A PERFORMANCE STUDY OF CERAMIC FILTER MADE WITH WOOD ASH

دراسة أداء فلتر خزفي مصنوع بأضافة رماد الخشب

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Abstract

Wood ash is a mineral waste cheap and available material, which has a high adsorption activity. It was used with clay mineral type paligorskite to manufacture the ceramic filter. The physical properties and mineral composition are measuered for the ceramic which is produced.

The efficiency of ceramic filter is measured to remove the heavy metals ions (Mn^{2+}, Cd^{2+} and Co^{2+}), from its aqueous solution with two concentration (1 and 10 *mg/l*) by the produceding ceramic. So, the ability to remove these ions as follows: 99.6 to 99.9% for the influxing concentration 1 *mg/l*, and 24 to 31% for the inflowing concentration 10 *mg/l* . The ability of the product to purify the raw water is measured, the producing ceramic reduces the concentration of water pollutants which are the acceptable ratios according to (WHO) drinking water specifications.

Key words: woodash, heavy metals, water pollutants, ceramic, raw water.

الخلاصة:

يعتبر رماد الخشب من المخلفات المعدنية المتوفرة و الرخيصة و التي تمتلك فاعلية عالية على الامتزاز. حيث تم استخدامه مع اطين الباليكورسكايت لتصنيع فلتر خزفي. وقد قيست المواصفات الفيزياوية والتركيب المعدني لهذا الخزف.
تم فحص كفاءة الفلتر المنتج لازالة ايونات المعادن الثقيلة((Mn^{2+}, Cd^{2+} and Co^{2+}) من محاليلها بتركيز (ا و 10 ملغم/لتر). و كانت قابليت الفلتر على ازالة الايونات كانت 99.6 الى 99.9% لتركز 1ملغم/لتر، و 24 الى 31% لتركيز 10 ملغم/لتر. و اختبرت كفاءة الفلتر لتنقية الماء الخام. وقد خفض الفلتر الخزفي ملوثات الماء الخام الى نسبب مقبولة حسب مواصفات منظمة الغذاء العالمية (WHO) لمياه الشرب.

INTRODUCTON

Increasing importance of healthy drinking water which contain low ratios of impurities with population growth, which is usually accompanied by a scarcity of drinking water due to environmental degradation caused by industrial development and its different contaminations. In order to preserve human health and the environment many types of filters were made to remove turbidity or smell and taste, or turbidity, taste and smell. Ceramic filters are concidered of the most important domestic water filters [1], and most common for easy making and mandated quality properties, where by means of them can get rid of plankton sizes up to parts of micron[2, and 3]. Muds are the raw material in the ceramic industry, where 60% of these muds in the world exploited in such industries. Palygorskite clays are one of these muds [4], and it has properties for adsorption and exchanging cations[5]. In addition to muds other materials are used to improve the specifications of the product, as needed, and that the multiplicity of the use of these filters. And of these additives are porcelinite, limestone plus some remnants of the membership (organic matter) such as wood remains, grain husks, such as husks of wheat, barley, corn ... etc [6], and leaven fermented materials, [7, and 8].

Wood ash is the residue powder left after the combustion of wood, such as burning wood in a home fireplace or an industrial power plant. Much wood ash contains calcium carbonate as its major component as shown in XRD pattern of wood ash sample at Fig.1. The hydration of wood ash has several beneficial chemical effects. Newly burnt ash, with Ca oxidised into the form of $Ca(OH)_2$ (Portlandite), on exposure to air and moisture results in carbonate formation $CaCO_3$(calcite).The consequence of this is(9, and 10):

i) Lowered solubility of Ca, through the formation of ettringite ($Ca_6Al_2(SO_4)_3(OH)_{12}$. $26H_2O$) with reduced calcium leaching rate.

ii) Reduced alkalinity and more moderate pH.

iii) Reduced rates of mobility of heavy metals.

Ceramic is produce by firing materials or mixture of materials of inorganic and non-metallic materials. Many types of additives can be used with the ceramic matrix before or after firing to improve its properties. Wood ash can be used as an additive to raw materials of ceramic filters to enhance its properties.

This research aims to study the hydraulic performance and purifying properties of the ceramic filters made of local materials with wood ash as additive.

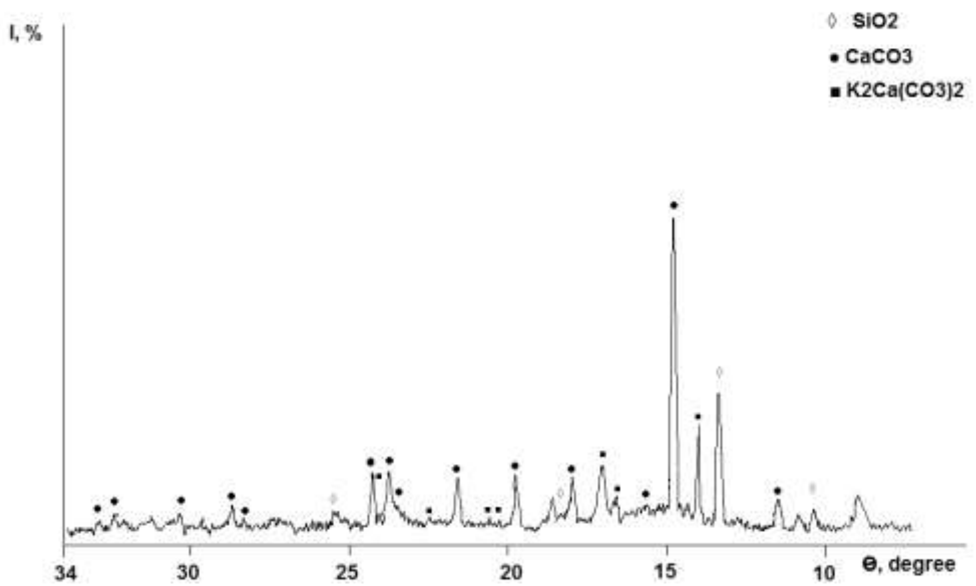

Fig. 1. XRD pattern of wood ash sample. [9]

PREPARING RAW MATERIALS AND PRODUCING CF

The ceramic raw materials that are used in this study are: palygorskite, Porcelanite, Limestone, and wood ash.

Raw materials were milled and sieved to be uniformly graded material to get porous ceramic[11].

The ceramic was produced by mixing the raw materials before firing. The mixture was used depending on the volume of the component used to the total volume of the mix used to produce the ceramic samples. Palygorskite formed the large ratio in the ceramic mixture contains. Then the ceramic was produced by adding wood ash to study its effect on the porosity and adsorption property of the ceramic product.

Wood ash was prepared from residue wood workshops. It has cleaned from any undesirable materials such as pins or any metallic residues. Then residue wood put burned. The output of burning was wood ash. It was added to raw ceramic materials. The Percentage of additive was used of 50% of the total mixture volume of the ceramic raw mixture.

Ceramic filter samples were manufactured in this study as cylindrical disc tablets of a diameter of 50 *mm* and thickness of 10 *mm*, using semi dry pressing method [5]. The sample was dried at 105 °*C* for 24*hr*, [12].

The firing process of the dry discs, previously prepared, was carried out at 1100° *C*. The firing was done by electrical muffle furnace.

PHYSICAL TESTS

The physical properties of the produced ceramic were measured by applying certain tests. These properties were apparent density and apparent porosity which concerning the hydraulic properties and strength of ceramic.

Density and Porosity Tests

The apparent density, apparent and true porosity of ceramic were carried according to ASTM-C 373 standards, 2006[13].

Apparent density is a dry density of a material. The compressive, tensile strength and porosity of ceramic are depend on its apparent density value. This property of ceramic body depends on the raw material gradation, method of shaping ceramic, and firing program, [14].

Porosity is defined as the percentage of pore space in a material. It depends on size gradation of ceramic raw materials and types of these materials such as compostable materials or thermal analytical, [15].

Hydraulic Conductivity Test

The hydraulic conductivity(HC) of a porous medium means ability of water to move through these medium.

The hydraulic conductivity is calculated by variable head method by applying the following equation, [16]:

$$HC = 2.3\frac{a\times L}{A_c\times t}\times \log_{10}\frac{ho}{h1} \quad \textbf{1}$$

where:a=cross section area of head column, m^2,A_c= cross section area of ceramic sample, m^2, h_o =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, [17]:

$$HC_s = HC_a\frac{\mu}{\mu 20} \quad \textbf{2}$$

where: HC_a=average saturated hydraulic conductivity, m/hr,μ=viscosity of water at any temperature, $Pa.s$, and μ_{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 Co(II), Mn(II), and Cd(II), were prepared as follows:

The required amount of metal salt was dissolved into one liter of Distilled water . 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:

$$M_a = 0.5(g.of\ metal)\frac{MW}{AW} \quad \textbf{3}$$

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 Co(II), Mn(II), and Cd(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 to100 ml, with distilled water[5].

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:

$$AP = \frac{Co - Ce}{Co} \times 100 \qquad \mathbf{4}$$

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*.

Water Purification Tests:

Water is an essential resource for living systems, industrial rocesses, agricultural production and domestic use. The principal factors that are taken into consideration when determining water quality are, WHO, 2006[18]

Turbidity, pH, EC, TDS, Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, HCO_3^{-}, SO_4^{2-}, NO_3^{-}.

The concentration of these factors were measured in the raw water before and after passing the filter.

Mineralogical Tests

Mineralogical tests of the produced ceramic discs were done by the x-ray reflection device. The samples were tested in Philips X-Ray Powder Diffractometer Vertical Gionometer PW 1050/10.

RESULTS, and DISCUSSION

Physical Properties of ceramic

Six tests were carried out to specify the physical properties of the produced ceramic discs. Values of apparent density, apparent porosity were: 1.13*gm/cm*^{3}, 57.33*%*. respectively. The high values n_a, and low values ρ_a of the new product were due to using woodash. The hydraulic conductivity was measured. It was 0.0081 m/hr.

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 tests, including one replication, were carried out on a per prepared solution of 1*mg/l* of each of seven heavy metals, Mn, Cd, and Co. Other six tests, including one replication, were carried out on per prepared solution of 10*mg/l* of each of these seven heavy metals.

According to Iraqi Specifications No 417[19], limits of these heavy metals in drinking waterare listed in **Table 1.**

Table 1. Iraqi specifications limitsof heavy metals in drinking water.

Heavy metal	Pb	Cd	Zn	Cu	Fe	Mn
Concentration, *mg/l*	0.05	0.01	1.0	0.5	0.5	0.1

Average results of test that were carried out to examine heavy metals adsorption properties of the produced ceramic using a per prepared solution of 1*mg/l* and 10 *mg/l* of each of the used heavy metals, Mn, Cd, and Co, are shown in **Table 2.** Generally, the results showed that the ceramic adsorbed most of the heavy metals ions at initial low concentration 1 *mg/l*. The removal varies between 99.50 and 99.9% of the initial concentration of each metal.

Table 2. Concentration of heavy metals of filtered Water through ceramic filter, initial concentrations 1*mg/l*, and 10 *mg/l*.

Heavy metals	Cd	Co	Mn
Outflow concentration, *mg/l*, initial concentration ***1mg/l***	0.004	0.001	0.005
Removal %	99.6	99.9	99.5
Outflow concentration, *mg/l*, initial concentration ***10mg/l***	6.9	6.98	7.6
Removal %	31	30.2	24

While at higher concentration 10 *mg/l*, the filter could remove some of these ions. The percentage of removal varies between 24 and 31% of the initial concentration of each ion.

Water Purification Tests:

Twenty water quality tests at two of each of EC, TDS, Ca^{2+}, Mg^{2+}, Na^{1+}, NO_3^{1-}, SO_4^{2-}, pH, Cl^{1-}, and turbidity. The results showed variable ability of purifying of produced filters.

The concentrations of EC, TDS, Ca^{2+}, Mg^{2+}, Na^{1+}, NO_3^{1-}, SO_4^{2-}, pH, Cl^{1-}, and turbidity of allowable concentrations according to Iraqi updated specification No.417 and concentrations of raw water were as shown in **Table 2.**

Table 2. List of tests carried on raw water, allowable concentrations according to the Iraqi Specification 417 and the concentrations in the used raw water.

Water quality parameter	Allowable concentrations according to the Iraqi specification	Concentrations in raw water	Concentration in purified water	% 0f removal
EC, *µm/cm*	Not available	2980	600	79.87
TDS, *mg/l*	1000	1740	300	82.76
Ca^{2+} , *mg/l*	200	678	435	35.84
Mg^{2+}, *mg/l*	150	331	300	9.37
Na^{1+},*mg/l*	200	131	122	6.87
NO_3^{1-}, *mg/l*	45	5.06	1.17	76.98
SO_4^{2-}, *mg/l*	400	820	539	34.27
HCO_3^{1-}, *mg/l*	Not available	317	261	17.67
pH	6.5-8.5	7.8	7	
Cl^{1-}, *mg/l*	200	214	200	6.54
Turbidity, *NTU*	5	123	0.05	99.96

Mineralogical Tests

Mineralogical test were carried on the produced ceramic filters according to the procedure explained befor. The resulting minerals were found by measuring their reflecting angles and their intensities as shown **Fig. 3,** which showed that the resulting minerals after burning at 1100 C° had formed: Anorthite ($CaAl_2Si_2O_8$), Beta-Quartz (SiO_2), Low Cristobalite (SiO_2), Tridoymite (SiO_2), Protoenstatite ($MgSiO_3$), Orthoclase ($KAlSi_2O_8 1/2(K_2O.Al_2O_3.6SiO_2)$, Plagioclase ($0.71NaAlSi_3O_3$, $0.29CaAl_2Si_2O_8$), and Larnite syn (Ca_2SiO_4. Here three phases of silica (SiO_2), Beta Quartz Tridoymite, and Low Cristobalite, in addition to Anorthite ($CaAl_2Si_2O_8$), Protoenstatite ($MgSiO_3$), Orthoclase ($KAlSi_2O_8.1/2(K_2O.Al_2O_3.6SiO_2)$, Plagioclase ($0.71NaAlSi_3O_3$, $0.29CaAl_2Si_2O_8$), and Larnitesyn (Ca_2SiO_4) had appeared. It means that Tridoymite and Low Cristobalite remained with their original form and didn't transform because they were the phases of silica which formed at high temperature (1470, 1705)°*C* respectively and since the firing temperature did not reach these high temperatures so they remained in the new composition of ceramic body. The Silica in initial composition transferred to Alpha-Quartz when temperature rose until 573 °*C* then it started to transform to Beta-Quartz until 870 °*C*. Then it reversed to Tridoymite then Cristobalite. The formation of Tridoymite and Cristobalite were speeded up by the addition of limestone and they were occurred at lower temperatures,(20). The Al^{3+} in initial Paligorskiet, Montmorilniet, and Kaolinite appeared at Anorthite ($CaAl_2Si_2O_8$) which is also called lime feldspar and it works as Flux in the ceramic body, [20]. Ca^{2+} and Mg^{2+} in initial Calcite, Paligorskiet and woodash were found in the composition of Diopside ($CaMg(SiO_3)_2$), Enstatite ($MgSiO_3$), and Larnite syn (Ca_2SiO_4) which is called unhydrated cement.

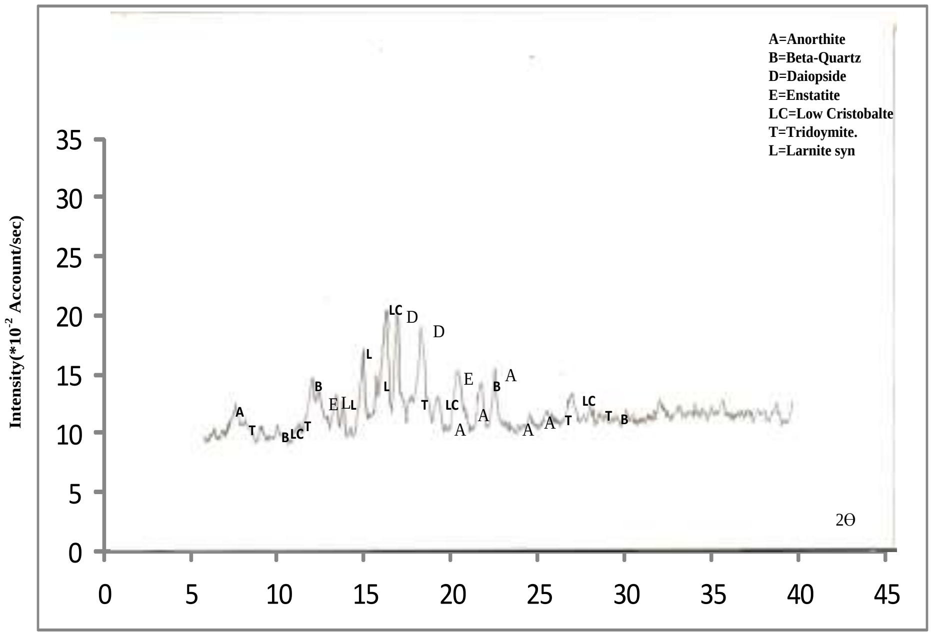

Fig. 2: X-Ray pattern of ceramic filter.

CONCLUSIONS

The increased needs to ceramic water filters of various capacities encourage efforts to study hydraulic performance and optimize their design and to introduce new ceramic materials and additives to enhance its effectiveness.

In this study, a mixture of Iraqi raw materials were used to produce of ceramic filters. Wood ash is a mineral waste cheap and available material, which has a high adsorption activity. It was used with clay mineral type paligorskite to manufacture the ceramic filter.

The physical test analysis showed that the average values of physical properties for the ceramic were: apparent density was 1.13 gm/cm^3, apparent porosity was 57.33%. The hydraulic conductivity was 0.0081 m/hr.

The produced ceramic filter removed heavy metals ions from there aqueous solutions. It has excellent adsorption ability at concentrations 1 and 10 *mg/l*. The percentages of removal of each of these metals vary between were 99.6 and 99.9% for 1 mg/l, and the percentage of removal varies between 24 and 31% of the initial concentration of 10 mg/l of each ion.

Filtration Properties tests results showed that the ceramic disc filters could remove, as an average percentages of removal, 99.96 of turbidity, 79.87 % of the electrical conductivity , 82.76 % of the total dissolved solids, 35.84 %of Ca^{++}, 9.37 %of Mg^{++}, 6.87 % of Na^{+}, %6.54 of Cl^{-}, %76.98of NO_3^{-}, %34.27 of $SO_4^{=}$, and 17.67 %of HCO_3^{-}.

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