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Production of a Potable System for Purification of Drinking Water.

A. O. Ette, O. Amali, E. I. Kucha, and D. U. I. Ogo.

Local raw materials were used to produce a potable porcelain water filter system with pore size of 73μm. The system has a flow rate which closely approximated Ergun's equation. Its binder at 10% weight fraction effectively provides clarified filtrate which is odourless and colourless. Microbial analysis shows system is capable of significantly filtering out bacteria and other microorganisms such as cyclops which cause diseases in man. Operational simplicity of the filter makes it easily adaptable to rural, industrial and institutional applications.

INTRODUCTION

Modern development in water quality control has provided commercial techniques for filtration and chemical treatment of water. Filtration in addition to removing particulate removes microorganisms. It also has relatively low cost in capital equipment over chemical treatment. It can therefore be adapted for use in rural or institutional communities.

A sterilizing filter's most major achievement is in its ability to retain at a high level of confidence, particulate and microoganisms [1,2]. This can be practically achieved by choosing a filter matrix of regular and defined pore size. This project involved design of a portable filter from siliceous and agro-based raw materials which are capable of restoring acceptable water quantities and eliminating disease causing microorganisms while providing acceptable flow rate.

MATERIALS AND METHODS

The materials were categorized into filter materials, test rig materials, chemicals, and water specimen. The filter materials comprise sand from Benue River, clay from a nearby clay deposit , surface active adsorbate (decolorizer) and binder. The largest particle size range of sand used was + 850μm while that of the binder was 112.5μm. The sand was classified into various particle size ranges into which predetermined proportion of clay, adsorbate and binder were added

A. O. Ette and D. U. I. Ogo are Senior lecturers; E. I. Kucha is Professor, Department of Mechanical Engineering, and O. Amali is Senior lecturer, Department of Biological Sciences, University of Agriculture, Makurdi.

The stratified layers of the filter mix were formed into a capsule and sintered in a muffle furnace. The effective surface area of the capsule and the thickness were fixed by the encapsulation process. The hardened filter capsule was then fitted into the test rig where efficacy of the filter was tested. The test rig was designed to hold the filter capsule such that only the effectice surface area is exposed to water for filtraton. It also provided a constant water pressure on the surface of the filter and ensured modular installation of the filter capsule. The rig was fabricated from steel pipe. The fabrication process comprised welding of pipes of varying heights but of same diameter to a chassis and stand. Provisions were made for screwing in filter capsule and water (filtrate) collecting trays at the upper and lower ends of the pipes respectively. Water from sources around catchment residents of the University of Agriculture, Makurdi, Nigeria was used for the filtration system. The usually browish water was collected in sterile bottles and analysis was carried out in less than twenty four hours to establish the level of bacterial growth in the samples.

RESULTS

Within range of 4.9 to 40 0% binder to sand ratio, the best qualitative characteristic was observed at ratio of 10.00% (Table 1). Below and above the ratio, the compact was weak and disintegrated when touched. The effect of moisture content on the stability of the sinter is shown in Table 2. Good binding was possible at a moisture to binder ratio of 50%. Increased binder concentration expectedly increased strength of the filter. The influence of the binder to sand ratio and the level of moisture on the degree of voidage is displayed in Figure 2. A peak in the flow rate occurred at the binder to sand ratio of 10.0% when the void fraction was 48%. This value is in line with the 46% minimum value suggested by Furnas[3]. There was a decrease in voidage with increased binder concentration and this could be attributed to efficient packing of the particles as the fines settle between the larger particles. The overall void fraction are reduced as more fines are added.

Table 3 and figure 3 show effect of pressure drop variation ΔP on the water (filter) flow rate. The filter with 10% binder gave higher flow rates at all pressure levels with the rate decreasing with increasing binder concentration. In Table 4 , the measured flow rate were compared with empirical relationships using Poiseiulle's law[4], Kozeny-Carmam equation [5] . Predictions based on streamline flows (Poiseiulle's, Kozeny-Carmam equations) and Ergun equation [6]. gave consistently very low values compared with the measured data. Ergun's equation, however, seems to give a better approximation ot the experimental values. At 0.485 and 0.135 void fractions, the measured specific flow rates were 85% respectively of the predictions using Ergun's equations.

The Reynold's number (Re) and the permeability (K) of the filter were determined at a void fraction (E) equal to 0.485 and were found as follows: $Re = 4.22$ and $K = 1.32 \times 10^{-10}$gm/cm, respectively. The associated pore diameter was calculated to be 73μm. Based on the value of the Reynold's number, the flow at 5.1cc/cm². sec. and 39.2kg/cm² pressure was turbulent.

The filter was used to filter water drawn from ponds (SBS1 and SBS2) where local community draws its drinking water. In figure 4, the culture shows heavy growth of microorganism from ten times dilution of SBS1 sample. The sample from SBS2 gave the growth shown in figure 5 at ten times dilution of the sample as received. The filtrates were colourless and odourless and were obtained at an average flow rate of 4.9cc/cm² . sec. The culture of SBS1 and SBS2 filtrates appear in figures 6 and 7 respectively. The heavy growth observed in figure 4 was almost completely eliminated at a single pass as seen in figure 6. Similarly, the growth was significantly reduced in figure 7 as compared with the raw sample shown in figure 5. The mostly fungal growth in figures 6 and 7 are likely due to contamination.

DISCUSSION

In the present project, a portable porcelain filter with a pore size of less than 73μm and a flow rate of 5.0cc/cm² sec. was developed. These characteristics of the filter make it valid as confirmed by Egun's equation[6]. Over the range of 4.9 to 40% binder to sand ratio, the best binding was obtained at 10%, ratio. This gives a void fraction of 48%, which is in line with the 46% minimum suggested by Furnas[3]. The filtrate obtained from the filter was colourless, odourless and free of most microorganisms. With the pore size of less then 73μm the filter developed in the present project is a far more effective devise than the sand or cloth filters recommended by UNICEF for control of guinea worm and other water-born diseases in rural endemic areas[9,8]. Figures 5 and 7 confirm capacity of the filter to retain most microorganisms initially found in the water samples collected. Furthermore, by its design, the filter developed can easily be adapted for rural, industrial or institutional applications without significant capital investment in infrastructural modifications or changes. It is also designed to capture the operational simplicity and affordability required for acceptance in rural areas where water-borne disease are most endemic.

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Table 1: Effect of Binder Concentration on the Characteristics of the Filter Medium.

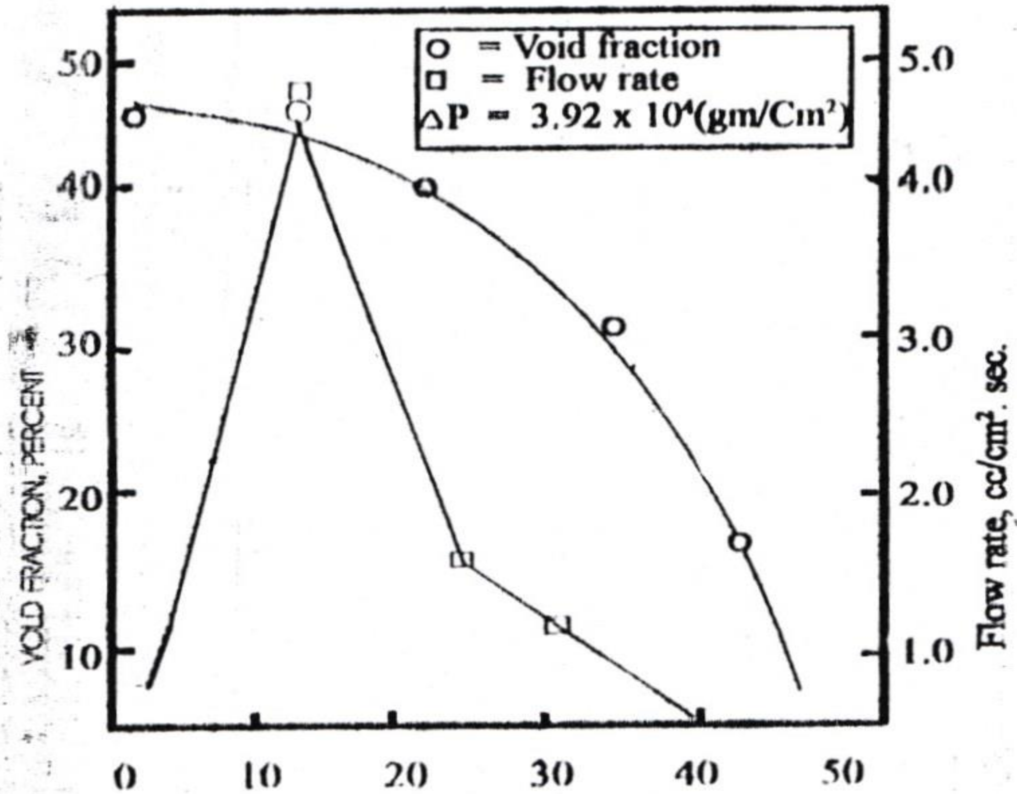
Sample No.	Binder/Sand Ratio (%)	Bindability	Remarks
1	4.9	Poor	Disintegrate with touch
2	10.0	Good	Formed solid sinter; good wet strength.
3	20.0	Poor	Disintegrate with touch, no wet strength.
4	30.0	Very poor	Collapses on touch; washable in contact with water.
5	40.0	Very poor	Individual Particles, no binding.

Table II: Efect Of Degree Of Moisture On The Strength Of The Filter Compact

Sample	Binder/Sand Ratio (%)	Bindability	Void Fraction	Remarks
1	4.9	Very Good	48.12	Very Good
2	10.6	Very Good	40.94	Hard
3.	15.8	Good	30.87	Very Hard Sinter
4.	24.5	Good	13.46	Overflow on Sintering

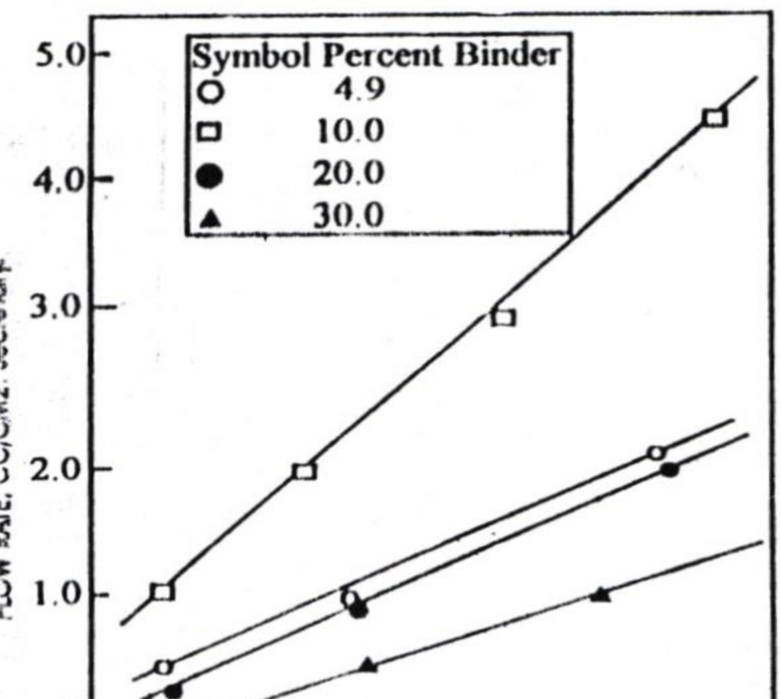
Tables 111: Effect of Pressure Drop on Flow Rate

Sample No	ΔP (gm/cm^2)	Area of filter(cm^2)	Flow Rate, Q, cc/cm^2. sec. Binder				
			4.9%	10%	20%	30%	40%
1.	3.92 x 10	4.909	1.53	5.09	1.27	0.49	0.04
2.	1.96 x 10	4.909	0.85	2.65	0.78	0.22	0.02
3.	9.81 x 10	4.909	—	1.70	0.57	0.11	0.018
4.	4.96 x 10	4.909	0.59	1.13	0.40	0.09	0.017



Binder To Sand Ratio, Percent

Figure 2: Effect Of Binder Concentration On Flow Rate And Void Fraction



Head Pressure ($\triangle P$), gm/cm² x 10^{-3}

Figure 3· Effect Of Pressure Drop On Flow Rate.

Table IV: Comparative flow Rate for Selected Flow Equations Using Experimental Data.

Binder/Sand Ratio (%)	Void Fraction (E)	Specific flow rate, cc/cm^2. sec.			
		Measured	Poiseuille's	Kozeny Çarman	Ergun's
4.9	0.48	1.53	5.0×10^{-3}	0.19	6.05
10.0	0.485	5.09	4.0×10^{3}	0.18	5.97
20.0	0.41	1.27	9.88×10^{-4}	0.07	3.06
30.0	0.31	0.49	1.31×10^{-4}	0.02	0.99
40.0	0.135	0.04	1.5×10^{-6}	9.2×10^{-4}	0.049

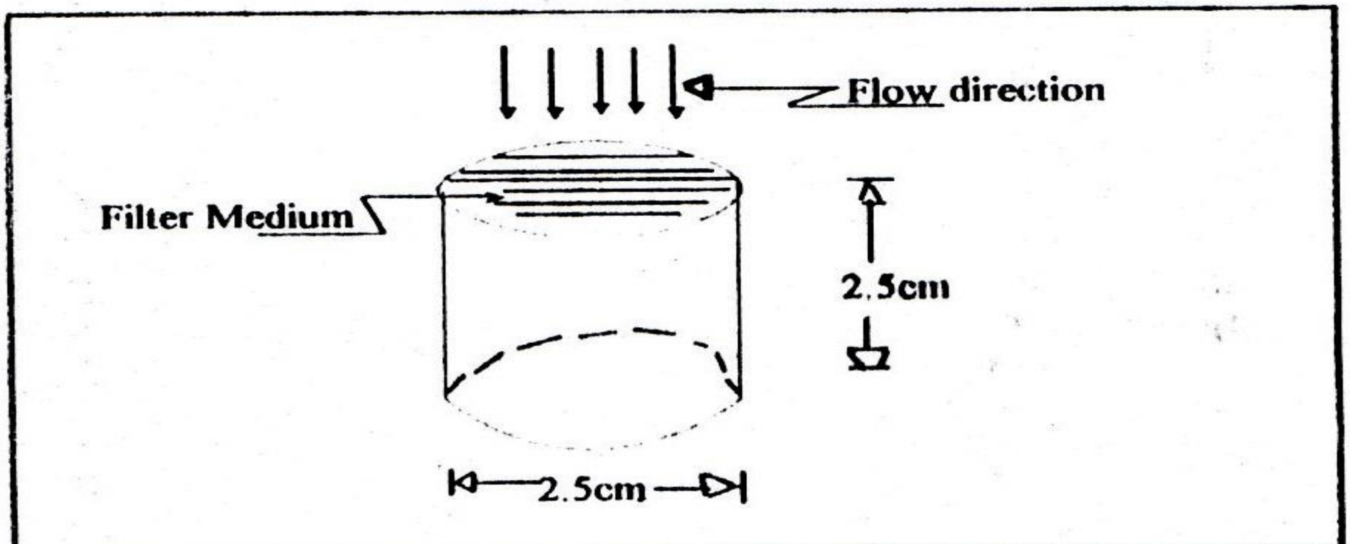


Figure 1: Typical Filter Capsule (not to scale)