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Feasibility Studies on an Eco-friendly Water Purification Unit using Polystyrene Beads

Shreyas B V[1], Dr.Sridhara S [2]

[1]shreyasbv2009@gmail.com, [2]sridharasid@gmail.com
[1,2]Assistant Professor
Department of Civil Engineering, Dayananda Sagar Academy of Technology and Management

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Abstract: Water is the basis of all life. But, the quality of drinking water has been deteriorated due to various anthropogenic activities. There is a need for an efficient and eco-friendly water treatment method as the conventional methods are inconsistent and release excess of waste water. Polystyrene, a synthetic resin can be used as a packed media filter to purify water by ion-exchange method. The ion-exchange process using synthetic resin is the most effective method for the removal of selective ions from water. This method is widely used for the removal of nitrates, fluorides, iron and hardness of water. Treatability studies will be conducted by filling the column with polystyrene beads as a packed media. In this research water quality assessment of both the sample water and the purified water will be done on a daily basis to check if the water quality standards will be achieved. Also, Media exhaustion studies will be conducted which determines the durability of the filter material for effective purification of water. Along with the life span of the material, observations will be made for degradation of filter material and release of any by-products such as styrene into purified water in the long run. Based on the results, Polystyrene beads will be used to develop a home-based water purification unit.

Keywords: Polystyrene beads; Conventional methods; Ion exchange; Treatability studies; Media exhaustion study; Water purification unit.

1. Introduction

Water, the 'Elixir of life' is a basic necessity of a human being. The quality of water resource is a subject of ongoing concern. About 71% of the planet is covered with water, and still less than 1% could be used for consumption purpose**.** Water available in various sources contains various types of impurities and cannot be directly used by the public for various purposes, before removing the impurities. Anthropogenic activities which pollute drinking water are application of fertilizers or pesticides, spills from industrial operations, urban runoff into the lakes, rivers and streams. Presence of impurities can cause various diseases such as cardiovascular problems, kidney stones, Methemoglobinemia, Cyanosis, Asphyxia, Hypercalcaemia, Hypermagnesemia, dental, skeletal disorders and so on [7].

These contaminants can be removed from water by applying various treatment methods which include aeration, precipitation, filtration, adsorption, etc. Performance of these conventional methods has been found to decline when the concentration of pollutant is significantly high and also the process produces a large quantity of by-product. Recently, due to increasing concern for the environment, eco-friendly alternatives such as synthetic polymers, resins and silica beads have been considered, as they can be reused, recycled and regenerated [8]. They are used as a media to adsorb or exchange the pollutant ion. Hence, an adsorption ion exchange unit continues to be the most feasible and effective treatment option for household water purification [3].

Polystyrene (PS) beads are polymers made of monomer styrene. They are used as an ion exchanger which exchange specific ions present in the polymer with ions in water. The synthetic resins are used primarily for purifying water, but also has various other applications including separating out some elements and has advantages such as long life, cost effective, low maintenance, easy to handle, easy recover and reuse, etc [3]. Keeping all the above facts in view, the present study is focused on using Polystyrene beads as fixed media and to evaluate the durability of the filter material to purify the drinking water effectively. Then develop a home-based water purification unit using Polystyrene beads as a packed media.

2. Review of Literature

Ion exchange is a water treatment method where one or more pollutant ionic contaminants are removed from water by exchange with another non-objectionable, or less objectionable ionic substance. Polystyrene beads were used to purify water based on the principle of ion exchange. Polystyrene beads were used in various forms (beads, grains and foam) and sizes (2mm, 4mm, 6mm) to purify water for drinking purpose. Examples of usage of Polystyrene to provide quantities of potable water suitable for home or other relatively limited uses are shown in various journals.

The water quality has to reach the required limits set by Bureau of Indian Standards in order to be used as a drinking water. Total Hardness test was done to check if the water sample is within the permissible limit (600 mg/L). Spectrophotometer method was used to check the concentration of Nitrates, Iron and Manganese in the water sample. The presence of fluoride in the water was determined to examine if the concentration was exceeding the required limit.

Water purification using Polystyrene beads

Experimental studies were conducted using polystyrene beads which were efficient in the removal of impurities from the water source. Column studies were carried out to determine the treatment efficiency of the Polystyrene beads. The groundwater was analysed to determine the characteristics of the water sample. Polystyrene beads of various sizes (2mm, 4mm, 6mm) with various flow rates (0.25, 0.5 and 0.75 L/min) were used as a packed media. Two columns were used. One was filled with Raw Polystyrene beads and the other with supersaturated NaCl Polystyrene beads. When the water was passed through, it was observed that the contaminants present in the water were removed. This was because the PS beads were saturated with sodium to cover the bead surface in the process of manufacturing. As water passed through the packed media, pollutant ions were attached to the beads and the loosely held sodium was released from the packed media to the water medium. The optimum flow rate and particle size for efficient removal of impurities from water was found to be 0.25 L/min and 2mm respectively. It was observed that, the removal efficiency of hardness and other impurities was more with smaller resin beads, this was mainly due to an increase in surface area and film diffusion rate. Polystyrene beads when supersaturated with NaCl solution had more efficiency in removal of Hardness, turbidity, Nitrates, Iron and Fluorides from water source when compared to Raw Polystyrene beads. This was due to increase in the exchangeable ions (i.e., Na) on the surface of the beads which were responsible for removal of iron and hardness causing ions. The removal of Fluorides and Nitrates was due to the attractive force on the counter ions or exchangeable ions (i.e., Cl) present on the surface of the Polystyrene beads. **[3] Madhukar, et.al., 2015.**

They investigated the results obtained when polystyrene beads were sulfonated using 95% concentrated sulfuric acid to remove Iron and Hardness from the groundwater sample. Sulfonated polystyrene beads were filled in a column reactor and the water sample was passed through the packed media. Different sizes of beads were used at different flow rates. 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. This was because sulfonation of the beads using 95% concentrated sulfuric acid resulted in increase of cation exchange capacity of the resin beads. The impurities in the purified water was below permissible limits which was essential to comply with drinking water quality standards. **[7]Lavanya, et,al., 2014.**

Water treatment unit using Polystyrene

Polystyrene foam filters were used to build a water treatment unit in Ukraine. They were used to treat groundwater and surface water for drinking purpose. Polystyrene beads when processed with hot water or steam formed Polystyrene foam. Polystyrene foam was used as a filter to purify drinking water. A scheme was proposed with hydraulic automatic device with switching modes and polystyrene foam filters in the water preparation for drinking purposes and assessed the economic efficiency of proposed solutions. Water treatment unit developed with this material was energy saving and cost efficient compared to the existing technological schemes. They provided savings in terms of capital investment, operating costs and electricity. They also reduced water consumption for own needs and the amount of buildings and structures **[2] Orlov, et,al., 2016.**

They evaluated how polystyrene granules can be used as media filters on rapid filters. A comparison between the Polystyrene filter and the combination of Sand and Anthracite filter was done. The filter performance was compared in terms of water quality, turbidity, apparent and true colour, conductivity, total dissolved solids, temperature, pH, residual aluminium, and removal of cyanobacterium under the same operating conditions of filtration. The quality of water produced by the Polystyrene filter turned out to be equal to the quality of water produced by the combination of Sand and Anthracite filter. The length of the filter runs was shorter in Polystyrene filters when compared to the other filter. Being a granular element with virtually spherical grains and small grain size, it presented lower bed porosity, which lead to the head loss of the PS filter to reach two meters more quickly, thus ending the runs early. In addition, Polystyrene granules did not release detectable amounts of styrene in water and can therefore be used as a filter element **[4] Juliana, et,al., 2015.**

They focused on the development of a water softening unit using Polystyrene beads. They explained the different types of water purification units that could be built based on the regeneration process and types of salts. Although, the desired quality of water was achieved, they stated some of the drawbacks of the filter. As sodium was added into the water during the process, people restricted on sodium diets due to health reasons should account for intake through softened water and consult their physician. Ion exchange method using

PS beads did not remove bacteria, hydrogen sulphide, lead, pesticides. Regular maintenance of the unit was a critical factor in maintaining the effectiveness of the unit **[6]Sharon, et,al., 2014.**

3. Summary of the Literature Review

The above papers discussed the environmental effects and physicochemical characteristics of surface water pollution through a review of works of previous authors. Previous authors viewed water pollution as a threat to the survival of the environment and mankind. They argued that anthropogenic activities were the major factors of water pollution and hence it was necessary for water treatment. The research papers confirmed that the PS beads can be used as a packed media for water purification. They presented that the beads were efficient in the removal of nitrates, fluorides, iron and total hardness of water. They were also efficient in the removal of turbidity from the water. Polystyrene beads could be used to develop a water purification unit based on water analysis and assessment of the individual home owners needs and situation.

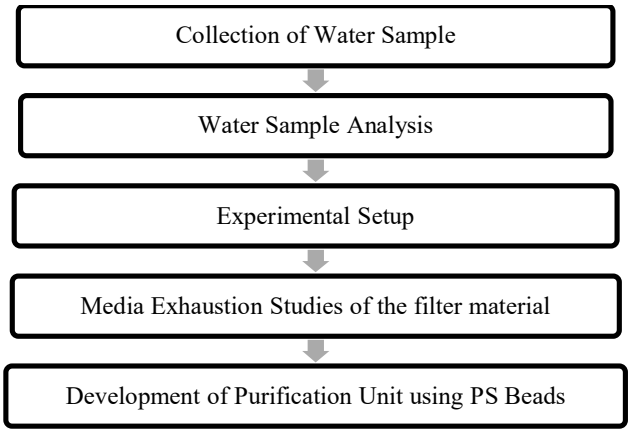
4. Materials and Methods

Materials

- **Polystyrene Beads:** Polystyrene beads are the main source of water purification. They act as a packed media for efficient removal of impurities in the water. When water passes through the packed media, they behave as ion exchange resins, by exchanging specific ions present in the polymer with the ions present in the water. The advantages of Polystyrene Beads are low cost, easy to handle, easy to recover and reuse.

- **NaCl Solution:** Polystyrene beads would be immersed in 10% Sodium Chloride and will be left to react under lab conditions for 24 hours. It will then be drained to dryness under laboratory conditions. Polystyrene beads contain a microporous exchange resin that are supersaturated with sodium to cover the bead surfaces. When the water passes through this resin bed, ions present in the water will get attached to the resin beads and the loosely held sodium will be released from the resin into the water.

Methodology



The tap water sample from DSATM campus will be collected and analysed for the various physio-chemical characteristics. Water sample analysis provides data on the concentration of impurities present in the water. Polystyrene beads would be used as a filter material. Polystyrene beads would be supersaturated with 10% Sodium Chloride solution and left to react under lab conditions for 24 hours. It will then be drained to dryness under laboratory conditions. The Polystyrene beads would be filled inside the column reactor as a packed media filter. Two meshes would be placed on the either ends of the column reactor to prevent the flow of the Polystyrene beads along with the water. Flow controllers would be used to regulate constant flow rates. The tap water would be collected and let into the column reactor at a constant flow rate using flow controllers. The tap water will be passed through the packed Polystyrene Beads. When water passes through this resin bed, ions present in the water will attach to the resin beads and the loosely held sodium ions will be released from the resin into the water. The purified water would then be collected and analysed. Analysis of purified water would be done to know whether the degree of purification has reached the required standards or not. The water sample will continuously run through the column reactor. The water quality assessment of both, the sample water and the purified water would be done on a daily basis. The process continues until the purified water reaches the required standards. Media exhaustion studies will be completed when the water quality of the purified water does not reach the required standards. The total quantity of impurities effectively removed by filter media before exhaustion would be calculated. A water purification unit would be designed using motor pumps, sensors and polystyrene bead filter. A motor driven pump would supply a feed stream to a packed polystyrene beads unit. The water would be purified as it passes through the polystyrene unit. The impurities in the water would be removed and the quality of water would reach the required standards.

5. Conclusions on the literature reviewed

Polystyrene beads can be used to develop an efficient water purification unit. Media Exhaustion Study should be carried out to determine the life span of Polystyrene beads, in terms of efficient removal of impurities from the water. Polystyrene should be monitored over the long term in order to verify its degradation, and the possibility of the release of styrene or byproducts into the water. The durability of the PS beads and the measure of release of styrene content over the period will be an important factor to develop a home-based water purification unit.

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