Water Softening and De-Ironing of Ground Water using Sulfonated Polystyrene Beads

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***Abstract* - Groundwater is a fresh water resource which accounts for a major part in meeting irrigation and drinking water demands. Ground water enrichment with dissolved solids has increased due to interference of anthropogenic activities. Incidence of Iron and hardness above desirable and permissible level is found in many places of India, which includes major cities and districts. The present research is contemplated on using sulfonated polystyrene (SPS) beads as packed media for removal of iron and hardness from groundwater. The removal efficiency of iron and hardness by sulfonated polystyrene beads (Ø 2 and 8 mm) were determined for varied flow rates 100, 200, 300 and 400mL/min. At flow rate of 100mL/min using 2 mm SPS beads hardness and iron removal efficiency was 63 and 54% respectively. Sulfonated Polystyrene beads proved to be efficient in removal of iron and hardness.**

Keywords - Sulfonated; Polystyrene; beads; Hardness; Iron; Packed media

I. INTRODUCTION

The quality of water resource is a subject of ongoing concern. A large section of rural population in India is solely dependent on ground water, which is depleting at a fast rate. It accounts for nearly 80% of the rural domestic water needs, and 50% of the urban water needs in India [1].

Various land uses, form a point or diffuse source of pollutants which eventually reaches ground water table [2]. Current practices which pollute groundwater are application of fertilizer or pesticides, spills from industrial operations, infiltration of urban runoff, and leachate from landfills. The ground water also gets enriched with salinity naturally dissolving from geological deposits; thereby increasing the concentration of certain elements such as calcium, magnesium, fluoride, iron, arsenic, strontium, selenium, etc [3, 4].

Hard water when used has effects like tasteless when directly consumed, salty deposits leading to corrosion of metals, increases detergent demand when used for laundry, requires long time to cook, etc. Using contaminated groundwater causes hazards to public health through poisoning or the spread of diseases. Presence of unfavourable concentration of hardness in drinking water can cause cardiovascular problems and kidney stones. The most common method for removing hardness at household level is boiling. Bureau of Indian standards for total hardness is prescribed as 300 and 600mg/L which are desirable and permissible limit respectively [5]. Presence of Iron concentration in drinking water supplies more than 0.3mg/L is of major concern since it promotes the growth of 'iron bacteria' in water conveyance and distribution system. Iron bacteria do not cause health problems in people, but they may have the following possible effects: corrosion of metal pipes and equipment, clogging, formation of offensive odor and imparts taste due to the death of the bacteria, etc [6].

However, there are various others methods for iron, calcium and magnesium hardness removal from groundwater such as reverse osmosis, ion exchange, chemical treatment with lime-soda ash method, chemical precipitation, adsorption filtration, absorption, aeration, etc. These conventional treatment methods have disadvantage of formation of sludge (chemical precipitation), clogging (filtration), difficult in maintaining the treatment efficiency (adsorption and aeration). The ion exchange process using synthetic resins and natural materials have proved to be the most effective method to remove selective ions from the groundwater. Other application of these synthetic resins is separating out some elements and has advantages such as long life, cost effective, low maintenance, easy to handle, easy recover and reuse, etc [7].

Keeping all the above facts in view, the present study, polystyrene matrix (resin) is customized through physico-chemical treatment to effectively remove the iron and hardness from water. The specific objectives included were to carryout performance evaluation studies at different flow rate, varied bead size and for raw and sulfonated Polystyrene to determine the optimum removal efficiency.

II. MATERIALS & METHODS

A. Ground Water Sampling

The groundwater is taken from a bore well near Dasanakoppalu, Mysore district, located in southern part of Karnataka, India. Standard sampling and analytical procedures were followed during the collection and analysis of ground water sample [8]. Total Hardness and Iron was analyzed to determine the concentration present in the sample. The sample was prepared synthetically for treatability studies carried out for Iron concentration removal and ferrous ammonium sulfate was added to the groundwater sample obtained.

B. Experimental Setup

The experimental setup consisted of two perplex column of height 20cm and diameter 6cm in which polystyrene beads (Raw and Sulphonated is used (Figure 1a). The perplex column is closed with end caps at both the ends as in figure 1b. Bottom end cap is fitted with outlet nozzle. Top end cap was fitted with inlet nozzle and air vent nozzle. Bottom end cap was bonded to perplex column using bonding agent where as the top end cap was kept detachable in order to remove and replace the raw and sulfonated polystyrene beads. Mesh was placed at bottom and on top in order to avoid flow down of beads from the column. The specifications of the material used in lab scale experimental set up are presented in Table 1. A flow controllable tap was used to regulate the flow of water.

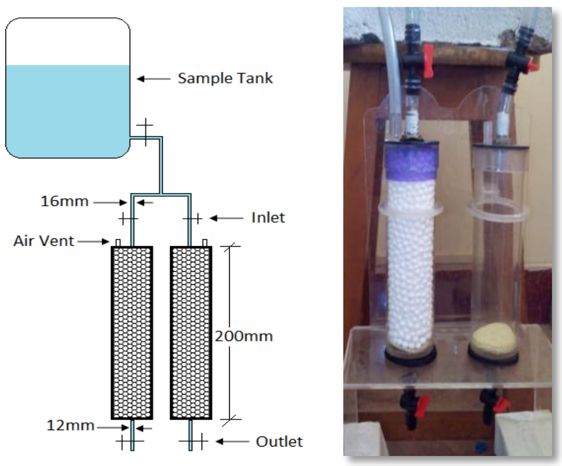

Figure 1 Schematic Representation and Laboratory Prototype Model of Experimental Setup

TABLE I MATERIALS AND SPECIFICATIONS

Materials	Specification
PS Beads	Size – 0.002m & 0.008m
Perplex Column	Dia – 0.06m; Height – 0.20m
Inlet tank	10 L
Outlet tank	500 mL
Air Vent	0.008m
Pipe	Inlet – 0.016m; Outlet – 0.012m

C. Sulfonated Polystyrene Beads

It was prepared according to the procedure given by Bekri et al, and Pentamwa et al (2011). In brief the raw polystyrene bead which was procured from local market was first immersed in 95% sulfuric acid and left to react under room temperature for 24hr. The remaining sulfuric acid was decanted and the beads were washed with de ionized water (6 – 7 times the volume of the beads taken). The beads were dried at 400^0C for 30mins. Then the beads were contacted with 0.2M sodium chloride solution for 2hr. this is to neutralize the beads and to convert from H+ to form to Na+. These beads were used as packed media for the column studies.

D. Column Studies

Column studies were carried out in two different phases. In phase 1 raw polystyrene beads were packed in the perplex column. The treatability studies were conducted for beads size of 2mm and 8mm diameter were used individually as packed media. The water sample was passed through the media at flow rates of 100mL/min, 200mL/min, 300mL/min and 400mL/min for each bead size tested. The water samples drawn were analyzed for iron and hardness to determine the removal efficiency and optimum flow rate.

Similarly, in phase 2 study only the media was changed i.e., in place of raw polystyrene beads, sulfonated polystyrene beads (2 and 8mm) was placed and removal efficiency of iron and hardness was determined for removal efficiency for the considered flow rate.

III. RESULTS & DISCUSSION

A. Sample

Groundwater characterization done showed the concentration of Iron and total hardness was 0.12 and 1360mg/L respectively. As per BIS 10500:2003 the total hardness was above the permissible limit of 600mg/L and iron concentration was below the desirable limit of 0.3mg/L. The sample pH was 7.7 and conductivity was 2890μS/cm. Thus ferrous ammonium sulfate was added to the sample to raise the iron concentration to 0.12 to 2.97mg/L.

B. Column Studies

The column studies were carried out to know the treatability of ground water in terms of total hardness and iron removal efficiency using raw polystyrene bead as packed media and the same is depicted in the Figure 2 and 3. For flow rate as operating parameter varying from 100 to 400mL/min, the removal efficiency of Total Hardness was observed to be increasing with decrease in flow rate (refer Figure 2). Similar, trend was observed for Iron removal which is shown in Figure 3. Column studies were also conducted for varied bead size 2 mm and 8mm , from the study it was evident that reduction in bead size resulted in better removal efficiency which might be due to the increased surface area (and reduced voids) of the packed media in the case of 2mm bead size. From Figure 2 at optimized flow rate of 100mL/min Total Hardness was reduced from 1360mg/L to 938 and 966mg/L when 2 and 8mm beads were used respectively. Similarly, at the same flow rate Iron a concentration was reduced from 2.3mg/L to 1.13 and 1.24mg/L with respect to 2 and 8mm bead size.

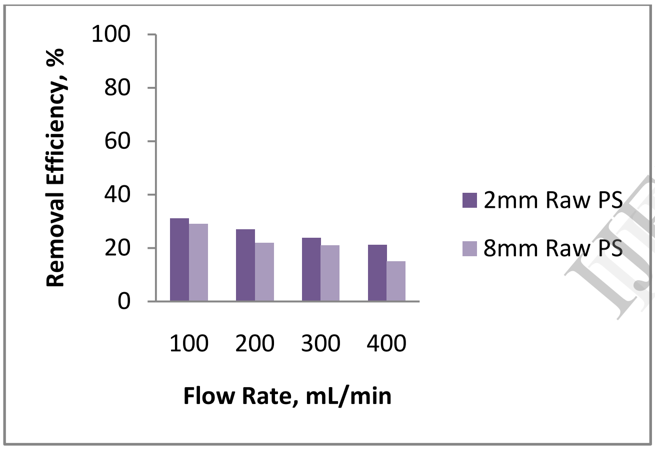

Figure 2 Total Hardness removal efficiency using raw polystyrene beads

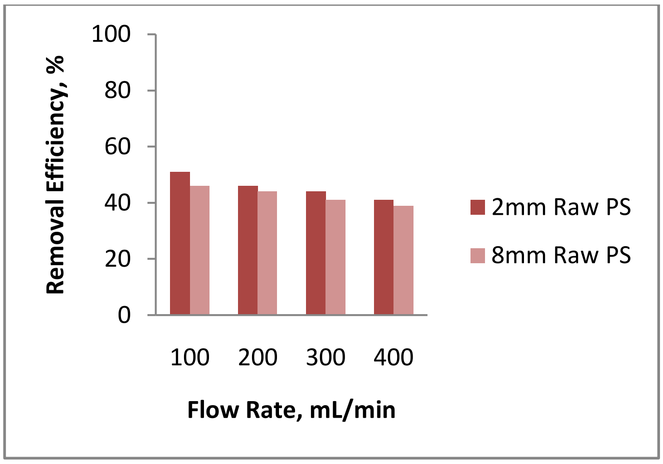

Figure 3 Iron removal efficiency using raw polystyrene beads

Even though the removal of Total Hardness and Iron observed to be less in terms of removal efficiency, the removal of those constituents in terms of concentration reduction is appreciable.

Further raw polystyrene beads were replaced by sulfonated beads to check the removal efficiency of polystyrene beads with and without sulfonation. Sulfonation of beads showed improved removal efficiency both for Total Hardness and Iron. The removal efficiency of considered parameters is shown in Figure 4 and 5. Total hardness removal was promising when sulfonated polystyrene beads were used. Maximum removal of 54% was observed when 2mm beads were employed. 1360mg/L of hardness was reduced to 572mg/L which is below the permissible limit of 600mg/L as prescribed in BIS 10500:2003. The Iron concentration was reduced from 2.3mg/L to 0.83mg/L at 100mL/min flow rate. The Iron concentration in treated water is within the permissible limit of drinking water quality standards (1mg/L). The increased removal efficiency might be due to increased cation exchange capacity by converting of H^+ form to Na^+ through neutralizing processes with NaCl. However significant removal efficiency was not observed for sulfonated 2mm & 8mm bead size as the efficiency was varying between 1 to 3%.

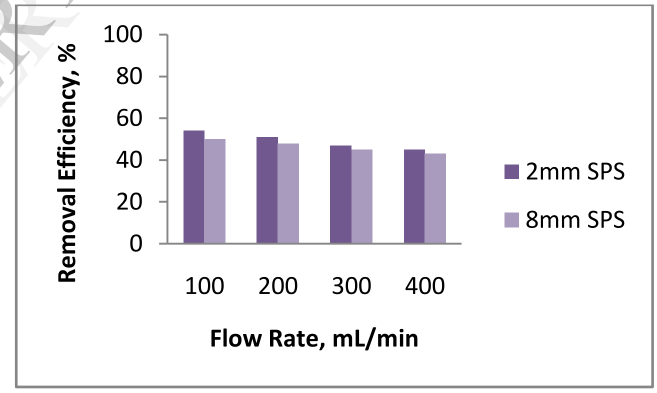

Figure 4 Total Hardness removal efficiency using sulfonated polystyrene beads

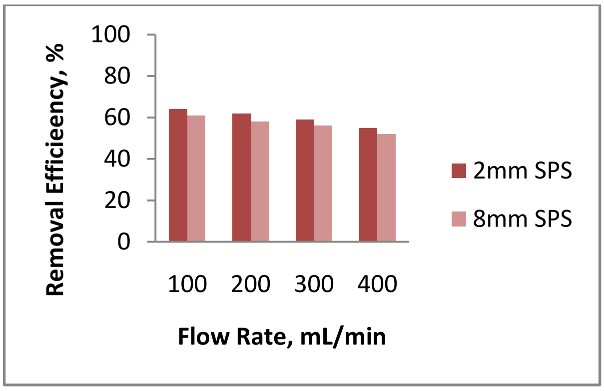

Figure 5 Iron removal efficiency using sulfonated polystyrene beads

IV. CONCLUSIONS

From treatability studies carried out at lab scale with aim of softening and deironing ground water using polystyrene beads following conclusions were drawn

- Flow rate of 100mL/min, bead size of 2mm, sulfonated polystyrene beads were found to be the optimized condition resulting in removal efficiency of 54% and 64% for total hardness and iron respectively.
- Sulfonation of the beads using 95% concentrated sulfuric acid resulted in increase of cation exchange capacity of the resin in comparison with non sulfonated polystyrene bead.
- Sulfonated beads were efficient in reducing the Iron and Hardness to below permissible limits which is essential to comply with drinking water quality standards.

SCOPE FOR FUTURE STUDY

The research can be extended to determine the removal efficiency of other parameters of environmental concern and for varied degree of sulfonation.

ACKNOLEDGEMENT

Authors, greatfully acknowledge financial assistance provided by TEQIP Phase-II, Sri Jayachamarajendra College of Engineering , Mysore and and also Mr. Madhukar M., Assistant Professor, Department of Environment, Vidyavardhaka College of Engineering, for his valuable guidance and support towards completing this research.

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