PRODUCING CERAMIC PURIFIERS MADE OF IRAQI BENTONITE WITH DIFFERENT ADDITIVES

Lecturer Dr. Sanaa Abdul-Razak Jassim: Dept. of surveying, Technical Institute of Babylon.

ABSTRACT

In this study, ceramic filters (CF) were produced from three different mixtures of Iraqi raw materials. These ceramic mixtures were prepared using Bentonite as a Clay, Porcelanite as a Silica, and Limestone as a flux, with three types of additives bran, vinger yeast and saw dust. All of the produced ceramic filters were formed by semi-dry compressing method and were fired at 1200 °C.

Tests Results of the physical properties of the produced ceramic filters showed that among all of the produced ceramic filters, those ceramic filters produced using saw dust as additive have the lowest apparent density, the highest apparent porosity and true porosity, and higher percentage of absorbed water.

A hydraulic test rig was constructed to study the hydraulic conductivity of the produced ceramic filters. The hydraulic conductivities of the produced ceramic filters vary between 56 to 200 times that of commercial types of ceramic filters.

The results showed that all the produced ceramic filters have excellent adsorption ability for solutes of seven heavy metals, Mn, Fe, Pb, Cd, Co, Cu and Zn, at a concentration of 1 mg/l each. Ceramic filters that were produced with different percentages of additives have a good to excellent ability to absorb these heavy metals at a concentration of 10 mg/l each.

INTRODUCTION

Water filtration means removing undesirable contaminates such as suspended solids, dissolved salts, microorganism, and other chemical substances from contaminated water. Filtration is done by passing water through a medium that allows only water with a quality that meets water standards of a specific purpose to pass through. Water filtration is a very important subject due to lack of water in some regions that require circulation and reuse of water.

Ceramic is produc by firing materials or mixture of materials of inorganic and non-metallic materials. Its properties can be controlled by developing technology to meet certain purposes. The pore size of the ceramic material can be made homogeneous and small within the range of microfiltration, which is excellent to remove most of the suspended solids and bacteria. Some of particles smaller than the ceramic pore size could be adsorbed by ceramic. CF can withstand solutions of high temperatures and a wide range of acidity that other microfiltration media can’t withstand. CF can be operated with a proper maintenance or stored for a long time without losing its filtration efficiency. Many types of additives can be used with the ceramic matrix before or after firing to improve its properties. CF can be used easily and they have no side effects, s they are environmentally friendly.

Generally, this research aims to study the hydraulic performance and adsorption propert of the CF made of local materials with different additives.

LABORATORY WORK

Laboratory work of this study includes preparing raw materials, producing the ceramic with additives, and the necessary test to get the physical and purification properties of the ceramic product.

PREPARING RAW MATERIALS AND PRODUCING CF

The ceramic raw materials that are used in this study are: Bentonite, Porcelanite, and Limestone. They were provided by General Company of Geological Surveying and Mineralization.

Bentonite is one of the clay minerals in Iraq (Bellen, et. al., 1959). It is composed of the following minerals: Montmorillonite, with 80%Alumino-Calcium Silicates(GCGSM, 2008). It consists of one sheet of Alumino-Silicates with varying water content and a little of Alkalis
Porcelanite is a siliceous rock. These rocks are found in Iraq in Akashatat the western desert. It is largely composed of sponge spicules and some other siliceous microfossils (Diatoms and Radiolarian), as well as silicified foraminifera and non-plankton. (Al-Bassam, et. al., 1993). It is composed of the following minerals: Cristobalite, Tridymite, and Calcite (GCGSM, 2008).

Limestone is a white rock found at Kerbela and the western desert in Iraq. It is mainly composed of Alcalsiet, CaCO₃ (GCGSM, 2008).

Raw materials were milled and sieved to be uniformly graded material to get porous ceramic (Albadry, 2000).

Generally, Clay plus Silica and fluxes are used to produce ceramic. Bentonite, as a clay, Porcelanite as a Silica, and Limestone as a flux were used in this study. The ceramic mixtures were used depending on the weight of the component used to the total weight of the mix used to produce the ceramic samples. Bentoniet formed the large ratio in the ceramic mixture contains comparable to the other component. Then the ceramic were produced by adding some kinds of additives to study the effects of these additives on the porosity and adsorption property of the ceramic product. Bran, saw dust, and vinegar yeast powder are three types of additives used in this study to be added to the ceramic raw material mixture.

Bran is an organic combustible material. It was brought from local market. It was left to dry in the room temperature then milled by using small electrical grinder and screened to the grade used for the other materials in the ceramic product. Percentage of additive was used of 10% of the total mixture weight of the ceramic raw mixture.

Vinegar yeast powder is kind of yeast found at the surface of old vinegar. It was separated from the vinegar carefully and left to dry at room temperature for several days. Then the dry yeast was grinded for few minutes. Percentage of additive was used of 20% of the total mixture weight of the ceramic raw mixture.

Saw dust is also an organic combustible material. It was prepared by the same procedure used for preparing bran. Percentage of additive was used of 50% of the total mixture volume of the ceramic raw mixture.

The additives of a specific weight or volume as a percentage of the total mixture weight or volume were added and mixed properly.

Mixtures were prepared by semi dried compressing method with 10% by weight of water content, (Hamilton, 1982).

CF samples were manufactured in this study as cylindrical disc tablets of a diameter of 50 mm and thickness of 10 mm, using semi drypressing method, Jassim, 2010. The sample was dried at 105 C for 24hr, (Barsaum, 2003).

The firing process of the dry discs, previously prepared, was carried out at at 1200 C.

The firing was done by electrical muffle furnace.

Six ceramic discs were produced including one replication. These discs were produced using different additives. Table 1 shows details of the produced ceramic discs.

Table 1: Details of the produced ceramic discs.

<table>
<thead>
<tr>
<th>Disc No.</th>
<th>Symbol</th>
<th>Clay</th>
<th>Silica</th>
<th>Flux</th>
<th>Additive</th>
<th>% of additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BB</td>
<td>Bentonite</td>
<td>Porcelanite</td>
<td>Limestone</td>
<td>Bran</td>
<td>10% by weight</td>
</tr>
<tr>
<td>2</td>
<td>BV</td>
<td>Bentonite</td>
<td>Porcelanite</td>
<td>Limestone</td>
<td>Vinger yeast</td>
<td>20% by weight</td>
</tr>
<tr>
<td>3</td>
<td>BS</td>
<td>Bentonite</td>
<td>Porcelanite</td>
<td>Limestone</td>
<td>Saw dust</td>
<td>50% by volume</td>
</tr>
</tbody>
</table>
PHYSICAL TESTS

Tests were carried out to examine the physical properties of the produced ceramic discs. The physical properties which may affect the durability and hydraulic conductivity of ceramic are the apparent density, porosity.

Density and Porosity Tests

Apparent density means dry density. It affects the compressive and tensile strength of ceramic. It also gives the indication to the porosity of ceramic. Apparent density of ceramic body depends on firing program, size graduation, applied pressure and water content during shaping process, (Serry and Hanna, 1979).

Porosity refers to the percentage of pore space in a material. An open pore is a cavity or channel that communicates with the surface of the particle.

The apparent density, apparent and true porosity of ceramic discs were measured according to ASTM-C 373 standards, 2006.

Hydraulic Conductivity Test

The hydraulic conductivity (HC) of a porous medium defines its ability to transmit water. It can be defined as the rate of flow per unit area of porous medium, which is perpendicular to the direction of flow, under unit hydraulic gradient. It has units of velocity (cm/sec, cm/min, m/hr, and m/day), (Hamil, and Bell, 1986):

\[ HC = \frac{q}{l} \]  

where: \( HC \) = hydraulic conductivity, cm/sec, cm/min, m/hr, and m/day, \( q \) = rate of water flow per unit cross sectional area, \( m^3/m^2/hr \), and \( i_h \) = hydraulic gradient. That is:

\[ i_h = \frac{\Delta h}{\Delta l} \]  

where \( \Delta h \) = loss in hydraulic head through flow path, \( m \), and \( \Delta l \) = length of flow path, \( m \).

The hydraulic conductivity is calculated by variable head method by applying the following equation, (Hamil, and Bell, 1986):

\[ HC = 2.3 \frac{a \times L \times \log_{10} \frac{h_0}{h_1}}{A \times t} \]  

where: \( a \) = cross section area of head column, \( m^2 \), \( A \) = cross section area of ceramic sample, \( m^2 \), \( h_0 \) = head exerted by water level at start, \( m \), \( h_1 \) = head exerted by water level after time \( t \), \( L \) = length of sample, \( m \), and \( t \) = time at which water level reach head \( h_1 \), hr.

Each test of HC of the ceramic disc test was carried out with one replication. Computing the average saturated hydraulic conductivity \( HC_a \) for each disc. Computing the standard hydraulic conductivity, \( HC_s \), for each disc according to equation, (Lamb, 1969):

\[ HC_s = HC_a \frac{\mu}{\mu_{20}} \]  

where: \( HC_a \) = average saturated hydraulic conductivity, m/hr, \( \mu \) = viscosity of water at any temperature, Pa.s, and \( \mu_{20} \) = viscosity of water at 20°C, Pa.s.

Adsorption Test

Adsorption test was carried for each produced ceramic disc. The test was carried out passing polluted water through the ceramic disc and measuring the concentration of pollution before and after passing. The polluted water was prepared at laboratory. 500 mg/l standard stock solutions of Pb(II), Co(II), Fe(II), Mn(II), Cd(II), Zn(II), and Cu(II) were prepared as follows:

The required amount of metal salt was dissolved into one liter of distilled water and stirred. Mass of metal salt was calculated as follows: 500 ppm = 500 mg/l. To make one liter of metal salt solute, 500 mg metal is needed, 0.50g of metal. That means:

\[ Ma = 0.5(g. \ of \ metal) \times \frac{MW}{AW} \]
Protection of environment and water quality: the basis for agricultural production, Food Security and sustainable development

2012

where: $Ma$ = mass of metal salt, $g$, $MW$ = molecular weight of the metal salt, $g$, and $AW$ = atomic weight of metal in salt, $g$.

Make up solutions of Pb(II), Co(II), Fe(II), Mn(II), Cd(II), Zn(II), and Cu(II) at concentration 1, and 10 mg/l of each of these ions by diluting 0.2, and 2 ml of the 500 mg/l standard solution to 100 ml with distilled water (Jassim, 2010).

Adsorption test was carried out at room temperature. The test was carried out for all filters together at one time.

The final concentrations of metal ions in the solution were determined by atomic absorption spectrometer, AAS, for residual metal content. The percentage adsorption was calculated as follows:

$$AP = \frac{Ce - Ce}{Co} \times 100$$

where: $AP$ = percentage of adsorption, %, $Co$ = initial concentration of metal ion in the aqueous phase, mg/l, $Ce$ = final concentration of metal ion in the aqueous phase, mg/l.

RESULTS, AND DISCUSSION

This paragraph presents the laboratory experiments results that were carried out to examine the physical properties, hydraulic performance, and adsorability of the produced ceramic discs.

LABORATORY EXPERIMENTS RESULTS

The laboratory work carried out on the produced ceramic discs follows the procedure that were presented before. Three different mixtures of raw materials were used to produce the ceramic filter. The first mixture BB contains 90% of (Bentonite plus Porcelanite and Lime stone) plus 10% of bran. The second mixture BV contains 80% of (Bentonite plus Porcelanite and Lime stone) plus 20% of vinger yeast. The percentages of mixing of these two mixtures were by weight. The third mixture BS contains 50% by volume of (Bentonite plus Porcelanite and Lime stone) plus 50% by volume of saw dust.

Physical Properties

Six tests were carried out to specify the physical properties of the produced CF discs. Values of apparent density, $\rho_a$, apparent porosity, $n_a$, were varied between these ceramic discs, due to difference in type of additives and percentages of mixing raw materials. These properties were also different than that of same ceramic without additives produced by Jassim, 2010. The results of physical properties tests are shown in Figs. 1, 2. Tests results showed the average values of $\rho_a$, $n_a$, of CF produced using BB mixture were: $\rho_a 1.24$ gm/cm$^3$, $n_a 49.5\%$. While for BV mixture, these average values were: $\rho_a 1.23$ gm/cm$^3$, $n_a 61.87\%$, respectively. When using saw dust as additive and using the mixing percentages by volume as in BS mixture, the average values of physical properties were: $\rho_a 1.13$ gm/cm$^3$, $n_a 66.67\%$. And a porous ceramic could be produced by using any of these types. While the ceramic produced by using the same raw materials B mixing without additives, these average values were: $\rho_a 1.43$ gm/cm$^3$, $n_a 48.1\%$, respectively, Jassim, 2010. The high values $n_a$, and low values $\rho_a$ of the new product were due to using additives with different percentages. Fig. 1 shows the variation in apparent density of each of the produced ceramic and that without additives which was produced by Jassim, 2010. While Fig. 2 shows the variation in apparent porosity of each of the produced ceramic and that without additives which was produced by Jassim, 2010.
Hydraulic Conductivity Test

Six HC tests, including one replication of each test, were carried out on CF to evaluate their hydraulic performance.

The tests were carried following the variable head method which was viewed previously. Fig. 3 shows the variation in HC of each of the produced ceramic and that without additives which was produced by Jassim, 2010.

The results showed that the average $HC_s$ of same ceramic without additives produced by Jassim, 2010., were 0.0023 m/hr, which is 56.5 times maximum $HC_s$ of the commercially available ceramic filters which is about 0.00004 m/hr, (Dies, 2003). Average $HC_s$ of filters BB was 0.0042 m/hr. $HC_s$ here was more than that of Jassim, 2010., by 82.6%, and it
was equivalent to 105 times maximum $HC_s$ of the commercially available CF. This was due to adding bran by 10 % (by weight) to the ceramic mixture. Average $HC_s$ of filters BV, was 0.0055 $m/hr$, that means more than that of Jassim, 2010., by 139%, and it was equivalent to 137.5 times maximum $HC_s$ of the commercially available CF. Which can be referred to adding vinger yeast by 20 % (by weight) to the ceramic mixture. Average $HC_s$ of filters BS, was 0.0095 $m/hr$, that means 4.13 times of Jassim, 2010., and 237.5 times maximum $HC_s$ of the commercially available ceramic filters. This can be referred to adding saw dust by 50 % (by volume) to the ceramic mixture.

Heavy Metals Adsorption Tests

Twelve adsorption tests, including one replication, were carried out to examine the adsorption of heavy metals properties of the produced ceramic filter disc. Six, including one replication, were carried out on a per prepared solution of $1mg/l$ of each of seven heavy metals, Mn, Fe, Pb, Cd, Co, Cu and Zn. Other six tests, including one replication, were carried out on per prepared solution of $10mg/l$ of each of these seven heavy metals.

According to Iraqi Specifications No 417, limits of these heavy metals, Mn, Fe, Pb, Cd, Co, Cu and Zn in drinking water are listed in Table 2.

Table 2. Iraqi specifications limits of heavy metals in drinking water.

<table>
<thead>
<tr>
<th>Heavy metal</th>
<th>Pb</th>
<th>Cd</th>
<th>Zn</th>
<th>Cu</th>
<th>Fe</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration, $mg/l$</td>
<td>0.05</td>
<td>0.01</td>
<td>1.0</td>
<td>0.5</td>
<td>0.5</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Average results of test that were carried out to examine heavy metals adsorption properties of the produced CF discs using a per prepared solution of $1mg/l$ of each of the seven heavy metals, Mn, Fe, Pb, Cd, Co, Cu and Zn, are shown in Fig. 4. Generally, the results showed that all the CF adsorbed most of the heavy metals ions. The removal varies between 99.10 and 100 % of the initial concentration of each metal. Comparing these results with removal of CF produced without additives by, Jassim, 2010, one can see no much difference in removal of this concentrate $1mg/l$ of the used heavy metals.

Fig. 5 showed the average results of test that were carried out to examine heavy metals adsorption properties of the produced CF discs using a per prepared solution of $10mg/l$ of each of the used seven heavy metals, Mn, Fe, Pb, Cd, Co, Cu and Zn. Generally, the results showed that all the ceramic filters adsorbed most of the heavy metals ions. Fig. 5 shows the variation in percentages of adsorption of the heavy metals with $10 mg/l$ concentrate of each of the produced ceramic and of that without additives which was produced by Jassim, 2010. The adsorption varies between 96.04 and 100 % of the initial concentration of each metal, for CF produced without additives, Jassim, 2010. While the adsorption varies between 47.19 and 99.97 % of the initial concentration of each metal, for CF produced with different percentages and types of additives. BB discs showed adsorption of heavy metals varies between 84.6 and 99.55 %, which are relatively near to that without additives, this was due to high permeability of this product. While BV discs showed adsorption of heavy metals varies between 96.47 and 99.97 %.
showed adsorption of heavy metals varies between 47.19 and 99.7%, and this was due to very high permeability of this product.

**REFERENCES**


   عبد عون، ميساء علي، 2003، تنقية المياه الصناعية من العناصر الثقيلة في مطروحة قسم التكملة التابع للشركة العامة للصناعات القطنية باستخدام خامات عراقية، اطروحة ماجستير، كلية العلوم، جامعة بغداد، العراق.


   البصام، خثومون. شلد، نوال أحمد، صالح، علي عباس، شاهرا، مي محمود، و كوريكس، سم، 1993، صلاحية صخور البوسنيت العراقية كمرشحات صناعية، الشركة العامة للمسح الجيولوجي والتعدين، تقرير داخلي.


   الشركة العامة للمسح الجيولوجي والتعدين، 2008، الموصفات الكيميائية والفيزيائية للصخور الصناعية المستخرجية، نشرة داخليه.

حمادي، احمد عبد، تطوير خامات عراقية لأنتاج البلاط السيراميكي بالحرق السريع المنفرد، إطروحة ماجستير، كلية العلوم، جامعة بغداد، العراق.


المواصفات القياسية العراقية رقم 417.


تمراغا، مازن يوسف، و عدنان حسن عفج، 2000، تصنيع مرشحات الماء الخزفية من اطيان الكاوولين العراقية، المجلة العراقية للعلوم.