

Application of a Guar Gum-g-Poly(Acrylic Acid) Superabsorbent for Water Removal from Liquid Fuel

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Abstract—

Superabsorbent polymers offer a promising route for water management because their cross-linked hydrophilic networks can retain large quantities of aqueous liquid. In this study, guar gum-g-poly(acrylic acid) superabsorbent polymer (SAC 1) was evaluated for water removal from a liquid-fuel/water system. SAC 1 was prepared by graft copolymerization of acrylic acid onto guar gum in aqueous medium using potassium persulfate (KPS) as initiator and N,N'-methylene bisacrylamide (MBA) as cross-linking agent. The optimized formulation contained 1.8% (w/v) guar gum, 6.0% (v/v) acrylic acid, 0.25% (w/v) initiator, and 1% (w/v) cross-linker, with the reaction conducted at 60 °C. For the application experiment, 0.1 g of SAC 1 was contacted with 25 mL of liquid fuel and 20 mL of tap water under atmospheric conditions. The sample was allowed to stand for 24 h and was subsequently weighed at 2-min intervals until constant mass was reached; four repetitions were performed for each experimental point. The observed application result was approximately 20 mL of water per 12 min. The findings demonstrate the feasibility of SAC 1 for water management in liquid-fuel systems while indicating the need for further studies on selectivity, residual water, fuel compatibility, regeneration, and scale-up.

Keywords—Guar gum; acrylic acid; superabsorbent polymer; water removal; liquid fuel; graft copolymerization; fuel storage

I. INTRODUCTION

Superabsorbent polymers are cross-linked hydrophilic materials capable of retaining substantial quantities of water within their three-dimensional polymer networks [1,2]. Natural polysaccharides are attractive substrates for such materials because they provide renewable polymer backbones containing functional groups that can participate in grafting reactions. Guar gum-based acrylic-acid graft polymers have been investigated for their water-absorption and water-retention properties [4–7]. Water can occur in fuel as dissolved, dispersed/emulsified, or free water, and its behavior depends on fuel composition and operating conditions [3].

The present study focuses on the application of guar gum-g-poly(acrylic acid) superabsorbent polymer (SAC 1) for water removal from a liquid-fuel/water system. Unlike a general evaluation of superabsorbent swelling, the objective here is to examine water uptake in the presence of a fuel phase and to assess the potential of the material for water-management applications in fuel-storage environments.

The specific objective was to evaluate the water-uptake behavior of SAC 1 under defined laboratory conditions and to identify experimental parameters that require further investigation before application at larger scale.

II. MATERIALS AND METHODS

A. Preparation and Characterization of the Superabsorbent

Guar gum-g-poly(acrylic acid) superabsorbent polymer (SAC 1) was prepared by graft copolymerization of guar gum (GG) with acrylic acid (AA) in aqueous medium using potassium persulfate (KPS) as the initiator and N,N'-

methylene bisacrylamide (MBA) as the cross-linking agent. Guar gum served as the polysaccharide backbone and provided hydroxyl groups for the grafting reaction. On heating, persulfate generates sulfate radicals that abstract hydrogen from hydroxyl groups of the guar gum backbone, producing active sites from which radical polymerization of acrylic acid can proceed. MBA provides intermolecular cross-linking and thereby produces a three-dimensional, water-insoluble network. The optimized formulation comprised 1.8% (w/v) guar gum, 6.0% (v/v) acrylic acid, 0.25% (w/v) KPS, and 1% (w/v) MBA, with the reaction conducted at 60 °C [4–7].

B. Swelling Measurement in Distilled Water

The water-absorption behavior of SAC 1 was evaluated by the free-swelling method. A 0.1-g dry sample was immersed in distilled water at room temperature for 24 h to reach swelling equilibrium. The swollen gel was removed and the excess surface water was eliminated by gently pressing the sample between folds of filter paper before weighing. The percentage swelling was calculated using Eq. (1):

$$\% \text{ Swelling} = [(W_2 - W_1) / W_1] \times 100, \quad (1)$$

where W_1 is the mass of the dry sample and W_2 is the mass of the water-swollen sample. Under the optimized conditions, SAC 1 exhibited 4600% swelling in distilled water.

C. Water Removal from Liquid Fuel

For the liquid-fuel application experiment, 0.1 g of SAC 1 was used. Liquid fuel (25 mL) and tap water (20 mL) were added to the sample under atmospheric conditions. The

sample was allowed to stand for 24 h before weighing. Thereafter, the superabsorbent was weighed at 2-min intervals until a constant mass was reached. Four repetitions were performed for each experimental point. The water-uptake behavior was compared between tap water and the water/liquid-fuel system. The application result was expressed as the amount of water absorbed over the specified time interval; under the investigated conditions, the observed value was approximately 20 mL of water per 12 min.

III. RESULTS AND DISCUSSION

A. Characteristics Relevant to Water Absorption

SAC 1 contains a cross-linked guar gum-g-poly(acrylic acid) network in which acrylic-acid-derived segments provide hydrophilic functional groups, while MBA contributes to network formation. The optimized material exhibited 4600% swelling in distilled water, demonstrating a high intrinsic water-uptake capacity. This free-swelling result represents equilibrium swelling behavior in water and should be distinguished from uptake in the liquid-fuel/water system, where the surrounding fuel phase may influence interfacial transport and water accessibility. The high water-absorption behavior of guar gum-based acrylic-acid graft systems is consistent with previously reported superabsorbent materials [1,4–7].

B. Water Removal from Liquid Fuel

The application experiment showed that SAC 1 was capable of taking up water in the presence of liquid fuel. Under the investigated conditions, 0.1 g of the superabsorbent was contacted with 25 mL of liquid fuel and 20 mL of tap water, and an absorption rate of approximately 20 mL of water per 12 min was observed. The absorption behavior differed between tap water alone and the water/liquid-fuel system, indicating that the surrounding fuel phase can influence water uptake.

From an application perspective, the ability of a hydrophilic, cross-linked material to retain water within its swollen structure may provide a basis for reducing free or dispersed water in fuel-storage environments. However, the present experiment does not establish the residual water concentration in the treated fuel, the selectivity of water uptake, the extent of fuel uptake by the polymer, or performance over repeated absorption cycles. These parameters require quantitative evaluation before practical deployment.

C. Mechanistic Interpretation

Water uptake can be attributed primarily to interactions between water molecules and hydrophilic functional groups within the grafted polymer network. Acrylic-acid-derived segments provide polar groups capable of interacting with water, while the cross-linked structure limits dissolution and allows absorbed liquid to be retained within the swollen matrix. In a water/liquid-fuel mixture, the hydrophilic network can therefore provide a favorable environment for

water uptake. The observed rate and extent of absorption may nevertheless depend on fuel composition, water dispersion, interfacial conditions, particle size, and cross-link density [1,4–7].

D. Practical Significance

The observed water uptake indicates that guar gum-g-poly(acrylic acid) is a promising candidate for water management in liquid-fuel storage systems. Its natural-polysaccharide backbone and high water-swelling behavior provide a useful basis for further application development [1,2,7]. For practical implementation, the absorbent should be incorporated into a recoverable configuration, such as a cartridge, pouch, filter bed, or other containment system, so that the swollen material can be removed from the fuel after treatment.

E. Limitations and Future Work

The present evaluation represents an initial laboratory assessment under a defined liquid-fuel/water system. Further experiments are required to establish robustness, selectivity, and practical performance. Important areas for future investigation include: (i) controlled water concentrations and droplet-size distributions; (ii) different liquid-fuel compositions; (iii) quantitative measurement of residual water before and after treatment; (iv) fuel uptake, swelling, or leaching by the superabsorbent; (v) absorption kinetics and capacity at different temperatures; (vi) regeneration and reuse; (vii) mechanical stability of the swollen material; and (viii) pilot-scale evaluation under representative fuel-storage conditions.

IV. CONCLUSION

Guar gum-g-poly(acrylic acid) superabsorbent polymer (SAC 1) was evaluated for water removal from a liquid-fuel/water system. The material was prepared by graft copolymerization of acrylic acid onto guar gum using KPS as initiator and MBA as cross-linking agent, and the optimized formulation exhibited 4600% swelling in distilled water. Under the liquid-fuel test conditions, 0.1 g of SAC 1 was contacted with 25 mL of liquid fuel and 20 mL of tap water, and water uptake was monitored at 2-min intervals after a 24-h standing period. An absorption rate of approximately 20 mL of water per 12 min was observed. The findings demonstrate the feasibility of SAC 1 for water management in liquid-fuel systems, while further quantitative evaluation of residual water, selectivity, fuel compatibility, regeneration, reusability, and scale-up performance is required before field application.

V. DECLARATIONS

A. Ethics Approval and Consent to Participate

Not applicable. The study did not involve human participants, human-derived data, or animals.

B. Consent for Publication

Not applicable. The manuscript does not contain identifiable personal data or images of individual participants.

C. Competing Interests

The author declares that there are no financial or non-financial competing interests that could have influenced the work reported in this manuscript.

D. Funding

No external funding was received for the research or preparation of this manuscript.

E. Author Contributions

Musarrat Khan: conceptualization, methodology, investigation, data curation, analysis and interpretation of results, manuscript preparation, writing—original draft, writing—review and editing, and final approval of the manuscript.

F. Data Availability

The data supporting the findings of this study are contained within the manuscript. Additional information may be made available by the author upon reasonable request, subject to applicable institutional or journal requirements.

G. Code Availability

Not applicable. No custom software or code was developed for this study.

H. Acknowledgements

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VI. REFERENCES

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