Evaluating Consumer Water Filter Performance for Ion Removal and Ion Exchange Resin Recharge Potential

Author: Ava Marszalek

Mentor: Thomas Riley

Advisors: Ana Teodorescu, Nancy Cizin

Affiliation: Brookdale Community College, NJ

Contact: avamarszalek@gmail.com

Abstract

This study evaluates the performance of Brita and PUR household water filters in removing calcium and potassium ions from a simulated hard water solution. Using Vernier ion-selective electrodes, both filters were tested for efficiency by filtering 1000 mL of calcium- and potassium-rich solutions. The results showed comparable calcium ion removal between brands, but the PUR filter removed potassium ions more effectively. Additionally, the reusability of ion exchange resins was tested by regenerating used filters with a concentrated sodium chloride solution. Post regeneration performance confirmed successful calcium ion removal, suggesting the potential for extending the Brita filter life through ion exchange resin recharging.

Problem Description and Literature Survey

Household water filtration pitchers are critical for improving water quality and minimizing mineral buildup in drinking water. Brita and PUR filters are among the most commonly used systems, both employing activated charcoal and ion exchange resins to remove dissolved ions such as calcium (Ca^{2+}) and potassium (K^{+}). Calcium is a primary contributor to water hardness and is linked to health issues such as kidney stones, hypercalcemia, and nutrient absorption interference. Potassium, while essential as an electrolyte, can affect water taste at elevated levels. With water filtration devices reaching a market size of $35.01 billion in 2024 and projected to grow significantly, understanding and improving filter performance is vital (Fortune 2023).

A study by Aljuaid (2024) focused on the impact of water filter pitchers on the mineral composition of tap water. The research found that most pitchers, except for a few, led to a decrease in calcium concentrations, with some filters showing statistically significant reductions.

The importance of water quality extends beyond taste and maintenance. Contaminants such as lead, mercury, and agricultural runoff can get into our water supplies, leading to a number of health risks. While many U.S. homes use water filters, the type of filter required varies based on

contamination levels. Options range from simple charcoal-filter pitchers like the ones in this study to advanced systems like reverse osmosis (Time, 2024).

Methods and Experimental Design

Materials and Preparation

Chemicals: Calcium chloride ($CaCl_2$), potassium chloride (KCl), sodium chloride (NaCl)
Equipment: Brita and PUR filters, Vernier ion-selective electrodes, LoggerPro software, deionized water (DH_2O)
Calibration Solutions: 1000 ppm and 10 ppm ion standards

Concentrated solutions simulating the ion load of 40 gallons of hard water were prepared:
- Calcium solution: 41.821 g of $CaCl_2$ in 1000 mL DH_2O
- Potassium solution: 0.6232 g of KCl in 1000 mL DH_2O

Filter Testing

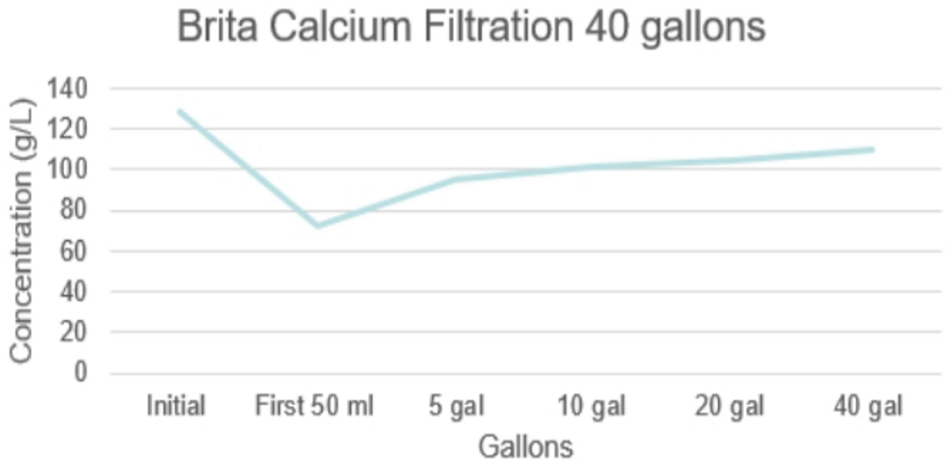
Filters were rinsed for 15 seconds with DH_2O before use. 1000 mL of each ion solution was passed through both Brita and PUR filters in triplicate. 50 mL samples of calcium chloride and potassium chloride were collected at intervals and analyzed for ion concentration. Baseline concentrations were recorded before filtration for comparison. Sample reading was done by the use of Vernier ion selective electrodes.

Electrode Use and Calibration

Each electrode was submerged in 1000 ppm and 10 ppm standard solutions for calibration. Samples were read once the electrode signal stabilized. Electrodes were cleaned with DH_2O and dried between samples to ensure accuracy.

Ion Exchange Resin Regeneration

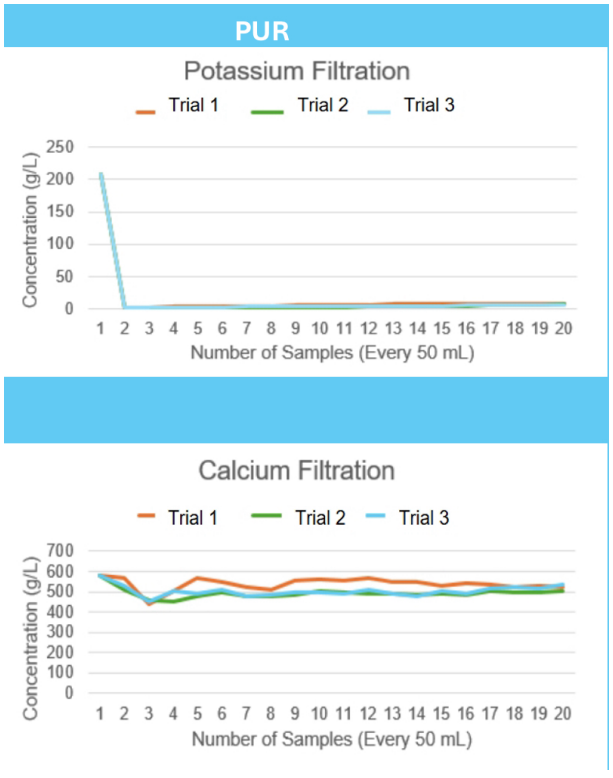
To test reusability: Test done on one individual Brita filter
1. One used Brita filter previously exposed to 40 gallons of calcium-rich solution was regenerated by filtering 1000 mL of 1 M NaCl solution.
2. A fresh calcium solution was then passed through the regenerated filter.
3. Sample analysis at 0 mL and 1000 mL confirmed the filter's reactivation.

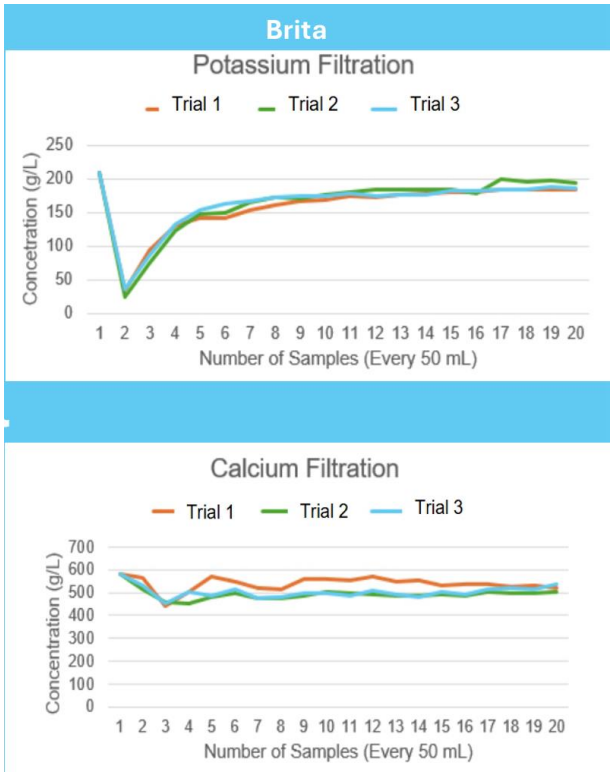


The final concentration of calcium in the 40 gallon test was 110 g/L. The results of the ion exchange resin recharge process showed significant filtration at the beginning with a concentration of 18.3 g/L in the initial 50 mL sample, and 52.4 g/L in the final 50 mL sample.

Results and Analysis

- Calcium Removal: Both filters demonstrated similar removal efficiency, showing rapid ion reduction in the first 150 mL and gradual decline thereafter.
- Potassium Removal: The PUR filter exhibited substantially better performance in removing K^+ ions compared to Brita.
- Resin Recharge: Post regeneration data showed a renewed capacity for calcium removal, supporting the feasibility of extending filter lifespan via recharging.





Conclusions

- PUR filters are more efficient than Brita at removing potassium ions, while calcium ion removal was comparable.
- Ion exchange resins in household filters can be effectively regenerated using a concentrated NaCl solution.
- Recharging filters could be a cost-effective method for extending filter usability and reducing waste.

Future Work

- Conduct additional resin recharge tests to assess long-term viability.
- Explore optimal NaCl concentrations and durations for maximum regeneration.
- Test additional ions common in hard water, such as magnesium or iron.
- Investigate environmental and economic impacts of household filter reusability.

References

Aljuaid, M. (2024). Impact of pitcher water filters on the mineral composition of tap water.

International Journal of Environmental Research and Public Health, 21(3).

https://pubmed.ncbi.nlm.nih.gov/39505386

Time. (2024, March 12). Do you really need a water filter? Here's what experts say. TIME

Magazine. https://time.com/7009156/do-you-need-water-filterMedlinePlus. (2021).

Hypercalcemia. U.S. National Library of Medicine.

https://medlineplus.gov/ency/article/001185.htm

NIH Office of Dietary Supplements. (2020). Calcium Fact Sheet.

https://ods.od.nih.gov/factsheets/Calcium-HealthProfessional/

National Kidney Foundation. (2020). Kidney Stones and Calcium.

https://www.kidney.org/atoz/content/kidney-stones

Fortune Business Insights. (2023). Water Purifier Market Size, Share & Growth Trends.

https://www.fortunebusinessinsights.com/water-purifier-market-103118