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DEVELOPMENT AND FABRICATION OF A CERAMIC FILTER FOR NATURAL WATER FILTRATION

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A ceramic filter is developed for producing drinking water from natural raw waters. The body composition of the filter consists of two locally available fire clays calcined at 1150° for $4\frac{1}{2}$ hr to yield a vitreous cage structure capable of eliminating most bacteria and suspended particulate matter from natural waters. The filter has a cylindrical configuration, 14 cm x 4.5 cm, having a wall thickness of 1 cm. At defined body composition the filter has a throughput of 1.5 l/h, and is capable of eliminating about 60% bacteria and a sizeable amount of suspended particulate matter, determined as a function of throughput. The filter does not impair in any way the physico-chemical balance of natural waters.

Key words: Water filter, Ceramic filter, Water purification.

Introduction

The role of filtration to obtain pure drinking water for human consumption is well recognized. Water-borne micro-organisms and particulate matter are responsible for many ailments and physicological disorders in human body. In recent years the development of ceramic or plastic filters having micro-pores in their body have been given due recognition in most advanced countries, especially Germany and Japan. Details on fabrication aspects alongwith technical know-how required for the production of such filters utilizing materials of various types are described in literature [1,2]. The application of such filters to situations other than purification of water is also known [3]. Glass ceramic filters have been introduced for the treatment of waste water [4,5] and for removal of suspended particulate matter from natural raw waters [6,7]. Filters based on two-way filtration process with autocleaning capability has been marketed recently [8-10]. Special filters for removing solid particles from natural waters of varied composition and for removal of dissolved organics from waste-waters have also been introduced [11,12]. The possibility of application of sintered glass for making open-pore filters operating at high flow rates has also been explored [13].

In Pakistan, like other developing countries, the health hazards arising from the use of natural raw waters are constantly on the increase. From a health hazard point of view, it is, therefore, imperative to control the quality of drinking waters through the use of suitable filtration devices. With this objectives in view, an attempt was made during the present investigation to develop and fabricate a ceramic filter for producing drinking water from natural waters. The body composition of the filter comprises of two locally available fire clays calcined in the presence of a binding material at high temperature to produce a vitreous cage structure capable of removing and retaining most suspended particulate matter and bacteria present in most natural waters. The filtration characteristics and working capacity of the filter in terms of throughput (measured as a direct measure of porosity) were tested at different compositions and the performance was optimized by a proper control of these parameters. With due modification, the filter has the potential of application to waste-water filtration.

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Experimental

The raw materials, Attock Clay (AC) and Nova Clay (NC) (PMDC based nomenclature) were procured from Punjab Mineral Development Corporation (PMDC), Attock. The binding material was developed by mixing the following finely ground (0.0139 inch) ingredients: calcium sulphate (1/2. H_2O) 40%, calcium hydroxide, 10%, lime stone 50%, all w/w.

The composition of the filter casting material was: 63% AC, 23% NC and 14% binding material. The fire clays were separately weighed and ground to pass through 354 micron (0.0139) sieve. They were then homogeneously mixed in an electric mixer. Enough water (about 50% of the total weight of material) was added quickly to the mixture with constant stirring to prepare a workable thick paste. The paste was immediately poured into the casting mould (Fig. 1) lined internally with filter paper to absorb excess water from the paste and to facilitate the withdrawal of the filter from the mould after about 10-15 min. The wet filter was kept in an electric oven at 50° for 24 hr. It was then fired at 1150° in an electric muffle furnace (Shimadzu Corporation, Japan) for $4\frac{1}{2}$ hr under cold-to-cold condition. The macronutrient contents of the pre-and post-filtered water were estimated on a Shimadzu atomic absorption spectrophotometer (Model - AA 670), with due rejection of about 8-10 L of water on initial

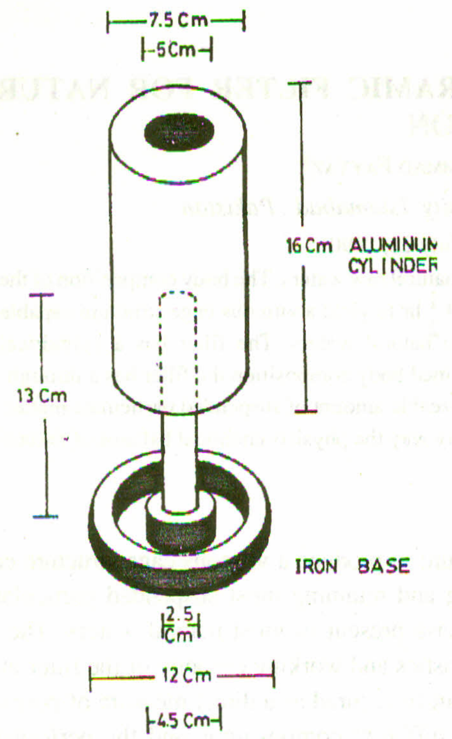

Fig. 1. Design details of the filter casting mould.

TABLE 1. SALIENT FEATURES OF THE FILTER

Feature	Description
Application	Water filteration of samples having ignition residue > 100 mg/L and electrical conductance = 10^{-4}S/cm
Type	Ceramic
Nomenclature	Filter element
Dimension	14 cm x 4.5 cm
Wall thickness	1cm
Installation	Plastic catridge cap screwable to any vessel
Renewal	Back flushing after continued use
Weight of element	250 g
Throughput*	1.5 L/h

*As a function of described composition

installation. The mackoney broth (Oxoid Limited) and mineral modification glutamate medium (Oxoide Limited) were used for bacterial growth study [14]. An aliquot of 5.0 ml of the water sample collected in autoclaved flask was mixed with 45.0 mL of autoclaved medium and incubated at 35° for 48 hr. Ten milliliters of culture were centrifuged in a preweighed centrifugation tube at 15000 rpm for 20 min. to pellet the micro-organisms. The supernatant liquid was discarded and the tube was reweighed to find the weight of microorganisms. The filtration rate was determined by fixing the filter in the upper housing of a twin, snap-on stainless steel vessel (capacity - 10L) and subjecting the water to flow from the upper housing through the filter into the lower part. The volume of water thus collected in a given interval of time was converted to the throuput (L/h).

Results and Discussion

In order to be able to remove a sizeable proportion of suspended particulate matter and the bacterial content of natural waters, the control over the porosity of the filter body is of utmost importance. The filter developed during the present work was fabricated by using locally available raw materials and clays by a simple procedure without involving any detailed technical know-how. Some of the salient features of the finished product are given in Table 1.

The two clays used for the production of the filter are abundantly available from the fire clay reserves in Attock. These clays are basically hydrated aluminium silicates of kaolinite (Al_2O_3. $2SiO_2$. $2H_2O$), montmorillonite (Mg, Ca) $0.Al_2O_3$. $5Si_2O$. nH_2O), and illite (H_2O. MgO, Al_2O_3. SiO_2. H_2O) types, all in variable amounts. The x-ray diffractograms of the Attock clays and the Nova clays are shown in Fig. 2. The selection of these clays was based on their ability to produce a porous vitreous body when calcined at 1150°. The Attock

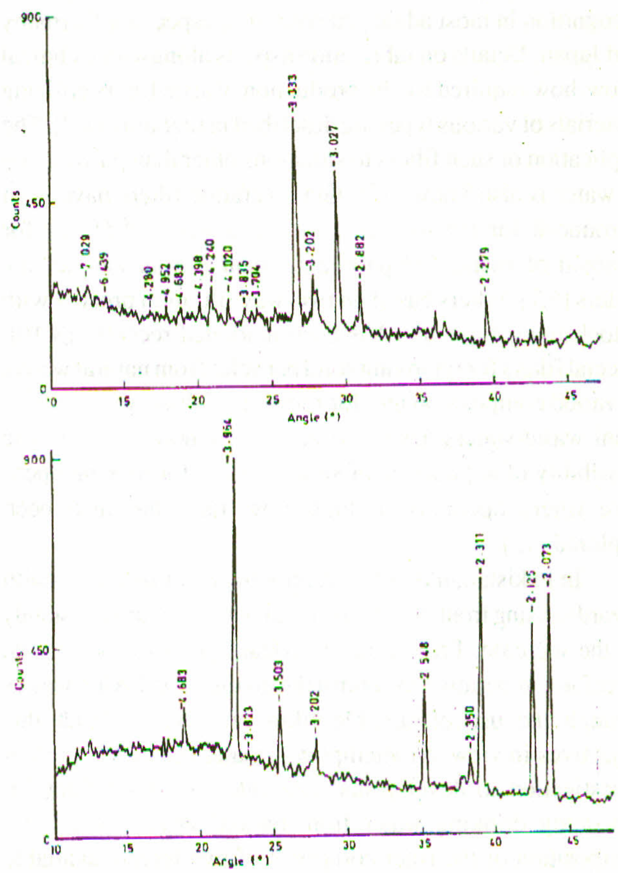

Fig. 2. X-ray diffractograms (a) Attock clay (b) Nova clay.

clay is basically a plastic clay in nature and is, therefore, easily mouldable when sufficiently pulverized. The Nova clay, on the other hand, is a high temperature, non-plastic clay with a firing temperature of about 1750°. The control of porosity in the filter body was achieved by effecting a suitable combination of the two clays to form a complex silicate structure at 1150°. During this process, some of the initial chemical changes that take place include dehydration (at 150-650°), calcination at (600-900°) and oxidation of organic matter (at 350-900°). The final process terminating at silicate formation is quite complex and is affected by changes in firing temperature and constituent ratio. For a given clay ratio (taken as weight percent) it was found that filters with lowest porosity had the greatest strength, thermal conductivity and heat capacity. Moreover, homogeniety of the mixed material largely depended upon the grinding process. Careful screening and recycling were, therefore, found to be of utmost importance for precise constant quality control. The porosity was controlled by preparing the porous body at a composition of Attock clay 63%, Nova clay 23% and binder 14%, all on w/w basis. This gave a filtration rate of 1.5 L/h. From the view point of practical application, lower or higher porosity compositions were not found to be tractable.

The cold-to-cold firing cycle was conducted for 24hr, including the initial 4 and a 1/2 hr firing spell. From the start of the firing spell, the desired constant temperature of 1150° was attained in about 60 min. after which additional 3 and 1/2 hr firing spell was allowed for the completion of the stipulated firing cycle. At this stage, the cooling cycle was allowed to be completed on its own by shutting off the furnace to acquire the initial temperature in about 20 hr. This prolonged cooling time allowed for the required slow cooling and annealing thus avoiding the appearance of cracks and deformations in the body of the filter due to the development of quick strains.

The effectiveness of the filter for the elimination of micro-organisms from natural waters was evaluated by measuring the growth of micro-organisms in prefiltered (raw) and post-filtered water samples. The growth of micro-organisms was compared to assess the extent of elimination of micro-organisms. Fig. 3 shows the relevant comparative data indicating an overall 60% reduction in micro-organism population in the filtered water sample. Additional reduction could be achieved by further cutting down the pore size, but at the sacrifice of throughput.

Pre-and post-filteration water samples were tested for macronutrient content such as Na, K, Ca and Mg. It was found that the post-filtration water showed an overall reduction in Na content of 5%, K content of about 10%, Ca of about 4.5% and Mg of about 6%. In case of heavy trace metals (such as

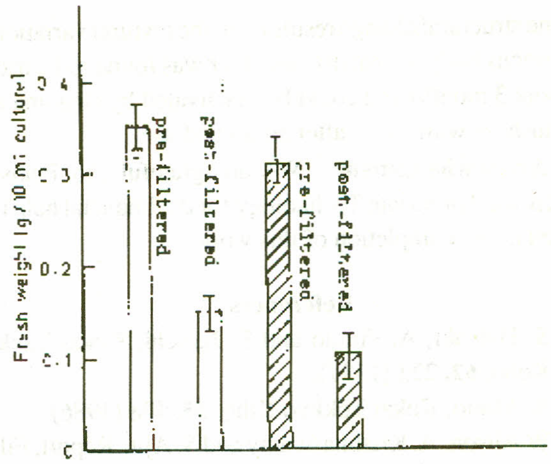

Fig. 3. Growth/rectification data in ☐ modified glutamate medium and ▨ Mackoney broth.

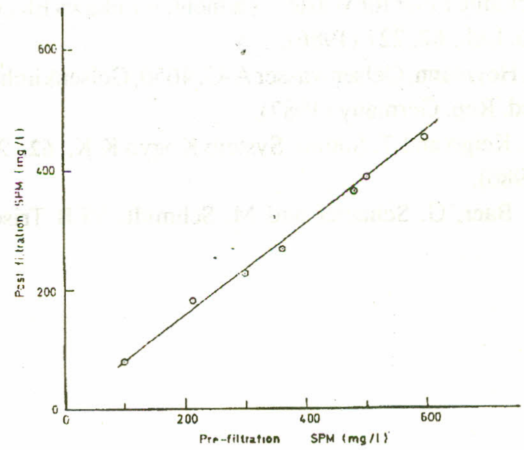

Fig. 4. Relationship between Pre and Post-filtration SPM.

Fe, Cr, Cu, Hg and Zn) there was no apreciable reduction in the concentration of these metals in post-filteration water samples. The filter was found to be very useful for removing particulate matter from raw waters of varied SPM content. Fig. 4 shows the relationship between pre-and post-filtration SPM. It is evident from the figure that higher % reduction in SPM could be achieved at higher SPM content of pre-filtratered waters. For highly turbid natural waters, the % reduction in SPM was found to go as high as 90%. The filtered waters thus conform to WHO standard of 300 mg/L SPM by simple application of the filter. The physical characteristics of waters such as pH, colour and taste remain unchanged. The electrical conductivity is only slightly decrease. Total hardness (as $CaCO_3$) is reduced by about 5%. Dissolved ions such as sulphate, nitrate and chloride are only insignificantly reduced in concentration. The filter can be modified in terms of its composition to work with pressurized water systems to yield a continuously filtered water supply. The finished filter was subjected to regular testing and it was found that the filtration could be achieved without any ill-effects, either due to blockage of micropores or some structural change resulting in the textural variation of the vitreous body. Normally, the filter was found to be useful for about 3 months and could be reactivated by cleaning and backflushing with water after continued use.

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