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Original Article

The Potential Use of Pottery Jugs as Drinking Water Filters

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Abstract

The use of porous pottery jugs (fired clay) to the purification of drinking water and reduction of heavy metals and other contaminants is the aim of this study. A total of twenty-eight samples of drinking tap water tested for pH, Turbidity, TDS, Electrical Conductivity, Salinity, TH, Ca^{++} hardness, Mg^{++} hardness and Total Coliform bacteria, in addition to some heavy metals (Pb, Zn, Mn, Fe, Cd and Cu) in water before and after filtration also inside the jugs through 24 hour. The paper discusses the ability for this technique to reduce such these pollutants that may be remaining after treatment. Pottery jugs (B) represented the best one in WQI and AWQI that may be due to its composition of silt and the high quality of clay. Pottery jugs (B) able to reduce the concentrations of turbidity, TH, Ca^{++} and Mg^{++} hardness. Also, improved its efficiency in decreasing levels of some heavy metals as Mn, Pb, and Cd. Statistical ANOVA tests showed a significant difference between pottery jugs with physicochemical parameters and filtration efficiencies. The concentrations of examined physicochemical parameters and heavy metals in drinking tap water and inside the pottery jugs and in the filtrate were within the safe limits of EMH (2007), WHO (2011) and Egyptian Standards (EEAA, 1994) regulations, except the concentration of Fe inside and in the filtrate, was above safe limit.

1. Introduction

The deadliest diseases being contacted from water are always from microbial particles or the presence of heavy metals that may be present in water through leaching or other processes. Most of the water resources in the countryside are contaminated with dissolved minerals and pathogenic organisms which can be highly infectious and disease-causing (Ajayi and Lamidi, 2015). Low scale water treatment techniques, boiling, chlorination, solar water disinfection, natural coagulation and bio-sand filtration are used to remove water related disease-causing microorganisms. Bio-sand filter can remove protozoa up to 100 %. Some of these techniques reduce the quality of water, and the side-products have an adverse effect on consumer health (Zereffa and Bekalo, 2017). Although municipal water in developed countries already falls into the World Health Organization (WHO) safe drinking water standards, water filters are still commonly used to improve taste or to eliminate any undesired matters. Various types of filters have been designed to be more suitable in the third world countries, but the cost is still not satisfactory, and many products are imported which further add to the cost. Their performance levels were determined by the removal efficiencies in terms of turbidity and microbiological parameters. Ceramic water filtration as defined by Brown *et al*. (2007) is the process that makes use of a porous ceramic (fired clay) medium to filter microbes or other contaminants from water. The pore size of the ceramic medium is sometimes small enough to trap anything bigger than a water molecule. A porous media of fired clay retains microbes by size exclusion and high tortuous properties (it traps microbes in the sharp bends) (Sobsey *et al*., 2008; Hunter, 2009 and van der Laan *et al.*, 2014). From the ancient times to the present, water filters have evolved out of necessity, first to remove materials that affect appearance, then to improve bad tastes and further to remove contaminants that can cause disease and illness, (Logsdon, 1990; LeChevallier and Au, 2000 and Ajayi and Lamidi, 2015). Baker (1948) he found that porous ceramic filters made of clay carved porous stone and other media used to filter water are rated to remove at least 99.9999% of bacteria, 99.99% of viruses, and 99.9% of *Giardia cysts*. Jaffar *et al.* (1990) used ceramic filters containing fired clay, limestone, lime and calcium sulfate have been produced for water filtration in Pakistan, and they found that the filters reduced turbidity by 90% and bacteria by 60%. Also, Ajayi and Lamidi (2015) improve that a ceramic water filter composition can be effective for the removal of heavy metals and correction of physiochemical parameters in-home use water.

Most of Damietta governorate lands with agricultural activities. Where using the pesticides and fertilizers increase the pollution in water and plants. Thus, the human health in

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dangerous in Damietta Governorate especially after the construction of the industrial area, Damietta harbor, reclamation projects and agricultural development. The drinking water resources in the Damietta governorate comprise both Damietta Nile branch surface and ground waters. Water pollution is the main environmental problem in Damietta Governorate and the whole Arab Republic of Egypt. Pollution sources of Damietta Nile Branches water come from agricultural drains, domestic sewage, industrial effluents and fish farms (Al-Asmar, 2006). The use of wastewater in irrigation and sewage sludge has further increased the quantity of heavy metals in agricultural soils. The agricultural run-off together with soil erosion is considered as the potential source of water pollution. Metals get into the body through air, food, water, or dermal exposure. Metals have to cross the plasma membrane to enter the cell to exert toxicity. If a metal is in a lipophilic form, such as methylmercury and arsenic compounds, it readily penetrates the membrane. When bound to a protein, such as cadmium metal, the metal is actively taken into the cell by endocytosis. Human exposure to metals occurred since pre-historic time in areas where the heavy metal content of water and food were naturally high (Hasballah and Beheary, 2016). Believe of citizens in Egyptian villages that pottery jugs, which were manufacturing by mixing of clay-rich soil with water, sand, and remained pottery jugs and pressing into the cylinder and firing them at 900 °c for eight hours can act as a filter for tap drinking water. Using of the filtrate in cooking and other purposes making us focus the study on the potential use of such these pottery jugs in the purification of drinking water and reduction of heavy metals, and this is the aim of this study.

1. Materials and Methods

2.1. Sampling

Four samples of drinking tap water were collected from four main districts of Damietta governorate in Egypt country (EL-Zarka, Faraskor, Kafr- Saad and Damietta City) Figure 1. Twelve pottery jugs were purchased from three different Governorates, (Damietta, El-Gharbia, and El-Mnya), four jugs of each and divided to three groups according to the governorate (A, B, and C); respectively, Figure 2. All jugs washed and filled with drinking tap water for one day then remove the water and filled again and prepared for analysis. Drinking tap water was collected from houses into 1000 ml acid-washed polyethylene (PE) bottles and was transported to the laboratory where they were stored at -4°C until analysis at the Faculty Laboratory, Accurate Analysis Unit, Damietta University. The pottery jugs filled with drinking tap water samples for 24 hours**,** physicochemical parameters of water samples were analyzed before putting the water in jugs and inside the pottery jug bodies, also the filtrate (the out of the pottery jug bodies) after 24 hours.

2.2. Physico-Chemical Analysis of Drinking Water Samples

Physical and chemical parameters of twenty-eight water samples (before, inside and filtrate) for each type of pottery jug bodies (A, B and C) were analyzed include: pH, Turbidity, Total dissolved solids (TDS), Electrical conductivity (EC), Salinity, Total Hardness (TH), Ca^{++} hardness and Mg^{++} hardness have been determined according to Standard Methods for Examination of Water and Wastewater (American Public Health Association), (APHA, 1992). Pottery jugs bodies' texture or composition was determined by Hydrometer Method as described by Piper (1947).

2.3. Total Coliform MPN Analysis of Drinking Water Samples

Multiple tube fermentation technique was performed according to APHA (1999). Presumptive phase MacConkey broth medium, which is commercially produced as a powder (OXOID, CM0505 (CM5a)) was used. 40 g of the medium was diluted in one liter of distilled water. Fermentation tubes were arranged in three rows of five tubes, and then Durham tube was added to each fermentation tube. The pH was adjusted at 7.4 ± 0.2. 10ml of the medium was distributed in each fermentation tube. Sterilization was done by autoclaving at 121˚C for 15minutes. Every five tubes were used for one dilution of sample (10, 1, 0.1ml of the sample). Inoculated tubes were incubated at 37˚C for 24hr. After 24 hr, tubes were examined for acid and gas production. If no gas or acidic growth has formed tubes were re-incubated at the end of 48hr. Then MPN was calculated.

2.4. Heavy Metals Analysis of Drinking Water Samples

Heavy metals concentration in drinking water was determined according to a method of AOAC (2000). A volume of 100 ml of sample was measured into a beaker, and 5 ml concentrated HNO_3 was added. The mixture was boiled slowly on a hot plate or a steam bath until the volume has evaporated down to about 20 ml. A further five mL of concentrated HNO_3 was added and the beaker covered with a watch glass and heated. Heating and adding concentrated HNO_3 were continued until the solution have appeared light colored and clear. A 1-2 ml aliquot of concentrated $HN0_3$ was added, and the mixture heated slightly to dissolve any remaining residues. The beaker walls and the watch glass were washed down with water which then is transferred to a 50 mL volumetric flask, cooled and the volume made up to the mark with water. The Inductively Coupled Plasma-Mass Spectrometry (ICP-OES 7000) was used for heavy metal analysis with an ultrasonic nebulizer (USN), this Nebulizer decrease the instrumental detection limits by 10%, this ICP instrument is Perkin Elmer Optima 3000, USA**.**

2.5. Calculation of Water Quality Index

WQI is a mathematical way of summarizing multiple properties into a single value. WQI is useful for comparing differences in water quality across a region, or for monitoring changes in water quality over time. In the present study, WQI was calculated using the equation developed by Tiwari and Manzoor (1988). The quality rating (qi) for the water quality parameter can be obtained by the following relation:

$$qi=100Vi/ Si...........(1)$$

Where Vi is the observed value of the parameter at a given sampling site, and Si is the stream water quality standard.

Equation (1) ensures that qi = 100 if the observed value is just equal to its standard value. Thus, the larger value of qi revealed polluted water. To calculate WQI, the quality rating qi corresponding to the parameter can be determined using equation (2). The overall WQI was:

$$WQI=\Sigma qi \text{ .... (2)} \qquad \text{Where } i=1$$

The average water quality index (AWQI) for n parameters was calculated using the following the equation (3):

$$AWQI=\Sigma qi/n \text{.............(3)}$$

2.6. Metal Pollution Index (MI)

The pollution index (PI) was used in this study to evaluate the degree of heavy metal contamination in water samples (Emoyan *et al.,* 2005 and Odukoya and Abimbola, 2010). The tolerable level is the element concentration in the water considered safe for human consumption (Lee *et al.,* 1998). Pollution index (PI) is based on individual metal calculations and categorized into five classes according to the following equation (Caerio *et al.,* 2005).

$$PI=\sum_{i=1}^{n}\left(\frac{C_i}{S_i}\right)/Nm$$

Where Ci = Heavy metal concentration in water; Si= permissible Level and Nm = Number of Heavy metals. Water sample with Pollution Index (PI) <1 is regarded as being no effect; (PI) = 1-2 (Slightly affected); (PI) = 2-3 (Moderately affected); (PI) = 3-5 (Strongly affected); (PI) = 4-5 (Seriously affected).

3. Results and Discussion

3.1. Physico-Chemical Analysis of Drinking Water Samples

pH is an important indicator of water quality and the extent of pollution (Badr *et al.* 2013). Through results in Table 1, the mean concentration of pH in water in pottery jugs (A, B and C) through all sites increased inside and increased in the filtrate, to become slightly alkaline this change may be due to different dissolved gases and solids (Patil *et al.* 2012). pH was positively correlated with electrical conductance and total alkalinity (Guptaa, 2009). The mean concentration of TDS increased from (226.75±14.08, 192.25±4.99 and 217.10±24.15 mg/l) to (256.50±11.01, 201.75±5.50 and 228.0±22.33 mg/l) inside and increase in the filtrate to (375.50±48.48, 246±9.42 and 571±83.57 mg/l), respectively. Also, the mean concentration of EC increase from (502±147.23, 336.25±74.97 and 443.25±60.95 µs/cm) to (508.50±19.07, 406.75±13.5 and 491.0±54.66 µs/cm) inside and increase in the filtrate to (776.0±115.14, 505.25±21.08 and 1022±142 µs/cm), respectively. TDS increased inside the jugs and in the filtrate that may be attributed to leaching the component of the pottery jugs that may be discharged into the water (Sagara, 2000), and that may be attributed to high porosity of the filter elements that resulted from the higher percentage of burnout material in the composition (Zereffa and Bekalo, 2017). And that was in agreement with the results in Table 2, which show the increasing of the sand fraction percentage which reached to (96, 90 and 90%) in pottery jugs (A, B and C), respectively. The mean concentration of salinity in water in pottery jugs (A, B and C) through all sites slightly increased from (0.20±0, 0.20±0 and 0.20±0 %) to (0.23±0.04, 0.20±0 and 0.23±0.04%) inside and increase in the filtrate to (0.35±0.05, 0.23±0.05 and 0.60±0.1%), respectively. The mean concentration of turbidity in water in pottery jugs (A and B) decreased from (2.35±1.35 and 2.63±0.56 NTU) to (1.45±0.48 and 1.79±0.67 NTU) inside and decreased in the filtrate to (1.20±0.24 and 1.60±0.29 NTU), respectively. On the other hand, the mean concentration of turbidity in water in pottery jugs (C) increased from 1.73±0.22 NTU to 2.22±0.46 NTU inside and increased in the filtrate to 2.85±1.74 NTU, the turbidity values of all water samples collected lies in the allowable limits of drinking water. The decreasing in turbidity in water in pottery jugs (A and B) may be attributed to the presence of clay and silt fractions which its percent reached to (4, 0 and 9, 1 %), respectively, Table 2. As silt able to adsorb the impurities and that agreed with Ajayi and Lamidi, (2015) who indicated that the pore size of the ceramic medium is sometimes small enough to trap anything bigger than a water molecule. Bielefeldt *et al.* (2010) mentioned that the pore sizes of ceramic water filters determine the ability to remove particles and pathogens from water. The results are in agreement with Zereffa and Bekalo (2017) who stated that the microbial removal efficiency of ceramic filters ranged from 80.00 % to 97.50 %; they added that the microbial and turbidity removal efficiency of the ceramic filters in crease with the increase of the percentage of clay in the composition.

The mean concentration of TH in water in pottery jugs (A and C) through all sites increase from (103.00±42.88 and 103.00±42.88 mg/l) to (120.00±6.53 and 142.00±10.07 mg/l) inside and increase in the filtrate to (381.10±53.36 and 494.50±86.09 mg/l), respectively. The mean concentration of TH in water in pottery jugs (B) decreased from 103±42.88 mg/l to 69.25±54.41 mg/l inside and reached to 97.0±41.58 mg/l in the filtrate. In addition, the mean concentration of Ca^{++} and Mg^{++} hardness in water in pottery jugs (A and C) increase inside and in the filtrate, while the mean concentration of Ca^{++} and Mg^{++} hardness in water in pottery jugs (B) decreased from (38.10±9.09 and 64.90±38.34 mg/l) to (20.44±19.83 and 48.73±42.37 mg/l) inside, respectively, and reached to (34.76±10.52 and 62.44±31.70 mg/l), respectively, in the filtrate. The results in Table 3 indicated that the removal efficiency of turbidity in pottery jugs (A) and (B) was 38.3 and 31.93 %, respectively, inside the jugs, while the percentage of removal reached to 48.9 and 39.16 %, respectively, in the filtrate for the same jugs. On the other hand, the removal efficiency of TH, Ca^{++} and Mg^{++} hardness in pottery jugs (A) were 32.7, 46.35 and 24.91 %, respectively, insides the jug, while reduced to 5.8, 8.76 and 3.79 %, respectively, in the filtrate.

On the contrary, pottery jugs (C) showed his lack of turbidity, TH, and Ca^{++} hardness removals were 0.0 %, except Mg^{++} hardness, its percentage of removal was 14.4 %. The removal of cations and anions might be due to the ion exchange on the ceramic surface, the central cations in clay structure, aluminum, and silicon, with higher charge might be replaced with lower charge ions such as magnesium and calcium by leaving net negative charge (Zereffa and Bekalo, 2017). Through the results, we found that pottery jugs (B) which purchased from Kafr El-Zyate city had high performance in decreasing turbidity, TH, Ca^{++} and Mg^{++}

hardness in drinking water. This result in accordance with Brown and Sobsey (2007) who found that the filter's demonstrated effectiveness in improving water quality and health, over a wide range of conditions, makes it among the best available options for household water treatment. Also, this was in agreement with Sagara (2000) who indicated that the filter systems had very high turbidity removal efficiencies and the system reduced the turbidity level of water to less than 1 NTU. The filtration process is a simple and an effective method of treating drinking water, and thus it is a suitable process to be used in point-of-use treatment systems. The filtration process does not require any addition of chemicals and can be operated without a power supply. It is also readily adaptable to household-scale systems. In the filtration systems, the most commonly used filter medium is sand; however, media such as anthracite, crushed magnetite, garnet, coconut, husks and other natural and inert synthetic materials are also used. Medium type, size, porosity, pore size and available surface area of the medium are factors determining the effectiveness of the filtration removal process. There are systems for removing hardness, and others to remove dissolved organics by adsorption filters (Sagara, 2000).

The values of WQI and AWQI in Table 4, were calculated according to EMH (2007) and Egyptian Standards EEAA (1994). According to Table 4, the concentrations of examined physicochemical parameters in drinking tap water and inside the pottery jugs and in the filtrate were within the safe limits. The results showed that AWQI values of drinking water samples in pottery jugs (A): (Before, inside and filtrate) were 41.86, 42.7 and 62.54, respectively, and in pottery jugs (B) were 39.9, 36.3 and 41.4, respectively. While AWQI values in pottery jugs (C) were 38.7, 45.9 and 96.8, respectively, that means that the drinking water samples in a pottery jug (A, B and C) are classified under good water quality during the sampling period. Pottery jugs (B) represented the best one in WQI and AWQI for inside and the filtrate. Also, Pottery jugs (B) improved its ability in the reduction of turbidity, TH, Ca^{++} and Mg^{++} hardness concentrations, that may be attributed to its body composition of silt and the high quality of clay. The water inside the pottery jugs (B) had high quality than in the filtrate.

3.2. Total Coliform MPN Analysis of Drinking Water Samples.

The results of the MTF technique for measuring total coliform bacteria are expressed in terms of the most probable number (MPN) index/100 ml of microorganisms, all drinking water samples of pottery jugs, before, inside and filtrate give negative results when five tubes are used per dilution (10 ml, 1 ml, 0.1 ml) and inoculated on Lauryl tryptose medium.

3.3. Heavy Metal Analysis of Drinking Water Samples

Results in Figure 3 indicated that the mean concentration of Fe in water in pottery jugs (B) through all sites increased from 195.5±22.1 to 488.8±450.0 µg/L inside the jugs and reached to 553.5±421.6 µg/L in the filtrate. While the mean levels of Zn, Cu, Mn and Pb decreased from (113.3±15.2, 165.3±121.8, 164.5±82.3 and 0.53±.39 µg/L, respectively,) to (108.3±74.3, 60.0±76.9, 97.3±126.2 and 0.04±0.04 µg/L, respectively,) inside the jugs. In contrast, the concentration of Cd increased from 0.07±0.03 to 0.11±0.04 inside the jugs. On the other hand, the mean concentration of Zn and Cu in water increased in the filtrate to 428.8±480.9 and 219.3±142.4 µg/L, respectively. In contrast, the mean concentration of Mn and Pb decreased in the filtrate to 94.3±73.0 and 0.12±0.013 µg/L, respectively.

Pottery jugs (B) improved its efficiency in decreasing concentrations of some heavy metals as Zn, Cu, Mn, Pb, and Cd. Heavy metals can enter a water supply by industrial and consumer waste, or even from rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater (El-Zeiny, 2010). Soils irrigated by wastewater accumulate heavy metals such as Cd, Zn, Cr, Ni, Pb, and Mn in surface soil. When the capacity of the soil to retain heavy metals is reduced due to repeated use of wastewater, soil can release heavy metals into groundwater or soil solution available for plant uptake (Sharma *et al.* 2006). Heavy metals (Zn, Cd, Cu Mn and Pb) values of the drinking tap water samples were below the permissible limits of EMH (2007), and WHO (2011), except the concentration of Fe inside and in the filtrate, was above the safe limit Table 5. That may be attributed to the pollution of fired clay or contamination of water used in manufacture by a high concentration of Fe. High level of iron may be due to soil pollution, vehicular and industrial emissions and crust re-suspension. Iron is originated mainly from the soil type and construction work materials. It is also clear that auto-exhaust Fe particulates were added to the natural Fe, which is a major constituent of earth crust (Hasballah and Beheary, 2016). Pollution index (PI) of drinking water in pottery jugs (C) showed that the degree of heavy metals contamination in water before, inside and in the filtrate is no effect (<1) Table 6.

In Table 7, the results of drinking tap water analysis in the pottery jugs (A, B and C) were analyzed by two ways ANOVA. TDS, pH, and turbidity showed a non-significant variation among jugs ($P > 0.05$), while salinity, EC, TH, Ca^{++} hardness showed highly significant variation ($P \leq 0.001$). Mg^{++} hardness showed an intermediate significant variation among jugs ($P \leq 0.01$). Moreover, pH, TDS, salinity, EC, TH, Ca^{++} and Mg^{++} hardness showed highly significant variation between filtration efficiency (before, inside and filtrate) ($P \leq 0.001$), except turbidity showed a non-significant variation. On the other hand, TDS, salinity, EC, TH and Ca^{++} hardness showed highly significant variation between jugs with filtration efficiency ($P \leq 0.001$), while pH and turbidity showed a non-significant variation. Mg^{++} hardness showed an intermediate significant variation between jugs with filtration efficiency ($P \leq 0.01$). In Table 8 the results of heavy metals in drinking tap water samples analysis in the different sites in pottery jug (B) were analyzed by one-way ANOVA. Fe, Zn, Cd, Cu, Mn, and Pb showed a non-significant variation ($P > 0.05$). These results are in accordance with El-Hamid and Hegazy (2017) who mentioned that there is no significant among heavy metals concentrations in groundwater samples assessed by one-way ANOVA.

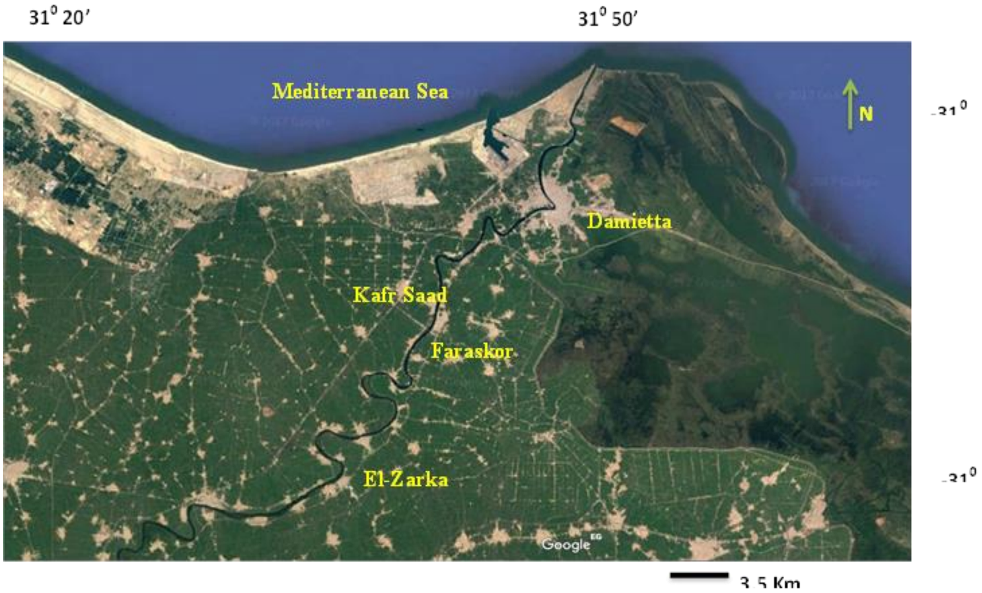

Fig. 1: Location map of the study area

Fig. 2: Pottery jug (A), four of it purchased from Damietta Governorate; pottery jug (B) four of it purchased from El-Gharbia Governorate and Pottery jug (C), four of it purchased from El-Menya Governorate.

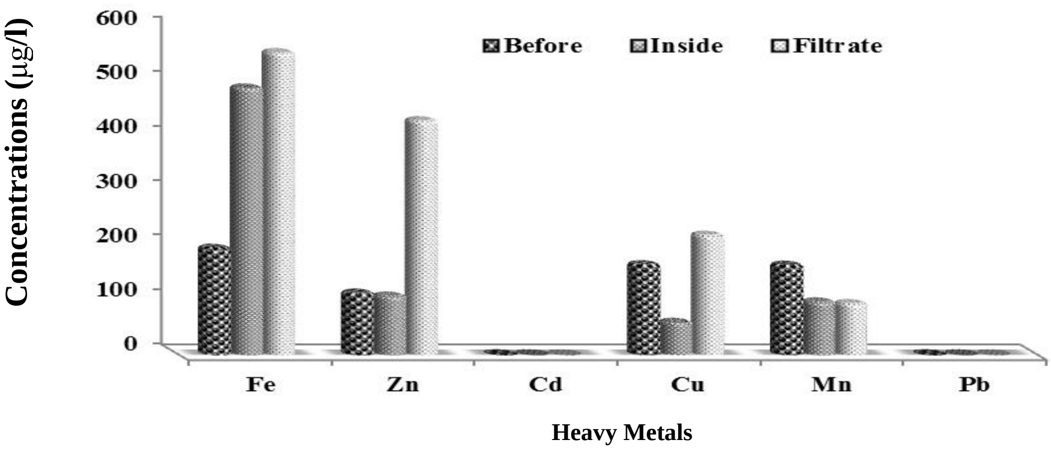

Fig. 3: Mean concentrations of heavy metals (µg/l) of drinking tap water through all sites in pottery jugs (B), before, inside and filtrate

Table 1: Mean Concentrations ± S.D* of physico-chemical parameters of drinking tap water through all sites in pottery jugs (A, B and C) SD*= Standard Deviation

Parameters	Before			Inside			Filtrate		
	(A)	(B)	(C)	(A)	(B)	(C)	(A)	(B)	(C)
Color	Colorless	Colorless	Colorless	Colorless	Colorless	Colorless	Colorless	Colorless	Slightly colored
Taste	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Tasteless	Objectionable
Odor	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless	Odorless
pH	7.81±0.5	7.35±0.2	7.36±0.3	8.08±0.2	8.40±0.3	8.25±0.3	8.35±0.40	8.78±0.05	8.25±0.34
Turbidity (NTU)	2.35±1.4	2.63±0.6	1.73±0.2	1.45±0.5	1.79±0.7	2.22±0.5	1.20±0.2	1.60±0.3	2.85±1.7
TDS (mg/L)	226.75±14.1	192.25±5.0	217.10±24.2	256.50±11.0	201.75±5.5	228.0±22.3	375.50±48.5	246±9.4	571±83.6
E.C (µs/cm)	502±147.2	336.25±75.0	443.25±61.0	508.50±19.1	406.75±13.5	491.0±54.7	776.0±115.1	505.25±21.1	1022±142
Salinity (%)	0.20±0	0.20±0	0.20±0.0	0.23±0.0	0.20±0	0.23±0.0	0.35±0.1	0.23±0.1	0.60±0.1
Total Hardnes (mg/L)	103.00±42.9	103±42.9	103.00±42.9	120.00±6.5	69.25±54.4	142.00±10.1	381.10±53.4	97.0±41.6	494.50±86.1
Ca^{++} Hardness (mg/L)	38.10±9.1	38.10±9.1	38.10±9.1	40.08±5.1	20.44±19.8	86.50±36.4	76.25±28.1	34.76±10.5	395.00±111.6
Mg^{++} Hardness (mg/L)	64.90±38.3	64.90±38.3	64.90±38.3	79.93±6.6	48.73±42.4	55.50±35.8	304.86±73.8	62.44±31.7	99.50±136.5
Total Coliform (MPN Index/100ml)	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative

Table 2: Composition of the pottery jugs body in percentage (%).

Composition (%)	Pottery jugs (A)	Pottery jugs (B)	Pottery jugs (C)
Sand	96	90	90
Clay	4	9	10
Silt	0	1	0

Table 3: Removal efficiency (%) of pottery jugs (A, B and C)

Jugs	Turbidity		Total hardness		Ca^{++} Hardness		Mg^{++} Hardness	
	Inside	Filtrate	Inside	filtrate	Inside	Filtrate	Inside	Filtrate
A	38.3	48.9	0.0	0.0	0.0	0.0	0.0	0.0
B	31.93	39.16	32.7	5.8	46.35	8.76	24.91	3.79
C	0.0	0.0	0.0	0.0	0.0	0.0	14.4	0.0

Table 4: WQI and AWQI of drinking tap water in Pottery jugs (A).

Parameters	Si	Pottery jugs (A)					
		Vi			qi=100[Vi/ Si]	qi=100[Vi/ Si]	qi=100[Vi/ Si]
		Before	Inside	Filtrate	Before	Inside	Filtrate
pH	6.5-9.5	7.81	8.08	8.35	97.6	101	104.4
Turbidity (NTU)	5	2.35	1.45	1.20	47	29	24
TDS (mg/L)	500	226.75	256.50	375.5	45.4	51.3	75.1
EC (µs/cm)	2500	502.0	508.5	776	20.1	20.3	31.04
TH(mg/L)	500	103.0	120.0	381.1	20.6	24	76.2
Ca^{++}(mg/L)	200	38.10	40.08	76.25	19.05	20.04	38.1
Mg^{++}(mg/L)	150	64.90	79.93	304.86	43.3	53.3	203.24
WQI=∑qi i=1	-	-	-	-	293.05	298.94	437.84
AWQI=∑qi/n	-	-	-	-	41.86	42.7	62.54

TDS: Total dissolved solids, EC: Electrical conductivity, TH: Total hardness, WQI: Water quality index, AWQI: Average water quality index

Table 4: Continued, WQI and AWQI of the drinking water in Pottery jugs (B).

Parameters	Si	Pottery jugs (B)					
		Vi			qi=100[Vi/ Si] Before	qi=100[Vi/ Si] Inside	qi=100[Vi/ Si] Filtrate
		Before	Inside	Filtrate			
pH	6.5-9.5	7.35	8.40	8.78	91.9	105	109.8
Turbidity (NTU)	5	2.63	1.79	1.60	52.6	35.8	32
TDS (mg/L)	500	192.25	201.75	246	38.45	40.35	49.2
EC (µs/cm)	2500	336.25	406.75	505.25	13.45	16.27	20.21
TH(mg/L)	500	103.42	69.25	97.0	20.7	13.9	19.4
Ca++(mg/L)	200	38.10	20.44	34.76	19.05	10.22	17.4
Mg++(mg/L)	150	64.90	48.73	62.44	43.3	32.5	41.6
WQI=∑qi i=1	-	-	-	-	279.45	254.04	289.61
AWQI=∑qi/n	-	-	-	-	39.9	36.3	41.4

Table (4): Continued, WQI and AWQI of the drinking water in Pottery jugs (C).

Parameters	Si	Pottery jugs (C)					
		Vi			qi=100[Vi/ Si] Before	qi=100[Vi/ Si] Inside	qi=100[Vi/ Si] Filtrate
		Before	Inside	Filtrate			
pH	6.5-9.5	7.36	8.25	8.25	91.9	103.1	103.1
Turbidity (NTU)	5	1.73	2.22	2.85	34.6	44.4	57.0
TDS (mg/L)	500	217.10	228.0	571.0	43.42	45.6	114
EC (µs/cm)	2500	443.25	491.0	1022.0	17.73	19.64	40.9
TH(mg/L)	500	103.0	142.0	494.50	20.6	28.4	98.9
Ca++(mg/L)	200	38.10	86.50	395.0	19.02	43.25	197.5
Mg++(mg/L)	150	64.90	55.50	99.50	43.3	37	66.3
WQI=$\sum q_i$ i=1	-	-	-	-	270.57	321.39	677.7
AWQI=$\sum q_i/n$	-	-	-	-	38.7	45.9	96.8

Table 5: Permissible limits for heavy metals of drinking water

	Metals (mg/l)					
	Cd	Cu	Mn	Pb	Fe	Zn
Permissible limit of WHO (2011)	0.003	2.0	0.4	0.01	0.3	3.0
Permissible limit of EMH (2007)	0.003	2.0	0.4	0.01	0.3	3.0

Table 6: Heavy metal pollution index (PI) of the drinking water in Pottery jugs (B).

Metal	Ci (before)	Ci (inside)	Ci (Filtrate)	Si	(Ci/Si)/Nm Before	(Ci/Si)/Nm inside	(Ci/Si)/Nm filtrate
Fe	0.20	0.49	0.80	0.3	0.042	0.272	0.443
Zn	0.11	0.11	0.43	3.0	0.009	0.009	0.024
Cd	0.00007	0.0001	0.00007	0.003	0.004	0.006	0.004
Cu	0.17	0.06	0.22	2.0	0.014	0.005	0.018
Mn	0.16	0.10	0.09	0.4	0.07	0.042	0.04
Pb	0.00053	0.00004	0.00012	0.01	0.009	0.0007	0.002
$PI = \sum_{i=1}^{n} \left(\frac{C_i}{S_i}\right) / Nm$					0.148	0.335	0.531

Table 7: Two-way analysis of variance (ANOVA) of physico-chemical parameters of drinking tap water samples through all jugs (A, B and C).

Non-significant ($P > 0.05$), * = low significant ($P \leq 0.05$),

** = intermediate significant ($P \leq 0.01$) and *** = highly significant ($P \leq 0.001$).

Parameters	Source	F	P
pH	Jugs	1.299	0.290^{oo}
	Filtration efficiency	24.565	0.000***
	Jugs* Filtration efficiency	2.208	0.096 ^{oo}
TDS	Jugs	1.157	0.359^{oo}
	Filtration efficiency	34.733	0.000***
	Jugs* Filtration efficiency	5.318	0.003**
Salinity	Jugs	18.233	0.000 ***
	Filtration efficiency	47.100	0.000***
	Jugs* Filtration efficiency	15.009	0.000***
EC	Jugs	96.753	0.000 ***
	Filtration efficiency	67.529	0.000***
	Jugs* Filtration efficiency	17.992	0.000***
Turbidity	Jugs	1.499	0.242^{oo}
	Filtration efficiency	0.854	0.437 ^{oo}
	Jugs* Filtration efficiency	2.284	0.087 ^{oo}
TH	Jugs	31.653	0.000***
	Filtration efficiency	76.283	0.000***
	Jugs* Filtration efficiency	18.200	0.000***
Ca^{++} Hardness	Jugs	39.059	0.000***
	Filtration efficiency	33.188	0.000***
	Jugs* Filtration efficiency	24.178	0.000***
Mg^{++} Hardness	Jugs	7.525	0.003**
	Filtration efficiency	8.558	0.001***
	Jugs* Filtration efficiency	5.175	0.003**

Table 8: One-way analysis of variance (ANOVA) of Heavy metals of water samples in pottery jugs (B).

Non-significant ($P > 0.05$), * = low significant ($P \leq 0.05$),

** = intermediate significant ($P \leq 0.01$) and *** = highly significant ($P \leq 0.001$).

Parameter	F. test	Significant
Fe	1.274	0.326°°
Zn	1.718	0.233°°
Cd	2.171	0.170°°
Cu	1.919	0.202°°
Mn	0.675	0.533°°
Pb	1.008	0.403°°

4. Conclusion

Pottery jugs (B) represented the best one in WQI and AWQI for inside and for the filtrate of drinking tap water and improved its efficiency in decreasing concentrations of some heavy metals in water as Zn, Cu, Mn, Pb and cd inside the jugs. That may be attributed to its composition of silt and the high quality of clay. Pottery jugs as a filter are recommended for use in water treatment at the household level. Further efforts are needed to define and implement appropriate manufacturing procedures and product performance characteristics of these filters in order to achieve products of acceptable quality, that are capable of adequate turbidity and some of heavy metals reductions from water, by adapting the local production of clay and other ceramic ware now used for other purposes to water treatment.

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الملخص العربي

امكانية استخدام الاواني الفخارية كمرشحات لمياة الشرب

أمانى فريد حسب الله
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تهدف هذه الدراسة الى امكانية استخدام الاوانى الفخارية ذات المساميه (الطين المحروق) فى تنقية مياه الشرب وتقليل نسبة المعادن الثقيلة وبعض الملوثات الاخرى التى قد تتبقى بعد عملية المعالجة. تم اختبار 28 عينه من مياه الشرب (ماء الصنبور) لبعض الخواص الفيزيائية والكيميائية والبيولوجية بالاضافة الى دراسة بعض المعادن الثقيلة ومنها (الرصاص ، الخارصين ،المنجنيز ، والحديد ،الكادميوم والنحاس). وقد تم اختبار هذه الخواص فى الماء قبل وضعه داخل الاناء الفخارى وداخل الاناء وايضا فى الرشيح الخارج من الاناء خلال 24 ساعه. وقد تبين من الدراسة ان مثل هذه الاوانى الفخارية لها القدره على اختزال وتقليل العكارة، والعسر الكلى واملاح الكالسيوم والماغنسيوم بالاضافه الى اختزال نسب من المنجنيز والرصاص والكادميوم وقد يرجع ذلك لاحتوائها على نسب من الطمى والطين ذات المسامية الدقيقه. وقد تبين من الدراسه ان تركيزات جميع العناصر المقاسة فى الحدود المسوح بها فيما عدا تركيز عنصر الحديد داخل وخارج الاناء.

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