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

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Objective

The objective of this experiment is to determine the efficiency of household water pitcher filters, with a focus on removal of aqueous ions and reusability of filters.

Background

Filtration Process: Filters use activated carbon and ion exchange resin to remove dissolved ions (K^+, Ca^{2+}) from water.

Brita & PUR Filters: Household filters combine activated carbon and ion exchange technology to improve taste and reduce certain mineral content.

Ion Exchange Resin: Exchanges calcium and potassium ions in water for sodium or hydrogen ions to reduce hardness and improve flavor.

Potassium (K^+): Essential nutrient but can make water taste salty, bitter, or metallic at higher levels *(NIH, 2020)*.

Calcium (Ca^{2+}): Affects water taste (chalky or mineral-heavy) and may cause health issues like kidney stones or hypercalcemia at high intake *(MedlinePlus, 2021)*.

Figure 1: Brita water filter

Figure 2: Pur water filter

Preparation

- Researched online articles about the function of ion exchange resins, focusing on their ability to remove calcium (Ca^{2+}) and potassium (K^+) ions from water through ion substitution.
- Investigated Brita and PUR water filter designs, including lifespan data; both brands recommend replacing filters after filtering approximately 40 gallons of water.
- Instead of using 40 gallons, 1000 mL concentrated calcium and potassium solutions were prepared to run though the filters instead.

Figure 3: Concentrated solutions of Calcium and Potassium

- Created three trials of calcium and potassium ion solutions using $CaCl_2$ and KCl.
- 1 molar solution NaCl was made to pass though filter to investigate recharging ion exchange resin
- Obtained Vernier ion-selective electrodes for precise measurement of Ca^{2+} and K^+ concentrations in (g/mL).

Figure 4: Boxes of filters

Experiment

Experimental

- •Created a **1000 mL concentrated solution** to simulate 40 gallons of tap water
- •Used precise amounts of:
- **•41.821 g calcium / 1000 mL DH_2O**
- **•0.6232 g potassium / 1000 mL DH_2O**
- •Followed manufacturer guidelines for filter use and maintenance.
- •Each filter rinsed with **DH_2O for 15 seconds** before testing.

Figures 5: Concentrated Calcium Chloride solution prep

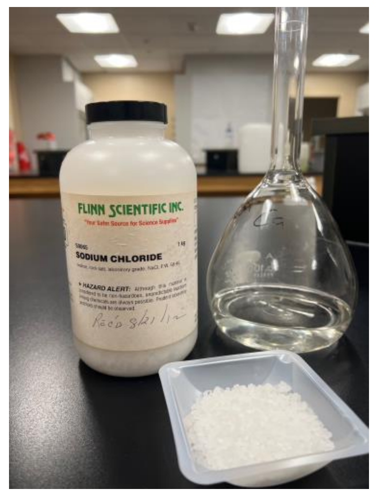

Figure 6: Concentrated Sodium Chloride solution for recharging ion exchange resin

Electrode Calibration & Use

- Used **Vernier ion-selective electrodes** for calcium and potassium testing
- Calibration:
  - **Soaked electrode in 1000 ppm solution** (30 min soak)
  - Then soaked in **10 ppm solution** for final calibration
- LoggerPro program used for calibration and data collection.
- For each sample the electrode is dipped into, the program gives a precise reading of the concentration (g/L) corresponding with that particular sample.

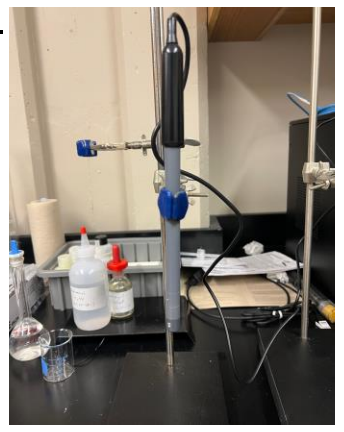

Figure: 7 Calcium Electrode

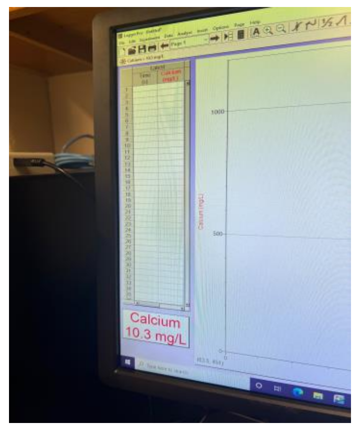

Figure 8: Logger Pro Program

Testing Procedure

- Passed each solution (1 solution per filter).
- Sampled stock solution and then every 50 mL passed though
- Tests run in **triplicate** for accuracy
- Concentrations tested with electrode
- Rinsed electrode with DH_2O + dried with KimWipe between samples

Resin Recharge Process

- After calcium test, filter regenerated using:
  - **1000 mL of 1 M NaCl solution in DH_2O**
- Then the same calcium solution was passed through again.
- Samples taken at **start and end** to compare performance post-recharge.
- Concentration tested with electrode.

Analysis

Pur

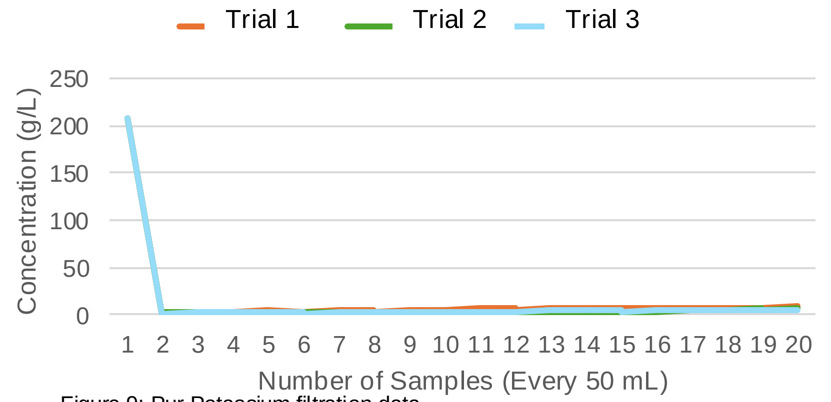

Figure 9: Pur Potassium filtration data

Brita

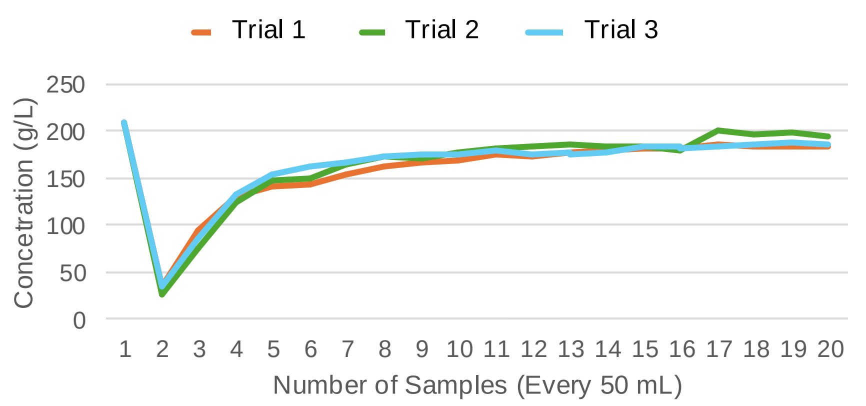

Figure 11: Brita Potassium filtration data

- **Calcium removal** was similar between Brita and PUR filters.
- **PUR filter** demonstrated significantly higher efficiency in **potassium removal** compared to Brita.
- Data showed consistent trends across all three trials, indicating reliable filtration performance.
- Initial filtration efficiency was high during first 3 trials, after 5th trial filter starting not working as well across all filters.

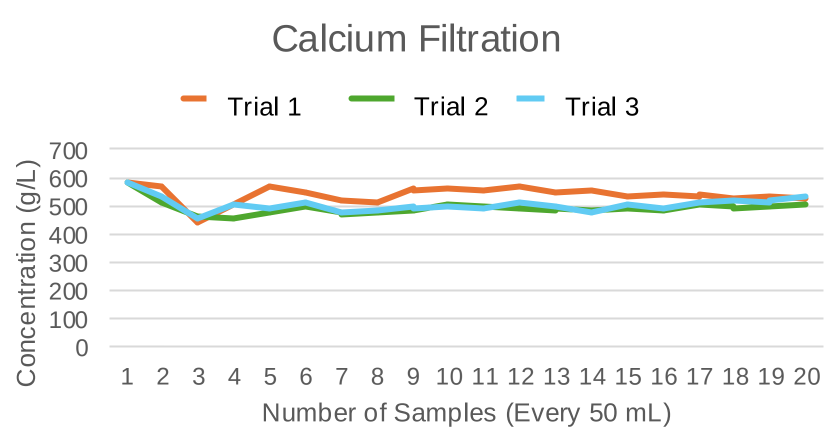

Figure 10: Pur calcium filtration data

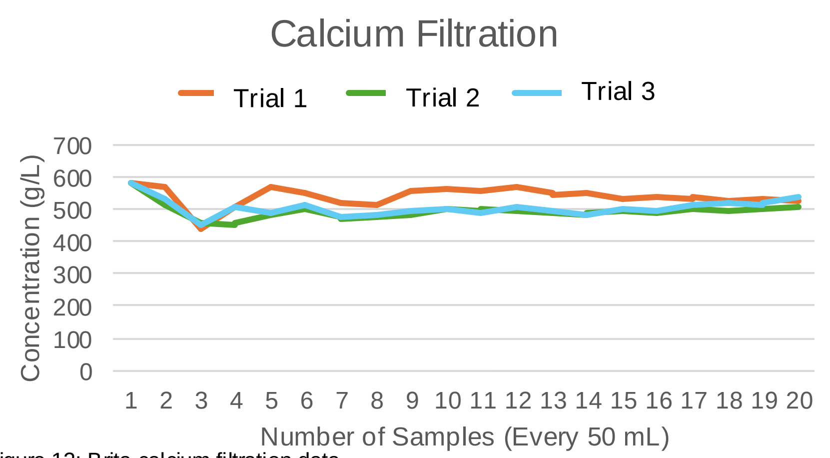

Figure 12: Brita calcium filtration data

Limitations

- Couldn't access chemicals without confirmation from chemical technician which prolonged experiment.
- Low budget.
- Broken calcium electrode, had to wait for new one to deliver which prolonged experiment.

Results and Future Work

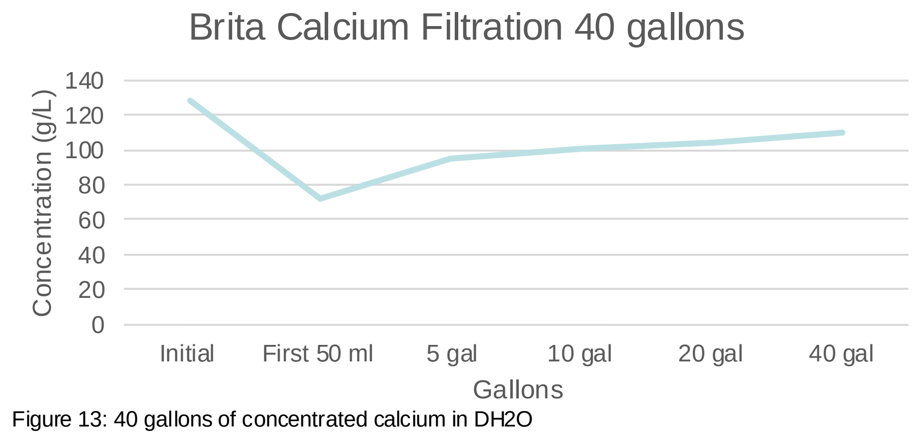

Figure 13: 40 gallons of concentrated calcium in DH2O

- This graph above shows filtration of a 40-gallon concentrated calcium solution. The filter preforms better when filtering 40 gallons, rather than filtering a 1000ml smaller concentrated amount (figure 13).
- Overall, the filter works more effectively when 40 gallons are passed through over time, rather than the filter being overloaded with a highly concentrated 1000 mL solution. It is believed that the filter was oversaturated too quickly and did not perform as well.

Calcium Concentration After Recharging Resin	
First 50 mL	18.3 g/L
Last 50 mL	52.4 g/L

Ion Exchange Resin Recharge

- Passing 1000 mL of 1 M NaCl solution through the filter effectively regenerated the ion exchange resin.
- After recharging, the filter successfully removed calcium from a fresh 1000 mL concentrated solution, confirming reactivation of filtering capability.

•Additional tests on resin recharging needed to verify consistency of regeneration process.

•Experimentation with different concentrations of NaCl recommended to determine optimal conditions for recharging effectiveness.

Acknowledgements

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