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Indian
Journal of Advances in
Chemical Science

Indian Journal of Advances in Chemical Science S1 (2016) 294-296

Development of Ion Exchange Media using Waste Ceramic and its Application in Water Treatment

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Received 01st April 2016; Revised 16th May 2016; Accepted 15th August 2016

ABSTRACT

Many ceramic industries will discard their defective and unsold fired products as waste material directly into the landfill site, which causes environmental problems. In this study an attempt is made to develop ion exchange media using waste ceramic materials and its application to remove pollutants from ground water. The waste ceramic is converted into zeolite by alkali fusion method and the developed zeolite was impregnated with silver nitrate of 0.5 mM. The developed silver impregnated zeolite had the properties such as high cation exchange capacity, large surface area, high porosity and antimicrobial properties. The batch studies were conducted using developed silver impregnated zeolite as ion exchange media for removal of hardness, and bacterial contamination from ground water. The batch studies conducted resulted in removal of hardness and bacterial contamination with 72% and 96% removal efficiency.

Key words: *Waste ceramic, Groundwater, Nitrate, Hardness, Bacteria, Zeolite, Silver impregnation.*

1. INTRODUCTION

Safe drinking water is essential to human health and development of a country. As per the World Health Organization [1], about 96.5 % water on the Earth is in oceans, 1.74% is from glaciers, 1.7% is groundwater and 0.76% is fresh water. Groundwater is the principle source of drinking water supply in rural areas of Karnataka state located in southern part of India. Groundwater systems are naturally well protected against contamination due to filtration and purification potential aquifer strata. Groundwater contamination occurs both naturally and manmade activities. Hardness in water is found throughout the world and can cause scaling which reduces efficiency on water heaters, boilers, cooling towers. Another major contaminant is bio contaminants [2] that are responsible for waterborne diseases. Conventional methods for treating hardness are boiling, distillation, coagulation, flocculation and membrane filtration. For removal of pathogenic bacteria disinfection is normally used. These treatment methods require energy and time consuming.

In coagulation the hazardous chemical sludge is produced which further causes disposal problems. Membranes are sensitive to hard water due to abrasive effect on materials by hard water results in membrane clogging. Zeolites are natural or synthetically occurring hydrated alumino silicates having high surface area and high external cationic exchange capacity [3]. The ion exchange process is widely used for water softening and water purification. Many ceramic industries will discard their defective and unsold fired products as waste material directly into the landfill site, which causes environmental problems. Synthetically prepared ceramic ion exchange media will lead to new technological revolution that may add great economic value to natural minerals that are existing all over the world. Silver particles have been widely used as an effective antimicrobial agent against, bacteria, viruses and fungi. Rodriguez *et al*., [4] investigated the inactivation of *Pseudomonas aeruginosa* and *Aeromonas hydrophila* using silver as a secondary disinfectant to reduce the level of chlorine. Nawaz *et al*., [5] evaluated the efficiency of silver ions ($AgNO_3$) in removing *P. aeruginosa* and *Escherichia coli* in rooftop harvested rainwater supplies.

The present study aimed towards removal of hardness and bacterial contamination using silver impregnated developed ion exchange media. The specific objective include synthesis of ion exchange media from waste ceramic. Removal efficiency with varied concentration of silver.

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2. MATERIALS AND METHODS

The groundwater water was collected from bore wells located in rural areas of Hunsur taluk, Mysore district, India. The water samples contained high concentration of hardness and bacterial contamination was observed. The water samples were analyzed for various drinking water quality parameters as per the standard methods [6].

The damaged and discarded ceramic collected from construction waste was used as media. Waste ceramic is mainly comprised of amorphous glass and crystalline phases such as quartz and mullite. The crushed ceramic was alkali fused according to the procedure mentioned elsewhere [7]. This mixture was placed in a mud pot and kept in muffle furnace for 7 h at 700°C. The fused material was cooled and washed with distilled water to maintain the pH between 7.5 and 9.0. The resultant material is dried in the hot air oven for 6 h at 105°C to get synthetically developed zeolite. The batch studies were carried out using this developed zeolite. Figure 1 shows the developed ion exchange media from waste ceramic.

For silver impregnation silver nitrate stock solution of 1 mM was prepared. This developed media is used as final ion exchange media for removal of hardness and bacteria from groundwater.

3. RESULTS AND DISCUSSION

Batch studies were conducted in the laboratory using developed media to treat the groundwater. Table 1 shows the characteristics of ground sample. All the parameters was more than the drinking water quality standards. In this study hardness and bacteria removal was considered. The hardness was removed by both with impregnation and without impregnation method. Figure 2 shows the removal of hardness from ground water with the developed media without impregnation of silver nitrate solution. The developed ion exchange media removed about 66% hardness from ground water without impregnation of silver nitrate solution. The hardness was removed by the developed media because the media was developed by alkali fusion method. The sodium ions present in the media was replaced with calcium and magnesium, thus reducing hardness content in the groundwater. Figure 3 shows the removal of hardness with impregnation of $AgNO_3$ solution. The percentage removal of hardness after silver impregnation was observed to be 72%.

Table 1: Characteristics of groundwater.

Parameters	CPHEEO standards	Results
pH	7-9.2	8.4
Turbidity, NTU	1-10	42
Conductivity, μScm^{-1}	-	3582
Total hardness, as $CaCO_3$	200-600	1460
Calcium hardness, $CaCO_3$	75-200	600
Magnesium hardness, $CaCO_3$	30-150	860
Chlorides, mgL^{-1}	200-1000	340
Nitrates, mgL^{-1}	0-45	200
Arsenic, mgL^{-1}	0.05	0.29
Total coliform, fecal coliform and fecal *Streptococcus*, MPN/100 ml	0/100 ml	1100+

Silver impregnated media was also used to remove the bacteria from groundwater [8]. The bacteria concentration in water was more than 1100+ MPN/100. Henceforth, different concentration of silver nitrate solution was tested to deactivate the bacteria from the groundwater (0.01, 0.1, 0.3 and 0.5 mM). The concentration with 0.01, 0.1, 0.3 mM showed 70-80%

Figure 1: Developed ion exchange media.

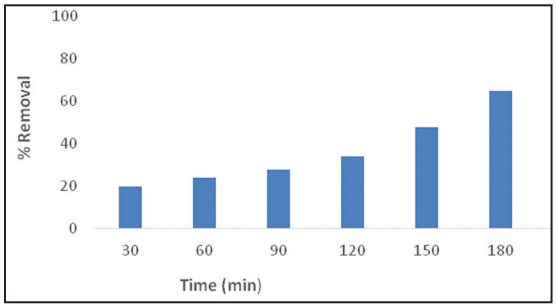

Figure 2: Hardness removal without impregnation.

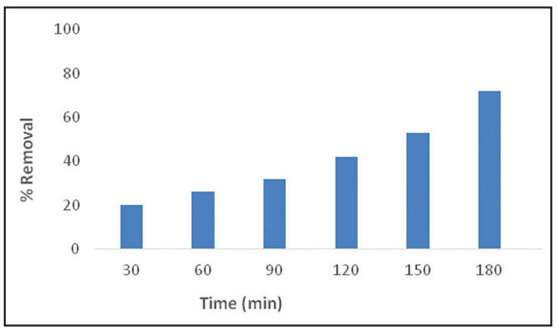

Figure 3: Hardness removal with impregnation method.

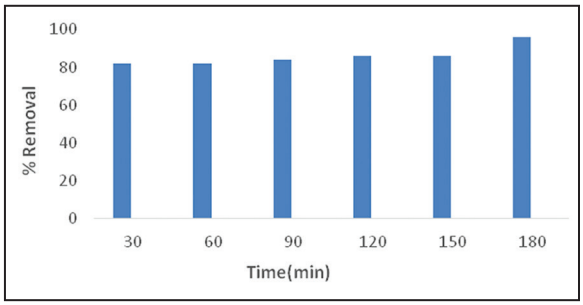

Figure 4: Bacteria removal with 0.5 mM of silver nitrate solution.

of removal efficiency while the concentration with 0.5 mM showed up to 88% of removal efficiency. Figure 4 shows the removal efficiency of bacteria with impregnation of silver nitrate solution of 0.5 mM.

Safe drinking water plays a significant role in preventing health risk from water borne diseases. Previous researches have adopted different methods and studied on different filter media for removal of hardness from water. Two filter media, blast furnace flag and zeolite modified filter were used for removal of hardness from water. Zeolite modified filter removed 66% of total hardness and blast furnace slag removed about 52% from the water [9,10]. In comparison to the above study, the present study could achieve 72% of total hardness with waste ceramic as ion exchange media.

4. CONCLUSION

In this study, an attempt has been made to use the waste ceramic to develop ion exchange media by alkali fusion method. The developed zeolite material were used to remove hardness and bacteria from the groundwater. The removal of bacteria was 96% with zeolite impregnated with 0.5 mM of silver nitrate solution. Hardness removal was 66% without silver impregnation and 72% with silver impregnated zeolite. This technology can offer relatively complete antimicrobial solutions to the rural communities.

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