Assessing Drinking Foutain Water Quality in On-Campus Dormitories at the University of Illinois Urbana-Champaign

CEE 449 Final Student Research Project Report

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EXECUTIVE SUMMARY

A recent survey revealed student distrust of drinking water quality from drinking fountains and bottle filling stations. This distrust may contribute bottled water purchases and excess single use plastic waste on campus. Students in CEE 449 (Environmental Engineering Laboratory) designed a water quality analysis project to investigate whether this distrust is justified by testing water quality in different types of fountains. We tested three types of water fountains filling stations: i) glass fillers, ii) bottle fillers, and iii) filtered bottle fillers. We analyzed key chemical indicators of water quality and safety including free chlorine, pH, dissolved copper, and dissolved lead to see how water quality varied and whether filtered made a meaningfully enhanced quality. Students also compared the efficacy of two point-of-use (POU) filters to the filters inside of enhanced bottle fillers in certain University Housing facilities on campus.

The students' results showed that all three types of fountains deliver water that meets EPA safety standards for free chlorine, pH as well as lead and copper. All measured parameters were well under EPA action levels, confirming that the water freely available in on-campus housing is safe, even in unfiltered fountains. This sampling data shows that filtered bottle filling stations reduce the variance in measure lead and effectively remove residual chlorine (80-95%) which may improve perceived taste. While residual chlorine may impact taste, its presence in unflitered samples is a clear indication that the water is adequately disinfected. Student research also showed that reusable bottles equipped with activated carbon and ultrafiltration membrane filters can achieve comparable chlorine reduction to the filtered bottle filling stations. Since the water is safe in all three fountain types, we don't believe the cost of installing new filtered fountains is justified. Instead, we recommend focusing efforts on increasing awareness of the excellent water quality with students to improve trust in the campus water system.

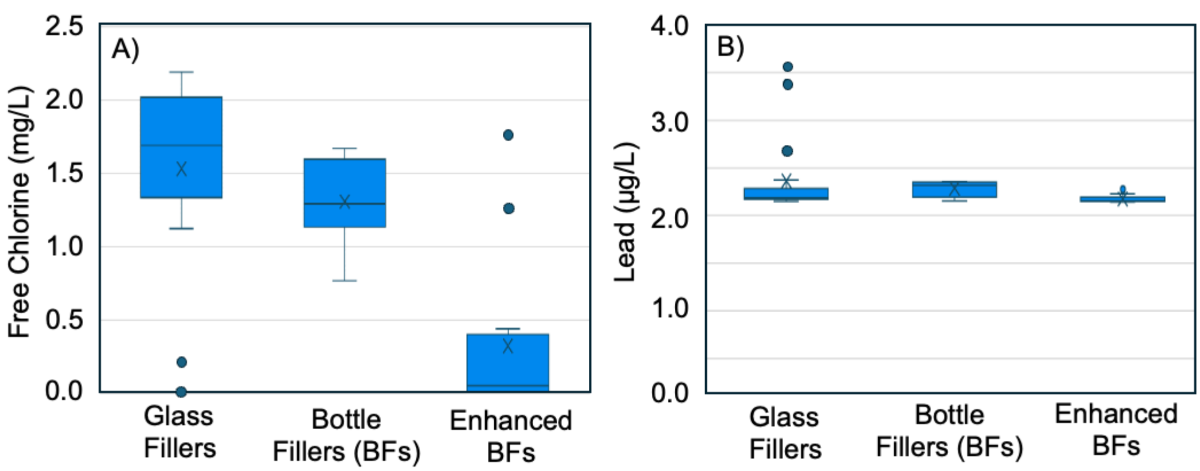

Figure E1: Comparison of A) Free Chlorine and B) Lead in samples collected from residence hall water fountains at the University of Illinois Urbana-Champaign.

INTRODUCTION

Many students across campus dormitories have a distrust of the water quality from drinking fountains and are opting to buy water bottles instead. This is not only a waste of money but also bad for the environment as it increases plastic waste. Our goal for this project is to assess and improve water quality across campus dormitories by identifying contamination sources and evaluating filtration system performance. We tested water samples at selected dormitories to measure the presence of inorganic pollutants: lead and copper. We also analyzed essential water quality parameters such as pH and free chlorine content. Additionally, we will analyze different filling station types to assess their impact on water quality and recommend infrastructure improvements. Some of our decision variables include the type of filler station (discrete), free chlorine level (continuous), copper and lead concentration (continuous), and our final recommendation for the feasibility of implementation (discrete). Acceptable ranges for our continuous variables will be discussed in the methodology of this report. We will group our samples by dormitory but also by water fountain type. The dormitories we are testing include Allen, Busey Evans, Clark Hall, Daniels, Goodwin & Green, Hopkins, Ike, LAR, Nugent, PAR, Scott, Sherman, Snyder, Taft Van-Dorn, and Weston residence halls. The water fountain types will include glass filling and bottle filling. Water bottles equipped with filters were also tested and compared to the filtration enhanced bottle filling stations.

SAMPLING METHODOLOGY

For this project we wanted to test and analyze three different types of water bottle filling stations on campus. These stations are glass fillers, bottle fillers, and enhanced bottle fillers. Glass fillers can be typically seen as your kitchen and bathroom sinks as well as many older water fountains are typically seen as glass fillers. Bottle fillers are your typical Elkay water fountain stations found all over campus while enhanced bottle filling stations are the same but differentiated using a filter status light in the top right. For this report, we will primarily be discussing the difference of glass and enhanced bottle fillers. The differences between these 3 stations are shown in the figure below.

Figure 1. Example of Different Filling Stations

Point of Use (POU) water bottle filters were also tested. A POU ultrafiltration (UF) filter (Membrane Solutions Portable Water Purification Unit) and a activated carbon (AC) cloth filter water bottle (Philips GoZero Water Bottle). Ultrafiltration uses pressure to force water through semi permeable membranes (pore sizes ranging from 0.01 – 0.1 micrometers) to remove particulate contaminants and harmful pathogens, and is increasingly employed at water treatment plants. Activated carbon filters is in the enhanced bottle filling stations and AC bottle leverage high surface area to adsorb contaminants and react with chloride to eliminate residual chlorine prior to consumption.

SAMPLE ANALYSIS PROCEDURE

For the testing of all samples, we analyzed free chlorine, pH, and lead/copper concentration levels. Free chlorine testing was conducted using a colorimeter, pH testing was conducted using a pH probe, and lead/copper concentrations were measured using Inductively Coupled Mass Spectroscopy (ICP-MS).

Free chlorine in drinking water is added during the disinfection process at the water treatment to inactivate harmful microorganisms and bacteria. Chlorine compounds is added during the final stage of the treatment process to kill pathogens and provide residual chlorine ensure safety during distribution up until the point of use. While minor free chlorine is relatively harmless, high concentrations can lead to certain adverse health effects such as respiratory, skin and eye infections. This is why it is an important parameter to test when analyzing drinking water quality. To test for free chlorine in each sample we collected, 10 mL portions of each sample were deposited into two vials. One vial served as the control sample while the other had a DPD free chlorine pillow added and dissolved into the vial. The control vial was then deposited into the colorimeter to set the baseline. The testing vial was then deposited afterwards to take the free chlorine reading of the sample. Results were then documented/recorded for each sample.

pH fluctuations can occur in drinking water when coagulants or disinfectants such as chlorine are added to the treatment process. pH is an important parameter to test for when discussing the quality of drinking water as extremely acidic or basic pH levels can cause corrosion in distribution pipes which can lead to the introduction of harmful metal ions into drinking water after treatment which can cause many adverse health effects. To test for pH each sample was tested twice using a pH probe where the probe was submerged in the sample until the pH reading stabilized. This was done twice for each sample.

Lead and copper can be introduced into drinking water after treatment from corrosion of distribution pipes and premise plumbing. While concentrations in safe drinking water are low, it is still important to test for when looking at drinking water quality and the local infrastructure quality of our drinking water distribution systems. Unsafe copper concentrations can cause gastrointestinal issues while unsafe lead concentrations can cause kidney damage and reproductive issues. Samples were prepared and deposited into an ICP-MS machine to test for lead and copper concentrations with values for each sample being recorded.

For our sampling campaign, our water quality benchmarks were taken from the EPA’s guidelines for water quality standards. The standards for each of our parameters as well as the adverse effects when outside these standards can be seen in the table below:

Table 1. Testing Parameters EPA Safety Standards [5]

Measurement	Adverse Effects	EPA Standard of Safety
pH	Leach metal from pipes supplying water	*6.5 - 9.5*
Free Chlorine	Respiratory, skin and eye irritation	*< 5 mg/L*
Copper Concentration	Gastrointestinal Issues	*< 1300 ppb*
Lead Concentration	Kidney damage, reproductive issues, increased blood pressure	*< 15 ppb*

RESULTS

The dormitories at UIUC use Elkay filters in their water filling stations. These are activated carbon filters, which use the process of adsorption to treat water. Activated carbon has a high surface area, so it is effective at collecting contaminants and reducing residual disinfectants.

Activated carbon filters remove chlorine through chemical reactions that reduce chlorine compounds to chlorine ions [1]. We found that the enhanced bottle filler stations had significantly lower free chlorine levels than glass fillers and standard bottle fillers, indicating that the filters worked correctly (Figure 4). Excluding a high outliers, none of the free chlorine readings exceeded 0.5 mg/L for the enhanced bottle filler station whereas the median level was around 1.5 mg/L for both glass fillers and standard bottle fillers (Figure 2). The outlier likely resulted from an error during analysis, since a much lower chlorine level was recorded the second day that we tested the outlier filling station. pH levels were similar across the three filter types (Figure 2). The enhanced bottle filling stations had a slightly lower median and mean pH (Figure 3). The filters may have reduced the concentration of organic compounds, some of which increase pH levels.

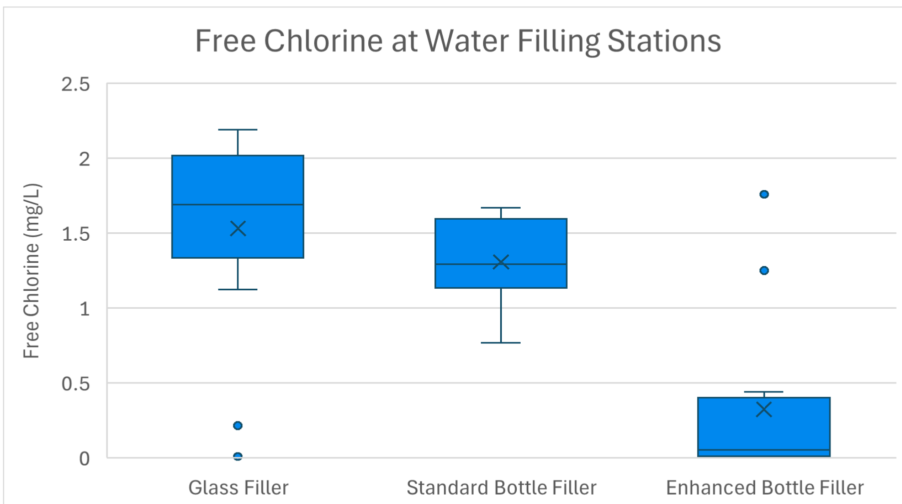

Figure 2. Free Chlorine Measurements

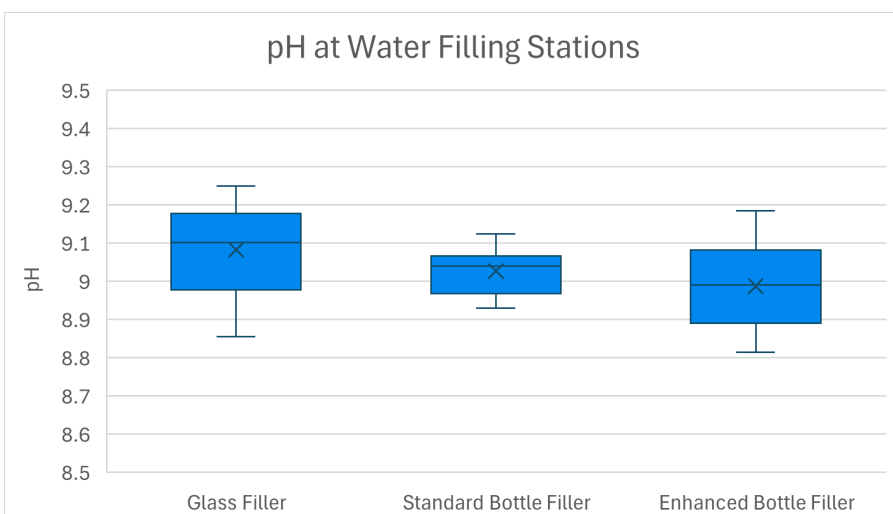

Figure 3. pH Measurements

Activated carbon filters have the ability to remove metals from water. Based on our testing, standard bottle filling stations had the highest median copper concentrations, while glass fillers had the lowest (Figure 4). However, the error bars overlap significantly across the three filter types (Figure 4). This indicates that the discrepancies are likely not statistically significant, and if we had continued testing in additional dormitories, the median and mean values may have become closer to each other. Elkay filters are advertised to reduce lead concentrations in drinking water. We found that the median lead levels were similar across the three water filling station types (Figure 5). However, the upper quartile and maximum values were much lower with the enhanced bottle filling station (Figure 5). Therefore, the enhanced bottle filling stations effectively reduced the risk of consuming trace levels of lead.

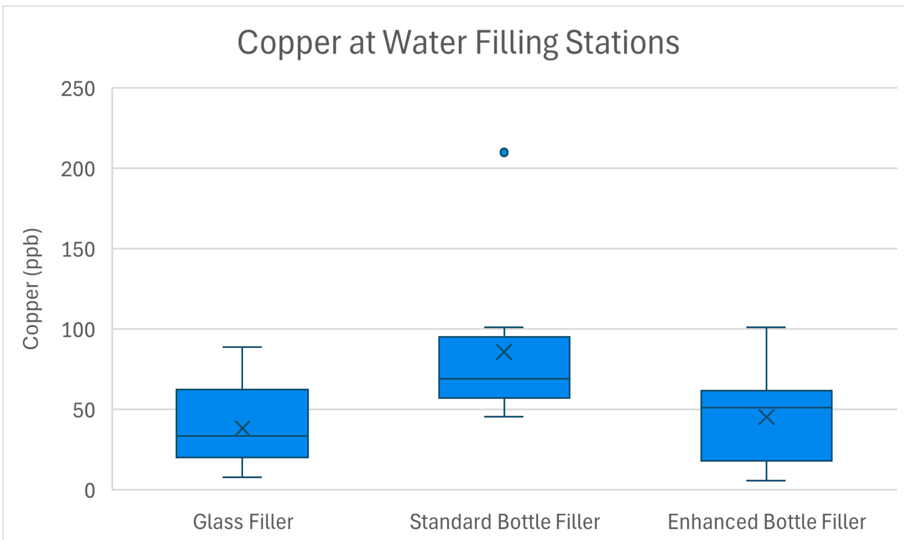

Figure 4. Copper at Water Filling Stations for All Water Groups

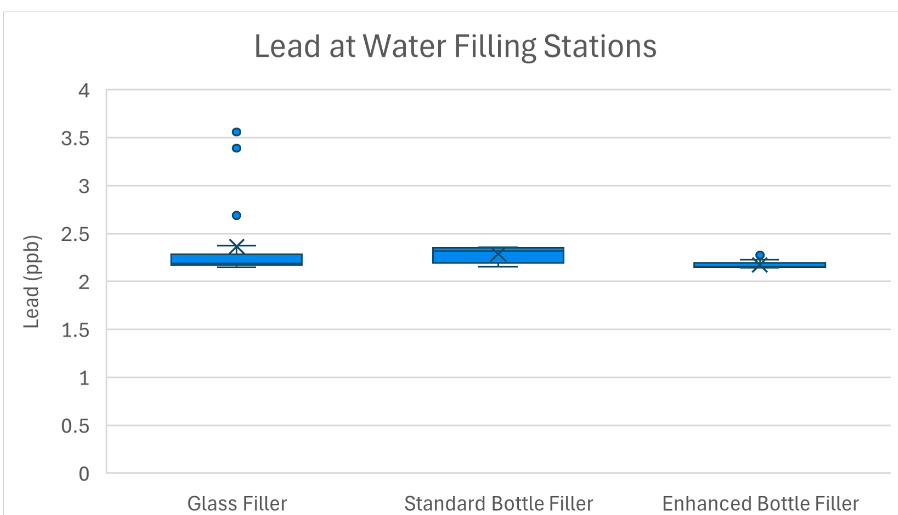

Figure 5. Lead at Water Filling Stations for All Water Groups

Although the three different water fountain types have some variability in results, it is important to interpret these results within the context of established safety standards. We can do this by comparing our contaminant concentration to the EPA's limits. The U.S. The Environmental Protection Agency (EPA) sets maximum contaminant levels (MCLs) based on extensive research to protect public health. Averages for copper were 40.19 ppb, 70.13 ppb and 47.32 ppb for glass filler, bottle filler and enhanced bottle filler respectively. The EPA limit for copper is 1300 ppb so these values are well below the action level. In Figure 5, the lead concentrations range from 2.1-2.5 ppb in all three fountains. Although they are similar to each other they all fall below the limit of 15 ppb. Based on these findings, we can conclude that all three water fountains are providing water that meets federal safety standards and is safe for consumption.

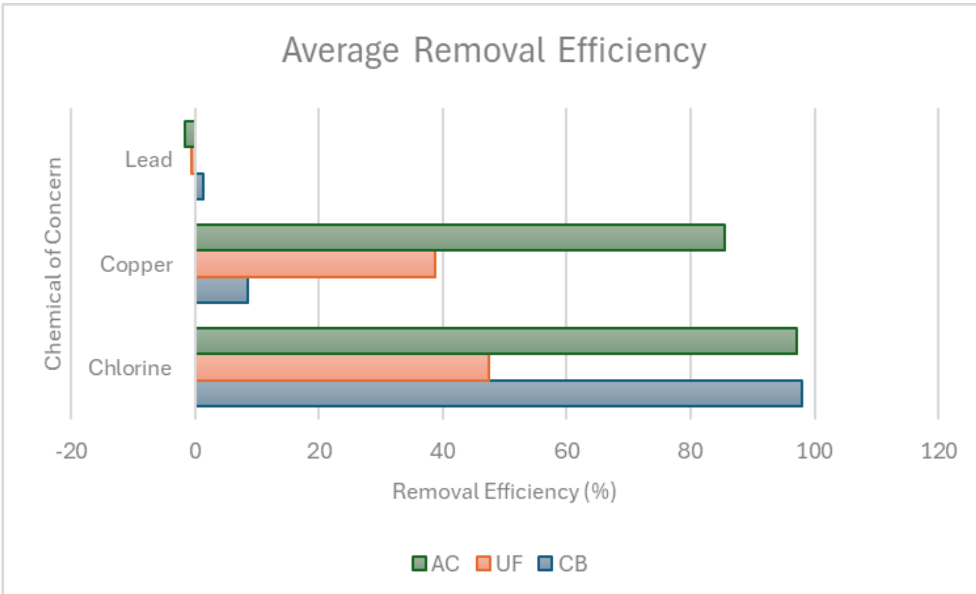

Figure 6. Average Removal Efficiency for Each Chemical of Concern by Filter Type

When analyzing the performance of POU bottle filters with the filtered bottle filling station (CB), we observed difference between each treatment technology (Figure 6). None of the three filters effectively removed lead, which was well below action levels. However, when it comes to copper removal, POU-AC and POU-UF both outperformed the CB bottle filling stations. The inconsistency in results between CB filters can likely be attributed to the fact that the POU-UF and POU-AC filters were bought new for this project, while the Elkay filters in bottle filling stations have each been in service for an indeterminable amount of time. Chlorine removal was higher for the enhanced bottle filling stations and the POU-AC as these filter materials are highly reactive with chlorine. Given the efficacy of POU bottle filters, we recommend that investments in chlorine removal should be made by students with filtered water bottles.

ECONOMIC ANALYSIS

We have completed a preliminary cost estimation of upgrading dormitories on campus with enhanced bottle fillers. For this estimate, we are considering the cost of equipment and installation expenses. An enhanced bottle filler can cost multiple thousands of dollars but for this project we are going to assume we are using a lower-end model. According to Elkay, a lower-end model enhanced bottle filler is approximately $1,500 [2]. The cost of installation can be difficult to estimate because multiple factors can affect the cost, but we are going to assume a general, rounded cost of about $1000 per fountain [3]. This brings our total upfront cost per fountain to roughly $2500. Additionally, filters need to be replaced twice per year at about $100 each, resulting in an annual maintenance cost of $200 per fountain. With 24 residence halls on campus, installing just one new fountain in each hall would amount to an initial investment of $60,000, not including ongoing maintenance. Realistically, to meet student demand and encourage widespread use, multiple fountains per hall would need to be installed. This would significantly increase the total cost. In total, upgrading fountains could improve water quality perception, but it would require a substantial financial investment.

CONCLUSIONS

The objective of this project was to assess water quality in campus dormitories and evaluate the extent to which different types of filtration systems meaningfully improved the safety of drinking water. This was achieved by testing for key parameters such as lead, copper, free chlorine, and pH across various dormitories and comparing results between glass fillers, standard bottle fillers, and enhanced bottle fillers. In doing so, we were able to assess compliance with EPA drinking water standards.

Our findings show that all three fountain types consistently delivered water within EPA safety limits, with enhanced bottle fillers performing slightly better in terms of chlorine and copper removal. Our sampling approach involved replication of samples across various campus dormitories and times to allow for reliable measurements without statistical bias. However, a limitation of our project is that the limited number of standard bottle filler samples constrains the statistical strength of our conclusions.

RECOMMENDATION

When we consider the high capital costs of installation for enhanced bottle fillers in dormitories and also account for possible maintenance costs over its lifetime, we believe that the benefits do not outweigh said costs. Instead, we recommend focusing efforts on increasing transparency of the results we have collected and convey it to students through signs or digital mediums to increase their trust in existing water filtration systems on campus.

Avenues for further exploration could include conducting seasonal sampling over longer time periods to monitor consistency in measurements. Testing filters right before they are about to be replaced may also provide unique insights into whether there is significant contaminant buildup in filters over their lifetime. Additional parameters such as bacteria, taste and odor can also be tested for. Tests can be compared with measurements taken from packaged bottle water to further the case for utilizing existing campus water filtration systems. Students can be surveyed to better understand their perspectives and knowledge gaps towards water quality on campus. Overall, we hope that the above study and further research can provide data to inform future campus infrastructure and the sustainable management and distribution of water resources.

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