Evaluating the Performance of Locally Made Ceramic Filters for Household Water Treatment

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Abstract— *Water pollution in India is a major problem. The root cause of a number of diseases is water pollution. Effective household water purification is needed to prevent the waterborne diseases. Need of water makes it important and without giving right to access it, the concept of welfare state cannot be fulfilled. So the water sources require specialized treatment methods and filters to make them safe for drinking .The main goal of this study is to produce a low cost filtration system using locally available materials and to find the suitability of those materials. For this study, Ceramic filters were prepared from locally available materials such as clay, sawdust, sand, laterite, ilmenite and garnet. The results showed that the ceramic filters prepared are effective in removing microbes resulting in waterborne diseases by 100% and turbidity to about 80-90%. The results were well within the permissible limits of BIS. The SEM images clearly revealed the presence of microscopic pores in the filter. Statsistical Analysis using SPSS software gave a good correlation study among the various parameters. Commonly used ceramic filters for the study were prepared from clay and sawdust. In order to improve the performance of ceramic filter,locally available materials that have good antibacterial properties were also chosen for this study.*

Keywords— Ceramic water filter, filtration, ilmenite, garnet, antibacterial, SEM, EDX

I. Introduction

Polluted water is the main cause of many diseases. Polluted water not only affects the life of present generation but also affects the life of future generations. In recent years, water pollution has become a serious problem across the country,which mainly happens due to the disposal of untreated effluents,chemicals,agricultural waste,etc. If in any area, the people is forced to drink the polluted water because they have no other options.[1]. Water pollution is to be considered as a serious problem. Pollution of water means the unsuitability of water for human consumption. Pollutants in water includes a wide range of chemical substances, pathogens, biological wastes etc. Pathogens can produce waterborne diseases such as typhoid, cholera, dysentery etc., to human beings is through contaminated water drinking. The major water quality problem associated with rivers in Kerala is bacterial contamination. Most of the people directly depend on the river water for their daily activities. So, the need of household water purifications also increasing to make the water safe for drinking[2]. Ceramic water filters (CWF) are now used for household water treatment solution were the people really depend on the uncontaminated water sources and in places where there is a chance of recontamination during the water supply or storage[3]

Ceramic water filter that are made from clay is commonly used by most countries [4]. These filters are basically mixture of clay, saw dust and water molded and fired. During firing at a temperature of around 400-500ºC, sawdust material is burned out and thus creating pores. The performance of the ceramic water filters have been investigated and reported by many groups of researchers. They had proven that the ceramic water filter can be effectively used for reducing the turbidity and bacteria by more than 99 % [5].

Several studies have proved the CWF removal of bacteria, such as total coliform and faecal coliform, which serves as the biological indicator for pathogenic contamination [5,6,7,8]. The main mechanism considered important in the microorganism's disinfection by the ceramic water filters is filtration by size exclusion removes the larger microorganisms such as protozoan and some bacteria and may be attributed to the initial pore sizes of the filters, and the solid filter cake that accumulates insides the filter will increase the efficiency of filtration. The advantage of using locally made ceramic filter are that they are simple to use, portable, light in weight, affordable and require low maintenance [7].

To increase the efficiency of ceramic filters and to decrease its cost of production, the materials used for this study are locally available materials that have good antimicrobial properties[8,9,10,11]. The raw materials used for the preparation of the ceramic water filters are clay, saw dust, sand, laterite, ilmenite and garnet.The microstructure characterization of the ceramic filter was carried out using SEM analysis.Statistical analysis was carried out by finding the Pearson's correlation between various parameters.

II. Objectives

The objectives of this study were

- To identify the materials that have antimicrobial properties and filtration ability
- To determine the suitability of some locally available materials for ceramic water filtration system
- To produce a low cost filter for household water treatment with good efficiency

III. Materials and Methods

A. Raw materials

The materials selected for the preparation of the ceramic filter well suits the property of water filtration. The basic raw materials used to make the ceramic water filters include clay, sand, laterite, Ilmenite, garnet and saw dust from wood. Clay forms the main base material of the ceramic water filter. It was preferred because it exhibits very high plasticity to fold the filter particles together and it changes chemically to become a strong porous material when fired in the kiln [12].

Saw dust is used as the combustible material. Saw dust was preferred because it does not cause bloating and

results in more uniform pore size distribution in the filters which helps to increase the porosity of the ceramic filter [14]. Laterite soil and silica sand was obtained from nearby localities. Ilmenite soil and garnet is mainly found in beach soil from Chavara [13; 15]. The water was got from the well. The water was used to mix the clay and other materials to form a semi plastic workable material.

Fig. 1: clay

Fig. 2: Saw dust

Fig. 3: Silica sand

Fig. 4: Laterite

Fig. 5: Ilmenite

Fig. 6: Garnet

B. Designing of filter

All the raw materials are mixed in various proportions and cylindrical shaped filters are made with the help of a cylindrical mold (Fig 7). The filters prepared are with uniform size having diameter 7cm and height 11.5cm (Fig 8).Table 1 shows the composition of materials in grams.

Sl.No.	Clay	Sawdust	Sand	Laterite	Ilmenite	Garnet
A	375	75	50	50	50	50
B	375	50	75	50	50	50
C	375	50	50	75	50	50
D	375	50	50	50	75	50
E	375	50	50	50	50	75

Table 1: Composition of materials in grams (g) (Total 650g)

Fig. 7: Mold

Fig. 8: Ceramic filters

C. Experimental Design

A laboratory scale test unit was used for the investigation of the performance of ceramic filter. The unit includes ceramic filter equipped with two plastic buckets for water holding as shown in fig 9. During the filtration process water passed through the filter by gravitational force, filtered water is then collected and analyzed using standard methods.

Flowing water was taken from Vamanapuram River, Attingal and was taken to the laboratory for preliminary analysis. The water was allowed to pass through the filter setup and the flow rate of the water samples was taken. The filtered water was then taken to the laboratory for further analysis. Filtered water samples were collected in sterile bottles and analyzed. Ceramic filter was prepared for

the material characterization before and after filtration process using SEM analysis.

Fig. 9: Pilot model of the water filtration system

D. Experimental method

Filtration test was carried out to measure the filtration rate. During the filtration test the water is allowed to pass through the filter by gravitational forces. Filtered water is then collected and analyzed.

The main parameters that determine the quality of drinking water is to be analyzed in the water quality analysis. Water quality analysis of the water samples (pre and post treatments) such as pH, Turbidity, Alkalinity, Total solids , Total dissolved solids , Total suspended solids , Total hardness, Dissolved oxygen, Total coliform, E.Coli are determined by using standard methods specified by BIS. Filtered water samples were collected in sterile sample bottles and analyzed.

Ceramic filter was prepared for material characterization before and after the filtration process. The material characterization is carried out to get the microstructure and surface characterization of the material selection and to know the phenomena that may affect in the filtration process. Scanning Electron Microscopy (SEM) analysis was carried out in the Material analysis process.

IV. RESULTS AND DISCUSSION

A. Characteristics of Raw Water Samples

From the results, it was found that the total solids, total dissolved solids, total suspended solids, Coliform count etc. of both the samples were not within the permissible limit as specified by Indian Standard for Drinking Water - Specification IS 10500: 199. For sample 1, it was found 62.1%, 49.5%, 90.9%, 100% increase in total solids, total dissolved solids, total suspended solids, total coliform respectively when compared with the corresponding permissible limits. For sample 2, it was found 57.94%, 30.5%, 99%, 100% increase in total solids, total dissolved solids, total suspended solids, total coliform respectively when compared with the corresponding permissible limits. Hence the water samples are not suitable for direct utilization. Bacteriological quality was an important factor in assessing the relationship between the drinking water safety and diseases transferred through water. Presence of microbial population such as total coliform and fecal coliform in the water sample can lead to various waterborne diseases. So the usage of this water without proper treatment leads to harmful diseases [16]. Biological analysis of water samples showed moderate organic pollution indicating vulnerability of the river water to various anthropogenic activities[17].Most of the people living in that locality depend on the river water for domestic usage.

Parameters	sample 1	sample 2
pH	8.25	8.05
Turbidity (NTU)	7	6
Conductivity(µS/cm)	326	319
Alkalinity(mg/l)	30	25
Total hardness(mg/l)	86	72
Calcium hardness(mg/l)	50	58
Total solids(mg/l)	1320	1189
Total dissolved solids(mg/l)	990	720
Total Suspended solids(mg/l)	330	369
Dissolved Oxygen(mg/l)	7.69	6.28
Total Coliform	$22x10^{-3}$/100ml	$33x10^{-3}$/100ml
Fecal coliform	$7x10^{-3}$/100ml	$9x10^{-3}$/100ml

Table 2: Physicochemical properties of raw water samples

B. Assessment of Filtration Rate

Pretreatment like soaking the ceramic filters in water for 24 hours was done and it helped to clean the filter pores from the dust and burning material. The flow rate was shown in Fig 10,which revealed that for all ceramic filters increased initially with time. Low flow rate was observed in the beginning of hours.

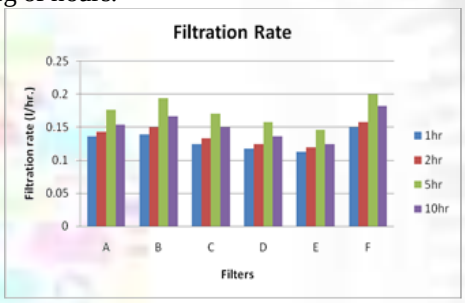

Fig. 10: Filtration rate at 1hr, 2hr, 5hr, 10hr

Low filtration rate was observed in the beginning of hours. It shows high rate at 5th hour. The filtration rate also become lower at 10th hour compared to the 5th hour. It may correlate with the fluid pressure on the filtration system. The water level of the upper bucket was decreasing during the filtration which results in lower pressure.

C. Comparative analysis of filter results with percentage decrease/increase

For the study 3 filtration systems of similar manner as shown in fig.9 was used. Initially study was carried out on Sample 1 treated using three filters A, B, C respectively. Next study was carried out on Sample 2 which was treated using the three filters D, E and F respectively. F was the filter available in market.

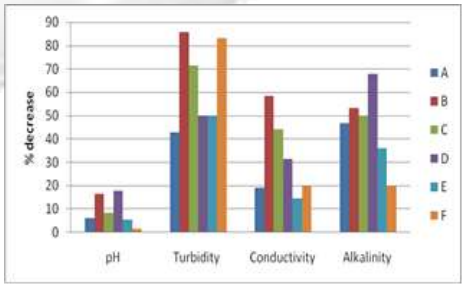

Fig. 11: Graph showing the comparative analysis of filters for the parameters such as pH, turbidity, conductivity, alkalinity

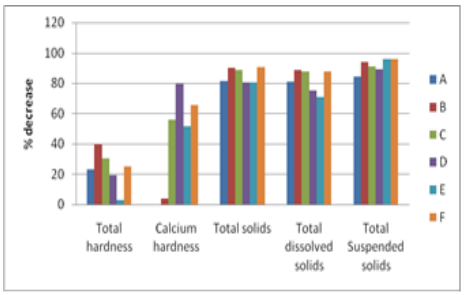

Fig. 12: Graph showing the comparative analysis of filters for the parameters such as Total hardness, Calcium hardness, Total solids, Total dissolved solids

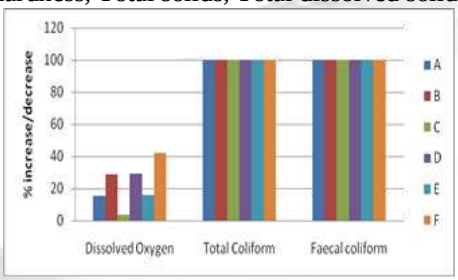

Fig. 13: Graph showing the comparative analysis of filters for the parameters such as Total suspended solids, Dissolved Oxygen and Coliform count

Among the 5 filters- A, B, C, D, E - Filter B shows high decrease in turbidity, conductivity, total hardness, total solids, total dissolved solids and total suspended solids and filter D shows high decrease in calcium hardness, alkalinity and pH. From this it was clear that almost all parameters decreased to more than 50% and filter B is more effective than other filters prepared. Its results were approximately near to the results of filter F.

D. Material Analysis

From the filtration test and measured flow rate it was found that filter B was effective compared to other filters prepared for the study. SEM was carried out for the material analysis of the ceramic filter B before and after the filtration process. They were carried out in SEM-EDS laboratory houses of CESS, Trivandrum. TESCAN VEGA 3 LMU high-performance, Variable Pressure Analytical SEM with LAB6 having high resolution of 2 nm, along with the most advanced LN2-free high-resolution, high-speed EDS (QUANTAX 200 with XFlash®6/30 SDD Detector) from Bruker with Energy resolution < 126 eV and a 30 mm2 active window area were used for the analysis.SE Detector provides Topographic Contrast Imaging using Secondary Electrons. Retractable BSE detectors with YAG scintillator provide compositional contrast, material contrast, phase contrast imaging and phase Identification using Back Scattered Electrons.

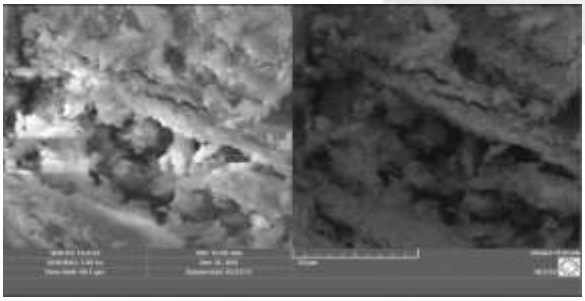

Fig. 14: SEM image of the ceramic filter before filtration

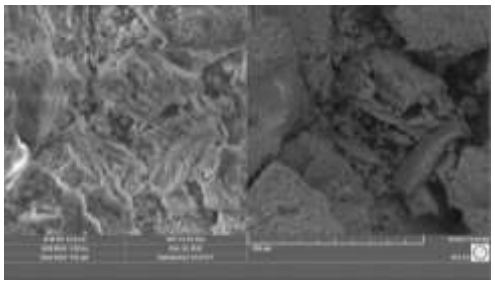

Fig. 15: SEM image of the ceramic filter after filtration

Figure 14 and 15 shows the SEM images of the ceramic filter B. The SEM images clearly revealed the presence of microscopic pores in the filter. As seen in the images, the microstructure of the ceramic filter has a rough texture. The pores in the filter were formed due to the volatilization of the burn out materials at high temperature. Pore area was showed by dark or brown colors while the clay granules and aggregate was showed by the white color.

The presence of open spores and sponge like pores are observed on the two different magnifications shows the bimodal distribution of the pores, both macro pores and micro pores. This pore distribution which forms a porous network may help in the transport of salts on the ceramic surface by capillarity action. However, the image also indicated that the pore structure did not distribute evenly and most of the pores within the filters were not interconnected. These pores will create some problems on the filtration rate as only interconnected pores can deliver the water when the filter is filled with water.

E. Statistical Analysis of Filter B

The various physicochemical characteristics such as pH, turbidity, conductivity, alkalinity, Total hardness, calcium hardness, total solids, total dissolved solids, total suspended solids, dissolved oxygen were determined. Pearson correlation two tailed test was used to determine the relationship between variables and to estimate the uncertainty in measured variables. Correlation is a statistical technique that shows how strongly the variables are related to each other or to find the degree of association between the variables. The correlation study was carried out using SPSS software.

In correlation studies, the coefficient r measures the strength and direction of linear relationship between the two variables. The value of r lies between +1 and -1.To interpret the values, r values are considered to know the relationship. For examples, the following relationship exists if the values of r are closest to:

- Exactly –1. A perfect downhill (negative) linear relationship
- –0.50. A moderate downhill (negative) relationship
- No linear relationship
- +0.50. A moderate uphill (positive) relationship
- Exactly +1. A perfect uphill (positive) linear relationship.

In the case of filter B, the Pearson's correlations between turbidity and TSS, alkalinity and TS were -1.000. It shows a strong negative correlation exists between them. pH and EC, calcium harness and total dissolved solids, DO and total solids also shows the Pearson's r correlations value between 0.95 and 1. So in between these variables also,

strong positive correlations exist. The Pearson's correlation between pH and total hardness is -0.985. The Pearson's correlation between EC and total hardness was -0.993. The Pearson's correlation between DO and alkalinity was -0.993. All these values were approximately equal to -1. So it can be concluded that a strong negative correlation exists between these variables.

V. CONCLUSION

There are various local methods available for water treatment; most of them are effective only in removing physical contaminants of water. These methods are not such effective in removing microbiological contaminants present in water. This study results showed that the ceramic filters prepared are effective in removing bacteria resulting in waterborne diseases by 100% and turbidity to about 80-90%. It takes the advantage of local materials and existing local knowledge. The ceramic filters were simple to use and easy to maintain. But the main drawback is there is a chance of recontamination in filtered water as there is no residual protection and the filtration rate is very low. To solve the constrain of lower filtration rate, the size expanding can be an alternating approach to obtain more volume of treated water.

The results showed that different composition of ceramic filter created drinking water of significantly different physical quality. Five types could remove 100% coliform bacteria. Of the five types, the best for practical use could not be determined using the physicochemical and bacteriological water quality results. Therefore, rate of filtration was also used as an additional choice for the selection of the best ceramic filter. The filtration rate was higher for the filter B in comparison to other filters. When the filtered water was compared with drinking water standards, the results were within the permissible limits. So the filter to be considered for practical purpose is filter B. The SEM images showed the pore distribution of the filter B. These pores help to maintain good porosity which helped to increase the efficiency of the filter. By providing affordable water filters like this to the society, we can greatly improve people's quality of living, and reduce the risk of any waterborne diseases therefore saving lives.

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