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A FEASIBILITY STUDY ON PRODUCING CERAMIC WATER FILTERS FROM LOCALLY AVAILABLE FIRE CLAYS

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Various locally available fire clays are screened for feasibility of producing ceramic filters for the purification of natural waters. The illite and kaolinite types of clays are found suitable for the production of ceramic filters by calcination at 1150° with a firing time of 4-1/2 hr extended to 24 hr for annealing in a cold-to-cold cycle. The debacterification aspect of the filters is studied as a function of porosity, which in turn is found to depend on the body composition (%, w/w). The throughput of the filter developed from the two types of clays is found to range between 1.1 - 2.0 L/h at nominal pressure head. The clays have shown promise for future application towards the development and fabrication of filters incorporating colour, odour and bacterial removal characteristics through the use of certain antibacterial ingredients in the filter body.

Key words: Fire clay studies, Ceramic filter, Water purification.

Introduction

In recent years the availability of pure drinking water has become a major concern in many countries of the world. Both rural and urban communities require today large supplies of drinking water to cope with the ever-increasing demand of expanding population [1]. The importance of the impact of the chemical composition and bacterial content of drinking water on human health is also well recognized [2]. This is specifically true of water-borne micro-organisms and suspended particulate matter [3,4] which are responsible for many ailments and disorders in human body. It is, therefore, necessary to undertake appropriate measures to control the physio-chemical parameters that govern the quality of natural waters.

The use of filtration devices for producing drinking water from naturally available raw waters in both time tested and time honoured. Many materials, including ceramic, plastic and cellulose, have been used for developing filtration devices having micropores in their structure [5,6]. Recently glass filters have gained popularity in Europe and Japan [7,8]. These filters are inexpensive and afford easy installation and operation. However, ceramic filters are by far the cheapest and the easiest renewable devices that have been marketed in many advanced countries. The chief purpose of using these filters is to remove suspended particulate matter from natural waters and thus to make them fit for human consumption.

An attempt has been made in the present work to undertake a feasibility study on locally available fire clays in order to produce inexpensive but efficient filtering devices to suit various requirements. Eight fire clays have been procured from the Fire Clay Project, Punjab Mineral Development Corporation, Attock. The mineral content of the clays was evaluated by x-ray diffraction. Various compositions of the clays, alongwith binding material were fired to obtain various porosities at firing temperatures as high as 1150°. The performance characteristics of the ceramic product were studied in terms of the macro-and micro-nutrient contents of the prefiltered and post-filtered water together with a bacterial growth study which was conducted to ensure the efficiency of the filter towards removal of bacteria from natural unfiltered waters.

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Experimental

The clays were separately pulverized in an electric grinder to pass through a 354 micron sieve. The binding material was developed by mixing the following finely ground ingredients: calcium sulphate (1/2 H_2O) 40 wt%, calcium hydroxide 10 wt%, lime stone 50 wt%. The composition for the body of the filter ranged for specific requirements of porosity from 50 to 70% of low temperature clay (hereafter called 'Attock clay') and 30 to 40% high temperature clay (hereafter called Nova clay) with about 14 to 15% binding material by weight. The body compositions were cast into a mould by preparing a thick slurry by adding about 50% (w/w) water. For various compositions the desired firing was done for 3 to 4.5 hr in an electric muffle furnace (Yamato, model FP31) followed by overnight annealing so that the cold-to cold state was achieved in 24 hr. The macro-nutrient contents (Ca, Na, K and Mg) in the pre and post-filtered waters were estimated through atomic absorption. The debacterification study was made by the Oxoid Limited Method [9].

Results and Discussion

Table 1 summarizes the composition of various fire clays based on the x-ray analysis presented for typical fire clays in Fig. 1 and 2. The information contained in the fig-

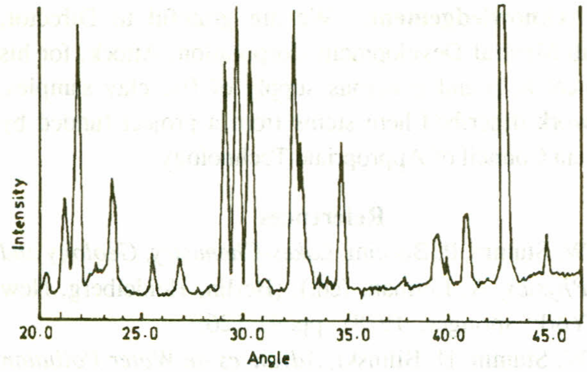

Fig. 1. A typical X-ray diffractogram of the Nova Clay showing major intensity peaks.

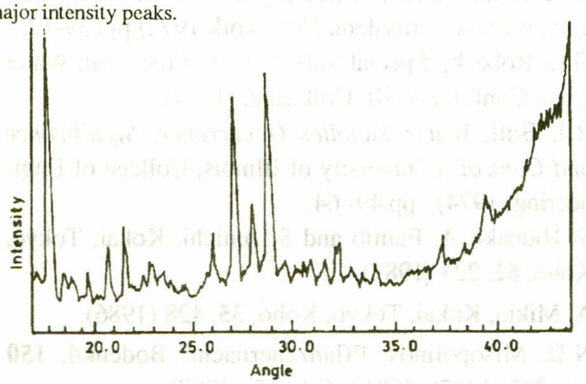

Fig. 2. A typical X-ray diffractogram of the Attock Clay showing major intensity peaks.

ures indicates that the clays are mostly of the illite (C-1 to C-6) and kaolinite (C-7 and C-8) type [10].

Table 2 summarizes various possible compositions of the two types of fire clays alongwith the working efficiency of the finished filters. Basically the low temperature clays (C-1 to C- 6) were mixed with the high temperature clays (C-7 and C-8) to produce the different vitreous compositions given in Table 2. The pairs of clay combinations in the Table represents Attock clay (clay 1) and Nova clay Clay 2) in the given proportions. The results indicate that a 60% illite and 30% kaolinite combination produces variable but acceptable porosity in the filter body. A porosity

TABLE 1. X-RAY DIFFRACTION BASED COMPOSITION* OF VARIOUS FIRE CLAYS.

Clay Code	Location	Major Composition
C-1	Attock Mines	Pot. Al. Silicate hydroxide, $KA1_2 (Si_3A10_{10})OH_2$
C-2	Attock Mines	Pot. Oxo. A1. Silicate hydroxide $(K, H_3O) Al_2Si_3 A10_{10}(OH)_2$
C-3	Attock Mines	Pot. A1. Silicate hydroxide $K_{0.7}A1_{2.1} (Si,A1)_4O_{10} (OH)_2$
C-4	Attock Mines	Pot. Al.. Silicate hydroxide $K_{0.7}A1_2 (Si, A1)_4O_{10} (OH)_2$
C-5	Attock Mines	Pot. Al. Silicate hydroxide $K_{0.7}A1_2(Si,A1)_4 O_{10} (OH)_2$
C-6	Attock Mines	Pot. Mag. A1. Silicate hydrate $(K,Na,Ca)_2O._3O.33 (Mg.Mn)O_{.4} 0.3 (A1.Fe.Ti)_2O_3 16 (Si.Al)O_2.4H_2O$
C-7	Nova Mines	Al.Silicate hydroxide $A1_2Si_2O_5 (OH)_4$
C-8	Nova Mines	A1.Silicate hydroxide $A1_2Si_2O_5 (OH)_4$

*Reference 10

corresponding to a throughput of 1.1 to 2.0 L/h could be obtained by these combinations and by proper control of temperature. It is found (Table 2) that low temperature firing is not helpful in creating a porous structure in the body of the filter. Since the filter is intended for use at a 'nominal'pressure head (defined as the pressure exerted by the water column contained in the annular internal region (2.5 cm x 14 cm) of the filter), the desired porosity was achieved in terms of control over composition of the mixed clays and the temperature.

The quantity of binding material in various filter compositions was adjusted to control the setting time of the mould between 10-15 min. Thereafter the moulds were dried at 80° in an electric oven and fired as described.

The sodium, potassium, magnesium and calcium contents in the post-filtered water were analysed by the atomic absorption method. It turned out that depending upon the original particulate matter content of a given water, the retention of these macro-nutrients in a single filtration cycle was within 2-4% of the original concentration (mg/L). The same was true about heavy metals, such as Pb, Cd, Hg, Ni

TABLE 2. COMPOSITION, FIRING AND DEBACTERIFICATION DATA FOR VARIOUS FIRE CLAYS.

Clay Combination	Body composition of filter (% w/w)			Firing Temperature (°C±5°)	Firing time (h)	Throughput (L/h***) (±0.02)	Debacterification efficiency (%) (±0.5)
	Clay 1	Clay 2	Binding material				
C^*_1-C^{**}_7	63	23	14	1150	4.5	1.5	78.0
C_1-C_7	50	36	14	1150	4.0	2.0	71.0
C_1-C_7	55	30	15	1150	4.0	1.7	76.0
C_2-C_8	60	25	15	950	3.0	1.1	85.0
C_2-C_8	50	36	14	950	3.0	1.2	82.0
C_2-C_7	63	23	14	1100	4.0	1.3	80.0
C_2-C_7	50	36	14	1100	4.0	1.6	78.0

*Called clay 1 (Attock clay) **Called clay 2 (Nova clay) *** at nominal pressure head and Cr. The observation will be investigated in detail during the course of future work to be done on the dependence of retention amounts on the filteration time.

The debacterification was found to depend largely on the size of the micropores in the filter body and not on the firing time. Data in Table 2 indicate that a decrease in porosity (taken directly proportional to the decrease in pore size) and hence in the output of water from the filter, results in an increase of the efficiency of the filter towards debacterification. On the whole, above 60% bacteria are removed during the filtration process even under prolonged use of the filter over several weeks.

The study revealed that various combinations of these clays with different amounts of binding material could be calcined at different temperatures. Table 2 gives detailed information on firing times for the combinations tried to produce a desirable porosity within the range of 1.1-2.0 L/h at nominal pressure head. The present investigation showed that the Attock clay and the Nova clay are suitable for developing a ceramic water filter. However, the Nova clay could be fired in conjunction with the Attock clay at a higher temperature close to about 1750° to produce a high performance but a less porous filter. Keeping in view the performance and economic feasibility of the use of these clays it is recommended that Attock and Nova clays are suitable for the production of water filters to work with local water supplies in rural and urban areas. The estimated cost per filter including over heads of power and binding chemicals amounts to about Rs. 12. Further work in terms of developing ceramic filters for the complete debacterification of natural waters through the use of certain active chemicals is continuing.

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