Evaluation of the Efficiency of Clay Pots in Removal of Water Impurities

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ABSTRACT

Recently, inexpensive technologies for drinking water supply in small communities are highly considered in developing countries. One of these technologies is the application of ceramic filters that are usually made of diatomaceous earth or clay soil. This research was carried out to determine the efficiency of clay pots (as a filter) in removing water impurities. Pilot and the related clay parts were manufactured and its efficiency in removing TDS, hardness, $NO3^-$, color and turbidity was measured by passing water through the clay pipes. The results showed that the clay filters had not the potential to remove hardness, EC, TDS and nitrate of water. However, they showed excellent efficiency in turbidity removal (≥ 90%) and could significantly decrease the color of the water (≥ 60%).

Keywords: *Water treatment, Ceramic filters, Small communities*

INTRODUCTION

The crisis of water shortage is still the most important global challenge of the twenty first century. In quantitative term, although 75 percent of the earth surface is covered by water, fresh water has the share of only 3 percent of this amount, from which only one percent is available for different human uses (AWWA, 1999; Hammer, 2001).
Iran is located in a zone where its average annual rainfall is less than 1/3 of the average global annual rainfalls. Furthermore, the local and time distribution of the rainfalls are highly unsuitable and major part of the country is dry with low-water sources. There are parts in Iran where there is neither a usable current surface water nor consumable underground water; therefore, the government has no other alternative than providing water demand of the residents in these regions from other sources (Kordavani, 2002). This constraint imposes large amount of costs to the government.
Based on the reports of World Health Organization (WHO), nearly 85 percent out of 1.5 billion population of the world has no access to healthy and uncontaminated water and live in small communities who need safe drinking water. A large part of Iran is dwelled by scattered and small communities Because of the high costs of water transfer projects and water treatment plant designs for small communities, inexpensive and appropriate technologies including Point of Use (POU) and Point of Entry (POE)

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are more considered (Cortruvo et al., 1999). Application of appropriate technology in the consumption and the entry points may significantly help water provision for small communities through considering a suitable and healthy quality for drinking water (USEPA, 1997). One of the methods of water purification in this category is the use of ceramic filters (Rob et al., 2003). These filters may be produced with different materials and in various forms; however, the most common ceramic filters in the world are diatomaceous filters, which are supplied in candle, plate and vase forms. These ceramic filters have become conventional in some parts of the world, such as India and Nepal (Mintz at al., 1995; NRC, 1997). In this research, the efficiency of water impurities removal by ceramic filters (made of ceramic soil) was studied.

MATERIALS AND METHODS

A literature review was made through searching in books, journals and different papers. The basic objectives of this study were determining the performance of the filter in mineral impurities removal and reduction of turbidity as well as water color. Water quality parameters which were studied are as follows: total and permanent hardness, total dissolved solids (TDS), electrical conductivity (EC), turbidity, color and nitrate (NO_3^-). Assuming a minimum decrease of 20 percent in water impurities by the clay filters (considering 5% precision) the number of samples was calculated by the following formula:

$n = Z^2 p (1-p)/ d^2$

$n = (1.96)^2 (0.2) (1-0.2)/ (0.5)^2 = 246$

Minitab and Statsdirect software were used to perform a statistical analysis of the results. To determine the sub-curve surface, the MMF mathematical model was used. To perform the tests of each impurity it was necessary to activate concerned clay parts with distilled water. After preparation of clay pipe, they were placed in the pilot and completely sealed. By turning the pump on, water entered the clay pipes and after a certain time, the water penetrated from the pipe walls and the treated water was collected at the bottom of the tank and sent for analysis (Fig.1).

Water samples to be used as pilot influent were collected from groundwater and surface water resources. Sometimes it was necessary to prepare synthetic samples with adding some components to water because we needed to have samples with different concentrations of impurities.

In order to determine EC removal efficiency of clay pipes, sample with constant EC was injected to the system (in 15 separate stages). The diagram of changes in amount of discharging salts (TDS_2- TDS_1) in time unit was drawn to calculate the amount of salts in clay pipes (V= volume of water discharging from clay pipes in each turn of test was equal to 300 ml). By using the MMF mathematical model and integrating the above-mentioned curve, the sub curve level that was equal to the amount of salt released in discharged water was calculated.

To study nitrate removal efficiency of clay pipes, sample with constant nitrate was injected to the system (in 15 separate stages). In order to determine the output of turbidity removal in clay pipes, different turbidities (5-92 NTU) were provided by adding clay soil to the input water and gradually, input water was injected into the system (in 15 separate stages). Also, the total hardness as well as the permanent water hardness in the input and discharged water were measured in two separate stages (first with constant input hardness and then with variable input hardness). As for color removal by clay pipes, different color levels (5-470 TCU) were provided by adding natural color to the input water and gradually, input water was injected to the system.

RESULTS

The output EC variations with constant input EC (500 μmohs/cm) are shown in Fig. 2. Output EC had a wide range of 8200-500 (µmohs/cm). The amount of salt released in discharged water was 1.39 mg/cm^2 of surface area of the clay pipes. Fig. 3 shows the results of the mathematical model.

The output nitrate variations with constant input nitrate of 45.5 mg/l are shown in Fig. 4. The output nitrate had a variable range of (51.5- 45 mg/l). System's efficiencies for turbidity removal (in different input turbidities) are shown in Fig. 5. The output hardness variations in constant input hardness (300 mg/l) are shown in Fig. 6. Comparison between input and output color (in different input conditions) is shown in Fig. 7.

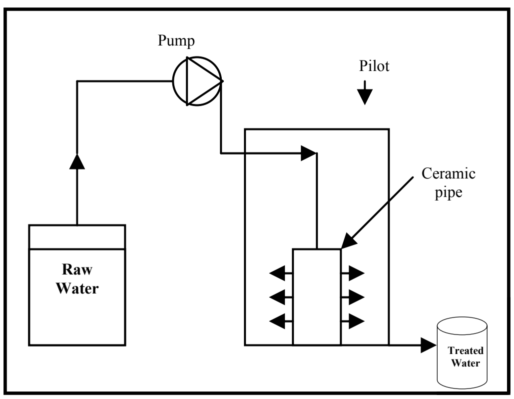

Fig. 1: Schematic design of the pilot

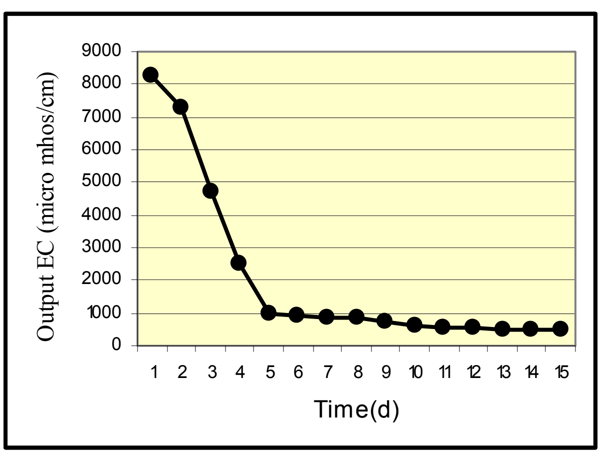

Fig. 2: EC variations in effluent water (in constant input EC: 500 µmohs/cm)

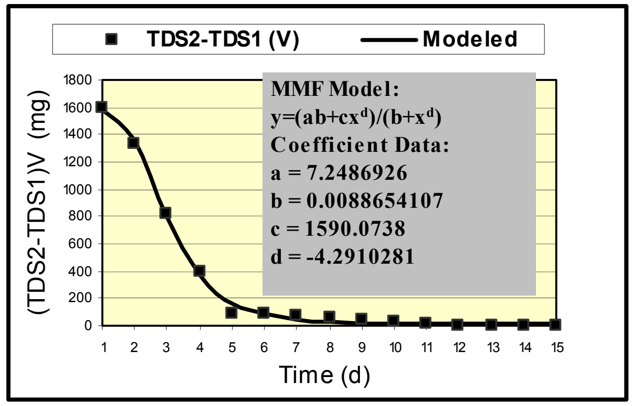

Fig. 3: Calculated amount of salt released in discharge water by mathematical model

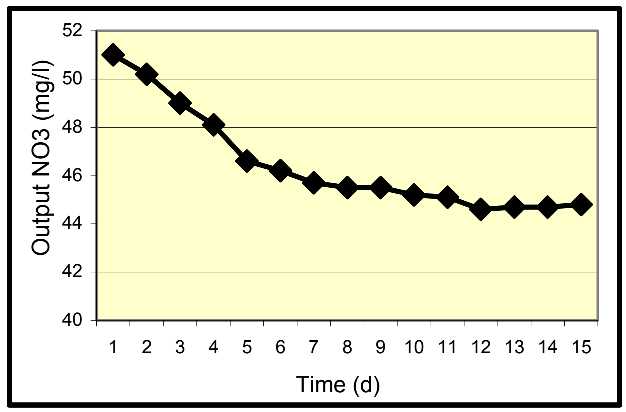

Fig. 4: Nitrate variations in effluent water (in input nitrate: 45.5 mg/l)

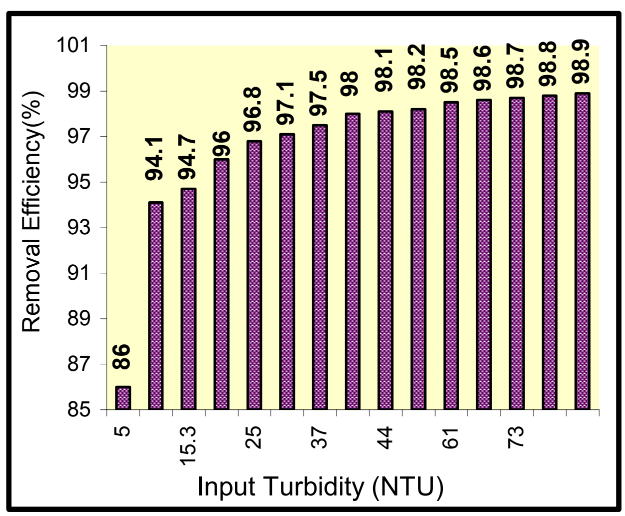

Fig. 5: Efficiency of system in turbidity removal

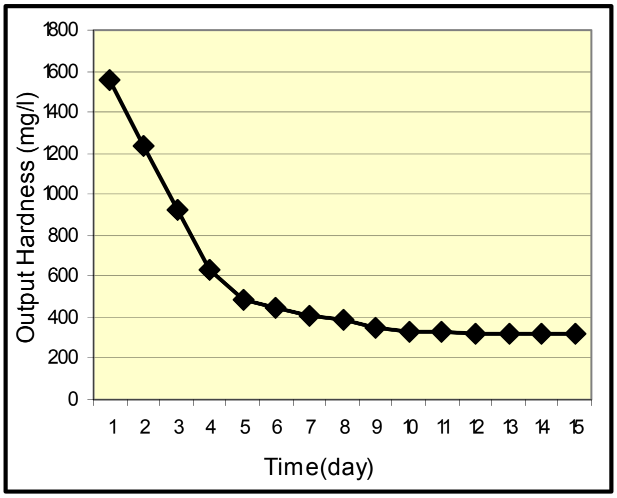

Fig. 6: Hardness variations in effluent water (in constant input hardness: 300 mg/l)

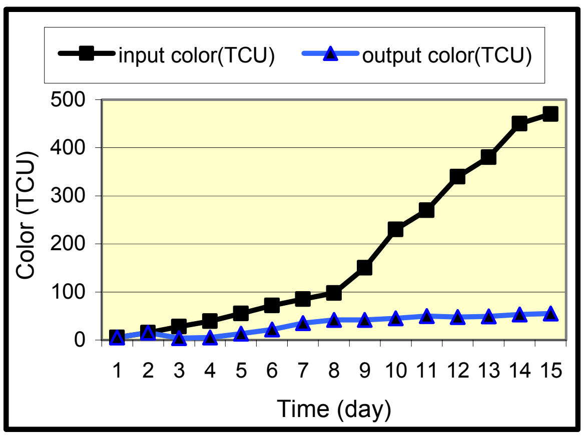

Fig. 7: Comparison of input and output color (in different input colors)

DISCUSSION

According to Fig.2, clay pipes did not show necessary potential in removing water EC. At the beginning of the test, due to the presence of different salts (which are found as a mixture with clay soil) the EC and TDS increased significantly; there was a direct relationship between EC and TDS. As the test stages increased, the discharging EC and TDS gradually decreased until reached to the initial amount in the input water.

Based on Fig. 4, system did not show appropriate potential in removing nitrate. Unexpectedly, in the initial stages of the test there was an increase in the amount of discharged nitrate; however, gradually and upon an increase in test stage, the amount of discharge nitrate decreased as much to reach the initial amount of nitrate in the input water.

Fig. 5 shows that the system was completely successful in removing water turbidity. The results showed that clay pipes could remove water turbidity to reach desirable standards of drinking water (less than 1 NTU).

According to Fig. 6, system did not show acceptable efficiency in removing water hardness. As the results showed, at the beginning of the test, we observed a significant increase in the hardness of water. By increasing the test stages, this diminishing process decreased and finally, the concentration of input and discharged hardness became equal. The level of decrease, which was observed in the discharged hardness at the end of the test stages, was not statistically significant and it could be clearly said that clay pipes were not successful in removing total hardness and permanent hardness. By measuring the ratio of the input permanent hardness to the total input hardness, and the discharged permanent hardness to the total discharged hardness and comparing these two ratios with statistical terms, it was observed that the difference in the two ratios was not significant and they were almost equal.

Fig.7 shows that the clay pipes were relatively successful in removing true color of the water. The results showed that clay pipes could remove water color significantly (more than 60%).

For the first time in this research under pressure clay pots were used as a water filter. Some other researches (AIIT, 2002; Rebecca, 2002; Kowalski, 2003) showed that clay pot (ceramic filter) had an excellent efficiency for removing of turbidity and microbial indicators. This research showed that the filters built as clay pot, lacked the potential to remove hardness, electrical conductivity, total dissolved solids and nitrate of water but they had high efficiency in turbidity removal (above 90%) and could significantly decrease the color of the water (more than 60%) .

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