

The size and weight of the unit is tolerable and can therefore be taken along when one is on journey, on outdoor games or camping exercise.

The prototype unit is considered durable judging by the quality of materials used for construction and the ease of carrying out maintenance activities.

The cost of the prototype drinking water treatment unit is far cheaper than the common Doulton filter in the market, and its efficiency is guaranteed. It is therefore expected that, the unit would be affordable by the local populace, for whom, the whole idea was conceived to solve their problem pertaining to obtaining portable drinking water.

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