Treatment of Domestic Water Using Ceramic Filter from Natural Clay and Fly-Ash

by Subriyer Nasir

TREATMENT OF DOMESTIC WATER USING CERAMIC FILTER FROM NATURAL CLAY AND FLY-ASH

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Abstract:
The declining water quality in Sriwijaya University has been caused by the presence of heavy metal contents such as Iron (Fe) and Zinc (Zn) in the treatment and distribution of water. A simple method is proposed in this work to minimize the heavy metal content in water by using filtration technology. This research was carried out using ceramic filter made of 77.5% natural clay, 20% fly ash, and 2.5% iron powder. The results showed an increase in the quality of raw water that is in accordance with the requirement of drinking water standard. The rejection percentage of TDS, Iron (Fe) and Zinc (Zn) content in feed water tended to be high and met the regulation number 492/MENKES/PER/IV/2010 for standards of drinking water in Indonesia.

Keywords: ceramic filter, natural clay, fly-ash, water treatment

1. INTRODUCTION

Sriwijaya University (Unsri) campus is situated at Indralaya, the district of Ogan Ilir, South Sumatra, Indonesia in an area of about 720 hectares. Unsri has 10 faculties with around 30000 student and 1200 lectures. The domestic water supply for Unsri campus has been established since 1993. There has been no serious problem in water supply and quality since last decade. However, old piping installation, poor maintenance, and unskilled manpower in water facility caused the decline in water quality. Therefore, the utilization of water in Unsri campus was limited only to rinse and wash. In this work, an effort was made to improve the water quality using ceramic filter filtration.

The Unsri campus has a water treatment system with 20 L/s of capacity using Kelekar River as a source of raw water. Unsri campus water supply intake is located at the border of Muara Penimbung and Tanjung Seteko villages. The raw water is collected in the cemented pond with a capacity of 150 m^3, which is injected using alum as a coagulant. Having a separate flock, the water was stored in a sedimentation tank and filtered using a sand filter. It is then injected with chlorine and stored in ten water reservoirs before distributed using the pipeline to all faculties in the campus.

Ceramic membrane has been attractive to the researchers in the last decade due to their superior thermal and chemical stability, better mechanical strength, and high resistance to acid and base and has good defouling properties [1, 2]. The successful applications of ceramic membranes were found in the chemical industry, metal industry, textile industry, and food and beverage [3].

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The conventional drinking water treatment of surface water involves chemical/physical removal of particulate matter by coagulation, flocculation, sedimentation, and filtration, and along with disinfection to inactivate any remaining pathogenic microorganisms [4, 5]. The use of fly ash as the raw material for crack-free ceramic microfiltration (MF) membranes showed the good performance for treatment of textile wastewater [6, 7], sand-filter backwash wastewater [8]. Ceramic MF membranes made from clays and phosphates were suggested to be used as a previous clarification step in textile water treatment [9]. In another study, simple ceramic filters manufactured from clay soil and rice bran can be applied to remove more than 95% of Fe through oxidation, co-precipitation and filtration [10].

In current research, a ceramic filter was made of a mixture of 77.5% natural clay, 20% fly ash and 2.5% of iron powder and was used to treat the water after distributed into faculties and other facilities in Unsri campus. The variables studied were feed flow rate and operation time.

2. EXPERIMENTAL SETUP

2.1. Materials

Materials used in this work include ceramic filters, rotameter, pressure gauge, PVC pipes, and pumps. Standard equipment for analysis such as pH meter, TDS meter, and Atomic Absorption Spectrometer (AAS) were used to determine the characteristics of permeates. Pores filter structure was examined using Scanning Electron Microscope (SEM) type JEOL 330.

Ceramic filters used in this study were made of a mixture of natural clay, fly-ash (500 μm of particle size) and iron powder (500 μm of particle size). Natural clay, fly-ash and iron powder were mixed with 30% (w/w) of clean water and molded in a local ceramic industry. The filter was dried at room temperature for 7 days and sintered at a temperature of 900-1000^{0}C for 12 hours. It has an inner diameter of 4 cm, an outer diameter of 5 cm, and 25 cm long.

2.2. Method

Tap water from Chemical Engineering department Faculty of Engineering Sriwijaya University was placed in 250 liters of tank capacity and pumped through the filtration system (silica, zeolites, active carbon and ceramic filter) using a centrifugal pump at a flow rate of 10 L/min and 12.5 L/min. To diminish the effect of concentration polarization, a filtering system was designed to operate in cross-flow filtration. Permeates were collected using a beaker glass after 15, 30, 45 and 60 minutes of operation time. The schematic of experimental set-up is illustrated in Figure 1.

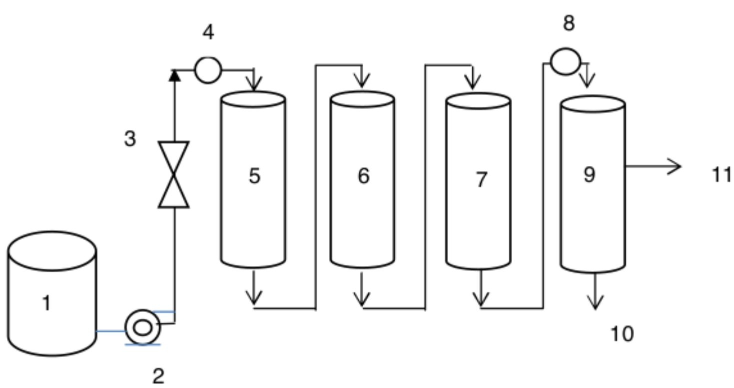

Fig. 1. Experimental set-up of the filtration system:
1 - Feed tank; 2 - Pump; 3-Rotameter; 4 - Pressure gauge; 5 - Silica filter; 6 - Zeolites filter; 7 - Activated carbon filter; 8 - Pressure gauge; 9 - Ceramic filter; 10 – Concentrate; 11 - Permeate.

3. RESULTS AND DISCUSSION

Table 1 shows the Unsri tap water analysis. Iron and zinc ion concentrations exceed the limit values of Indonesian drinking water standard of 0.3 and 3.0 mg/L respectively. This suggests that the higher concentration of iron and zinc ions in tap water samples was due to the corrosion of old pipe system.

Table 1. Tap water analysis.

Parameter	Unit	Values	Indonesian Standards (SNI)
pH	-	6.55	6.5 - 8.5
TDS	mg/L	133	500
Iron	mg/L	6.15	0.3
Zinc	mg/L	12.33	3.0

As can be seen from Table 2, a decrease of TDS in permeates was evidenced in the filtering system. The average reduction in percentage of the TDS are in a range of 73–84% and the pH of permeate tends to be neutral. There was no significant effect of feed flow rate on the TDS reduction. However, iron and zinc ion concentration in permeates was decreased significantly by more than 96%.

Table 2. TDS and pH of Permeates.

Feed flow rate (L/min)	time (min.)	A		B		C		D	
		TDS	pH	TDS	pH	TDS	pH	TDS	pH
10	15	35	6.54	32	6.54	52	6.37	25	6.96
	30	33	6.55	33	6.52	50	6.56	23	6.93
	45	34	6.54	31	6.56	51	6.57	22	6.92
	60	37	6.54	32	6.55	54	6.57	25	6.91
Average rejection percentage (%)		73.8	-	75.9	-	61.1	-	82.1	-
12.5	15	30	6.55	27	6.54	44	6.56	20	6.94
	30	31	6.54	25	6.53	42	6.53	21	6.93
	45	31	6.55	26	6.51	44	6.57	23	6.93
	60	32	6.53	28	6.56	45	6.59	22	6.90
Average rejection percentage (%)		76.7	-	80.1	-	67.1	-	83.8	-

A - outlet of silica filter, B - outlet of zeolite filter, C - outlet of active carbon filter and D - outlet of ceramic filter

Figure 2 shows the relationship between water flux and operation time. As can be seen, the flux was slightly decreasing as operation time increases. There was no significant effect of feed flow rate on the permeate flux. However, the permeate flux was decreasing with an increase in operation time. For instance, at 10 L/min of feed flow rate and 15 minutes of operation time, permeate flux was 19.8 $L/m^2 \cdot hr$ and decreased to 18.3 $L/m^2.hr$ after 60 minutes. At 12.5 L/min of feed flow rate, water flux declined to 18.4 $L/m^2 \cdot hr$ after one hour of operation time. The decline in permeate flux was due to the presence of solute particles which is retained on the filter surface. This suggests that the filter formed an incompressible cake thus increasing the resistance on the filter surface.

The addition of iron powder in the composition of the filter resulted in the increase of filter mechanical strength. However, it can also lead to the compactness of filter. As a consequence, the diffusion of liquid to the pores of the filter was blocked by solute particles, resulting in the decrease of water permeate fluxes.

Table 3 depicts the removal percentage of Iron and zinc in permeate. It shows that the use of ceramic filter made from natural clay and fly ash was effective for removing the iron and zinc with more than 99% and 96% respectively.

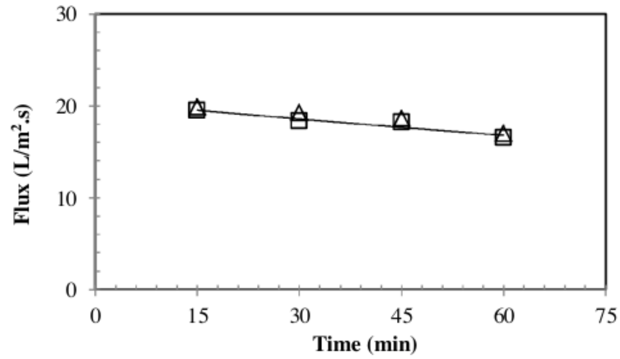

Fig. 2. Permeate fluxes vs time (Δ- 10 L/min, □-12.5 L/min).

Table 3. Iron and zinc removal percentage.

Feed Flow rate (L/min)	Time (min)	Fe (mg/L)	Removal Percentage	Zn (mg/L)	Removal Percentage
10	15	0.061	99.90	0.039	96.68
	45	0.050	99.92	0.033	96.41
12.5	15	0.060	99.90	0.028	96.97
	45	0.010	99.84	0.020	96.84

Ceramic filter structure was determined using Scanning Electron Microscope as shown in Figure 3. It appears that filter pores have a random structure with pore diameter around 10 μm. Therefore, the filter can be classified as microfiltration filter.

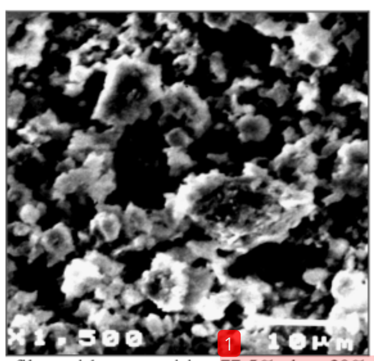

Fig. 3. SEM image for ceramic filter with composition 77.5% clay, 20% fly ash and 2.5% iron powder.

4. CONCLUSIONS

The performance of ceramic filter in water quality improvement was evaluated. Ceramic filter made of a mixture of clay, fly ash and iron powder was effective in producing good permeate quality. The obtained reduction percentages of Fe and Zn ions in water samples are more than 99% and 96% respectively.

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