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Evaluation of Adsorption Capacity by Ceramic Filter Made of Palygorskite and Vinger Yeast to Heavy Metals Ions

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Abstract

In this study, ceramic filter (CF) was produced from a mixture of Iraqi raw materials. This ceramic mixture was prepared using paligorskiet as a Clay, Porcelanite as a Silica, and Limestone as a flux. Viger yeast was used as an additive to the raw materials.

Physical properties of the produced CF were measured. The hydraulic conductivity of the produced was measured. The average hydraulic conductivity of the produced CF was 110 times that of commercial types of ceramic filters.

The mineral composition of the produced ceramics was found by X-Ray tests. Tests results showed that all of the produced ceramics filters composed mainly of low Cristobalte and Tridoymite in addition to some of other minerals.

The results showed that CF has excellent adsorption ability for solutes of four heavy metals, Cd, Co, Fe, and Zn, at concentrations of 1 *mg/l* each and 10 *mg/l* each. The adsorption capacities of each filter to adsorb four heavy metals were computed according to kinematic energy models. They were Langmuir model and Freundlich models. The results showed variety in adsorption capacities for each heavy metal.

Keywords: Key words: vinger yeast, heavy metals, water pollutants, ceramic, raw water.

انتاج منقيات مياه خزفية مصنعة من طين الباليكورسكايت مع خميرة الخل

الخلاصة

في هذه الدراسة تم انتاج منقي خزفي مصنع من مواد اولية عراقية. هذه المواد هي طين الباليكورسكايت مع سليكا البورسيلينايت و حجر الكلس كمادة معجلة. واستعملت خميرة الخل كمادة مضافة.
لمعرفة التركيب المعدني للخزف المنتج فحصت النماذج المنتجة بواسطة حيود الاشعة السينية .واظهرت النتائج للخزف المنتج يتكون بصورة رئيسية من الكرستوبالايت الواطىء والترادومايت اضافة الى بعض المعادن الاخرى.
تم قياس الايصالية العيدروليكية للخزف المنتج و بينت النتائج ان الايصالية الهيدروليكية للمنقي المنتج للمرشحات المصنعة تساوي 55 مرة بقدر الايصالية الذيدروليكية للانواع التجاريةللمرشحات الخزفية .قيست الخواص القيزيائية للخزف .
اوضحت النتائج ان المرشحات الخزفية المصنعة لها قابلية ممتازة على امدصاص اربعة من العناصر الثقيلة التي استخدمت في التجارب وهي الحديد و الزنك و الكوبالت والكادميوم بتركيز1 ملغم/لتر و % 10 لكل عنصر .تم حساب سعة الامدصاص لكل مرشح من هذه العناصر الثقيلة حسب مويل لانكميور وموديل فريوبيلج .وكانت سعة الامدصاص مختلفة لكل من هذه الايونات الثقيلة.

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].

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 grind the dry yeast for few minutes and screened on sieve of 63μm opening.

Ceramic is produc 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. Vinegar yeast can be used as an additive to raw materials of ceramic filters to inhence its properties.

Generally, this research aims to study the hydraulic performance and purifying properties of the ceramic filters made of local materials with vinegar yeast as additive.

Preparing Raw Materials and Producing Cf

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

Raw materials were milled and sieved to be uniformly graded material to get porous ceramic[9].

To simplify the manufacturing process, maintain consistency across a range of samples and allow for simplicity and versatility in filtration testing techniques, 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, **Fig .1.** Carbonate steel mold was manufactured to produce the ceramic discs as shown in **Fig. 2.** The mold should be cleaned and lubricated by thin oil (glycerin) before each pressing.

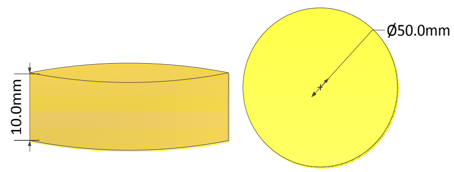

Fig. 1– Filter Ceramic Disc Dimensions.

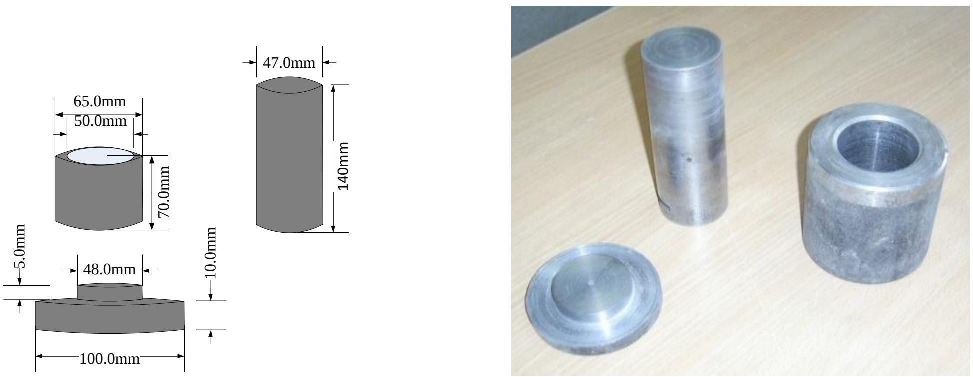

Fig. 2. Manufactured Carbonate Steel Mold

The creamic was produced by mixing the raw materials befor 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 were produced by adding vinegar yeast to study its effect on the porosity and adsorption property of the ceramic product.

Vinegar yeast was prepared from residue wood workshopes. It has cleaned from any undesirable materials such as pins or any metallic residues. Then residue wood put burned. The output of burning was woodash. 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 drypressing method, [5]. The sample was dried at 105 C° for 24*hr*, [10].

The firing process of the dry discs, previously prepared, was carried out at 1100 C^{o}. The firing was done by electrical muffle furnace.

Physical Tests

Apparent density and apparent porosity are the physical properties that related to the hydraulic properties and strength of the ceramics. These properties of the produced ceramic were measured by applying certain tests.

Density and Porosity Tests

The apparent density, apparent and true porosity of ceramic were carried according to ASTM-C 373 standards, 2006[11].

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 gradiation, method of shaping ceramic, and firing program, [12].

Porosity is defined as the percentage of pore space in a material. It depends on size gradiation of ceramic raw materials and types of these materials such as compostable materials or thermal analytical, [13].

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, [14]:

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

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, [15]:

$$HC_s = HC_a\frac{\mu}{\mu 20}$$

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, $Pa.s$.

Equipment was used for measuring hydraulic conductivity **Fig. 3[5]** shows the general view of the hydraulic conductivity equipment that was constructed to be used to measure *HC* described by **equation 1 .** The equipment consists of a plastic or glass tube with a 52 *mm* diameter and 150 *mm* height in which the ceramic disc was fixed inside it and sealed with silicon to prevent water from passing through the open between tube and ceramic disc. The tube placed between two galvanized steel covers containing valves for inlet and outlet water. The test collection placed at an aluminum frame in order to raise the head reservoir to the desired head. **Fig. 4** shows the test set up view

Fig. 3: General view of hydraulic conductivity test equipment**[5]**

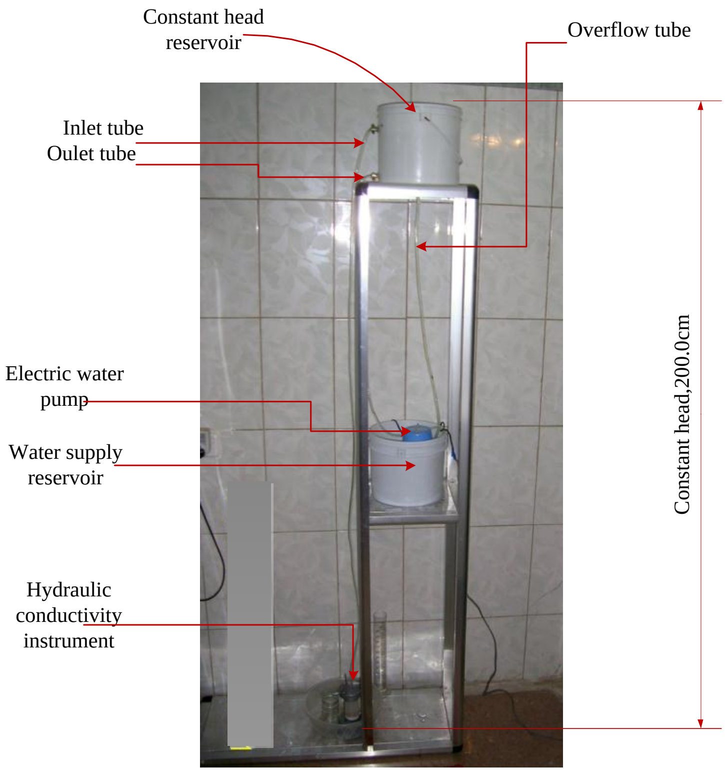

Fig. 4: General View of hydraulic conductivity test rig**[5]**

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 Cd(II), Co(II), Fe(II) and Zn(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, 0.50*g* of metal. That means:

$$Ma = 0.5(g.\ of metal) \times \frac{MW}{AW} \qquad \mathbf{3}$$

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 of Cd(II), Co(II), Fe(II) and Zn(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:

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

4 where: *Ap*=percentage of adsorption, *%*. *Co* =initial concentration of metal ion in the queous phase, *mg/l*, *Ce* =final concentration of metal ion in the aqueous phase, *mg/l*.

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 vigeryeast. The hydraulic conductivity was measured. It was 0.0044 m/hr.

Heavy Metals Adsorption Tests

Six adsorption tests, including one replication, were carried out to examine the adsorption of heavy metals properties of the produced ceramic filter disc. Three, including one replication, were carried out on a per prepared solution of 1*mg/l* of each of four heavy metals, Cd, Co, Fe, and Zn. Other six tests, including one replication, were carried out on per prepared solution of 10*mg/l* of each of these four 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	Cd	Zn	Fe
Concentration, *mg/l*	0.01	1.0	0.5

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, Cd, Co, Fe, and Zn 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 99.40 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	Fe	Zn
Outflow concentration, *mg/l*, initial concentration ***1mg/l***	0.006	0.001	0.002	0.002
Removal %	99.4	99.9	99.8	99.8
Outflow concentration, *mg/l*, initial concentration ***10mg/l***	2.9	7.87	4.2	3.8
Removal %	71	21.3	58	62

While at hgier concentration 10 *mg/l*, the filter could remove some of these ions. The percentage of removal varies between 21.3 and 71% of the initial concentration of each ion.

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Mineralogical Tests

Mineralogical test were carried on the produced ceramic filters according to the procedure explained befor. The initial raw materials composed of Paligorskiet ($(Mg,Al)_2Si_4O_{10}(OH).4(H_2O)$), Montmorilniet ($(Ca,Na)Mg_2Al_{10}Si_{24}O_{60}(OH)$), Kaolinite ($Al_2O_3.2SiO_4.2H_2O$), Low Cristobalite ($SiO_2$), Tridoymite ($SiO_2$), Calcite ($CaCO_3$), and organic matters of vinegar yeast, respectively. The resulting minerals were found by measuring their reflecting angles and their intensities as shown **Fig. 5,** which showed that the resulting minerals after burning at 1100 C^o had formed: Anorthite ($CaAl_2Si_2O_8$), Beta-Quartz ((SiO_2), Low Cristobalite (SiO_2), Protoenstatite ($MgSiO_3$), Tridoymite (SiO_2), Orthoclase ($KAlSi_2O_8$ $1/2(K_2O.Al_2O_3.6SiO_2)$), and Larnite syn (Ca_2SiO_4. Here also the three phases of silica (SiO_2), Beta Quartz, Tridoymite, and Low Cristobalite, in addition to Anorthite ($CaAl_2Si_2O_8$), Protoenstatite ($MgSiO_3$), Orthoclase($KAlSi_2O_8$ $1/2(K_2O.Al_2O_3.6SiO_2)$, and Larnite syn (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^o 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^o then it started to transform to Beta-Quartz until 870 C^o. 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, and Paligorskiet 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.

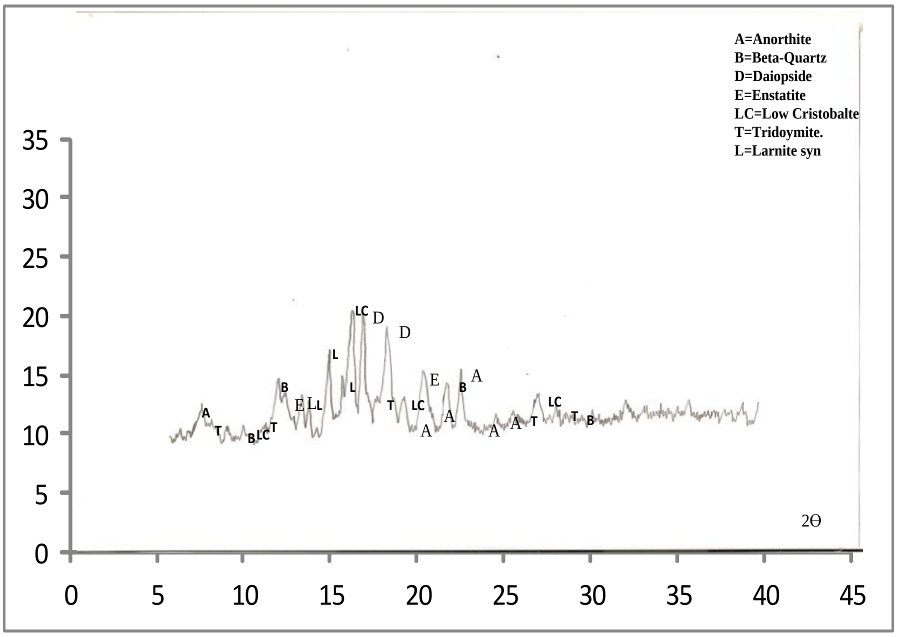

Fig. 5: X-Ray pattern of ceramic filter.

Adsorption Capacity

Adsorption capacities of the ceramic filter, were measured according to the procedure mentioned befor. The polluted water with fout heavy metals (Cd, Co, Fe, and Zn), at (20, 40, 60, and 80 *mg/l*) of each metal. The remaining concentrations (Ce *mg/l*) of these metals after passing through these filters were measured. Adsorption capacity (qe *mg* of metal adsorbed by one *gram* of adsorbent) at each concentrate were calculated as shown in chapter three. Then graphs were plotted according to both Langmuir and Freundlich methods. The data used for measuring filters capacity is given in **Table 3**

Results of adsorption capacities according to Freundlich model were: Co>Cd> Zn>Fe. Where maximum capacity was for Co (3.678*mg/g*), and minimum was for Fe(2.521 *mg/g*). While the results according to Langmuir model were: Fe> Zn> Co> Cd**,** and maximum capacity was for Fe (1.026 *mg/g*), and minimum was for Cd (0.969 *mg/g*).

Table 3. Adsorption Capacities of Ceramic Filter for the Heavy Metals

metal ion	Adsorption capacity (mg/g) (Langmuir model)	R^2	Adsorption capacity (mg/g) (Freundlich model)	R^2
Co	0.969	0.9847	3.678	0.991
Cd	0.964	0.9939	3.577	0.9955
Zn	0.995	0.9773	2.790	0.9925
Fe	1.026	0.9752	2.521	0.9849

The adsorption capacity results showed that the produced filter had different adsorption capacities for the tested heavy metals ions.

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