**Sufficient Types and Constituent Ratios for Clay-Pot Water Filters to Improve the Quality of Drinking Water**

Project By:

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This study aimed to investigate suitable types and ratios of materials for making clay-pots, and their performance to improve the physical and bacteriological quality of drinking water instead of tap water. Synthetic water was prepared and used to select suitable types and ratios for clay-pot water filters. The clay-pots were prepared by combining clay with sand, coconut-shell charcoal, and rice-husk charcoal, at various ratios. The results indicated that all types and ratios could remove 100% of coliform bacteria and *Escherichia coli*, and were thus suitable for treating drinking water. However, for practical use, the system should have real-world application. Therefore, filtration rate/inner surface area/time was used as a criterion to determine suitable types and ratios. Different types of clay-plot water filter yielded significantly different filtration rates (*p<0.01*). Clay with coconut-shell charcoal generated the maximum filtration rate of 0.44 ± 0.11 mL/cm2/hr. Different ratios of clay-pot water filter did not yield significantly different filtration rates (*p>0.01*). A ratio with a maximal filtration rate of 60:40(0.38 ± 0.28 mL/cm2/h) was found to be suitable. The quality of filtered water was acceptable in terms of turbidity, coliform bacteria level, and *Escherichia coli*, according to WHO (World Health Organization) drinking-water quality guidelines.

**1. Introduction**

Saudi Arabia is the largest country in the Middle East and constitute the bulk of the Arabian Peninsula as an area of about two million square kilometers.

Varied topography of the Kingdom due to the large area extends in Saudi Arabia two Coastal plain the first in the west along the Red Sea to the east, and the other in the east along the Arabian Gulf to the west and the total area covered by these two coastal plain about 15 765 square kilometers which, or about 0.8% of the area The kingdom.

It is the largest part of the Kingdom of Saudi Arabia within the desert region is so dry tropical climate of the Kingdom of drought throughout the year, and high temperatures, especially in the summer.

Geographical region of the Kingdom of Saudi Arabia lacks fresh water, did not receive natural sources such as springs, rivers and lakes with poor rains or lack thereof in some areas. And limited natural resources in the kingdom on some wells and pools of rainwater and floods, which were not sufficient to meet the basic needs of all time. As a result of the tremendous development and progress of civilization and economic and industrial and population growth, the demand for potable water has increased to a much higher than those available from natural sources, making the eyes are to the desalination of sea water as a strategic option to secure the water supply.

Desalination started since the year 1348 AH / 1928 AD, and continued to expand over the years, the General Establishment for Water Desalination and has a government institution, means desalinate sea water and electricity production, and delivery of fresh water produced for the various regions of the Kingdom, the establishment of desalination plants giant bridge developmental needs. In a country with an average consumption of water per person per day to 250 liters. Even the amount of water produced amounted to five million cubic meters per day, equivalent to 1.3 billion cubic meters annually. Making the kingdom the world's largest producer of desalinated sea water a day.

There is no doubt that the nature of desalinated water and its characteristics do not fully match the nature and characteristics of natural freshwater because of desalinated water produced operations are characterized by speed and coercion under high pressure and using the tremendous energies of thermal, mechanical, electrical , and are filtered and sterilized in haste chemicals, mechanical and radiological and ways. It is also during that lose them of oxygen and useful metal salts and takes place in pipes and pass receptacles exposed to chemical reaction with water produces minute particles of harmful substances on water produced or melt them. Desalinated water also washed away on the way to the consumer trace amounts of harmful substances left over from desalination and technical process and sterilization. In addition, the desalinated water completely devoid of oxygen, that is, dead water you need to find ways to revive it.

**2. Research Questions and Hypothesis**

*1. What is the Most Efficient Type and Constituent Ratio for Clay-Pot Water Filters to Improve the Quality of Drinking Water?*

*2. What is the Quality of Drinking Water to WHO Standards?*

*3. What are the Types and Constituent Ratios for Clay-Pot Water Filters?*

*2.1 Importance of the research:*

So the main reason for writing this paper to find another way to purify desalinated water easy and effective means do not consume electricity in the water purification process and this method has several benefits, including:

**1. Cooling Water:**

We all remember the good old days when we would drink water stored in the Matkas. Scientists claim that storing water in a clay water pot is the best way. Clay pots not only cool the water down, they also provide healing with the elements of earth. Most significantly, clay pots transfer the chill to the water based on the climate. This quality of a clay pot is unique, and no other container has the same quality.

**2. Porous:**

Clay is porous. In the same way, a clay pot is also porous. When you store water in a clay pot, the evaporation happens. This process causes cooling as water particles gain energy in the form of heat, then change to gas and get mixed with air. A clay pot has small holes visible at the microscopic level through which water seeps out and gains energy to become gas and gets evaporated causing cooling. Heat and moisture circulate throughout the pot, quite opposite to the metal or enamel-lined crockery that we use today. Some pots are made of a special type of clay containing speckles of mica, colloquially known as ‘micaceous’ clay. Mica is a natural insulator.

**3. Alkaline:**

Another benefit of clay water pots is the alkaline nature of clay. The alkaline clay interacts with the acidity of water and provides the proper pH balance. This water can help curb acidity and in turn provides relief from gastronomic pains. This nature of clay is quite useful and is one of the few well-documented benefits of drinking water from an earthen pot. When acidic food like meat or milk is cooked in an earthen pot, the clay helps to neutralize the overly acidic qualities of food as well.

**4. Improves Metabolism And Virility:**

Drinking the right amount of water every day can help us boost metabolism. We usually store water in plastic containers, without realizing that there are harmful chemicals like BPA (Bisphenol A) in plastic that cling onto the water molecules and pose a health hazard. Alternatively, drinking water from a clay pot can help improve metabolism without dangerous chemicals like BPA added to the fray. Drinking water from a clay pot can also help maintain a level of testosterone in your body, as opposed to plastic, which in turn reduces the amount of testosterone in our body. Clay water tastes natural, pleasantly chilled and also helps improve metabolism and virility.

**5. Gentle On The Throat:**

Remember the summer vacations, when we came back from the park after a nice game of football or hopscotch. Mum or Grandma would insist on drinking water from the Matka rather than the fridge. Although we never knew why, one of the reasons could have been to avoid sunstroke. And the other reason could have been that the sudden temperature change could make us sick.

What we did not realize though, is that the water stored in an earthen pot is gentle on the throat. It is an ideal drink for people suffering from cough or cold.

*2.2 WHO for Drinking-water Quality:*

The [World Health Organization](https://en.wikipedia.org/wiki/World_Health_Organisation) (WHO) Guideline for Drinking-water Quality (GDWQ) include the following recommended limits on naturally occurring constituents that may have direct adverse health impact:

* Arsenic 10μg/l
* Barium 10μg/l
* Boron 2400μg/l
* Chromium 50μg/l
* Fluoride 1500μg/l
* Selenium 40μg/l
* Uranium 30μg/l

**Organic species:**

* Benzene 10μg/l
* Carbon tetrachloride 4μg/l
* 1,2-Dichlorobenzene 1000μg/l
* 1,4-Dichlorobenzene 300μg/l
* 1,2-Dichloroethane 30μg/l
* 1,2-Dichloroethene 50μg/l
* Dichloromethane 20μg/l
* Di(2-ethylhexyl)phthalate 8 μg/l
* 1,4-Dioxane 50μg/l
* Edetic acid 600μg/l
* Ethylbenzene 300 μg/l
* Hexachlorobutadiene 0.6 μg/l
* Nitrilotriacetic acid 200μg/l
* Pentachlorophenol 9μg/l
* Styrene 20μg/l
* Tetrachloroethene 40μg/l
* Toluene 700μg/l
* Trichloroethene 20μg/l
* Xylenes 500μg/l
  1. *Tap Water Impact on Human Health:*
* **the effect of impurities bacteria**

Bacteria in drinking water is responsible for many of the Gastroenterology crossbar, could worsen the situation of human and exposed to serious diseases because of the flora heat resistance.

* **the impact of the absence of metal salts**

The absence of mineral salts that your body needs for vital activity of drinking water leads to lethargy and depression. Despite the addition of some salt water produced from desalination processes may not be adequate.

* **the impact of the absence of oxygen**

There are expectations that the dead drinking water that does not contain oxygen may lead to cancer or slow death. At best, the dead water unpalatable taste and may have led to unrest in the cells absorbed water in the digestive tract.

* **the impact of water infrastructure**

Besides, the sensitivity to the change in the structure of the installation of water may lead to the production of free cracks in the body. Although the age of the complex chemical combinations is too short they are primarily responsible for the beginning of the formation of malignant tumors.

That is why the drinking tap water is a major health hazard in all the big cities, especially densely populated capitals, despite the rigorous standards imposed by some countries and directives issued by the World Health Organization that. This is not confined to the inside of the national limited countries. The water tap in Paris, London, New York and Rome is not only undrinkable but cause illness may end illnesses undesirable consequences such as Aldsntara. And less of those health diseases damage is diarrhea, which can lead to dehydration in the digestive tract of the species of flora or amoeba that causes severe inflammation of the large intestine. However, the people of the city usually gain immunity over time is not affected even if outwardly healthy diseases of that affect arrivals from the city, or a dose of water to drink bacteria will live in their bodies.

For these reasons, it created a health drinking bottled water companies, which are based on desalinated water desalination again, and this way there is a very large water and a large consumption of electricity and the arrival of the product to the consumer consumption at high prices.

**3. Materials and Methods**

This was a laboratory-scale experimental research study. All seven types and all nine percentages of clay-pot water filter were prepared and used for the experiments on the physical and bacteriological quality of treated drinking water. The performance of the clay-pot water filter was determined by physical and bacteriological quality, and filtration rate. The methods used to determine these characteristics followed the standard methods for water and wastewater examination (American Public Health Association, 2005). Differences in turbidity, coliform bacteria, *Escherichia coli,* and filtration rate, were analyzed by one-way ANOVA. Significance was set at 1%. All the experiments were carried out in quintuplicate.

**Table 1. Material mixtures and ratios**

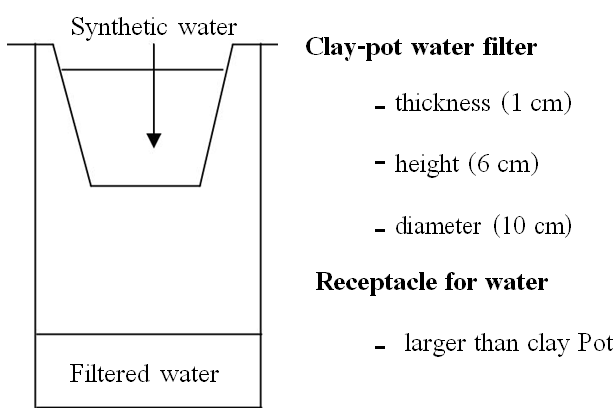
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Type | Materials |  |  | Percentage |  |
|  | Two materials |  |  |  |  |
| 1 | Clay: Sand | 60: 40 | 70:30 | 80:20 | 90:10 |
| 2 | Clay: Coconut-shell charcoal | 60: 40 | 70:30 | 80:20 | 90:10 |
| 3 | Clay: Rice-husk charcoal | 60: 40 | 70:30 | 80:20 | 90:10 |
|  | Three materials |  |  |  |  |
| 4 | Clay: Sand: Coconut shell: charcoal | 60: 20: 20 | 70:15:15 | 80:10:10 | 90:5:5 |
| 5 | Clay: Sand: Rice-husk charcoal | 60: 20: 20 | 70:15:15 | 80:10:10 | 90:5:5 |
| 6 | Clay: Coconut-shell charcoal: Rice-husk charcoal | 60: 20: 20 | 70:15:15 | 80:10:10 | 90:5:5 |
| 7 | Clay | 100 |  |  |  |

*3.1 Clay-pot water filter preparation*

Total number of examined clay-pots was consisted by 6 combinations of materials and 4 ratios of composition plus one original material (100%clay) as shown in Table 1.

*3.2 Mold of clay-pot water filter*

Each type and ratio of clay-pot water filter was sintered at 600oC for 5 hours (biscuit firing). After sintering, the clay-pot water filter was dried at room temperature for 3 days before conducting the filtration process. At the beginning of the study, the clay-pot water filters were cleaned with tap water and sterilized in a hot-air oven at 180oC for 2 hours. The clay- pot water filter was used with a receptacle container as illustrated in the schematic diagram (Fig. 1).



**Figure 1. Design of clay-pot water filter**

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*3.3 Synthetic water preparation*

Synthetic water was prepared by mixing coliform bacteria with distilled water sterilized at 121oC for 15 minutes. To this was added a colony of *Enterobacter* spp., *Klebsiella* spp., and *Escherichia coli,* with the use of a loop. Finally, sterilized soil was added. Turbidity, coliform bacteria, and *Escherichia coli* levels were controlled at 55-60 NTU, 2.4 x 107 MPN/100mL, and 2.4 x 104 MPN/100 mL, respectively. The synthetic water was poured into the clya0pot water filter and percolated through the filter element into the receptacle below. Water in the receptacle was analyzed for all parameters; turbidity, coliform bacteria, *Escherichia* *coli* and filtration rate/ inner surface/ hour.

**4. Results and discussion**

In this study, main research focused on selecting suitable types and ratios of clay-pot water filter, to improve the quality of surface water and to get safe and clean water for consumption. The results were shown in Table 2.

In order to determine the suitable materials and proper percentage of mixing materials, One-way ANOVA analysis at *0.01* significance level was performed the different concerned parameters namely; turbidity, pH and filtration rate. The results indicated that the different types of clay-pot water filter yield different degrees of turbidity (*p* > 0.01) except the mixing of clay and rice husk charcoal (*p* value = *0.005*) as shown in

Table 3. However the pH of treated water were significant different (*p* value < *0.001*) except the clay: sand (*p* value = *0.106*), and clay: coconut-shell-charcoal(*p* value = *0.026*), In case of filtration rate, all are significant different

(*p* value < *0.001*). Turbidity in the other types was also acceptable; all are less than 5 NTU according to the WHO standard (WHO, 2004). Six types of clay-pots could remove 100% of coliform bacteria and *Escherichia* *coli.* In the case of pure clay, the physical and bacteriologicalquality could not be measured due to the inadequate volume of water. However, this result was similar to the research study by Murphy *et al.* (2009), who tried to decrease microorganism contamination in water using a clay-pot water filter composed of crushed bricks, rice husk, and laterite. In addition, when it was promoted for use in rural areas of Cambodia, diarrheal diseases were reduced by 50%. The ceramic water filter effectively removed up to 99.99% of total coliform in water samples (Van, 2006). In addition, the *E. coli* and bacteriophage MS2 in drinking water were removed by ceramic water filtration in the study by Brown (2007).

All types and ratios could remove turbidity, coliform bacteria, and *Escherichia coli* to acceptable WHO standards. Thus, all the types and ratios could be used for water treatment. However, for use in a real-world situation, its filtration rate should also be considered.

The inner surface area was calculated from sum of side and bottom surface areas. The inner surface area was 201.06 sq cm. Clay: coconut-shell charcoal type with percentage of 60:40 provided the highest filtration rate; 127.0 mL/hr. This was consistent with the study by

Murphy *et al.* (2009), who suggested a clay-pot water filter made of crushed, sun-dried clay bricks, local rice-husk waste, and laterite, could remove coliform bacteria. The burnt rice husk allowed for increased porosity, and with a large portion of coconut-shell charcoal, resulted in a highly porous clay-pot water filter, with a satisfactory filtration rate.

In order to use for the real situation, the filtration rate was also studied to determine the limitation. The mixing percentage of material 60:40 was used for study the variation. At the filtration was started, the filtration rate of water was gradually increased from 0.54 mL/ hr. and reached 240 mL/hr. After that, it was gradually decreased to the increase of water volume. However, it could be observed that the filtration rate of water trends to fluctuate when the experiment was started in each day such as at 13, 25, 37, 49, 61, 73, 85, 97, 109, 121 and 133 h since it was daily paused for every 12 hour.

Fig. 2 shows the trendency of filtration rate of water by clay pot at 60:40 of clay and coconut shell charcoal.

According to the experiment, the volume of water that poured into the clay pot filter was 300 mL at first hour. In addition, the surface water was refilled into the clay pot again until it is fully. Therefore, the approximate 12 times per day of filtration could be done. After twelve hour, then clay pot was covered with aluminum foil to protect contaminant of water. The filtration rate of water depends on the turbidity of influent water. Murphy *et al.* (2009) showed that when influent water has higherturbidity, the filtration rate was lower. At this point, however, the filtration rates were gradually decreased again. At second day of experiment, the turbidity of surface water decreased to 44.45 - 48.54 NTU.

Similar to the previous experiment, the filtration rate of water seem to be lower at the first hour of experiment compared to that at the last experiment on previous day. Also, the higher filtration rate was observed in the next hour. Similar to the previous day, the filtration rate trends to decrease to the number of experiment or volume of water.

The observed higher filtration rate at the fourth hour of experiment compared to the starting point may be due to there is higher water addorption in dry clay pot. Raimondo *et al.* (2009) showed that the filtration rates of water collected first to third hour are generally lower than that sample collected at fourth hour. The new dry clay used to filter water can absorb influent water inside.

That causes the lower water volume is generally found in the effluent. After the water is saturated at fourth hour, therefore, there is no water absorbed. This experiment is consistent with the research of Van (2006). They showed the increase of filtration rates at the fourth hour of filtration. Ceramic pot filter was gradually absorbed water in the fifth hour of filtration. When ceramic pot filter was saturated, almost influent water could be released in the fourth hour (Fig. 2). Accumulation of sediment leads to reduction of filtered water volume. Inner surface of clay pot water filter was accumulated with sediment. Van (2006) found that filter clogging is normally resulting from colloidal particles. Direct effects may be identified from the decrease of flow rate and frequent scrubbing. The maintenance procedure is generally scrubbing the filter when clogging was observed. Frequent scrubbing, however, may cause recontamination of water and breakage of filter. As show previously, the relatively high porosity and low

Table 2. Average± SD values of turbidity, coliform bacteria, *Escherichia coli,* and filtration rate after filtration via clay-pot water filter

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Types | Percentage | Turbidity  (NTU)  55-60 | pH  2.4 x 107 | Coliform  bacteria  (MPN/100 mL)  2.4 x 104 | Filtration rate  (mL/h) |
| Initial water quality  Clay: sand | 60: 40 | 1.03 ± 0.23 | 7.03 ± 0.08 | < 2.2 | 14.8 ± 1.64 |
| 70: 30 | 0.82 ± 0.28 | 7.00 ± 0.07 | < 2.2 | 11.6 ± 1.82 |
| 80: 20 | 0.64 ± 0.41 | 6.97 ± 0.05 | < 2.2 | 9.80 ± 1.64 |
| 90: 10 | 0.60 ± 0.55 | 6.93 ± 0.04 | < 2.2 | 6.60 ± 1.82 |
| Clay: coconut shell  charcoal | 60: 40 | 0.72 ± 0.32 | 8.45 ± 0.05 | < 2.2 | 127.0± 1.22 |
| 70: 30 | 0.70 ± 0.24 | 8.41 ± 0.05 | < 2.2 | 112.4± 3.36 |
| 80: 20 | 0.66 ± 0.23 | 8.40 ± 0.02 | < 2.2 | 96.0 ± 3.16 |
| 90: 10 | 0.35 ± 0.25 | 8.36 ± 0.02 | < 2.2 | 82.8 ± 1.79 |
| Clay: rice husk  charcoal | 60: 40 | 0.88 ± 0.22 | 8.78 ± 0.02 | < 2.2 | 99.2 ± 3.90 |
| 70:30 | 0.79 ± 0.15 | 8.72 ± 0.02 | < 2.2 | 67.0 ± 2.92 |
| 80: 20 | 0.74 ± 0.15 | 8.68 ± 0.03 | < 2.2 | 59.4 ± 3.44 |
| 90:10 | 0.42 ± 0.15 | 8.61 ± 0.01 | < 2.2 | 51.6 ± 2.41 |
| Clay: sand:  coconut shell  charcoal | 60: 20: 20 | 1.03 ± 0.30 | 8.03 ± 0.05 | < 2.2 | 59.4 ± 2.88 |
| 70: 15: 15 | 1.02 ± 0.18 | 7.92 ± 0.04 | < 2.2 | 45.8 ± 2.59 |
| 80: 10: 10 | 1.00 ± 0.31 | 7.83 ± 0.03 | < 2.2 | 39.4 ± 3.44 |
| 90: 5: 5 | 0.99 ± 0.31 | 7.73 ± 0.06 | < 2.2 | 33.8 ± 3.03 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Clay: sand: rice  husk charcoal | 60: 20: 20 | 1.51 ± 0.38 | 8.11 ± 0.03 | < 2.2 | 46.2 ± 3.11 |
| 70: 15: 15 | 1.27 ± 0.27 | 7.99 ± 0.04 | < 2.2 | 36.0 ± 3.87 |
| 80: 10: 10 | 1.25 ± 0.32 | 7.70 ± 0.04 | < 2.2 | 30.6 ± 3.87 |
| 90: 5: 5 | 1.00 ± 0.26 | 7.67 ± 0.04 | < 2.2 | 27.2 ± 2.68 |
| Clay: coconut shell  charcoal: rice husk  charcoal | 60: 20: 20 | 1.22 ± 0.26 | 9.04 ± 0.04 | < 2.2 | 89.8 ± 3.61 |
| 70: 15: 15 | 1.10 ± 0.50 | 8.95 ± 0.03 | < 2.2 | 93.0 ± 3.52 |
| 80: 10: 10 | 1.07 ± 0.29 | 8.87 ± 0.03 | < 2.2 | 74.4 ± 3.06 |
| 90: 5: 5 | 0.90 ± 0.40 | 8.82 ± 0.02 | < 2.2 | 62.6 ± 1.82 |
| Clay | 100: 0: 0 | - | - | - | 1.80 ± 0.84 |

The symbol-means not detectable, since the filtered water volume was very small

Table 3. Analysis of variance (ANOVA) of water quality in difference types

|  |  |  |  |
| --- | --- | --- | --- |
| Types | Parameter | *p-value* | *F-value* |
| Clay: sand | Turbidity | 0.312 | 1.290 |
| pH | 0.106 | 2.396 |
| Filtration rate | <0.001 | 19.578 |
| Clay: coconut shell charcoal | Turbidity | 0.102 | 2.440 |
| pH | 0.026 | 4.041 |
| Filtration rate | <0.001 | 285.074 |
| Clay: rice husk  charcoal | Turbidity | 0.005 | 6.191 |
| pH | <0.001 | 51.029 |
| Filtration rate | <0.001 | 211.558 |
| Clay: sand: coconut  shell charcoal | Turbidity | 0.993 | 0.029 |
| pH | <0.001 | 39.206 |
| Filtration rate | <0.001 | 67.437 |
| Clay: sand: rice husk  charcoal | Turbidity | 0.118 | 2.287 |
| pH | <0.001 | 159.985 |
| Filtration rate | <0.001 | 32.645 |
| Clay: coconut shell  charcoal: rice husk  charcoal | Turbidity | 0.774 | 0.372 |
| pH | <0.001 | 46.325 |
| Filtration rate | <0.001 | 107.955 |

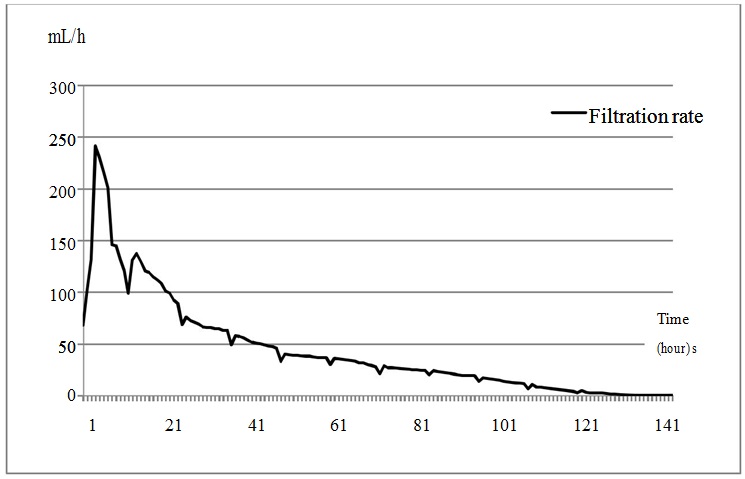
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Figure 2. Filtration rate of filtered water over time (hour)

strength may enhance clay pot breaking and clogging from scrubbing. Clay pot filter can remove coliform bacteria in surface water. This study showed that after pouring 6.28 liter of water filtration found coliform bacteria less than 2.2 MPN/100 mL which meet to the acceptable level of WHO drinking water standard (2004). Sui and Huang (2003) showed the potential of gradient ceramic membrane to remove 100% of pathogenetic bacteria such as; *E.coli,* Salmonelle, microzyme, staphylotoxin, *Psuedomonas aeruginosa*, mold, rust, worm and suspension particles in water. The removal efficiency for pathogenic bacteria by filtration through clay pot filter at 60:40 ratios of clay: coconut shell charcoal varied between 98% and 99.9%. It can be suggested clay pot filter at 60:40 ratio of clay: coconut shell charcoal can be used as filter for drinking water treatment. However, the filtration period and treated volume were limited since it can be used only in the short period. To solve the constrain mentioned above the size expanding can be alternative approach to obtain more volume of treated water. The another issue to be concerned is the turbidity level, therefore the correlation between turdibity and filtration rate should be taken into account for further study.

**5. Conclusion**

The results showed that different types of clay-pot water filter created drinking water of significantly different physical quality (*p<0.01*). Different ratios of clay-pot water filter yielded significantly different turbidity levels (*p<0.01*). Six types and eight ratios could remove 100% of coliform bacteria and *Escherichia* *coli.* Of the different types and ratios of clay-pot waterfilter, the best r for practical use could not be determined on physical and bacteriological quality factors alone.

Therefore, filtration rate/inner surface area/time was added as a variable to aid selection. Different types of clay-pot water filter yielded significantly different filtration rates (*p<0.01*). The maximum filtration rate was 0.44 ± 0.11 ml/cm2/h in the ratio 60:40 of clay: coconut-shell charcoal. When the filtered water was compared with the drinking-water standard by WHO, the types and ratios of clay-pot water filter were within the acceptable range for turbidity, coliform bacteria, and *Escherichia coli.*

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