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RESEARCH

Water Hardness Removal by Using Waste Polystyrene

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CONFLICTS OF INTEREST
THERE ARE NO CONFLICTS OF INTEREST FOR ANY OF THE AUTHORS.

ABSTRACT:
The possibility of using waste polystyrene to remove the hardness of water has been investigated. Waste of polystyrene is consisting of white coffee cups and foams and they were converted into adsorbent by heterogeneous sulfonation.

Consequently, Infra-red technique has been used to confirm the sulfonation. Degree of sulfonation and cation exchange capacity has been determined by titration. Hard water has been prepared by dissolving Mg or Ca salts in distilled water. The modified polymer provides high purification of hard water comparable to conventional adsorbent.

INTRODUCTION

According to The Statistics published on 2005/2006, Egypt produces around 970 MT Per annum of Plastic Wastes. Around 30 % from waste plastics are recycled. The Egyptian Styrene and Polystyrene Production Company E-STYRENICS is The Only Source for Producing Polystyrene in Egypt, The Company Produces 200,000 MTA Polystyrene.

The possibility of using waste polystyrene to remove the hardness of water has been investigated. Waste of polystyrene is consisting of white coffee cups and foams and they were converted into adsorbent by heterogeneous sulfonation. Infra-red technique has been used to confirm the sulfonation. Degree of sulfonation and cation exchange capacity has been determined by titration. Hard water has been prepared by dissolving Mg or Ca salts in distilled water. The modified polymer provides high purification of hard water comparable to conventional adsorbent.

PROBLEMS INVESTIGATIONS

Polystyrene is an inexpensive and hard plastic, structurally; it's a long hydrocarbon chain with a phenyl group attached to every carbon atom. Polystyrene is produced by free radical vinyl polymerization from styrene. A large portion of polystyrene's production goes into packaging (cups, plates, bowls, trays, clamshells, meat trays, yogurt and cottage cheese containers) and protective packaging (shaped and pieces used to ship electronic goods such as audio/visual cassettes). Unfortunately, only few amounts of waste polystyrene are recycled. In fact, there are three main types of waste polystyrene recycling, that is; material recycling, thermal recycling and chemical recycling. The material recycling is a simple method to reuse waste plastics, and which has been applied in the plastics processing industries. The thermal recycling is to get thermal energy by burning waste plastics, but this technique requires high calorie incinerator.

Moreover, it produces harmful gases such as dioxin and hydrogen chloride gases while burning. The chemical recycling is to convert waste polystyrene into styrene or hydrocarbons. Recently, a new technique of polystyrene recycling has been developed and which seems to be more efficient. This process's goal is to convert polymer waste into functional polymer with a new application and added value. It is well known that the sulfonation of polystyrene allows the obtaining of interesting product such as: cationic exchanger resin, polyelectrolyte and fuel cell membrane. Therefore, the new developed process is based on the sulfonation of waste polystyrene to produce a new functional polymer more valuable than virgin material or hydrocarbons.

By using this method waste polystyrene which consists of foams into a polyelectrolyte, the process used is an homogenous sulfonation with fuming sulfuric (SO_3, content 60 wt %). has converted waste consisting of foam poly-styrene into a cation exchange resin by dissolving waste into styrene and then co-polymerization with a cross linking agent, and sulfonating the mixture.

These techniques have the disadvantage of being expensive, and very complicated for a laboratory experiment. For that reason, the first objective of the present research is to obtain a polymeric exchanger from common packaging waste polystyrene with a simple and less expensive procedure of sulfonation. The technique to sulfonate polystyrene just on the surface and to keep the core of the material unmodified.

This partial sulfonation, in the absence of solvent, keeps the new sulfonated polystyrene insoluble in water and attaches sulfonic groups to polymer chains and consequently it could be used as resin for ion exchange applications such as the softening of hard water. On the other hand, water is a vital solvent which must be tasteless, colorless, and odorless. As water moves through soil and rock, it dissolved very small amounts of minerals and holds them in solution. Calcium and magnesium dissolved in water are the two most common minerals that make water "hard". The degree of hardness becomes greater as the calcium and magnesium content increases.

To control the hardness of water, cation exchange resins are widely used. In this process, water passes through the resin, usually sulfonated polystyrene beads, and the hardness minerals attach themselves to the resin beads while sodium on the resin beads is released simultaneously into the water. In this paper a technique of recycling waste polystyrene consisting of waste polystyrene into a cation exchange resin and the use in the softening of hard water.

MATERIALS & EXPERIMENTAL WORK PROCEDURES

MATERIALS

Virgin Polystyrene and Off spec Polystyrene

Polystyrene had been obtained from the Egyptian Styrene and Polystyrene Company as well as from crushed cups. Screen Analysis were made the taken sample had average Particle Size = 0.237 mm.

Sulfuric Acid

It is obtained from Chemajet Chemical Company, M.wt. = 98.0789.

Toluene , Methanol and EDTA

FTIR

Dr-3900 Benchtop Spectrophotometer

The DR 3900 guides step-by-step through the testing procedure like a GPS to obtain accurate results. Scratched, flawed, or dirty glassware becomes a non-issue when DR-300 takes 10 readings and eliminates outliers, It is operating mode is Transmittance (%), Absorbance and Concentration, Scanning.

Experimental Work Procedures

Polystyrene (On-Spec Product and Waste Product) were Crushed, Grinded and Screened till obtaining particles with the size of 0.2–0.3 cm, afterwards 5 g of dry material and 100 ml of dense sulfuric acid, 95%, were introduced to a flask and were left to react under agitation while time and temperature are varied.

When the reaction period is complete, the slurry was filtered with a funnel and washed with 250 ml portions of distilled water, after the sixth washing a portion of filtrate was checked with pH paper to ensure the residual sulfuric acid has been removed from the resin, and then the sulfonated resin was dried at 40°C for 30 min.

Neutralization has for objective the conversion of the resin into its Na+ form. It consists of a saturation of the polymer with Na+ ions by stirring the polymer for 2 h at 500 mL 1 M NaCl solution.

The ion exchange capacity (with unit of mmol/g of dry polymer) of sulfonated polystyrene was determined by measuring the concentration of H+ that was exchanged with Na+ when acid-form of sulfonated polystyrene was equilibrated with NaCl solution.

The colorimetric method for measuring hardness supplements the conventional titrimetric method because the colorimetric method can measure very low levels of calcium and magnesium.

The indicator dye is Calmagite, which forms a purplish-blue color in a strongly alkaline solution and changes to red when it reacts with free calcium or magnesium.

Calcium and magnesium determinations are made by chelating calcium with EGTA to destroy any red color due to calcium and then chelating the calcium and magnesium with EDTA to destroy the red color due to both calcium and magnesium.

By measuring the red color in the different states, calcium and magnesium concentrations are determined. Test results are measured at 522 nm.

The Test runs were made for two samples, on-spec product and waste product. The effect of changing process parameters on the removal capacity of Ca ions and Mg ions were investigated.

RESULTS

1.FTIR Analysis

The characterization of FTIR technique for polystyrene Sulfonated sample shows the success of the reaction, it can be seen the presence of sulfonic acid group at 1019 cm-1

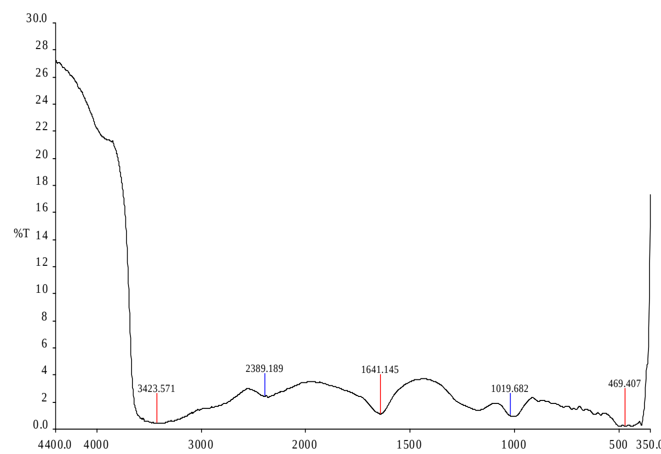


Figure. 1.1. FTIR for Sulfonated Polystyrene Sample

2.Effect of Varying Time of Reaction

As the time of reaction increases, the capacity of removal calcium ions and magnesium ions increases; it was found that the best conditions are when time of reaction is 120 min.

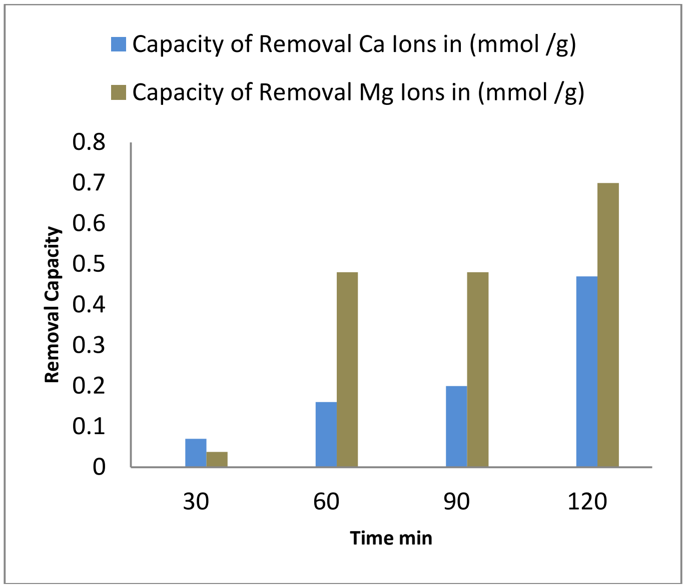


Figure 1.2. Effect of Varying Time of Reaction on Removal Capacity of Ca and Mg Ions for Waste Sample and Virgin Sample (at Temperature = 45°C, RPM = 600, Solid to Liquid Ratio is 1/5 and acid concentration is 95 %)

3.Effect of Varying Reaction Temperature

As temperature of reaction increases, the capacity of removal calcium ions and magnesium ions increases, it was found that the best reaction temperature is 30°C while time of reaction is two hours or 60°C , while the time of reaction is 30 minutes.

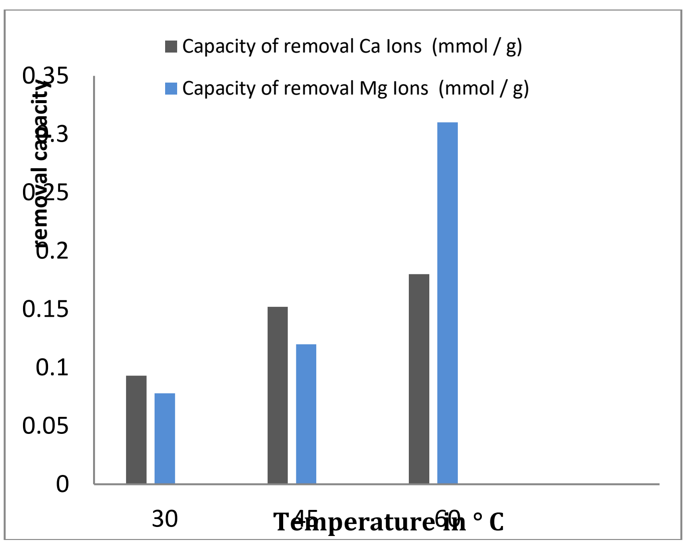


Figure 1.3 Effect of Varying reaction temperature on Removal Capacity of Ca and Mg Ions for virgin sample (at RPM = 600, acid concentration is = 95 %, Time of reaction 30 minutes and acid Solid to Liquid Ratio is 1/5)

4.Effect of Varying Solid to Liquid Ratio

As Solid to Liquid Ratio decreases, the capacity of removal calcium ions and magnesium ions increases; it was found that the best conditions are when solid to liquid ratio is 1/15.

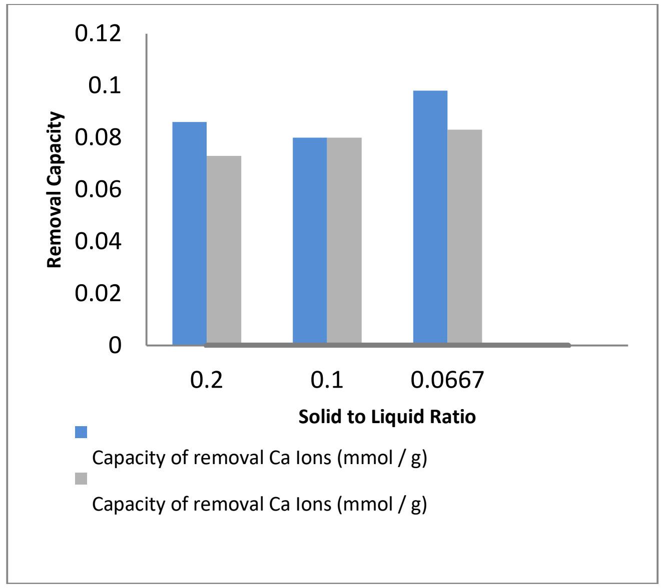
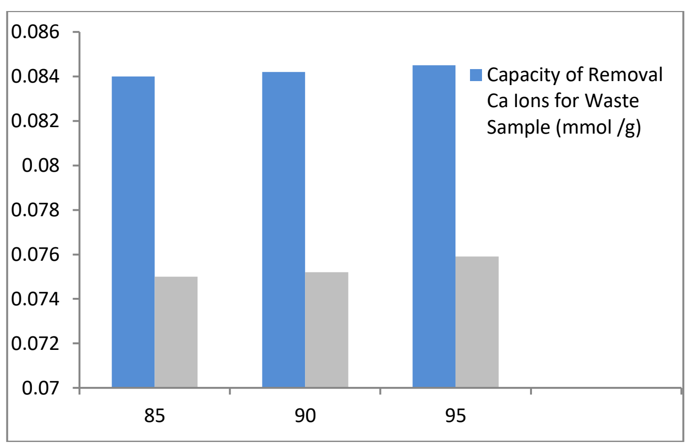


Figure 1.4. Effect of Varying Solid to Liquid Ratio on Removal Capacity of Ca and Mg Ions for waste Sample (at Temperature = 45°C, RPM = 600, Time of reaction 30 minutes and acid concentration is 95 %)

5.Effect of Varying Acid Concentration

As the concentration of sulfuric acid increases, the capacity of removal calcium ions and magnesium ions increases; it was found that the best conditions are when acid concentration is 95 %, but the effect of the efficiency of removal capacity of calcium ions and magnesium ions is not considered to be high with changing the concentration of acid, since due to partial sulfonation.



6.Effect of Varying RPM

As the speed of the agitator increases, the capacity of removal calcium ions and magnesium ions increases; it was found that the best conditions are when RPM is 800.

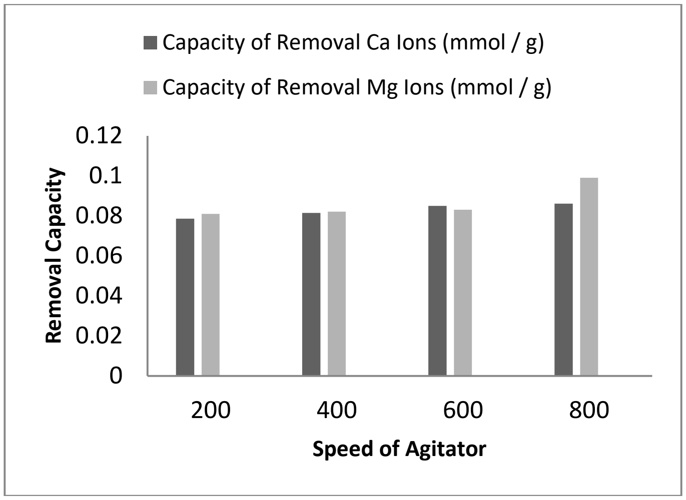


Figure 1.6. Effect of Varying stirring rate on Removal Capacity of Ca and Mg Ions for virgin sample (at Temperature = 45°C, acid concentration is = 95 %, Time of reaction 30 minutes and acid Solid to Liquid Ratio is 1/5)

SUMMARY

1. A large portion of polystyrene's production goes into packaging (cups, plates, bowls, trays, clamshells, meat trays, yogurt and cottage cheese containers) and protective packaging (shaped and pieces used to ship electronic goods such as audio/visual cassettes). Unfortunately, only few amounts of waste polystyrene are recycled.
2. In fact, there are three main types of waste polystyrene recycling, that is; material recycling, thermal recycling and chemical recycling.
3. The material recycling is a simple method to reuse waste plastics, and which has been applied in the plastics processing industries.
4. The thermal recycling is to get thermal energy by burning waste plastics, but this technique requires high calorie incinerator.
5. Moreover, it produces harmful gases such as dioxin and hydrogen chloride gases while burning. The chemical recycling is to convert waste polystyrene into styrene or hydrocarbons.
6. Recently, a new technique of polystyrene recycling has been developed and which seems to be more efficient.
7. This process's goal is to convert polymer waste into functional polymer with a new application and added value.
8. It is well known that the sulfonation of polystyrene allows the obtaining of interesting product such as: cationic exchanger resin, polyelectrolyte and fuel cell membrane. Therefore, the new developed process is based on the sulfonation of waste polystyrene to produce a new functional polymer more valuable than virgin material or hydrocarbons.
9. By using this , converted waste polystyrene a polyelectrolyte, the process used is an homogenous sulfonation with fuming sulfuric has converted waste consisting of foam poly-styrene into a cation exchange resin by dissolving waste into styrene and then co-polymerization with a cross linking agent, and sulfonating the mixture.
10. These techniques have the disadvantage of being expensive, and very complicated for a laboratory experiment. For that reason, the first objective of the present research is to obtain a polymeric exchanger from common packaging waste polystyrene with a simple and less expensive procedure of sulfonation.
11. The technique developed in our laboratory in front of this problem was to sulfonate polystyrene just on the surface and to keep the core of the material unmodified. This partial sulfonation, in the absence of solvent, keeps the new sulfonated polystyrene insoluble in water and attaches sulfonic groups to polymer chains and consequently it could be used as resin for ion exchange applications such as the softening of hard water.
12. On the other hand, water is a vital solvent which must be tasteless, colorless, and odorless. As water moves through soil and rock, it dissolved very small amounts of minerals and holds them in solution. Calcium and magnesium dissolved in water are the two most common minerals that make water "hard".
13. The degree of hardness becomes greater as the calcium and magnesium content increases.
14. To control the hardness of water, cation exchange resins are widely used. In this process, water passes through the resin, usually sulfonated polystyrene beads, and the hardness minerals attach themselves to the resin beads while sodium on the resin beads is released simultaneously into the water.
15. In this paper, a technique of recycling waste polystyrene consisting of waste polystyrene into

a cation exchange resin and the use in the softening of hard water.

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